Lattice Energy LLC

HESS Collaboration has published important paper in *Nature*

Detected gamma rays coming from Milky Way's black hole indicating that PeV cosmic rays come from same source

Widom-Larsen-Srivastava theory provides many-body collective mechanism that can accelerate protons to PeV and higher energies in immediate vicinity of such black holes

Artist's impression shows surroundings of supermassive black hole
Credit: ESO / L. Calçada

Lewis Larsen
President and CEO
March 17, 2016

Contact: 1-312-861-0115 Chicago, Illinois USA
lewisglarsen@gmail.com

Laura13

Science story about *Nature* paper by HESS Collaboration

"Milky Way's black hole may be spewing out cosmic rays"

By Daniel Clery March 16, 2016 3:15 PM in Science

http://www.sciencemag.org/news/2016/03/milky-way-s-black-hole-may-be-spewing-out-cosmic-rays?et_rid=17056540&et_cid=344959

" … new study has fingered a second source: the supermassive black hole at the heart of the Milky Way. With this new result, the search for cosmic ray origins, which has frustrated scientists for more than 100 years, has taken an unexpected new twist.

'It's very exciting,' says astrophysicist Andrew Taylor of the Dublin Institute for Advanced Studies. 'This has probably shaken the field quite a lot. People will need to reassess their models'."

"Cosmic rays pose a mystery for astronomers because they don't follow a straight path through space. They get tugged and pushed by magnetic fields, so it is almost impossible to figure out where particular particles have come from. So instead, researchers have looked at gamma rays, high-energy photons that are thought to be produced at or near the source of the cosmic rays. Find out where the gamma rays come from, and you've probably found the source of cosmic rays."

"Although many of the cosmic rays from within our galaxy appear to be blasted out from supernova explosions at blistering speeds, such explosions can't explain the highest energy cosmic rays: those with energies measured in peta-electronvolts (PeV, or 10^{15} eV). (Here on Earth, 1 PeV is the total energy that the Large Hadron Collider can achieve when slamming together lead ions.)"

Science story about *Nature* paper by HESS Collaboration

"Milky Way's black hole may be spewing out cosmic rays"

Science AAAS By Daniel Clery March 16, 2016 3:15 PM in Science Science AAAS

http://www.sciencemag.org/news/2016/03/milky-way-s-black-hole-may-be-spewing-out-cosmic-rays?et_rid=17056540&et_cid=344959

"In the new study, Hofmann and colleagues used the High Energy Stereoscopic System (HESS), an array of five telescopes in Namibia, which can detect such radiation. HESS has been studying the galactic center for about a decade, Hofmann says, simply because it is an interesting source of gamma rays. In recent years, his team has carried out more detailed observations. And, as it reports online today in *Nature*, the distribution of gamma rays coming from around the galactic center is exactly what you would expect if some process, close to the black hole, is firing out protons with PeV energies."

"Many of those protons may much later arrive at Earth as PeV cosmic rays, but some are colliding with gas molecules close to their source and producing gamma rays. It is these gamma rays HESS is able to pick up, revealing the origin of these superfast protons. 'It really demonstrates that there is a central source [of protons],' Hofmann says."

" 'This is a great result. It's very fascinating,' says astrophysicist Pasquale Blasi of the Arcetri Astrophysical Observatory in Florence, Italy. 'For the very first time we have almost direct evidence of the acceleration of protons to these energies'."

