Commercializing a Next-Generation Source of Safe Nuclear Energy

Low Energy Nuclear Reactions (LENRs)

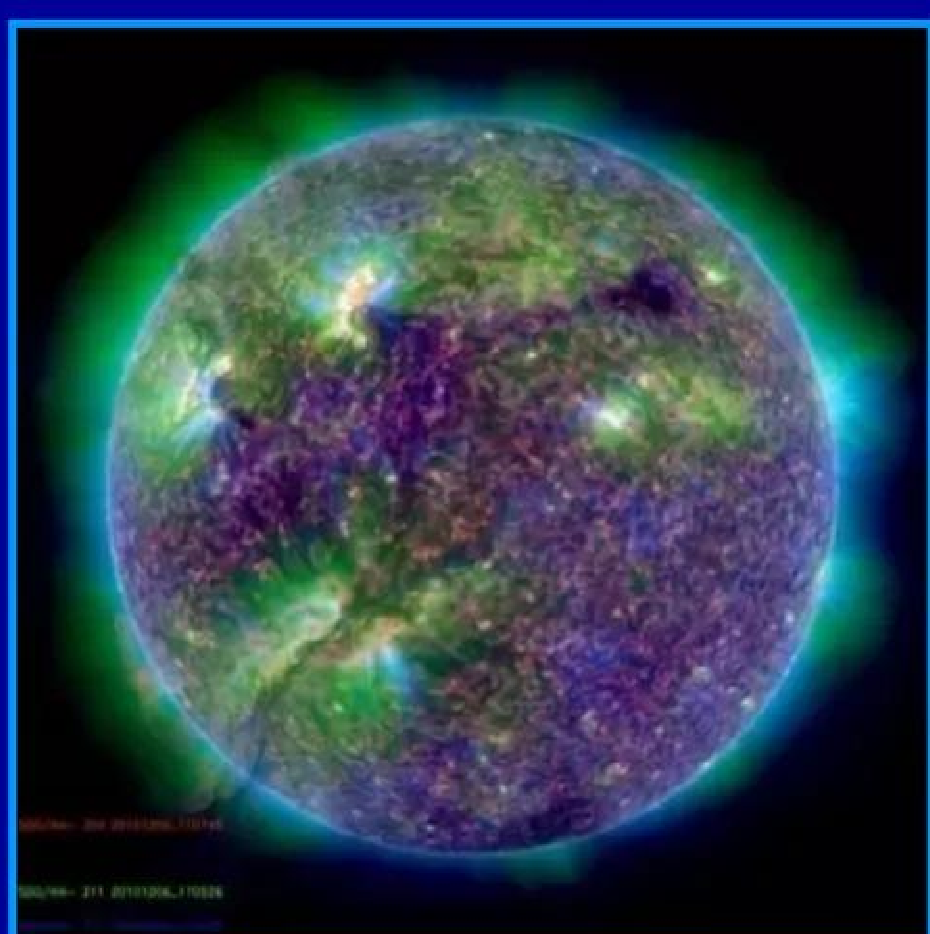
Nov 21 *New Scientist* article re variations in rates of nuclear decay

Extension of Widom-Larsen theory of LENRs can explain this data

Local interactions with neutrino fluxes from $e^- + p^+ \rightarrow lepton + X$ electroweak processes in sun may be cause

Technical Comments re Article

False-color X-ray image of the Sun



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

Lewis Larsen, President and CEO

Lattice Energy LLC

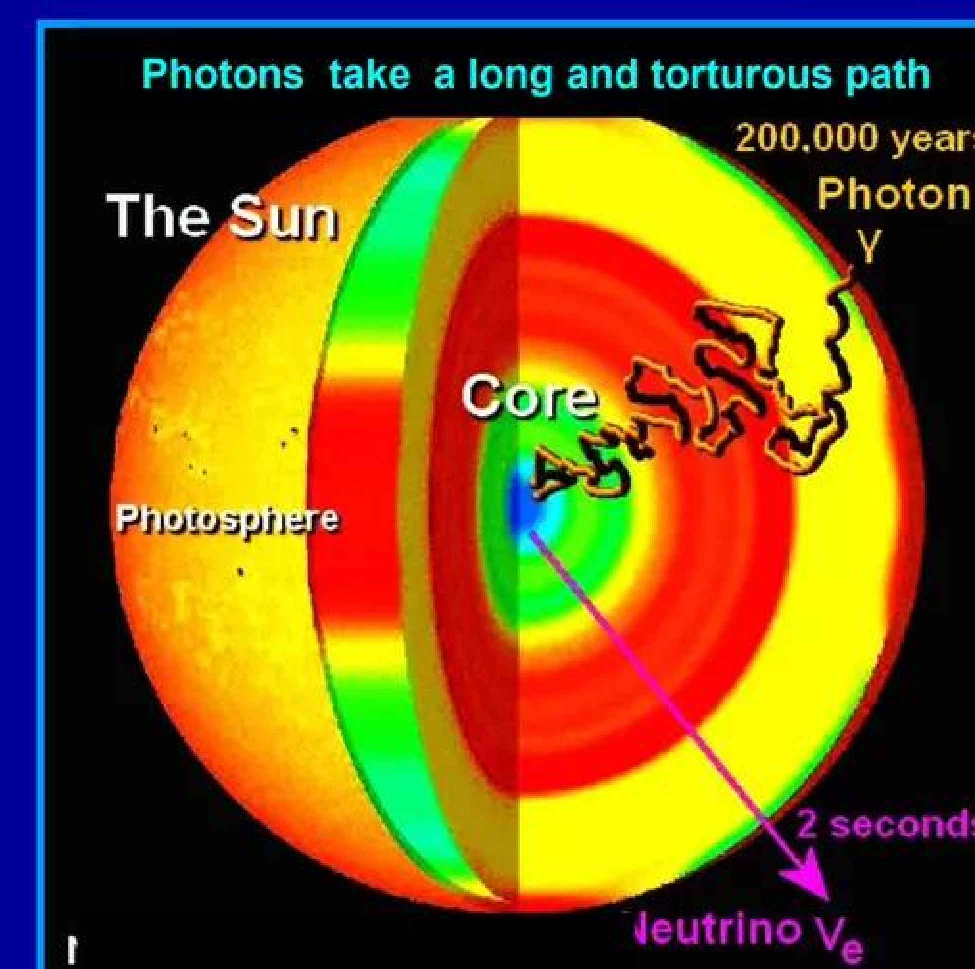
November 23, 2012

"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

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

Conceptual schematic of the Sun



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

Key Documents

Please see:

"Half-life strife: Seasons change in the atom's heart"
Stuart Clark
New Scientist **magazine issue #2891**
November 21, 2012
http://www.newscientist.com/article/mg21628912.300-halflife-strife-seasons-change-in-the-atoms-heart.html?full=true

Also please see:

"New possibilities for developing minimal mass, extremely sensitive, collective many-body, quantum mechanical neutrino 'antennas' "
Lewis Larsen, Lattice Energy LLC
January 10, 2012 (SlideShare document)
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-collective-manybody-qm-neutrino-antennasjan-10-2012

Summary of Key Ideas in Presentation

- ✓ An extension of the Widom-Larsen theory of LENRs published on Jan. 10, 2012, in a 3-page MS-Word document titled, "*New possibilities for developing minimal mass, extremely sensitive, collective many-body, quantum mechanical neutrino 'antennas'*," successfully explains the published experimental results of Jenkins and Fischbach with regard to Manganese-54 (^{54}Mn) and other isotopic decays involving the weak interaction (e.g., beta decays and inner-shell electron captures)

- ✓ This theoretical explanation for the phenomenon involves a straightforward application of the Pauli Exclusion Principle to all types of neutrinos, which are fermions (NOT bosons). Changes in nuclear decay rates observed in laboratory samples of beta-decaying isotopes located on earth are caused by local interactions of beta-unstable atoms in samples with varying fluxes of speed-of-light neutrinos emitted from various electroweak processes occurring in the sun's core, in the "*carpet*" of magnetic flux tubes on its 'surface', and in the organized magnetic structures of energetic solar flares

- ✓ Analogous changes of decay rates in the Cassini RTG power source are not observed simply because Plutonium-238 (^{238}Pu or Pu-238 - the decay of which releases heat that is converted into electricity by integrated thermoelectric modules) is unstable to alpha-decay with a 100 percent branching ratio. Importantly, alpha particles (i.e., He-4 atoms) are bosons which do not obey the Pauli Exclusion Principle; hence the sun will not have comparable long-range effects on nuclear decay rates of alpha-emitting isotopes such as Pu-238

- ✓ Therefore, no supposed "*fifth force of Nature*" nor new, recently conjectured “*neutrello*” particle mentioned in Nov. 21 *New Scientist* article are needed to explain this fascinating data

Contents

Other 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

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

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

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
- 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

High current

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

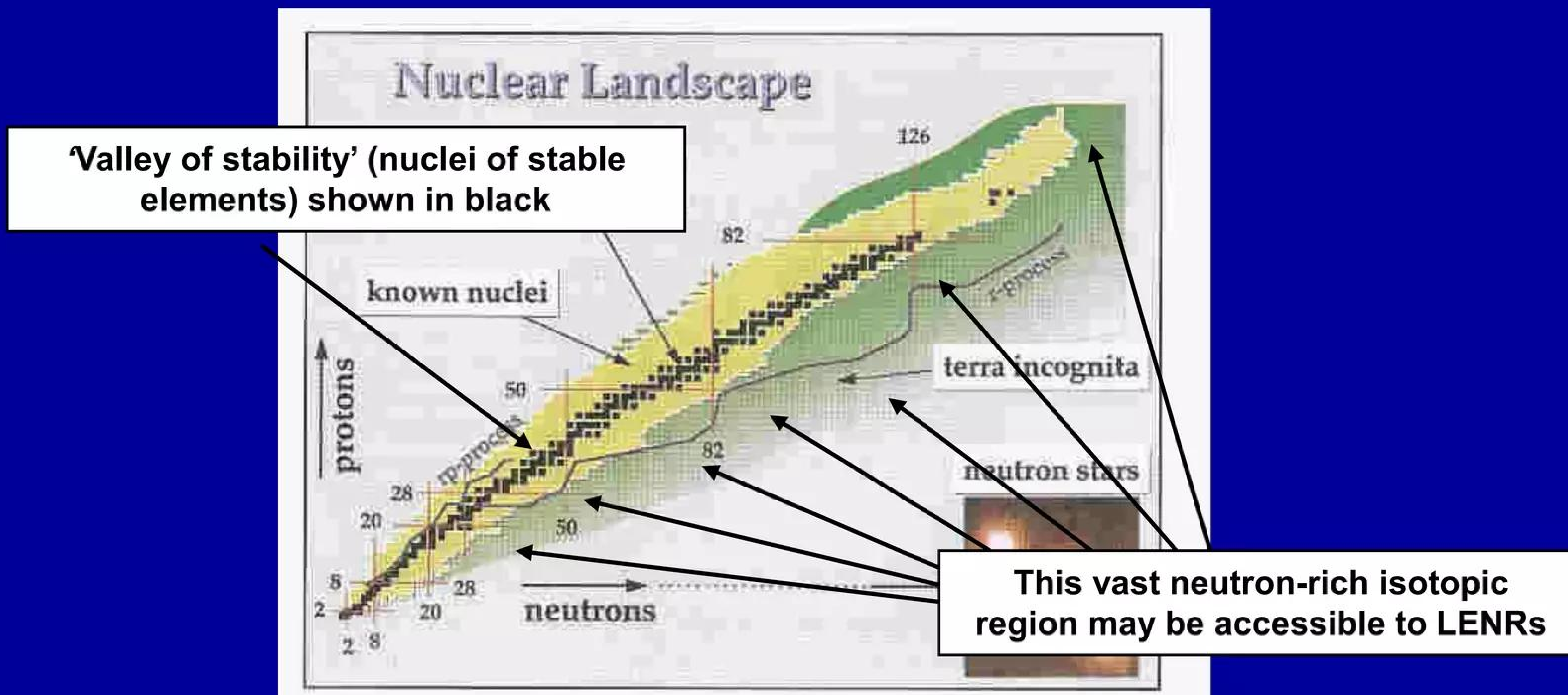
Different from stars in that neutrons created via the weak interaction in CM LENR systems can be ultra low momentum; vastly larger capture cross-sections

