Commercializing a Next-Generation Source of Safe Nuclear Energy

Low Energy Nuclear Reactions (LENRs)

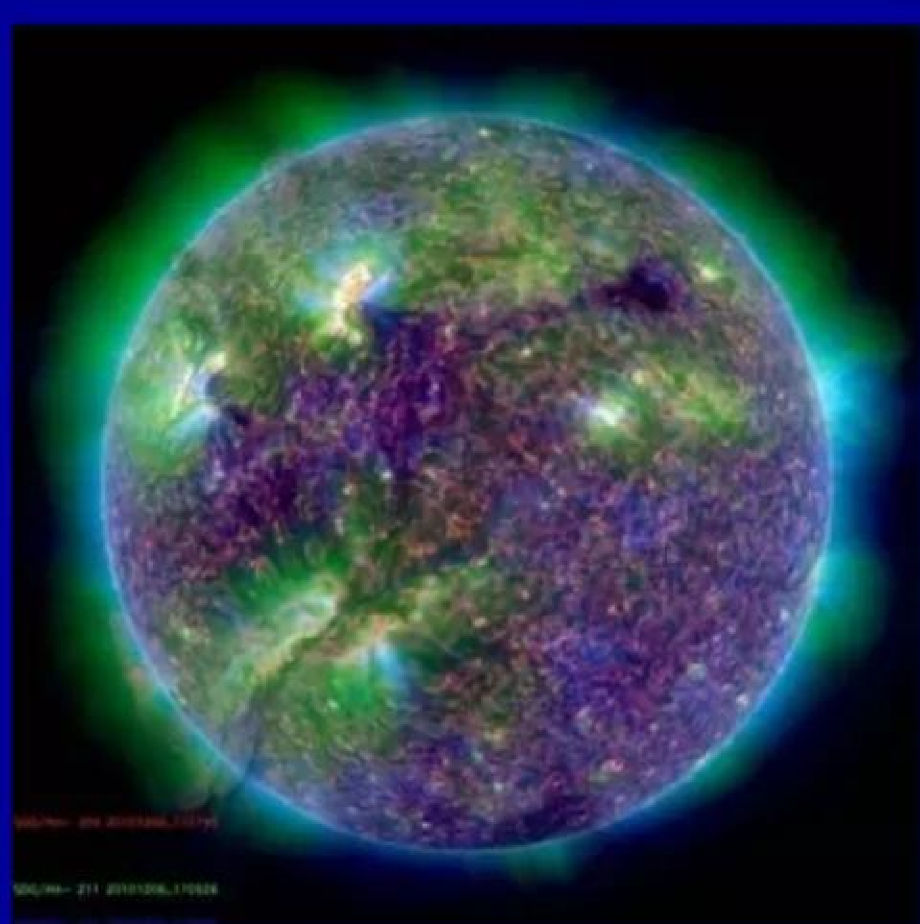
Claimed observations of variations in rates of nuclear β-decay

Evidence for dynamic behavior of nuclei responding to their immediate physical environment?

Changes in neutrino fluxes from $e^- + p^+ \rightarrow lepton + X$ weak interactions in large solar flares may be the cause

Technical Overview

False-color X-ray image of the Sun



$$e^* + p^+ \rightarrow n + v_e$$
$$e^- + p^+ \rightarrow lepton + X$$

Lewis Larsen, President and CEO
Lattice Energy LLC

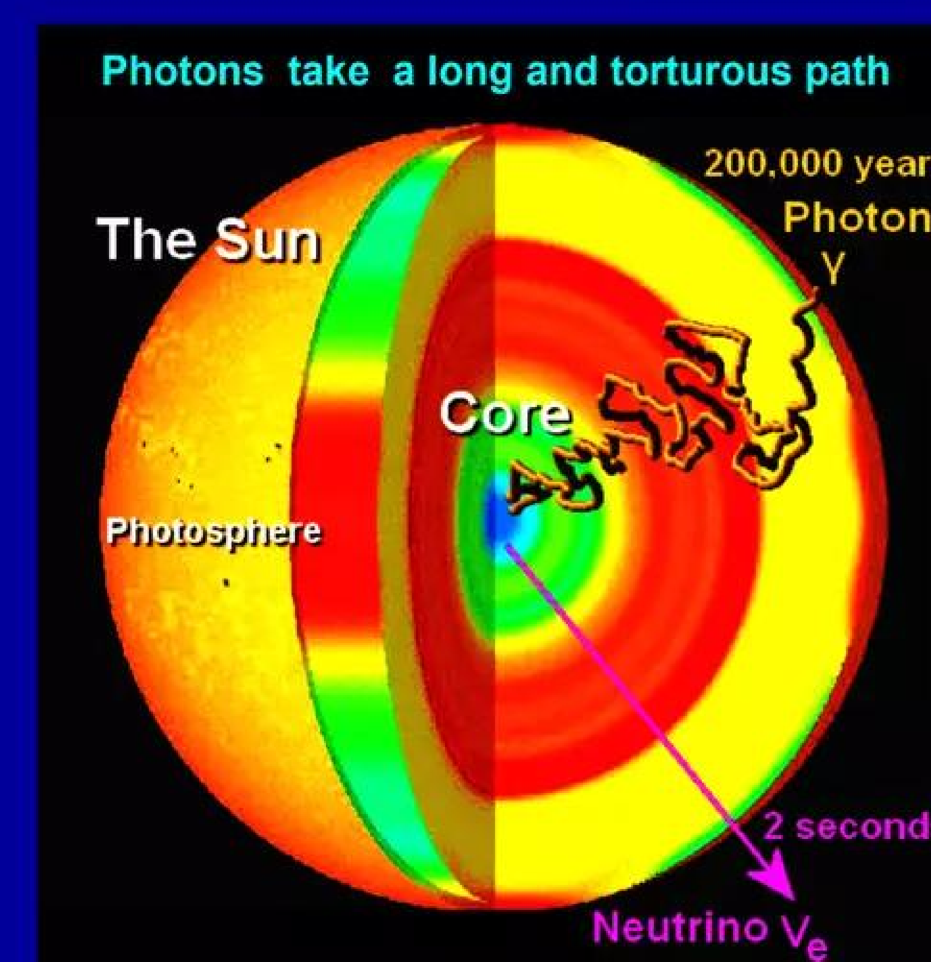
June 3, 2011

"It is of the highest importance in the art of detection to be able to recognize, out of a number of facts, which are incidental and which vital. Otherwise your energy and attention must be dissipated instead of being concentrated."

Sherlock Holmes, "The Reigate Squires" 1893

$$(Z, A) \rightarrow (Z + 1, A) + e^- + \bar{v}_e$$

Conceptual schematic of the Sun



$$e^* + p^+ \rightarrow n + v_e$$
$$e^- + p^+ \rightarrow lepton + X$$

Contents

Main objectives of this presentation

Nucleosynthesis not limited to cores of stars, fission reactors, and supernovae

- ✓ Highlight selected features of W-L theory that apply mainly to astrophysical realms
- ✓ Outline our theory of a simple, many-body collective magnetic mechanism that we believe explains anomalously high temperatures observed in the solar corona versus temperatures found in the photosphere that forms the 'surface' of the Sun
- ✓ Provide high-level conceptual overview that shows how the very same mechanism enables significant amounts of nucleosynthesis to occur at locations well-outside stellar cores; this is mildly contrary to presently accepted astrophysical paradigms
- ✓ Show examples of experimental (observational) evidence that support our new way of thinking about the possibility of many different locations for nucleosynthesis as it may affect patterns of galactic, solar system, and/or planetary chemical evolution
- ✓ Discuss new and exciting experimental data which suggests that beta-decaying isotopes (controlled by weak interaction) located on Earth may be locally responding to significant changes in neutrino fluxes emanating from the Sun. Importantly, this data provides direct evidence for our mechanism noted above
- ✓ In conclusion: although stars are still very likely the overwhelmingly dominant locations for nucleosynthetic processes in the Universe, a new paradigm is slowly emerging from W-L theory that opens-up incredible opportunities for new research

W-S-L theory suggests nucleosynthesis may be widespread

Cores of stars, fission reactors, and supernovae not required

Lightning is like exploding wires

Earth: LENRs in many places

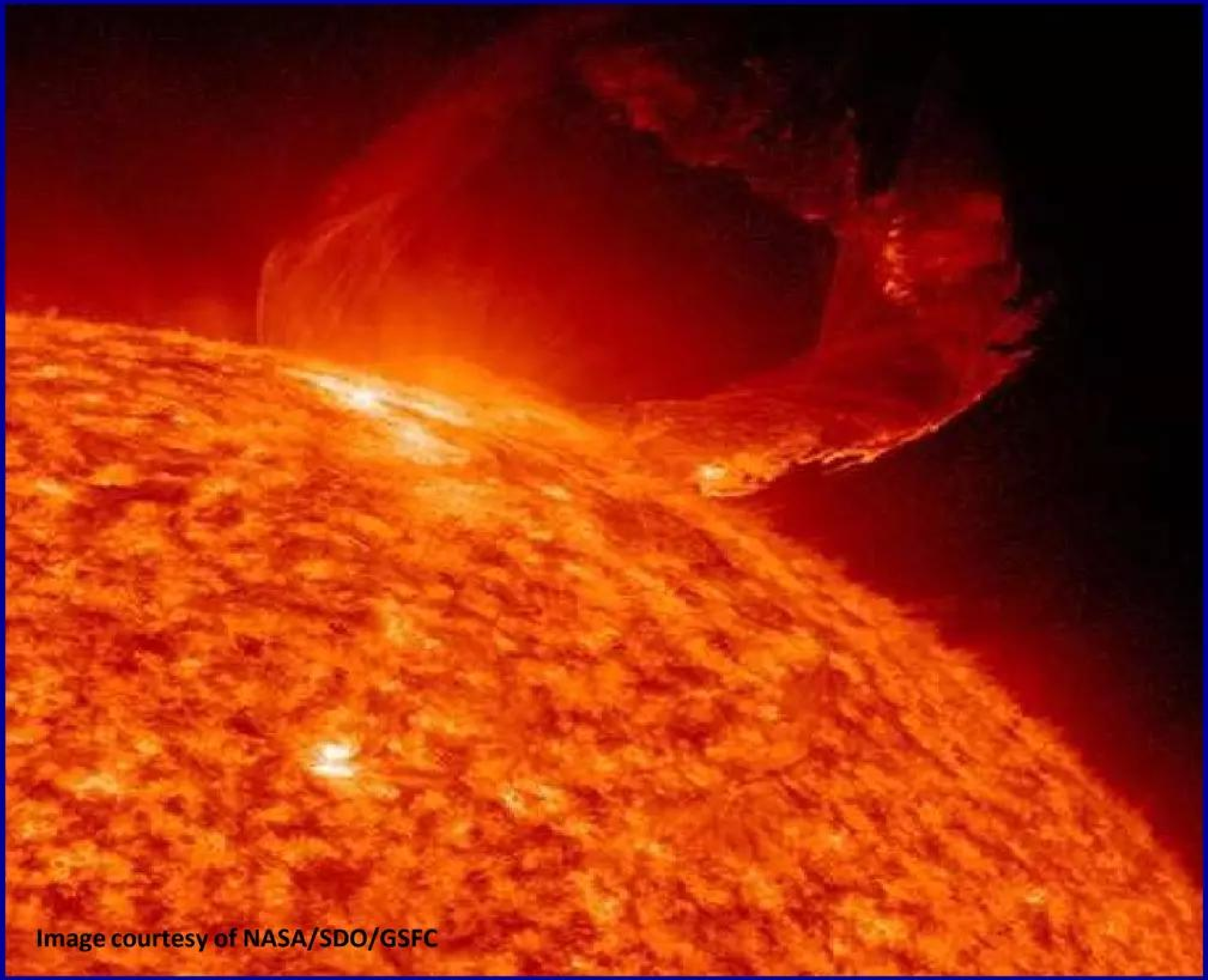
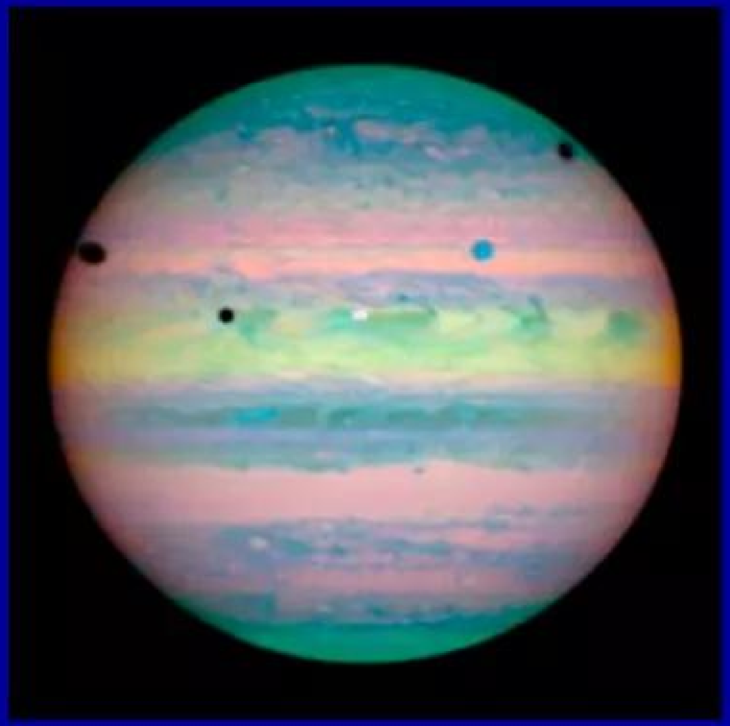


Image courtesy of NASA/SDO/GSFC

March 19, 2011 – image of major eruption on the surface of the Sun
Nucleosynthesis also occurs in photosphere, flux tubes, and corona

Very dusty Eagle Nebula



Jupiter is not just a 'failed star'

Many-body collective effects are commonplace in Nature

Paradigm shift: welcome to the New World of nucleosynthesis!

"I am increasingly persuaded that all physical law we know about has collective origins, not just some of it.“

"… I think a good case can be made that science has now moved from an Age of Reductionism to an Age of Emergence, a time when the search for ultimate causes of things shifts from the behavior of parts to the behavior of the collective ….. Over time, careful quantitative study of microscopic parts has revealed that at the primitive level at least, collective principles of organization are not just a quaint sideshow but everything --- the true essence of physical law, including perhaps the most fundamental laws we know … nature is now revealed to be an enormous tower of truths, each descending from its parent, and then transcending that parent, as the scale of measurement increases.”

“Like Columbus or Marco Polo, we set out to explore a new country but instead discovered a new world."

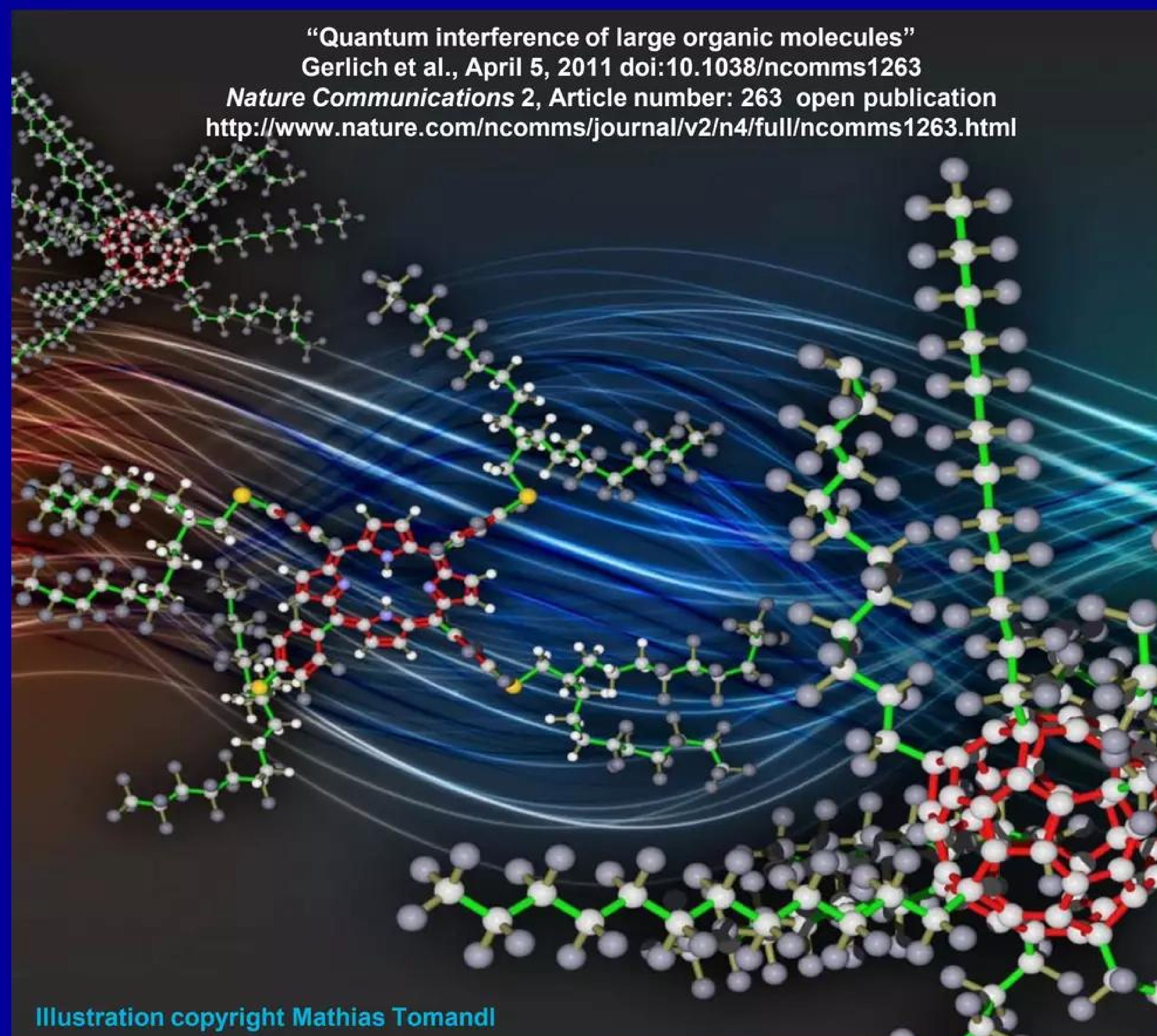
Robert Laughlin, "A Different Universe - Reinventing Physics from the Bottom Down,” Basic Books, 2005, pp. xv and 208

Commercializing a Next-Generation Source of Safe Nuclear Energy

Many-body collective effects are commonplace in Nature

Certain quantum mechanical effects are key to LENRs in realm of condensed matter

"PFNS10 and TPPF152 contain 430 atoms covalently bound in one single particle. This is ~350% more than that in all previous experiments and it compares well with the number of atoms in small Bose–Einstein condensates (BEC), which, of course, operate in a vastly different parameter regime: The molecular de Broglie wavelength λ_{dB} is about six orders of magnitude smaller than that of ultracold atoms and the internal molecular temperature exceeds typical BEC values (T<1 μK) by about nine orders of magnitude. Although matter wave interference of BECs relies on the de Broglie wavelength of the individual atoms, our massive molecules always appear as single entities."



Artistic view of most complex and massive molecules (PFNS-10, TPP-152) brought to quantum interference by Gerlich et al. (2011)

"Our experiments prove the quantum wave nature and delocalization of compounds composed of up to 430 atoms, with a maximal size of up to 60 Å, masses up to *m*=6,910 AMU and de Broglie wavelengths down to $\lambda_{dB}=h/mv \simeq 1$ pm ... In conclusion, our experiments reveal the quantum wave nature of tailor-made organic molecules in an unprecedented mass and size domain. They open a new window for quantum experiments with nanoparticles in a complexity class comparable to that of small proteins, and they demonstrate that it is feasible to create and maintain high quantum coherence with initially thermal systems consisting of more than 1,000 internal degrees of freedom."

Many-body collective effects are commonplace in Nature

Certain quantum mechanical effects are key to LENRs in realm of condensed matter

"Another biological process where entanglement may operate is photosynthesis, the process whereby plants convert sunlight into chemical energy. Incident light ejects electrons inside plant cells, and these electrons all need to find their way to the same place: the chemical reaction center where they can deposit their energy and sett off reactions that fuel plant cells. Classical physics fails to explain the near-perfect efficiency with which they do so."

"... In a quantum world, a particle does not just have to take one path at a time; it can take all of them simultaneously. The electromagnetic fields within plant cells can cause some of these paths to cancel one another and others to reinforce mutually, thereby reducing the chance the electron will take a wasteful detour and increasing the chance it will be steered straight to the reaction center."

"The entanglement would last only a fraction of a second and would involve molecules that have no more than about 100,000 atoms. Do any instances of larger and more persistent entanglement exist in nature? We do not know, but the question is exciting enough to stimulate and emerging discipline: quantum biology."

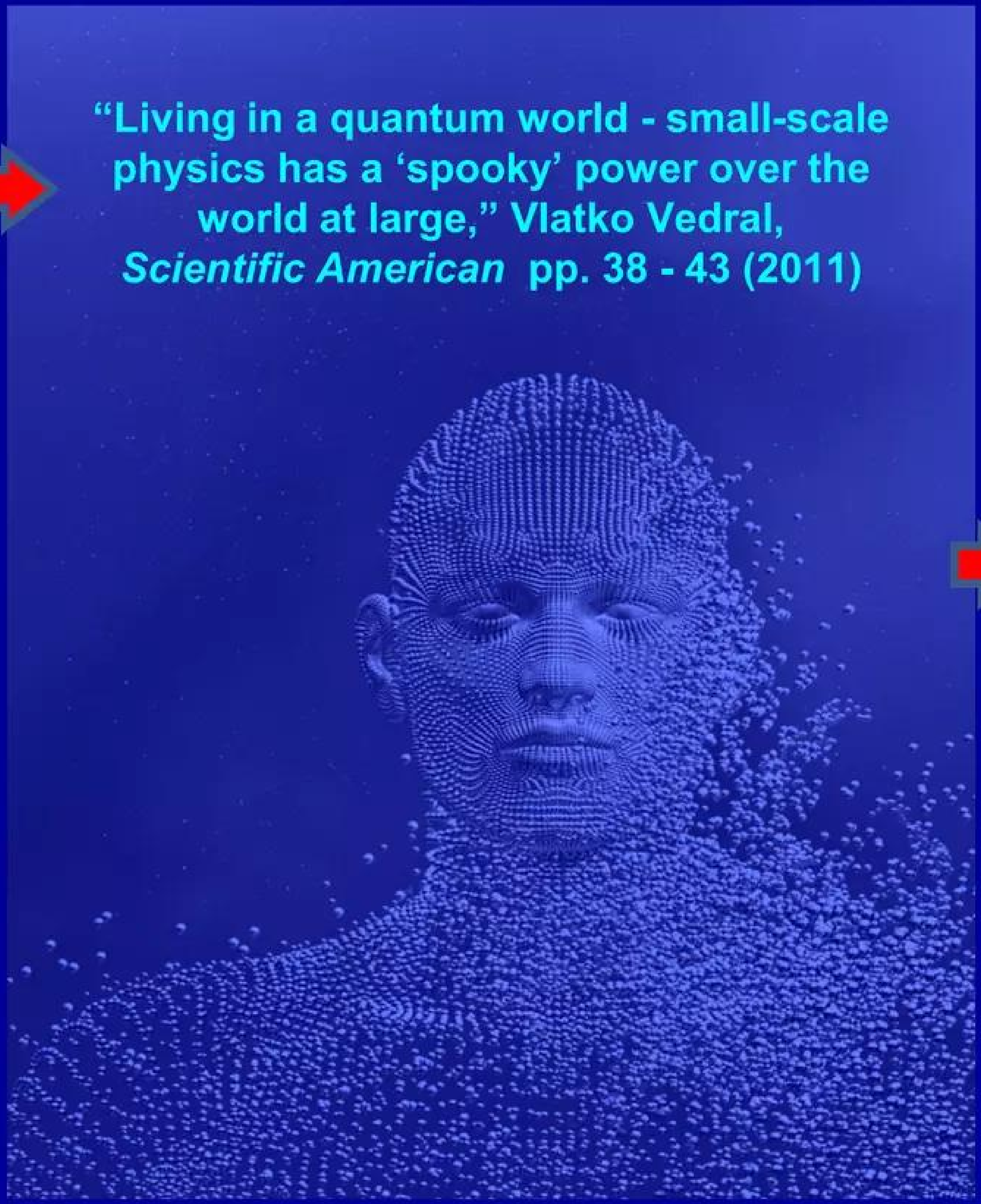


Image credit : Kenn Brown, Mondolithic Studios
Cover of *Scientific American* June 2011

"Not only is the universe stranger than we imagine, it is stranger than we *can* imagine."

Often misattributed to Sir Arthur Eddington; more likely adapted from J.B.S. Haldane (1927)

Many-body collective effects are commonplace in Nature

- ✓ Many-body collective oscillations and mutual quantum entanglement of protons (as well as deuterons and tritons) and electrons (e.g., SPPs on metallic hydride surfaces), in conjunction with a breakdown of the Born-Oppenheimer approximation, appear to be relatively common in nature, occurring in many different condensed matter systems
- ✓ While these many-body collective processes chronicled by Chatzidimitriou-Dreismann et al. operate very rapidly and nanoscale coherence can only persist for time spans on the order of femtoseconds (10^{-15} sec) to attoseconds (10^{-18} sec), nuclear processes such as weak interaction ULM neutron production and neutron capture operate on even faster time-scales: 10^{-19} to 10^{-22} sec. Therefore, LENRs as explained by the Widom-Larsen theory can easily take advantage of such many-body collective quantum effects as an integral part of their amazing dynamical repertoire
- ✓ It is well-known that metallic surface nanostructures and SPP electrons can have configurations that are able to effectively absorb E-M energy over a wide area, transfer and concentrate it, and in conjunction with contiguous surface 'patches' of collectively oscillating protons, create extremely high local electric fields. According to W-L theory, ULM neutron production may then follow

→ C. A. Chatzidimitriou-Dreismann (Technical University of Berlin) and his collaborators have published extensively on collective proton dynamics since 1995. Please also see:

→ "Attosecond quantum entanglement in neutron Compton scattering from water in the keV range" (2007); can be found at

http://arxiv.org/PS_cache/cond-mat/pdf/0702/0702180v1.pdf

"Several neutron Compton scattering (NCS) experiments on liquid and solid samples containing protons or deuterons show a striking anomaly, i.e. a shortfall in the intensity of energetic neutrons scattered by the protons; cf. [1, 2, 3, 4]. E.g., neutrons colliding with water for just 100 − 500 attoseconds (1 as = 10^{-18} s) will see a ratio of hydrogen to oxygen of roughly 1.5 to 1, instead of 2 to 1 corresponding to the chemical formula H_2O. … Recently this new effect has been independently confirmed by electron-proton Compton scattering (ECS) from a solid polymer [3, 4, 5]. The similarity of ECS and NCS results is striking because the two projectiles interact with protons via fundamentally different forces, i.e. the electromagnetic and strong forces."

→ Also, J. D. Jost et al., "Entangled mechanical oscillators" *Nature* 459 pp. 683 – 685 (2009) in which "mechanical vibration of two ion pairs separated by a few hundred micrometres is entangled in a quantum way."

Selected Technical Publications

"***Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces***" Eur. Phys. J. C **46**, pp. 107 (March 2006) Widom and Larsen – initially placed on arXiv in May 2005 at http://arxiv.org/PS_cache/cond-mat/pdf/0505/0505026v1.pdf; a copy of the final *EPJC* article can be found at: http://www.newenergytimes.com/v2/library/2006/2006Widom-UltraLowMomentumNeutronCatalyzed.pdf
"***Absorption of nuclear gamma radiation by heavy electrons on metallic hydride surfaces***" http://arxiv.org/PS_cache/cond-mat/pdf/0509/0509269v1.pdf (Sept 2005) Widom and Larsen
"***Nuclear abundances in metallic hydride electrodes of electrolytic chemical cells***" http://arxiv.org/PS_cache/cond-mat/pdf/0602/0602472v1.pdf (Feb 2006) Widom and Larsen
"***Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces***" http://arxiv.org/PS_cache/nucl-th/pdf/0608/0608059v2.pdf (v2. Sep 2007) Widom and Larsen
"***Energetic electrons and nuclear transmutations in exploding wires***" http://arxiv.org/PS_cache/arxiv/pdf/0709/0709.1222v1.pdf (Sept 2007) Widom, Srivastava, and Larsen
"***Errors in the quantum electrodynamic mass analysis of Hagelstein and Chaudhary***" http://arxiv.org/PS_cache/arxiv/pdf/0802/0802.0466v2.pdf (Feb 2008) Widom, Srivastava, and Larsen
"***High energy particles in the solar corona***" http://arxiv.org/PS_cache/arxiv/pdf/0804/0804.2647v1.pdf (April 2008) Widom, Srivastava, and Larsen
"***A primer for electro-weak induced low energy nuclear reactions***" Srivastava, Widom, and Larsen Pramana – Journal of Physics **75** pp. 617 (October 2010) http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

Selected Technical Publications - Primer on W-S-L theory

"***A primer for electro-weak induced low energy nuclear reactions***" Srivastava, Widom, and Larsen
Pramana – Journal of Physics **75** pp. 617 (October 2010) http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

- ✓ **Summarizes results of all of our other technical publications about the W-L theory at a lower level of mathematical detail; more conceptually oriented. Since W-S-L impinges many areas of study, readers are urged to start with the *Primer* and then examine details in other papers as dictated by specific interests**
- ✓ **Focusing on astrophysical environments, we will now draw attention to selected aspects of the *Primer***
- ✓ **Please note that in magnetically organized astrophysical plasmas (which typically occur on relatively large length-scales, as opposed to nanometers to microns for LENR processes in condensed matter) W-L theory involves *many-body collective magnetic effects.* Also note that under these conditions, neutrons produced via weak interactions per W-L theory are not necessarily ultra low momentum (ULM); in stars' magnetic flux tubes and more violent events like solar flare 'explosions', neutrons and a varying array of particles (e.g., protons, positrons) may be created at energies that range all the way up to 500 GeV and even beyond**
- ✓ **In the case of *dusty astrophysical plasmas* in regions where average temperatures are such that intact embedded dust grains and nanoparticles (which may be strongly charged) can exist for a time therein, W-L condensed matter LENRs producing ~ULM neutrons may also occur on the surfaces of such particles**
- ✓ **Quoting from the conclusions: "Three seemingly diverse physical phenomena, viz., metallic hydride cells, exploding wires and the solar corona, do have a unifying theme. Under appropriate conditions which we have now well delineated, in all these processes electromagnetic energy gets collectively harnessed to provide enough kinetic energy to a certain fraction of the electrons to combine with protons (or any other ions present) and produce neutrons through weak interactions. The produced neutrons then combine with other nuclei to induce low-energy nuclear reactions and transmutations."**

Selected Technical Publications - Primer

"***A primer for electro-weak induced low energy nuclear reactions***" Srivastava, Widom, and Larsen
Pramana – Journal of Physics **75** pp. 617 (October 2010) http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

- ✓ **"As stated in Section 2, oppositely directed Amperian currents of electrons and protons loop around the walls of a magnetic flux tube which exits out of one sun spot into the solar corona to enter back into another sun spot. The magnetic flux tube is held up by magnetic buoyancy. We consider here the dynamics of how very energetic particles are produced in the solar corona and how they induce nuclear reactions well beyond the solar photosphere. Our explanation, centered around Faraday's law, produces the notion of a solar accelerator very similar to a betatron. A betatron is a step-up transformer whose secondary coil is a toroidal ring of particles circulating around a time-varying Faraday flux tube."**

- ✓ **"We can view the solar flux tube to act as a step-up transformer which passes some circulating particle kinetic energy from the solar photosphere outward to other circulating particles in the solar corona. The circulating currents within the photosphere are to be considered as a net current I_p around a primary coil and the circulating currents high up in the corona as a net current I_S. If K_p and K_s represent the kinetic energies, respectively, in the primary and the secondary coils, the step-up transformer power equation ... where V_p and V_s represent the voltages across the primary and the secondary coils, respectively."**

- ✓ **"In essence, what the step-up transformer mechanism does is to transfer the kinetic energy distributed amongst a very large number of charged particles in the photosphere - via the magnetic flux tube - into a distant much smaller number of charged particles located in the solar corona, so that a small accelerating voltage in the primary coil produces a large accelerating voltage in the secondary coil. The transfer of kinetic energy is *collective* from a larger group of particles into a smaller group of particles resulting in the kinetic energy per charged particle of the dilute gas in the corona becoming higher than the kinetic energy per particle of the more dense fluid in the photosphere."**

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- ✓ **"If and when the kinetic energy of the circulating currents in a part of the floating flux tube becomes sufficiently high, the flux tube would become unstable and explode into a solar flare which may be accompanied by a coronal mass ejection. There is a rapid conversion of the magnetic energy into charged particle kinetic energy. These high-energy products from the explosion initiate nuclear as well as elementary particle interactions, some of which have been detected in laboratories."**
- ✓ **"Recent NASA and ESA pictures show that the surface of the Sun is covered by a carpet-like interwoven mesh of magnetic flux tubes of smaller dimensions. Some of these smaller structures possess enough magnetic energy to lead to LENRs through a continual conversion of their energy into particle kinetic energy. Occurrence of such nuclear processes in a roughly steady state would account for the solar corona remaining much hotter than the photosphere."**
- ✓ ***"... our picture belies the notion that all nuclear reactions are contained within the core of the Sun."***
- ✓ **"On the contrary, it provides strong theoretical support for experimental anomalies such as short-lived isotopes that have been observed in the spectra of stars having unusually high average magnetic fields."**
- ✓ **"For the transformer mechanism to be fully operational in the corona, the coronal electrical conductivity must not be too large ... [in summary] we note that the typical conductivity of a good metal would be more than ten orders of magnitude higher [than the corona]. The corona is close to being an insulator and eons away from being a metal and there is no impediment toward sustaining electrical fields within it. ... our proposed transformer mechanism and its subsequent predictions for the corona remain intact."**

Selected Technical Publications - Primer

"***A primer for electro-weak induced low energy nuclear reactions***" Srivastava, Widom, and Larsen
Pramana – Journal of Physics **75** pp. 617 (October 2010) http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

- ✓ **"The spectacular solar flare, which occurred on 14 July 2000 and the measurement of the excess muon flux associated with this flare by the CERN L3+C group [23] offered a unique opportunity to infer that protons of energies greater than 40 GeV were produced in the solar corona. Likewise, the BAKSAN underground muon measurements [47] provided evidence for protons of energies greater than 500 GeV in the solar flare of 29 September 1989. The very existence of primary protons in this high-energy range provides strong evidence for the numbers provided in eq. (21). Hence, for large solar flares in the corona, electrons and protons must have been accelerated well beyond anything contemplated by the standard solar model. This in turn provides the most compelling evidence for the presence of large-scale electric fields and the transformer or betatron mechanism because we do not know of any other process that could accelerate charged particles to beyond even a few GeV, let alone *hundreds* of GeVs." [eqs. 20-21: we calculate mean acceleration energy of ~300 GeV]**

- ✓ **Total rate of positron production in a solar flare: "... we estimate the total rate of positrons produced in a solar flare through the reaction $e^- + p^+ \rightarrow e^+e^- + X$. The rate of production of e^+e^- pairs is equal to the rate of production of $\mu^+\mu^-$ pairs. After a while, however, all the muons will decay and from each muon (outside the corona) we shall get one electron (or one positron)... [in the conclusion of the calculation] Inserting these values in eq. (71) we obtain the number of positrons (300 GeV) in a flare as approximately equal to 11.2 x 10^{21} /s. Under the simplifying assumption that the positron production is isotropic, the differential positron flux before reaching the Earth's atmosphere is given by eq. (73) $F(e^+)$ = 0.04 m^2-s-sr."**

- ✓ **"This should be compared with the overall positron flux estimate for all cosmic rays (integrated over positron energies >8.5 GeV) which is about 0.12 /m^2-s-sr. Thus, our acceleration mechanism is not only capable of accelerating electrons and protons in a solar flare to hundreds of GeV but it also yields a high-energy positron flux which is a substantial fraction of the overall cosmic ray positron flux. We are unaware of any similar theoretical estimate in the literature."**

Selected Technical Publications - Primer

"***A primer for electro-weak induced low energy nuclear reactions***" Srivastava, Widom, and Larsen
Pramana – Journal of Physics **75** pp. 617 (October 2010) http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

