

Puzzles of the Cosmic Ray Anisotropy

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Basic characteristics of the anisotropy:

A – amplitude of the first harmonic

I_{\max}

Φ – phase: equatorial coordinate
of the direction to the *I_{max}*

I_{\max}

1964

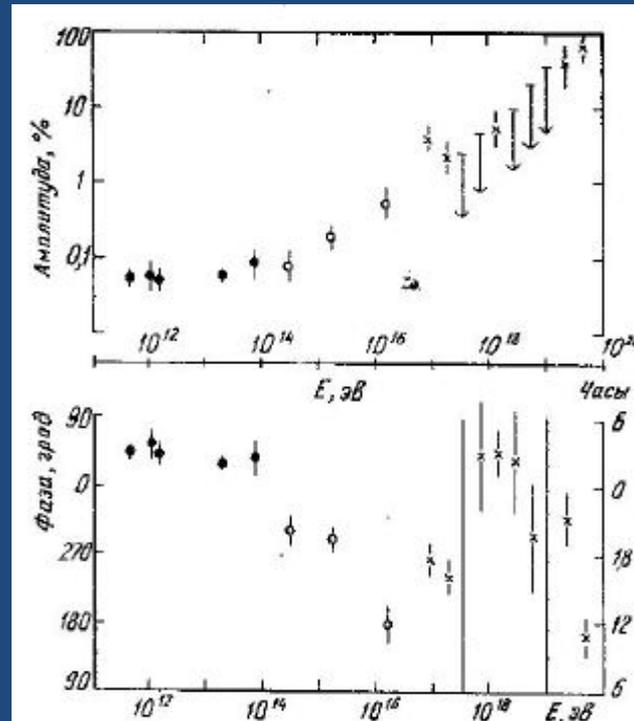
Ginzburg V.L. and Syrovatskii S.I.
'Origin of Cosmic Rays'

A < 1 %

1984

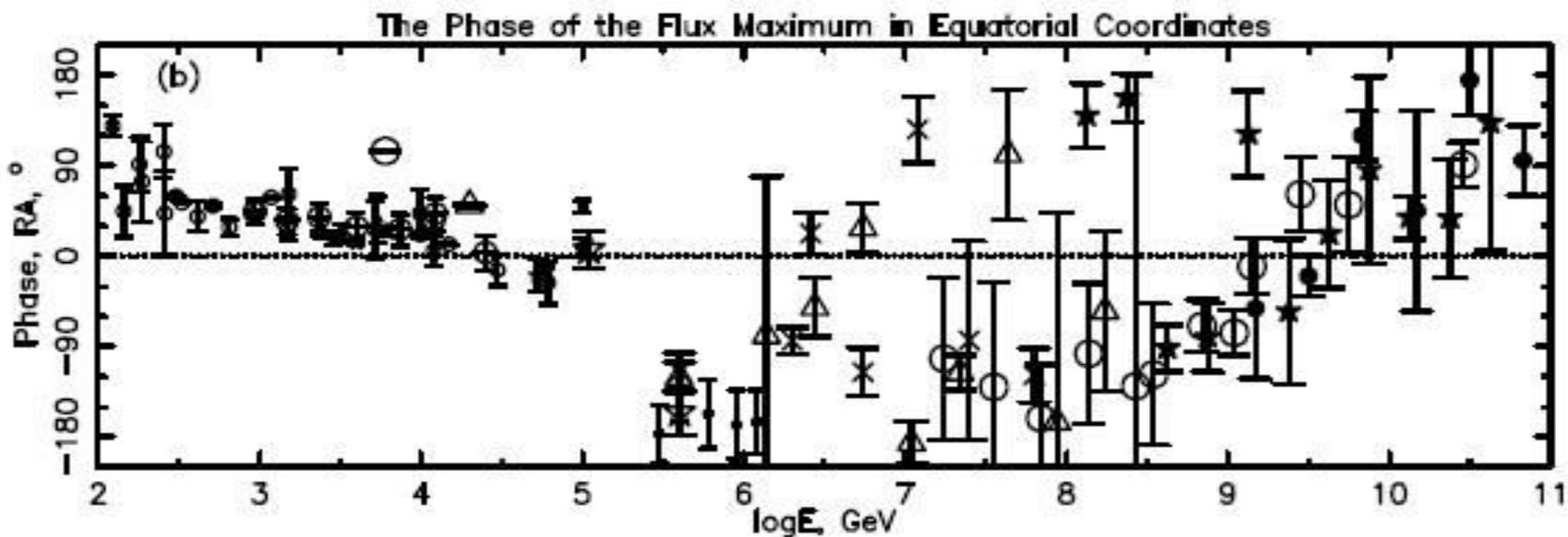
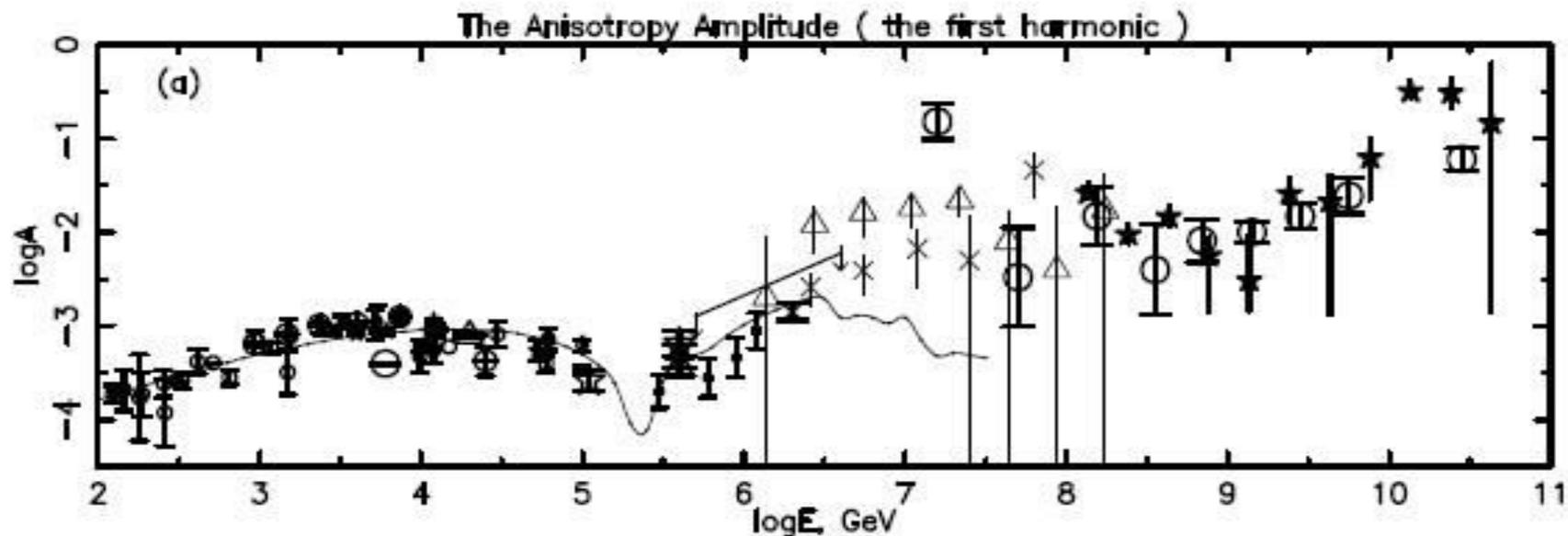
'Astrophysics of Cosmic Rays'