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

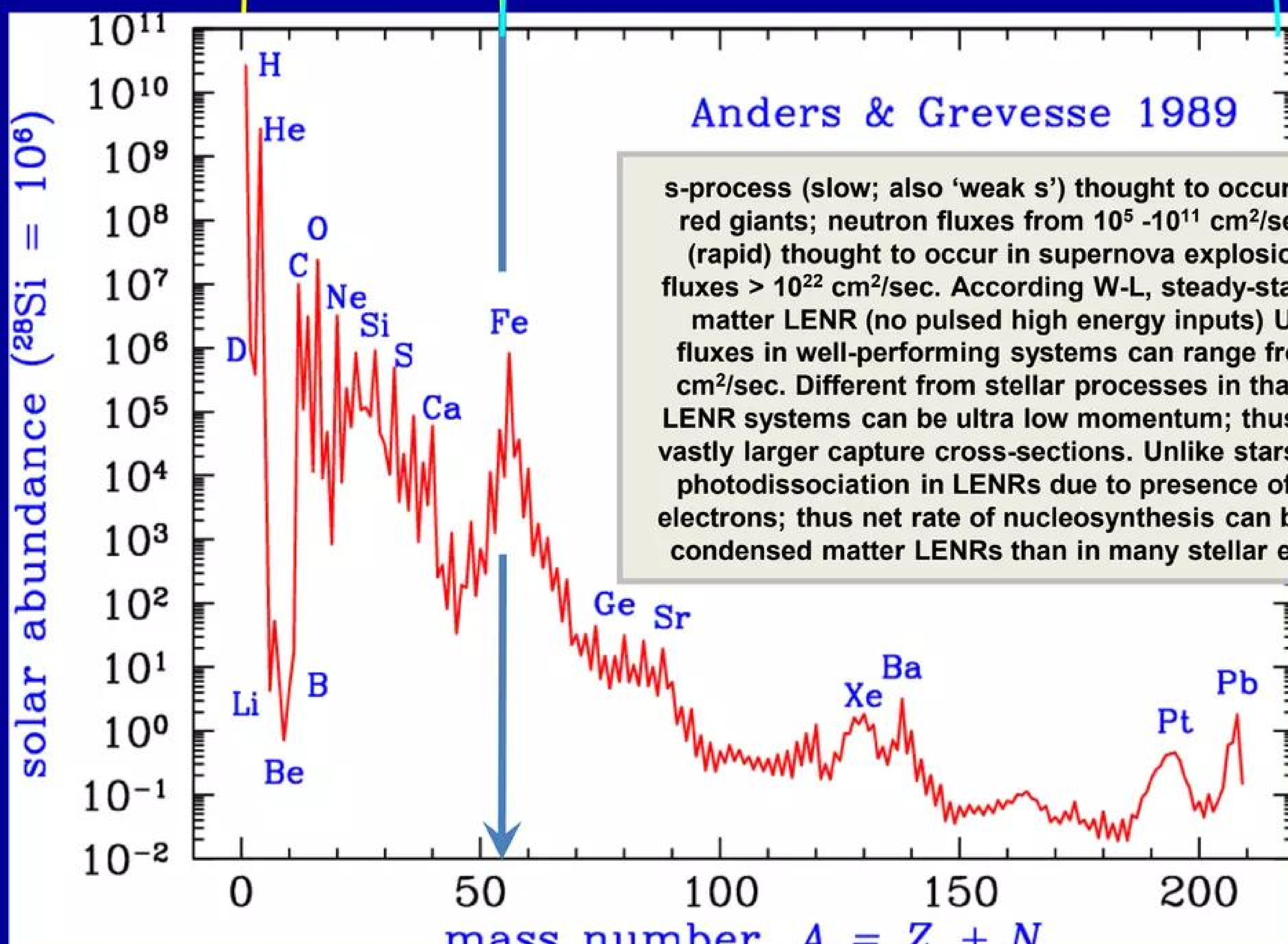


LENR neutron-catalyzed weak interaction transmutations: involve a combination of neutron production, neutron capture, and energetic beta decays of neutron-rich isotopes. LENRs can move back and forth between producing stable products in the (black) valley of stability to unstable β-decay isotopes located 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

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

Region of charged-particle nuclear fusion reactions in stars

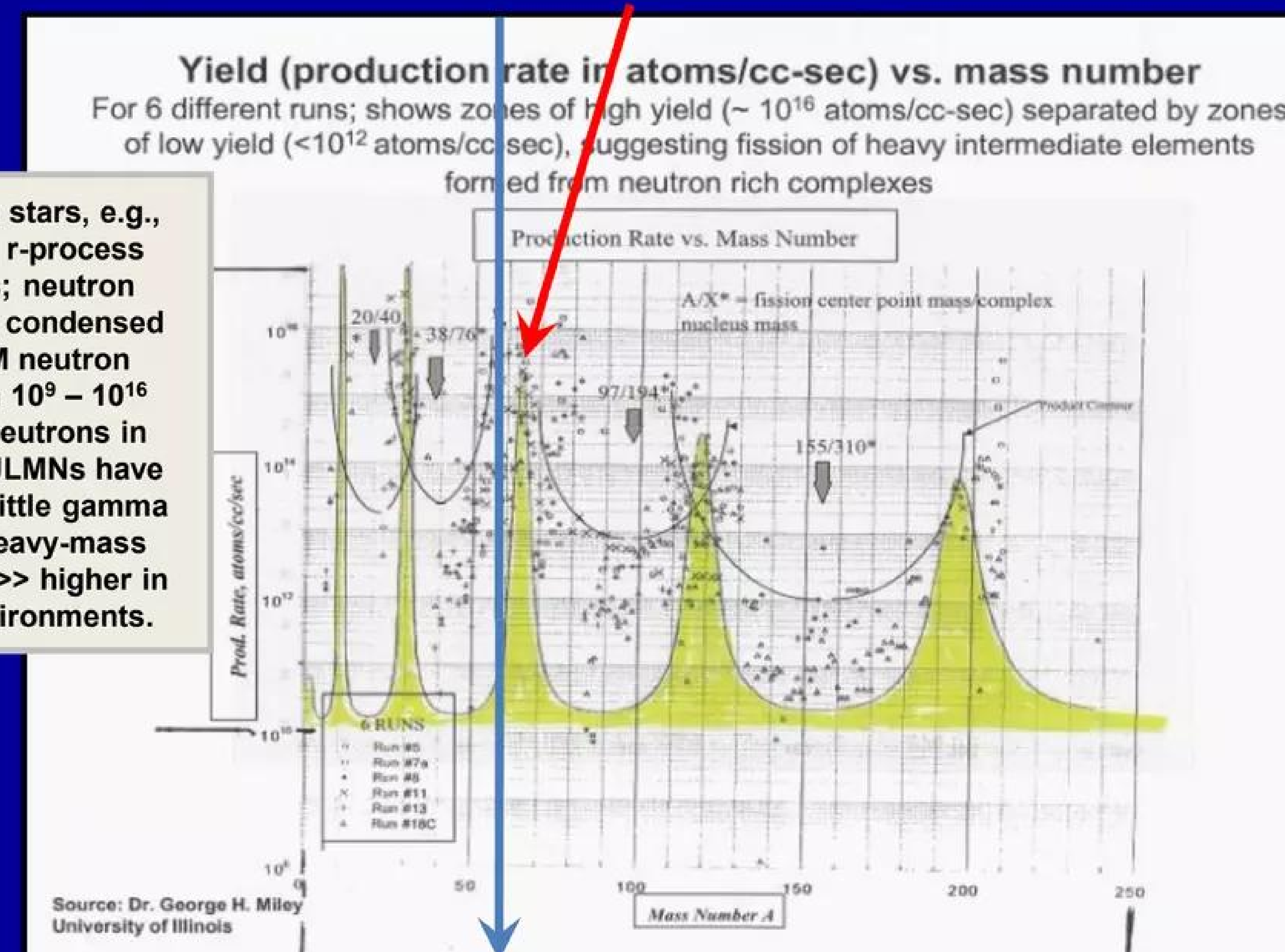
Region of stellar nucleosynthetic processes driven by neutron production and capture: mixture of so-called s- and r-processes



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

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 *Prime*r 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

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- ✓ **"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]**

- ✓ **<u>Total rate of positron production in a solar flare</u>: "... 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

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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 ..."]**

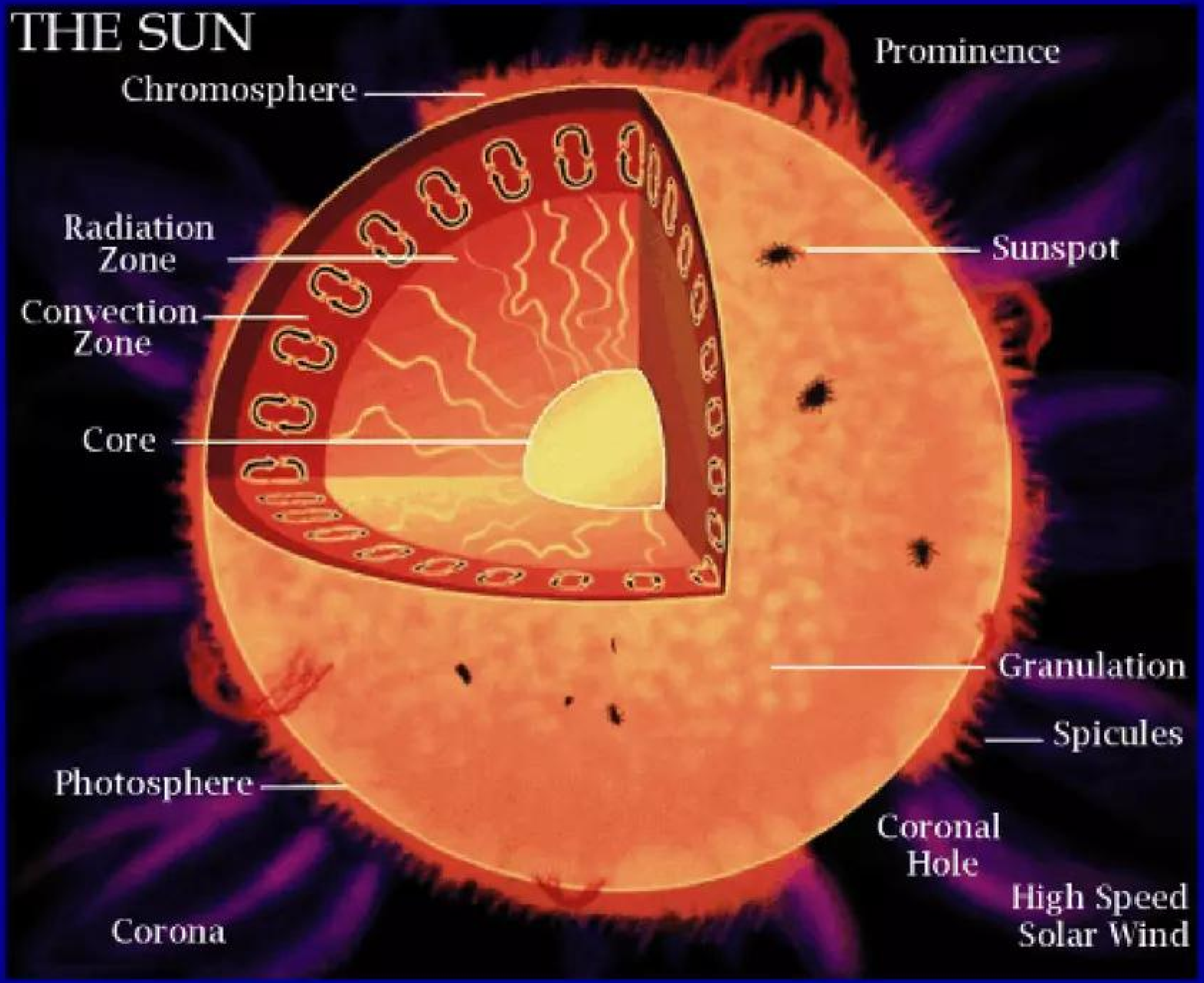
- ✓ **"Let us estimate the integrated cosmic flux of primary protons (before reaching the atmosphere). From cosmic rays section of PDG, we find (after performing an integration with a power-law exponent α = 3) that $F_{\text{cosmic protons}}$ with (E > 40 GeV) is approximately equal to 6 x 10^{-3} cm^2-s-sr; (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 x 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."**

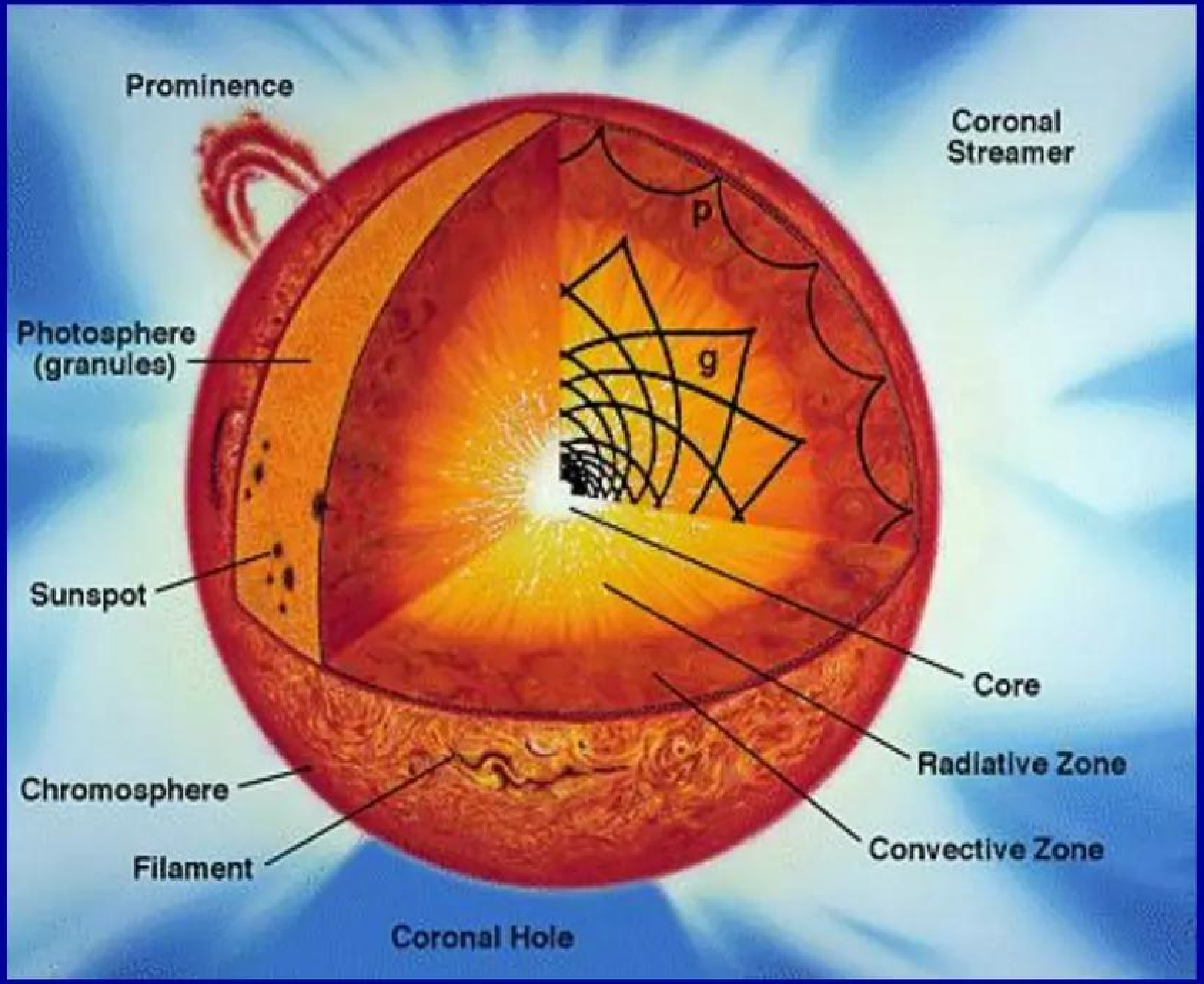
- ✓ **"The above result is quite significant in that our proposed mechanism of acceleration is unique in predicting primary protons from a solar flare in this very high-energy range."**