- ✓ **Total proton flux estimate for the 14 July 2000 solar flare: "As mentioned earlier, the L3+C Collaboration measured the muon flux from 14 July 2000 solar flare arrived at their detector. Through this measurement, they were able to estimate the primary proton flux for protons with energies greater than 40 GeV. In this section we compare their value with an estimate of the overall cosmic ray flux of protons with energies greater than 40 GeV." [quoting further from S. Al-Thoyaib, *J. King Saud Univ*. 18 pp. 19 - 34 (2005): "... this flare occupied an extended area along the solar equator and ... involved the whole central area of the Sun and ... had the highest flux recorded since the October 1989 event ..."]**

- ✓ **"Let us estimate the integrated cosmic flux of primary protons (before reaching the atmosphere). From cosmic rays section of PDG, we find (after performing an integration with a power-law exponent $\alpha = 3$) that $F_{\text{cosmic protons}}$ with ($E > 40$ GeV) is approximately equal to 6×10^{-3} cm^2-s-sr; (74) to be compared with the L3 Collaboration estimate of the primary proton flux from the giant solar flare of 14 July 2000 $F_{\text{L3 flare protons}}$ with ($E > 40$ GeV) is approximately equal to 2.6×10^{-3} cm^2-s-sr; (75) which is a significant fraction of the total cosmic ray proton flux. It is in reasonable agreement with the neutron monitors which report a fraction ranging between 0.2 and 0.6 as the increase in the number of observed particles for the same flare as compared to the background cosmic ray particle yields."**

- ✓ **"The above result is quite significant in that our proposed mechanism of acceleration is unique in predicting primary protons from a solar flare in this very high-energy range."**

- ✓ **"Lest it escape notice let us remind the reader that all three interactions of the Standard Model (electromagnetic, weak and nuclear) are essential for an understanding of these phenomena. Collective effects, but no new physics for the acceleration of electrons beyond the Standard Model needs to be invoked. We have seen, however, that certain paradigm shifts are necessary."**

Collective many-body nuclear effects occur in two realms

Condensed matter electromagnetic realm: mainly $e^* + p^+ \rightarrow n + \nu_e$ followed by n captures

- ✓ Substantial quantities of Hydrogen isotopes must be brought into intimate contact with 'fully-loaded' metallic hydride-forming metals; e.g., Palladium, Platinum, Rhodium, Nickel, Titanium , Tungsten, etc.; please note that collectively oscillating, 2-D surface plasmon (SP) electrons are intrinsically present and cover the surfaces of such metals. At 'full loading' of H, many-body, collectively oscillating 'patches' of protons (p^+), deuterons (d^+), or tritons (t^+) will form spontaneously at random locations scattered across such surfaces
- ✓ Or, delocalized collectively oscillating π electrons that comprise the outer 'covering surfaces' of fullerenes, graphene, benzene, and polycyclic aromatic hydrocarbon (PAH) molecules behave very similarly to SPs; when such molecules are hydrogenated, they can create many-body, collectively oscillating, 'entangled' quantum systems that, within context of W-L theory, are functionally equivalent to loaded metallic hydrides
- ✓ Born-Oppenheimer approximation breaks down in tiny surface 'patches' of contiguous collections of collectively oscillating p^+, d^+, and/or t^+ ions; enables E-M coupling between nearby SP or π electrons and hydrogen ions at these locations --- *creates local nuclear-strength electric fields*; effective masses of coupled electrons are then increased to some multiple of an electron at rest ($e \rightarrow e^*$) determined by required simultaneous energy input(s)
- ✓ System must be subjected to external non-equilibrium fluxes of charged particles or E-M photons that are able to transfer input energy directly to many-body SP or π electron 'surface films.' Examples of such external energy sources include (they may be used in combination): electric currents (electron 'beams'); E-M photons (e.g., emitted from lasers, IR-resonant E-M cavity walls, etc.); pressure gradients of p^+, d^+, and/or t^+ ions imposed across 'surfaces'; currents of other ions crossing the 'electron surface' in either direction (ion 'beams'); etc. Such sources provide additional input energy that is required to surpass certain minimum H-isotope-specific electron-mass thresholds that allow production of ULM neutron fluxes via $e^* + p^+$, $e^* + d^+$, or $e^* + t^+$ weak interactions

Plasma electromagnetic realm: mainly $e^- + p^+ \rightarrow lepton + X$ and on dust grains $e^* + p^+ \rightarrow n + \nu_e$

- ✓ At minimum, one needs protons (p^+ Hydrogen) and electrons embedded in organized magnetic fields with variable geometries; this is what we call the "W-L magnetic field regime on large length scales" --- it involves transfers of energy between collections of charged particles via magnetic fields (high, short-range electric fields not important). When charged nanoparticles (dust grains) are also present within a plasma (dusty plasma) condensed matter ULM neutron LENRs may occur on dust surfaces in parallel with plethora of high-energy charged particle reactions in gas

W-L theory extends from microcosm to macrocosm

Many-body collective effects occur from nano up to very large length-scales

Electromagnetic regimes encompass realms of condensed matter and plasmas

Length Scale	Type Of System	Electromagnetic Regime	Collective LENR Phenomena	Comment
Submicron	Certain earthly bacteria and fungi	Very short-range electric or magnetic fields	Transmutations, high level gamma shielding	Obtain unavailable trace elements; survive deadly gamma/X-ray radiation
Microns	Hydrogen isotopes on metallic surfaces	Very high, short-range electric fields on solid substrates	Transmutations, high level gamma shielding, heat, some energetic particles	This regime is useful for small-scale commercial power generation
Microns to Many Meters	Exploding wires, planetary lightning	Dusty plasmas: mixed high-current and high local magnetic fields	Transmutations, 'leakier' gamma shielding, heat; X-rays up to 10 keV, larger energetic particle fluxes	This regime is useful for large-scale commercial power generation
Many Meters to Kilometers	Outer layers and atmospheres of stars (flux tubes)	Dusty plasmas: high mega-currents and very large-scale, highly organized magnetic fields	Transmutations, large fluxes of energetic particles (to GeVs), limited gamma shielding, X-rays	Solves mysteries of heating of solar corona and radioactive isotopes in stellar atmospheres
Up to several AU (distance from earth to sun)	Active galactic nuclei in vicinity of compact, massive objects (black holes)		Energetic particles (GeVs), gamma-ray bursts (GRBs) and ultra-high energy cosmic rays (TeVs)	Solves several unexplained astronomical mysteries

N.B. - mass renormalization of electrons by high local E-fields *not* a key factor in magnetically dominated regimes on large length scales

Neutron/charged particle energies range from ULM to TeVs

Short-Range Collective Electric Field Effects Dominate

Longer-Range Collective Magnetic Field Effects Begin to Dominate

Long-Range Collective Magnetic Field Effects Dominate

Regime of mostly low energy nuclear reactions: LENRS dominate

W-L: $e^* + p^+ \rightarrow$ 1 neutron + neutrino or $e^* + d^+ \rightarrow$ 2 neutrons + neutrino

Neutron production & capture release energy, create transmutation products

low or no current

- Microorganisms – biological transmutations by certain types of earthly bacteria & fungi
- Pressure gradients across membranes – e.g., Iwamura, Li, & Arata/Zhang - gas phase
- Current-driven P&F-type chemical cells - liquid phase; glow discharge cells - gas phase
- Laser-triggered chemical cells – e.g., Letts, Cravens, Violante, etc. - liquid or gas phase
- RF-triggered dusty plasmas - gas phase

High current

- Current-driven dusty plasmas - gas phase
- Vacuum diodes – e.g. Proton-21, Kiev, Ukraine, Sandia NL (US) in 1970s - gas phase
- Exploding wires – e.g., Wendt & Irion, Chicago 1922; Z-pinch, Sandia NL - gas phase
- Magnetic flux compression generators, e.g. US (LANL), Russia
- Lightning (terrestrial, planetary, nebular), especially in dusty environments – e.g., Dwyer
- ULMN-catalyzed subcritical fission reactors (<<< nuclear waste) - reprocess old wastes

Higher fluxes of neutrons

Scales-up to very large length scales — Wide range of magnetic field strengths

W-L mixed regime: high energy particle reactions and/or LENRs on 'dust'

Magnetic effects dominate large length-scale plasmas: $e^- + p^+ \rightarrow$ lepton + X

mega currents

- Stars – additional nuclear reactions occur in photospheres and further out thru coronas
- Dusty, hydrogen-rich nebular plasma clouds exposed to stellar photon and particle radiation
- Magnetars/active galactic nuclei: W-L-S mechanism can theoretically create UHE cosmic rays)

>>>> fluxes

~0 eV Ultra low momentum neutrons .... MeV neutrons ...GeV neutrons ...TeVs

Increasing neutron and charged particle energies

W-L: nucleosynthesis also occurs *outside* of stellar cores

- ✓ Except for Big Bang hydrogen/deuterium and helium, the vast majority of astrophysicists believe that most elements in the Universe lighter than Iron (Fe) were created by charged-particle fusion reactions inside cores of stars
- ✓ Elements heavier than Fe thought to be created mainly via neutron capture (absorption) nucleosynthetic reactions in stars. Two major types of such neutron capture processes thought to occur in hot stellar plasmas:
  - ✓ s-process (slow) occurs in stars, e.g., red giants; neutron flux $10^5 – 10^{11}$ cm^2/sec
  - ✓ r-process (rapid) occurs in supernova explosions; neutron flux > 10^{22} cm^2/sec
- ✓ Heavier elements (A > Fe) are mostly thought to be formed in successive cycles of neutron creation, neutron capture, neutrino production, beta decays of unstable neutron-rich isotopes, and ultimately, stable element production

Artist's conception: red giant star from surface of an orbiting planet

Condensed matter (CM) LENRs:

are similar to stars in that W-L ULM neutron fluxes in CM can range from 10^9 - 10^{16} cm^2/sec

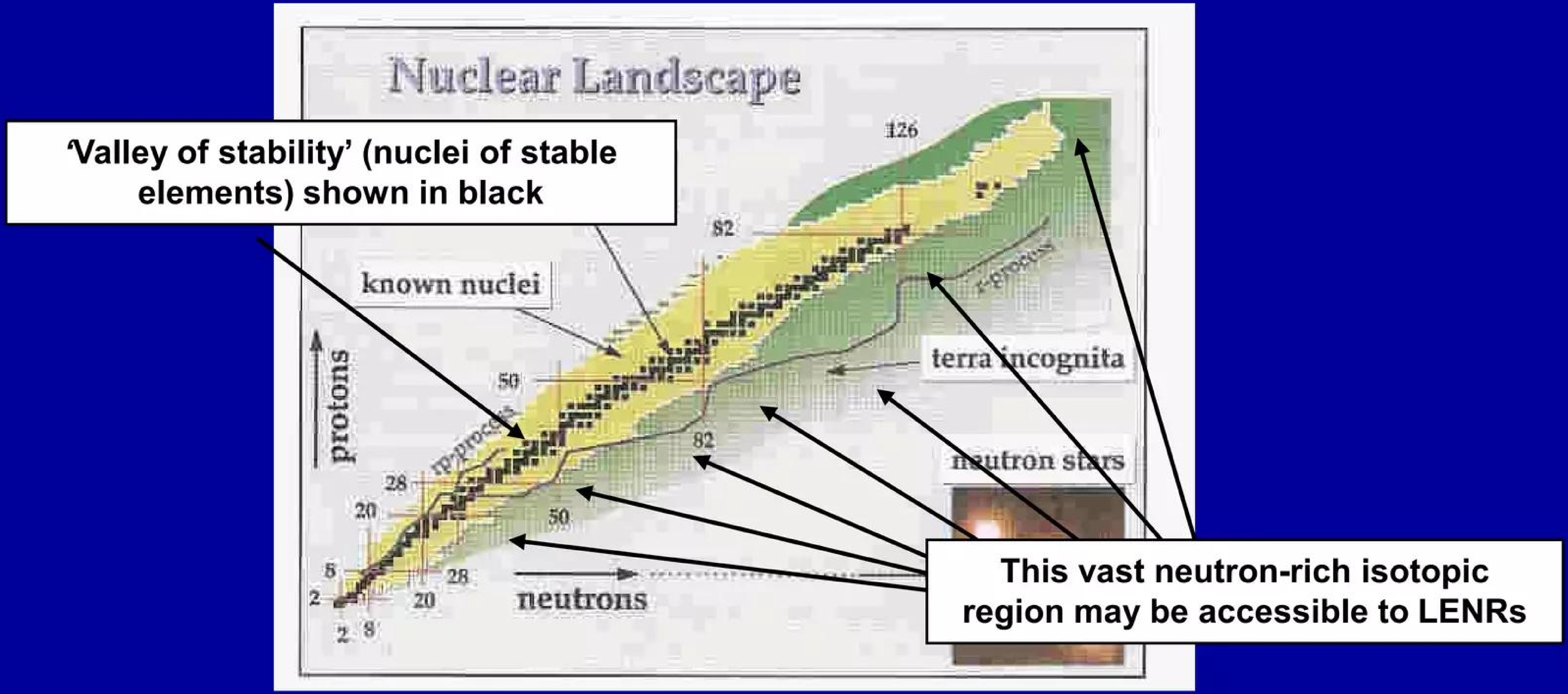
Different from stars in that neutrons created via the weak interaction in CM LENR systems can be ultra low momentum; vastly larger capture cross-sections

Also unlike stars, little gamma photodissociation in CM; net rate of nucleosynthesis can sometimes be higher in CM LENR systems than in many stellar environments


Supernova remnant

Vast isotopic parameter space may be accessible to LENRs

'Map' of stable and unstable isotopes that might be produced in LENR condensed matter systems



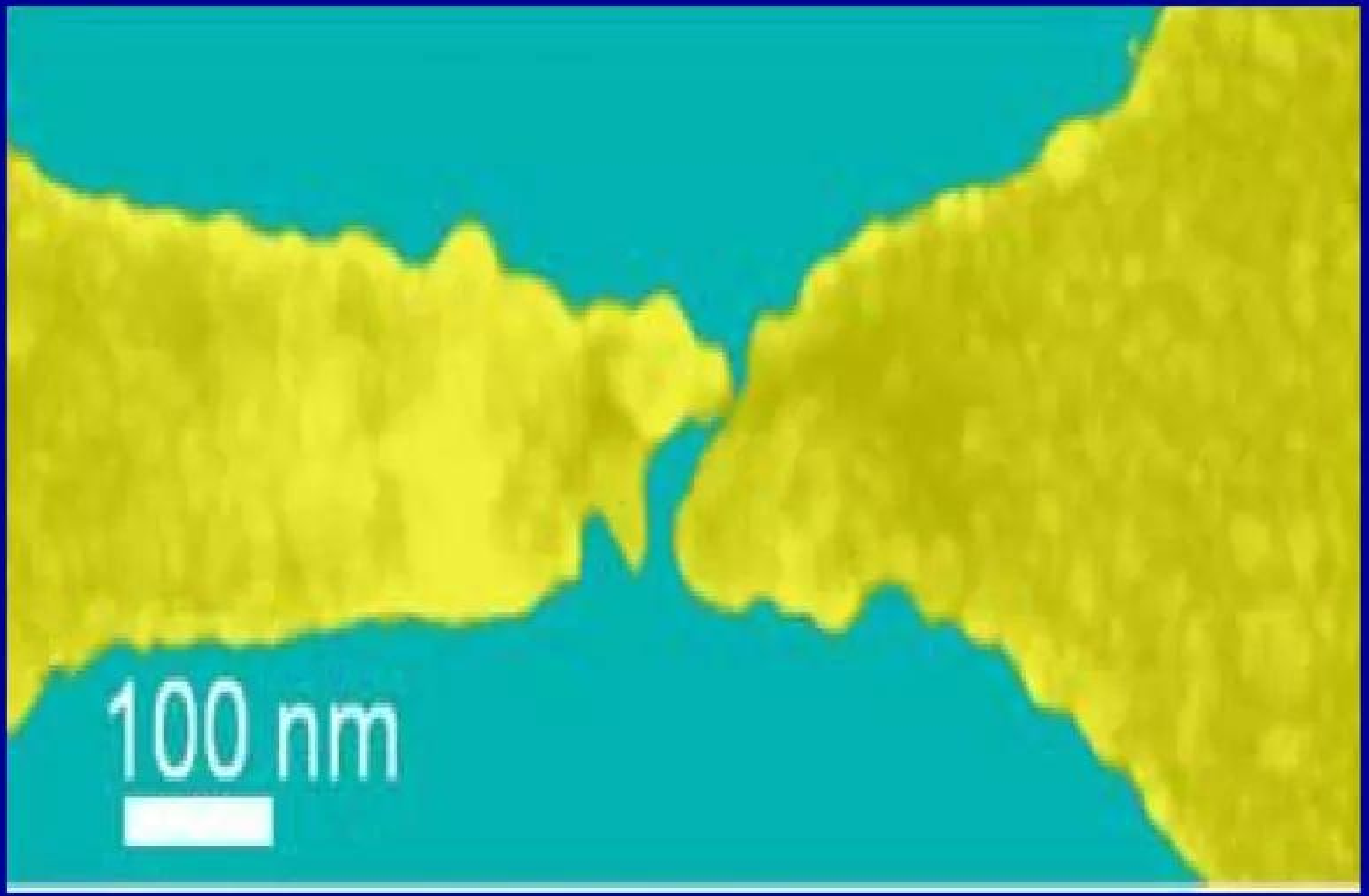
LENR neutron-catalyzed weak interaction transmutations: involve a combination of neutron production, neutron capture, and energetic beta decays of neutron-rich isotopes. LENRs can move back and forth between producing stable products in the (black) valley of stability to unstable β-decay isotopes located in neutron-rich (greenish) regions to the right of it. This is very similar to s- and r-process neutron-capture nucleosynthesis in stars, only at vastly lower temperatures/pressures

Commercializing a Next-Generation Source of Safe Nuclear Energy

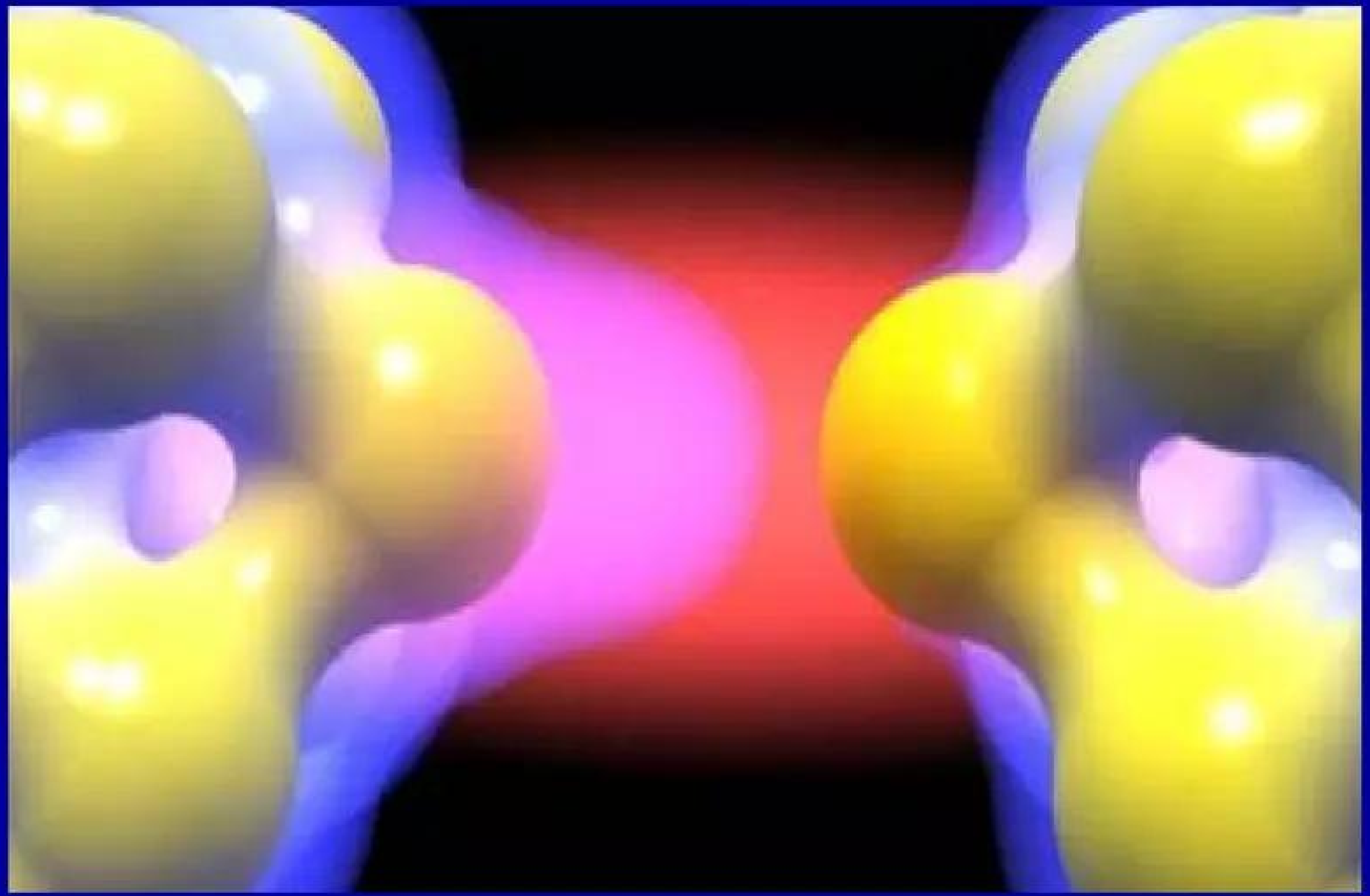
Condensed matter realm: LENR-active surfaces on dust

Time-varying E-M, chemical, and nuclear processes operate together

Artist's rendering (right) shows how surface plasmons on the surface of a pair of nanoscale gold (Au) nanotips (SEM image to left) concentrate incident light from a commercial laser, amplifying it locally by a factor of 1,000x



Credit: Natelson Lab/Rice University



Credit: Natelson Lab/Rice University

Reference for two above images: "Optical rectification and field enhancement in a plasmonic nanogap," D. Ward et al., *Nature Nanotechnology* 5 pp. 732–736 (2010)

"Metal nanostructures act as powerful optical antennas because collective modes ... are excited when light strikes the surface ... [their] plasmons can have evanescent electromagnetic fields ... orders of magnitude larger than ... incident electromagnetic field ... largest field enhancements ... occur in nanogaps between ... nanostructures."

Similarly: "Extraordinary all-dielectric light enhancement over large volumes," R. Sainidou et al., *NANO Letters* 10 pp. 4450–4455 (2010)

" ... allow us to produce arbitrarily large optical field enhancement using all dielectric structures ... measure the enhancement relative to the intensity of the incident light. ... if absorption losses are suppressed, resonant cavities can pile up light energy to create extremely intense fields ... no upper bound to the intensity enhancement factor that these structures can achieve ...[certain factors] limit it to around 4 orders of magnitude in practice."

Condensed matter realm: LENR-active surfaces on dust

Time-varying E-M, chemical, and nuclear processes operate together

- ✓ LENR 'hot spots' create intense local heating and variety of surface features such as 'craters'; over time, LENR-active surfaces experience major micron-scale changes in nanostructures/composition. On LENR-active substrate surfaces, there are a myriad of different complex, nanometer- to micron-scale electromagnetic, chemical, and nuclear processes *operating in parallel.* LENRs involve interactions between surface plasmons, E-M fields, and many different types of nanostructures with varied geometries, surface locations relative to each other, and chemical/isotopic compositions
- ✓ To greater or lesser degrees, many of these very complex, time-varying surface interactions are electromagnetically coupled on many different physical length-scales; E-M resonances are important
- ✓ Surface plasmons and their interactions with nanostructures/nanoparticles enable physics regime that permits LENRs to occur in condensed matter systems under relatively mild *macroscopic* conditions (cores of stars, fission reactors, or supernovas are not required). In concert with many-body, collective Q-M effects, SPs also function as two-way 'transducers,' effectively interconnecting the otherwise rather distant realms of chemical and nuclear energies
- ✓ Please be aware that a wide variety of complex, interrelated E-M phenomena may be occurring simultaneously in parallel in different nm to μ-scale local regions on dust grain surfaces. Some regions may be absorbing E-M energy locally, while others nearby can be emitting energy (e.g., as energetic electrons, photons, other charged particles, etc.). At the same time, energy can be transferred from regions of resonant absorption or 'capture' to other regions in which emission or 'consumption' is taking place: e.g., photon or electron emission, and/or LENRs in which [E-M field energy] + $e^- \rightarrow e^* + p^+ \rightarrow n_{ulm} + \nu$ --- in LENRs, electrons and protons (particles) are truly destroyed!

W-L: nucleosynthesis can also potentially occur on ‘dust’

Mixed regime of high energy particle reactions and LENRs

- Stars – additional nuclear reactions occur in photospheres and out thru coronas
- Dusty, hydrogen-rich nebular ‘clouds’ commonly found in star-forming regions
- Magnetars & active galactic nuclei (W-L-S mechanism creates UHE cosmic rays)

- ✓ Very dusty, hydrogen-rich nebular ‘clouds’ found in star-forming regions of galaxies provide a comparatively low-energy, less ionized astrophysical environment in which an array of carbon-based molecules can coexist in abundance. Within these comparatively dense, somewhat opaque ‘clouds,’ carbon-based moieties coexist with hydrogen and are intimately associated with dust particles (which themselves contain a wide variety of elements, including many metals)
- ✓ All of this matter is periodically bathed in varying amounts of stellar photon radiation ranging from infrared to ultraviolet wavelengths; in some cases, it is also directly exposed to streams of charged particles, e.g., protons from stellar ‘winds.’ Some astrophysicists even believe that huge lightning bolts occur inside such clouds; may also happen in atmospheres of gas giant planets
- ✓ Astronomers have detected large quantities of PAHs, e.g., Phenanthrene, in such star-forming regions; many believe that PAHs are actually synthesized therein through an interaction of energetic photon radiation with simpler carbon structures on dust surfaces
- ✓ While hydrogen gas pressures are vastly lower in such stellar nurseries, physical conditions inside them otherwise resemble Mizuno’s Phenanthrene experiments in many key ways. If that analogy is proper, then W-L theory would predict that LENR nucleosynthesis can occur there

LENRs may occur on 'dust' in many parts of the Universe

"The composition, structure, and size distribution of interstellar grains is the result of injection of dust from stellar outflows into the interstellar medium (ISM), followed by destruction, growth, coagulation, and photoprocessing of interstellar grains. The balance among these poorly-understood processes is responsible for the mix of solid material present in the ISM. **Most interstellar grain material present in the diffuse ISM must be grown *in* the ISM**. The amorphous silicate and carbonaceous materials that form the bulk of interstellar dust must therefore be the result of grain growth in the presence of ultraviolet radiation. **Dust in high-Z systems such as J1148+5251 is also produced primarily in the ISM, with supernova-produced dust contributing only a small fraction of the total dust mass."**

"The wavelength-dependent extinction of starlight – the so-called "extinction curve" – remains the principal source of information about interstellar dust ... The extinction curve contains spectral features that constrain the composition of the dust. The strongest feature by far is a broad "bump" peaking near 2175°A. The strength of this feature requires that it be produced by a substance composed of high-abundance elements, such as C, Mg, Si, or Fe (Draine 1989). The position of the feature, and its width, are strongly suggestive of π -> π^* excitations in aromatic carbon, such as graphite or polycyclic aromatic hydrocarbons. Some authors (e.g., Draine & Li 2007) think that the **feature is produced by the large population of polycyclic aromatic hydrocarbons that is required to explain a number of infrared emission features."**

"Large a > 0.02μm grains in the local starlight background will be heated to a more-or-less steady temperature of 15 - 20K. However, very small grains (1) absorb photons much less frequently, and (2) have very small heat capacities, so that one absorbed photon can raise the grain to a high temperature, followed by very rapid cooling …. Perhaps 2/3 of C is in dust … There is a substantial population of PAHs that contains ~10–20% of the interstellar C in the Milky Way; ~4 - 5% of the total grain mass is contributed by PAHs in the Milky Way and other star-forming galaxies with ~solar metallicity (Draine et al. 2007) … ***Most interstellar dust is not stardust*** … Stardust accounts for only ~4% of the total mass of interstellar dust … *Most of the material in interstellar grains was formed in the ISM* … . The resulting grain material(s) will undergo heavy UV irradiation … Hydrogenation … This surface site is being bombarded by H atoms at a rate …Observations of quasars and luminous galaxies at high redshift have detected large masses of dust in a number of systems (Wang et al. 2008) …Grain destruction in the ISM is such that ~<10% of the interstellar dust mass consists of "stardust" from stellar sources, including supernovae. ***The bulk of interstellar dust has been grown in the ISM.*** **" [per W-L, LENRs may occur in such systems]**

B. T. Draine, "Interstellar Dust Models and Evolutionary Implications," arXiv:0903.1658v1 [astro-ph.GA] 9 Mar 2009

See: http://arxiv.org/PS_cache/arxiv/pdf/0903/0903.1658v1.pdf

Isotope anomalies in solar dust-derived meteoritic materials

Extraordinary Nitrogen isotope anomalies in Isheyevo primordial chondrite - I

- ✓ **If as we have just discussed, LENR-based nucleosynthesis associated with PAHs theoretically occurred on surfaces of dust particles in the early solar nebula 4^{+} billion years ago, then what sort of experimental evidence of such ancient, ex-core nuclear processes might be found today?**

  - **Criteria 1: such isotopic anomalies produced by LENRs should be found in micron-scale 'patches,' probably no larger than 100 - 200 microns in diameter, located on the surfaces of so-called 'primordial grains' of material (xenoliths) embedded in somewhat younger, thermally processed materials comprising meteoritic bodies such as chondrites**

  - **Criteria 2: residues of some sort of organic carbon-based molecules (especially PAHs) should also be detected in some fashion at such sites**

  - **Criteria 3: if LENRs took place with ULM neutrons being captured by PAH ring carbon atoms located in PAH 'patches' on nebular dust grain surfaces, Nitrogen should be produced by the W-L Carbon-seed nucleosynthetic network (SlideShare Sept. 3, 2009). Similar to $^{14}N/^{15}N$ anomalies that IAEA found in coke ovens at a South African steelmaking facility, there should also be significant enrichment of neutron-rich ^{15}N in such locations and accordingly anomalous $^{14}N/^{15}N$ isotopic ratios at those same localized sites**

- ✓ **As we predicted: just such local anomalies involving neutron-rich ^{15}N meeting these criteria have been observed and were reported in a paper by Briani et al. that was published in the *PNAS* in May 2009, "Pristine extraterrestrial material with unprecedented nitrogen isotopic variation"**

Isotope anomalies in solar dust-derived meteoritic materials

Extraordinary Nitrogen isotope anomalies in Isheyevo primordial chondrite - II

- ✓ Isotopic data reported in Briani et al.'s paper is truly fascinating. To obtain it, they utilized a unique, multi-million $ mass spectroscopy instrument, a CAMECA NanoSIMS 50, that has the ability to perform detailed isotopic analyses on surface 'spots' down to 50 nm in size
- ✓ Quoting: "Pristine meteoritic materials carry light element isotopic fractionations that constrain physiochemical conditions during solar system formation. Here we report the discovery of a unique xenolith in the metal-rich chondrite Isheyevo … PX-18 is a dark xenolith (380 x 470 microns^2), dominated by a very fine-grained matrix, mainly composed of anhydrous Mg-rich silicates with tiny Fe-Ni sulfides grains and magnetite … In addition to the diffuse distribution of ^{15}N-enriched material, forty-six ^{15}N hotspots with extremely high $^{15}N_{AIR}$ were observed in PX-18 (Fig. 2B). These hotspots, with areas of approximately 1 micron^2, are distinct from the aforementioned, broad ^{15}N-enriched zones … These hotspot subregions are the highest $^{15}N_{AIR}$ values ever measured in solar system material … Together, these observations lead to the conclusion that ^{15}N hotspots in PX-18 are due to the presence of organic matter (OM)."
- ✓ Comment: as predicted, they observed a high localization of ^{15}N isotope anomalies in micron-scale 'hot spots' that were clearly associated with organic matter. Briani et al. could not fully explain the anomalies with 'fractionation' processes and concluded that, "The results call for a new theoretical and experimental approach."

Please see:

→ "Pristine extraterrestrial material with unprecedented nitrogen isotopic variation," G. Briani, , M. Gounelle, Y. Marrocchi, S. Mostefaoui, H. Leroux, E. Quirico, and A. Meibom, *PNAS* 10.1073 – pnas 0901545106 (2009)

The 6-page article can be purchased from PNAS for $10 and downloaded from the following URL:

http://www.pnas.org/content/early/2009/06/15/0901546106.abstract

→ A free package of supplementary technical information may be downloaded from:

http://www.pnas.org/content/suppl/2009/06/15/0901546106.DCSupplemental/0901546106SI.pdf

→ A free copy of a conference presentation summary may be downloaded from:

http://www.lpi.usra.edu/meetings/lpsc2009/pdf/1642.pdf [two Figs. from this appear on the next Slide]

→ Quoting from the abstract: "An extreme continuum of N isotopic variation is present in this xenolith: from very light N composition similar to that inferred for the solar nebula to the heaviest ratios measured in any solar system material."

