Nearby Quasar Remnants And UHECRs

Elihu Boldt

Pranab Ghosh (Tata Institute, Mumbai)

Diego Torres (ICREA CSIC-ICE, Barcelona)

Amir Levinson (Tel Aviv University)

Mike Loewenstein

Tim Hamilton (Shawnee State University)

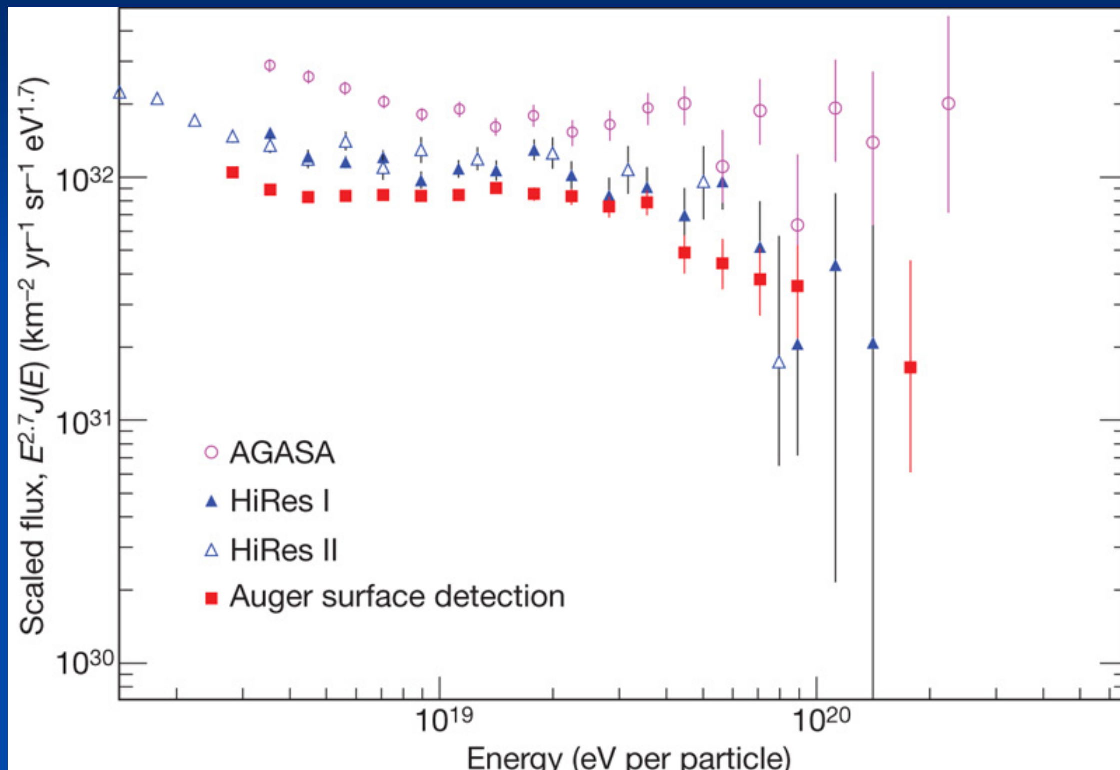
A Little Background

- CRs discovered in 1912, named in 1926, identified as VHE in the 30's
- The 1st astroparticle physics, HEA
- Charged particles with energies of 1-10^{12} GeV
- LHEA involvement

Overview of UHECRs

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

UHECR data from different experiments.



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

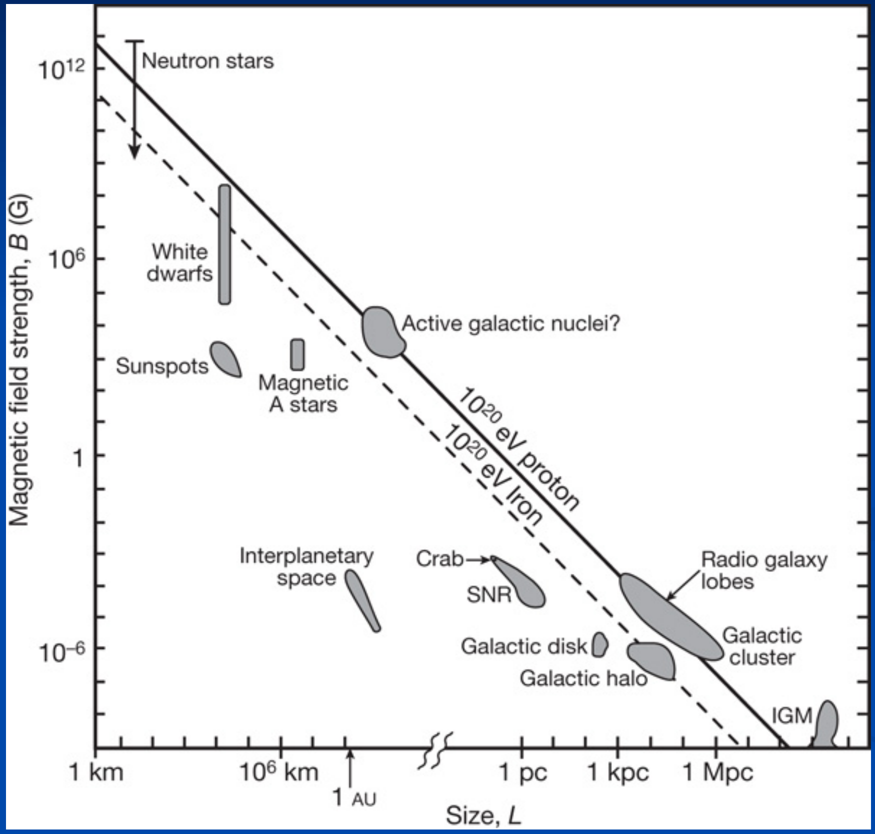
Spectral index ~ 3, with GZK feature (???)