by Berezhinsky V.S., Bulanov S.V., **Ginzburg V.L.**, Dogiel V.A., Ptuskin V.S.



$A < 0.1\%$ and rises with energy

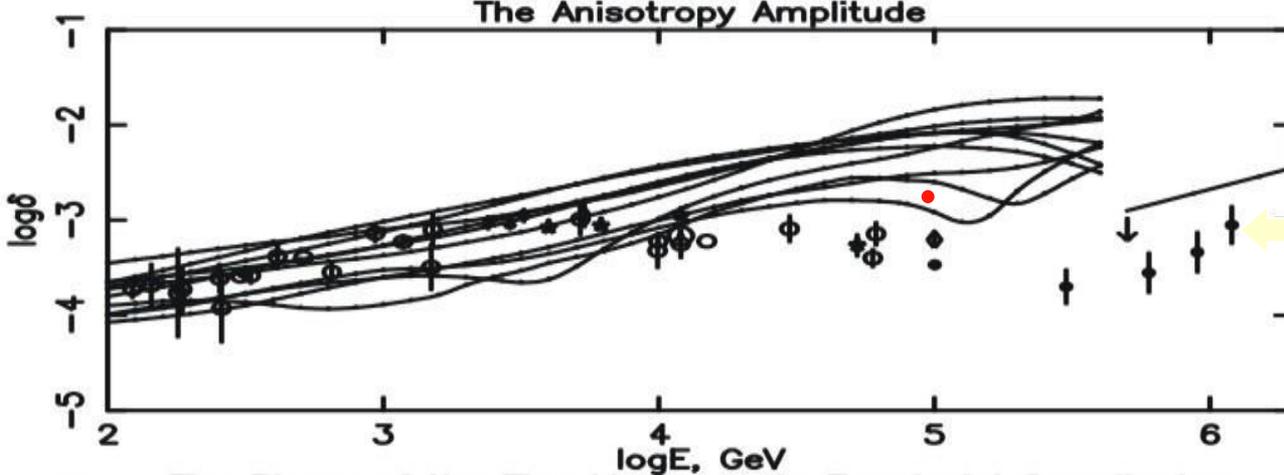
Present time



PUZZLE 1:

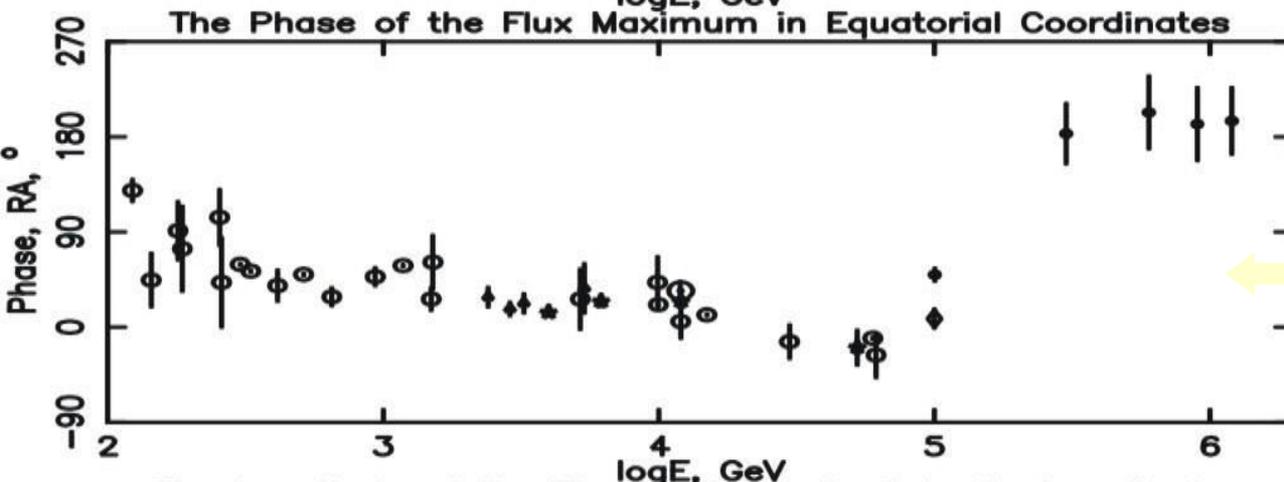
inverse anisotropy

Inspite of that most cosmic ray sources (SNR, Pulsars etc) are in the **Inner** Galaxy cosmic rays come preferentially from the **Outer** Galaxy