Isotope anomalies in solar dust-derived meteoritic materials

Extraordinary Nitrogen isotope anomalies in Isheyevo primordial chondrite - III

Quoting from their conference presentation: "These observations lead to the conclusion that ^{15}N isotopic variation in PX-18 are due to the presence of diffuse organic matter with a range in $\delta^{15}N^{AIR}$ that greatly expands the range for a single extraterrestrial object or isolated IOM. Excluding a stellar nucleosynthesis origin (i.e. related to presolar grains) for the observed N isotopic anomalies, values of $\delta^{15}N^{AIR}$ as high as those observed in PX-18 can be produced only by low-temperature ion-molecule reactions. In the most recent model for N-containing molecules chemistry under dark molecular cloud conditions [15], values of $\delta^{15}N^{AIR}$ > 9000‰ are obtained for external layers of NH^3 ice accreted on dust grains. Transfer of fractionated N from NH^3 ice to organic matter is possible by UV-induced transformations in poly-cyclic aromatic hydrocarbons [16]. However, a fundamental problem is that low temperature ion-molecule reactions are also predicted to produce strong deuterium enrichments in organic matter [17], which are not found in Isheyevo PX-18 or any other xenolith in Isheyevo. **These results call for a new theoretical and experimental approach, which must be able to provide an explanation for the decoupling of these light elements isotopic variations as well as for the high values measured in the hotspots."**

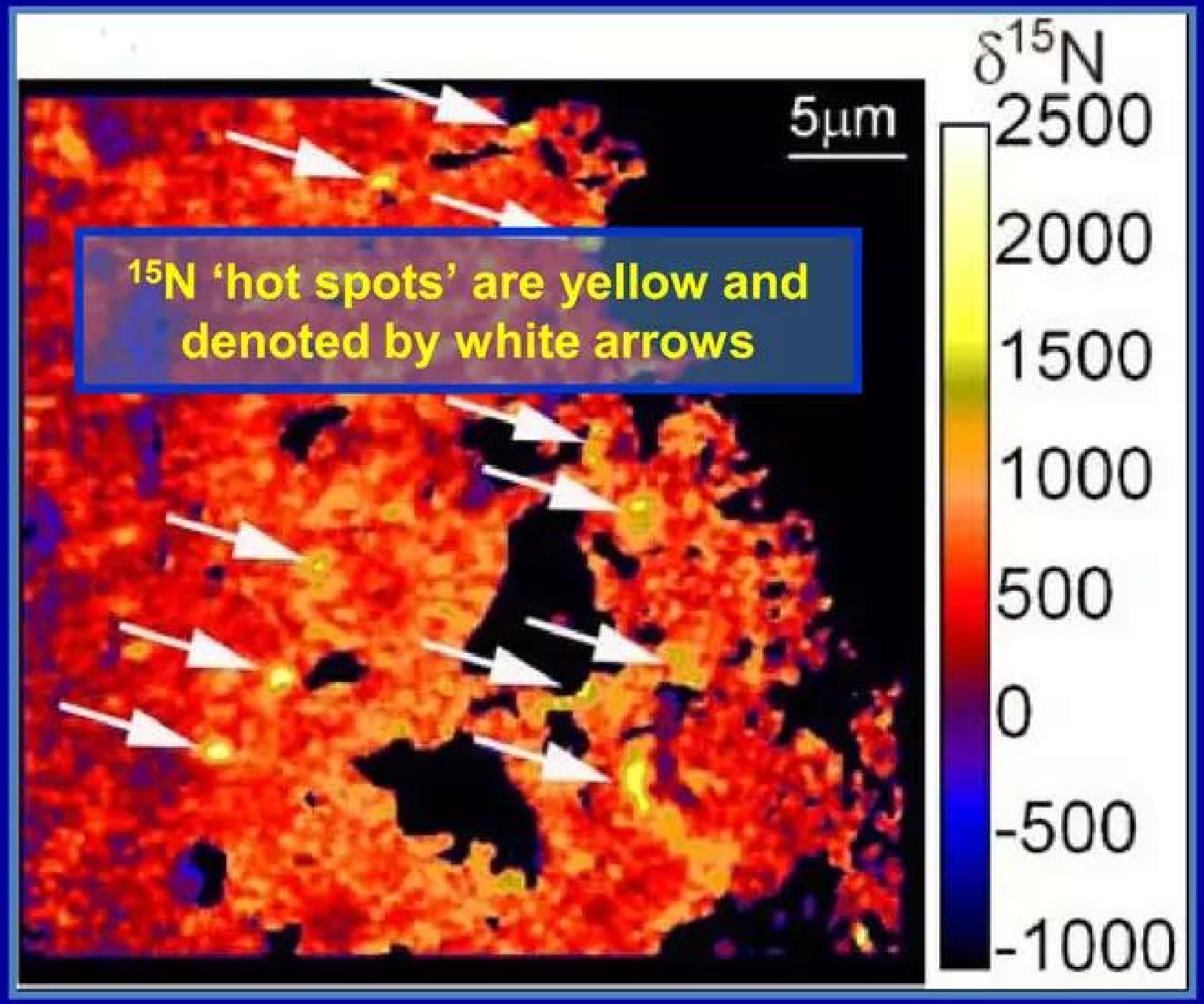


Figure 2. $\delta^{15}N^{AIR}$ **distribution of a 40×40 μm² region in PX-18, with mean** $\delta^{15}N^{AIR}$ **= 640 ± 11‰. About 90% of this image is characterized by** $\delta^{15}N^{AIR} \geq$ **250‰. Several hotspots are also visible (white arrows).**

Source: http://www.lpi.usra.edu/meetings/lpsc2009/pdf/1642.pdf

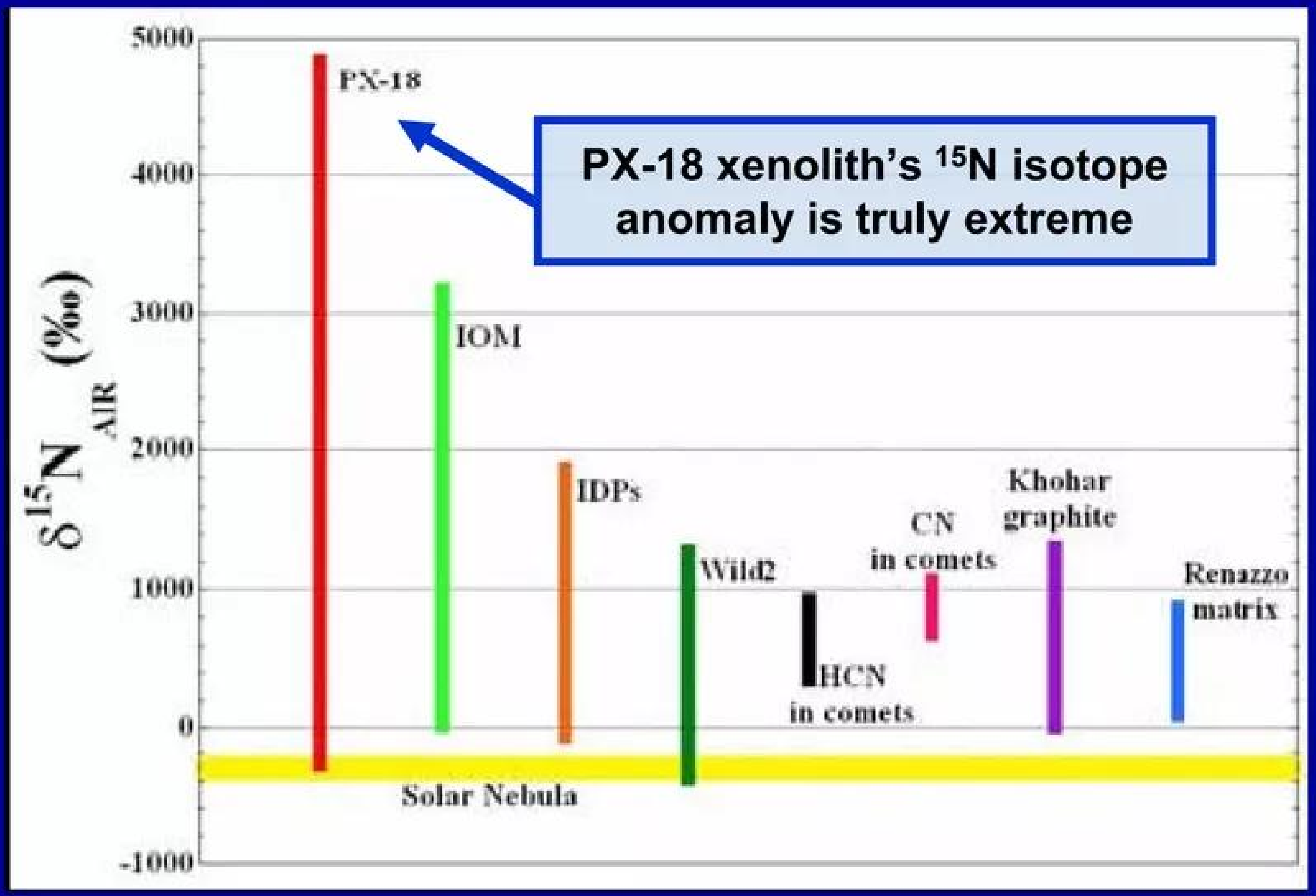
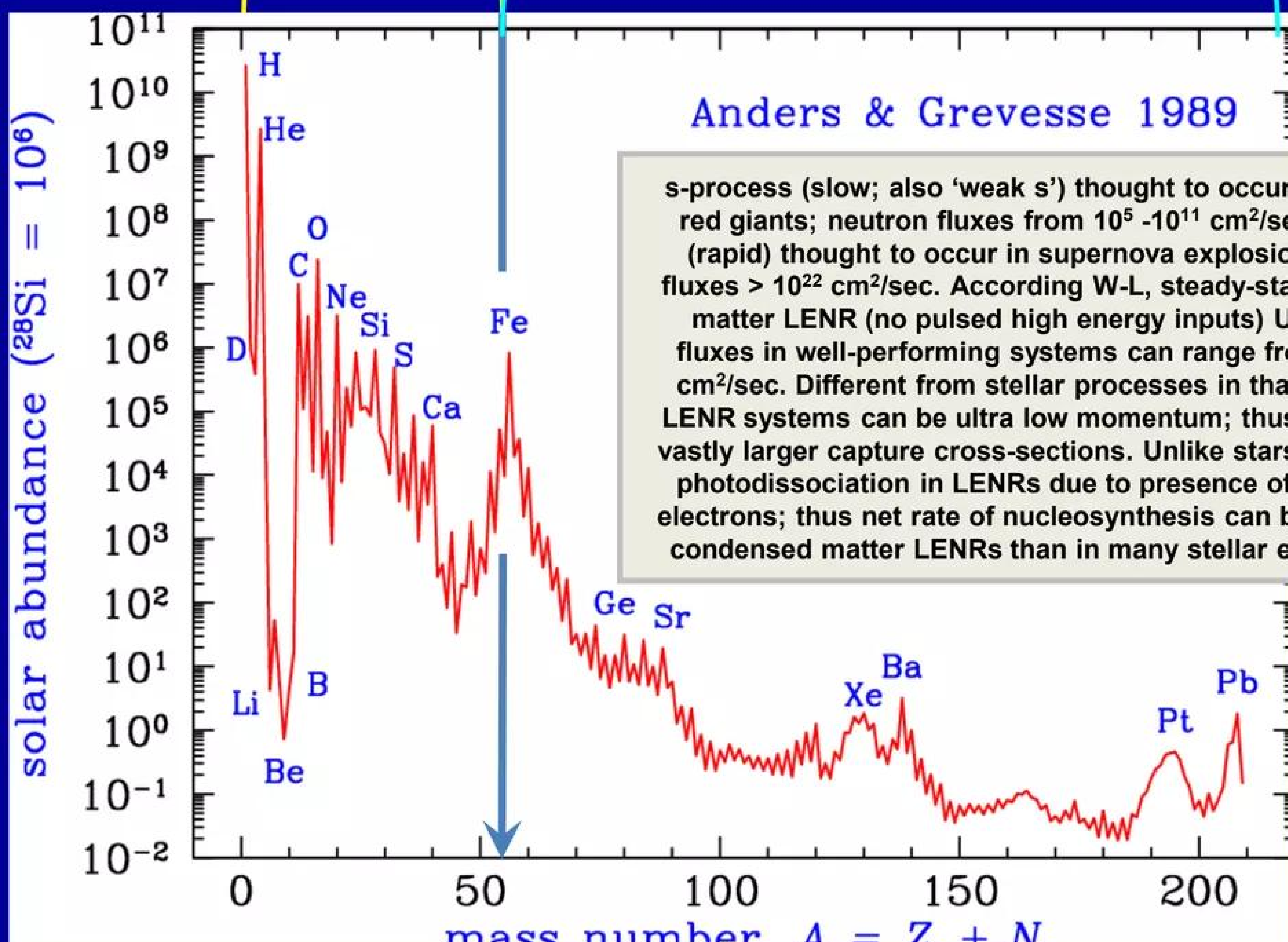


Figure 3. $\delta^{15}N^{AIR}$ **values measured in PX-18, compared with previous measurements in other Solar System materials. Ranges reported in the figure comprise results from bulk measures as well as from hotspots (data from literature).**

W-L optical model & Miley exp. data vs. solar abundance

Region of charged-particle nuclear fusion reactions in stars

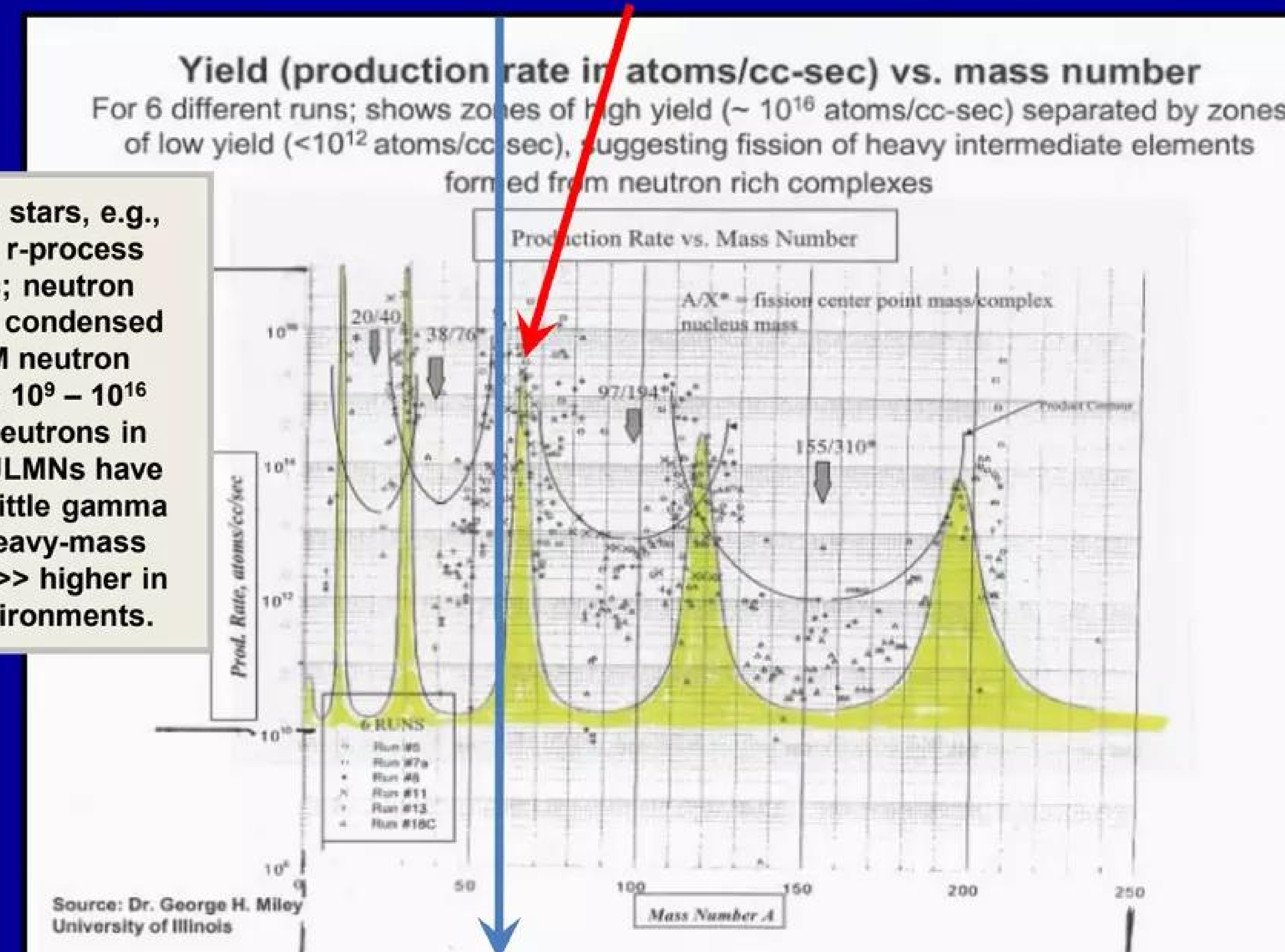
Region of stellar nucleosynthetic processes driven by neutron production and capture: mixture of so-called s- and r-processes



s-process (slow; also 'weak s') thought to occur in stars, e.g., red giants; neutron fluxes from 10^5 -10^{11} cm^2/sec; r-process (rapid) thought to occur in supernova explosions; neutron fluxes > 10^{22} cm^2/sec. According W-L, steady-state condensed matter LENR (no pulsed high energy inputs) ULM neutron fluxes in well-performing systems can range from 10^9 – 10^{16} cm^2/sec. Different from stellar processes in that neutrons in LENR systems can be ultra low momentum; thus ULMNs have vastly larger capture cross-sections. Unlike stars, little gamma photodissociation in LENRs due to presence of heavy-mass electrons; thus net rate of nucleosynthesis can be >> higher in condensed matter LENRs than in many stellar environments.

Solar abundance data ca. 1989 per Anders & Grevesse

Peak Point #3: W-L optical model predicts that stable LENR transmutation products should strongly accumulate at approximately Mass # A ~ 63 - 66; this corresponds well to Miley condensed matter transmutation data. Condensed matter LENR neutron capture processes can operate at all values of A from 1 (H) to 200+ (beyond Pb)



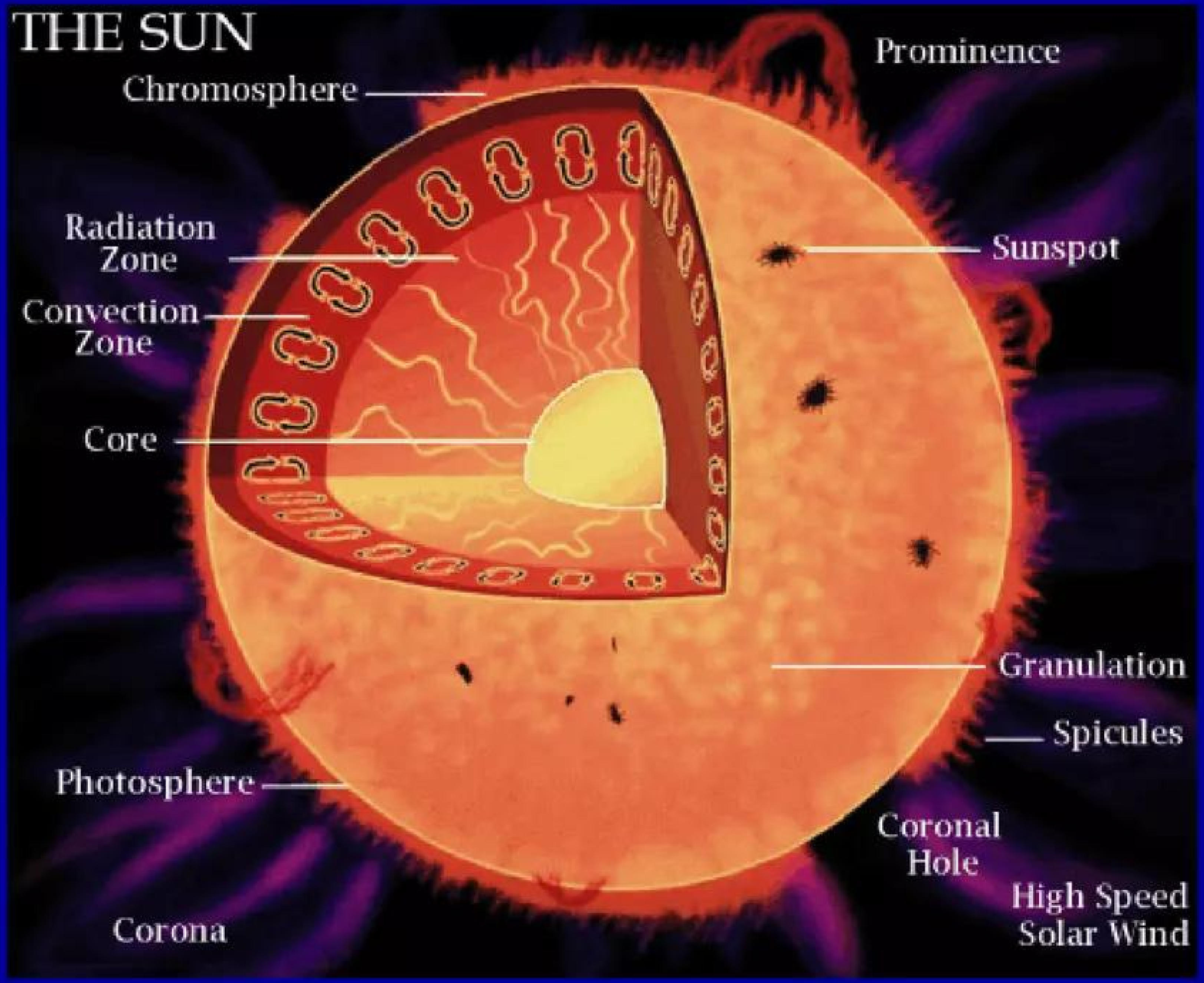
Fe at A ~56

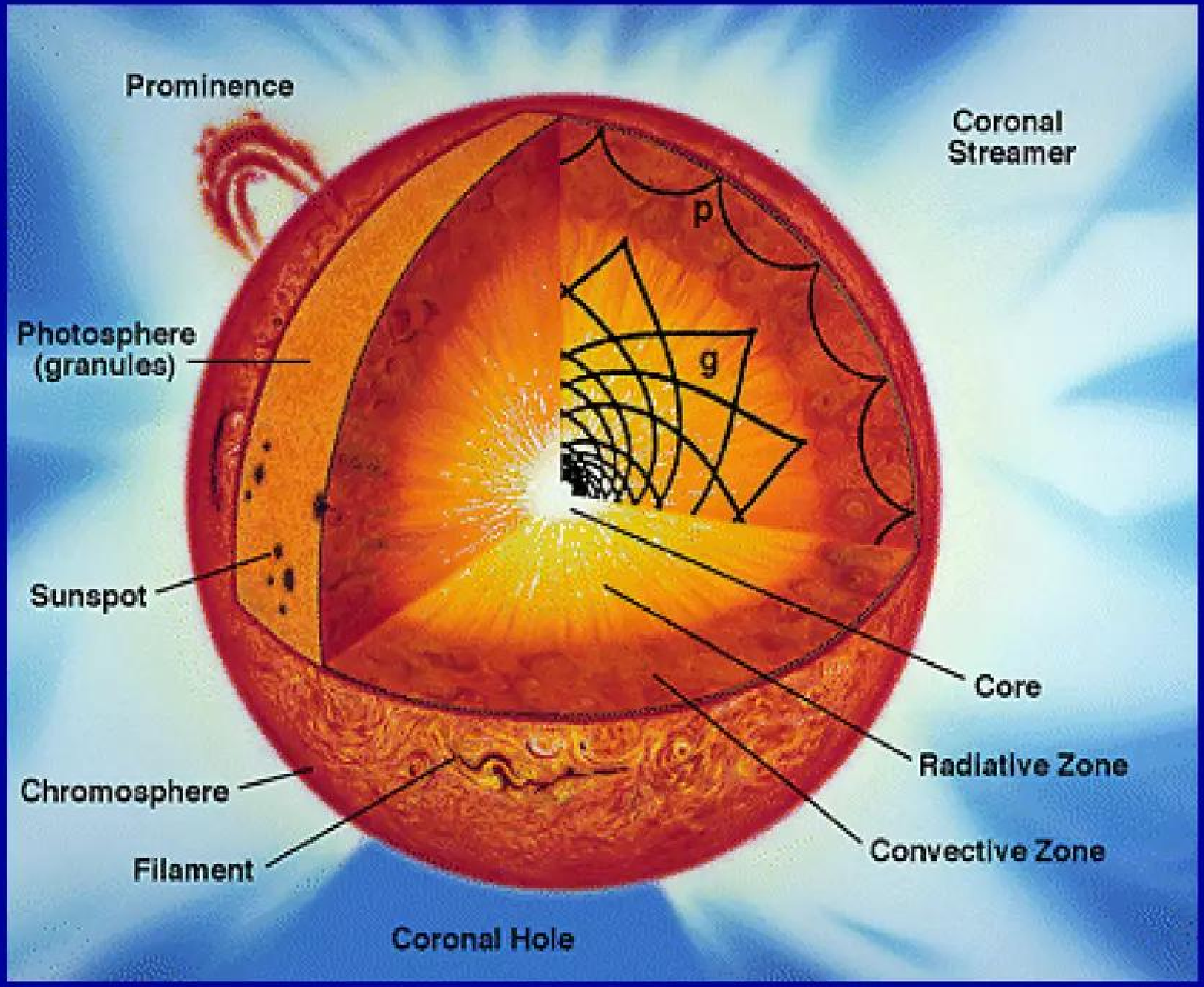
W-L optical model superimposed on G. Miley's ca.1996 data

Solar abundance data reflects the integrated cumulative results of stellar nucleosynthetic processes operating in super-hot plasmas across distances of AUs to light years and time spans of up to billions of years. By contrast, Miley's condensed matter LENR transmutations occurred in a volume of less than a liter over several weeks at comparatively low temperature and pressures

Present astrophysical paradigms - Sun's internal structure

Modern thinking about solar structure and nucleosynthesis began in 1938-39



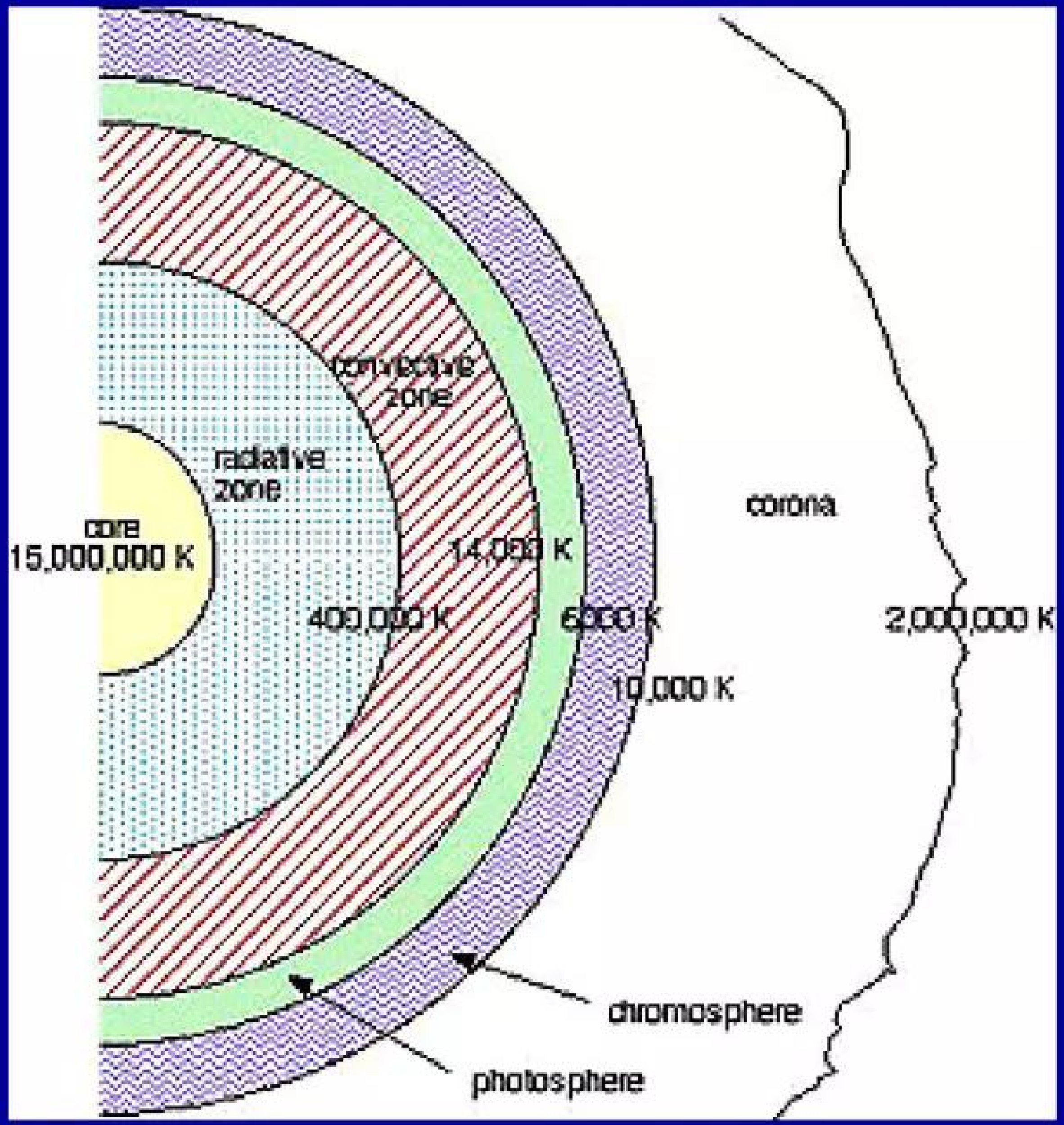


Our modern understanding of stellar nuclear processes really began with key concepts presented in Hans Bethe's landmark paper, "Energy production in stars," *Physical Review* 55 pp. 434 - 456 (1939). If you would like to read this seminal work, for free copy go to URL = http://prola.aps.org/pdf/PR/v55/i5/p434_1

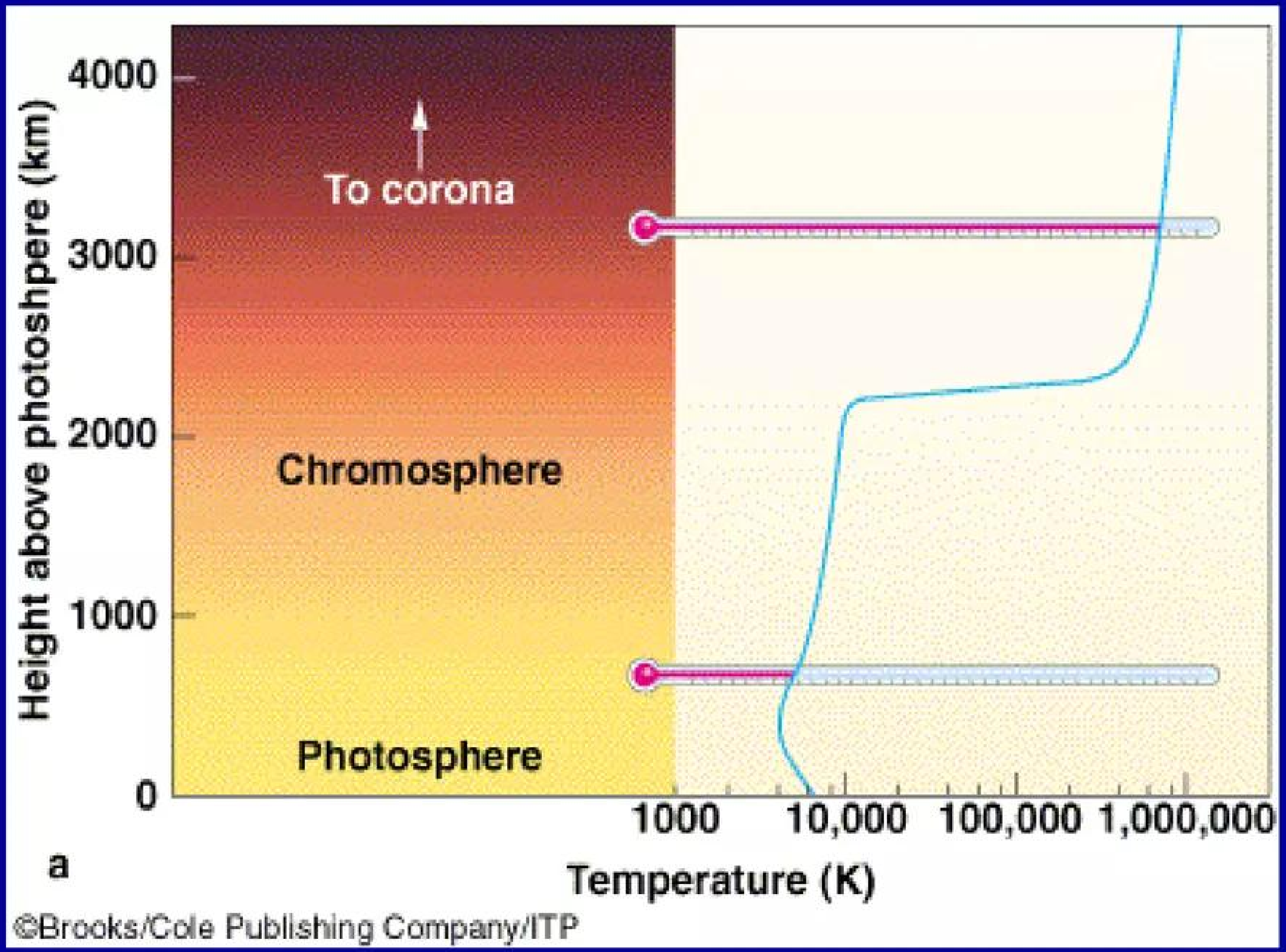
Based on this early work, energy production in stars like the Sun or smaller is presently thought to occur mostly via *pp* chains; in many larger, hotter stars the CNO cycle appears to be a widespread mechanism

Present astrophysical paradigms - Sun's internal structure

Schematic side view: layers and temperatures inside Sun



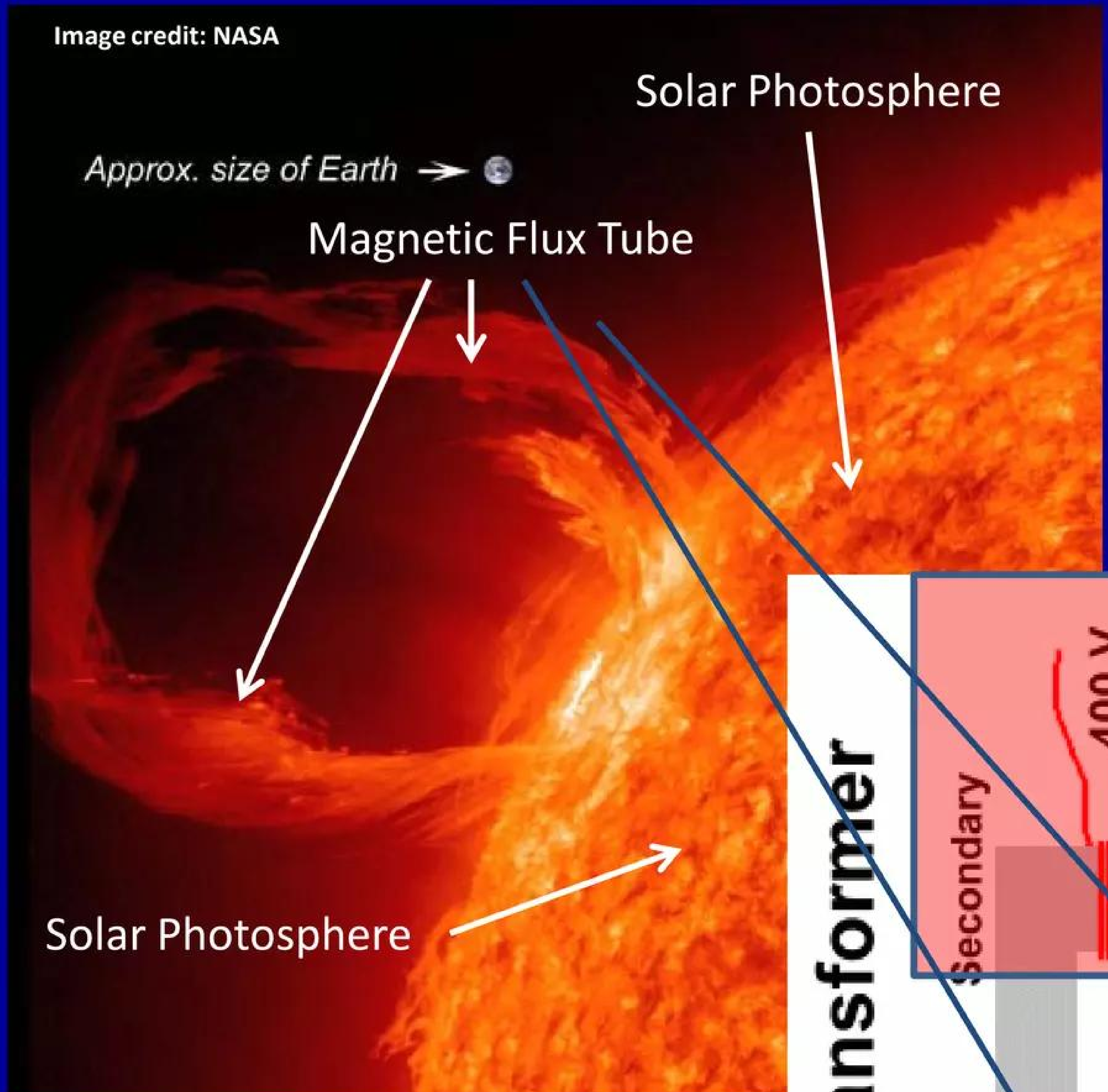
Sun's layers and temperatures vs. height (km) above photosphere

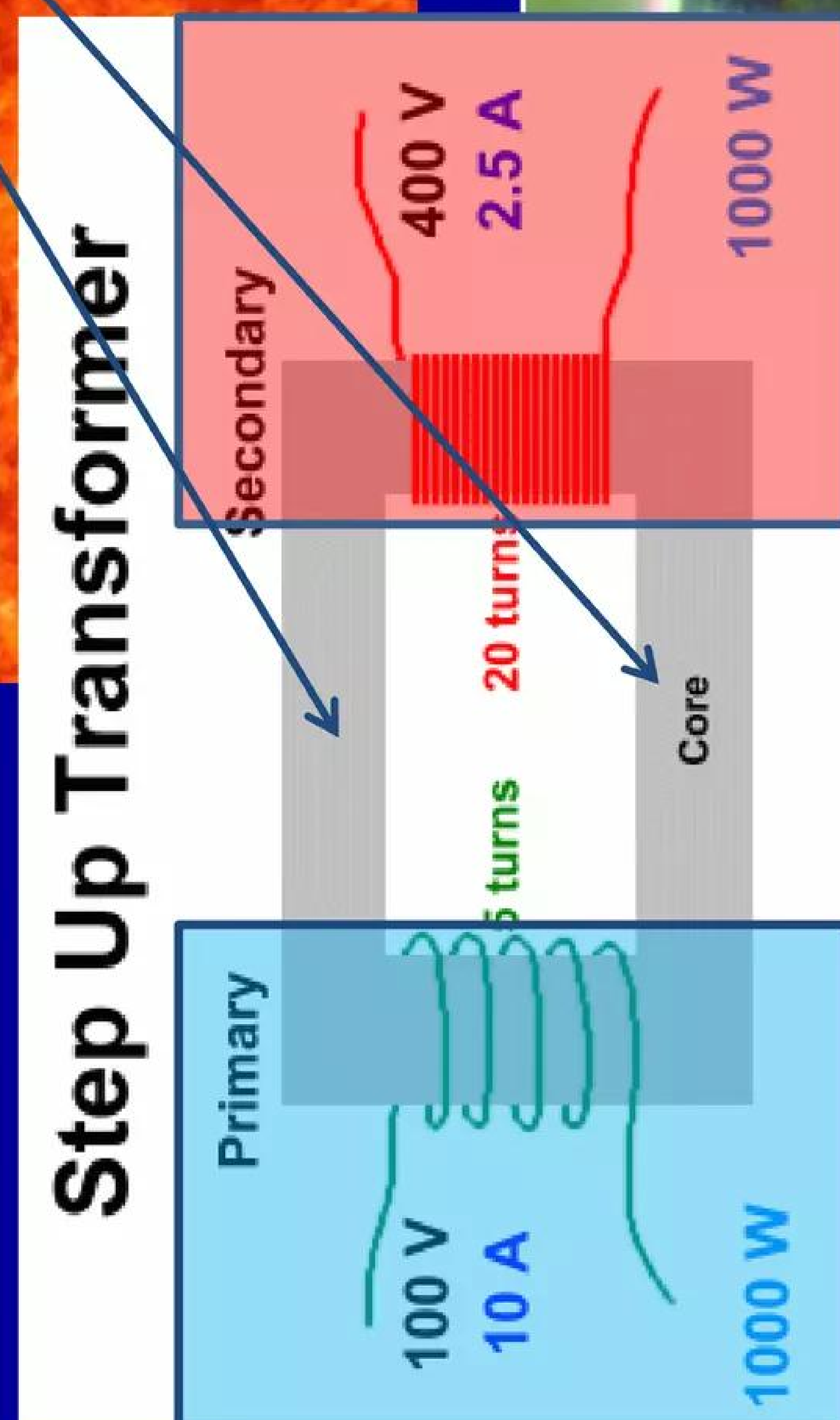


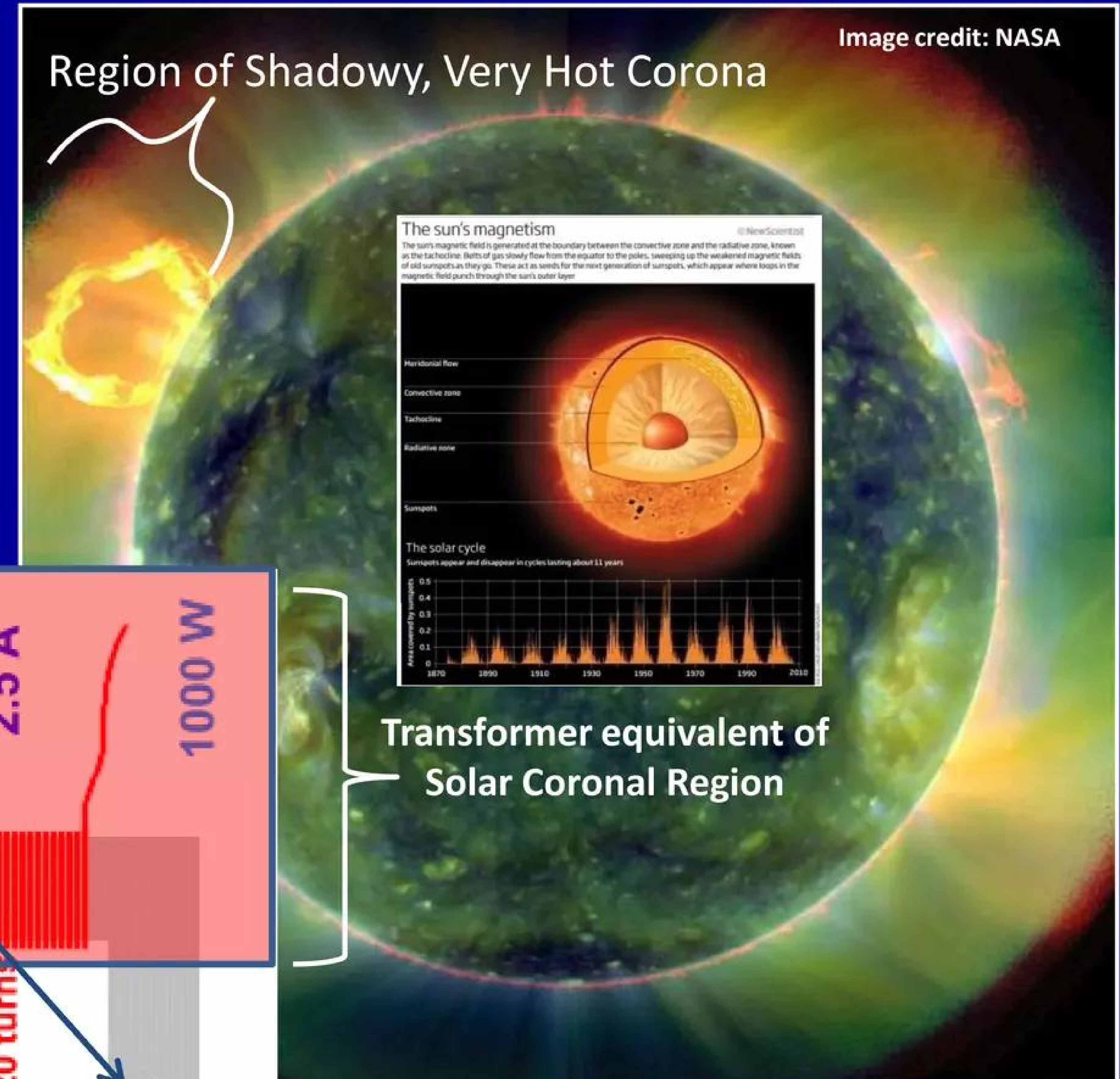
Sun's core is at temperature of ~15 million degrees K; 'surface' of the photosphere and chromosphere at ~6,000 K and 10,000 K respectively; but corona region at ~ 2 million K is much hotter than 'surface' of sun. This anomaly appears to contradict laws of thermodynamics. How might this mystery be explained?