Abstract of important *Nature* paper by HESS Collaboration

"Acceleration of petaelectronvolt protons in the Galactic Centre"

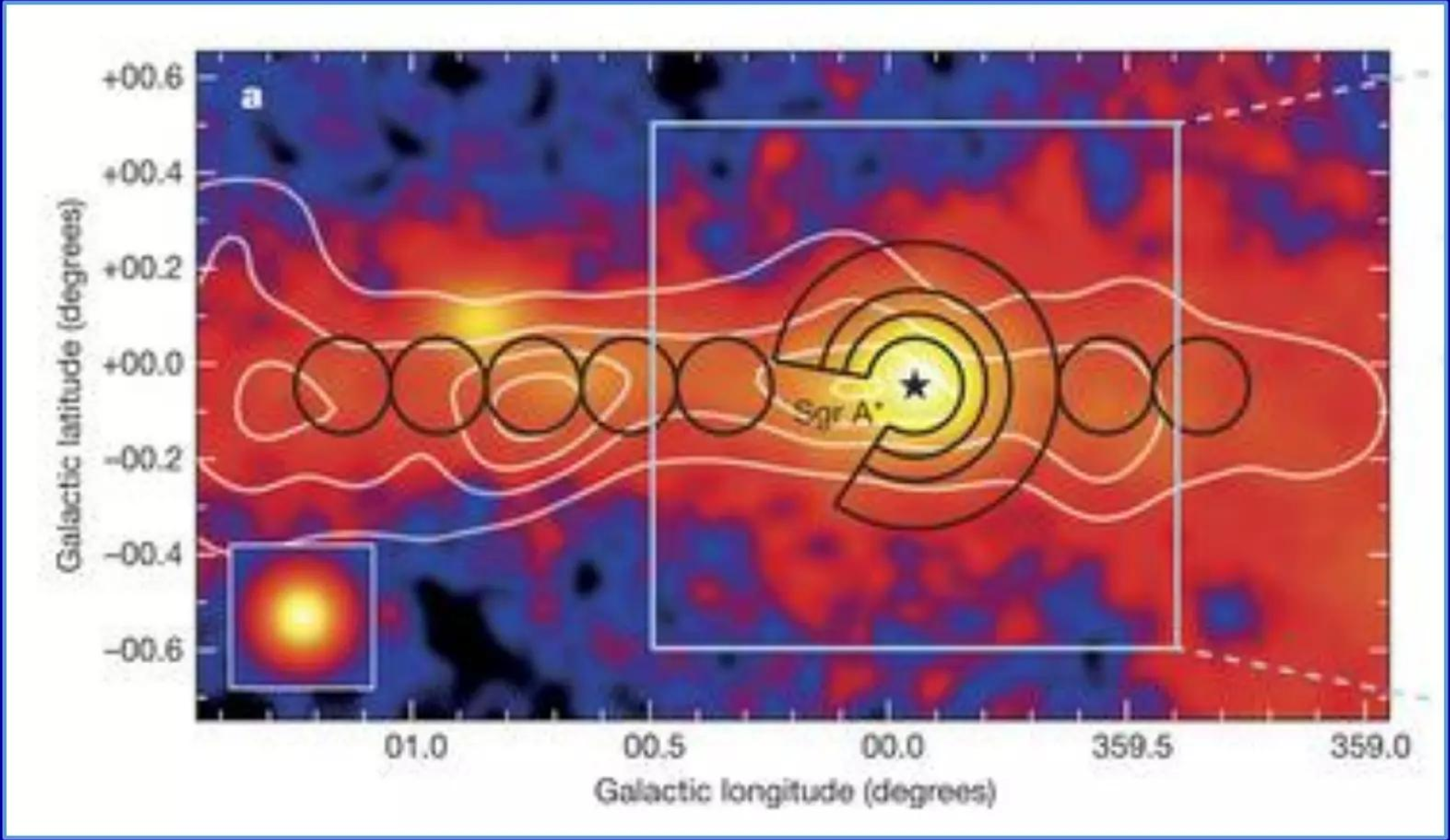
nature — HESS Collaboration in *Nature* - published online March 16, 2016 — nature

