The Anisotropy of TeV Cosmic Rays:

An interpretation

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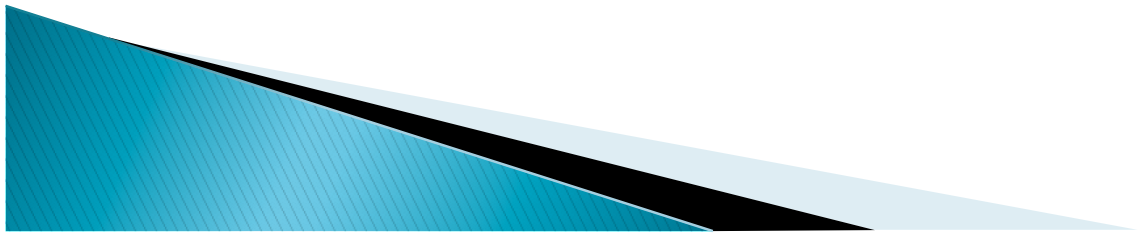
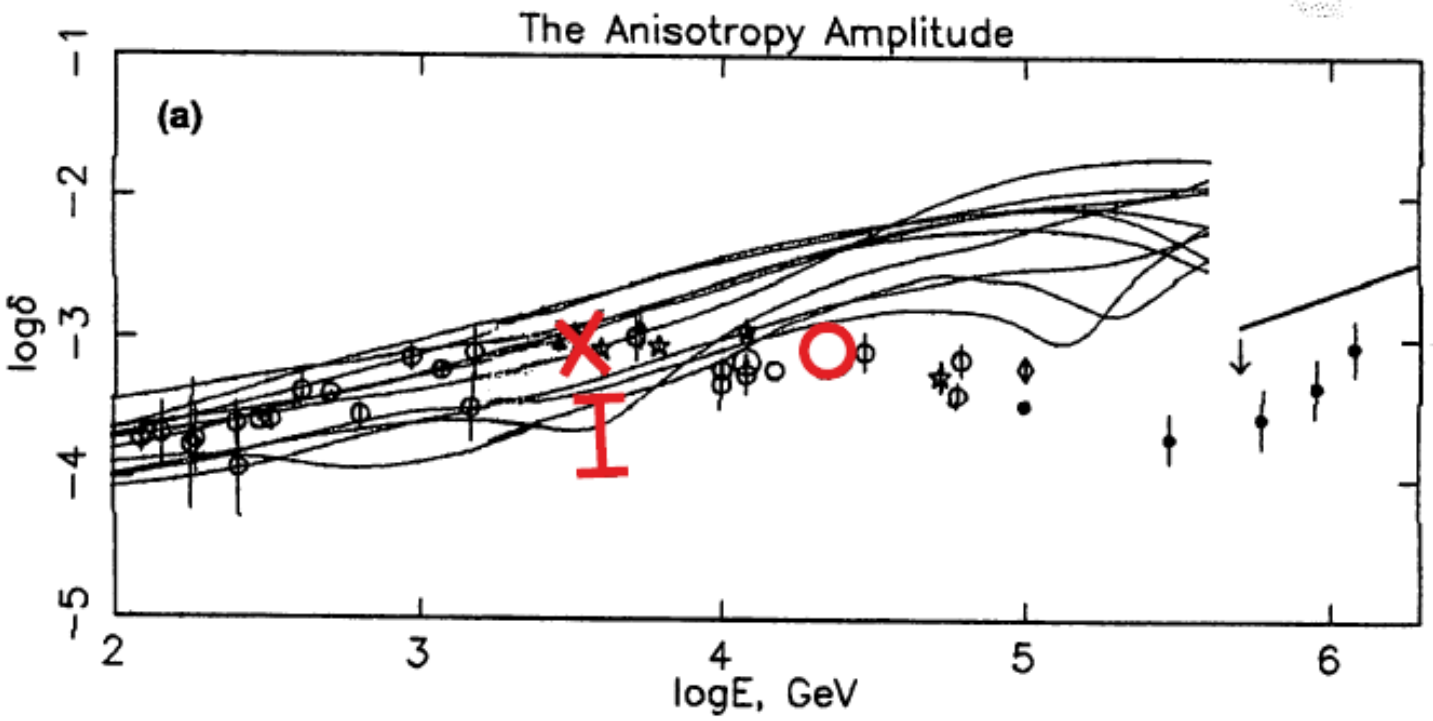
Scope of the Lecture

