

Nearby Quasar Remnants And UHECRs

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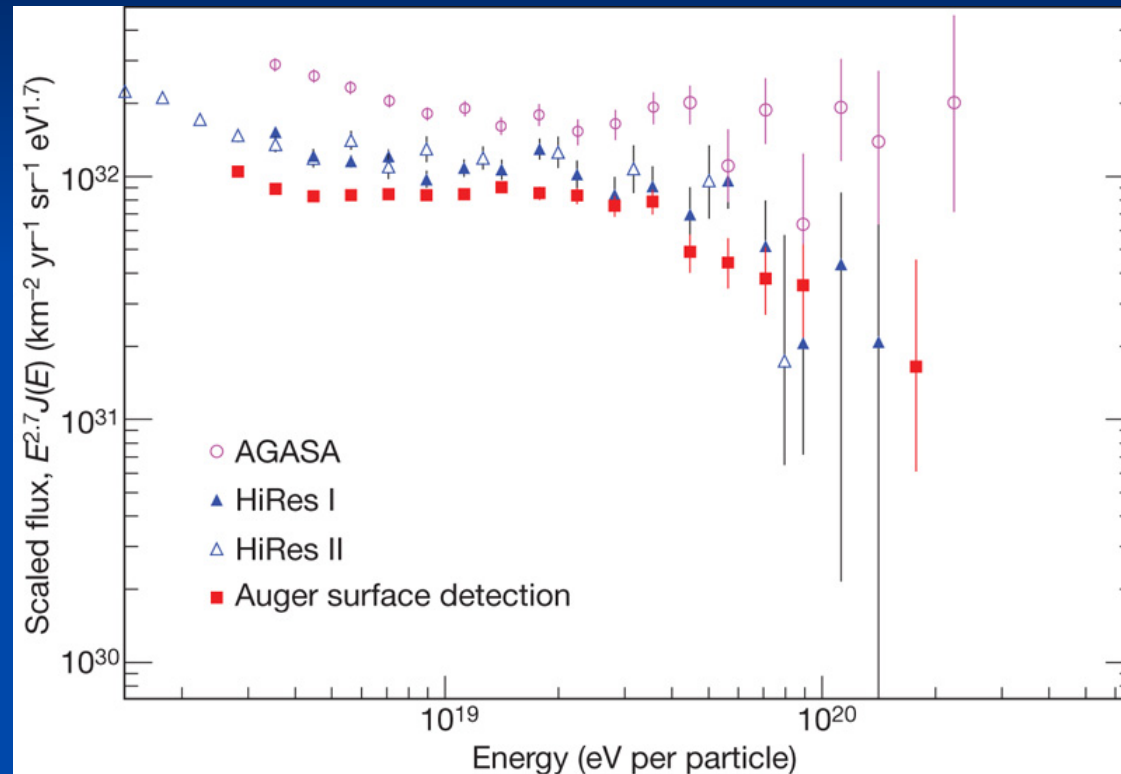
A Little Background

- CRs discovered in 1912, named in 1926, identified as VHE in the 30's
- The 1st astroparticle physics, HEA
- Charged particles with energies of 1-10¹² GeV
- LHEA involvement

Overview of UHECRs

- $E \sim 10^{18-20.5} \text{ eV}$ (LHC $\sim 1 \text{ TeV}$)
- For $E > 4 \cdot 10^{19} \text{ eV}$, attenuation through π^0 production from interactions with CMB γ s;
 $\lambda \sim 50 \text{ Mpc}$
- $U_{\text{uhocr}} \sim U_{\text{grb}}$
- Too isotropic to be Galactic

UHECR data from different experiments.