- ✓ **"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."**

Present astrophysical paradigms - Sun's internal structure

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



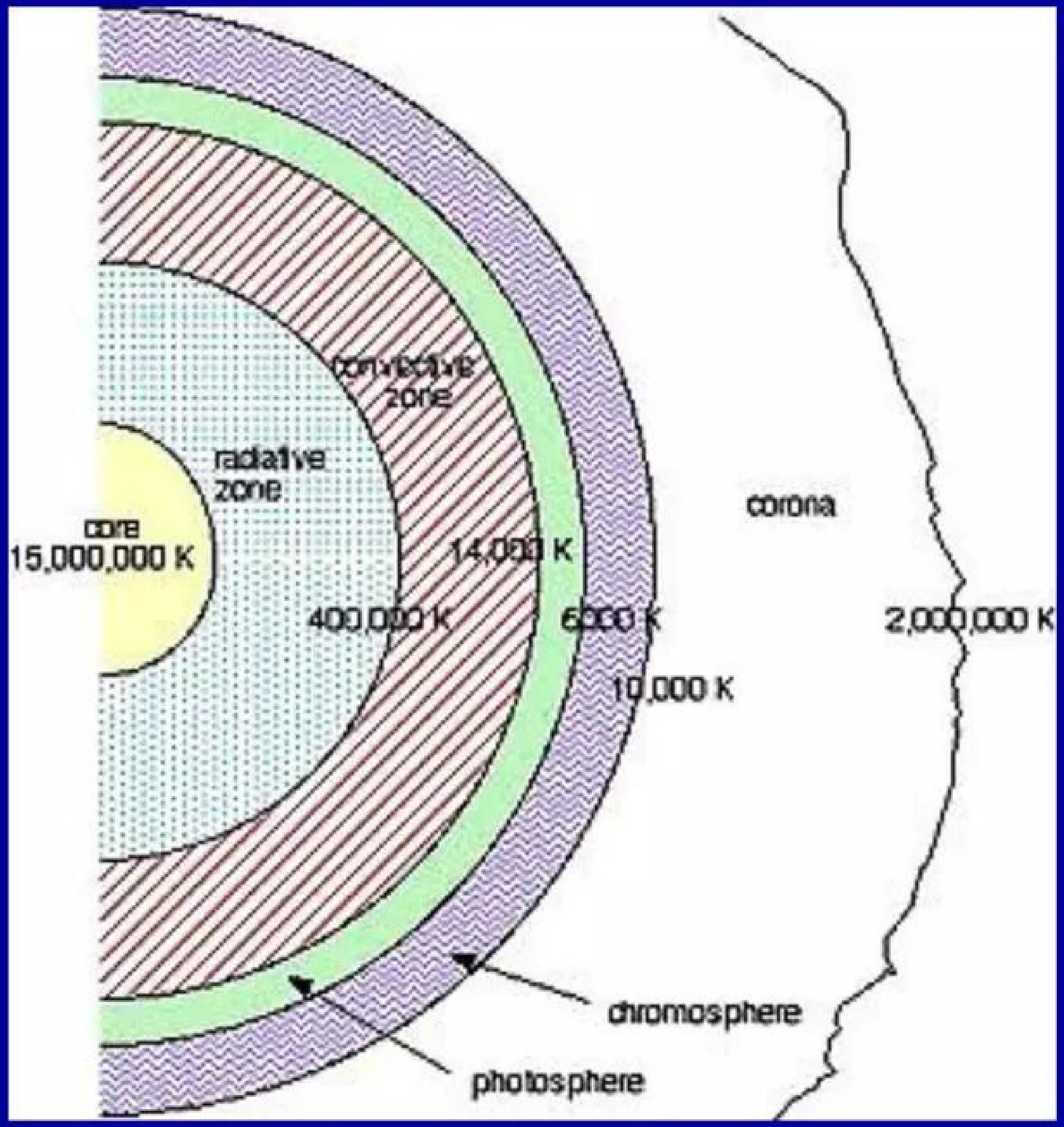


Our modern understanding of stellar nuclear processes really began with key concepts presented in Hans Bethe's landmark paper, "Energy production in stars," *Physical Review* 55 pp. 434 - 456 (1939). If you would like to read this seminal work, for free copy go to URL = http://prola.aps.org/pdf/PR/v55/i5/p434_1

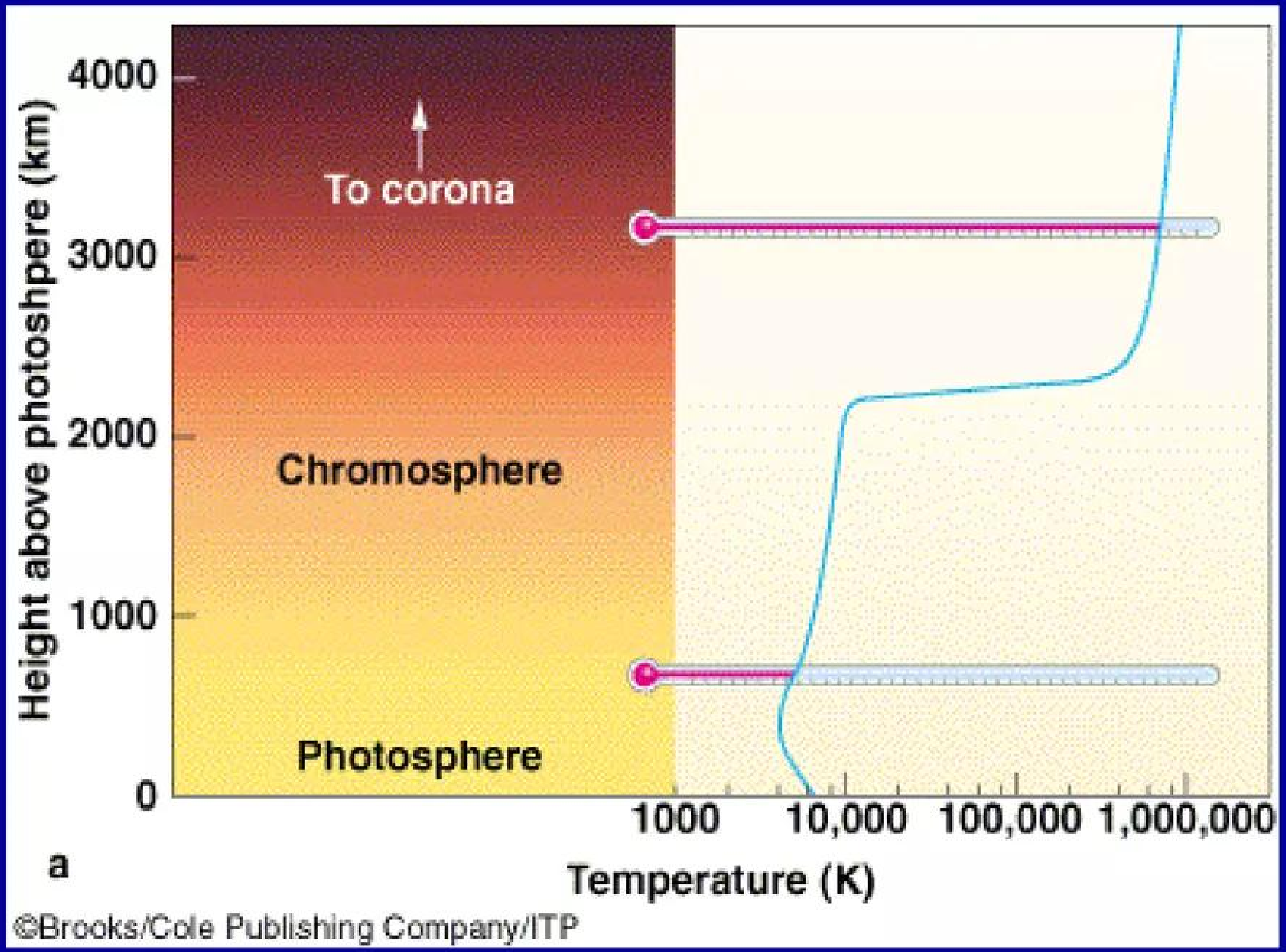
Based on this early work, energy production in stars like the Sun or smaller is presently thought to occur mostly via *pp* chains; in many larger, hotter stars the CNO cycle appears to be a widespread mechanism

Present astrophysical paradigms - Sun's internal structure

Schematic side view: layers and temperatures inside Sun



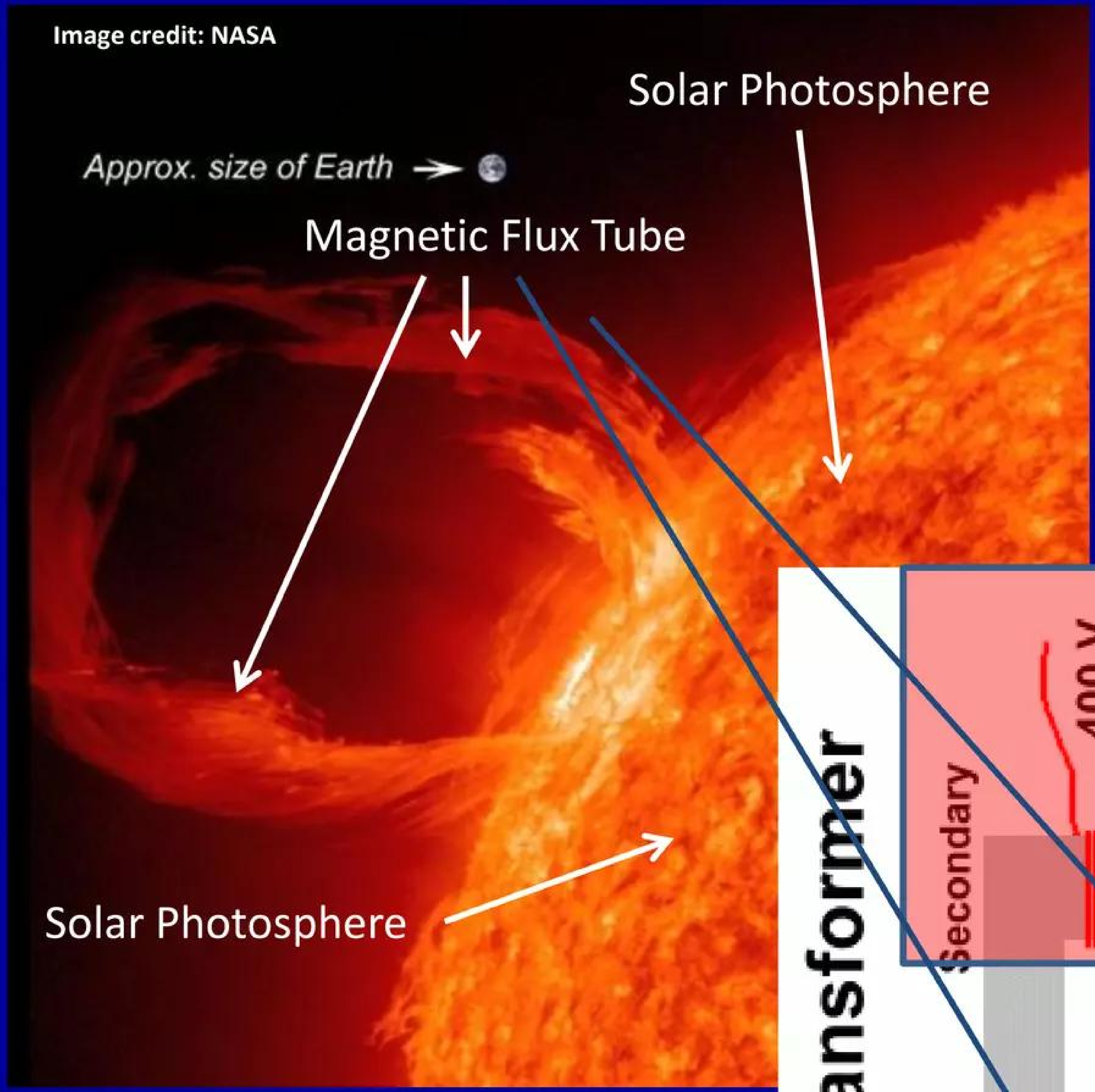
Sun's layers and temperatures vs. height (km) above photosphere