- ‘Dipole Anisotropy’, in its historical setting.
- Likely trend at post ~100 TeV energies.
- Possible ‘fine-structure’ at TeV energies



Data to 2006 – amplitude of 1st harmonics



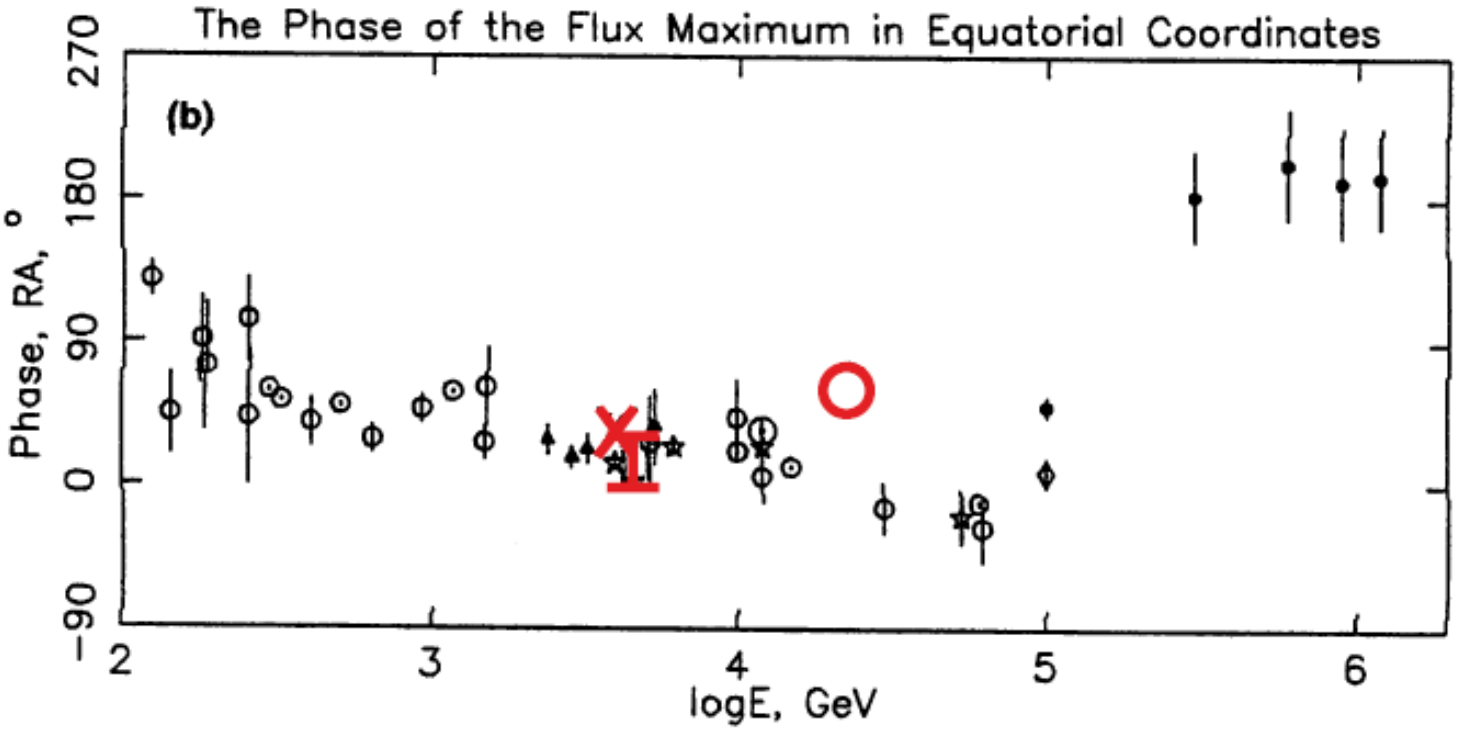
Recent amplitudes added

O ICECUBE

I MILAGRO

X TIBET