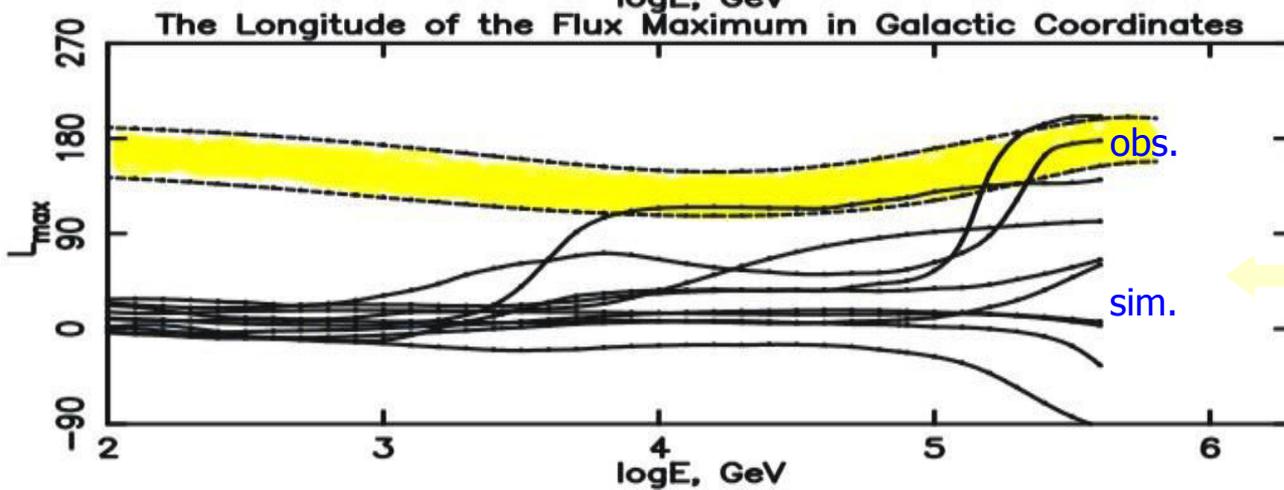


Comparison with observations

Amplitude

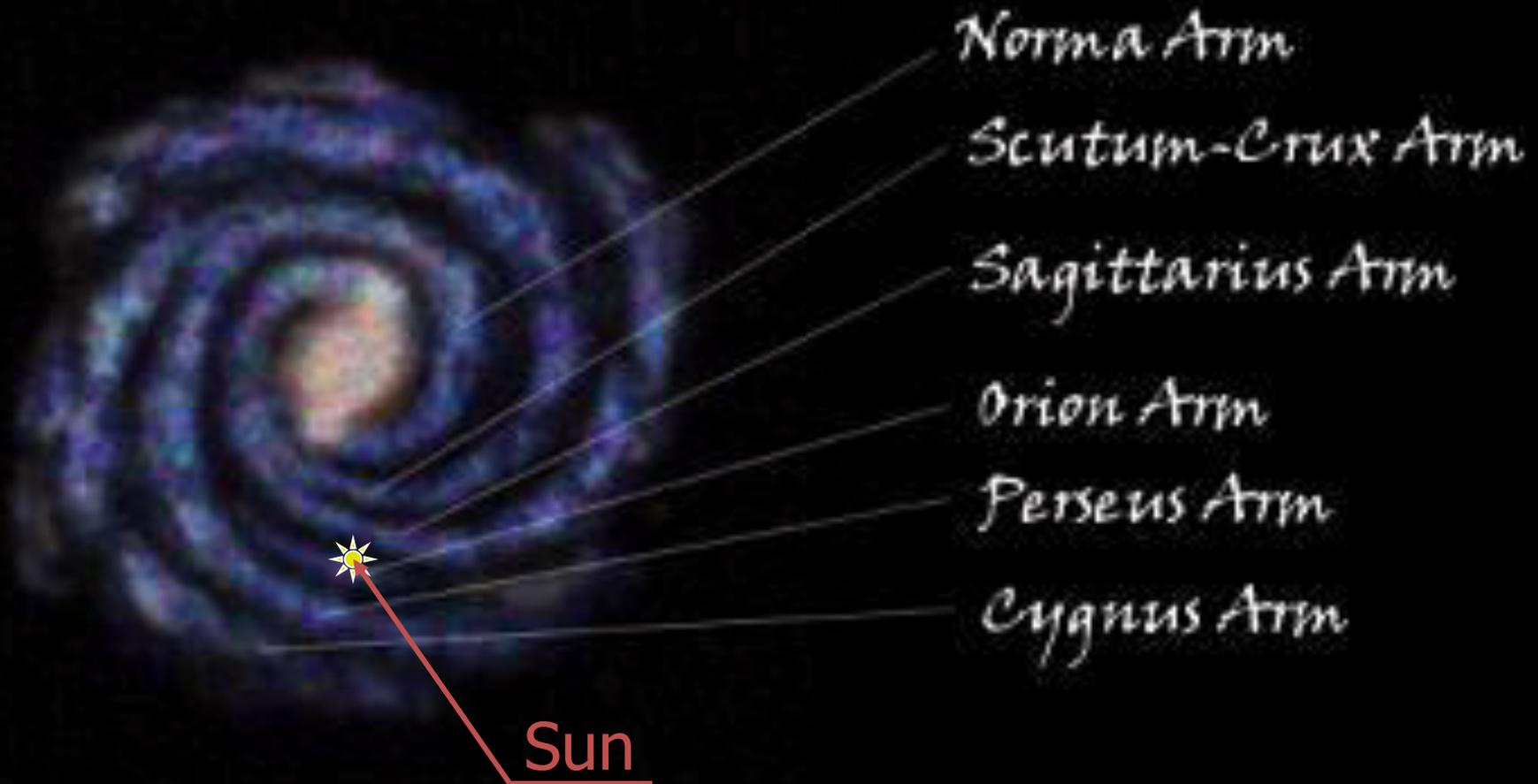