Flux above 10^{20} ~ 1/km^2/100 yrs

nature

Candidate sources:

Hillas diagram.



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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, $L<0.0001 L_{edd}$ (Bondi accretion, ADAF)
- The prediction: UHECR/QR correlation

UHECRs from Quasar Remnants

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

- Individual $M>10^9M_{\odot}$ 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

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

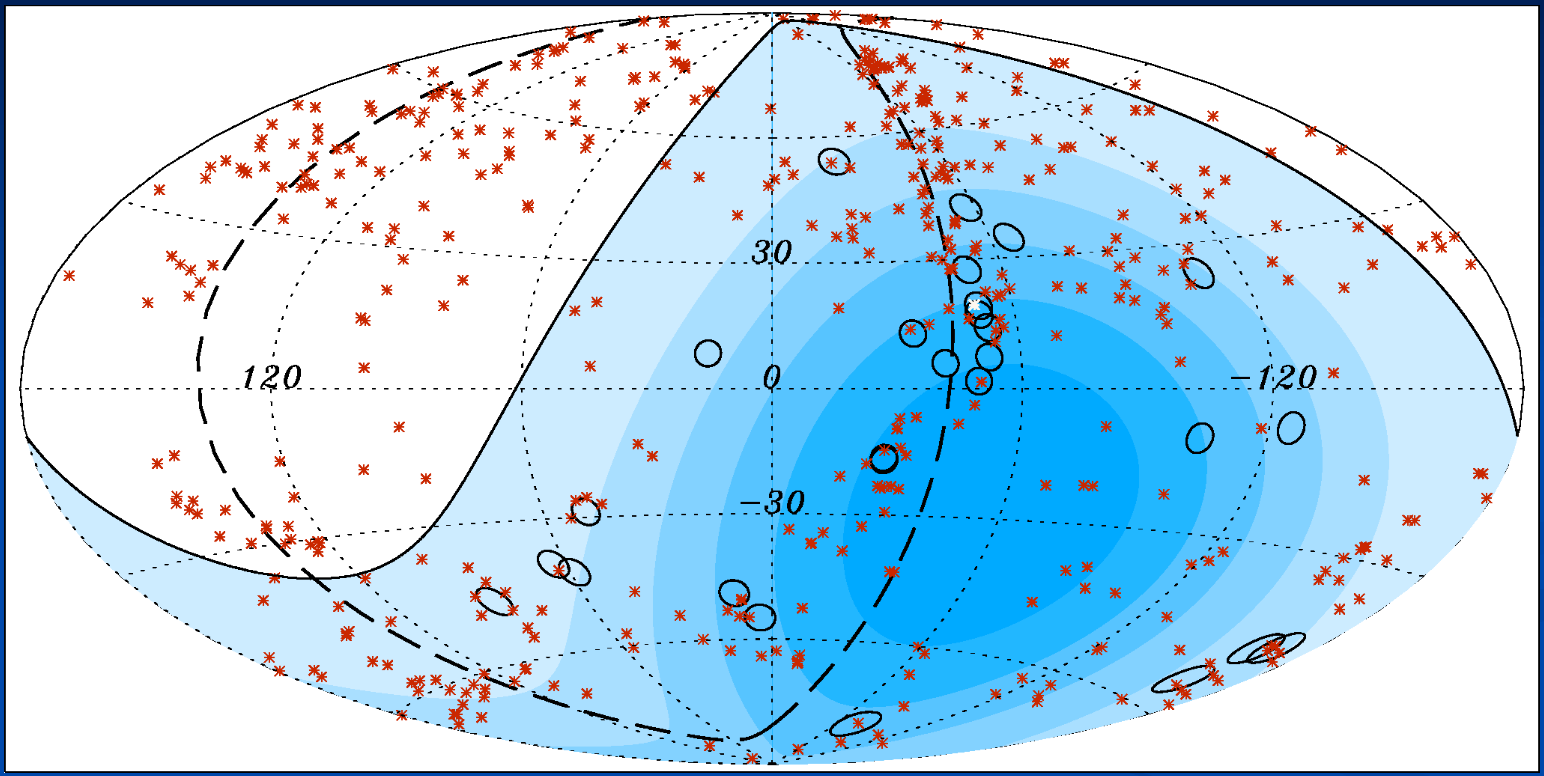
Spinning Black Holes May Act Like Giant Batteries (Space.com)

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 x 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???)