http://www.nature.com/nature/journal/vaop/ncurrent/full/nature17147.html

"Galactic cosmic rays reach energies of at least a few petaelectronvolts (of the order of 10^{15}electronvolts). This implies that our Galaxy contains petaelectronvolt accelerators ('PeVatrons'), but all proposed models of Galactic cosmic-ray accelerators encounter difficulties at exactly these energies. Dozens of Galactic accelerators capable of accelerating particles to energies of tens of teraelectronvolts (of the order of 10^{13} electronvolts) were inferred from recent γ-ray observations. However, none of the currently known accelerators - not even the handful of shell-type supernova remnants commonly believed to supply most Galactic cosmic rays - has shown the characteristic tracers of petaelectronvolt particles, namely, power-law spectra of γ-rays extending without a cut-off or a spectral break to tens of teraelectronvolts. Here we report deep γ-ray observations with arcminute angular resolution of the region surrounding the Galactic Centre, which show the expected tracer of the presence of petaelectronvolt protons within the central 10 parsecs of the Galaxy. We propose that the supermassive black hole Sagittarius A* is linked to this PeVatron. Sagittarius A* went through active phases in the past, as demonstrated by X-ray outbursts and an outflow from the Galactic Centre. Although its current rate of particle acceleration is not sufficient to provide a substantial contribution to Galactic cosmic rays, Sagittarius A* could have plausibly been more active over the last 10^6 - 10^7 years, and therefore should be considered as a viable alternative to supernova remnants as a source of petaelectronvolt Galactic cosmic rays."

Graphic in important *Nature* paper by HESS Collaboration

Figure 1: VHE γ-ray image of the Galactic Centre region



"The colour scale indicates counts per 0.02° × 0.02° pixel. **a**, The black lines outline the regions used to calculate the cosmic-ray energy density throughout the central molecular zone. A section of 66° is excluded from the annuli."

PRAMANA
journal of
physics

A primer for electroweak induced low-energy nuclear reactions

Y N SRIVASTAVA[1,*], A WIDOM[2] and L LARSEN[3]
[1]Dipartimento di Fisica & INFN, Università degli Studi di Perugia, 06123 Perugia, Italy
[2]Physics Department, Northeastern University, Boston, MA 02115, USA
[3]Lattice Energy LLC, 175 North Harbor Drive, Chicago, IL 60601, USA
[*]Corresponding author. E-mail: yogendra.srivastava@gmail.com

MS received 28 January 2010; revised 9 May 2010; accepted 21 May 2010

Abstract. Under special circumstances, electromagnetic and weak interactions can induce low-energy nuclear reactions to occur with observable rates for a variety of processes. A common element in all these applications is that the electromagnetic energy stored in many relatively slow-moving electrons can – under appropriate circumstances – be collectively transferred into fewer, much faster electrons with energies sufficient for the latter to combine with protons (or deuterons, if present) to produce neutrons via weak interactions. The produced neutrons can then initiate low-energy nuclear reactions through further nuclear transmutations. The aim of this paper is to extend and enlarge upon various examples analysed previously, present order of magnitude estimates for each and to illuminate a common unifying theme amongst all of them.

Keywords. Nuclear transmutations; low-energy nuclear reaction; electroweak.

Indian Academy of Sciences | Springer

Exploding magnetic flux tubes accelerate charged particles

Eq. 20 calculates the mean acceleration energy for a flux tube explosion

On the other hand, for a spectacular solar flare which lasts for a time Δt, the loss of magnetic flux tube would yield a mean Faraday law acceleration voltage $\bar{V}$ around the walls given by

$$\bar{V} = \frac{\Delta\Phi}{c\Delta t}. \tag{18}$$

Inserting $\Delta\Phi = B\Delta S$ as before, where B denotes the mean magnetic field before the explosion and ΔS is the inner cross-sectional area of the flux tube, we have for the mean acceleration energy

$$e\bar{V} = (eB)\frac{\Delta S}{\Lambda}, \quad \text{where } \Lambda = c\Delta t. \tag{19}$$

For a cylindrical geometry, we can again rewrite it in a useful form

$$e\bar{V} \approx (30 \text{ GeV})\left(\frac{B}{\text{kG}}\right)\left(\frac{\pi R^2}{\Lambda - \text{km}}\right). \tag{20}$$

For a coronal mass ejecting coil exploding in a time $\Delta t \approx 10^2$ s, we may estimate

$$R \approx 10^4 \text{ km}$$

$$B \approx 1 \text{ kG}$$

$$\Lambda \approx 3 \times 10^7 \text{ km}$$

$$e\bar{V} \approx 300 \text{ GeV}. \tag{21}$$

Physically, it corresponds to a colliding beam of electrons and protons with a centre of mass energy of 300 GeV. More on these matters can be seen in §5.