Phase in equatorial coordinates



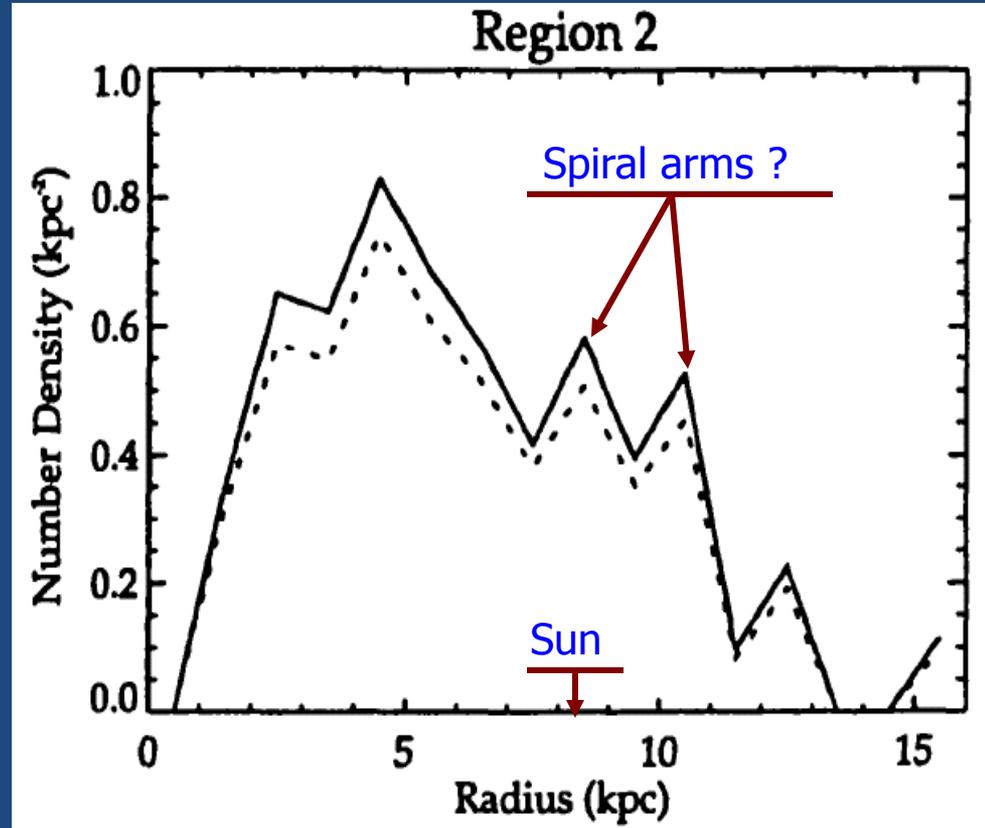
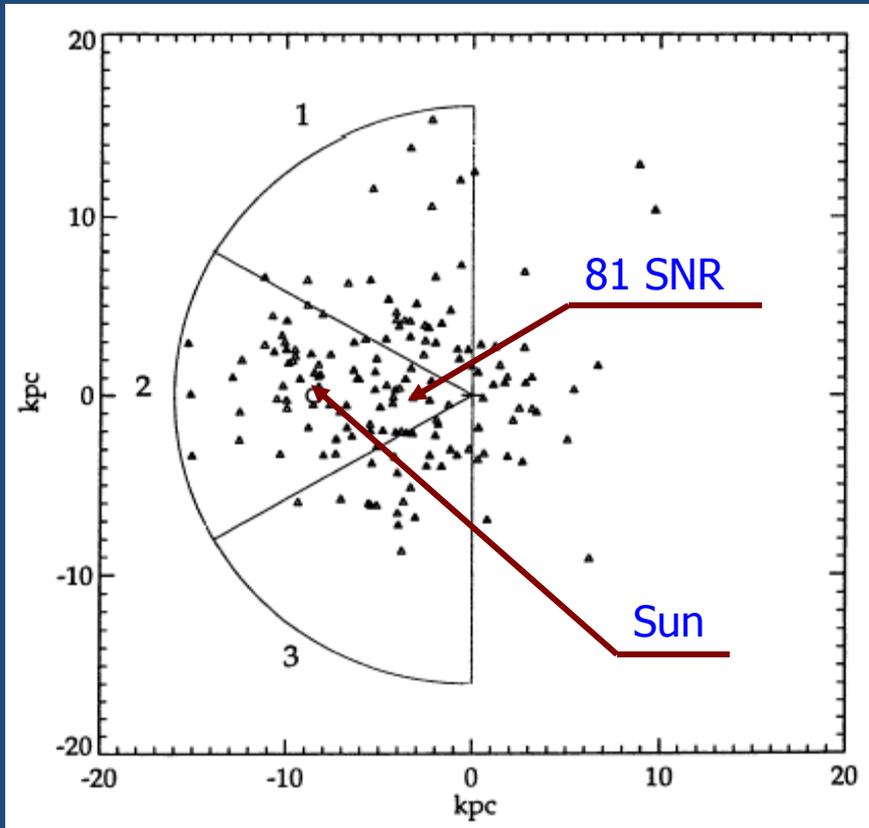
Phase in galactic coordinates