In our 2008 arXiv paper "High energy particles in the solar corona," we explain the anomalous high temperature of the solar corona with simple analogy to a step-up transformer. Quoting, "The essence of the step up transformer mechanism is that the kinetic energy distributed among a very large number of charged particles in the photosphere can be transferred via the magnetic flux tube to a distributed kinetic energy shared among a distant much smaller number of charged particles located in the corona, i.e. a small accelerating voltage in the primary coil produces a large accelerating voltage in the secondary coil. The resulting transfer of kinetic energy is collective from a large group of charged particles to a smaller group of charged particles. The kinetic energy per charged particle of the dilute gas in the corona may then become much higher than the kinetic energy per charged particle of the more dense fluid in the photosphere."

Magnetic-regime LENRs can occur in Sun's photosphere and corona







"High Energy Particles in the Solar Corona"
- Widom, Srivastava, and Larsen (April 2008)

Abstract: collective Ampere law interactions producing magnetic flux tubes piercing through sunspots into and then out of the solar corona allow for low energy nuclear reactions in a steady state and high energy particle reactions if a magnetic flux tube explodes in a violent event such as a solar flare. Filamentous flux tubes themselves are vortices of Ampere currents circulating around in a tornado fashion in a roughly cylindrical geometry. The magnetic field lines are parallel to and largely confined within the core of the vortex. The vortices may thereby be viewed as long current carrying coils surrounding magnetic flux and subject to inductive Faraday and Ampere laws. These laws set the energy scales of (i) low energy solar nuclear reactions which may regularly occur and (ii) high energy electro-weak interactions which occur when magnetic flux coils explode into violent episodic events such as solar flares or coronal mass ejections.

$$V_p I_p = V_s I_s$$

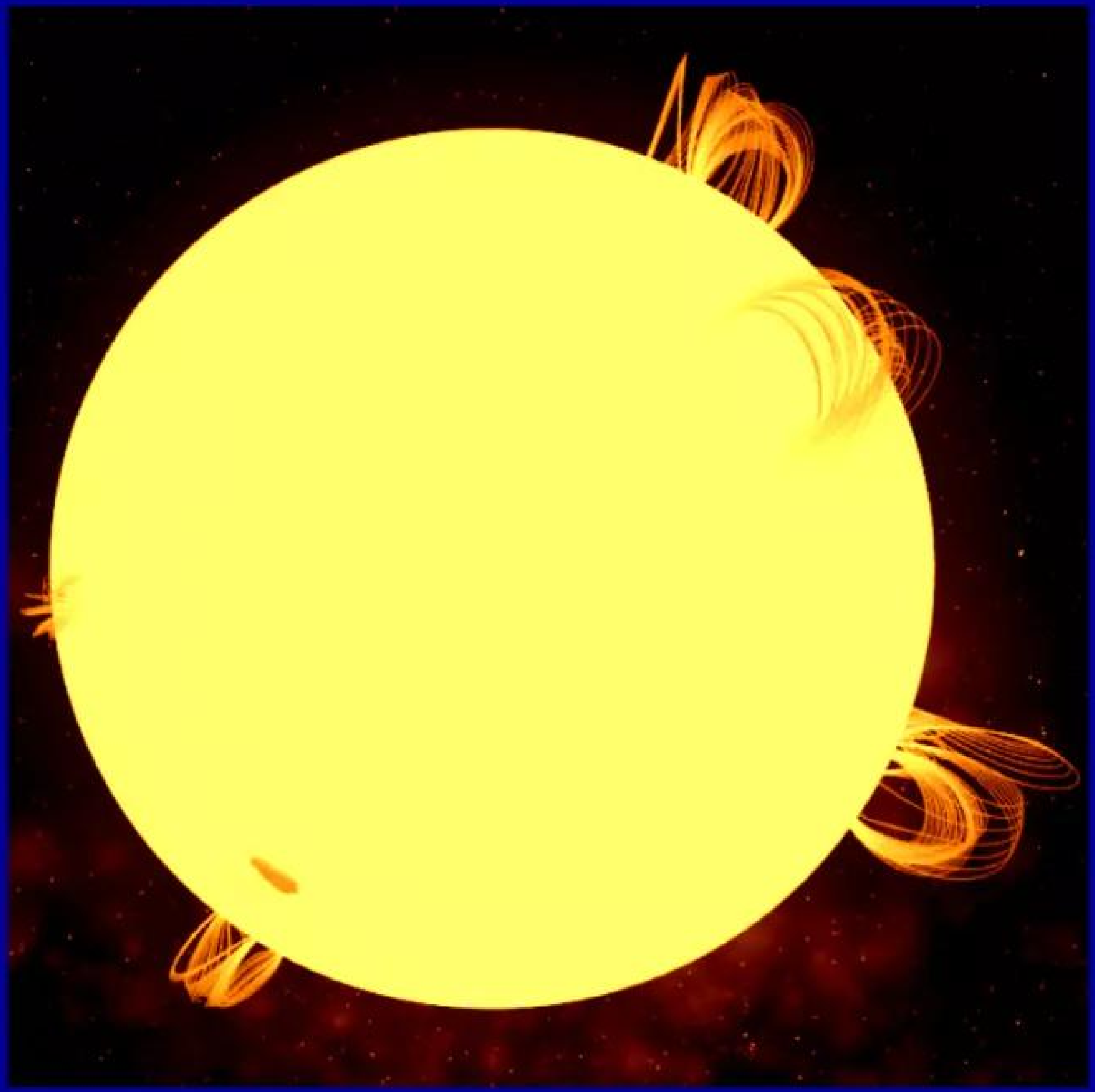
Transformer equivalent of Solar Photosphere

Electric utility transformers

Present astrophysical paradigms - flux tubes and coronas

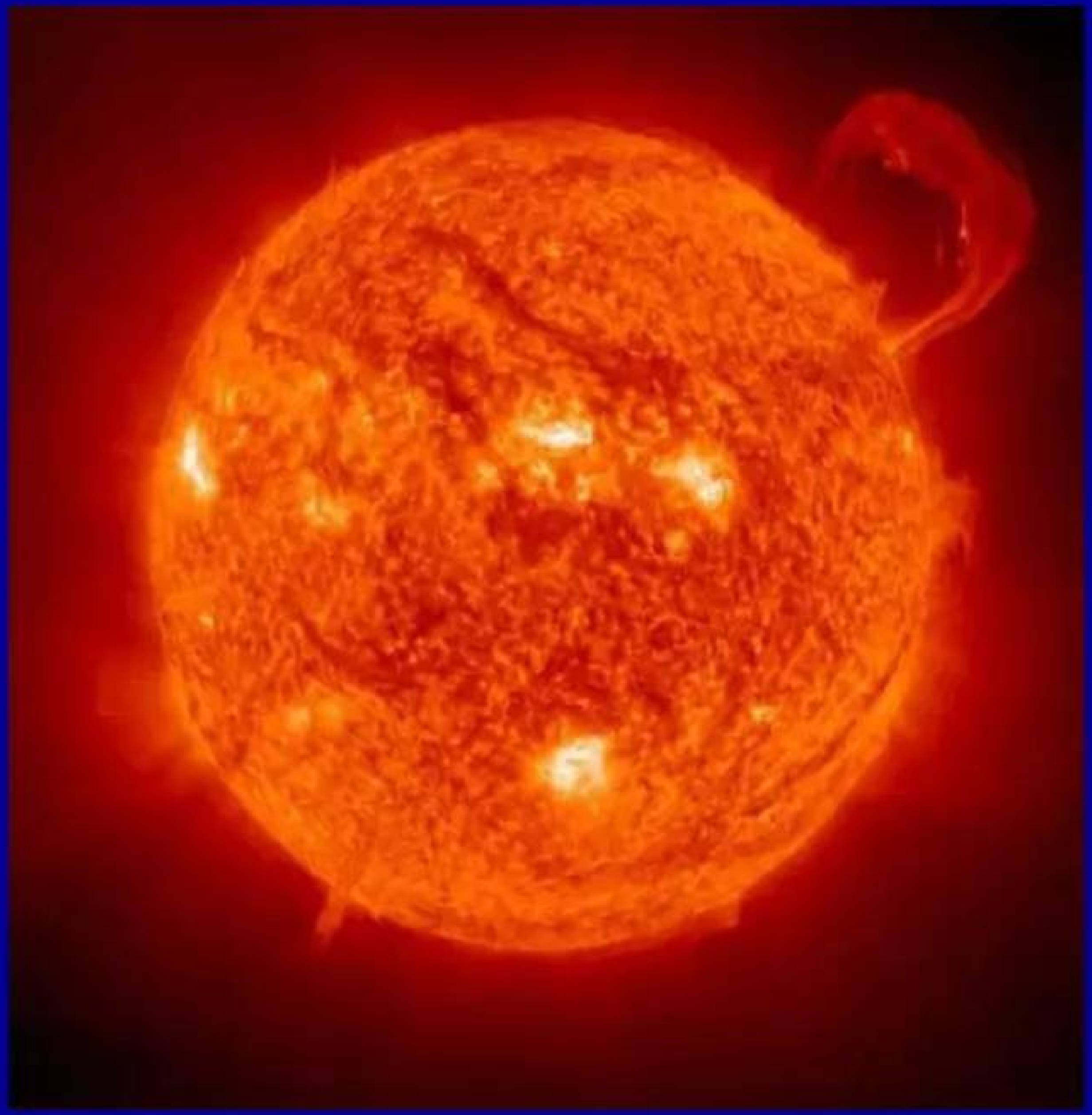
Idealized graphics and image illustrate two important types of structures

Flux tubes that occur on Sun and other stars are large length-scale, organized magnetic structures



Idealized graphic of magnetic flux tubes 'anchored' in Sun's 'surface'

Shadowy, very hot corona surrounds almost the entire Sun

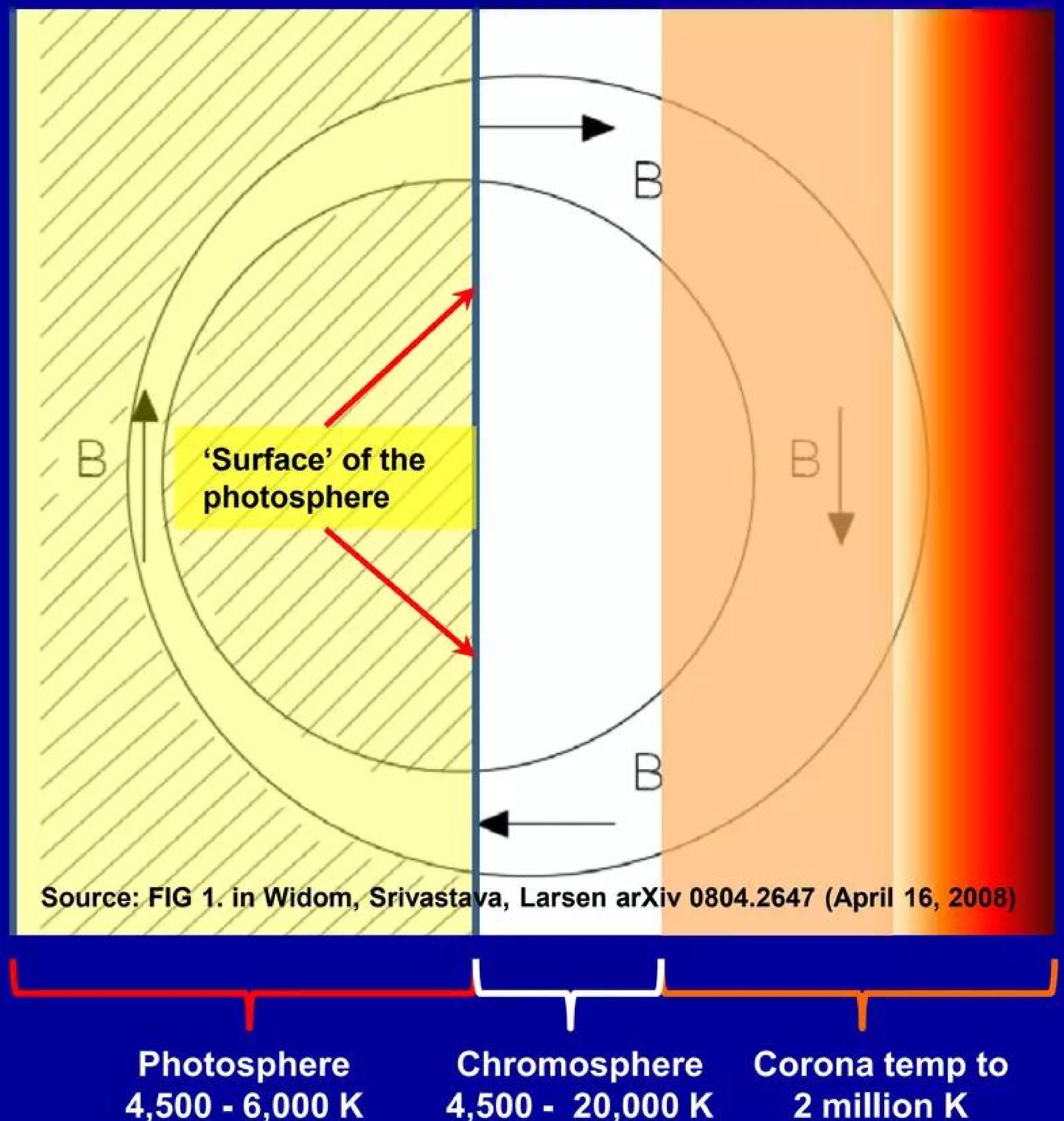


Credit: NASA SOHO – false-color image of the actual Sun in extreme ultraviolet

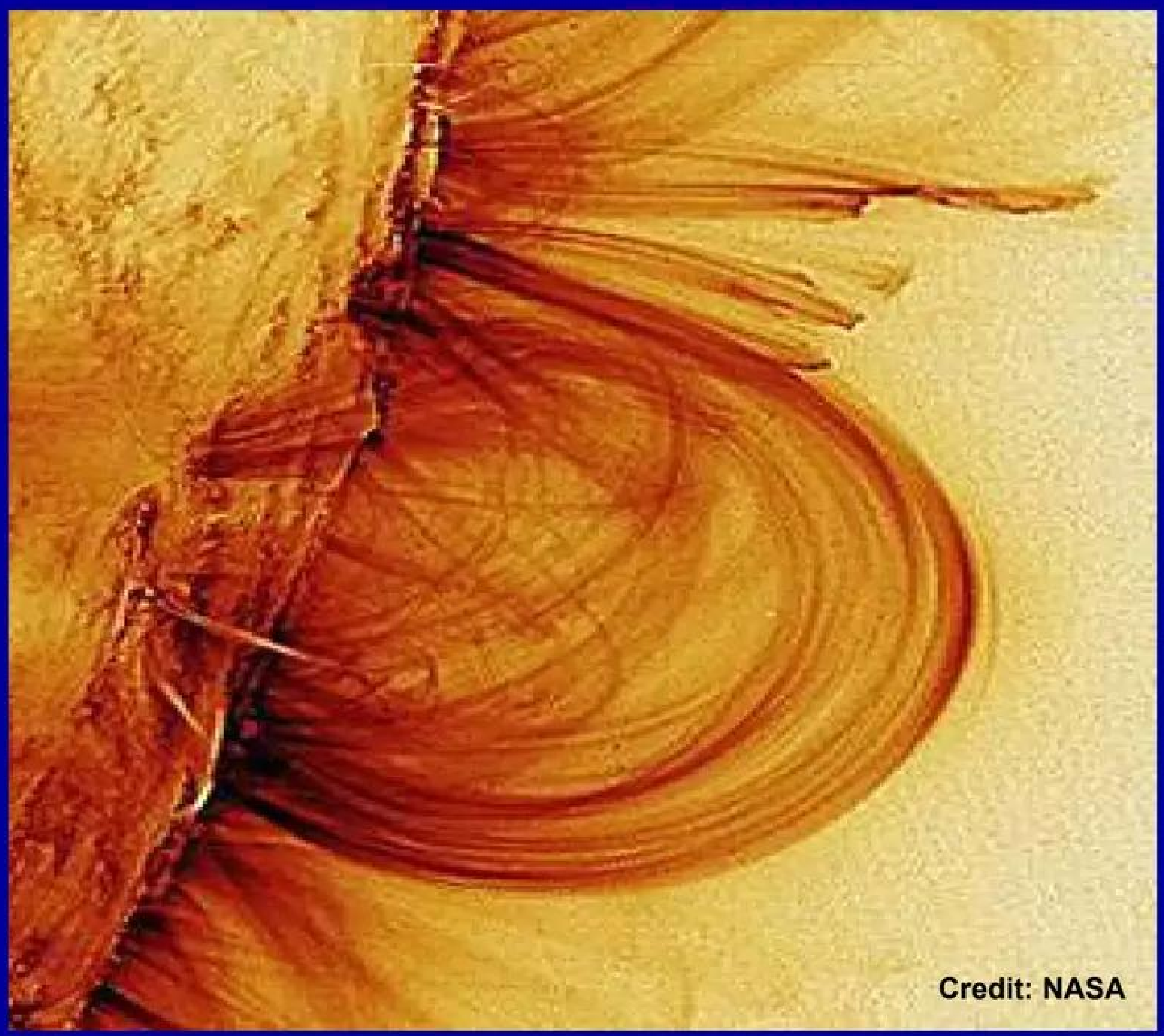
Present astrophysical paradigms - magnetic flux tubes

Idealized graphics and image illustrate key type of magnetic structure on Sun

Schematic side view of one magnetic flux tube; not to scale



Actual false-color image of magnetic flux tubes on Sun

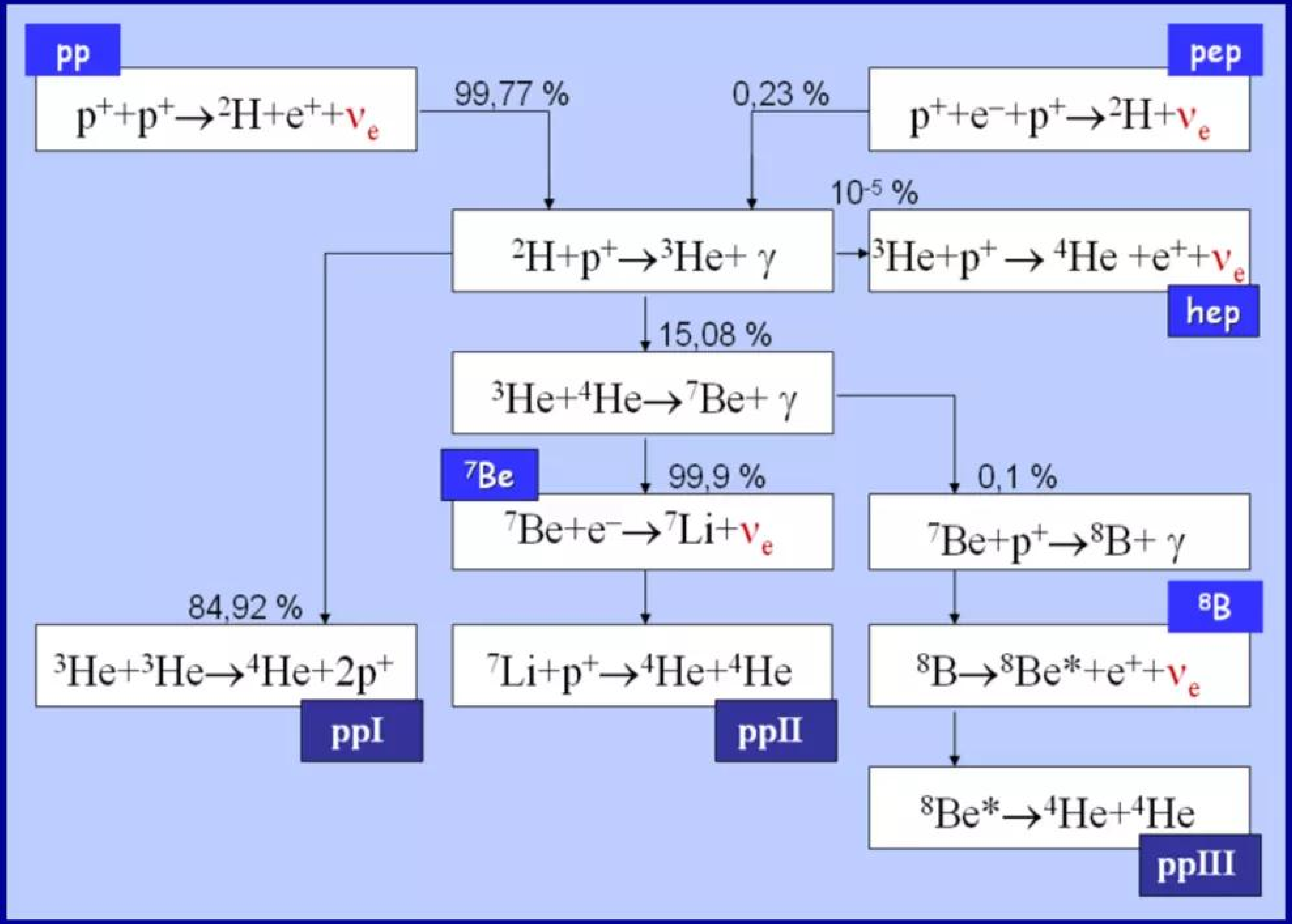


Basic transformer equation is: $V_p I_p = V_s I_s$

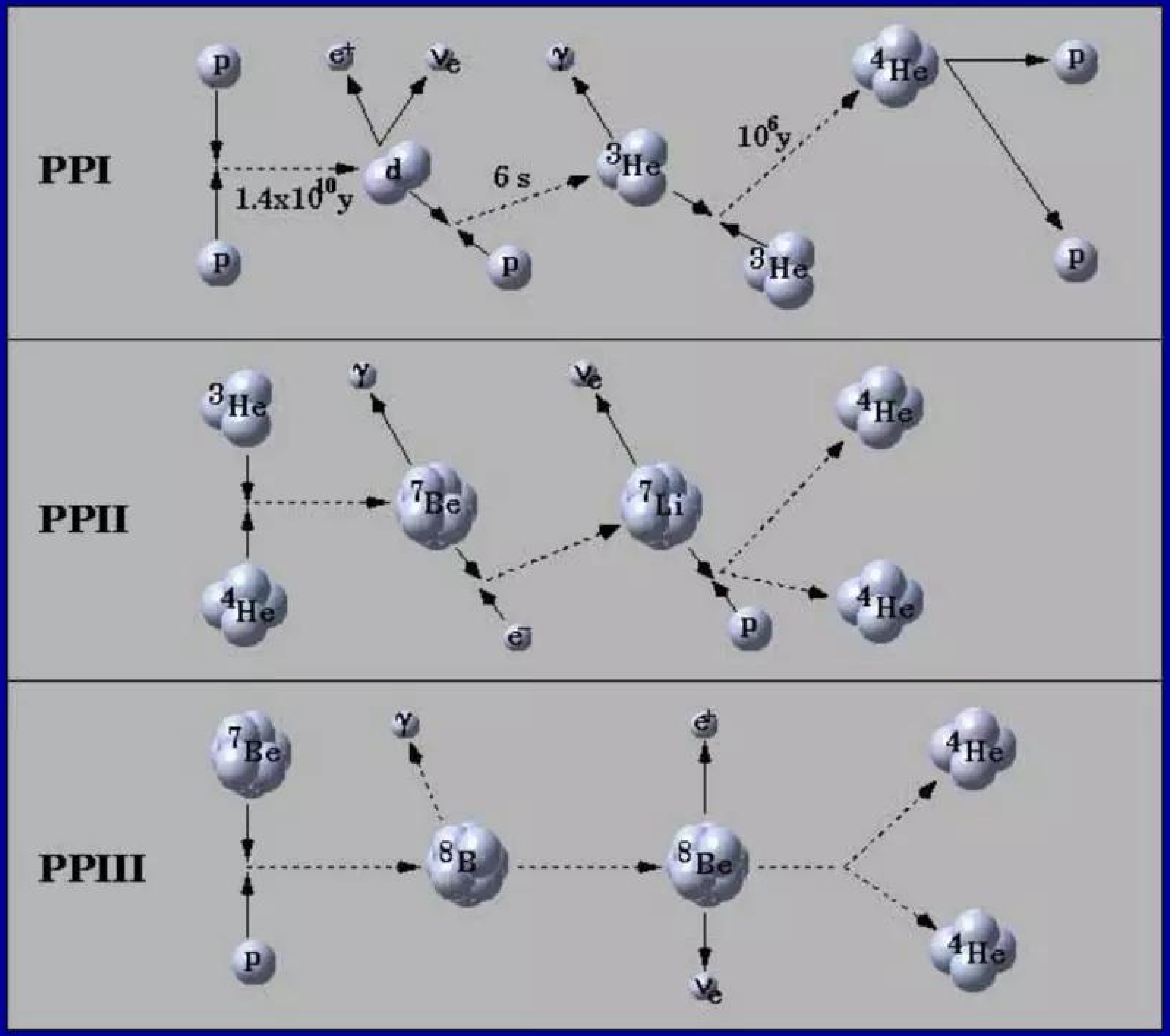
Present astrophysical paradigms - *pp* 'chains' in Sun

Current thinking: p-p fusion reactions produce energy in Sun and smaller stars

Summary of main types of hypothesized stellar *p-p* charged particle fusion reactions in Sun



Source: Wikipedia as of May 17, 2011

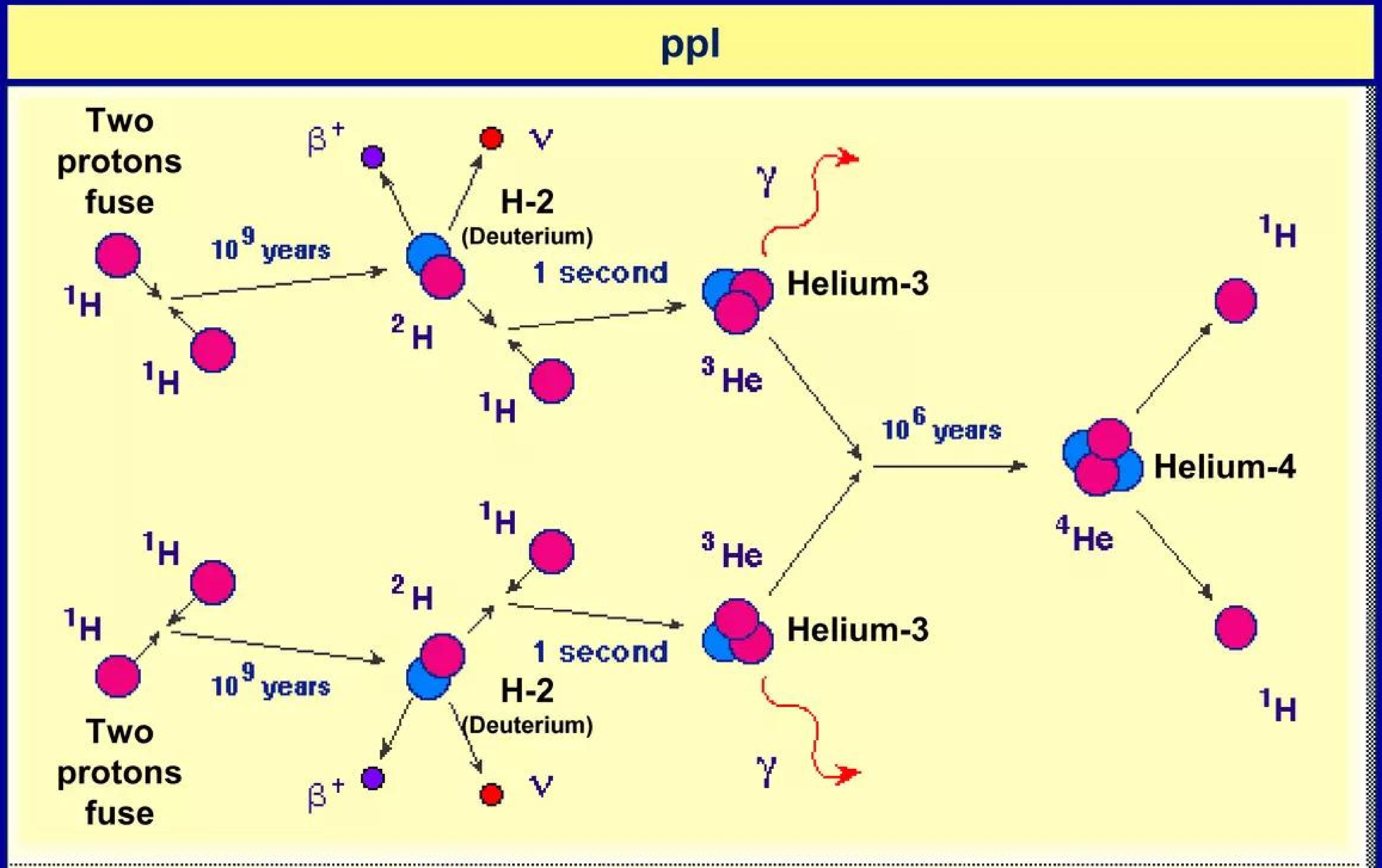


Credit: Prof. Vik Dhillon

Present astrophysical paradigms - *pp* 'chains' in Sun

Current thinking: p-p chain reactions dominate in Sun and smaller stars

ppI is the very beginning of the proton-proton charged-particle fusion chain reaction



Main branch of the proton–proton chain.