"A primer for electro-weak induced low energy nuclear reactions", Y. Srivastava, A. Widom, and L. Larsen, *Pramana - Journal of Physics* 75 pp. 617 - 637 (2010)

W-L-S theory spans vast range of length-scales and energies

E-fields in condensed matter vs. B-field particle acceleration in plasmas

Short-range collective electric field effects dominate

Longer-range collective magnetic field effects begin to dominate

Long-range collective magnetic field effects dominate

local electric fields

Organized magnetic fields with plasmas

Low - medium electric and/or ion currents

Regime: ultralow energy neutron reactions (LENRs) in condensed matter

$e^* + p^+ \rightarrow$ 1 neutron + neutrino or $e^* + d^+ \rightarrow$ 2 neutrons + neutrino

Neutron production, capture, release energy, and transmutation products

- 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

High currents: electrons and/or ions

- 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
- Piezoelectric and pyroelectric processes in solid-state materials – Carpinteri, Naranjo
- Magnetic flux compression generators, e.g. US (LANL), Russia
- Lightning (terrestrial, planetary, nebular), especially in dusty environments – e.g., Dwyer
- ULMN-catalyzed subcritical fission reactors (<<< nuclear waste) - reprocess old wastes

Higher fluxes of neutrons

Scales-up to very large length scales | Huge range of magnetic field strengths

Mega-scale currents

Mixed regime: high energy particle reactions and/or LENRs on dust

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

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

>>>> fluxes

~0 eV Ultra low energy neutrons ……… MeV neutrons …GeV…TeVs …EeVs

Increasing neutron and charged particle energies

Many-body collective effects span vast range of length-scales

W-L-S theory and its collective effects extend from LENRs in condensed matter regimes to environments found in high-current exploding wires, e.g., large wire inductors, as well as up to large-length-scale, magnetically dominated regimes that occur in astrophysical systems

Length Scale	Type of System	Electromagnetic Regime	Many-body Collective Phenomena	Comment
Submicron	Certain earthly bacteria and some fungi	Very high, short-range electric fields	Transmutations, high level of gamma shielding	Obtain unavailable trace elements; survive deadly gamma or X-ray radiation
Microns	Hydrogen isotopes on metallic surfaces	Very high, short-range electric fields on solid substrates	Transmutations, high level of 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)	Ideal and dusty plasmas: high mega-currents of electrons, protons, and ions inside large-scale, ordered magnetic structures with substantial internal fields	Energetic charged particles and neutrons (MeVs to EeVs), X-rays, gamma-ray bursts, and ultra-high-energy cosmic rays (TeVs to EeVs)	Provides explanation for heating of solar corona and radioactive isotopes in stellar atmospheres
Up to several AU (distance from earth to Sun)	Neutron stars and active galactic nuclei in vicinity of compact, massive objects (black holes)			Provides mechanism for creating extremely high energy particles in plasma-filled magnetic flux tubes with sufficient field strengths

Note: mass renormalization of electrons by high local E-fields not a key factor in magnetically dominated regimes on large length scales

Many data suggest strong magnetic fields near black holes

New measurements suggest ordered magnetic fields near event horizons

"Resolved magnetic-field structure and variability near the event horizon of Sagittarius A* "
M. Johnson *et al.*, *Science* 350 pp. 1242 - 1245 (Dec. 4, 2015)