Spiral arms of the Galaxy

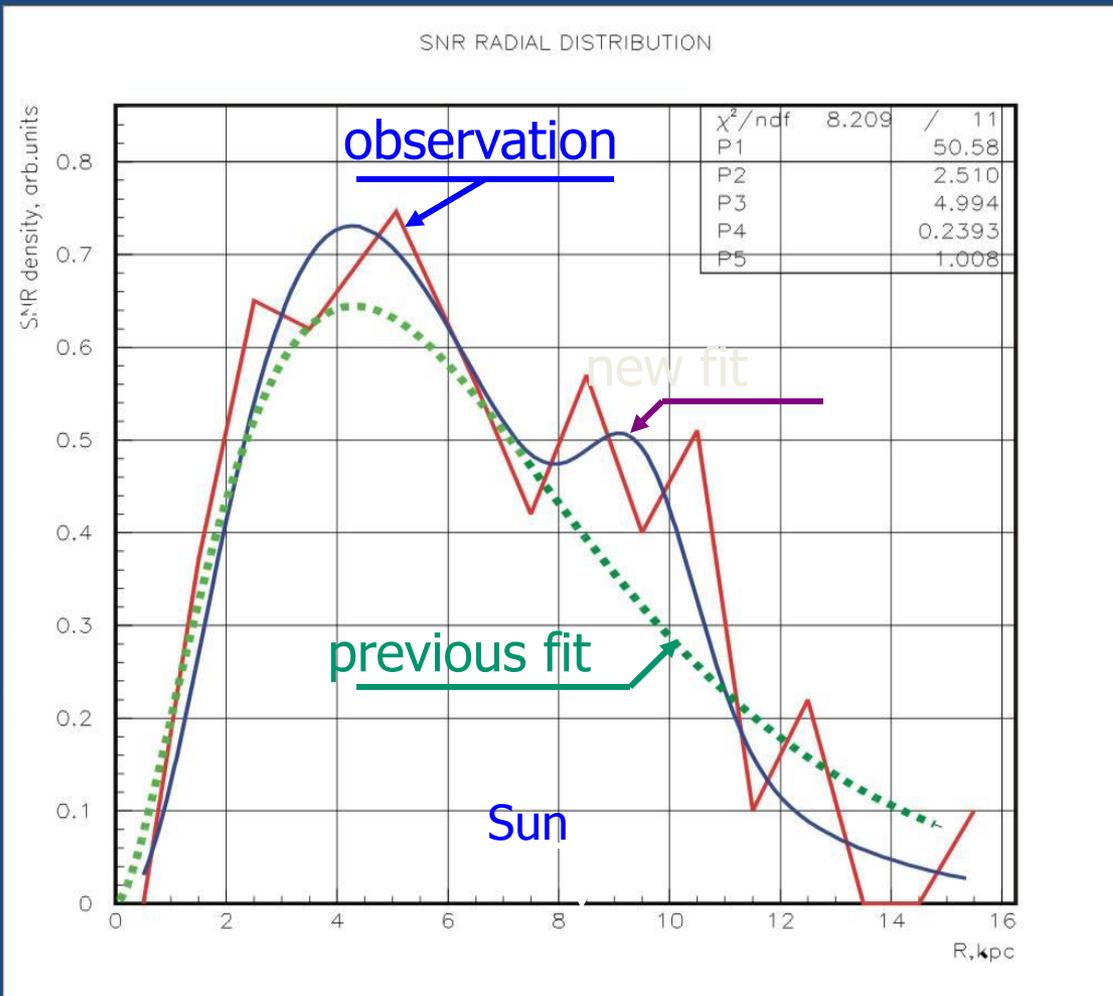


Experimental data used for the fit of the radial SNR distribution

(Case G. & Bhattacharya D., 1996, A&AS, 120,437)