Source: http://atropos.as.arizona.edu/aiz/teaching/a250/pp.html

Note: the proton-proton fusion reaction (^{1}H + ^{1}H) is slowest (10^9 years); second-slowest step in ppI chain is the ^{3}He + ^{3}He fusion reaction (10^6 years)

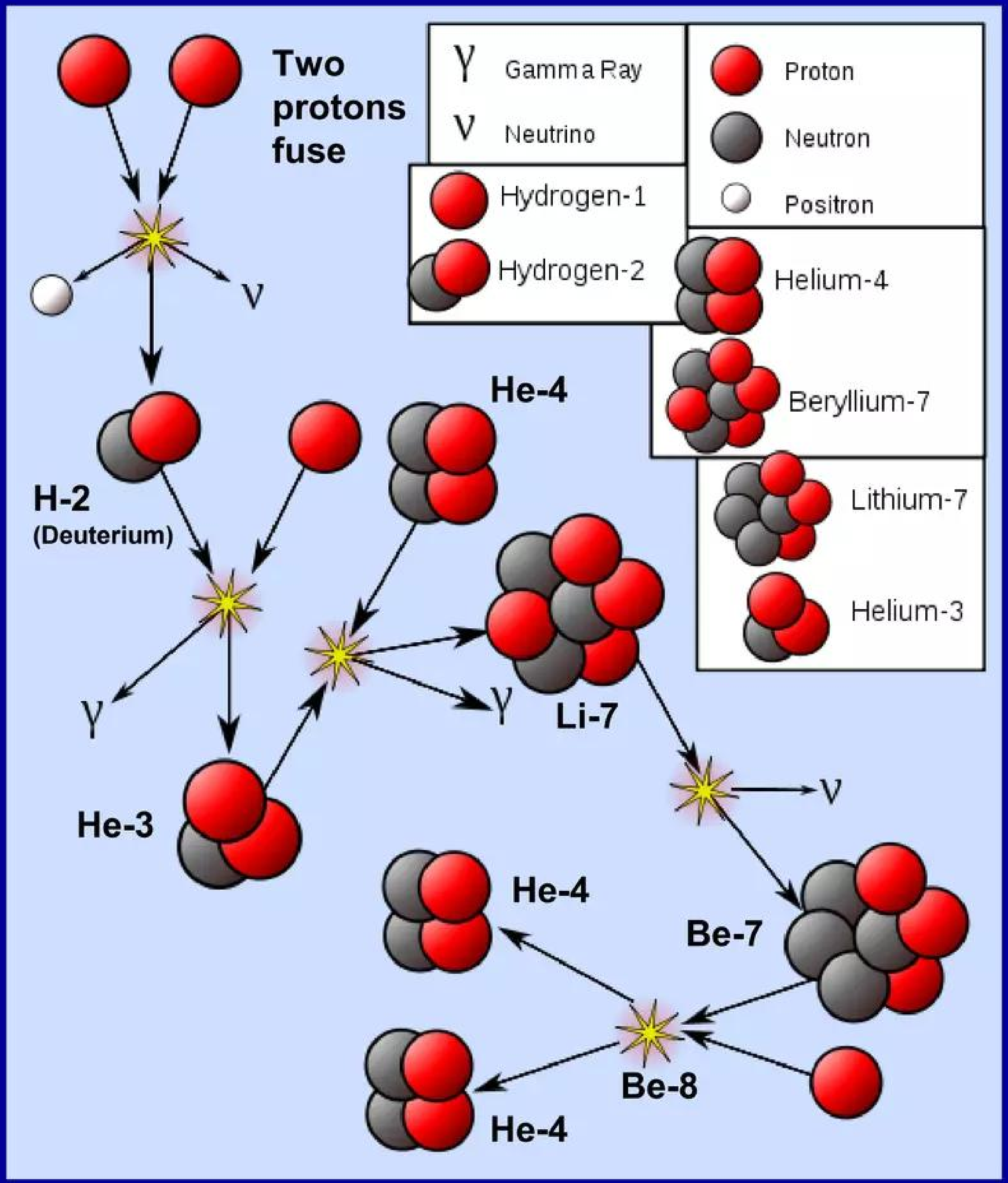
$$p + p \rightarrow {}^2H + e^+ + \nu_e \quad \text{(twice)}$$
$$p + {}^2H \rightarrow {}^3He + \gamma \quad \text{(twice)}$$
$${}^3He + {}^3He \rightarrow {}^4He + p + p$$

If these key fusion reactions occurred at substantially higher rates than those shown, the Sun's lifetime before exhausting its total supply of proton 'fuel' would only be millions of years, *not* billions

Present astrophysical paradigms - *pp* 'chains' in Sun

ppII and ppIII produce isotopes up to Beryllium-8, which decays into 2 He-4

- ✓ **ppI chain is dominant at stellar core temperatures of 10 - 14 million degrees K and has positive Q-value (energy release) of 26.7 MeV; below 10 million K, ppI does not produce much He-4**
- ✓ **ppII chain dominates at core temperatures of 14 - 23 million K; ~90% of the neutrinos produced in this chain have energies of 0.861 MeV, the remaining 10% are at 0.383 MeV (depends on whether Li-7 is excited)**
- ✓ **ppIII is dominant if temperature exceeds 23 million K; not a major source of energy in the case of the Sun (only ~0.11%) but unlike ppII, it produces very distinctive high-energy neutrinos up to 14.06 MeV**
- ✓ **Neutrinos in ppI, ppII, ppIII chains carry away 2.0%, 4.0%, and 28.3% of the total Q-values of the three important pp chains, respectively; just radiated into space --- don't add to heating**
- ✓ ***p-e-p* reaction, which is presently thought to be rare in the Sun (estimated *pep:pp* ratio is 1:400), also produces Deuterium (H-2) and a neutrino; in contrast to pp chain, this reaction produces sharp-energy-line neutrinos at 1.44 MeV**
- ✓ **Additional arrays of charged-particle fusion reactions in stars create elements from Beryllium (Be) all the way up to Iron (Fe)**

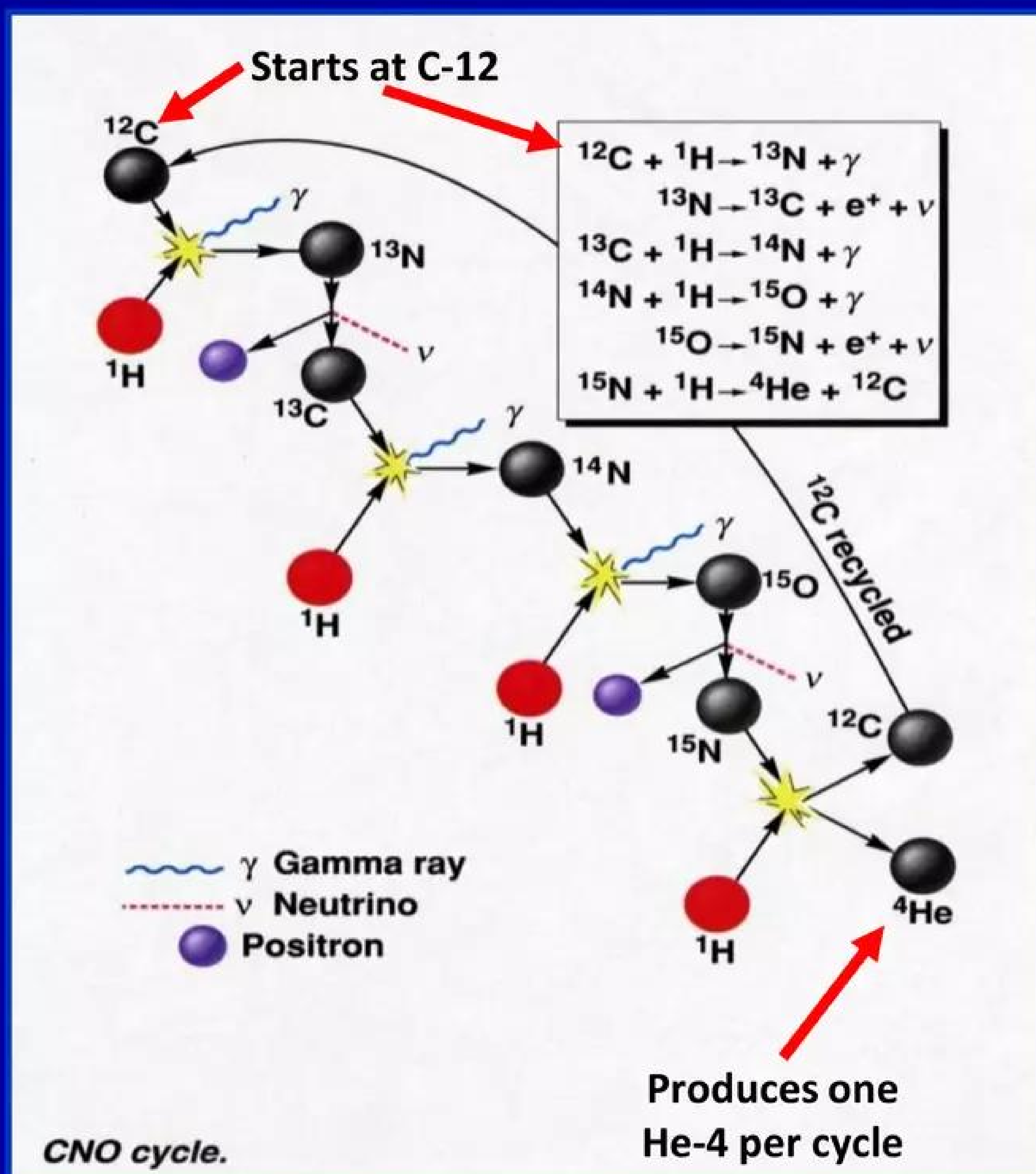


Source: adapted from Wikipedia as of May 17, 2011

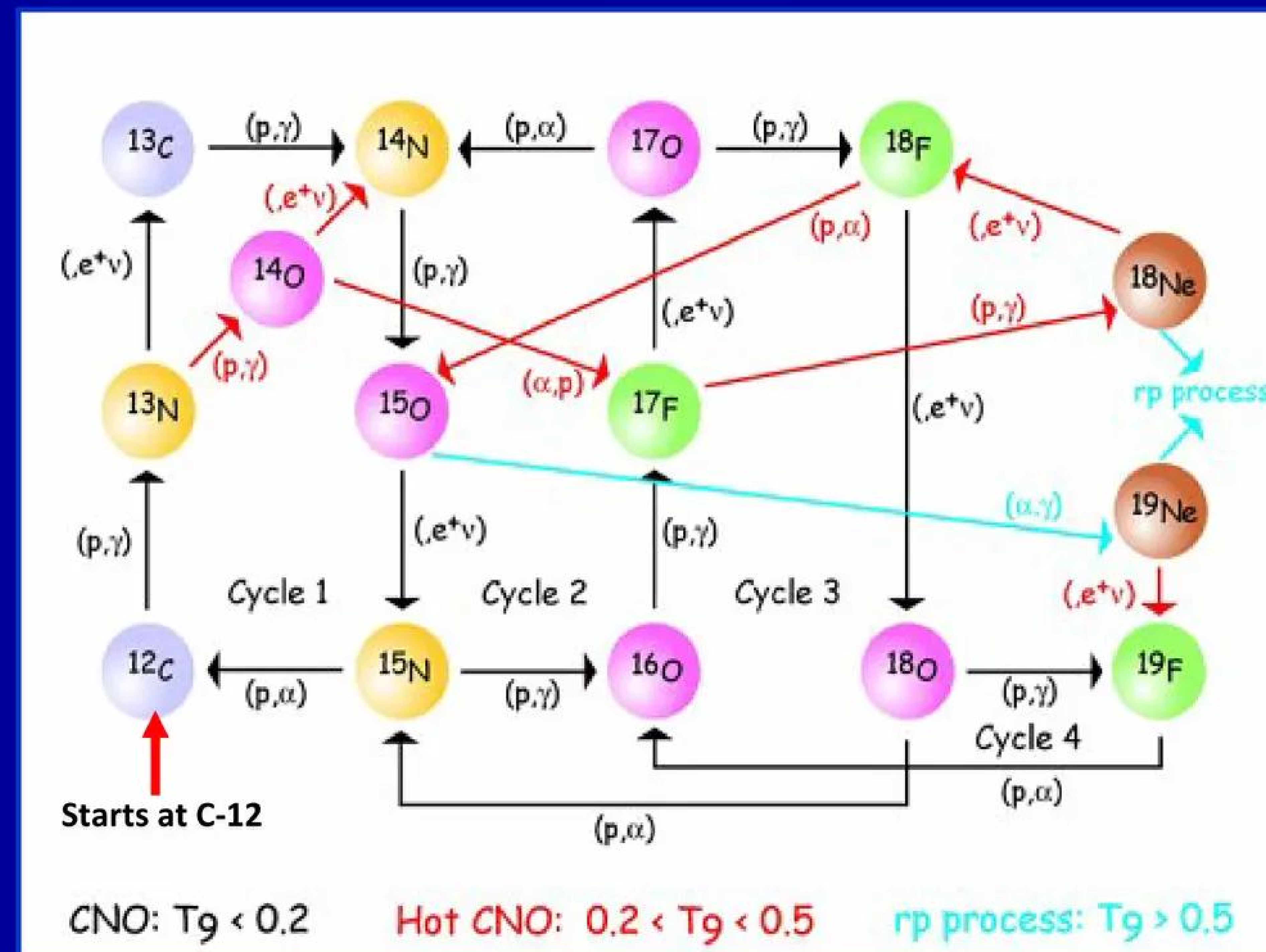
Present astrophysical paradigms - CNO cycle

Current thinking about the CNO fusion reaction cycle in stars - 1

Cycle 1: stellar CNO nucleosynthetic cycle



Cycles 1 – 4: CNO + 3 nucleosynthetic cycles thru Ne-18 and Ne-19



Comments: in the Sun's CNO cycle only C-12 is recycled; in LENR-based carbon cycles, C-12, C-13, and C-14 are all potentially regenerated. In general, ULMN catalyzed nucleosynthetic networks involve production of substantially more neutron-rich isotopes than stellar networks, e.g., C-14⇨C-20; N-14⇨N-23; O-19⇨O-24; F-19⇨F-27; and Ne-20⇨Ne-27. Alpha decays are far more common events in low-A stellar fusion processes

Present astrophysical paradigms - CNO cycle

Current thinking about the CNO fusion reaction cycle in stars - 2

"The CNO cycle (for carbon-nitrogen-oxygen), or sometimes Bethe-Weizsäcker-cycle, is one of two sets of fusion reactions by which stars convert hydrogen to helium, the other being the proton-proton chain. Unlike the proton-proton chain reaction, the CNO cycle is a catalytic cycle. Theoretical models show that the CNO cycle is the dominant source of energy in stars more massive than about 1.3 times the mass of the Sun. The proton-proton chain is more important in stars the mass of the sun or less. This difference stems from temperature dependency differences between the two reactions; pp-chain reactions start occurring at temperatures around 4 x 10^6 K, making it the dominant force in smaller stars. The CNO chain starts occurring at approximately 13 x 10^6 K, but its energy output rises much faster with increasing temperatures. At approximately 17 x 10^6 K, the CNO cycle starts becoming the dominant source of energy. The Sun has a core temperature of around 15.7 x 10^6 K and only 1.7% of He-4 nuclei being produced in the Sun are born in the CNO cycle. The CNO process was independently proposed by Carl von Weizsäcker and Hans Bethe in 1938 and 1939, respectively."

"In the CNO cycle, four protons fuse, using carbon, nitrogen and oxygen isotopes as a catalyst, to produce one alpha particle, two positrons and two electron neutrinos. The positrons will almost instantly annihilate with electrons, releasing energy in the form of gamma rays. The neutrinos escape from the star carrying away some energy. The carbon, nitrogen, and oxygen isotopes are in effect one nucleus that goes through a number of transformations in an endless loop."

Source: Wikipedia as of May 17, 2011 at http://en.wikipedia.org/wiki/CNO_cycle

Present astrophysical paradigms - widely held belief

Vast majority of Sun's pp 'chain' nuclear fusion reactions occur in core

Computer model of the Sun at 4.5 billion years; core generates ~99% of its total fusion power

% of radius	Radius (10^9 m)	Temperature (10^6 K)	% Luminosity	Fusion Rate (joules/kg-sec)		Fusion Power Density (joules/sec-m^3)
0	0.00	15.7	0	0.0175		276.5
9	0.06	13.8	33	0.010		103.0
12	0.08	12.8	55	.0068		56.4
14	0.10	11.3	79	.0033	Core	19.5
19	0.13	10.1	91	.0016		6.9
22	0.15	9.0	97	0.0007		2.2
24	0.17	8.1	99	0.0003		0.67
29	0.20	7.1	100	0.00006		.09
46	0.32	3.9	100	0		0
69	0.48	1.73	100	0		0
89	0.62	0.66	100	0		0

From: B. Stromgrew (1965) reprinted in D. Clayton, "*Principles of Stellar Evolution and Nucleosynthesis*". New York: McGraw-Hill, 1968

Online source of Table: http://fusedweb.llnl.gov/CPEP/Chart_Pages/5.Plasmas/SunLayers.html

Present astrophysical paradigms: modern era began in 1957

Modern concepts of stellar nucleosynthesis were 'codified' in B^2FH

- ✓ **Beginning with *pp* chains, charged-particle light element fusion reactions in stars require very high temperatures and extreme matter densities to overcome large Coulomb repulsion barriers to fusion; thus are restricted almost entirely to extremely hot, dense stellar cores**

- ✓ **Curve of nuclear binding energy is such that direct charged-particle fusion reactions are not energetically favorable beyond Iron (Fe) at atomic mass A = ~60; beyond Fe, neutron capture and various combinations of decay processes (mainly β^+ , β^-, α, electron capture, and fission) operate to create the remaining array of elements found in the periodic table**

- ✓ **Beyond Fe, charged-particle reactions that produce free neutrons can 'donate' them to be captured by other nuclei (half-life of an isolated free neutron to beta-decay is ~13 minutes). Repeating cycles of neutron production, capture, and decays of unstable isotopes gradually build-up heavier stable isotopes in stars; there are presently thought to be two main types of neutron-capture nucleosynthetic processes in stars: the s- (slow) and r- (rapid) process**

- ✓ **Modern concepts of stellar nucleosynthesis (*pp* chains, CNO cycle, more charged-particle fusion reactions, and s-/r-processes) was first articulated in a famous paper referred to shorthand as B^2FH: "Synthesis of the elements in stars," M. Burbidge, G. Burbidge, W. Fowler, and F. Hoyle, *Reviews of Modern Physics* 29 pp. 547 - 655 (1957). Free copy of this remarkable work (~25 MB image file) is at URL = http://rmp.aps.org/pdf/RMP/v29/i4/p547_1**

Present astrophysical paradigms: modern era began in 1957

Modern thinking about stellar nucleosynthesis largely reflects B^2FH

"The study of the chemical evolution of the Galaxy relies not only on accurate determination of chemical abundances, but also on a solid understanding of the different nucleosynthesis processes responsible for the formation of the different elements. Apart from the very light species (from hydrogen to boron) that formed during the Big Bang or follow from **spallation reactions**, elements in the Periodic Table up to $Z \sim 30$ form via fusion in stars. Charged particle processes work well up to the iron-peak, beyond which further fusion becomes energetically too demanding. Formation of heavier elements requires extra energy, iron-peak seeds (as well as neutrons), and available production channels. These channels are mainly neutron capture processes, which play a major role in the production of what we commonly call 'heavy' elements ($Z > 30$). Depending on the number of available neutrons, the processes take place on different timescales. At relatively low ($\sim 10^8$ cm^{-3}) neutron densities (Kappeler et al. 1989; Busso et al. 1999), a long duration process will take place, whereas in environments with higher ($n_n \sim 10^{26}$ cm^{-3}) neutron densities (Kratz et al. 2007) a shorter one will exist. These two scenarios correspond to the so-called slow and rapid neutron-capture processes (s- and r-, respectively)."

"Nature, however, is more complex than this and both these processes appear to have multiple components. The main component of the s-process is linked to both thermally pulsating asymptotic giant branch (AGB) and red giant branch (RGB) stars with stellar masses in the range 1.5 to 8 $M_\odot$ (Sneden et al. 2008) yielding nuclei with atomic masses $90 \leq A \leq 209$ (Heil et al. 2009). This process is generally associated with carbon-rich environments and the neutrons are a by-product of ^{13}C reactions. The weak component, instead, takes place in more massive stars ($M \geq 8\ M_\odot$), during their He core burning phase, and the neutrons come primarily from ^{22}Ne reactions. This component is responsible for the formation of lighter elements ($56 \leq A \leq 90$) (Heil et al. 2009; Pignatari et al. 2010)."

"Supernovae (SN) offer higher neutron densities than AGB stars, thus SN have been identified as one of the possible sites for the origin of the r-process. However, this process is not yet very well understood. Several sites have been suggested and investigated: neutron star mergers (Freiburghaus et al. 1999), high mass supernova (Wasserburg & Qian 2000), neutrino-driven winds (Wanajo et al. 2001), low mass O-Ne-Mg SN (Wanajo et al. 2003), core-collapse SN (Argast et al. 2004), and high-entropy winds (Farouqi et al. 2010), but without reaching a firm conclusion. Recent studies (Burris et al. 2000; Sneden et al. 2003; François et al. 2007; Montes et al. 2007) have suggested that this process may also work via two distinct channels, depending on the neutron density of the surrounding environment: high n-density regions would be connected to the main component, whereas lower n-densities ($\sim 10^{20}$ cm^{-3}, Kratz et al. 2007) would favour the so-called weak r-process (Wanajo et al. 2001) (or a second r-process) and be responsible for the formation of the $40 \leq Z \leq 47$ elements in low metallicity environments. Montes et al. (2007) identified the upper end of this range as the possible key to prove the existence and eventually characterise the second r-process component, but so far these elements (Mo, Pd and Ag) have scarcely been studied."

Source: "The origin of palladium and silver," C. Hansen and F. Primas, *Astronomy & Astrophysics* 525.L5 (2011)

Present astrophysical paradigms - spallation processes

Question: could some nucleosynthesis be occurring outside of stars' cores?

Ex-core nucleosynthesis could readily occur via spallation reactions with fluxes of energetic particles

Spallation reaction:

A nuclear reaction that can take place when two nuclei collide at very high energy (typically 500 MeV per nucleon and up), in which the involved nuclei are either disintegrated into their constituents (protons and neutrons), light nuclei, and elementary particles, or a large number of nucleons are expelled from the colliding system resulting in a nucleus with a smaller atomic number. This mechanism is clearly different from fusion reactions induced by heavy or light ions with modest kinetic energy (typically 5 MeV per nucleon) where, after formation of a compound nucleus, only a few nucleons are evaporated. A spallation reaction can be compared to a glass that shatters in many pieces when it falls on the ground. The way that the kinetic energy is distributed over the different particles involved in a spallation reaction and the process whereby this results in residues and fluxes of outgoing particles are not well understood."

"Spallation reactions take place in interstellar space when energetic cosmic rays (such as high-energy protons) collide with interstellar gas, which contains atoms such as carbon, nitrogen, and oxygen. This leads to the synthesis of light isotopes, such as 6-Li, 9-Be, 10-Be, and 11-B, that cannot be produced abundantly in nucleosynthesis scenarios in the big bang or stellar interiors."

"In terrestrial laboratories spallation reactions are initiated by bombarding targets with accelerated light- or heavy-ion beams, and they are used extensively in basic and applied research, such as the study of the equation of state of nuclear matter, production of energetic neutron beams, and radioactive isotope research."

Source: McGraw-Hill Science & Technology Encyclopedia

Present astrophysical paradigms: ‘cracks’ appear in 1965

Fowler et al. suggest nucleosynthesis might also occur outside of stars’ cores

- ✓ After publishing B^2FH in 1957 (which still overshadows astrophysics today, 46 years later), Fowler, both Burbidges, and Hoyle went even further with their thinking in attempting to explain anomalous elemental abundances spectroscopically measured in the atmospheres of certain “chemically peculiar” (CP) A and B stars having much-higher-than-normal atmospheric magnetic fields

- ✓ In that regard, eight years after B^2FH Fowler et al. published yet another very prescient paper, “The synthesis and destruction of elements in peculiar stars of Types A and B,” W. Fowler, E. Burbidge, G. Burbidge, and F. Hoyle, *The Astrophysical Journal* 142 pp. 423 - 450 (1965); free copy available at source URL = http://adsabs.harvard.edu/full/1965ApJ...142..423F

- ✓ Summarizing: to explain anomalous atmospheric abundances in CP stars that appeared to be inconsistent with ‘core-only’ nucleosynthesis, they proposed several alternative mechanisms. While no final conclusion was reached, they did note one (now heretical) possibility (quoting p.430): “We then developed a theory for the production of anomalous abundances in a thin atmospheric layer by surface nuclear reactions, the energy for which came from the star’s magnetic field. We postulated that large fluxes of protons were accelerated in spot regions in the surface and gave rise both to spallation in the highest levels and to a neutron flux through (p, n)-reactions lower in the atmosphere, and that these neutrons were captured to produce the overabundances of the heavy elements.”

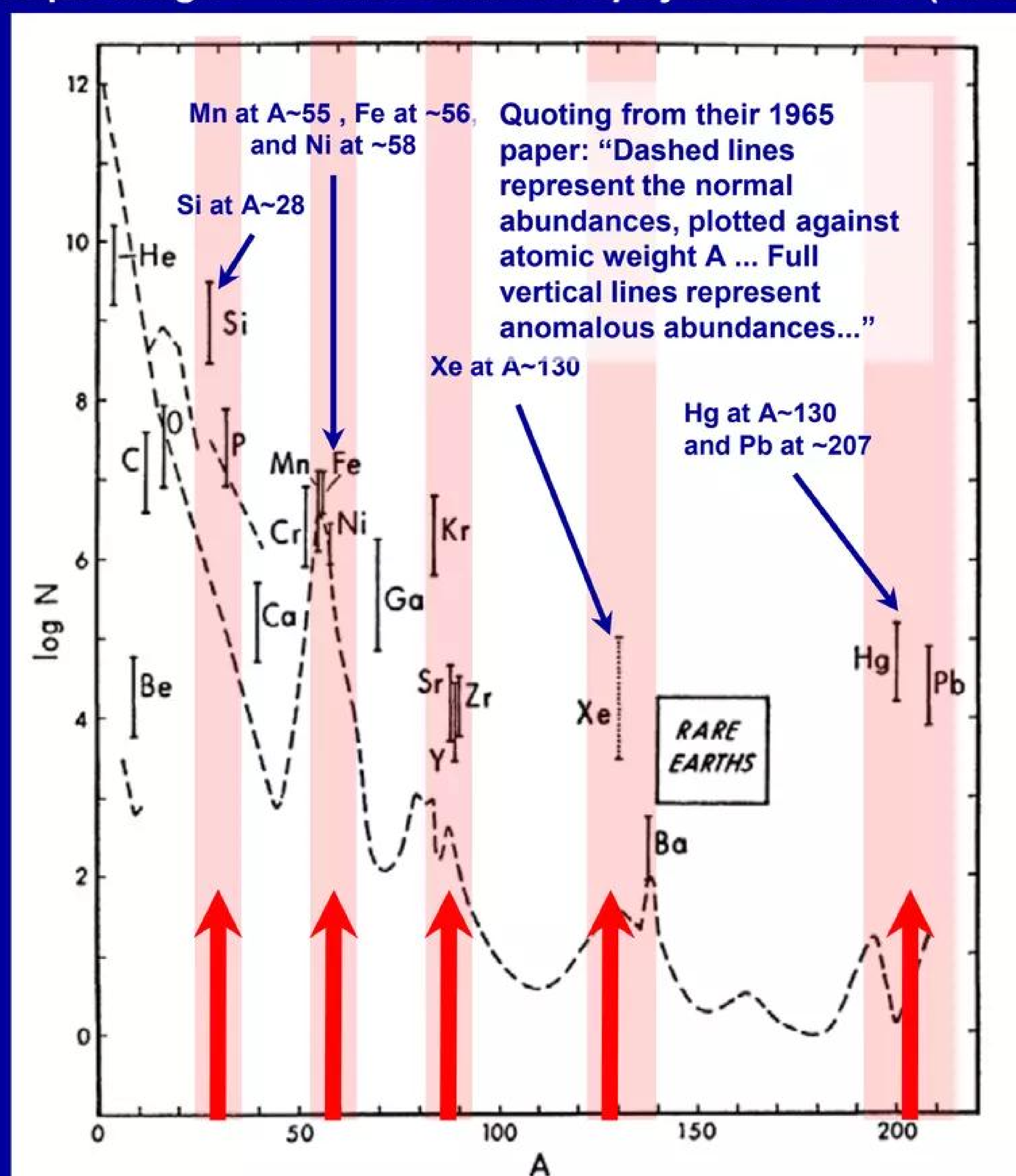
- ✓ In spite of having very high professional stature, their thoughtful speculation about the possibility of additional nucleosynthetic processes operating well-outside of stellar cores not widely embraced by the astrophysics community; today, their still-relevant 1965 paper is seldom cited by anyone

Present astrophysical paradigms: 'cracks' appear in 1965

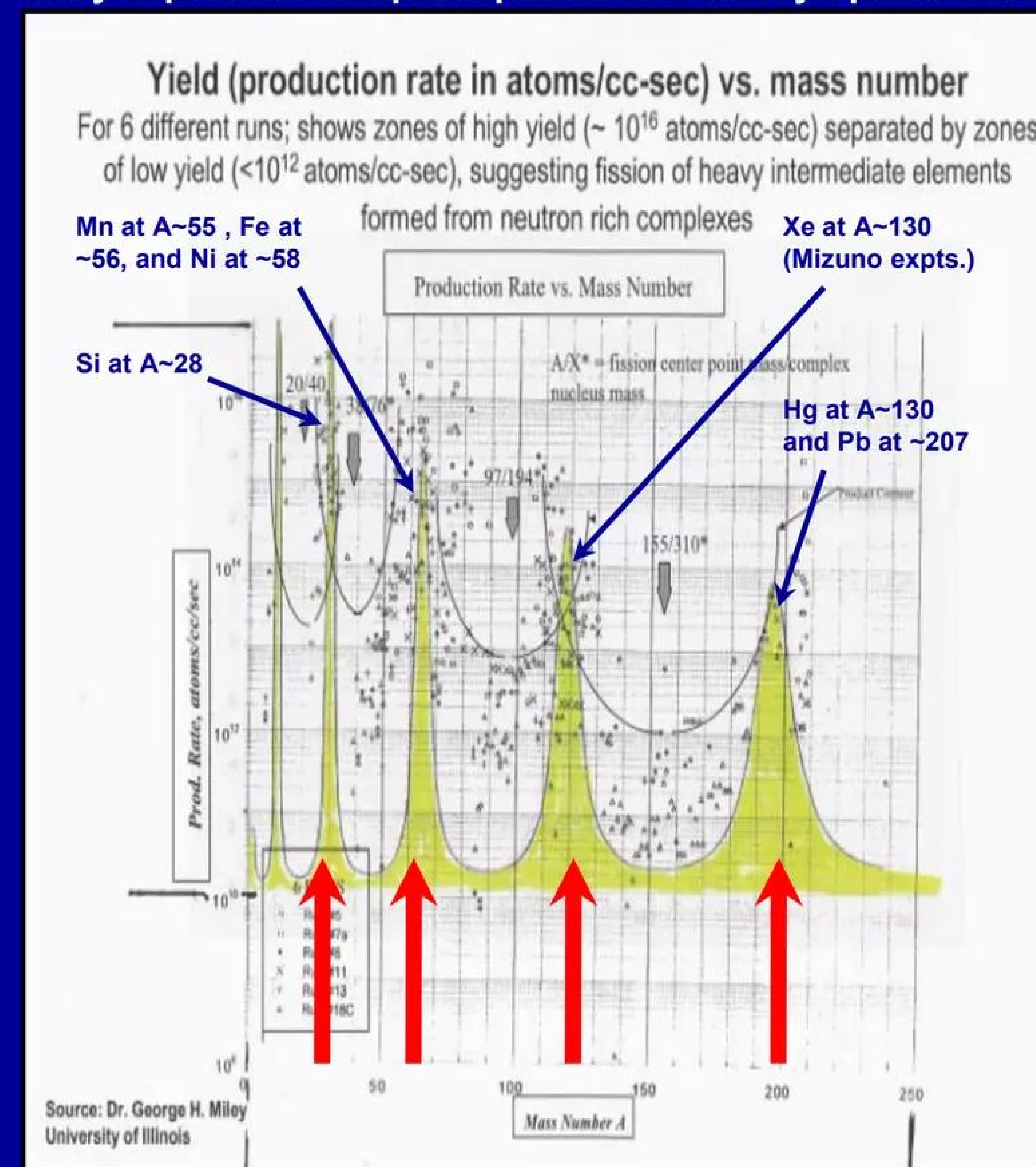
Fowler et al. Fig 2. data compared to 1996 LENR data in light of W-L theory

Anomalous overabundance peaks in *Ap* stars compared to peaks in Miley data and W-L optical model

Adapted Fig. 2 – Fowler et al. *Astrophysical Journal* (1965)



Miley exp. data w. superimposed W-L theory optical model



Effective elemental abundance

Atomic weight A from 0 to 200+

Present astrophysical paradigms: more 'cracks' in 2007

Goriely proposed that nuclear reactions occur on surface of HD 101065

Fast forward to S. Goriely, Institute of Astronomy and Astrophysics, Free University of Brussels

- ✓ **"Nucleosynthesis by accelerated particles to account for the surface composition of HD 101065," S. Goriely, *Astronomy & Astrophysics* 466 pp. 619 - 626 (2007)**
  For free copy see URL = http://www.aanda.org/articles/aa/pdf/2007/17/aa6583-06.pdf

- ✓ **HD 101065 is another name for very chemically peculiar (CP) Przybylski's Star (Ap class), first discovered by the astronomer Antoni Przybylski in 1961 and discussed by Fowler et al. (*APJ* 1965). It has since drawn wide attention because its spectra indicate the presence of highly anomalous array of different elements in its atmosphere, including rare earth elements (REEs) and Actinides; for an older review article, "HD 101065:Przybylski's Star," E. Munoz, J. Crepp, and A. Narayanan see URL = http://www2.astro.psu.edu/~ealicea/research/gradschool/przyreport.pdf**

- ✓ **Quoting from Goriely, "The mechanisms responsible for exciting roAp stars and other physical parameters that distinguish them from nonpulsating CP stars remain an open question. The CP stars exhibit a remarkable variety of elemental enhancements and depletions in their photospheres, sometimes 5 to 6 orders of magnitudes different than found in the sun (Cowley & Bord 2004) ... Various scenarios have been suggested to account for the origin of CP stars, including contact binaries that transfer mass to each other and eventually merge into a single star. However, quantitatively, the CP-star abundance peculiarities have been explained almost uniquely on the basis of diffusion processes, i.e. the diffusive segregation of ionic and isotopic species resulting from the balance between radiative and gravitational forces within the atmosphere and subatmospheric regions (Michaud 1970, 2004)."**

Present astrophysical paradigms: more 'cracks' in 2007

Goriely created a theoretical nuclear reaction network model to explore idea

- ✓ **Quoting further from Goriely, "Recent observations suggest the presence of short-lived radioactive elements, such as Tc, Pm, and 84 ≤ *Z* ≤ 99 elements, at the surface of the CP *roAp* star HD 101065, also known as Przybylski's star."**
- ✓ **"But if confirmed, it can in no way be explained by diffusion processes. Only nuclear reactions could possibly be responsible for the synthesis of such short-lived radioelements (in particular, Pm's longest isotopic half-life is 17.7 yr). The large magnetic fields observed in *Ap* stars (in the case of HD 101065, the magnetic field amounts to *B* = 2300 *G*) could be at the origin of a significant acceleration of charged particles, mainly protons and α-particles, that in turn can modify the surface content by interaction with the stellar material." [via spallation processes]**
- ✓ **"Due to the exploratory nature of the present study, no effort has been made to understand the possible mechanisms that could be held responsible for accelerating the energetic particles. As already discussed, these particles could be locally accelerated, but they could also come from an external source. A purely parametric approach is followed by taking the properties of the accelerated proton and α-particle fluxes as free parameters." [W-S-L theory provides a mechanism]**
- ✓ **"To describe the changes in abundance of the nuclei as a result of the interaction of the energetic incident particles with the low density stellar atmosphere, a nuclear reaction network including all relevant reactions is used. All nuclei with 0 ≤ *Z* ≤ 102 and located between the proton drip line and the neutron-rich side of the valley of stability are included in the network. The chosen set of nuclear species are then coupled by a system of differential equations corresponding to all the reactions affecting each nucleus, i.e. mainly proton, α and neutron captures, β- and α-decays, as well as spontaneous fission decays."**

Present astrophysical paradigms: more 'cracks' in 2007

Goriely concluded: accelerated charged-particle fluences can explain data

- ✓ "In the present work, special attention is paid to the role played by the neutrons emitted during the spallation process."
- ✓ "In this specific scenario, if fluences of the order 10^{26-27} cm^{-2} can be achieved, can the abundances of the elements heavier than iron not only be increased by 5 orders of magnitude, but also the neutron flux becomes strong enough to bridge the $N > 126$ α-unstable region between Po and Fr and produce actinides with a charge as high as Z ~100 in large amounts. This is essentially due to the high neutron densities of N_n ~10^{15} cm^{-3} reached under these specific conditions."
- ✓ "... nuclear flow at an irradiation time greater than some 1000 s is shifted to the neutron-rich side of the valley of stability. This property has the decisive effect of enabling a significant production of actinides."
- ✓ "From the general study of Sect. 3, the present nucleosynthesis turns out to be attractive in many respects to explain the abundance estimated at the surface of the CP star HD 101065. First of all, it can be held responsible for a significant production of elements heavier than iron by a few orders of magnitude, without having to call for additional diffusive processes. This nucleosynthesis can be accompanied by a significant production of radioelements, not only Tc or Pm, but also Actinides ranging from Po to Fm, at least for the extreme conditions discussed in Sect. 3.2. ... if we assume that Pm in particular is still present in the atmosphere of HD 101065, the time elapsed between the nucleosynthesis and the observation cannot be much longer than a few years."
- ✓ "In summary, many spectroscopic observations of HD 101065 can be met if we assume that extremely high proton and α-particle fluences have irradiated solar-like material."