Data to 2006 – phases of 1st harmonics



Recent amplitudes added

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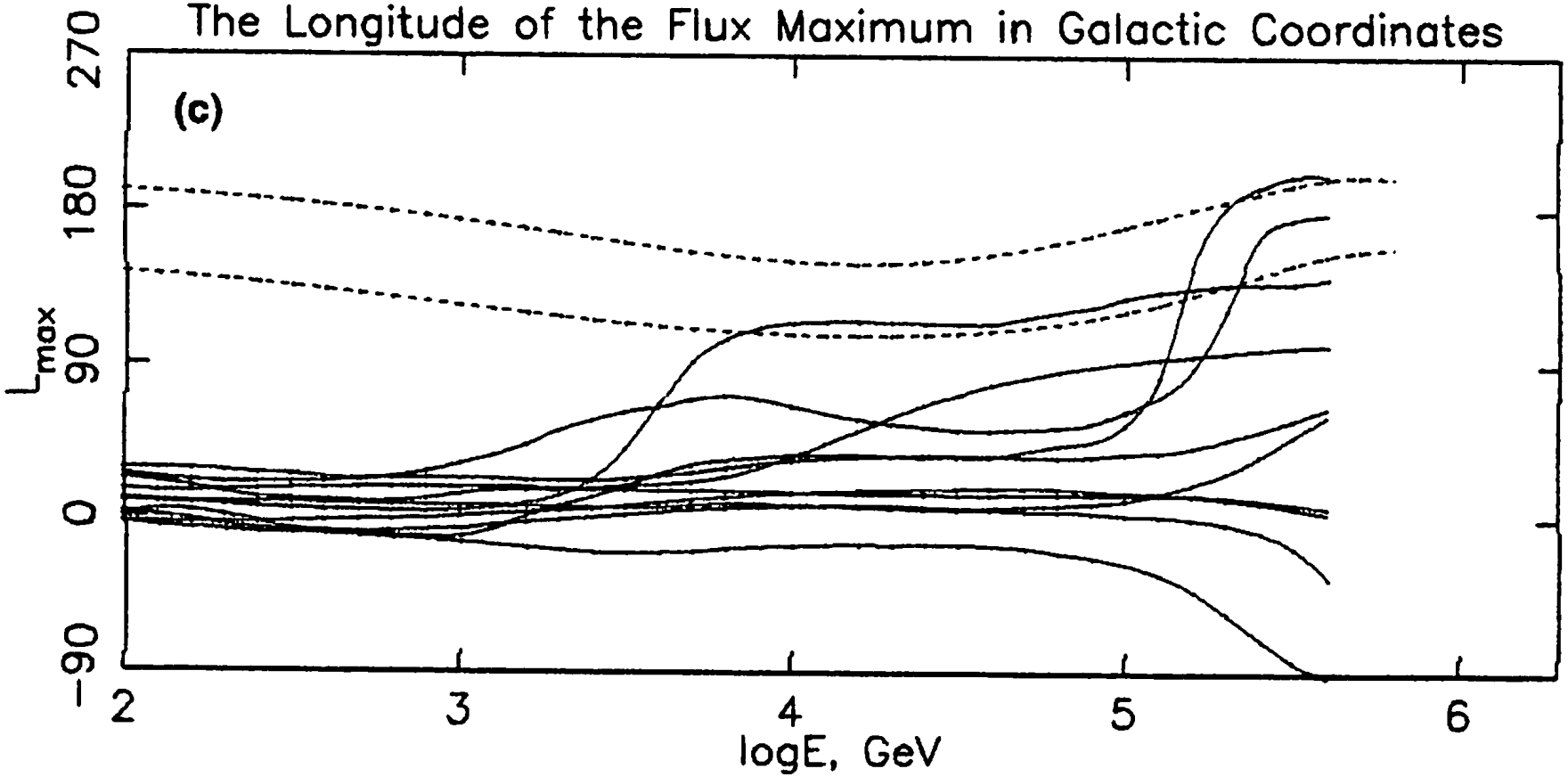
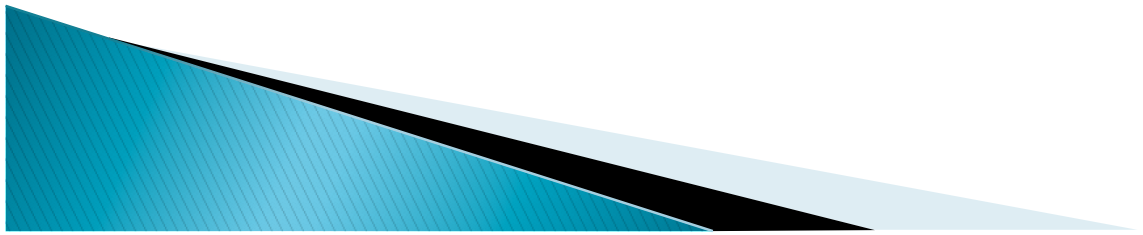
Longtitude of Flux magnitude from SNR (random) calculations (EW, 2006)