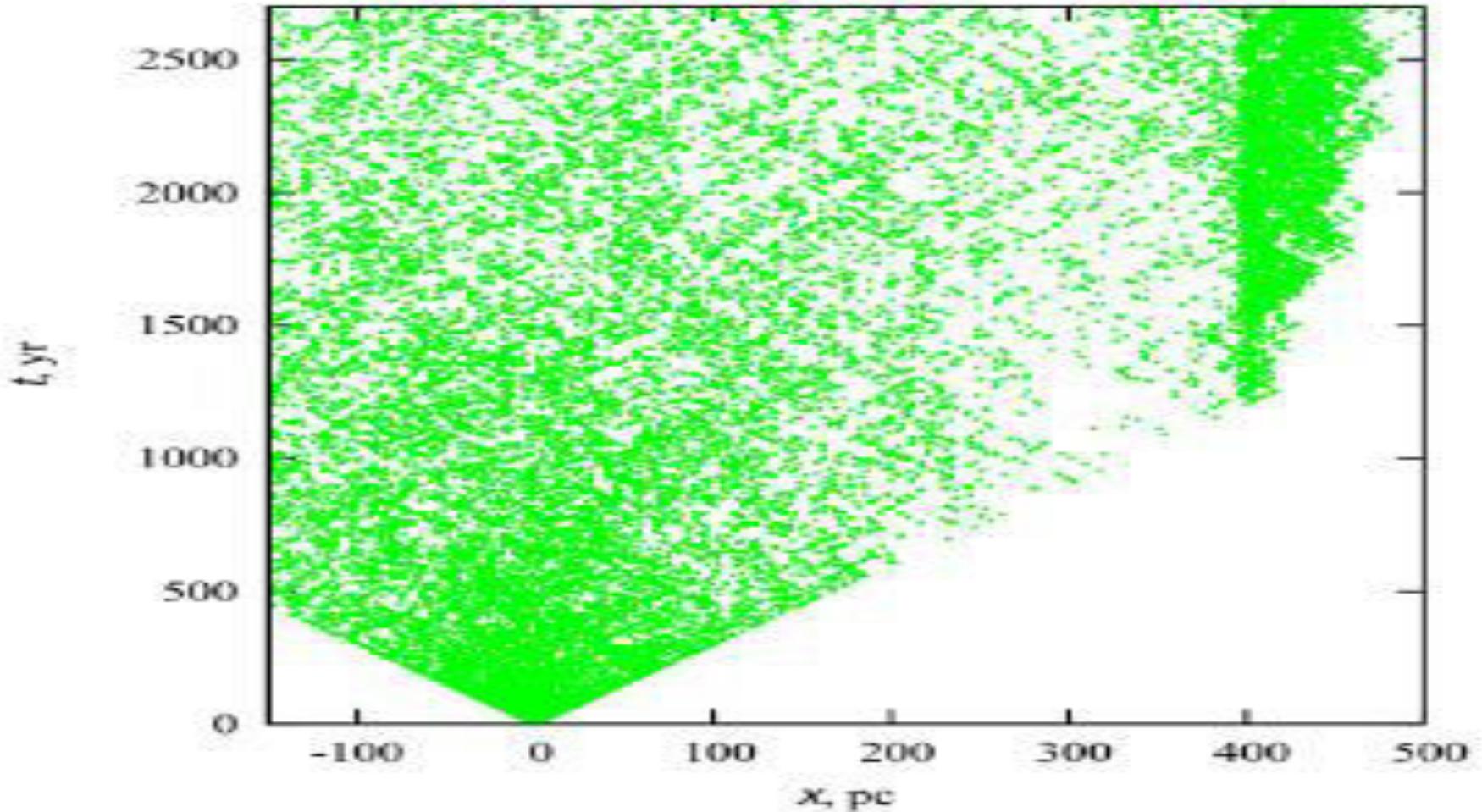
Fits of the SNR radial distribution



In the study of the anisotropy it is better to use the distributions which reproduce **local environment**

Propagation in the heterogenous medium

$\alpha=0.75, \mu=0.1 \text{ pc}^{-\alpha}, \lambda=6 \text{ pc}$



Possible explanation of the Puzzle 1:

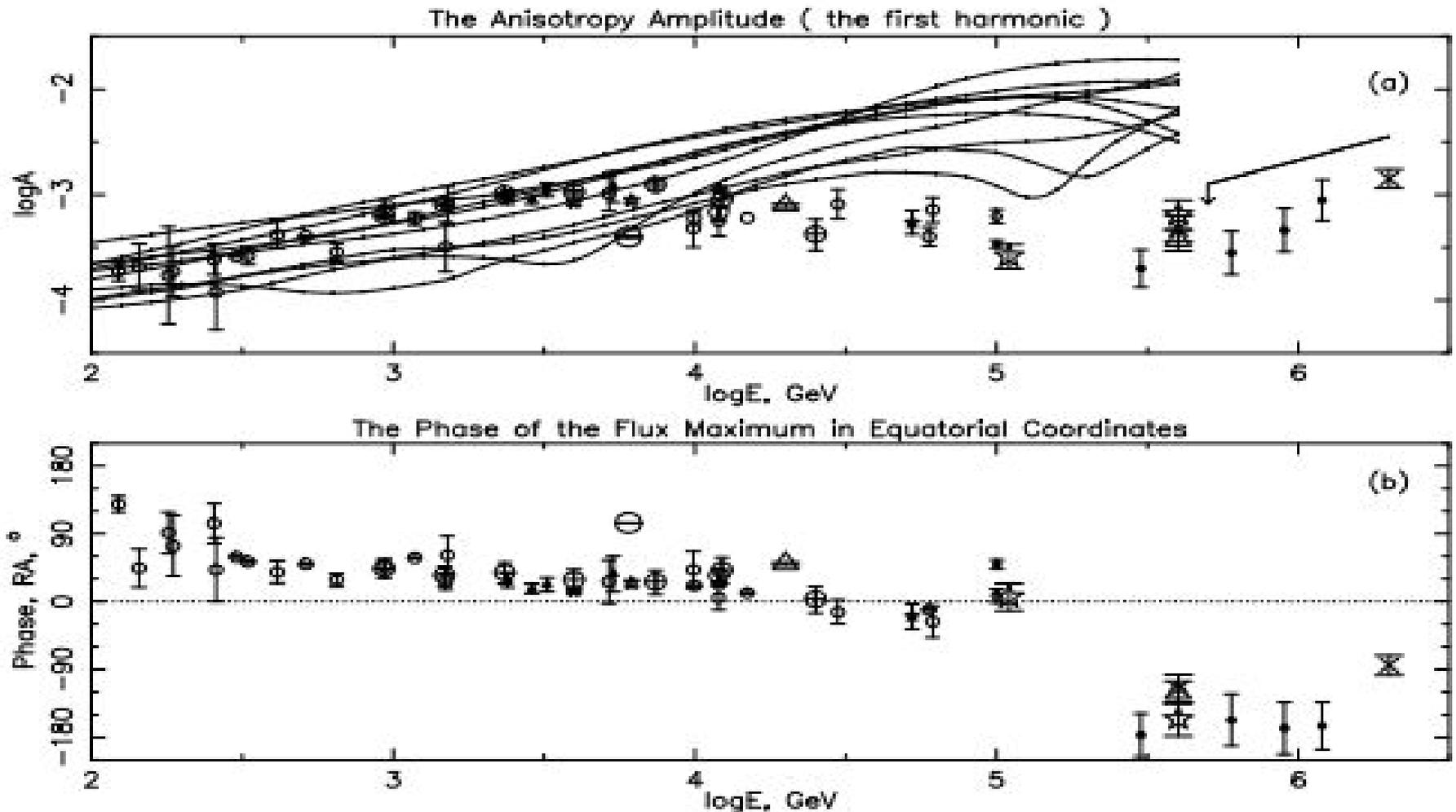
Inverse anisotropy is a 'local' phenomenon.
which is caused by the 'reflection' of CR from
a nearby region of higher density interstellar
medium