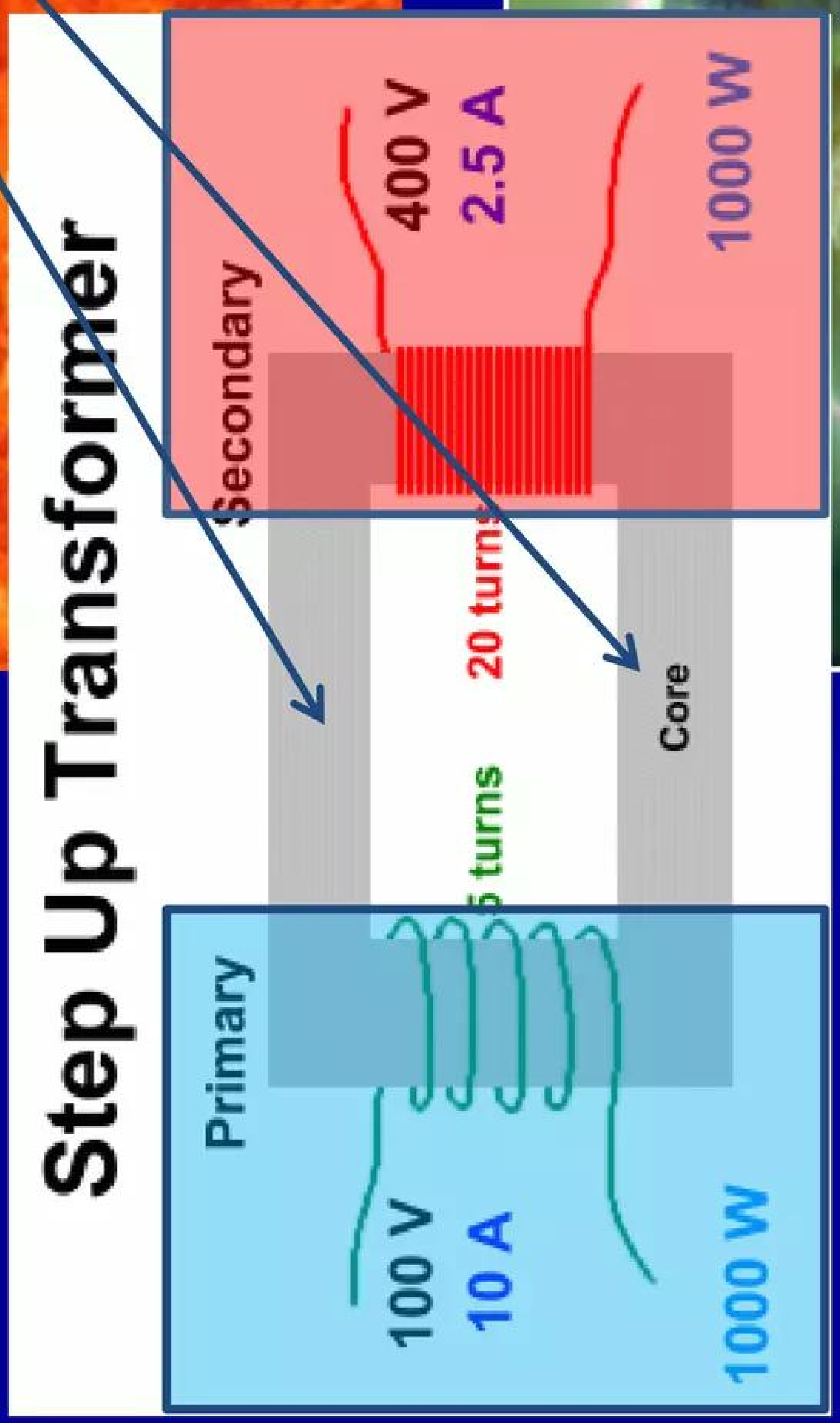


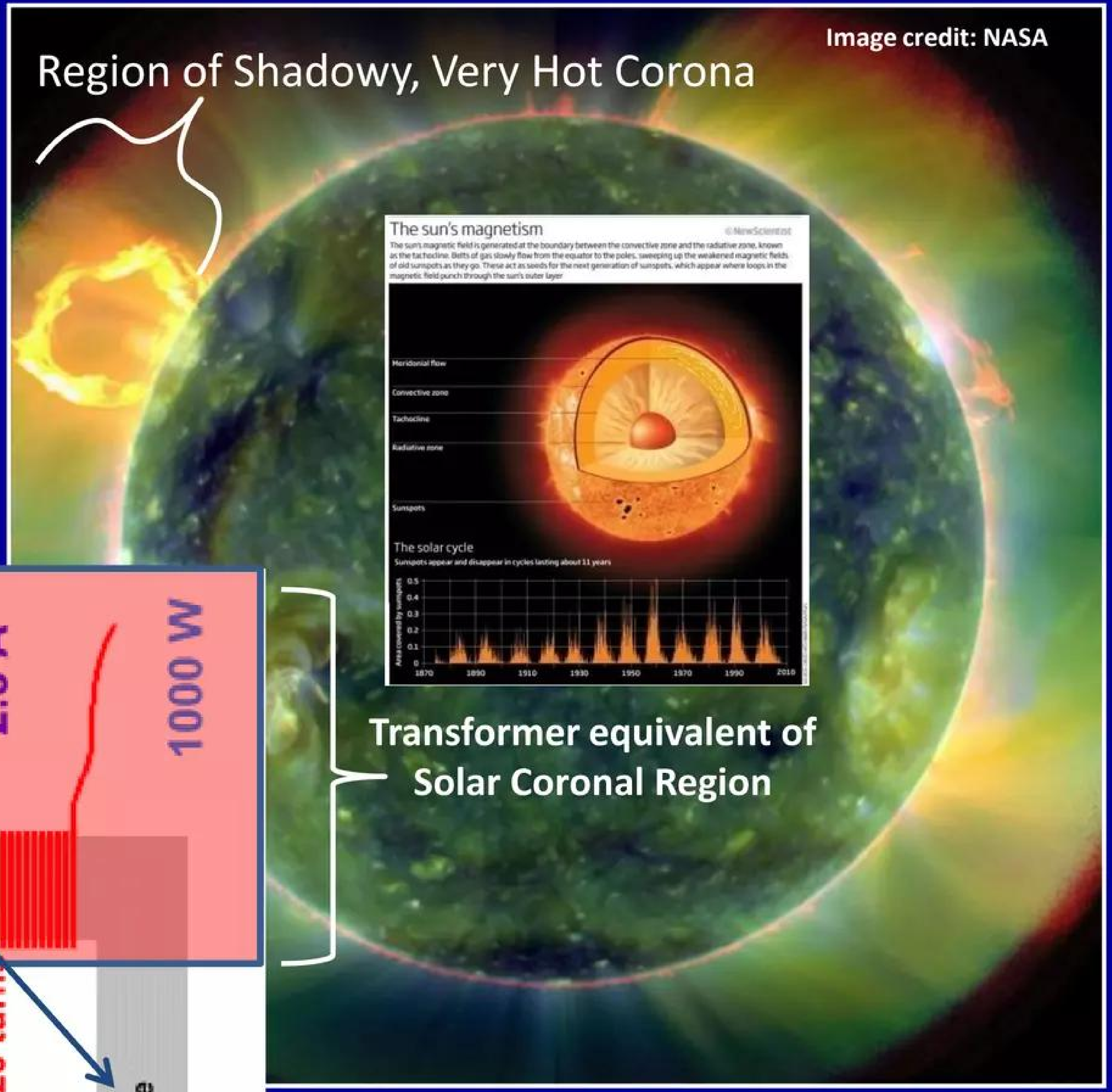
Sun's core is at temperature of ~15 million degrees K; 'surface' of the photosphere and chromosphere at ~6,000 K and 10,000 K respectively; but corona region at ~ 2 million K is much hotter than 'surface' of sun. This anomaly appears to contradict laws of thermodynamics. How might this mystery be explained?

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







$$V_p I_p = V_s I_s$$

Transformer equivalent of Solar Photosphere

Electric utility transformers

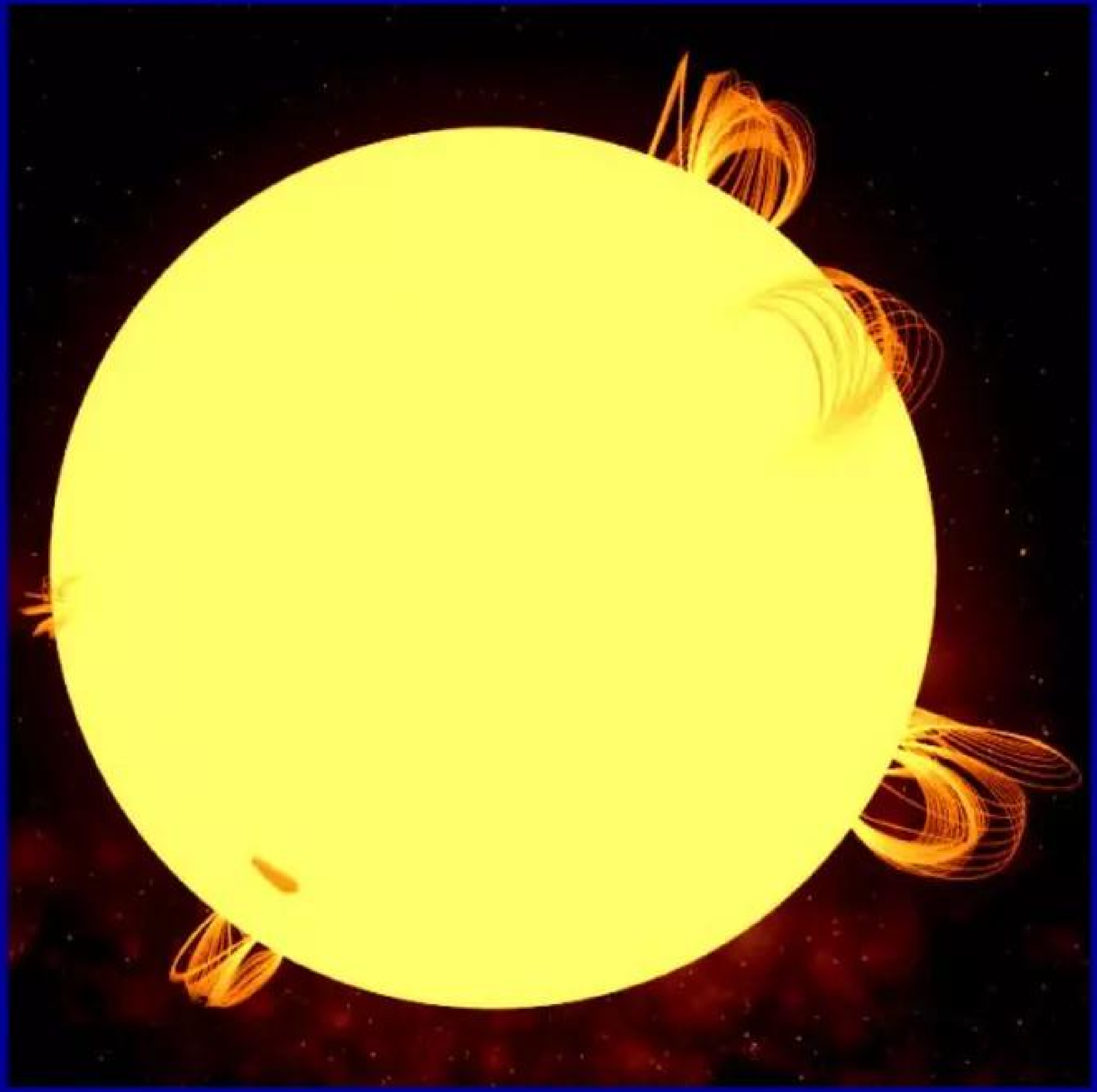
"High Energy Particles in the Solar Corona"
- Widom, Srivastava, and Larsen (April 2008)

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.

Present astrophysical paradigms - flux tubes and coronas

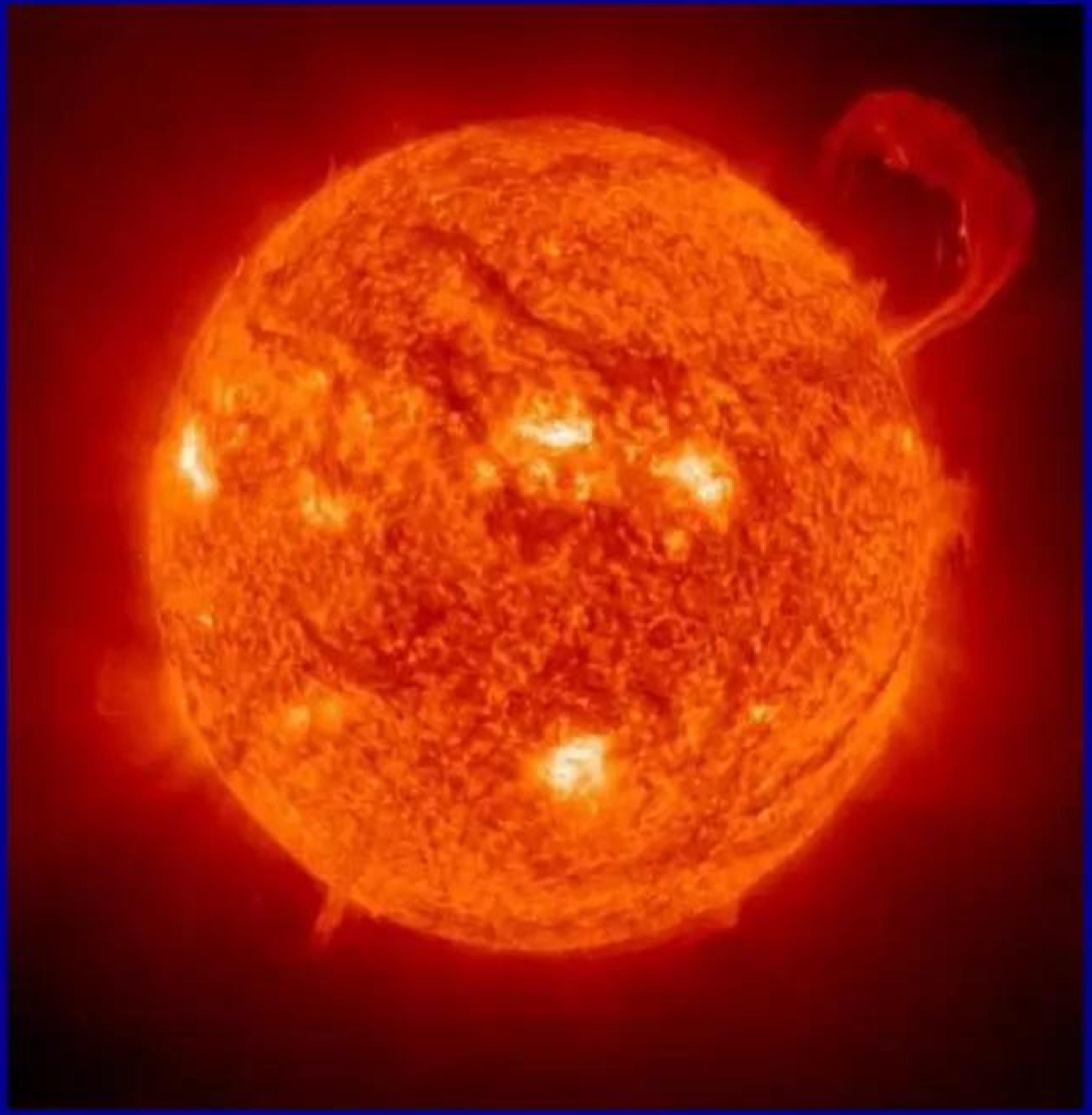
Idealized graphics and image illustrate two important types of structures