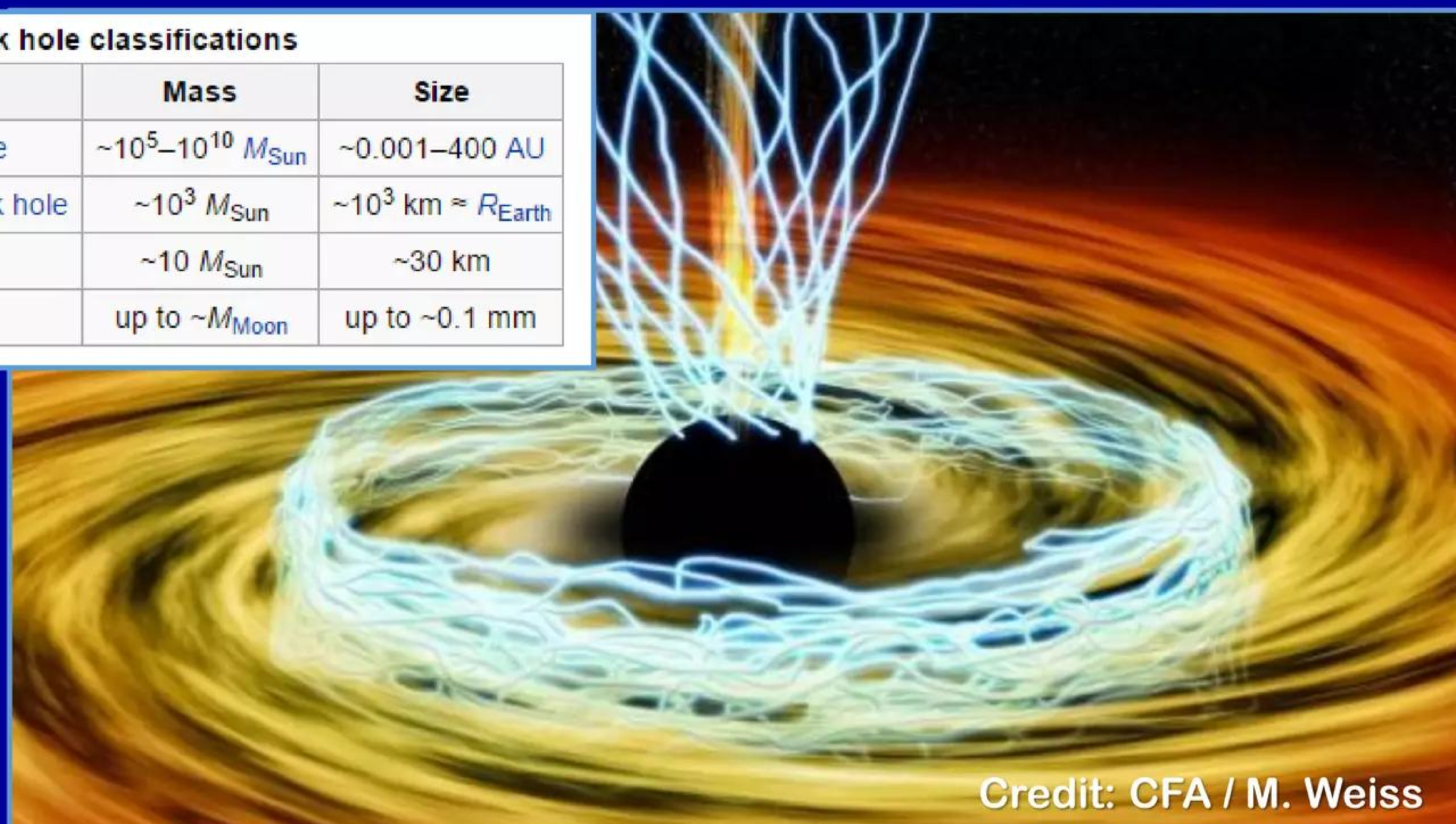
http://www.sciencemag.org/content/350/6265/1242

http://arxiv.org/pdf/1512.01220v1.pdf

Black hole classifications

Class	Mass	Size
Supermassive black hole	~10^5–10^{10} M_{Sun}	~0.001–400 AU
Intermediate-mass black hole	~10^3 M_{Sun}	~10^3 km ≈ R_{Earth}
Stellar black hole	~10 M_{Sun}	~30 km
Micro black hole	up to ~M_{Moon}	up to ~0.1 mm

