Propagation of the highest energy cosmic rays

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Sky distribution

- At 3 10^{19} eV the sky is homogeneous, as far as the data go.
- So many sources: However, all possible astronomical sources are not homogeneous, if the distance is given by the GZK distance.
- Sky is only homogeneous for distances far beyond GZK. Possible solution new particle physics (e.g., Biermann & Frampton).
- Sources that are homogeneous within GZK volume are also new physics, like the Z-burst mechanism (e.g., Weiler), or defect decay (e.g., Sigl et al.).

Method to identify source candidates

- First step: Complete sample, at 5 GHz, 60 microns, 2 microns, optical, X-rays, gamma-rays: e.g. IceCube collaboration and Biermann (astro-ph/0609534); work by Alina Istrate, to flux density limit, to redshift limit
- Second step: Other criteria, flat radio spectrum, radio + far infrared, flat radio spectrum + GeV emission (critical catalogue: Véron-Cetty & Véron 2006):
- Starbursts versus AGN hypotheses
- Develop null hypothesis: homogeneous sources, or distributed as matter (Galaxy, supergalactic plane, large scale structure)
- Develop null hypothesis for the magnetic field of the Galactic halo wind: Events from homogeneous source distribution can be all mangled up by Galactic magnetic fields

Magnetic Fields: Galactic Winds

- Many galaxies have winds, visible in radio polarization data (Cracow group).
- All galaxies which make stars also have magnetic fields.
- The origin of the magnetic fields is the battery mechanism in rotating stars; a dynamo acting in the stars; the spreading by wind and explosion of stars. Then a dynamo in the galaxy.
- The cosmic ray driven dynamo implies a galactic wind, and is fast enough (Cracow group).
- Unsolved question: Why the magnetic field is so well correlated around galaxies.
- Conclusion: All galaxies which make stars have a magnetic wind.

Magnetic Fields: Galactic Magnetic Field

- Galaxy has wind (confirmed by Westmeier et al. AA 2005), driven by cosmic rays, then magnetic field topology as in Solar Wind
- Magnetic fields start tangentially to minimize angular momentum transport
- $B_\phi \sim \sin\theta/r$ dominant
- turbulence spectrum k^{-2} in wavenumber for adopted isotropy in wave number phase space, since shock driven
- Plots: Sky distribution for strong and weak turbulence, work by Alex Curuţiu

Conclusions

- Magnetic fields around galaxies in winds can disperse the injection locations
- Magnetic fields in the wind of our Galaxy can disperse the arrival directions
- Magnetic fields can delay the arrival of intermittent sources for lower energies
- At highest energies propagation should be closer to a near straight line path, both in source region, and in our Galaxy

Acknowledgements

Support for PLB is coming from the AUGER membership and theory grant 05 CU 5PD 1/2 via DESY/BMBF.

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