Present astrophysical paradigms: more 'cracks' in 2008

W-S-L arXiv preprint: collective mechanism explains nucleosynthesis in flares

Further evidence that W-S-L mechanism and its $e + p \rightarrow$ reactions occur on the Sun and other stars

- ✓ **"Nucleosynthesis in stellar flares," V. Tatischeff, J-P. Thibaud, and I. Ribas (2008) for free copy see URL = http://arxiv.org/PS_cache/arxiv/pdf/0801/0801.1777v1.pdf**
- ✓ **Quoting directly from the paper: "The solar-flare gamma-ray line emission testifies that fresh nuclei are synthesized in abundance in energetic solar events ... Solar-type activity is believed to be a phenomenon inherent to the vast majority if not all main-sequence stars. The Sun is not an active star in comparison with numerous stellar objects in the solar neighbourhood that show much higher luminosities in emissions associated with coronal and chromospheric activities. Although gamma-ray line emission from other flaring stars cannot be observed with the current sensitivity of the gamma-ray space instruments, it is more than likely that the Sun is not the only star producing surface nucleosynthesis in flares."**
- ✓ **"Enormous enhancements of accelerated ^{3}He are measured in impulsive solar flares: the ^{3}He/α ratios found in these events are frequently three to four orders of magnitude larger than the corresponding value in the solar corona and solar wind, where ^{3}He/^{4}He $\sim 5 \times 10^{-4}$."**
- ✓ **"Asplund et al. have recently reported the detection of ^{6}Li at $\geq 2\sigma$ confidence level in nine halo stars of low metallicity, [Fe/H] < -1, situated in the turnoff region of the Hertzsprung-Russel diagram. The ^{6}Li abundances measured in these objects are far above the value predicted by Big Bang nucleosynthesis and cannot be explained by galactic cosmic-ray interactions in the interstellar medium either."**

Present astrophysical paradigms: more 'cracks' in 2008

W-S-L arXiv preprint: collective mechanism explains nucleosynthesis in flares

- ✓ Continuing to quote from: "Nucleosynthesis in stellar flares," V. Tatischeff, J-P. Thibaud, and I. Ribas, for free copy see URL = http://arxiv.org/PS_cache/arxiv/pdf/0801/0801.1777v1.pdf\
- ✓ "Tatischeff & Thibaud have shown that a significant amount of ^{6}Li can be produced in the atmospheres of metal-poor halo stars from repeated solar-like flares during their main-sequence evolution ... The Li/H ratios measured in these clusters were found to depend on stellar rotation and activity: the most rapid rotators, which are also the most active stars in chromospheric and coronal emissions, appear to be the most Li rich... Li-activity correlation is not well understood."
- ✓ "... we assess the possibility that the observed Li-rotation correlation is due to a significant *in situ* production of Li by stellar flares in the most active main sequence stars [and] assume that the Li atoms produced by nonthermal reactions in the atmosphere of a given star are mainly evacuated by the stellar wind on a relatively short timescale, rather than being mixed into the bulk of the star convection zone. Comparison of the solar wind ^{6}Li abundance with calculations of the production of this isotope in solar flares has shown that this assumption is reasonable for the ... Sun."
- ✓ "We see that the flare contribution to the total Li abundance can be significant for active stars [and] can explain the non-negligible amounts of Li detected in Pleiades stars [and] Li abundances in very active stars ... [and] dispersion in Li abundances observed in young open clusters like the Pleiades and α Persei ... we have shown that stellar flares could account for significant ^{6}Li production in these objects, thus avoiding the need for a new pre-galactic source of this isotope, such as non-standard Big Bang nucleosynthesis and cosmological cosmic rays."

Solar high-energy neutron and pion-decay gammas (2009)

Review discussed data consistent w. W-S-L collective magnetic mechanism

- ✓ See: "High energy neutron and pion-decay gamma-ray emissions from solar flares," E. Chupp and J. Ryan, *Research in Astronomy and Astrophysics* 9 pp, 11 - 40 (2009) See URL = http://www.raa-journal.org/raa/index.php/raa/article/view/50

- ✓ Quoting: "Solar flare gamma-ray emissions from energetic ions and electrons have been detected and measured to GeV energies since 1980. In addition, neutrons produced in solar flares with 100MeV to GeV energies have been observed at the Earth. These emissions are produced by the highest energy ions and electrons accelerated at the Sun and they provide our only direct (albeit secondary) knowledge about the properties of the accelerator(s) acting in a solar flare. The solar flares, which have direct evidence for pion-decay gamma-rays, are unique and are the focus of this paper. We review our current knowledge of the highest energy solar emissions, and how the characteristics of the acceleration process are deduced from the observations."

- ✓ "We focus on solar flare events in which there exists clear evidence for meson production by the interaction of >180 MeV protons or ions with the solar atmosphere. The presence of these mesons is indicated by the detectable emission of neutral meson-decay gamma-rays. By inference, events where secondary neutrons at ground level are detected belong to this class of events, even though no data may be available for the attendant gamma-rays. A goal of such investigations is to determine the mechanism(s) that accelerate the ions and electrons to such energies. We review, in Section 2, the basic gamma-ray and neutron production mechanisms and in Section 3, the properties of several selected events with pion decay gamma-ray emission, some of which provide evidence for high energy neutrons (>50 MeV) and possible relativistic electron acceleration to several hundred MeV. In Section 4 we briefly mention some proposals for the acceleration mechanisms."

Solar high-energy neutron and pion-decay gammas (2009)

Review discussed data consistent w. W-S-L collective magnetic mechanism

- ✓ See: "High energy neutron and pion-decay gamma-ray emissions from solar flares," E. Chupp and J. Ryan, *Research in Astronomy and Astrophysics* 9 pp, 11 - 40 (2009) see URL = http://www.raa-journal.org/raa/index.php/raa/article/view/50
- ✓ Quoting: "Morrison (1958) predicted that nuclear reactions from accelerated particle interactions in the solar atmosphere during a solar flare could produce a neutron-proton capture line at 2.223 MeV detectable at the Earth. Later Lingenfelter & Ramaty (1967) computed the expected emission of gamma-ray lines, continuum and high energy neutrons produced during a solar flare. These early predictions were confirmed during a series of solar flares in August 1972 with the Gamma-Ray Monitor on the OSO-7 spacecraft (Chupp et al. 1973). The detections of the neutrons at the Earth and the higher energy gamma-rays resulting from the decay of neutral pions, was yet to come. The ability to detect and measure high energy photons and neutrons came with the Solar Maximum Mission that carried on the Gamma Ray Spectrometer."
- ✓ "Among the many interesting aspects of this phenomena are the mechanisms capable of accelerating ions and/or electrons to GeV energies... Four basic processes are candidates: (1) second-order Fermi acceleration in a large magnetic trap, (2) betatron acceleration, (3) statistically coherent electric fields over a large current sheet and (4) downstream diffusion of ions from a large coronal (and eventually interplanetary) shock (first order Fermi acceleration) onto the solar surface. All four have their strengths but suffer weaknesses too."
- ✓ "We wish to emphasize that solar-flare particle acceleration cannot be understood unless the problem of production of ions and electrons to GeV energies is *solved!* This requires confronting any theoretical model with multiwavength observations of several flares."

GeV photon/particle energies and large solar flares (2009)

Concluded high-energy protons are produced during main flare energy release

- ✓ See: "Appearance of high-energy protons at the Sun and the GLE onset," B. Yushkov, V. Kurt, and A. Belov, Proceedings of the 31st ICRC, Lodz, Poland (2009) see URL = http://icrc2009.uni.lodz.pl/proc/pdf/icrc0590.pdf

- ✓ Abstract: "High-energy protons accelerated during large solar flares can be observed not only near the Earth but immediately at the Sun as well. This is possible through the detection of high-energy (>100 MeV) gamma-ray emission produced by pion decay. In turns neutral pions are generated in interactions of high-energy (>300 MeV) protons with the ambient solar atmosphere. Such a pion-produced gamma-ray emission was detected in 12 solar flares, and GLE particles were presented after 5 of them. Appearance of the bulk of solar protons was preceded by enhancement observed by several neutron monitors. Comparing the time of an appearance of pion produced gamma rays with onset time of these GLE we found that accelerated protons are able to escape the Sun immediately after their acceleration without any delay."

- ✓ "If certain portion of accelerated particles, 'the lucky ones', directly access the shortest IMF lines existing in this time and if the particle transport is a simple adiabatic motion characterized by the lack of scattering then the distance covered by these particles is close to the length of smoothed spiral IMF lines. In this case a weak burst of such 'lucky' particles could be detected before the arrival of the main particle bulk. This burst caused by 'lucky' particles will be called a precursor."

GeV photon/particle energies and large solar flares (2009)

Concluded high-energy protons produced during main flare energy release

- ✓ **See: "Appearance of high-energy protons at the Sun and the GLE onset," B. Yushkov, V. Kurt, and A. Belov, Proceedings of the 31st ICRC, Lodz, Poland (2009) see URL = http://icrc2009.uni.lodz.pl/proc/pdf/icrc0590.pdf**

- ✓ **Continuing: "It is possible to estimate an expected delay of this precursor relative to the appearance of gamma-ray emission caused by neutral pion decay i.e. after particle acceleration by taking into account the following considerations: *i*) at the values of solar wind speed of 300-800 km/s the most probable IMF field lines lengths lie within the interval 1.08 - 1.4 AU. The low limit of the distribution of these lengths is close to 1 AU; *ii*) effective energy of particles detected by NM stations located at high latitudes has been estimated to be »1 GeV, corresponding to the velocity *v* = 0.875 *c* (*c* = speed of light). It is so, because particles with higher energies are the earliest."**

- ✓ **"Let us make an example. It takes 500 s for photons to propagate from the Sun to Earth. The propagation time of 1 GeV protons along the path of 1.2 AU is equal to 685 s. If photons and protons were released simultaneously then at Earth the second ones will be detected with about 3 min delay after the observation of the gamma emission... the time delay of the 'lucky particles' relative to the beginning of the gamma emission from the neutral pion decay can be calculated."**

- ✓ **"Comparison of the GLE onset with one of the gamma ray burst lead to the conclusion that high-energy protons detected at the Earth escaped the Sun immediately after their acceleration ... Thus particles had to arrive to the Earth later on 100 s than photons and similar delay value was observed by NM South Pole. ... As it was found at least by one NM station the burst of gamma-ray emission was followed by the precursor spike reaching the statistic level higher than 3σ. The time delay delta t between the gamma burst and the precursor was 1-6 min. Confidence of observation of such precursor varied from 100 percents for 15 June 1991 (GLE52) to the threshold of statistical significance for GLE51 and GLE65. We ... have no full assertion of the proposal that these precursors really exist, only strong indications."**

- ✓ **In conclusion: "An existence of precursors is a strong argument in favor of an acceleration of high-energy protons along with the main flare energy release. Acceleration of these protons during the following flare phase contradicts with observed onset times of precursor."**

GeV particle acceleration associated w. solar flares (2011)

Origin? heliospheric CME shockwaves or directly in flares (consistent w. W-S-L)

- ✓ See: "GeV particle acceleration in solar flares and ground level enhancement (GLE) events," M. Aschwanden, see URL = http://arxiv.org/PS_cache/arxiv/pdf/1005/1005.0029v4.pdf [please note that v4 posted to the arXiv server on May 12, 2011; v1 version posted in 2010]

- ✓ "A key aspect that motivated this review is the question whether ground level enhancement (GLE) events, which apparently require acceleration processes that produce > ~1 GeV particles, originate from flare regions in the solar corona or from shocks driven by coronal mass ejections propagating through the corona and interplanetary space. GLE events represent the largest solar energetic particle (SEP) events that accelerate GeV ions with sufficient intensity so that secondary particles are detected by ground-level neutron monitors above the galactic cosmic-ray background (Lopate 2006; Reames 2009b). A catalog of 70 GLE events, occurring during the last six solar cycles from 1942 to 2006, has been compiled (Cliver et al. 1982; Cliver 2006), which serves as the primary database of many GLE studies. So, GLE events are very rare, occurring only about a dozen times per solar cycle, which averages to about one event per year. While GLE events with 1 GeV energies represent the largest energies produced inside our solar system, they are at the bottom of the cosmic ray spectrum, which covers an energy range of $10^9 - 10^{21}$ eV, exhibiting a 'spectral knee' between particles accelerated inside our galaxy ($10^9 - 10^{16}$ eV) and in extragalactic sources ($10^{16} - 10^{21}$ eV). While coronal mass ejections (CMEs) are widely considered as the main drivers of geoeffective phenomena, as pointed out in the so-called 'solar flare myth' paradigm (Gosling 1993), the acceleration site of high-energy particles detected in-situ in the heliosphere can often not unambiguously be localized, and thus we have to consider both options."

GeV particle acceleration associated w. solar flares (2011)

Origin? heliospheric CME shockwaves or directly in flares (consistent w. W-S-L)

- ✓ See: "GeV particle acceleration in solar flares and ground level enhancement (GLE) events," M. Aschwanden, see URL = http://arxiv.org/PS_cache/arxiv/pdf/1005/1005.0029v4.pdf [please note that v4 posted to the arXiv server on May 12, 2011; v1 version posted in 2010]

- ✓ "Flare Observations of GLE Events: all GLE events are associated with solar flares of the most intense category, i.e., GOES X-class flares in most cases, although there are exceptions, e.g., see the 1979 August 21 event (Cliver et al. 1983) or the 1981 May 10 event (Cliver 2006). At the same time, coronal mass ejections (CME) were reported in all recent cases. Thus we can say that flares and CMEs are both necessary conditions for a GLE event, but it leaves us with the ambiguity where the acceleration of GeV particles responsible for GLE events takes place. In the following we investigate and review various observational aspects of relevant flare data that could shed some light into this question."

- ✓ "Prompt Flare-Associated Acceleration of GLE Protons: most GLE events exhibit a prompt component (PC) and a delayed component (DC), which were identified in nearly all events in a recent study of 35 large GLE events during the period of 1956-2006 (Vashenyuk et al. 2011). The prompt component prevails at the beginning of the event and is characterized by an impulsive profile, strong anisotropy, and by an exponential energy spectrum, i.e. $J(E) \propto \exp(-E/E_0)$ with $E_0 \approx 0.5$ GeV (within a range of 0.3 GeV $\leq E_0 \leq$ 1.8 GeV). The delayed component dominates during the maximum and decay phase of the events, has a gradual intensity profile, a moderate anisotropy, and a power law energy spectrum (with a typical slope of $\delta \approx 5 \pm 1$). Since CME-associated shocks last much later than the impulsive flare phase, shock accelerated particles are likely to increase in number and are subject to a gradual release as long as the shock lasts, and thus cannot explain the short impulsive time profile in a natural way, while flare-associated hard X-rays exhibit the same impulsive time profile of particle acceleration naturally. The fact that most GLE events (29 out of 35) analyzed in Vashenyuk et al. (2011) exhibit a prompt component, together with our finding that the GLE start times occur during the impulsive hard X-ray phase in 50%, supports the interpretation of flare-associated acceleration for the prompt component."

Commercializing a Next-Generation Source of Safe Nuclear Energy

GeV particle acceleration associated w. solar flares (2011)

Origin? heliospheric CME shockwaves or directly in flares (consistent w. W-S-L)

- ✓ **See: "GeV particle acceleration in solar flares and ground level enhancement (GLE) events," M. Aschwanden, see URL = http://arxiv.org/PS_cache/arxiv/pdf/1005/1005.0029v4.pdf [please note that v4 posted to the arXiv server on May 12, 2011; v1 version posted in 2010]**

- ✓ **"Height of Acceleration Region: since we have a temporal coincidence of GLE particle acceleration with respect to flare hard X-ray emission in at least 50%, we turn now to the question of the spatial localization of acceleration sources ... From statistics of 42 flares, an average height ratio of $h/h_{loop} \approx L/L_{loop}$ = 1.4 ± 0.3 was obtained Aschwanden et al. 1996), for flare loop radii of r_{loop} 2 − 20 Mm. Thus, the height range of acceleration regions in flares amounts to $h \approx 4-40$ Mm, which corresponds to ≤ 5% of a solar radius. In summary, since about 50% of the GLE events are consistent with a particle release time during the flare hard X-ray phase, they are expected to have acceleration heights of h ≤ 0.05 solar radii."**

- ✓ **"Conclusions: we explored here the question whether the largest SEP and GLE events that accelerate ions with energies of ≥1 GeV could be accelerated in solar flare regions, in contrast to the generally accepted paradigm of acceleration in heliospheric CME shocks. We reviewed the pro and con aspects from the solar flare site that are relevant to answer this question, while the complementary aspects from CME-associated shocks are discussed in the companion article by Gang Li. The conclusions are based on observations of 70 GLE events over the last six decades, in particular on the 13 GLE events during the last solar cycle 23 (1998-2006) that provided excellent new imaging data in gamma rays and hard X-rays (RHESSI), in soft X-rays and EUV (TRACE, SOHO/EIT), and particle data from IMP, WIND, and ACE."**

GeV particle acceleration associated w. solar flares (2011)

Origin? heliospheric CME shockwaves or directly in flares (consistent w. W-S-L)

- ✓ See: “GeV particle acceleration in solar flares and ground level enhancement (GLE) events,” M. Aschwanden, see URL = http://arxiv.org/PS_cache/arxiv/pdf/1005/1005.0029v4.pdf [please note that v4 posted to the arXiv server on May 12, 2011; v1 version posted in 2010]

- ✓ “Conclusions (continued): “... acceleration time of GLE particles is consistent with the flare site in 50% of the cases, taking the full duration of impulsive flare hard X-ray emission (t_x ≈ 3 -13 min) into account ... In the remaining cases, 6 our of 12 occur delayed to the flare peak by 10 − 30 min, but observational signatures of extended acceleration and/or particle trapping are evident in all strongly delayed cases, and thus all GLE events could potentially be accelerated in flare sites. The alternative explanation of delayed second-step acceleration in CME-associated shocks cannot be ruled out, however, possibly constituting a secondary gradual GLE component ... height of the acceleration region of ≤ 1 GeV electrons and ions depends on the interpretation, being h ≤ 0.05 solar radii for flare site acceleration (according to electron time-of-flight measurements), or h ≈ 2 - 5 solar radii for CME shock acceleration ... magnetic topology at the particle acceleration site is not well-known from magnetic modeling or tracing of coronal structures... recently discovered strong correlation between the spectral soft-hard-harder (SHH) evolution of solar hard X-rays and SEP events poses a new challenge. It is presently unclear how the SHH evolution can be explained in the context of the standard scenario in terms of SEP acceleration in CME-associated shocks... maximum particle energies observed in solar flares reach up to several 100 MeV for electrons and above 1 GeV for ions.”

- ✓ Final conclusions: “... acceleration of GeV particles in flare sites is a possibility that cannot be firmly ruled out with the current localization capabilities of energetic particles. Certainly we have evidence for both acceleration in coronal flare sites and in heliospheric CME shocks, often appearing concomitantly, but with different (impulsive vs. gradual) time scales, relative timing, and charge state characteristics. While one-sided emphasis has been given to both, either flares (the ‘big flare syndrome’), or CMEs (the ‘flare myth’; Gosling 1993), there is a consensus now that both flare and CME phenomena are part of a common magnetic instability, and that both are being able to accelerate particles to high energies. The remaining questions are then mostly what the relative proportions of both components are and how we can discriminate between them. A preliminary answer is that the observations are mostly consistent with a flare-associated ‘prompt GLE component’ and a CME-associated ‘delayed GLE component’.”

Solar flare neutrino bursts alter *β*-decay rates on earth (2009)

W-S-L theory predicts neutrino bursts in large flares from e^- + p^+ weak reactions

- ✓ **Our theoretical collective magnetic mechanism, as described in the preprint "High energy particles in the solar corona" (*arXiv* 2008) and "Primer" (*Pramana*, 2010), posits that magnetic field energy contained in flux tubes is collectively transferred from one collection of charged particles to another, thus ~continuously heating the solar corona relative to Sun's photosphere**
- ✓ **In violent events like flares in which spatially organized, ~circular/tubular structures of magnetic flux tubes are physically destroyed, magnetic energy contained in 'dying' flux tubes' *B* fields is rapidly 'dumped' into kinetic energies of a variety of charged particles embedded within them**
- ✓ **In both cases, nuclear reactions of the general form: $e^- + p^+ \rightarrow lepton + X$ can occur at substantial rates via our mechanism. While a plethora of different particles can potentially be produced in such reactions, one way or another, neutral leptons, i.e. neutrinos, will end-up comprising a substantial portion of the final emitted products. These surface-produced neutrinos will then contribute to much larger, *roughly steady-state* fluxes of neutrinos that are continuously being created by p^+-p^+ and other charged-particle nuclear reactions occurring deep in the Sun's core**
- ✓ **All that being the case, if our collective magnetic mechanism were in fact operating in and around the 'surface' and atmosphere of the Sun, we would expect that large, especially violent solar flares would produce 'bright' localized bursts of neutrinos that might be 'visible' against the large ~steady-state background flux of neutrinos constantly being emitted from the solar core**
- ✓ **Question: is their any plausible observational evidence that such localized neutrino bursts may actually be occurring during solar flares? Interestingly, the answer is yes, as we shall see shortly**

Discussed manipulation of *β*-decay rates in patent (2005)

US Patent #7,893,414 --- filed in 2005; issued by the USPTO on February 22, 2011
"Apparatus and Method for Absorption of Incident Gamma Radiation and its Conversion to Outgoing Radiation at Less Penetrating, Lower Energies and Frequencies"
Inventors: Lewis Larsen and Allan Widom
Clean electronic copy at source URL = http://www.slideshare.net/lewisglarsen/us-patent-7893414-b2

Quoting from columns 33 – 34: "In addition to their utility as an effective gamma shield, the heavy electrons and ultra low momentum neutrons of the invention can also be used to control the transition rates of weak nuclear interactions, in particular beta decay. The number of beta decay events can be increased or decreased depending on the number of surface heavy electron states created in the vicinity of the beta decaying nucleus ... "

i.e., a nucleus with *Z* protons and (*A - Z*) neutrons transmutes into a new nucleus with (*Z* + 1) protons and (*A – Z –* 1) neutrons emitting and electron e- and an anti-neutrino. The decay arte depends strongly on the energy of the electron plus the energy of the neutrino which together determine the nuclear heat of reaction. The larger the heat of reaction the faster the beta decay rate. Any increase in the electron mass due to condensed matter renormalization, lowers the heat of reaction and thereby lowers the rate of beta decay ... "

"Here p^+ represents a proton. The neutron will decay if isolated in a vacuum. The neutron will not decay if it is located inside a nucleus which is stable to beta decay because the heat of reaction would be negative. A neutron within a nucleus will decay if the heat of beta decay reaction is positive. The more positive the heat of reaction [Q-value], the faster will be the beta decay rate."

"The decay of a single neutron will be slowed down if the final electron state has a higher mass because the resulting heat of reaction will be smaller. On[e] may thereby control the rate of beta decay reactions of nuclei on the surface of metallic hydrides by controlling the surface density of heavy electron states. Since the heavy mass states are central for neutron catalyzed nuclear transmutations, the control of the density of heavy electrons states also controls the rates of nuclear transmutation catalysis."

Solar flare neutrino bursts alter β-decay rates on earth (2009)

W-S-L theory predicts neutrino bursts in large flares from e^- + p^+ weak reactions

- ✓ See: "Perturbation of nuclear decay rates during the solar flare of 13 December 2006," J. Jenkins and E. Fischbach, *Astroparticle Physics* 31 pp. 407 - 411 (2009) - can purchase for $31.50 at URL = http://www.sciencedirect.com/science/article/pii/S092765050900070X free arXiv preprint (2008) see URL = http://arxiv.org/ftp/arxiv/papers/0808/0808.3156.pdf

- ✓ Abstract of peer-reviewed version: "Recently, correlations have been reported between fluctuations in nuclear decay rates and Earth-Sun distance, which suggest that nuclear decay rates may be affected by solar activity. In this paper, we report the detection of a significant decrease in the decay of ^{54}Mn during the solar flare of 2006 December 13, whose X-rays were first recorded at 02:37 UT (21:37 EST on 2006 December 12). Our detector was a 1 μCi sample of ^{54}Mn, whose decay rate exhibited a dip coincident in time with spikes in both the X-ray and subsequent charged particle fluxes recorded by the Geostationary Operational Environmental Satellites (GOES). A secondary peak in the X-ray and proton fluxes on December 17 at 12:40 EST was also accompanied by a coincident dip in the ^{54}Mn decay rate. These observations support the claim by Jenkins et al. that nuclear decay rates may vary with Earth-Sun distance."

- ✓ Comment: designated as GLE#70, the solar flare of 13 December 2006 was a very large ground level enhancement (GLE) event; according to Aschwanden (2011), "GLEs ... represent the largest class of *solar energetic particle* (SEP) events that require acceleration processes to produce > 1 GeV ions in order to produce showers of secondary particles in the Earth's atmosphere with sufficient intensity to be detected by ground-level neutron monitors, above the background of [high energy] cosmic rays ... the association of GLE events with both solar flares and coronal mass ejections (CMEs) is undisputed ..."

Solar flare neutrino bursts alter β-decay rates on earth (2009)

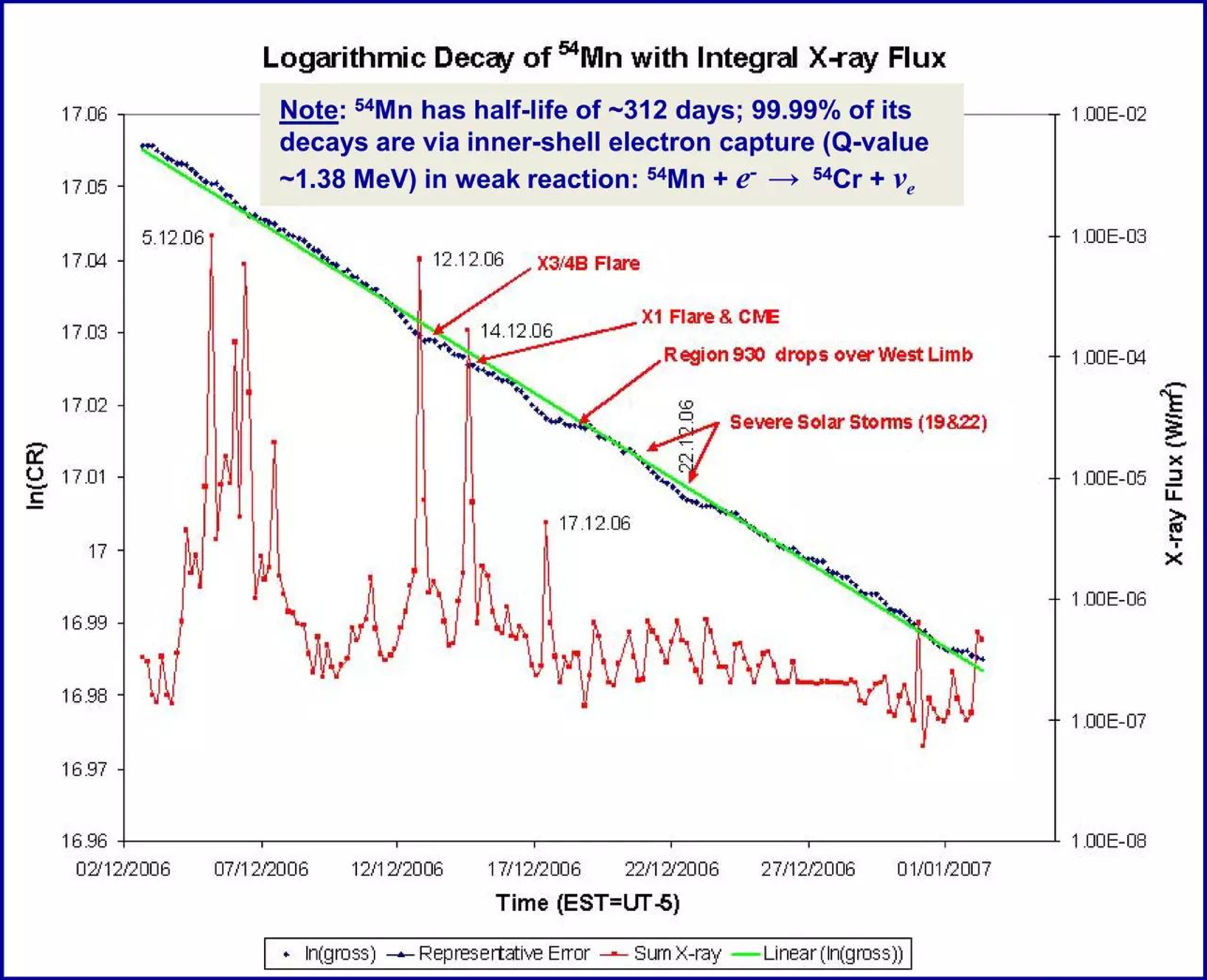


Figure 1. J. Jenkins and E. Fischbach, *Astroparticle Physics* 31 pp, 407 - 411 (2009)

Quoting caption from paper:

"Figure 1. December 2006 ^{54}Mn data, and GOES-11 x-ray data, both plotted on a logarithmic scale. For ^{54}Mn, each point represents the natural logarithm of the number of counts ~2.5 x 10^7 in the subsequent 4 hour period, and has a *N* statistical error shown by the indicated error bar."

"For the GOES-11 x-ray data, each point is the solar flux in W/m^2 summed over the same real time intervals as the corresponding decay data."

"The solid line is a fit to the ^{54}Mn data, and deviations from this line coincident with the x-ray spikes are clearly visible on 12/12 and 17/12. "

"As noted in the text, the deviation on 22/12 was coincident with a severe solar storm, with no associated flare activity. The dates for other solar events are also shown by arrows."

Solar flare neutrino bursts alter *β*-decay rates on earth (2009)

W-S-L theory predicts neutrino bursts in large flares from e^- + p^+ weak reactions

- ✓ Continuing discussion of: "Perturbation of nuclear decay rates during the solar flare of 13 December 2006," J. Jenkins and E. Fischbach, *Astroparticle Physics* 31 pp, 407 - 411 (2009)

- ✓ Quoting from their paper: "Solar flares are periods of increased solar activity, and are often associated with geomagnetic storms, solar radiation storms, radio blackouts, and similar effects that are experienced here on Earth. It has been speculated that the increased activity associated with solar flares may also produce a short-term change in the neutrino flux detected on Earth.[1,2,3,4,5,6] To date, there appears to be no compelling experimental evidence of an association between neutrino flux and solar flares,[1,2,4,6] and this is due in part to the relatively low neutrino counting rates available from even the largest conventional detectors."

- ✓ "The object of the present paper is to use data we obtained during the solar flare of 13 December 2006 to suggest that neutrinos from the flare were detected via the change they induced in the decay rate of ^{54}Mn. The present paper supports the work of Jenkins et al. who present evidence for a correlation between nuclear decay rates and Earth-Sun distance[7]. Taken together, these papers suggest that nuclei may respond to changes in solar activity, possibly arising from changes in the flux of solar neutrinos reaching the Earth. The apparatus that was in operation during the solar flare is described in detail in the Supplemental Material. During the course of the data collection in the Physics building at Purdue University which extended from 2 December 2006 to 2 January 2007, a solar flare was detected on 13 December 2006 at 02:37 UT (21:37 EST on 12 December) by the Geostationary Operational Environmental Satellites (GOES-10 and GOES-11). Spikes in the x-ray and proton fluxes were recorded on all of the GOES satellites.[8] The x-ray data from this X-3 class solar flare are shown in Figures 1-3 along with the ^{54}Mn counting rates." [see paper for details]

Solar flare neutrino bursts alter β-decay rates on earth (2009)

W-S-L theory predicts neutrino bursts in large flares from e^- + p^+ weak reactions

- ✓ Continuing discussion of: "Perturbation of nuclear decay rates during the solar flare of 13 December 2006," J. Jenkins and E. Fischbach, *Astroparticle Physics* 31 pp, 407 - 411 (2009)
- ✓ Quoting further from their paper: "Before considering more detailed arguments in support of our inference that the ^{54}Mn count rate dips are due to solar neutrinos, we address the question of whether the coincident fluctuations in the decay data and the solar flare data could simply arise from statistical fluctuations in each data set ... If we interpret Eq. 1 in the conventional manner as a ~7σ effect, then the formal probability of such a statistical fluctuation in this 84 hour period is ~3 x 10^{-12}. Evidently, including additional small systematic corrections would not alter the conclusion that the observed fluctuation in runs 51-71 is not likely a purely statistical effect."
- ✓ "We next estimate the probability that a solar flare would have occurred during the same 84 hour period shown in Fig. 3 ... In total, the frequency of storms with intensity ≥ S2 is ~39 per 11 year solar cycle, or 9.7 x 10^{-3}, and hence the probability of a storm occurring at any time during the 84 hour window in Fig. 3 is ~3.4 x 10^{-2}. Evidently, if the x-ray and decay peaks were uncorrelated, the probability that they would happen to coincide as they do over the short time interval of the solar flare would be smaller still, and hence a conservative upper bound on such a statistical coincidence occurring in any 84 hour period is ~(3 x 10^{-12})(3 x 10^{-2}) ≈ 1 x 10^{-13}."