Conclusions at this stage

- Rough consistency of the measurements

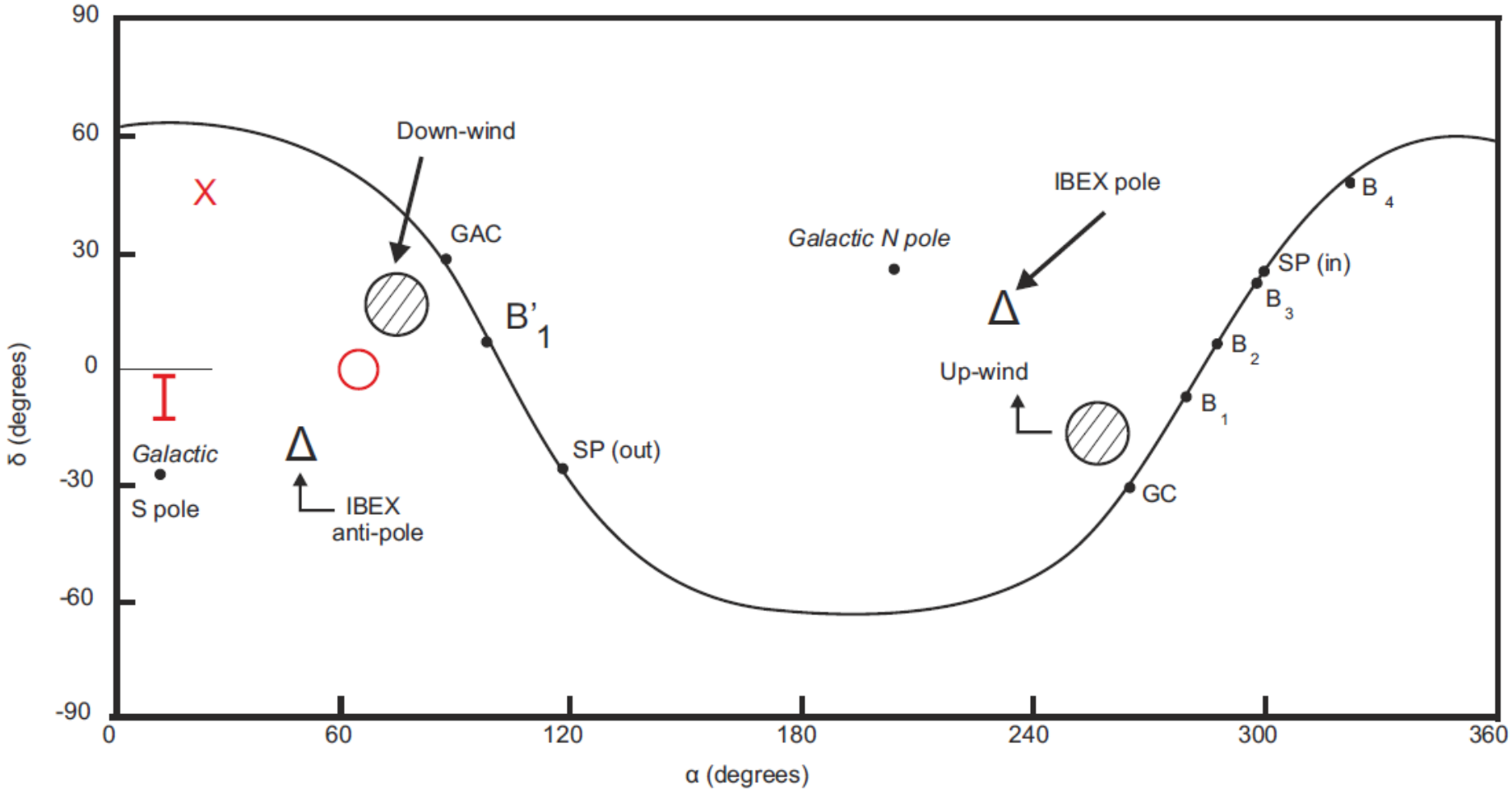
- Slow changes of amplitude and phase (of the 1st harmonic) with increasing energy