PM Bauleo & JR Martino *Nature* **458**, 847-851 (2009) doi:10.1038/nature07948

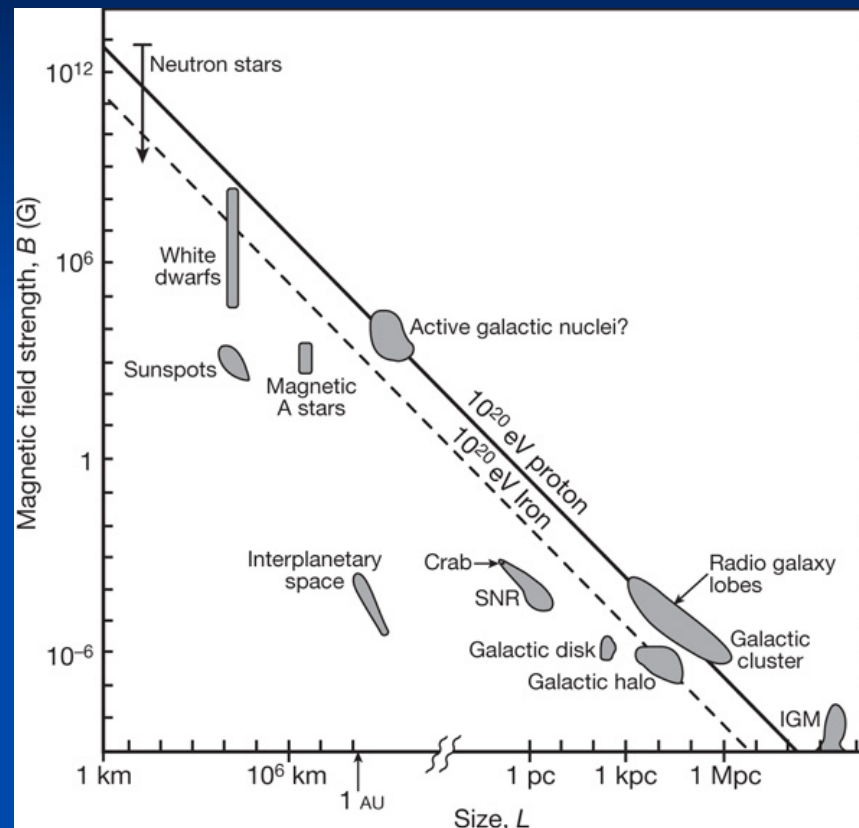
Spectral index ~ 3 , with GZK feature (???)

Flux above $10^{20} \sim 1/\text{km}^2/100$ yrs

nature

Candidate sources:

Hillas diagram.



PM Bauleo & JR Martino *Nature* **458**, 847-851 (2009) doi:10.1038/nature07948

Regular appearance on top ten
unsolved physics mysteries

nature

Elihu recognized that QRs met all the criteria to be the origin of UHECRs

- Energetics
- Common in the nearby universe
- Stellar mass loss in QR hosts can initiate an ADAF that can provide a large B-field and a low photon density
- A new type of AGN dominated by high energy particle and TeV γ radiation?

UHECRs from Quasar Remnants

Boldt and Ghosh (1999: MNRAS, 307, 491)

- Inspired by a single Fly's Eye UHECR event, and the ubiquity of dormant SMBHs (XRB, QLF evolution, Magorrian)
- The concept: acceleration by black hole dynamo associated with spinning, magnetized BHs
- The requirements: $M > 10^9 M_{\odot}$, $B > 10^4$ G, $L < 0.0001 L_{\text{edd}}$ (Bondi accretion, ADAF)
- The prediction: UHECR/QR correlation

UHECRs from Quasar Remnants

EB and ML (2002: MNRAS, 316, L29)

- Individual $M > 10^9 M_{\odot}$ cases where the photon and IS environments were well-determined by Chandra
- ADAF modeling of the SED and accretion flow to determine the radiation field and magnetic field
- Included losses from curvature radiation (A. Levinson) as well as photo-pion production
- NGC 1399, M49, M60 feasible, M87 not

UHECRs from Quasar Remnants

DFT, EB, TH, and ML (2002: PhysRevD)

■ Correlation of >40 EeV CRs (AGASA) with nearby galaxies (NOG) with most massive expected SMBHs

NewScientist.com

Cosmic ray mystery solved

12.30.22 April 02
Eugene Samuel, Albuquerque

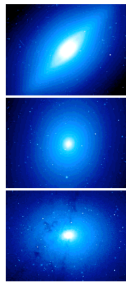
The mysterious source of the highest energy cosmic rays has been found, claim astronomers. They say the rays are probably flung out by retired quasars.