Puzzle 2:

irregular behaviour of A and Φ

At $E > 10 \text{ TeV}$ A starts to fall down, at $E \sim 200 \text{ TeV}$ has a minimum and after $E \sim 1000 \text{ TeV}$ it rises again.

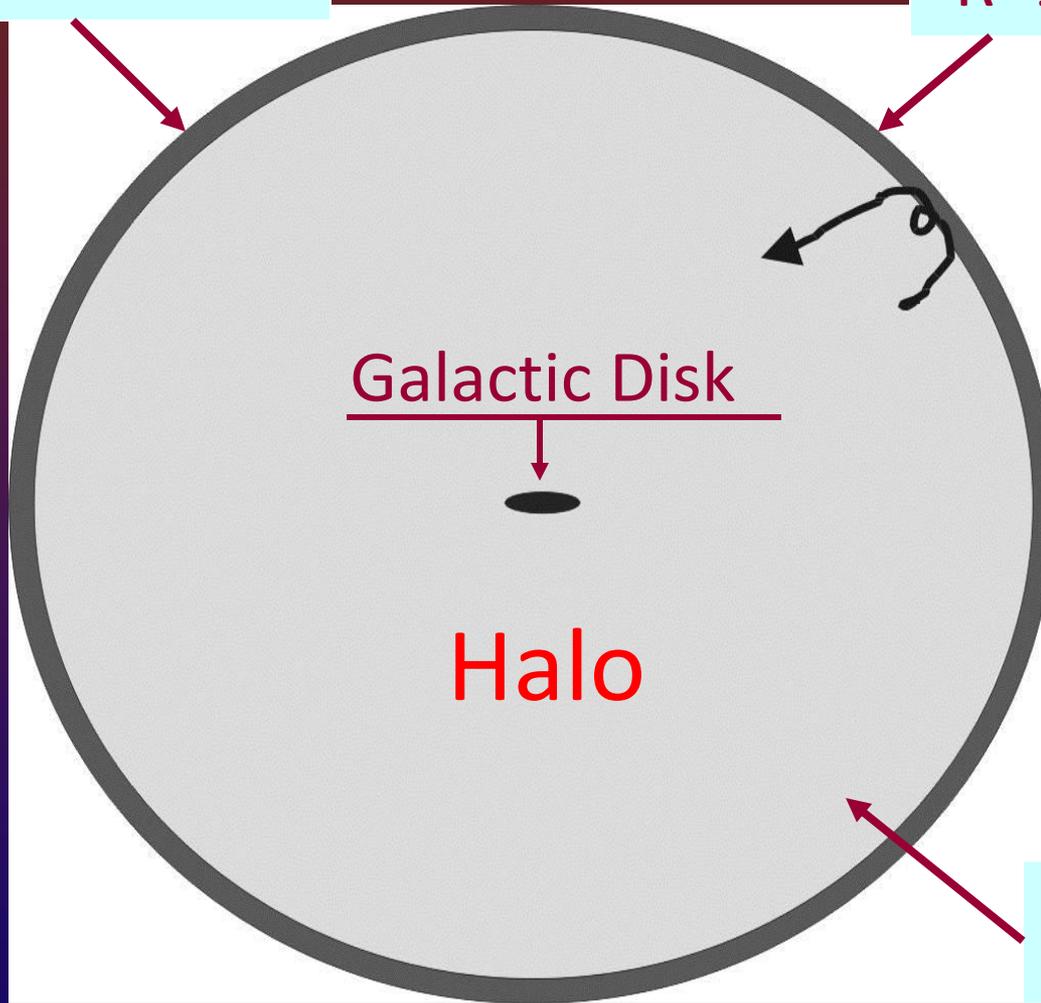
Φ changes to the opposite one at $E > 100 \text{ TeV}$



Possible explanation: Galactic Halo (proposed by V.L.Ginzburg)
and Single Source (proposed by EW)

