

Multi-Messenger

Astronomy of Cosmic Rays



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Open Questions

1. The sources of cosmic-rays (all energies, note $\sim 10^{17}$ eV)
* G/XG transition
2. HE: Composition
3. CR propagation (all energies, note TeV aniso.)
4. B and CRs in extra-Galactic objects
MW Galactic B
5. The physics of HE sources
 - Particle acceleration & radiative processes
 - Modeling SNR/GRB/AGN...
6. "New physics"
 - ν physics (UHE σ , oscillations, gravity, LI, WEP)
 - UHE nucleon interaction σ
7. GW

Fast experimental progress

- Ground/Space γ
- Ground/Space CR
- v telescopes join the game

Multi-Messenger Rational: I. LE-CR

- Source identification
 - Prime ground-gamma effort, SNR TeV observations
Despite detection- still debated: hadronic/leptonic origin
 - ν detection may resolve the Q
 - However, ν signal is expected to be low (few--10/yr),
for extended SNRs not clearly above bgnd
 - Identifying the "right place" to look crucial, requires
 γ observations and SNR modeling,
"stacking" proper candidates

- If SNRs confirmed accelerators, are they the dominant sources?
 - Better understanding of CR propagation
 - CR propagation constrained by diffuse ν/γ observations
 - Joint ν/γ study of candidates, eg unidentified TeV sources

Multi-Messenger Rational: II. HE-CR

- Direct identification of the sources- unlikely
 - CR detectors: May identify anisotropy= sources follow LSS
May identify transients (vs steady)
 - ν detectors: Unlikely to detect steady sources ($A_\nu/A_{CR} \sim 10^{-7}$)
May detect transients, like GRBs ($\Delta t_\nu/\Delta t_{CR} \ll 1$)
Detection only at relatively low energy, \sim PeV
 - γ detectors: Indirect via sub-TeV "halos" or temporal "tails"

- Composition/ Non-standard UHE σ_{pp}
 - Evidence from Auger? Discrepancy w/ HiRes
 - GZK ν 's
 - Energy dependence of anisotropies

Some comments on What's next experimentally?

- γ - LHASSO
 - * Space wide field monitoring
- ν - 1Gton too small?
 - * Radio
- CR- Can the exposure be significantly increased?
Can the composition be better constrained?
More focus on $\sim 10^{17.5}\text{eV}$?
- EM detection of ν /GW signal crucial for detection & science
 - * Wide field transient monitoring