Source: Wikipedia



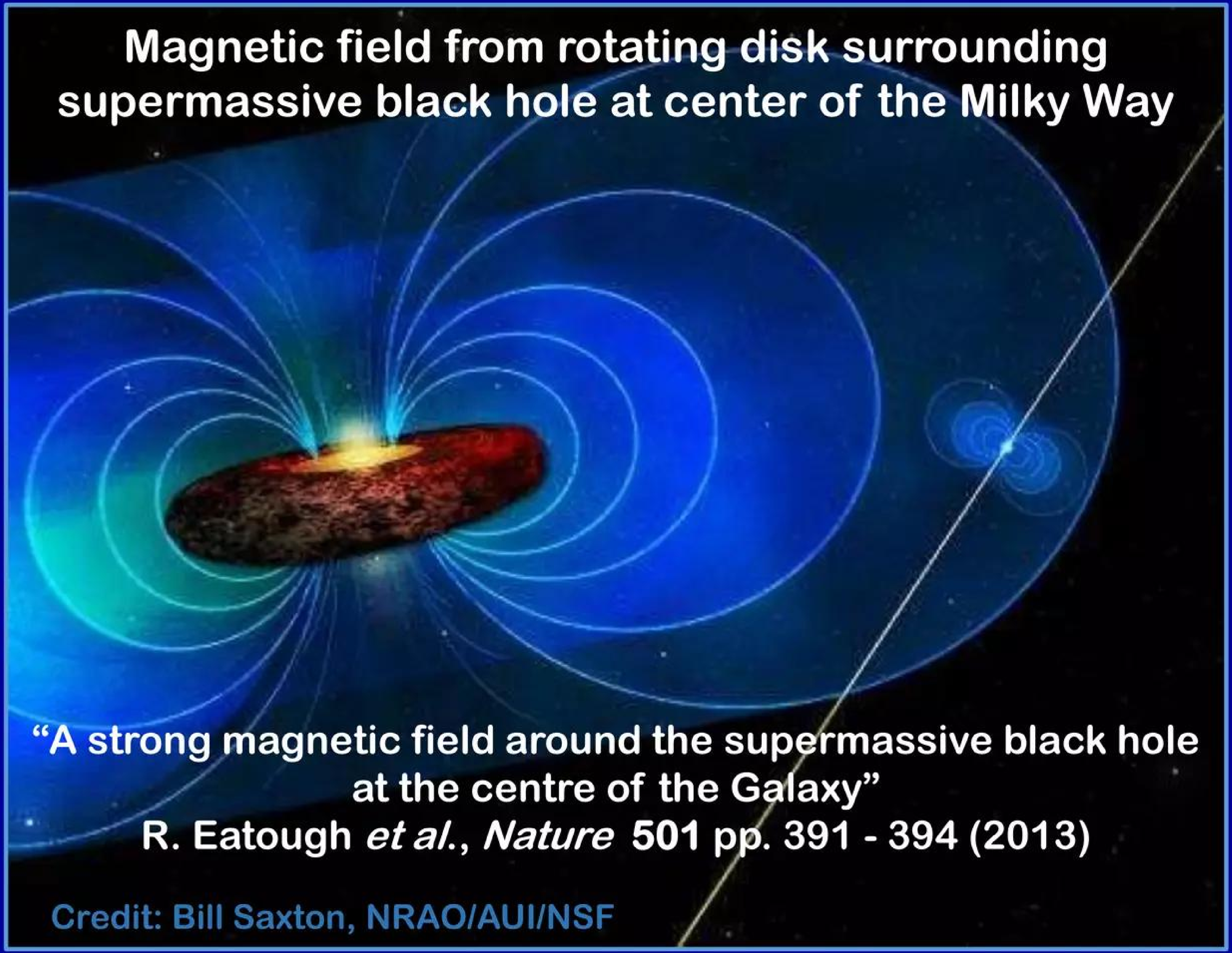
http://www.astro.phys.s.chiba-u.ac.jp/mhd2005/presentation/y_kato.pdf