SPACEFLIGHT NOW

Retired quasars generate most energetic cosmic rays

NASA/GODDARD NEWS RELEASE
Posted April 13, 2002

They are old but not forgotten. Nearby "retired" quasars generate most energetic cosmic rays. The mysterious source of the highest energy cosmic rays has been found, claim astronomers. They say the rays are probably flung out by retired quasars.



Baseball caps

The world's largest collection of baseball caps is now on display at the Smithsonian National Museum of American History.

Cosmic Rays Phone Home

ALBUQUERQUE, NEW MEXICO—Single protons usually don't pack much punch, but the universe copes a precision fire of them which impact at a grid ball driven by Tigris Woods—and that name. Now, after years of straining to catch even a few dozen of these pugnacious particles, physicists are seeing the first hints of their origins. The candidates include colliding galaxies and dormant quasars in our backyard.

The particles, called ultra-high-energy cosmic rays (UHECRs), are the alpha males of the cosmic rays that continually thrash into our planet. Occasionally—perhaps once per century over each square kilometer of the planet's surface—a fantastically energetic cosmic ray will crash into Earth with energies 100 million times higher than the 700-megawatt Fermilab in Batavia, Illinois, the foremost particle accelerator on Earth (ScienceNOW, 8 May 2001). These minibiasts spit out billions of subatomic particles, which detection on the surface can spot.

Some physicists have theorized that massive relic particles from the big bang embolden our galaxy and unleash super-cosmic rays when they decay, which would form a random pattern on the sky. However, an experiment in Japan now suggests that some UHECRs stream regularly from the same place. Of the 50 most energetic events recorded between 1990 and 2000 by the Akeno Giant Air Shower Array (AGASA) near Tokyo, three came from the direction of a colliding galaxy system called V141. Five other spots in the sky—not yet associated with astrophysical sources—sprung two events each. "This is clear statistical evidence" that the rays originate from particular sources, says Akeno Observatory director Masahito Teshima, who spoke here 20 April at a meeting of the American Physical Society.

A few of these sources may be nearby supermassive black holes, according to another report at the meeting. A team led by physicist Diego Torres of Princeton University selected a dozen bright galaxies so close to our Milky Way that cosmic rays could travel here without getting slowed down by other matter. Of that group, one galaxy matched the ones of isolated UHECRs spotted by AGASA and other instruments. "These are the descendants of quasars that are now dormant," says team member Elinor Bold of NASA's Goddard Space Flight Center in Greenbelt, Maryland. Black holes spinning at the cores of these galaxies may fling protons so powerfully that they zip toward Earth with little bending by intervening magnetic fields.

"A number of possible sources for UHECRs have been identified, and that's qualitatively new," says physicist Michael Cherny of Louisiana State University, Baton Rouge. However, he notes that his colleagues want to see many more high-energy events before a consensus emerges about whether such sources are the culprits.

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Tuesday, 23 April 2002, 11:06 GMT 12:06

Cosmic ray mystery 'solved'



Scientists have identified the cosmic rays, the highest energy Universe. The BGC is not responsible for the content of external internet sites. Top Sci/Tech stories more! Astronomy's next big thing Ancient rock points to life's origin Mating again in the sea? Giant telescope project gets boost New hope for Aids vaccine Risperidone could treat obsessive drugs Wireless internet arrives in China Links to more Sci/Tech stories are at the foot of the page.

The fact that these four giant elliptical galaxies are apparently inactive makes them viable candidates for generating ultra-high-energy cosmic rays. The fact that these four giant elliptical galaxies are apparently inactive makes them viable candidates for generating ultra-high-energy cosmic rays. The fact that these four giant elliptical galaxies are apparently inactive makes them viable candidates for generating ultra-high-energy cosmic rays.

bits of matter, proton, electron, and such have been stripped of their outer, gigantic, exploding stars, have died as the source of most rays, the sub-energy rays has been mere

RETIRE QUASARS LIVE ON TO GENERATE THE FASTEST, MOST ENERGETIC COSMIC RAYS

They are old but not forgotten. Nearby "retired" quasars galaxies, billions of years past their glory days as the brightest beacons in the Universe, may be the current source of rare, high-energy cosmic rays, the fastest-moving bits of matter known and whose origin has been a long-standing mystery, according to scientists at NASA and Princeton University.