Solar flare neutrino bursts alter *β*-decay rates on earth (2009)

W-S-L theory predicts neutrino bursts in large flares from e^- + p^+ weak reactions

- ✓ **Continuing discussion of: "Perturbation of nuclear decay rates during the solar flare of 13 December 2006," J. Jenkins and E. Fischbach, *Astroparticle Physics* 31 pp, 407 - 411 (2009)**
- ✓ **"We begin by noting that the x-ray spike occurred at ~21:40 EST, approximately 4 hours after local sunset, which was at ~17:21 EST on 12 December 2006. As can be seen from Fig. 4, the neutrinos (or whatever agent produced this dip) had to travel ~9,270 km through the Earth before reaching the ^{54}Mn source, and yet produced a dip in the counting rate coincident in time with the peak of the x-ray burst."**
- ✓ **"Significantly, the monotonic decline of the counting rate in the 40 hours preceding the dip occurred while the Earth went through 1.7 revolutions, and yet there are no obvious diurnal or other periodic effects. These observations support our inference that this effect may have arisen from neutrinos, or some neutrino-like particles, and not from any conventionally known electromagnetic effect or other source, such as known charged particles."**
- ✓ **"If the detected change in the ^{54}Mn decay rate was in fact due to neutrinos then one implication of the present work is that radioactive nuclides could serve as real-time neutrino detectors for some purposes. In principle, such 'radionuclide neutrino detectors' (RNDs) could be combined with existing detectors, such as Super-Kamiokande, to significantly expand our understanding of both neutrino physics and solar dynamics."**

Solar flare neutrino bursts alter *β*-decay rates on earth (2009)

W-S-L theory predicts neutrino bursts in large flares from $e^- + p^+$ weak reactions

- ✓ **Continuing discussion of Jenkins & Fischbach, *Astroparticle Physics* 31 pp, 407 - 411 (2009):**

- ✓ **Lattice comments: in our view, Jenkins & Fischbach were properly circumspect --- they thoughtfully examined possible sources of significant errors or potential artifacts in their measurements of ^{54}Mn decay rates; none were obvious or apparent. That caution, coupled with the fact that somewhat analogous perturbations in β decay rates have been observed by others, e.g., see recent arXiv preprints posted by A. Parkhomov, "Researches of alpha and beta radioactivity at long-term observations" at URL = http://arxiv.org/ftp/arxiv/papers/1004/1004.1761.pdf (April 2010) and "Periods detected during analysis of radioactivity measurements data" at URL = http://arxiv.org/ftp/arxiv/papers/1012/1012.4174.pdf (December 2010), suggests that their data is probably sound and that they have demonstrated a cause-and-effect temporal correlation between a very large flare on the Sun and changes in the observed electron capture decay rate of a macroscopic sample of ^{54}Mn atoms here on the earth**

- ✓ **What effect might be causing Jenkins & Fischbach's anomalous data? 99.99% of ^{54}Mn atoms decay (half-life ~312 days) via K-shell electron capture, which involves the weak interaction as follows: $^{54}Mn + e^- \rightarrow {}^{54}Cr + \nu_e$; please recall that neutrinos obey Fermi-Dirac statistics (they behave like Fermions). Given that constraint, in order to successfully decay, a ^{54}Mn nucleus must be able to emit an electron neutrino (ν_e) into *an unoccupied fermionic state in the local continuum*. If all such local states are momentarily filled, a given nucleus cannot decay until an unoccupied 'slot' opens-up. Now imagine a ^{54}Mn atom located on earth bathed in a more-or-less steady-state flux of electron neutrinos coming from the Sun. At every instant, every unstable ^{54}Mn atom is quantum mechanically interrogating the local continuum 'world' outside its nucleus via its electron capture channel in order to 'decide' whether it is permissible to decay by emitting a neutrino. In doing so, ^{54}Mn's internal 'nuclear decay clock' is effectively modified by changes in fine details of external neutrino fluxes in terms of *experimentally observed decay rates of such atoms.* For example, imagine that a very large flare occurred on the Sun in which copious weak interactions $e^- + p^+ \rightarrow lepton + X$ took place. Let us further suppose that the energy spectrum of such a 'bright' burst of neutrinos emitted in that particular solar flare *just happened to strongly overlap the spectrum that would normally be emitted by ^{54}Mn nuc*lei. In that case, one could reasonably expect that one might be able to observe a measurable temporary decrease in the decay rates of ^{54}Mn nuclei in a macroscopic sample being monitored experimentally here on earth. That being the case, if correct, their data is direct evidence for operation of the W-S-L collective magnetic mechanism in at least one large solar flare**

Other neutrino sources: local geo-neutrinos from the earth

Borexino measured flux emanating from core; somewhat higher than expected

While more data is needed, suggests possibility that models of Earth's interior may need improvement

- ✓ **See: "Observation of geo-neutrinos," G. Bellini et al. (Borexino Collaboration), *Physics Letters B* 687 pp. 289 - 304 (2010) - free arXiv preprint at URL = http://arxiv.org/PS_cache/arxiv/pdf/1003/1003.0284v2.pdf**

- ✓ **Also see: "Geo-neutrinos and Earth's interior," G. Fiorentini, M. Lissia, and F. Mantovani (2007) Free arXiv preprint at URL = http://arxiv.org/PS_cache/arxiv/pdf/0707/0707.3203v2.pdf**

- ✓ **Quoting abstract of G. Bellini et. al (2010): "Geo-neutrinos, electron anti-neutrinos produced in *β* decays of naturally occurring radioactive isotopes in the Earth, are a unique direct probe of our planet's interior. We report the first observation at more than 3σ C.L. of geo-neutrinos, performed with the Borexino detector at Laboratori Nazionali del Gran Sasso. Anti-neutrinos are detected through the neutron inverse *β* decay reaction. With a 252.6 ton yr fiducial exposure after all selection cuts, we detected 9.9 geo-neutrino events, with errors corresponding to a 68.3% (99.73%) C.L. From the ln$\mathcal{L}$ profile, the statistical significance of the Borexino geo-neutrino observation corresponds to a 99.997% C.L. Our measurement of the geo-neutrinos rate is 3.9 events/(100 ton yr). The observed prompt positron spectrum above 2.6 MeV is compatible with that expected from European nuclear reactors (mean base line of approximately 1000 km). Our measurement of reactor anti-neutrinos excludes the non-oscillation hypothesis at 99.60% C.L. This measurement rejects the hypothesis of an active geo-reactor in the Earth's core with a power above 3 TW at 95% C.L."**

Other neutrino sources: local geo-neutrinos from the earth

Borexino measured flux emanating from core; somewhat higher than expected

Bellini et a. (2010) Table 3 – Comparison : the Borexino measurement of geo-antineutrinos with predictions See text in published paper for details, including model descriptions, estimated margins of error and references	
Source of data being compared:	**Geo-antineutrino rate [events/(100 ton yr)]**
Borexino Collaboration measurements	3.9
Basic Silicate Earth model – BSE [16]	2.5
Basic Silicate Earth model – BSE [31]	2.5
Basic Silicate Earth model – BSE [5]	3.6
Maximum "radiogenic Earth" model	3.9
Minimum "radiogenic Earth" model	1.6

Discussion of Table 3 in Bellini et. al (2010): "In Table 3 we compare the measured rate with predictions of some of the most interesting geophysical models. In particular, we report as terms of comparison upper and lower bounds on the BSE models, considering the spread of U and Th abundances and their distributions allowed by this geochemical model; the expectation under the Minimal Radiogenic Earth scenario, which considers U and Th from only those Earth layers whose composition can be studied on direct rock-samples; the expectation under the Maximal Radiogenic Earth scenario, which assumes that all terrestrial heat (deduced from measurements of temperature gradients along ~20,000 drill holes spread over the World) is produced exclusively by radiogenic elements ... The results for the geo-neutrinos rate, summarized in Table 3, hint at a higher rate for geo-neutrinos than current BSE predicts. However, the present uncertainty prevents firm conclusions ... The data presented in this Letter unambiguously show, despite the limited statistics, the sensitivity of Borexino for detecting geo-neutrinos."

Other neutrino sources: local geo-neutrinos from the earth

Borexino measured flux emanating from core; somewhat higher than expected

- ✓ Lattice comments on geo-neutrino data: please recall that neutrino production is a principal and characteristic signature of neutron-catalyzed LENR nucleosynthetic networks; that is, neutrinos carry away a portion of energy emitted during weak interaction ULM neutron production a la the Widom-Larsen theory and in the course of 'typical' decays of neutron-rich, beta-unstable isotopes produced as a result of ULM neutron capture processes
- ✓ If W-L theory is correct, it implies that complex collective, many-body neutron-catalyzed LENR nucleosynthetic networks can potentially occur in a very broad range of 'milder' natural environments besides hot plasmas in stars and supernovas, and outside of manmade environments like fission or fusion reactors and detonating nuclear weapons
- ✓ In various PowerPoint presentations that are publicly available on Slideshare.net at URL = http://www.slideshare.net/lewisglarsen , we have provided examples of experimental evidence that LENR transmutation reactions may be occurring abiologically: e.g., in T. Mizuno's prosaic P/T/phenanthrene/hydrogen/metal/time reactor vessels; somewhere inside the coking ovens found at an integrated South African steelmaking plant (^{15}N); in the electrolytic cells of a commercial manganese separation plant; catalytic converters of cars and trucks, as well as on the surfaces of primordial presolar dust. Similarly, we have also provided and discussed examples of plausible experimental evidence from Russia and elsewhere concerning what appear to be biological LENR transmutations and heavy-electron gamma shielding by certain species of bacteria, fungi, and yeasts

Other neutrino sources: local geo-neutrinos from the earth

Borexino measured flux emanating from core; somewhat higher than expected

- ✓ Latticed comments continued: in the first-ever geo-neutrino rate data presented in Table 3 of Bellini et al. (2010), the observed rate of 3.9 events/100 ton*yr is significantly higher than the geo-neutrino production rate predicted by two BSE models (2.5 and 2.5, respectively) and slightly higher than that of another BSE model in which they used a new, *ad hoc* rationale to rate predicted by the "maximum radiogenic earth" model; quoting, "… the expectation under the Maximal Radiogenic Earth scenario, which assumes that all terrestrial heat (deduced from measurements of temperature gradients along ~20,000 drill holes spread over the World) is produced exclusively by radiogenic elements"
- ✓ Interestingly, if a variety of heat/neutrino-producing LENRs were also taking place within the Earth in parallel with the previously assumed limited suite of radiogenic decays (i.e., U-series, Th-series, ^{40}K), it might help close the gap between the lower geo-neutrino flux predictions of the most popular BSE models versus Borexino's measured geo-neutrino production rate of 3.9
- ✓ It is presently unclear how commonly abiological and/or biological LENR nucleosynthesis might be occurring inside the earth or the rates at which such processes might operate over geologic time. That said, based what has been observed experimentally to date, it would seem likely that just the right combinations of physical conditions (pressure, temperature, time) and assemblage of necessary materials in intimate proximity to each other (e.g., certain metals, hydrogen, and organic molecules such as PAHs) could plausibly occur often enough at different locations and times inside our planet to potentially be a new factor in Earth's long geochemical history, thus potentially meriting further investigation by interested geophysicists, mineralogists, microbiologists, and geochemists

Nucleosynthesis in exploding wires and lightning

Exploding wires and lightning with embedded particles are dusty plasmas

Presence of particles can significantly alter charged particle equilibrium --- non-Hamiltonian systems

"***Energetic electrons and nuclear transmutations in exploding wires***" **Widom, Srivastava, and Larsen** *arXiv* preprint (September 2007)	http://arxiv.org/PS_cache/arxiv/pdf/0709/0709.1222v1.pdf
"*A* ***primer for electro-weak induced low energy nuclear reactions***" **Srivastava, Widom, and Larsen** *Pramana – Journal of Physics* **75** pp. 617 (October 2010)	http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

Abstract (arXiv W-S-L 2007): "Nuclear transmutations and fast neutrons have been observed to emerge from large electrical current pulses passing through wire filaments which are induced to explode. The nuclear reactions may be explained as inverse beta transitions of energetic electrons absorbed either directly by single protons in Hydrogen or by protons embedded in other more massive nuclei. The critical energy transformations to the electrons from the electromagnetic field and from the electrons to the nuclei are best understood in terms of coherent collective motions of the many flowing electrons within a wire filament. Energy transformation mechanisms have thus been found which settle a theoretical paradox in low energy nuclear reactions which has remained unresolved for over eight decades. It is presently clear that nuclear transmutations can occur under a much wider range of physical conditions than was heretofore thought possible."

Dusty plasma: is a plasma containing nanometer or micrometer-sized particles suspended in it. Dust particles may be charged and the plasma and particles behave as a plasma, following electromagnetic laws for particles up to about 10 nm (or 100 nm if large charges are present). Dust particles may form larger particles resulting in "grain plasmas"

Dust plasma component	Temperature
Dust temperature	10 K
Molecular temperature	100 K
Ion temperature	1,000 K
Electron temperature	10,000 K

See: http://en.wikipedia.org/wiki/Dusty_plasma

Temperature of dust in a plasma may be quite different from its environment (for example, see Table to left). If relativistic electrons are actually charging dust gains, then the dust may charge up to several kilovolts. Field electron emission (reduces negative potential) can be important due to the small size of the particles; E-field gradients can be >> 1,000 Volts per micron!

Nucleosynthesis in exploding wires and lightning

Exploding wires and lightning with embedded particles are dusty plasmas

- ✓ **Quoting from our arXiv preprint: "Over eighty years ago, Wendt and Irion[1] reported nuclear reactions in exploding wires. The transmuted nuclear products emerged after a large current pulse was passed through a Tungsten wire filament which exploded. Sir Ernest Rutherford[2] expressed doubts as to whether the electrons flowing through the wire could carry enough energy to induce nuclear reactions. The exploding wire current pulse had been produced by a capacitor discharge with an initial voltage of only thirty kilovolts. On the other hand, Rutherford had employed a high energy but dilute beam of 100 KeV electrons fired into a Tungsten target. Rutherford did not observe any nuclear reactions. Wendt[3] replied to the Rutherford objections, asserting that the peak power in the exploding wire current pulse was much larger than the relatively small power input to Rutherford's electron beam. Most importantly, a large energy transfer from the many electrons in the wire to the nuclei could occur collectively which would allow for the nuclear transmutation energy."**

- ✓ **"This very old but important debate between Wendt and Rutherford has presently been experimentally settled in favor of Wendt. The more recent[4, 5, 6, 7, 8, 9] exploding wire experiments have, beyond any doubt, detected fast emerging neutrons capable of inducing nuclear transmutations. These observed fast neutrons have often been attributed to the products of deuteron fusion but we find that hypothesis unlikely to be true. Firstly, fast neutrons have been seen in exploding wires even though there were no deuterons initially present [4, 5]. Secondly, the [~23 MeV] gamma emission signature of deuterium fusion has not been observed. It is much more likely that the fast neutrons are products of inverse beta transitions of very energetic electrons being absorbed by protons and producing fast neutrons and neutrinos. The protons may be Hydrogen atomic nuclei or the protons may be embedded within more massive nuclei... theoretical side of the difference of opinion between Wendt and Rutherford concerning how large amounts of energy can be transferred to and from the electrons in the wire has remained unresolved... purpose [herein] is to explain how this collective energy transfer may occur."**

Nucleosynthesis in exploding wires and lightning

Exploding wires and lightning with embedded particles are dusty plasmas

- ✓ **Quoting from our arXiv preprint**: "The scale of wire currents required to induce nuclear reactions may be found by expressing the rest energy of the electron mc^2 in units of a current I_o; i.e. by employing the vacuum impedance R_{vac} one finds $I_o \approx 1.704509 \times 10^4$ Ampere"
- ✓ "If a strong current pulse, large on the scale of I_o, passes through a thin wire filament, then the magnetic field exerts a very large Maxwell pressure on surface area elements, compressing, twisting and pushing into the wire. If the magnetic Maxwell pressure grows beyond the tensile strength of the wire material at the hot filament temperature, then the wire begins to melt and disintegrate. If the heating rate is sufficiently fast, then the hot wire may emit thermal radiation at a very high noise temperature. The thermal radiation for exploding Tungsten filaments exhibits X-ray frequencies indicating very high electron kinetic energies within the filament. Due to the electron kinetic pressure, the wire diameter starts to increase yielding a filament dense gas phase but still with some liquid droplets. The final explosive product consists of a hot plasma colloid containing some small dust particles of the original wire material. These products cool off into a gas and some smoke as is usual for explosions."
- ✓ "A change in the collective current dI yields a changing single electron momentum and thereby a change in the single electron energy dW wherein v is the velocity of that electron. The single electron energy can thereby reach values far above the electron rest energy for a pulse peak current large on the scale of I_o."
- ✓ "Many electrons acting cooperatively contribute energy $W_{magnetic}$ to inverse beta transitions even though only one of those electrons is destroyed. The Wendt-Irion peak current ratio I/I_o was as high as two hundred[3] yielding $W_{magnetic}$ ~200 MeV x v/c. If the electron velocity in the filament is small, say $v/c \sim 0.1$, then $W_{magnetic}$ is more than sufficient for an inverse beta transition."

Nucleosynthesis in exploding wires and lightning

Exploding wires and lightning with embedded particles are dusty plasmas

- ✓ Quoting from our arXiv preprint: "The following comments are worthy of note: (*i*) The electromagnetic field configuration when the current pulse passes through the wire is a magnetic field tangent to the wire surface and normal to the wire axis and an electric field parallel to the cylinder. This is the low circuit frequency limit of the surface plasma polariton mode previously employed in the explanation[11] of inverse beta transitions in chemical cells. However, the natural surface patches whereon the long wavelength neutrons would form are in the case of thin wire filaments destroyed by the explosion. (*ii*) Radiation losses have not been included in the above discussion. These losses are not large because of the collective nature of the current."

- ✓ "A single charged accelerating particle emits copious radiation whereas many electrons contributing to a smooth current in a wire will hardly radiate at all. However, some resistive wire heating energy will be removed from the wire filament as hot emitted thermal radiation. (*iii*) The Maxwell electromagnetic energy and pressure are largely due to the Ampere's law mutual attraction between electrons moving in the same direction. When an electron is combined with a proton to produce a neutron and a neutrino, the required energy is in part the attractive energy due to all of the other parallel moving electrons in the wire albeit only one electron is actually destroyed."

- ✓ Quoting from *Pramana* (2010): "A typical electron in the current with a mean kinetic energy of 15 keV would have an average speed $(v/c) \approx 0.25$. On the other hand, even for such low mean speed, the chemical potential given in eq. (11), for $(I/I_o) \approx 200$ becomes large $\mu \approx (mc^2)(200)(0.25) = 25$ MeV; (55) comfortably sufficient for an electron to induce a weak interaction LENR. Overall energy conservation will of course require that only a certain fraction of about (15 keV/25 MeV) = 6×10^{-4} of the total number of electrons in the current will be kinematically allowed to undergo weak interactions. Let us now briefly discuss why Rutherford with his much higher energy ---but dilute --- beam of electrons did not observe any nuclear reactions. The reason is rather simple. In the vacuum, there is a mutual Coulomb repulsion between the electrons in the beam which compensates the mutual Amperian current attraction. In the exploding wire filament, on the other hand, the repulsive Coulomb part is screened by the background positive charge but *leaves intact the Amperian current attraction thereby allowing the possibility of nuclear reactions*."

- ✓ N.B.: above also true for lightning with particles embedded in it and solar flux tubes with proton and electron currents

High-energy processes in lightning laced with dust/aerosols

Terrestrial gamma-ray flashes, x-rays, and neutrons: W-S-L mechanism at work?

Is nucleosynthesis occurring in high-current lightning emitting bursts of γ-rays, x-rays and neutrons?

Generalist Wikipedia article at URL = http://en.wikipedia.org/wiki/Terrestrial_gamma-ray_flash

- ✓ **See: "Electron-positron beams from terrestrial lightning observed with Fermi GBM," M. Briggs et al., *Geophysical Research Letters* 38, L02808 (2011) - free copy of preprint at URL = http://sciences.blogs.liberation.fr/files/article-de-grl-sursaut-gamma-sur-terre.pdf**
- ✓ **Also: "Origin of neutron flux increases observed in correlation with lightning," L. Babich and R. Roussel-Dupre´, *Journal of Geophysical Research* 112 D13303, doi:10.1029/2006JD008340 (2007) http://crdlx5.yerphi.am/files/thunder/2007Babich0.pdf**
- ✓ **Quoting abstract of Briggs et. al (2011): "Terrestrial Gamma-ray Flashes (TGFs) are brief pulses of energetic radiation observed in low-earth orbit. They are associated with thunderstorms and lightning and have been observed both as gamma-ray and electron flashes depending on the position of the spacecraft with respect to the source. While gamma-ray TGFs are detected as short pulses lasting less than 1 ms, most TGFs seen by the Fermi Gamma-ray Burst Monitor (GBM) with durations greater than 1 ms are, instead, the result of electrons traveling from the sources along geomagnetic field lines. We perform spectral analysis of the three brightest electron TGFs detected by GBM and discover strong 511 keV positron annihilation lines, demonstrating that these electron TGFs also contain substantial positron components. This shows that pair production occurs in conjunction with some terrestrial lightning and that most likely all TGFs are injecting electron-positron beams into the near Earth environment."**

High-energy processes in lightning laced with dust/aerosols

Terrestrial gamma-ray flashes, x-rays, and neutrons: W-S-L mechanism at work?

- ✓ **Quoting abstract of Babich and R-Dupre (2007): "The past decade of research into the phenomenon of lightning has seen an accumulation of evidence for the existence of penetrating radiation (*X*- and *γ*-rays) in direct association with many forms of discharges. As a result, our basic understanding of the mechanisms that produce lightning has shifted from the present paradigm based on conventional breakdown to a picture that incorporates the acceleration and avalanche of energetic particles. *Experiments conducted at high mountainous facilities in Gulmarg, India, have further confirmed the need for a paradigm shift.* These measurements have shown an enhancement in neutron flux in the atmosphere in correlation with lightning electromagnetic pulses. We demonstrate here that the prevailing neutron generation theory based on synthesis of deuterium nuclei in the lightning channel is not feasible. Instead, this phenomenon is most likely connected with photonuclear reactions produced as part of the recently elaborated theory of relativistic runaway breakdown."**

- ✓ **Duke University researcher comments on M. Griggs' January 10, 2011, presentation at the Winter Meeting of the American Astronomical Society: "The idea that any planet has thunderstorms that not only produce antimatter but then launch it into space seems like something straight out of science fiction," commented Steven Cummer of Duke University in Durham, North Carolina, who was not part of the study. "That our own planet does this, and has probably done it for hundreds of millions of years, and that we've only just learned it, is amazing to me."**

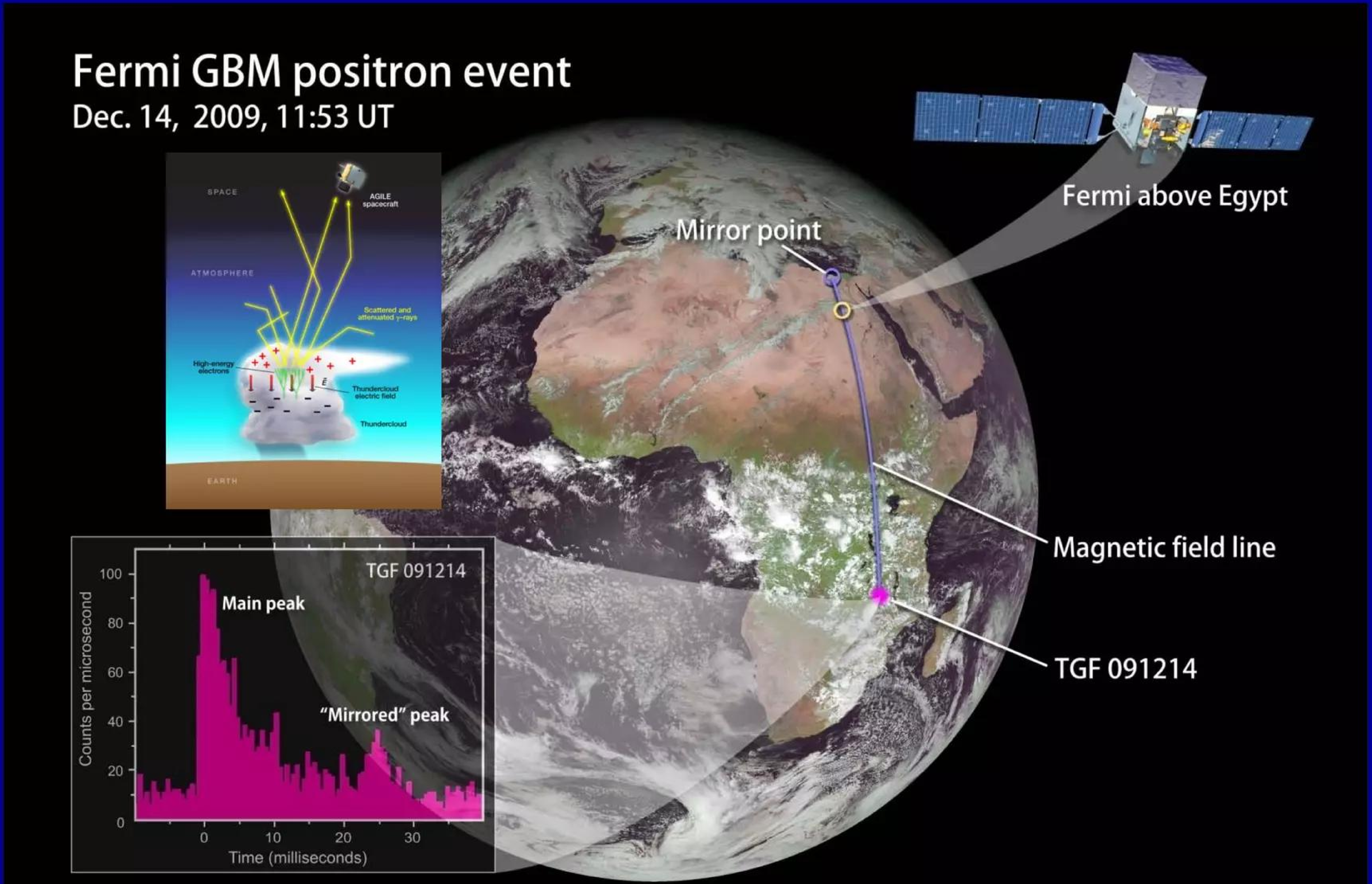
- ✓ **Lattice remark: too conservative; if the Fermi Gamma-ray Space Telescope's data and Griggs et al.'s interpretation are right, high-energy processes have been occurring in lightning for *billions* of years**

High-energy processes in lightning laced with dust/aerosols

Terrestrial gamma-ray flashes, x-rays, and neutrons: W-S-L mechanism at work?

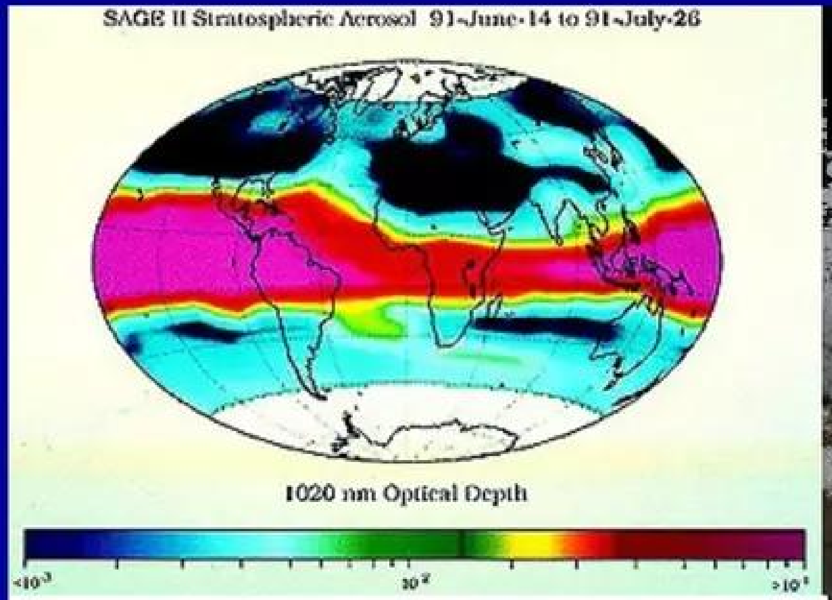
- ✓ **Lattice comments: on Earth, bolts of lightning can last for 30 - 50 microseconds and are well-known to involve electrical current pulses on the order of 30,000 to 100,000 Amperes (3 x 10^4 A to 1 x 10^5 A). Importantly, such values for peak current easily exceed a key threshold identified in our theoretical work, $I_o \approx 1.704509 \times 10^4$ Ampere (~17,000 A), that is required for the possibility of triggering weak interaction production of neutrons and/or creating energetic charged particles via $e^- + p^+ \rightarrow lepton + X$ reactions in lightning channel plasmas or $e^* + p^+ \rightarrow n + \nu_e$ reactions and subsequent neutron captures by atoms located on surfaces of 'dust' particles that are trapped within lightning channels during discharge**
- ✓ **Also, please recall from our arXiv and *Pramana* papers that (quoting), "In the vacuum, there is a mutual Coulomb repulsion between the electrons in the beam which compensates the mutual Amperian current attraction. In the exploding wire filament, on the other hand, the repulsive Coulomb part is screened by the background positive charge but *leaves intact the Amperian current attraction thereby allowing the possibility of nuclear reactions*."**
- ✓ **Thus, all other things being equal this implies that: within reasonable limits, the 'dustier' the plasma (dust particles assist by 'donating' emitted positive ions that help screen electron Coulomb repulsion) and the higher the electrical current pulse, the easier it becomes to increase a plasma's chemical potential to the point where nuclear reactions of the general forms shown above can be triggered**
- ✓ **This line of reasoning would suggest that, on Earth and other planets where atmospheric lightning occurs, manifestations of high-energy electronic and nuclear processes in lightning discharges (x-rays, γ- rays, neutrons, 'hot' electrons, positrons, etc.) should be more commonly observed in regions where there are higher levels of dust/aerosol particles that could be trapped in lightning channels. We shall now examine some crude qualitative evidence which suggests that this might be true here on Earth**

High-energy processes in lightning laced with dust/aerosols



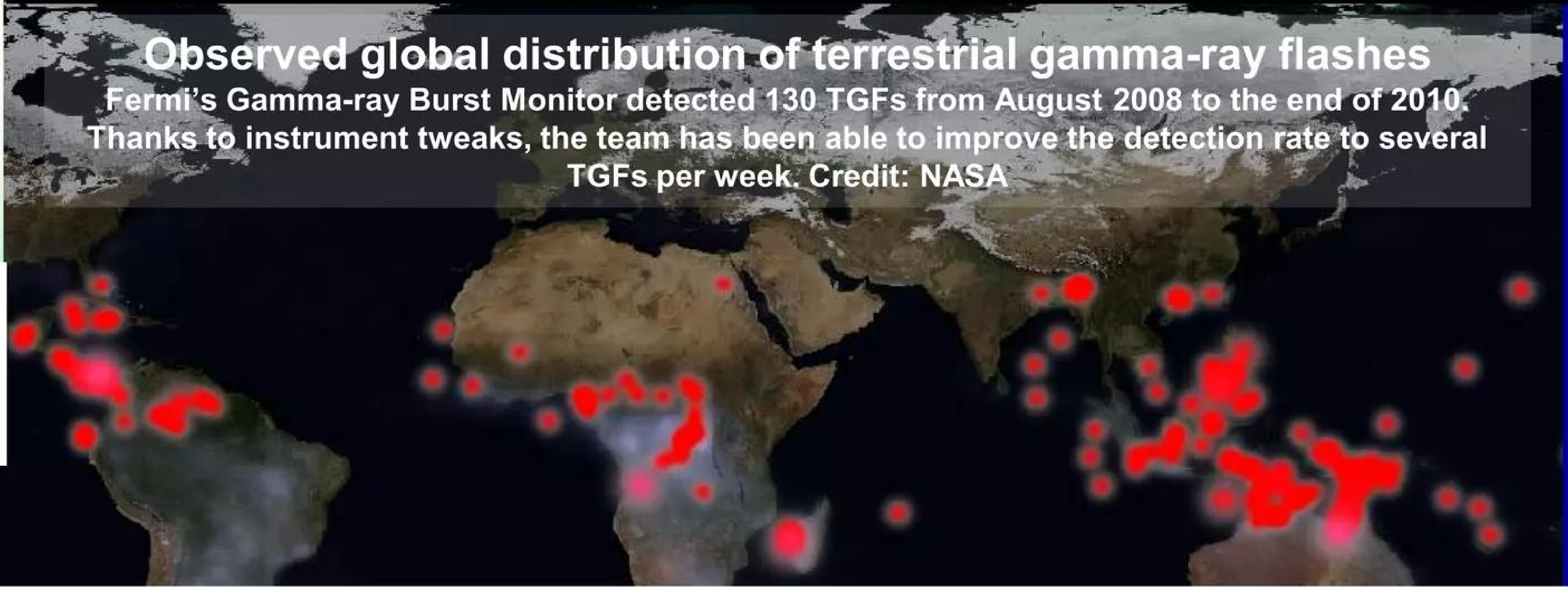
See source URL = http://www.nasa.gov/mission_pages/GLAST/news/fermi-thunderstorms.html
Related paper is at URL = http://sciences.blogs.liberation.fr/files/article-de-grl-sursaut-gamma-sur-terre.pdf

High-energy processes in lightning laced with dust/aerosols



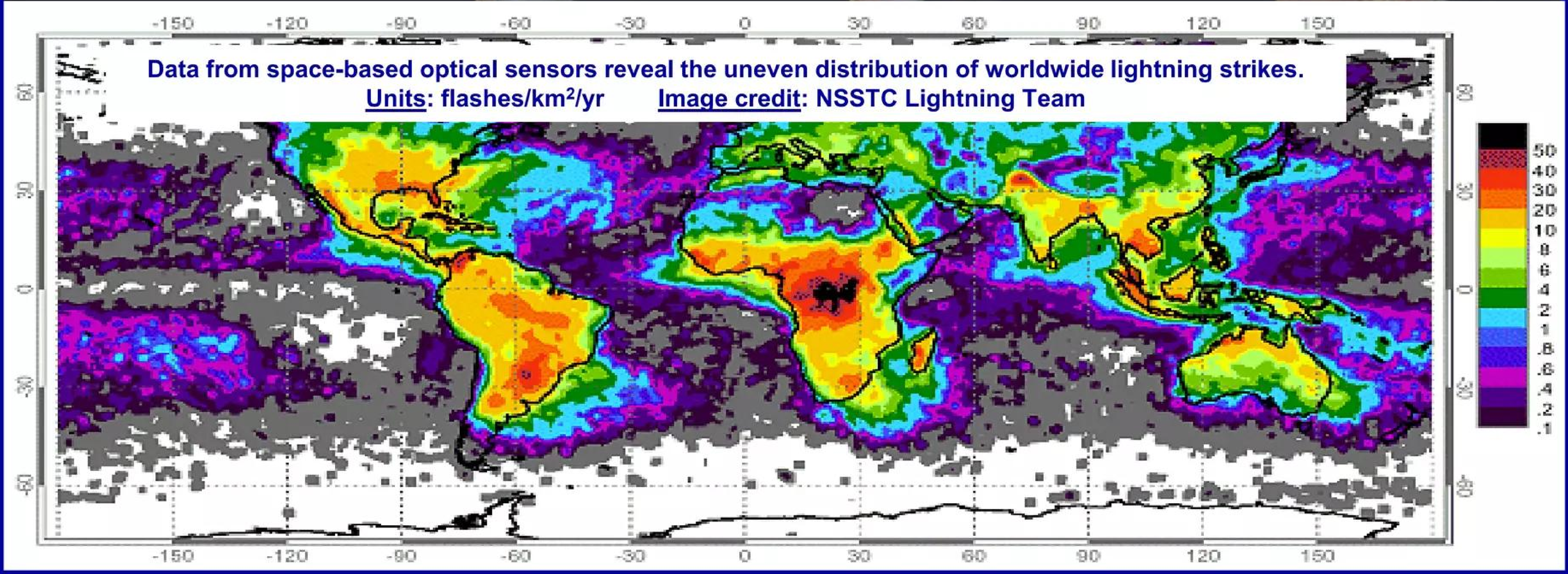
Shown above are aerosol concentrations over a period of six weeks, during summer 1991, as measured by SAGE-II. Note: these instruments flew on other satellites, including two in the NOAA series.