Many data suggest strong magnetic fields near black holes

W-L-S: 100s of Gauss in *very* large flux tube provides huge acceleration

"Simple $B \propto r^{-1}$ scaling would … provide several hundred Gauss magnetic fields"

http://www.nature.com/nature/journal/v501/n7467/full/nature12499.html



http://arxiv.org/pdf/1308.3147v1.pdf

See online Lattice PowerPoint for detailed explanation

Shows how our mechanism can accelerate protons to PeV$^+$ energies

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-many-body-collective-magnetic-mechanism-creates-ultrahigh-energy-cosmic-rays-jan-1-2016

Magnetic flux tubes may form on black hole accretion disks

Magnetic fields of ~7.0 x 10^8 Gauss develop on upper edge of such disks

Case #1: mechanism accelerates protons to center-of-mass energies ≈2 x 10^{17} eV

Accelerated particles center-of-mass energy for exploding flux tube

$$e\bar{V} \approx (30\ \mathrm{GeV})\left(\frac{B}{\mathrm{kG}}\right)\left(\frac{\pi R^2}{\Lambda - \mathrm{km}}\right).$$

Eq. (20) in *Pramana* paper (2010)

Assumptions: magnetic flux tube forms on *supermassive* black hole accretion disk and initially contains protons, electrons, some neutrons, and traces of other elemental ions if any infalling matter is present; hypothetical flux tube parameters comparable to those of a similar structure on the Sun, namely that its radius = 10^4 km and time $\Delta t = 10^2$ seconds but much higher magnetic field inside B = 7.0 x 10^8 Gauss (7.0 x 10^5 kilogauss) per de Gouveia Dal Pino & Lazarian in *A&A* (2005)

Calculation based on Eq. 20 presuming that flux tube destabilizes and explodes:

$\Lambda = c\,\Delta t = (2.998 \times 10^5) \times (1 \times 10^2\ \mathrm{sec}) = 2.998 \times 10^7\ \mathrm{km} \approx 3.0 \times 10^7\ \mathrm{km}$

$B = 7.0 \times 10^5\ kG$

$\pi r^2 = 3.1416 \times (1 \times 10^4)^2 = 3.1416 \times (1 \times 10^8) \approx 3.1 \times 10^8\ \mathrm{km}^2$

$e\bar{V} \approx [\,(30.0) \times (7.0 \times 10^5)\,] \times (3.1 \times 10^8 / 3.0 \times 10^7) \approx [\,2.1 \times 10^7\,] \times (1.03 \times 10^1)$

$e\bar{V} \approx 2.16 \times 10^8\ \mathrm{GeV} \approx 2.16 \times 10^{17}\ \mathrm{eV} \approx 2.2 \times 10^{17}\ \mathrm{eV}$

Magnetic flux tubes may form on black hole accretion disks

Magnetic fields of ~7.0 x 10^{10} Gauss develop on upper edge of such disks

Case #2: mechanism accelerates protons to center-of-mass energies ≈ .9 x 10^{19} eV

Accelerated particles center-of-mass energy for exploding flux tube

$$eV \approx (30\ \mathrm{GeV}) \left(\frac{B}{\mathrm{kG}}\right) \left(\frac{\pi R^2}{\Lambda - \mathrm{km}}\right).$$

Eq. (20) in *Pramana* paper (2010)

Assumptions: magnetic flux tube forms on *supermassive* black hole accretion disk and initially contains protons, electrons, some neutrons, and traces of other elemental ions if infalling matter present; in this case flux tube parameters as follows: radius r = 6.4 x 10^3 km (same as radius of the earth) and time $\Delta t = 10^2$ seconds and its internal magnetic field averages even higher B = 7.0 x 10^{10} G while flux tube exists