The scientists have identified four elliptical galaxies that may have started this second career of cosmic ray production, all located above the handle of the Big Dipper and visible with backyard telescopes. Each contains a central black hole of at least 100 million solar masses that, if spinning, could form a colossal battery sending atomic particles, like sparks, shooting off towards Earth at near light speed.

These findings are discussed today in a press conference at the joint meeting of the American Physical Society and the High Energy Astrophysics Division of the American Astronomical Society in Albuquerque, N.M. The team includes Dr. Diego Torres of Princeton University and Dr. Elinor Bold, Timothy Hamilton and Michael Leventis of NASA's Goddard Space Flight Center in Greenbelt, Md.

Quasar galaxies are thousands of times brighter than ordinary galaxies, fueled by a central black hole swallowing copious amounts of interstellar gas. In galaxies with so-called quasar remnants, the black hole nucleus is no longer a strong source of radiation.

"Some quasar remnants might not be so hidden after all, keeping busy in their later years," said Torres. "For the first time, we see the hint of a possible connection between the arrival directions of ultra-high-energy cosmic rays and locations on the sky of nearby dormant galaxies hosting supermassive black holes."

Ultra-high-energy cosmic rays represent one of astrophysics' greatest mysteries. Each cosmic ray—essentially a single subatomic particle such as a proton traveling just below light speed—packs as much energy as a major league baseball pitch, over 40 million trillion electron volts. The rest energy of a proton is about a billion electron volts. The particles, some coming within 20 million light years of Earth, for cosmic rays have traveled this distance would lose energy as they traveled through the murky cosmic microwave radiation pervading the Universe. There is considerable uncertainty, however, over what kinds of objects within 200 million light years could generate such energetic particles.

"The very fact that these four giant elliptical galaxies are apparently inactive makes them viable candidates for generating ultra-high-energy cosmic rays," said Bold. Depending radiation from an active quasar would dampen cosmic ray acceleration, supporting most of their energy, Bold said.

The team concludes it cannot determine if the black holes in these galaxies are spinning, a basic requirement for a compact dynamo to accelerate ultra-high-energy cosmic rays. Yet scientists have confirmed the existence of at least one spinning supermassive black hole, announced in October 2001. The prevailing theory is that supermassive black holes spin up as they accrete matter, absorbing orbital energy from the infalling matter.

Retired Quasars Live on to Generate The Fastest, Most Energetic Cosmic Rays (NASA News)