Source URL = http://www.nasa.gov/mission_pages/GLAST/news/fermi-thunderstorms.html



Observed global distribution of terrestrial gamma-ray flashes

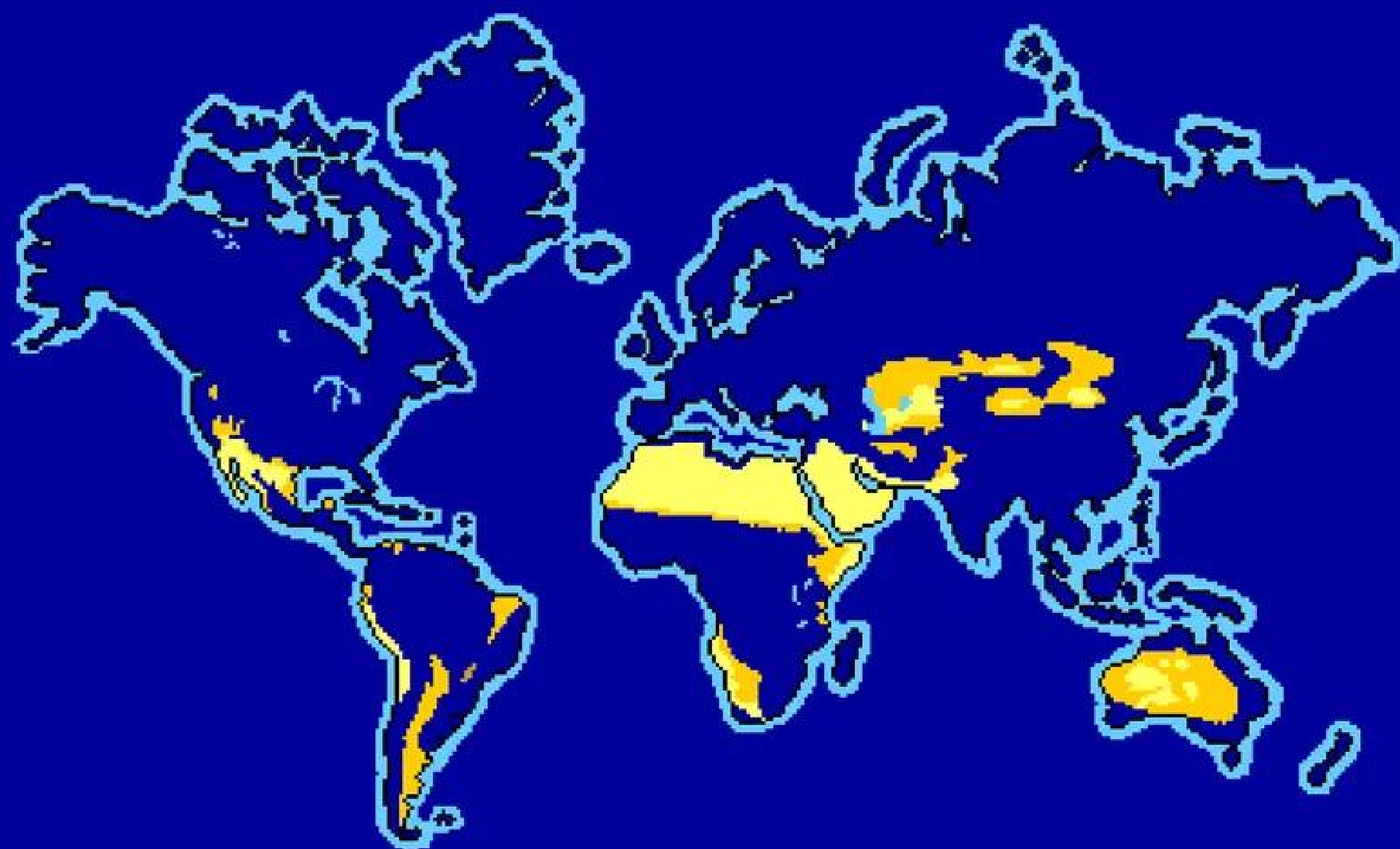
Fermi's Gamma-ray Burst Monitor detected 130 TGFs from August 2008 to the end of 2010. Thanks to instrument tweaks, the team has been able to improve the detection rate to several TGFs per week. Credit: NASA



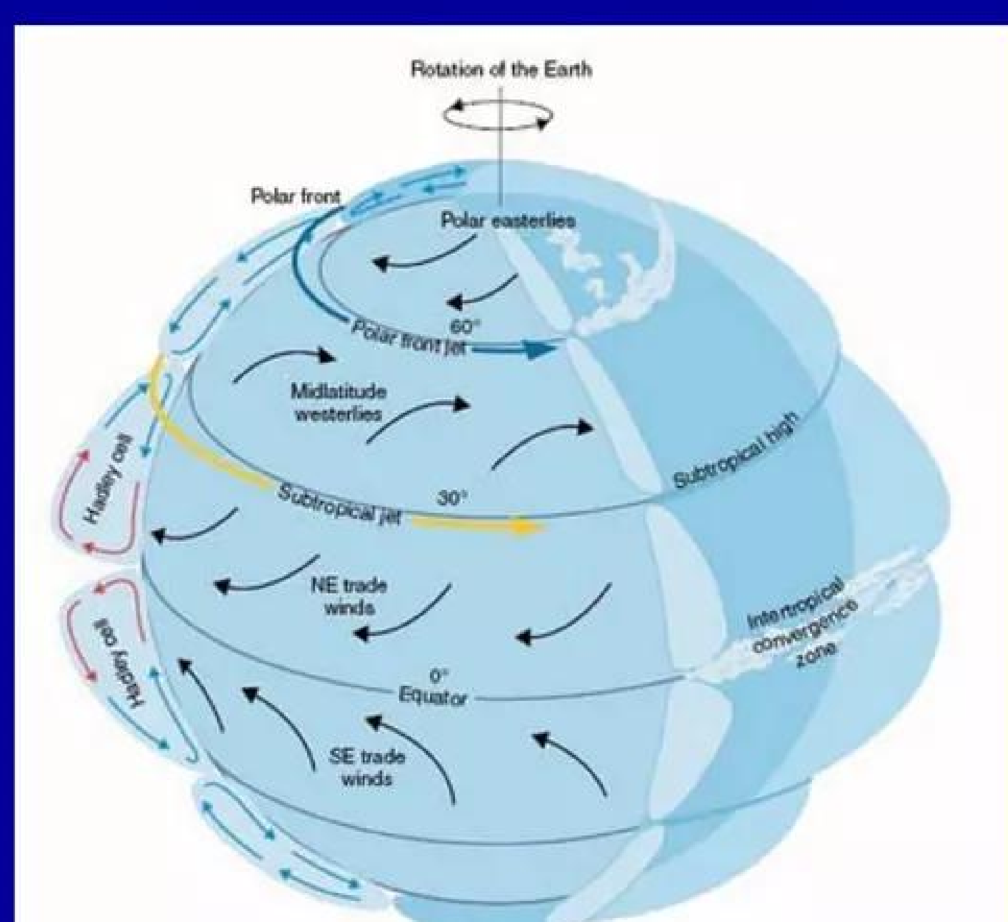
Data from space-based optical sensors reveal the uneven distribution of worldwide lightning strikes.
Units: flashes/km^2/yr Image credit: NSSTC Lightning Team

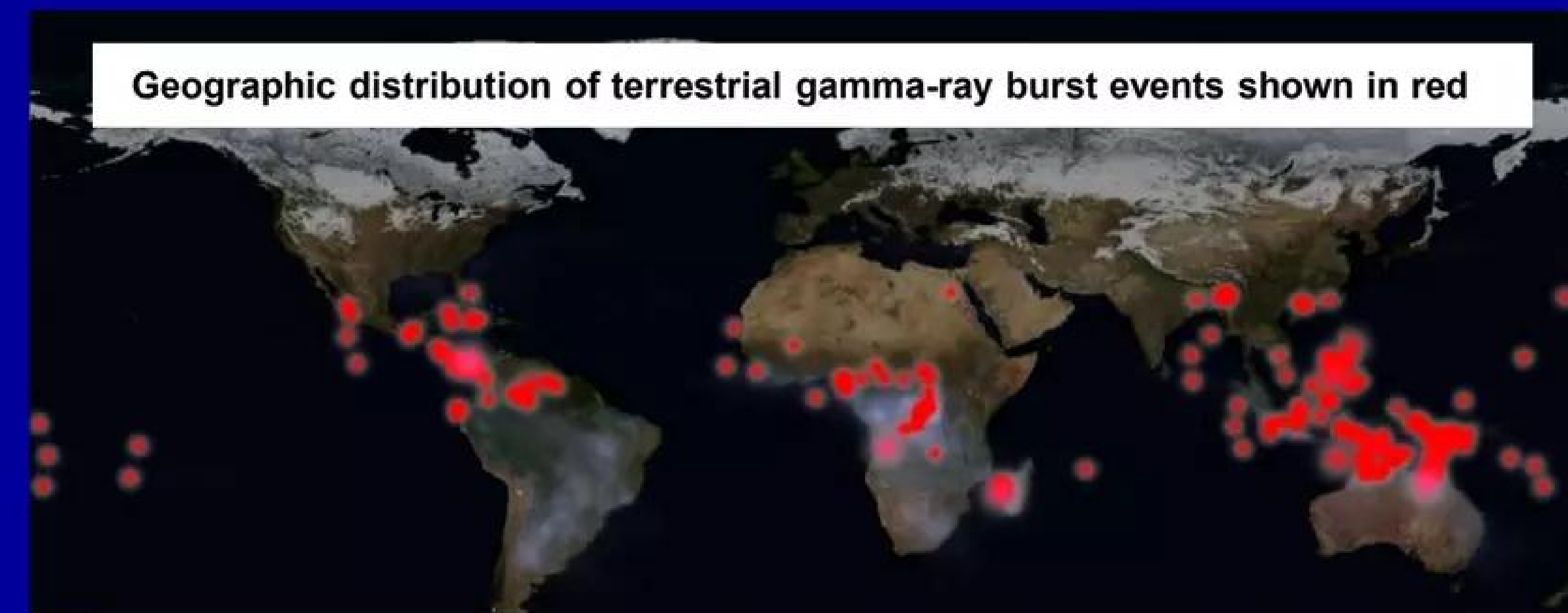
High-energy processes in lightning laced with dust/aerosols

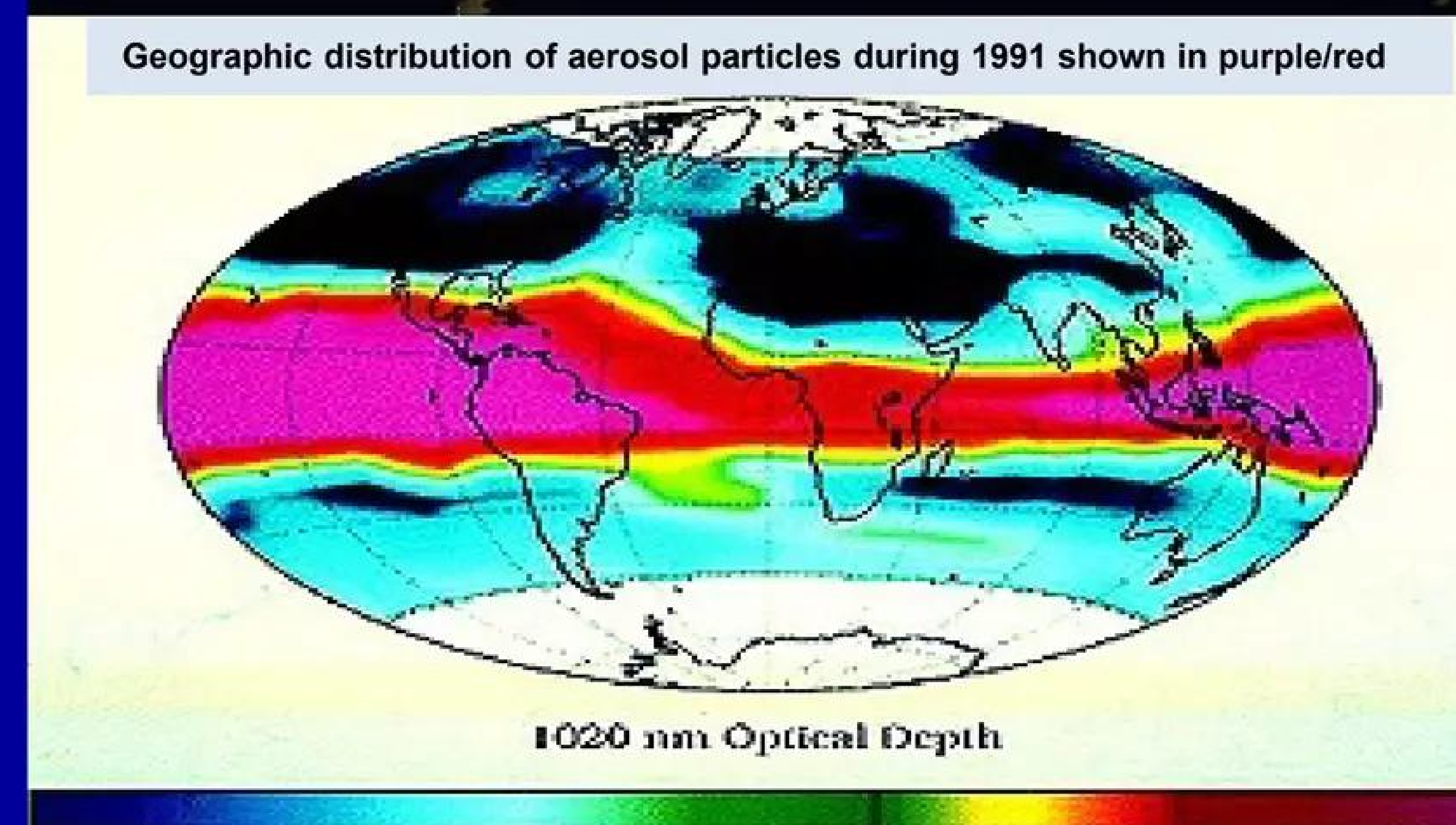
Earth's present deserts

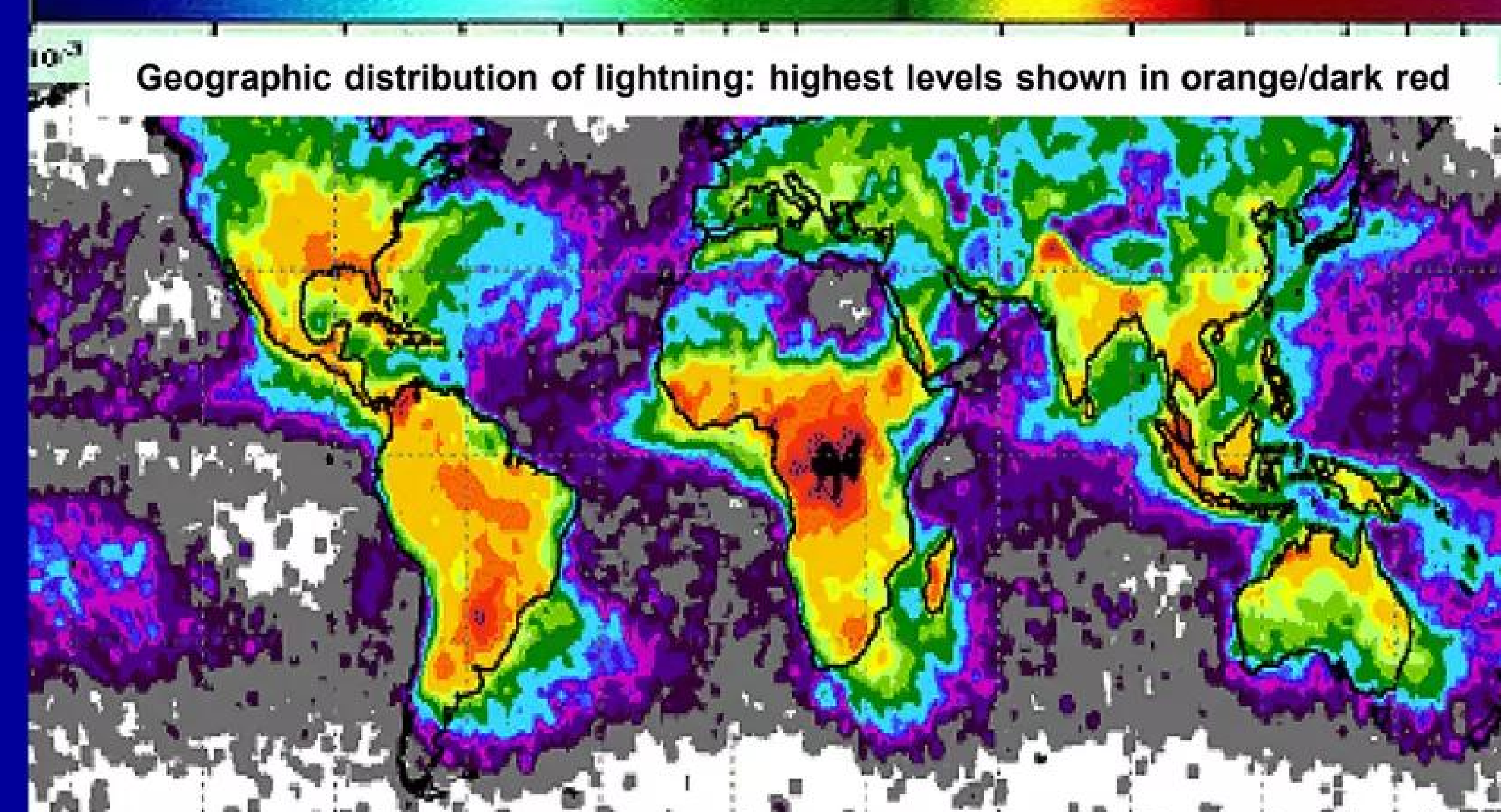


Earth's prevailing winds









High-energy processes in lightning laced with dust/aerosols

Terrestrial gamma-ray flashes, x-rays, and neutrons: W-S-L mechanism at work?

- ✓ **Lattice speculative conjecture: TGFs were first discovered in 1994 by the BATSE instrument on NASA's then-new Compton Gamma-ray Observatory spacecraft; the newer RHESSI satellite has observed higher-energy gamma emissions (up to 20 MeV) than BATSE did**

- ✓ **Latest observations see only ~50 TGFs/day, larger value than previously thought but still a very tiny fraction of the estimated total world lightning strikes of 3 - 4 million/day; thus, TGFs appear to be a comparatively rare phenomenon on the Earth compared to 'ordinary' lightning discharges**

- ✓ **A naïve assumption would be that the global distribution of observed TGFs should closely mirror the global geographic distribution of lightning activity; as one can see from visual inspection of the previous charts, that notion is somewhat, but not rigorously true. For example, a region northwest of Australia is a major 'hot spot' for TGFs, yet that area does not seem to be characterized by unusually high levels of lightning activity --- ditto for Central America versus Brazil; look for yourselves**

- ✓ **So what else might help explain the distribution of TGFs? Well, deserts scoured by winds can put particles into the air; so can volcanic activity (aerosols as well as particulate dust). When one mentally superimposes the distributions of dust/aerosols on top of the distribution of lightning activity, distribution of TGFs then seems to make better sense; using a logical AND: lightning discharges + embedded dust/aerosols → TGFs**

- ✓ **A great deal of additional investigation and data collection would have to be performed to thoroughly evaluate this conjecture; that nontrivial task will be left to specialists if they have the interest and time to do so**

W-S-L mechanism: lightning with embedded dust & aerosols

Intense lightning activity observed in atmospheres of gas giant planets

Could lightning-driven nucleosynthesis provide an additional heat source on other planets?
Could such processes also potentially contribute to various types of isotopic anomalies?

- ✓ **Lattice speculative conjecture: thanks to interplanetary probes, it is now well known that substantial amounts of violent lighting occurs in the atmospheres of Jupiter, Saturn, Neptune, and to a much lesser degree, Uranus. It is also well-known that their atmospheres are all rich in Hydrogen in various forms and contain variable quantities of dust --- thus, they possess all the necessary ingredients for the W-S-L nucleosynthetic mechanism. It is also well known that Jupiter radiates ~2.7 times as much energy as it receives from the Sun; Saturn ~3.0x; Neptune ~2.7x; and Uranus ~1.0x. *We wonder whether W-S-L nucleosynthetic processes could be contributing to such energy production?***

- ✓ **Up until now, most of us (the author included) have thought in terms of there being a sharp line of demarcation between "stars" and "planets," stars being where fusion-driven nucleosynthesis took place and planets where almost entirely chemical processes occurred. Viewed through that long-standing conceptual paradigm, Jupiter and like gas-giant planets were regarded by many as "failed stars." Well, that view may have to be revised. *Perhaps there exists a continuum of energy-producing objects between radiologically dead rocky planets and super-hot fusion stars* --- the middle-ground being occupied by nucleosynthetically dynamic objects with increasing amounts of LENRs taking place in them. *Maybe Jupiter, Saturn, and "brown dwarfs" didn't fail?***

- ✓ **Again, a great deal of additional investigation and data collection would have to be conducted to thoroughly evaluate this additional conjecture based on our theoretical work. That admittedly daunting, definitely nontrivial task will be left to specialists if they have the time, resources, and interest to do so**

New isotopic measurements: Genesis Discovery Mission

NASA collected pristine solar wind samples; returned to Earth for analysis (2004)

Pattern of isotopes found in pristine solar wind upsets present ideas about solar system abundances

- ✓ **See: "Solar composition from the Genesis Discovery Mission," D. Burnett and Genesis Science Team, *PNAS Early Edition* published ahead of print doi:10.1073/pnas.1014877108 (May 2011) Free copy at URL = http://www.pnas.org/content/early/2011/05/05/1014877108.full.pdf**

- ✓ **Overview: "Launched in 2001, Genesis placed a spacecraft at the easily reached L1 Lagrangian point, approximately 1% of the distance to the Sun, but away from perturbing influences of the terrestrial magnetic field. After collection, solar wind samples were returned to Earth in 2004." This paper provides a brief overview of some of the mission's important analytical results regarding isotope measurements**

- ✓ **Quoting: "The link between solar and planetary matter is that they have a common origin in the original cloud of gas and dust from which the solar system formed 4.57 x 10^9 years ago. Our gas-dust cloud is the first step in what cosmochemists regard, at least implicitly, as a 'Standard Model' for the origin of planetary materials. The formation of the Sun by gravitational collapse of the cloud occurs by the flow of material through an equatorial disk, the 'solar nebula,' onto the Sun, a process now directly observable in star-forming regions. The Standard Model regards elemental (the relative amounts of different elements) and isotopic (the relative amounts of the isotopes of individual elements) compositions of the solar nebula as homogeneous, at least on large scales relative to the size of individual dust grains. The planetary objects (planets, moons, asteroids, etc.) of the solar system are notable for their amazing degree of diversity yet they appear to have formed from a homogenous starting point. Most of the material in the solar nebula flowed to the Sun, thus in the solar surface layers, isolated from nuclear transformations in the solar core, the original average nebular composition is preserved for the vast majority of elements and isotopes. The Standard Model appears to be sufficiently accurate to serve as a starting point; it obviously leaves a lot to be desired in terms of specificity, and most interestingly, *it is clearly wrong in terms of the variations in the isotopic composition of some elements*. For example, at the level of a few percent or less, there are variations in the isotopic composition of O among inner solar system materials available for laboratory study."**

New isotopic measurements: Genesis Discovery Mission

NASA collected pristine solar wind samples; returned to Earth for analysis

Pattern of isotopes in solar wind upsets widely accepted ideas about solar system abundances

- ✓ **Quoting: "Oxygen isotope analyses - Fig. 3 shows schematically the variations in O isotopic compositions among inner solar system materials (8). The Genesis solar wind composition, measured with the UCLA MegaSIMS (Fig. 1A), is very different from most inner solar system materials, but lies near the linear trend set by meteoritic Ca-Al-rich inclusions (CAI). Models of solar wind acceleration (9) predict that O isotopes in the solar wind will be richer in ^{16}O than the Sun, with the amount of correction shown by the dashed line in Fig. 3. It is possible that the amount of correction shown is too large, so within present errors, the solar composition could lie on the CAI line. Several well studied natural processes exist which fractionate isotopes relative to the assumed Standard Model values, but none of these explain the variations shown on Fig. 3. A specific model based on the effects of self-shielding of ultraviolet radiation from the early Sun (10) predicts that the solar O isotopic composition would be ^{16}O-rich, lying along the CAI trend. The details of how this process would affect all of the material in the inner solar system are not clear. Conceivably, UV radiation plays a role in the growth of grains from micron to kilometer size. The Genesis $^{18}O/^{16}O$ ratio is lower by 17% from the ratio derived from intensities of solar molecular CO lines (11). It appears unlikely that Sun-solar wind isotopic fractionation of this magnitude has occurred; the origin of the discrepancy is unknown."**

- ✓ **Quoting: "Nitrogen isotope analyses - The variations in $^{15}N/^{14}N$ among solar system materials are much larger than for O and cannot be explained by well studied mechanisms of isotope fractionation. Although one analysis has given a higher ratio for as-yet-unknown reasons (12), Genesis data overall (13–17) show that the Sun is like Jupiter and very distinct from any known inner solar system material (Fig. 4). In this case four independent replicate analyses using different instruments was able clearly to recognize an anomalous result, illustrating the major advantage of sample return missions (Advantage iii above). No good models exist to explain the large solar system N isotopic variations."**

New isotopic measurements: Genesis Discovery Mission

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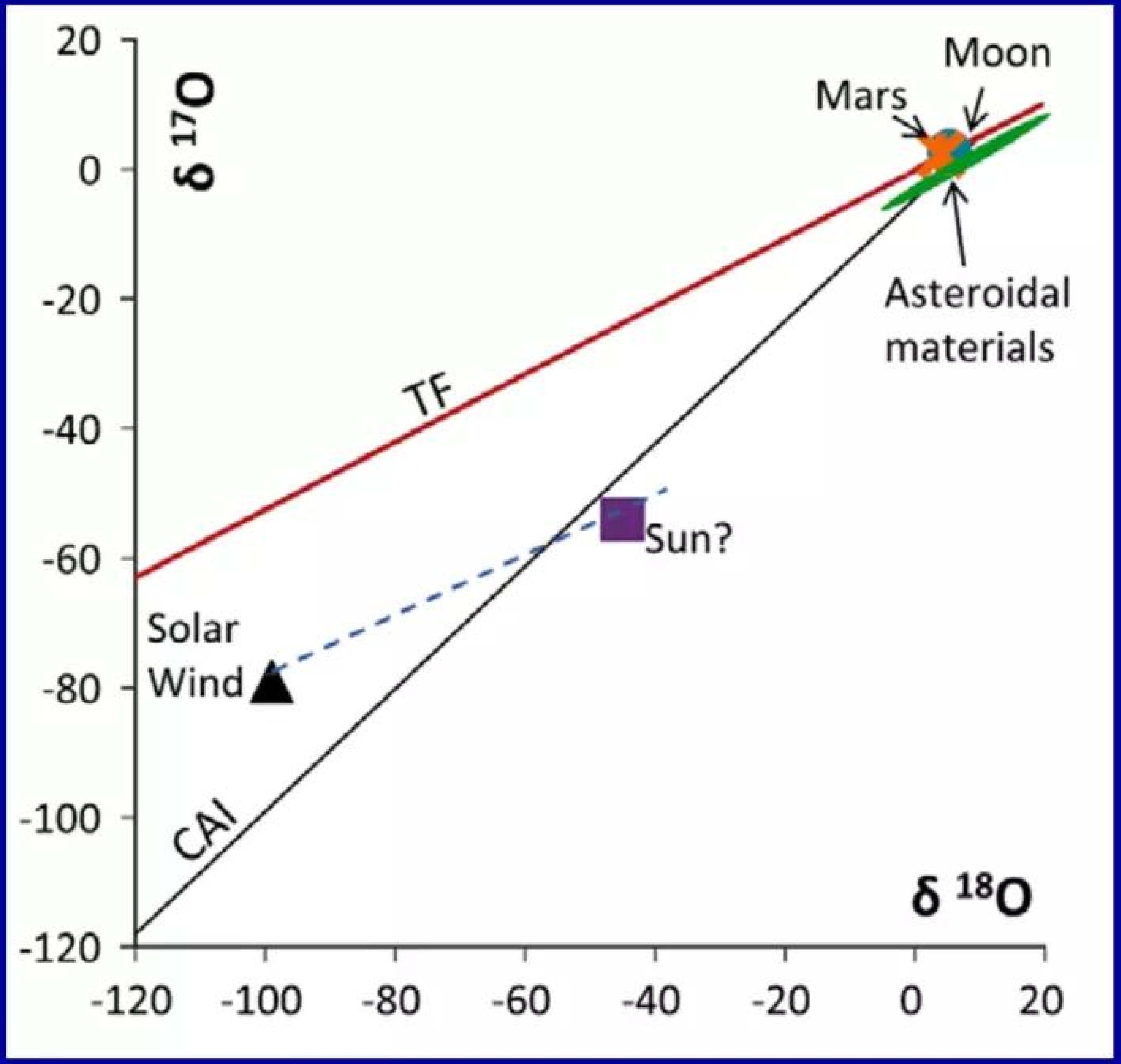
Pattern of isotopes in solar wind upsets widely accepted ideas about solar system abundances

Quoting comment made in May 2011 PNAS paper: "Several well studied natural processes exist which fractionate isotopes relative to the assumed Standard Model values, but none of these explain the variations shown on Fig. 3."

Quoting: "Fig. 3. A mass spectrometer measures separately the ion currents for the different isotopes of an element. Oxygen has three isotopes, allowing two isotopic abundance ratios to be calculated. Intersample variations are calculated as the fractional deviation *δ* of the measured $^{18}O/^{16}O$ or $^{17}O/^{16}O$ from terrestrial ocean water (‰ units are permil, parts in 1,000). Terrestrial geochemical processes produce a wide range in O [Oxygen] isotope fractionations, but these variations lie almost entirely on the line labeled TF (terrestrial fractionation). The Genesis solar wind composition (8) is very different from the major inner solar system objects (Earth, Moon, Mars) and most asteroidal (meteoritic) materials, but lies close to the trend set by unique high temperature Ca-Al-rich inclusions (CAI). Theoretically, solar wind acceleration fractionates isotopes by the amount shown by the line between the solar wind and the Sun? point (9)."

Oxygen Isotopes Figure 3. Burnett et al., *PNAS* (2011)



New isotopic measurements: Genesis Discovery Mission

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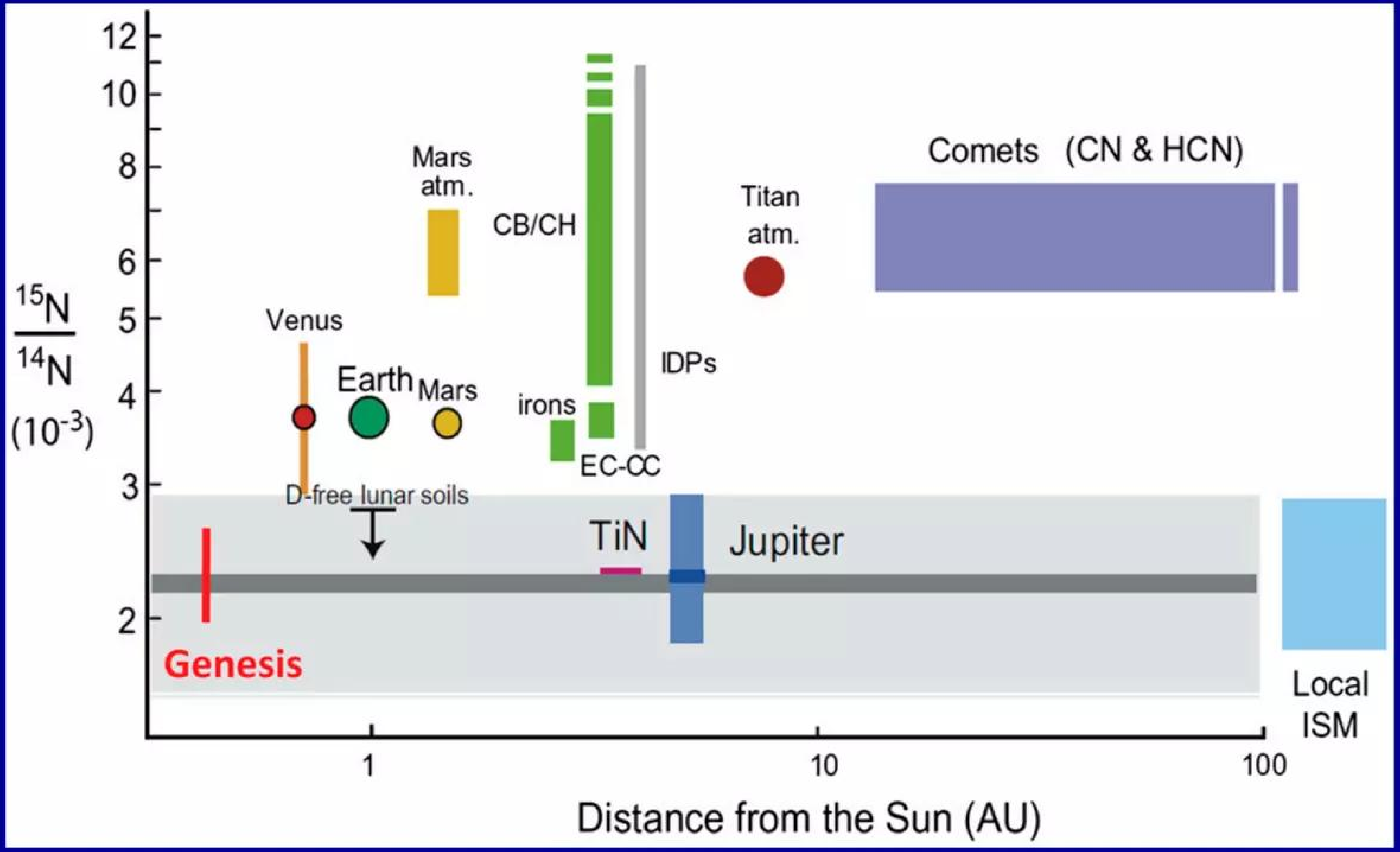
Pattern of isotopes in solar wind upsets widely accepted ideas about solar system abundances

Quoting comment made in May 2011 PNAS paper: "The variations in $^{15}N/^{14}N$ among solar system materials are much larger than for O and cannot be explained by well studied mechanisms of isotope fractionation."

Quoting: "Fig. 4. N isotopic compositions in solar system objects, [modified from Marty et al., (13)] vary widely, showing no simple heliocentric distance trend. Genesis data (13–16) show that the Sun is like Jupiter, whereas all inner solar system samples show much larger amounts of ^{15}N. The TiN analysis refers to a mineral from an unusual meteorite (17). The origins of these variations are unknown."

Nitrogen Isotopes Figure 3. Burnett et al., *PNAS* (2011)



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- ✓ **Lattice comments**: present astrophysical and geochemical thinking assume that fresh local nucleosynthesis of elements/isotopes (out beyond the photosphere of the solar system's protosun) had effectively ceased prior to condensation of materials comprising the primordial presolar nebula into a myriad of various-sized solid bodies, and prior to Earth becoming recognizable as a planet. In that view, only unstable isotopes with extremely long half-lives, e.g., the progenies of the U-series, Th-series, and ^{40}K, would be around long-enough to still be producing radiogenic heat inside planet-like bodies that comprise today's solar system

- ✓ In several SlideShare presentations, we have discussed some of the problems and inherent limitations of present-day chemical fractionation theories; see http://www.slideshare.net/lewisglarsen/lattice-energy-llc-len-rs-in-catalytic-convertersjune-25-2010 and http://www.slideshare.net/lewisglarsen/bacteria-lenrsand-isotopic-shifts-in-uraniumlarsenlattice-energy-dec-7-2010-6177275 (catalytic converters & biological LENRs)

- ✓ If one grants the possibility that nucleosynthesis can potentially occur (albeit at vastly lower aggregate rates than what may happen within hot stellar cores or supernovas) *outside the Sun's core*, elsewhere out in today's solar system, then many of the puzzling isotopic anomalies revealed in the Genesis Discovery Mission's data, that are inexplicable with present theories of chemical fractionation processes, might be better understood by utilizing W-S-L theory to help explain anomalous isotope production and related ratios

- ✓ **Interesting footnote - in 2010 a new heretically titled article was added to Wikipedia**: "Solar surface fusion" see URL = http://en.wikipedia.org/wiki/Solar_surface_fusion ; while its focus is (quoting) "... fusion reactions occurring at or above the photosphere, most likely in the chromosphere," the fact that such an article exists suggests that the 'core only' paradigm is weakening and that more researchers are trying to come to grips with new observational data which strongly indicates that nucleosynthetic processes may not be strictly limited to cores of stars, natural and manmade fission reactors, and supernovae

Conclusions and final quotation

"Mystic Mountain" - Hubble Space Telescope image taken by Wide Field Camera 3 in February 2010; colors in this composite image correspond to the glow of oxygen (blue), hydrogen and nitrogen (green), and sulphur (red). This turbulent cosmic pinnacle, 3 light-years high, lies within a tempestuous stellar nursery called the Carina Nebula, located 7500 light-years away in the southern constellation of Carina. Scorching radiation and fast winds (streams of charged particles) from super-hot newborn stars in the nebula are shaping and compressing the pillar, causing new stars to form within it. The denser parts of the pillar are resisting being eroded by stellar radiation. Nestled inside this dense 'mountain' of dust and gas are fledgling stars; there are swirling discs of dust and gas around these young stars, which allow nebular material to slowly accrete onto their photospheric 'surfaces'.

If nucleosynthetic processes are as widespread and they appear to be, they are occurring at varying rates throughout such volumes of space.

Credit: NASA, ESA, M. Livio and the Hubble 20th Anniversary Team (STScI)

Conclusions

- ✓ While debate still rages in the literature about precise locations at which particle acceleration occurs in the Sun and various mechanisms that might be responsible for it, we believe that the relatively simple W-S-L collective magnetic mechanism does the best job of explaining the observed production and emission of the highest-energy charged particles and solar neutrons
- ✓ In our papers, we provide realistic calculations with reasonable assumptions about key physical parameters that show how mean acceleration energies of at least ~300 GeV can readily be achieved in real-world solar flares with accompanying CMEs. That said, we agree with Aschwanden (2011) that several different acceleration mechanisms probably operate in parallel. In particular, CME (MHD) shocks and coherent electric fields (reconnection models) are also very likely to play a role in such processes. We do not believe that presently available observational evidence points to there being *only one* overwhelmingly dominant charged-particle acceleration mechanism taking place on the Sun and other stars
- ✓ We have also shown how our collective magnetic mechanism can help explain anomalous abundances of very heavy and/or short-lived elements that are spectroscopically observed in the atmospheres of chemically peculiar Ap stars with very high ‘average’ magnetic fields
- ✓ Lastly, we have provided a plausible mechanism whereby nucleosynthetic processes could potentially occur in high-current atmospheric lightning discharges happening on Earth, as well as on other planets, moons, and hydrogen-rich regions of dusty nebulae subjected to large fluxes of energetic photon and particle radiation emitted by nearby stars
- ✓ Nucleosynthesis could be occurring at varying rates in more places in the Universe than any of us have ever imagined. This possibility opens-up huge new vistas for future research and promises further exciting insights into the long, rich pageant of galactic chemical evolution

Commercializing a Next-Generation Source of Safe Nuclear Energy

"A scientist is supposed to have a complete and thorough knowledge, at first hand, of some subjects and, therefore, is usually expected not to write on any topic of which he is not a master. This is regarded as a matter of noblesse oblige. For the present purpose I beg to renounce the noblesse, if any, and to be freed of the ensuing obligation. My excuse is as follows:

We have inherited from our forefathers the keen longing for unified, all–embracing knowledge. The very name given to the highest institutions of learning reminds us, that from antiquity and throughout many centuries the universal aspect has been the only one to be given full credit. But the spread, both in width and depth, of the multifarious branches of knowledge during the last hundred odd years has confronted us with a queer dilemma. We feel clearly that we are only now beginning to acquire reliable material for welding together the sum–total of all that is known into a whole; but, on the other hand, it has become next to impossible for a single mind fully to command more than a small specialized portion of it.

I can see no other escape from this dilemma (lest our true aim be lost forever) than that some of us should venture to embark on a synthesis of facts and theories, albeit with second–hand and incomplete knowledge of some of them – and at the risk of making fools of ourselves."

Erwin Schrödinger, "What is life?" (1944)

Image: high resolution spectrum of the Sun showing thousands of elemental absorption lines called Fraunhofer lines