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

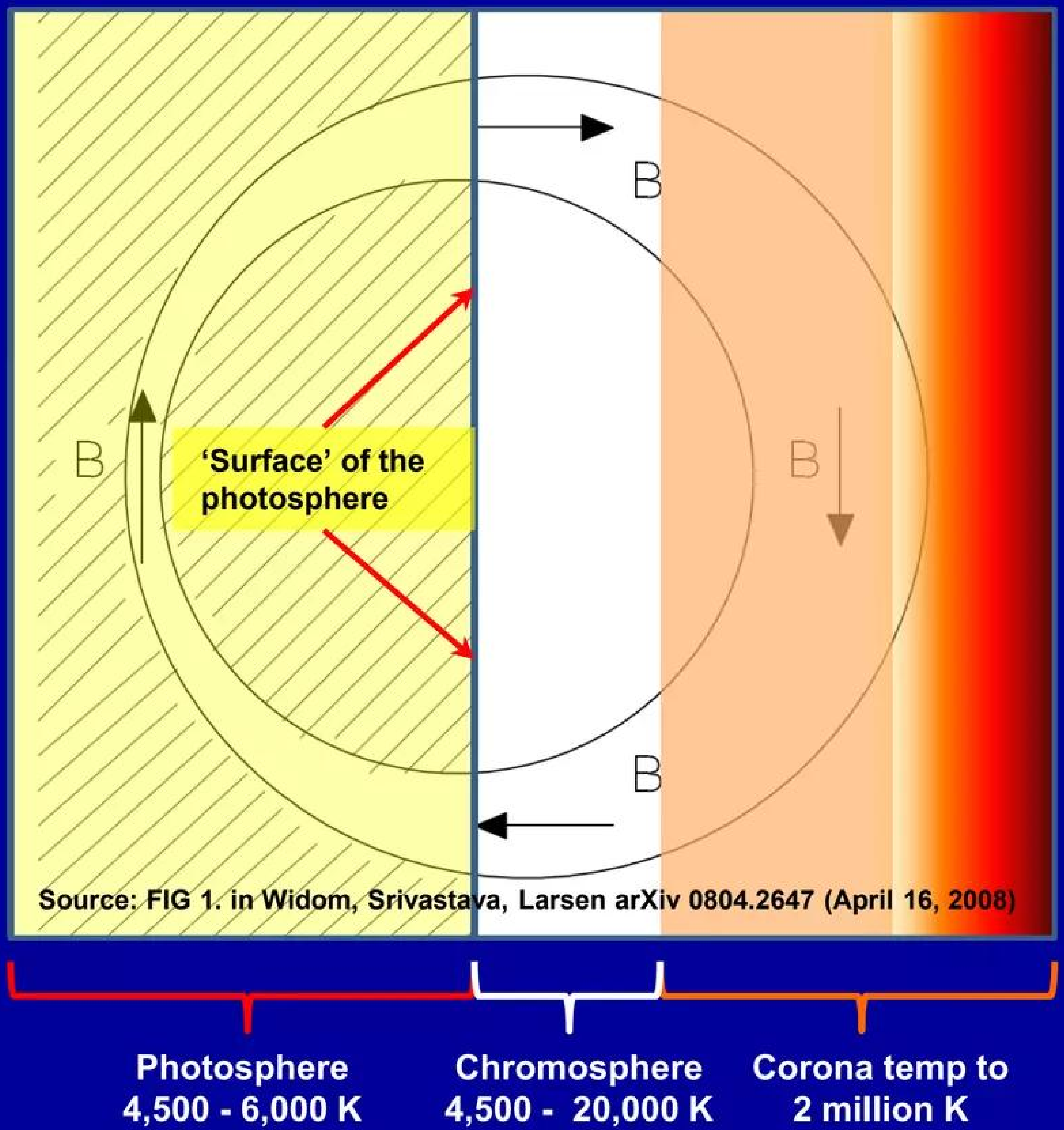


Credit: NASA SOHO – false-color image of the actual Sun in extreme ultraviolet

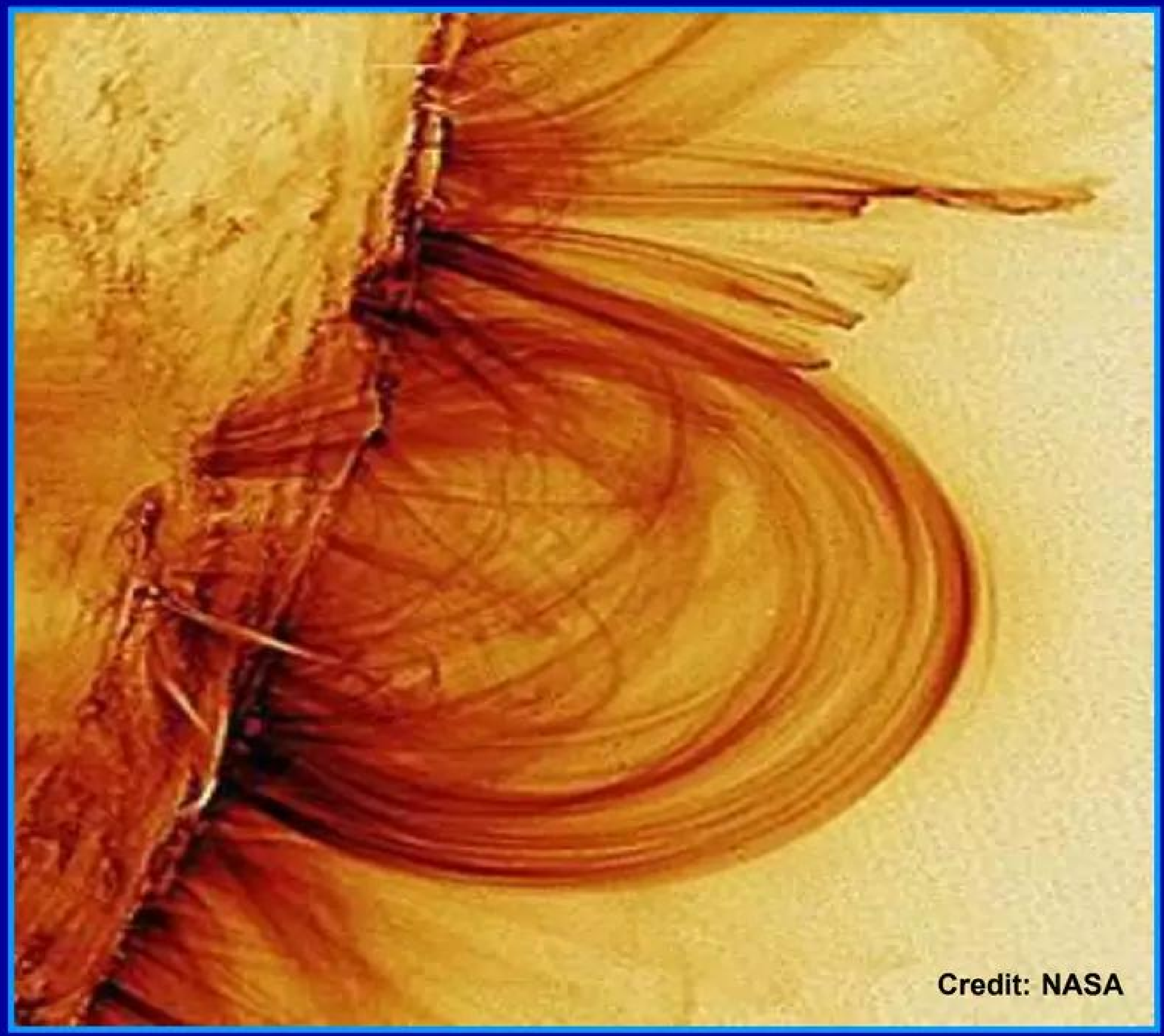
Present astrophysical paradigms - magnetic flux tubes