Calculation based on Eq. 20 presuming that flux tube destabilizes and explodes:

$\Lambda = c\,\Delta t = (2.998 \times 10^5) \times (1 \times 10^2\ \text{sec}) = 2.998 \times 10^7\ \text{km} \approx 3.0 \times 10^7\ \text{km}$

$B = 7.0 \times 10^7\ kG$

$\pi r^2 = 3.1416 \times (6.4 \times 10^3)^2 = 3.1416 \times (41.0 \times 10^6) \approx 128.8 \times 10^6 \approx 1.288 \times 10^8\ \text{km}^2$

$\overline{eV} \approx [\,(30.0) \times (7.0 \times 10^7)\,] \times (1.288 \times 10^8 / 3.0 \times 10^7) \approx [\,2.1 \times 10^9\,] \times (0.43 \times 10^1)$

$\overline{eV} \approx 0.90 \times 10^{10}\ \text{GeV} \approx 0.9 \times 10^{19}\ \text{eV}$

“Magnetic tower” flux tubes may form near black hole jets

Large tube: radius = 10^6 km, magnetic field = 7 x 10^8 Gauss, time = 10^2 s

Widom-Larsen mechanism accelerates protons to mean energies of ~2.0 x 10^{21} eV

Accelerated particles center-of-mass energy for exploding flux tube

$$eV \approx (30\ \mathrm{GeV}) \left(\frac{B}{\mathrm{kG}}\right) \left(\frac{\pi R^2}{\Lambda - \mathrm{km}}\right).$$

Eq. (20) in *Pramana* paper (2010)

Assumptions: magnetic flux tube develops near base of relativistic jet as it is forming on a supermassive black hole; tube initially contains mixture of protons, electrons, some neutrons, and traces of other elemental ions if any infalling matter is present; in this case, the flux tube’s parameters are as follows: r = 1 x 10^6 km and time $\Delta t = 10^2$ seconds while internal magnetic field B = 7.0 x 10^8 Gauss (7.0 x 10^5 kilogauss); these parameters represent transient values before tube violently destroyed by explosion

Calculation based on Eq. 20 presuming that this flux tube destabilizes and explodes:

$\Lambda = c\,\Delta t = (2.998 \times 10^5) \times (1 \times 10^2\ \mathrm{sec}) = 2.998 \times 10^7\ \mathrm{km} \approx 3.0 \times 10^7\ \mathrm{km}$

$B = 7.0 \times 10^5\ kG$

$\pi r^2 = 3.1416 \times (1.0 \times 10^6)^2 = 3.1416 \times (1 \times 10^{12}) \approx 3.14 \times 10^{12}\ \mathrm{km}^2$

$e\overline{V} \approx [\,(30.0) \times (7.0 \times 10^5)\,] \times (3.14 \times 10^{12} / 3.0 \times 10^7) \approx [\,21.0 \times 10^6\,] \times (1.05 \times 10^5)$

$e\overline{V} \approx 22.05 \times 10^{11}\ \mathrm{GeV} \approx 2.205 \times 10^{12}\ \mathrm{GeV} \approx 2.21 \times 10^{21}\ \mathrm{eV} \approx 2.2 \times 10^{21}\ \mathrm{eV}$

Theory of many-body collective electroweak processes

Three key documents beginning in March 2006 are referenced below

Many-body collective effects enable electroweak catalysis in condensed matter

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen
European Physical Journal C - Particles and Fields 46 pp. 107 - 112 (2006)

http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen
Pramana - Journal of Physics 75 pp. 617 - 637 (2010)

http://www.slideshare.net/lewisglarsen/srivastava-widom-and-larsenprimer-for-electroweak-induced-low-energy-nuclear-reactionspramana-oct-2010

"Index to key concepts and documents"
v. #20 updated and revised through Jan. 8, 2015
L. Larsen, Lattice Energy LLC, May 28, 2013
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-index-to-documents-re-widomlarsen-theory-of-lenrsmay-28-2013