Comparison with expectation

- Amplitudes: Good below 10 TeV but smaller than expected above

- Phases: See next figure.



Some important directions. X, I and O: CR TeV energies

Caption continued

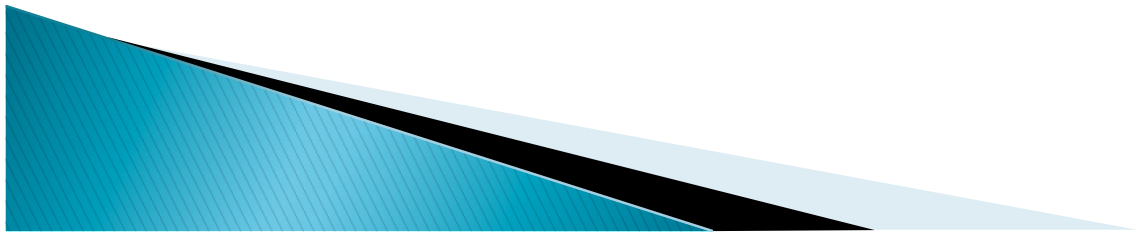
- GC: Galactic Centre; GAC : Galactic Anti-centre
- Upwind and Down-wind; Local Interstellar Medium, out to about 10pc (Frisch, 2003)
- IBEX: Solar System interacting with the local ISM (McComas et al., 2009 etc.)
  Pole (and anti-Pole) of symmetry.
- B_1, B_2 ...field directions to 200, 500...pc (Kiraly et. al., 1979)

Comments

- 1. Larmor radius of 20TeV proton in the ISM is ~1300AU (7.10^{-3}pc) but the diffusive scattering length is $\simeq$ 2-10pc; thus $\simeq$ distance to the nearest stars.
- 2. By extrapolation from lower energies, anisotropy amplitude due to Solar System effects should be quite negligible ($\simeq 10^{-6}$).
- 3. Phase of first harmonic not far from 'Down-wind', B_1', 'IBEX anti-pole'.