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

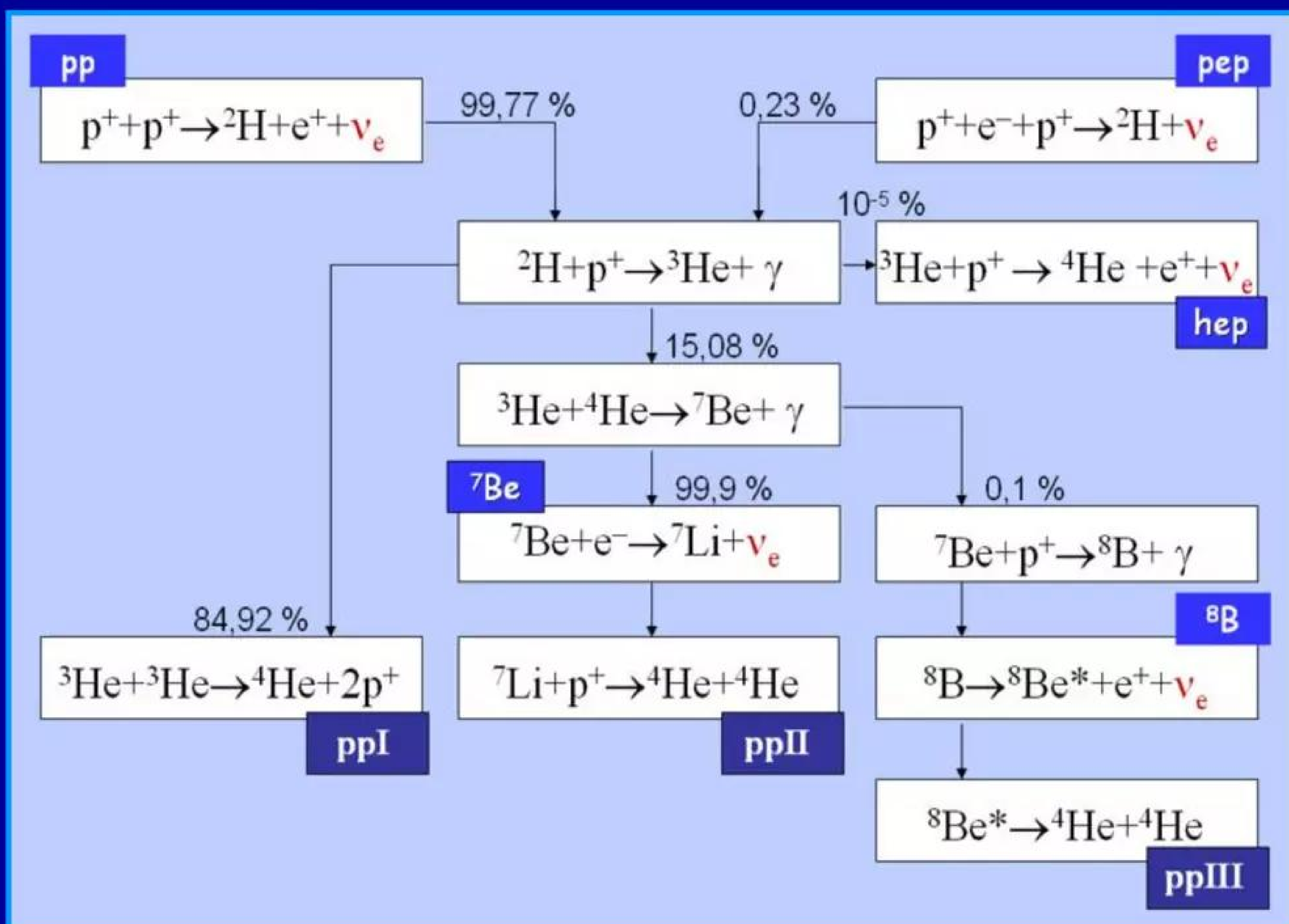


Basic transformer equation is: $V_p I_p = V_s I_s$

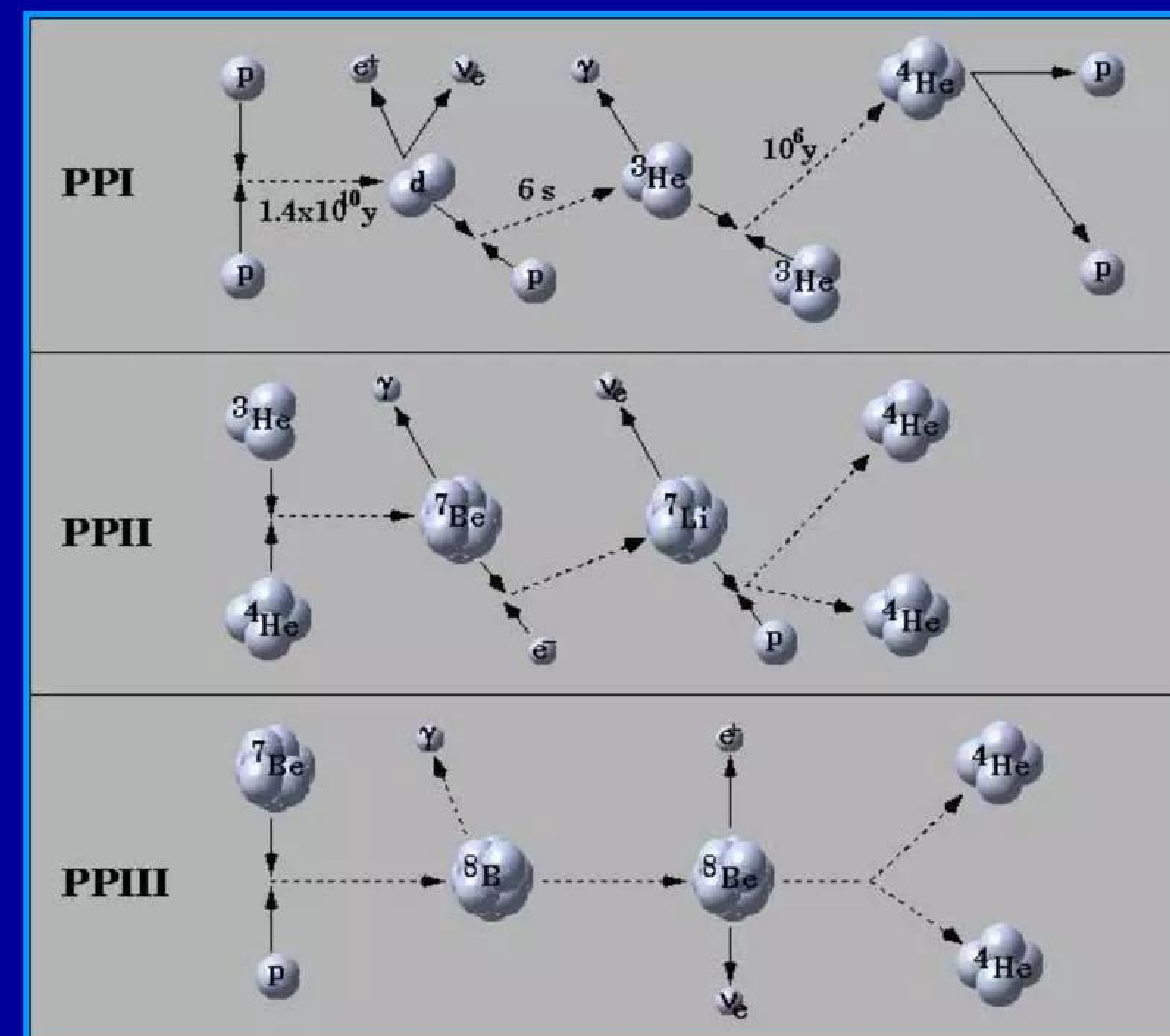
Present astrophysical paradigms - *pp* 'chains' in Sun

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

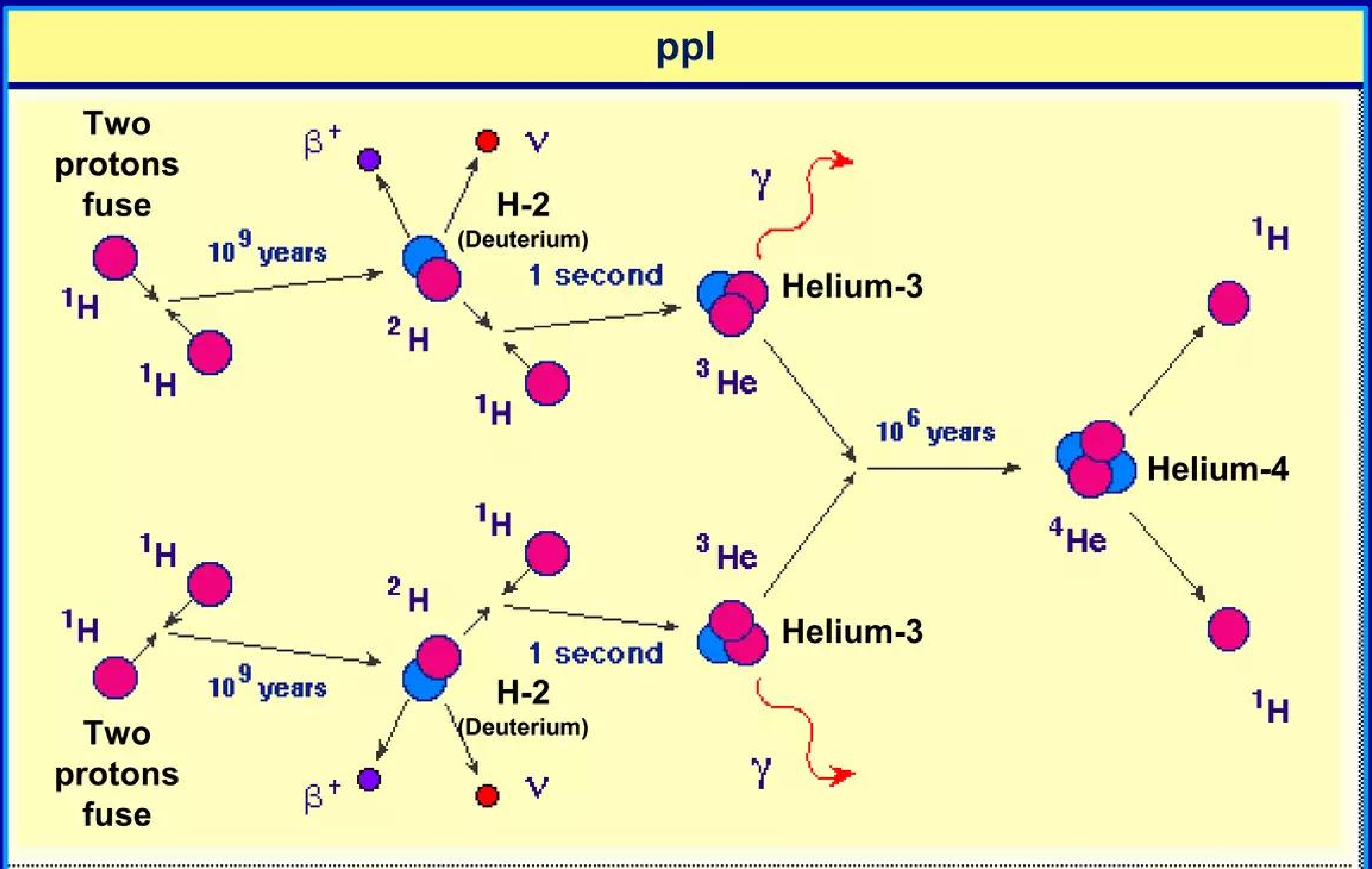


Credit: Prof. Vik Dhillon

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

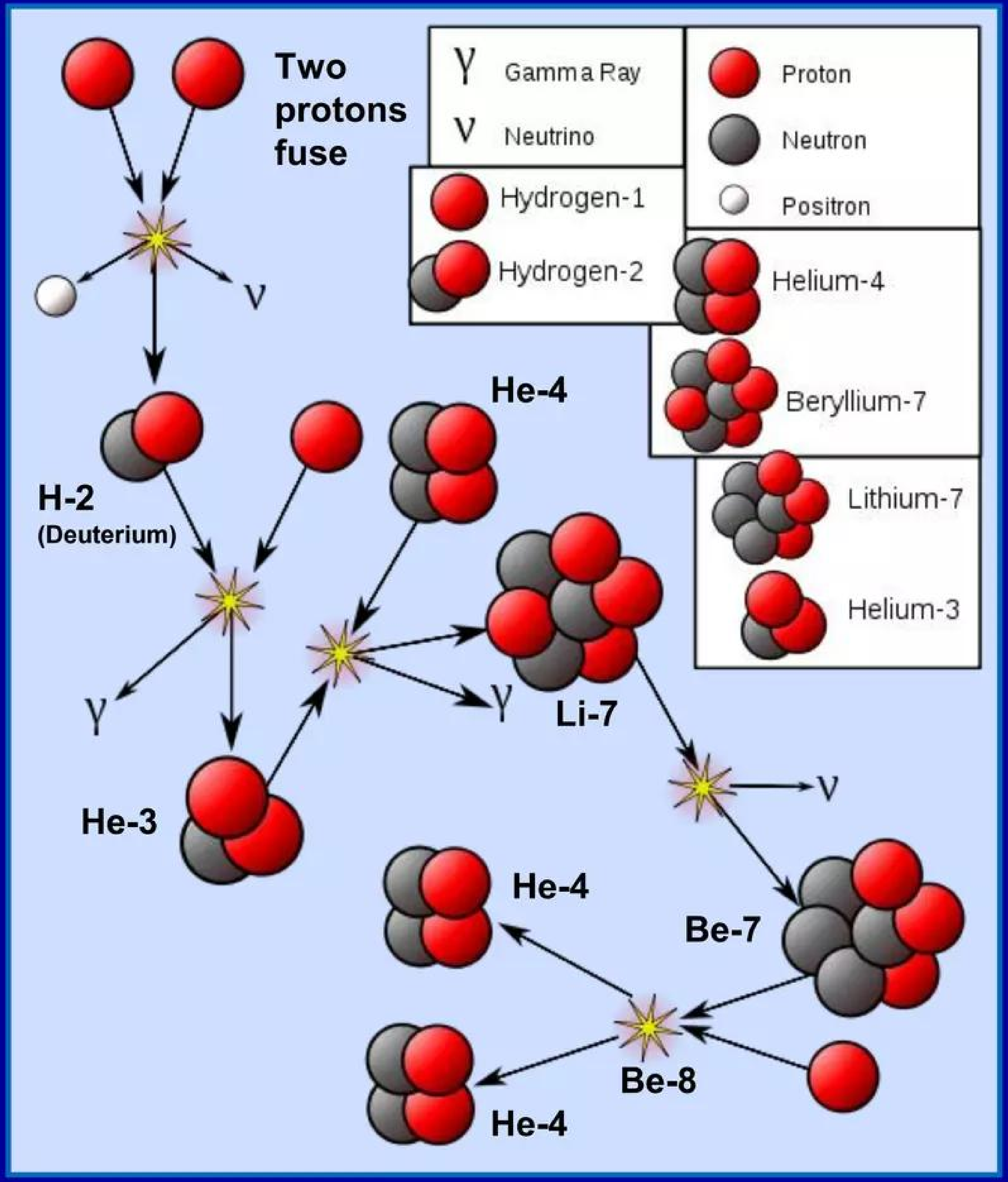
$$p + p \rightarrow {}^2H + e^+ + \nu_e \quad \text{(twice)}$$
$$p + {}^2H \rightarrow {}^3He + \gamma \quad \text{(twice)}$$
$${}^3He + {}^3He \rightarrow {}^4He + p + p$$