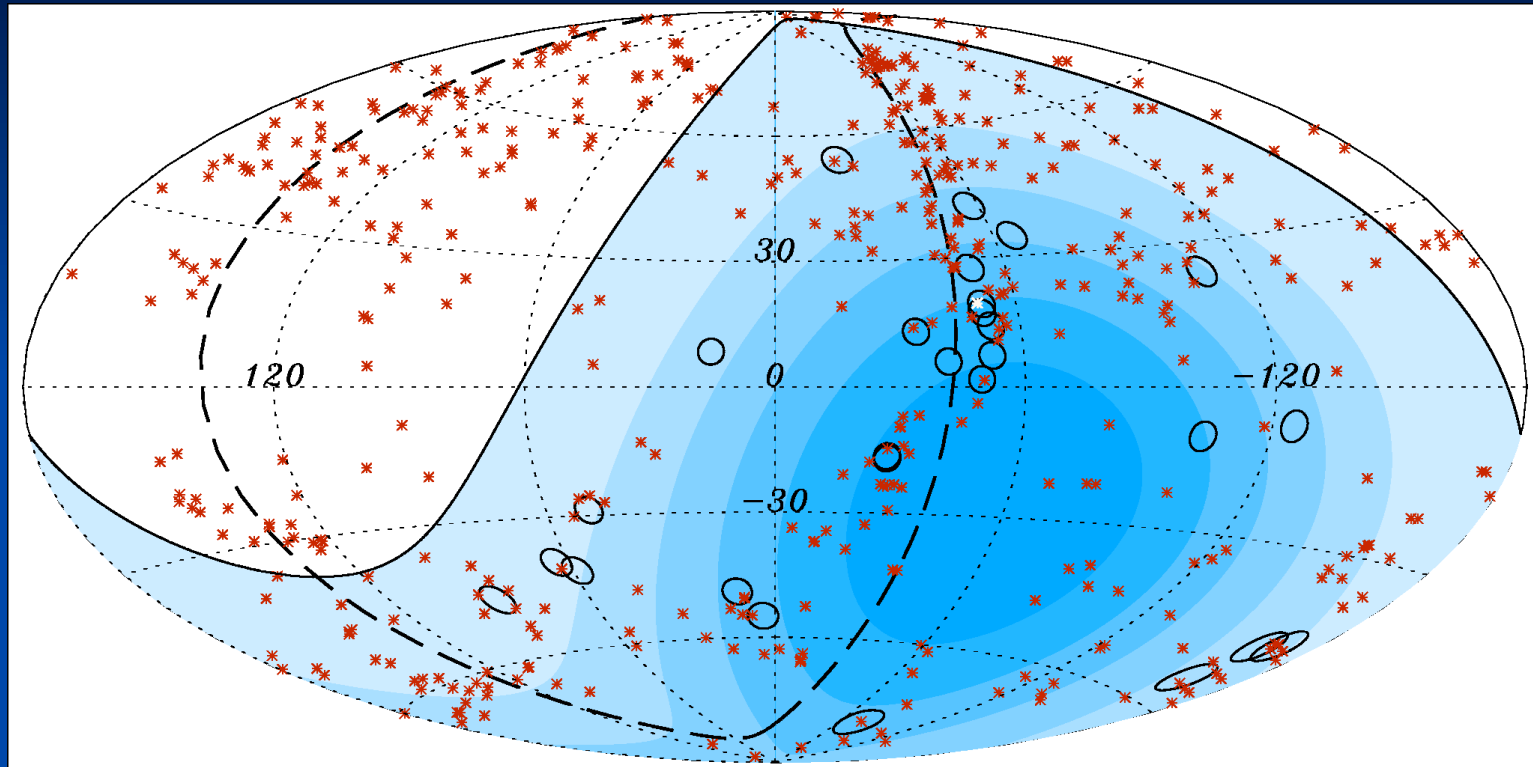
Spinning Black Holes May Act Like Giant Batteries (Space.com)

Cosmic ray mystery solved (NewScientist.com)

Are Dormant Quasars Throwing “Baseballs” at Us? (Sky & Telescope)

Cosmic Rays Phone Home (Science Now)

Recent Developments



The celestial sphere in galactic coordinates (Aitoff projection) showing the arrival directions of the 27 highest energy cosmic rays detected by Auger. The energies are greater than 57×10^{18} eV (57 EeV). These are shown as circles of radius 3.1° . The positions of 472 AGN within 75 megaparsecs are shown as red *'s. The blue region defines the field of view of Auger; deeper blue indicates larger exposure. The solid curve marks the boundary of the field of view, where the zenith angle equals 60° . The closest AGN, Centaurus A, is marked as a white *. Two of the 27 cosmic rays have arrival directions within 3° of this galaxy. The supergalactic plane is indicated by the dashed curve. This plane delineates a region where large numbers of nearby galaxies, including AGNs, are concentrated. **Click on the image for a better view.**

Recent Developments

Correlation with nearby AGN

Or...

IRAS Galaxies (Takami et al.)

Local LSS with galaxy bias (Kashti and Waxman)

Local LSS with hard X-ray AGN bias (George et al.)

Spiral galaxies (Ghisellini et al.)

FR I galaxies (Takami and Sato)

FR II radio galaxies (van Putten et al.)

LLAGN (Zaw et al.)

Local (<10 Mpc) galaxies (Cuesta and Prada)

Fueled renaissance in theory and IG B-field

Future: more PAO and JEM-EUSO (2013???)