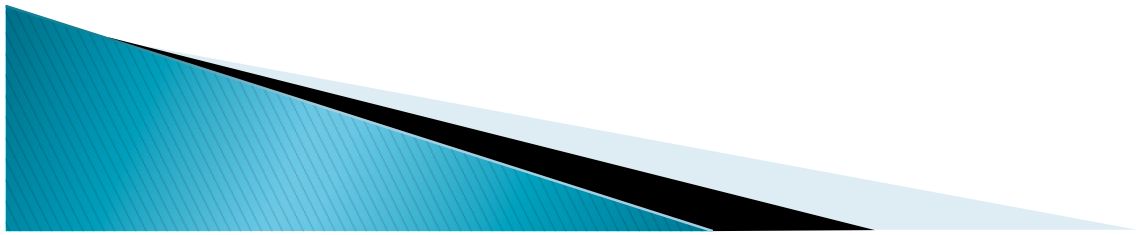
Trend of anisotropy with increasing energy

- Amplitudes are falling and phases are changing.
- Above 10s of TeV, random SNR model predicts big changes occasionally (EW, 2006 and others) – due to 'local' SNR.
- Eventually, changes in mass composition will reduce the amplitude (Kiraly et.al, 1979 and others).



Fine structure in the anisotropy maps.

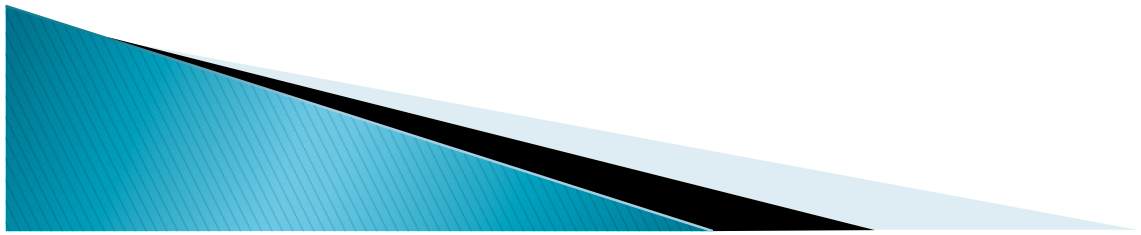
- 1. When anisotropy maps have 1st (and 2nd) harmonic patterns removed, structure remains.
- 2. Is it genuine? Striations in ICECUBE data.
- 3. If so, what is it's source?
- 4. Detailed examination of many maps (X-rays, radio etc.) fails to identify the source.



Magnetic Irregularities

- Perhaps CR studies alone can elucidate?

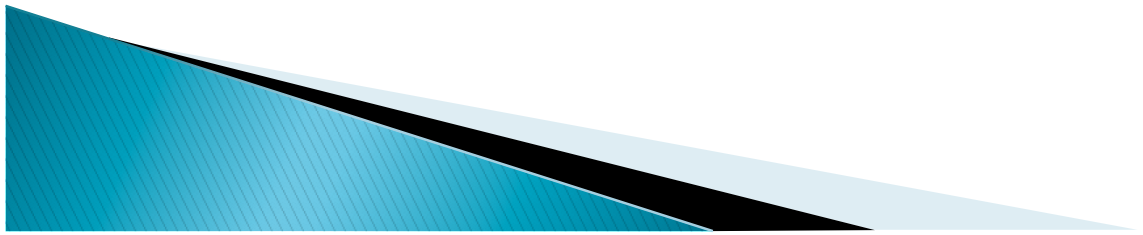
- If λ (scatt.) ~ 2pc and the mean relevant distance is a few times this, then the measured angular scale (20^o) can be understood.
- But as E goes up we go further out and the angular scale will fall.



Time dependence of the anisotropies

- A weak shock in the ISM of 50kms^{-1} corresponds to 5.10^{-5} pc/year. Surely too small to have an effect?

- Instrumental effects?



Conclusions

- 1. Streaming direction roughly understood
- 2. Fine structure uncertain both experimentally and theoretically.
- 3. The topic is an exciting one.