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)**

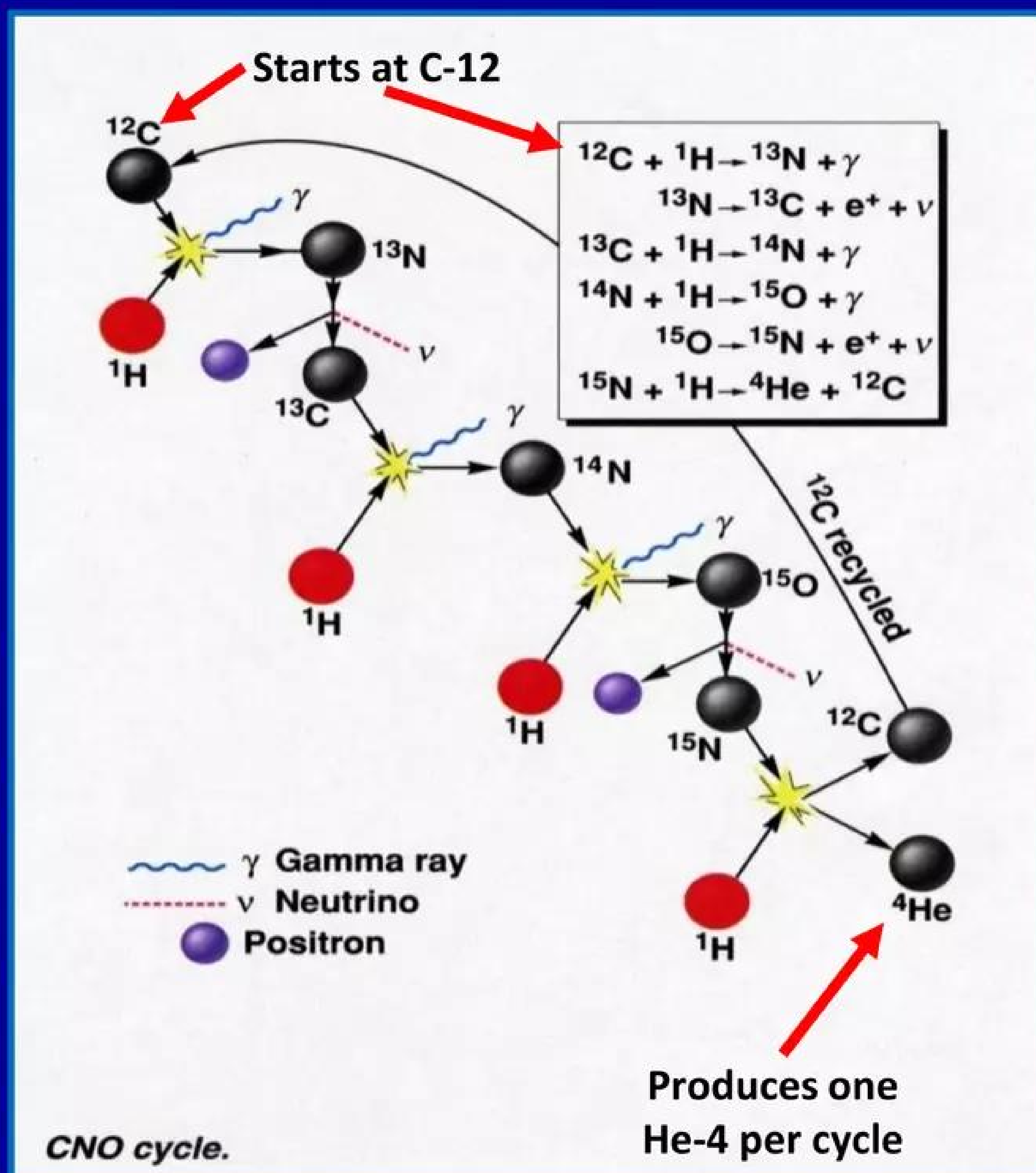


Source: adapted from Wikipedia as of May 17, 2011

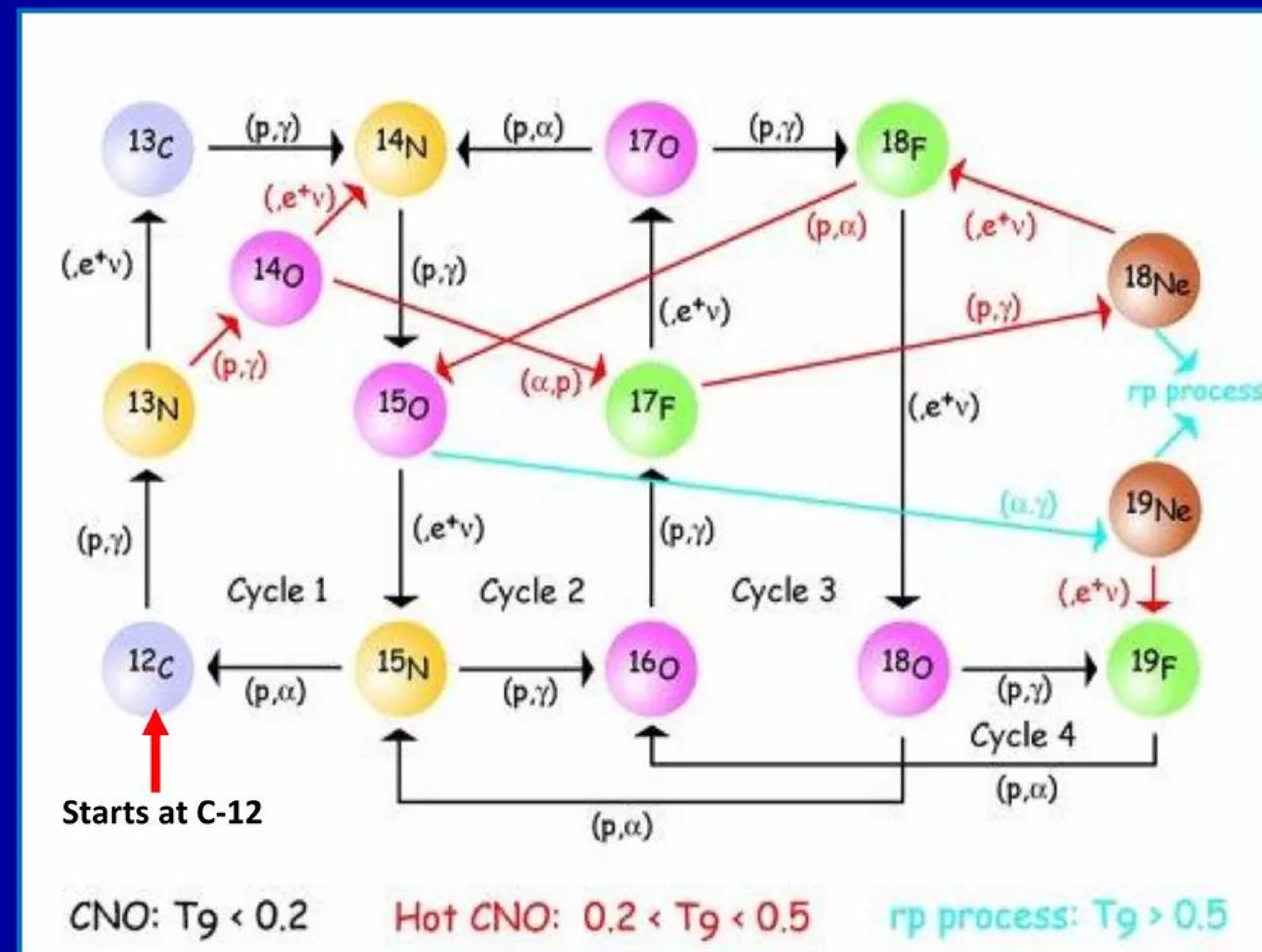
Present astrophysical paradigms - CNO cycle

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 4×10^6 K, making it the dominant force in smaller stars. The CNO chain starts occurring at approximately 13×10^6 K, but its energy output rises much faster with increasing temperatures. At approximately 17×10^6 K, the CNO cycle starts becoming the dominant source of energy. The Sun has a core temperature of around 15.7×10^6 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	Core	276.5
9	0.06	13.8	33	0.010	Core	103.0
12	0.08	12.8	55	.0068	Core	56.4
14	0.10	11.3	79	.0033	Core	19.5
19	0.13	10.1	91	.0016	Core	6.9
22	0.15	9.0	97	0.0007	Core	2.2
24	0.17	8.1	99	0.0003	Core	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 ~ 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 ≤ A ≤ 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 ≥ 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 ≤ A ≤ 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 ≤ Z ≤ 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

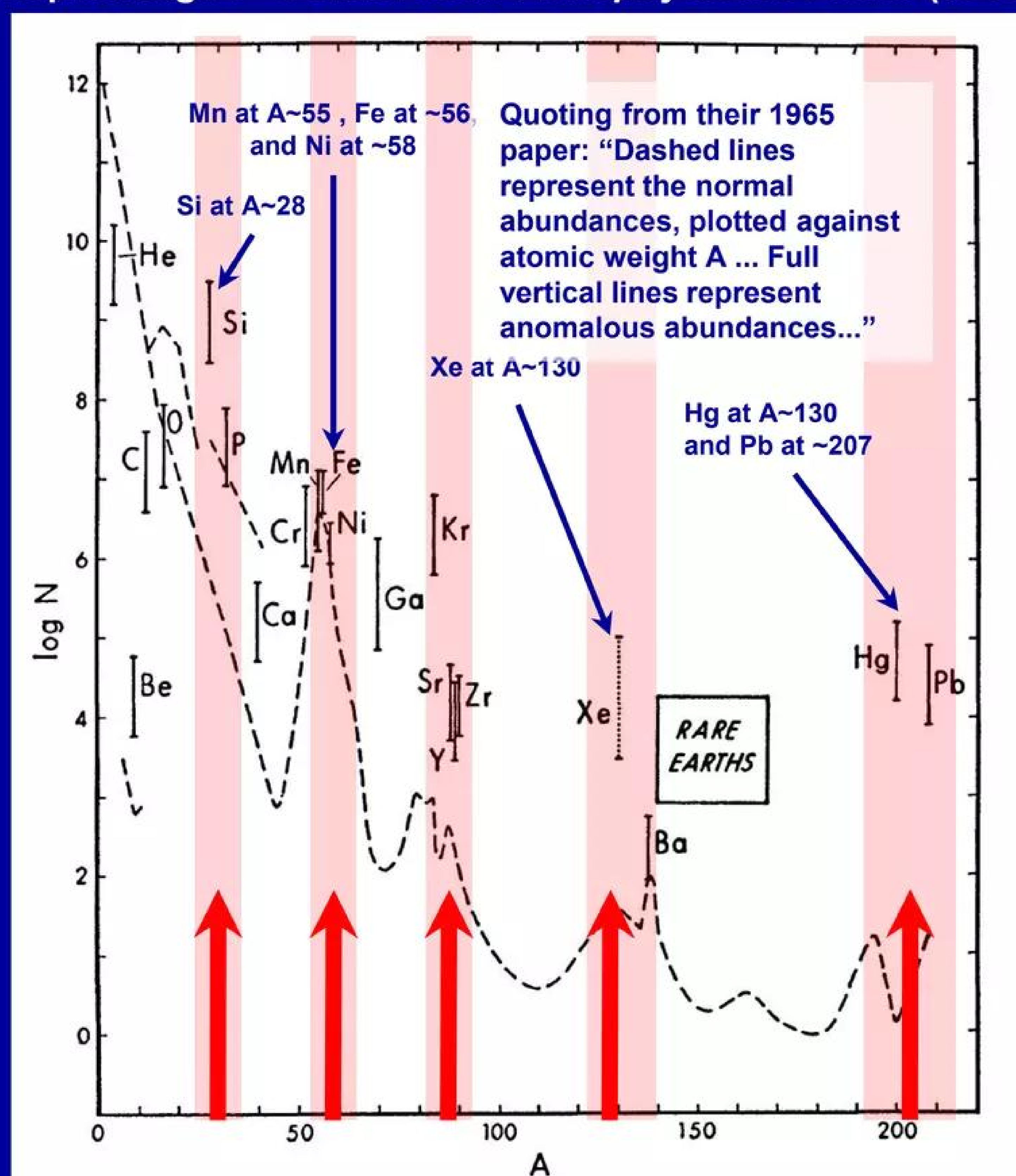
- ✓ After publishing B^2FH in 1957 (which still overshadows astrophysics today, 46 years later), Fowler, both Burbidges, and Hoyle went even further with their thinking in attempting to explain anomalous elemental abundances spectroscopically measured in the atmospheres of certain "chemically peculiar" (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

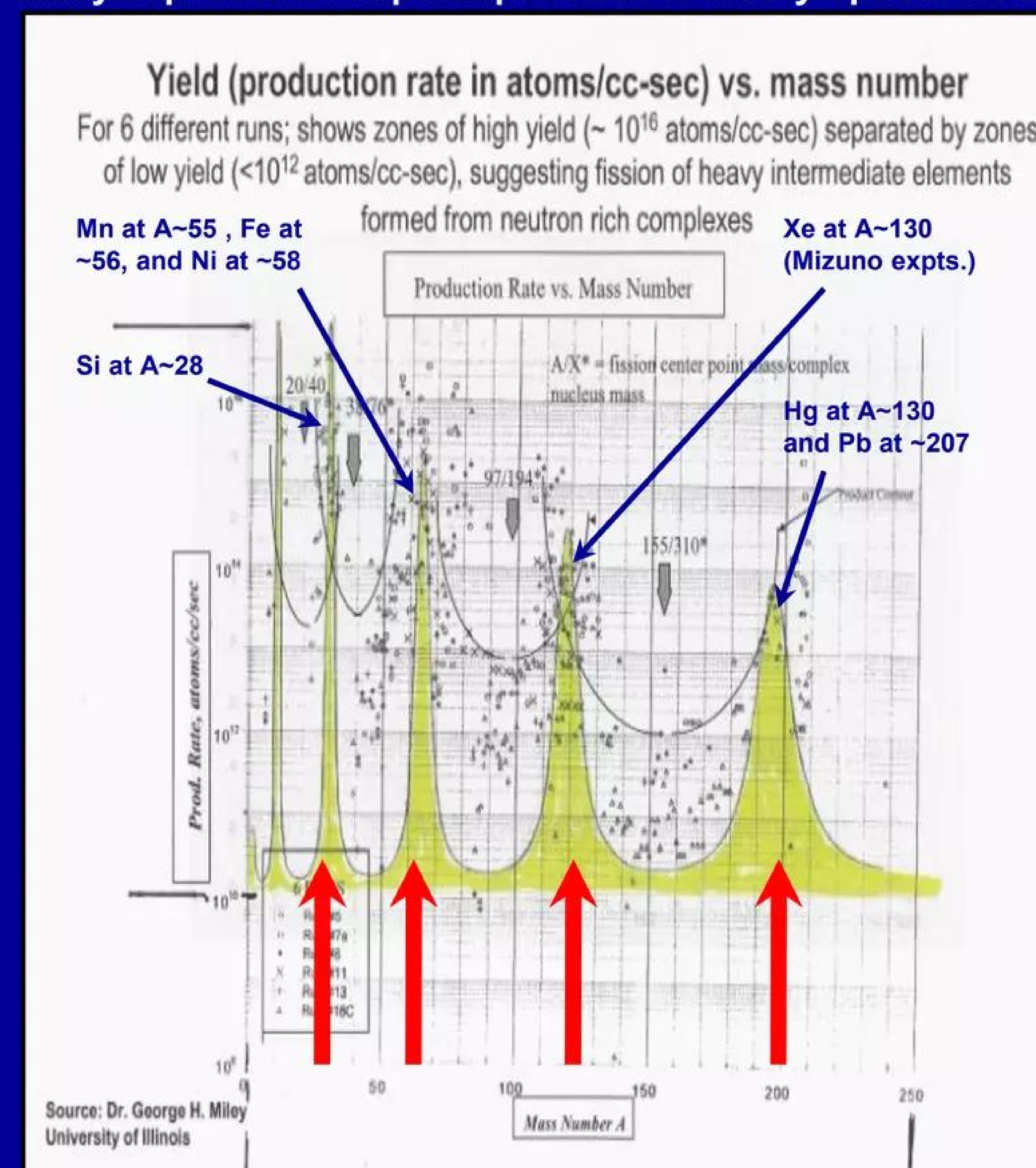
Fowler et al. Fig 2. data compared to 1996 LENR data in light of W-L theory

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 x 10^{-4}."
- ✓ "Asplund et al. have recently reported the detection of ^{6}Li at ≥ 2σ 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."

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 $h/h_{loop} \approx L/L_{loop} = 1.4 \pm 0.3$ 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 ($t_x \approx$ 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'."

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

- ✓ 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^+ → *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

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

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- ✓ 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 *µ*Ci 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)

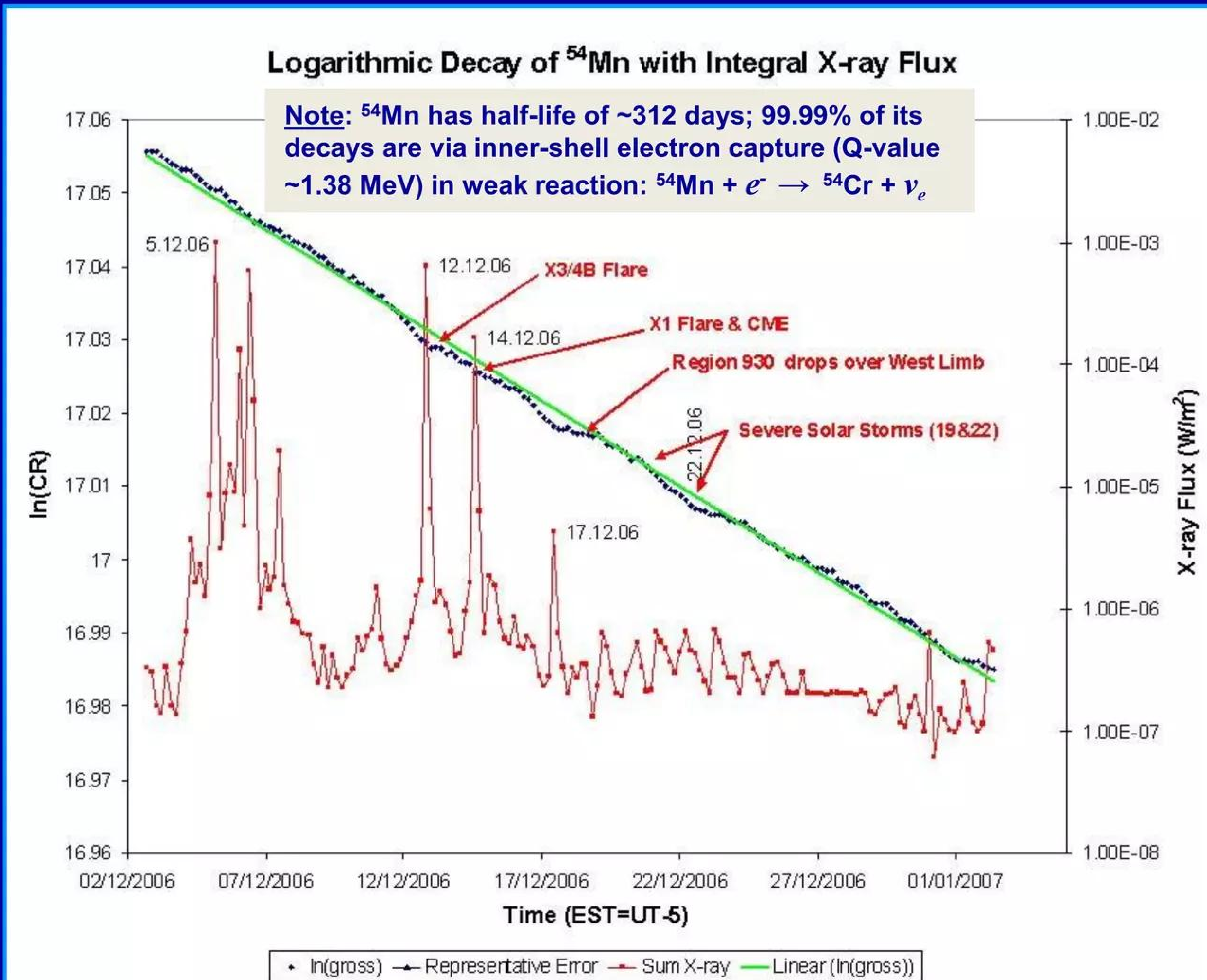

Figure 1. J. Jenkins and E. Fischbach, *Astroparticle Physics* 31 pp, 407 - 411 (2009)

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 + ν_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^+ → *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 nu*clei. 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 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 In☹ 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 earth

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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 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 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

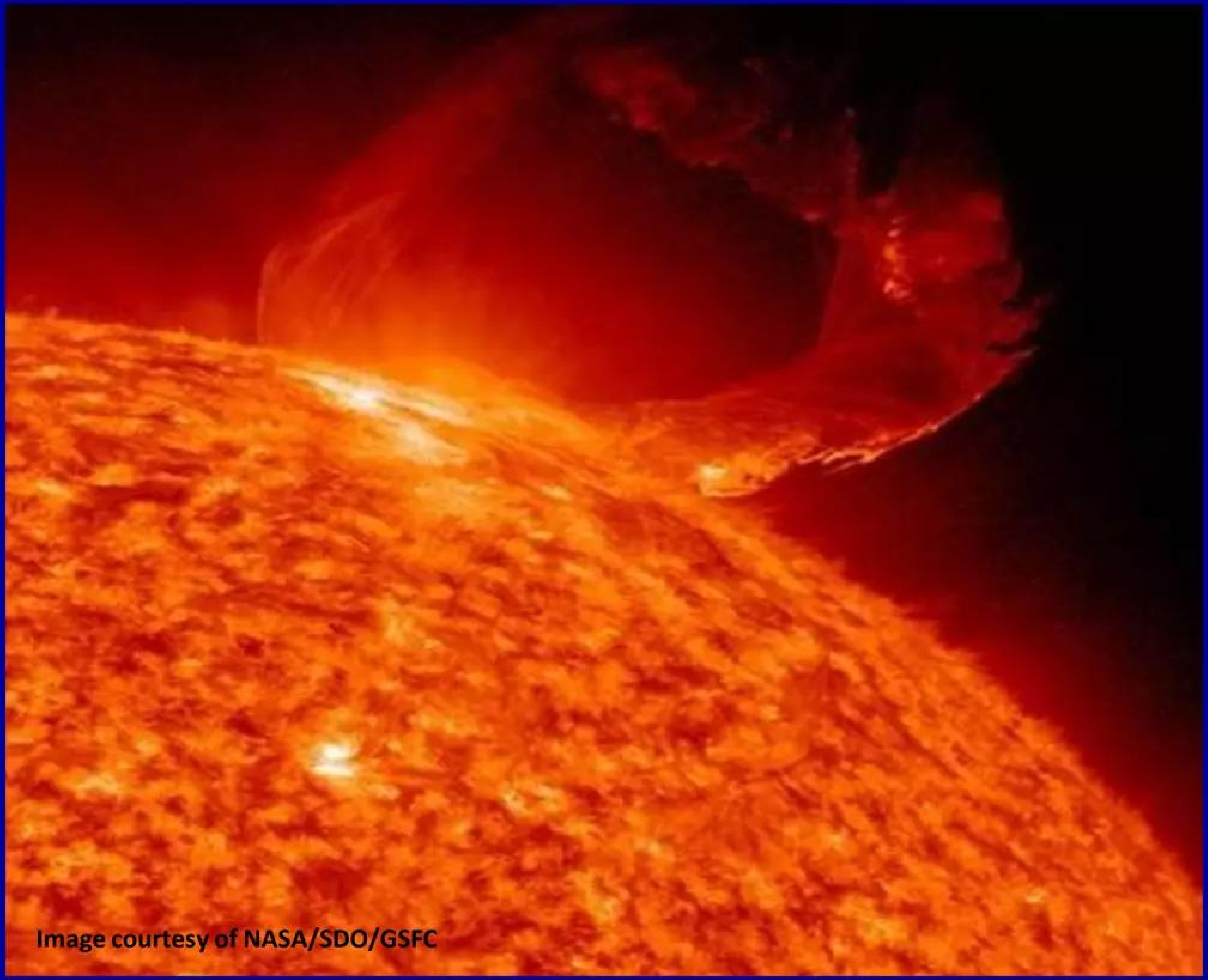
Commercializing a Next-Generation Source of Safe Nuclear Energy

W-S-L theory suggests nucleosynthesis may be widespread

Cores of stars, fission reactors, and supernovae not required

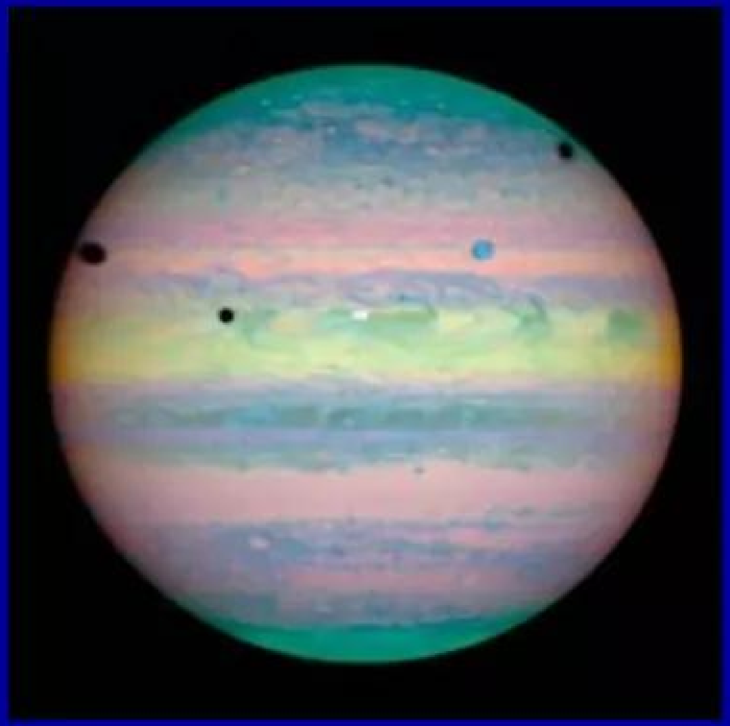
Lightning is like exploding wires

Earth: LENRs in many places



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'

Concluding comments 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)

Concluding comments re Nov. 21 article in *New Scientist*

Jenkins & Fischbach's published experimental data appears consistent with conjectures:

- ✓ About 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 (i.e., 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-up, a given nucleus cannot decay until an unoccupied 'slot' opens-up. Now imagine a ^{54}Mn atom located on earth bathed in a varying 'bright' flux of neutrinos coming from the general direction of the Sun. At every instant, unstable ^{54}Mn atoms are quantum mechanically interrogating the local continuum 'world' outside the nuclei via the available electron capture channel in order to 'decide' whether it is 'permissible' to decay by emitting a neutrino. In doing so, a given ^{54}Mn atom's internal 'nuclear decay clock' is effectively modified by changes in fine details of impinging external neutrino fluxes in terms of decay rates that are experimentally observed for such atoms

- ✓ For example, imagine that a very large flare occurred on the Sun in which copious weak interactions *e- + p+* → *lepton + X* took place via the Widom-Larsen many-body collective magnetic mechanism. Further suppose that the energy spectrum of such a 'bright' burst of electron neutrinos emitted from the specific flare that occurred during their experiment strongly overlapped the normal spectrum emitted by ^{54}Mn nuclei. In that event, one might expect that a measurable temporary decrease would occur in the decay rates of ^{54}Mn nuclei in a macroscopic sample being monitored experimentally on earth. *In fact, this is what occurred in Jenkins & Fischbach's ^{54}Mn sample*

Concluding comments re Nov. 21 article in *New Scientist*

- ✓ ***This result suggests that the Widom-Larsen collective magnetic mechanism could have operated in a large solar flare that was temporally coincident with the statistically significant perturbations in the ^{54}Mn nuclear decay rate observed by Jenkins & Fischbach***

- ✓ **Importantly, Jenkins & Fischbach's experimental data on ^{54}Mn allows has enabled them to work *backwards* and calculate an estimated effective interaction cross-section of electron neutrinos coming from $e^- + p^+ \rightarrow$ *lepton* + X reactions in the solar flare (which are predicted by W-L theory published in *Pramana*) that are impinging on ^{54}Mn atoms present in their measured sample of ^{54}Mn over the time interval of the measurements. The apparent cross-section that emerges from their straightforward calculation is on the order of ~10^9 - 10^{10} times *larger* than what one would expect with 'normal' interactions between neutrinos and atomic nuclei. *How can one explain this unexpected and deeply anomalous result?***

- ✓ **If my above-explained theoretical conjectures were true, and if the "*local continuum*" that ^{54}Mn nuclei exposed to a distant electron neutrino point source (located in the co-temporal solar flare) 'see' really begins just a little ways beyond the fuzzy quantum mechanical boundaries of a ^{54}Mn atom's very last occupied outer (valence) electron shell (i.e., the entire ^{54}Mn atom), then one might consequently expect that the value of the cross-sectional area (πr^2) of the entire ^{54}Mn atom divided by the cross-sectional area (πr^2) occupied by a ^{54}Mn nucleus should be about the same magnitude as the rather anomalously high neutrino interaction cross-section that is suggested by the results in Jenkins & Fischbach's published experimental data. *<u>That is in fact the case</u>: amazingly, both numerical values are very similar at 10^9 - 10^{10}. It seems unlikely that this is just a random accidental coincidence***

Concluding comments re Nov. 21 article in *New Scientist*

- ✓ **Widom-Larsen theory and Jenkins & Fischbach's experimental data suggest that weak-interaction-based detection devices could potentially be designed and built to function as passive, many-body, collective quantum mechanical neutrino 'antennae' with very high neutrino interaction efficiencies, as well as high directional sensitivity and energetic specificity to neutrino fluxes emitted from distant point sources (in theory, more sensitive than existing neutrino detectors by a factor of ~10^9 - 10^{10}). This could potentially be a game-changer in the technological ability to monitor neutrino fluxes of interest in the context of WMD and nuclear proliferation issues, as well as basic science research such as measuring solar neutrinos**

- ✓ **If prototype detectors based on these new insights can successfully 'image' fixed, land-based fission reactors in preliminary experiments (has recently occurred), then with further development it would seem possible that one might eventually be able to successfully detect the locations of moving neutrino sources located *anywhere* in the near-earth environment. Techniques to estimate neutrino spectral 'signatures' for various types of fission reactors have already been developed; some such signatures have also been measured**

- ✓ **If these new types of Q-M-based neutrino detection and measurement systems finally achieved satisfactory sensitivity/reliability and were practical and cost-effective to engineer, and since such Q-M neutrino antennas could likely be ultra compact and relatively low-mass, they could potentially be deployed on various types of mobile platforms to mitigate global nuclear proliferation risks by identifying and locating undeclared/clandestine fission reactors**

"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