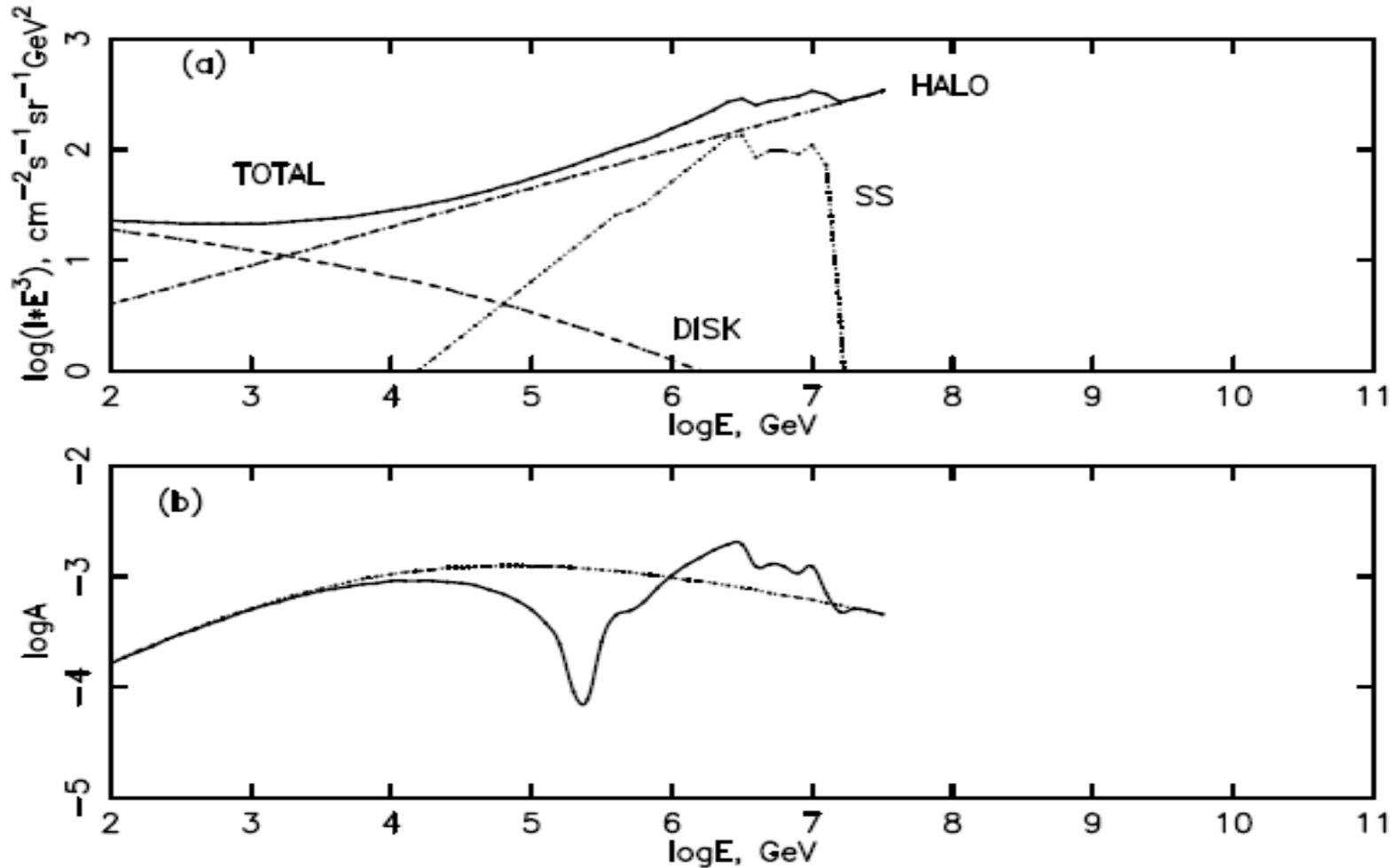
termination shock

$R=100\text{kpc}$

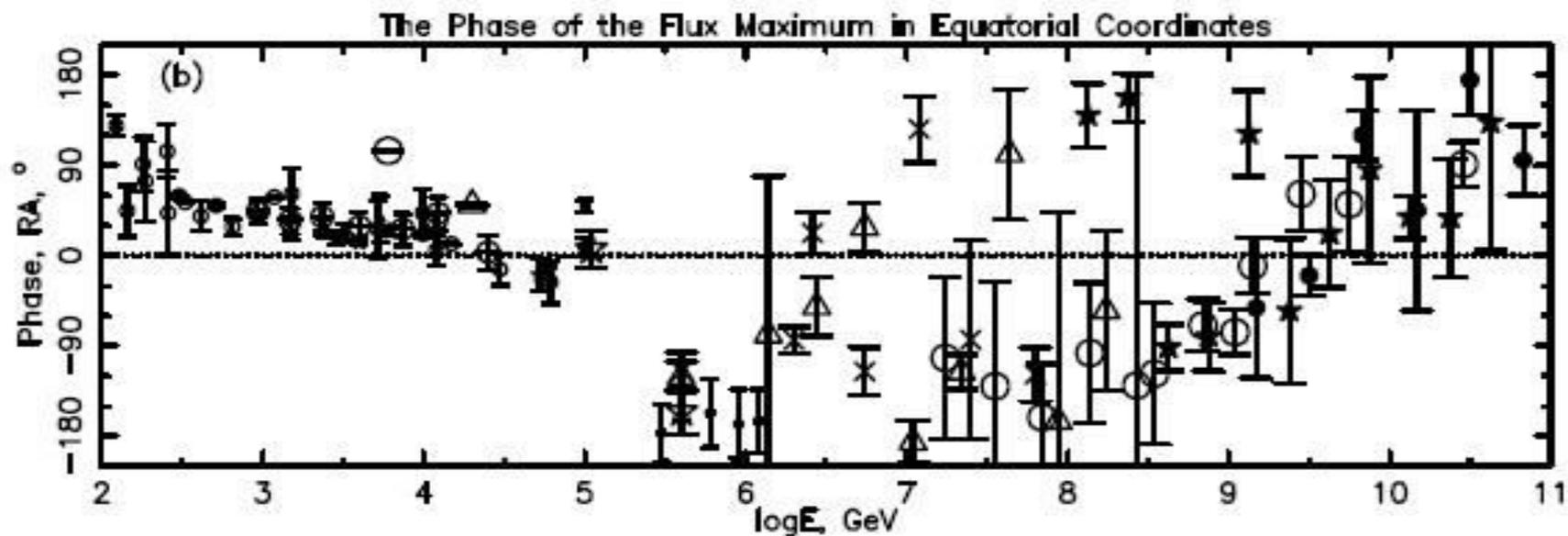
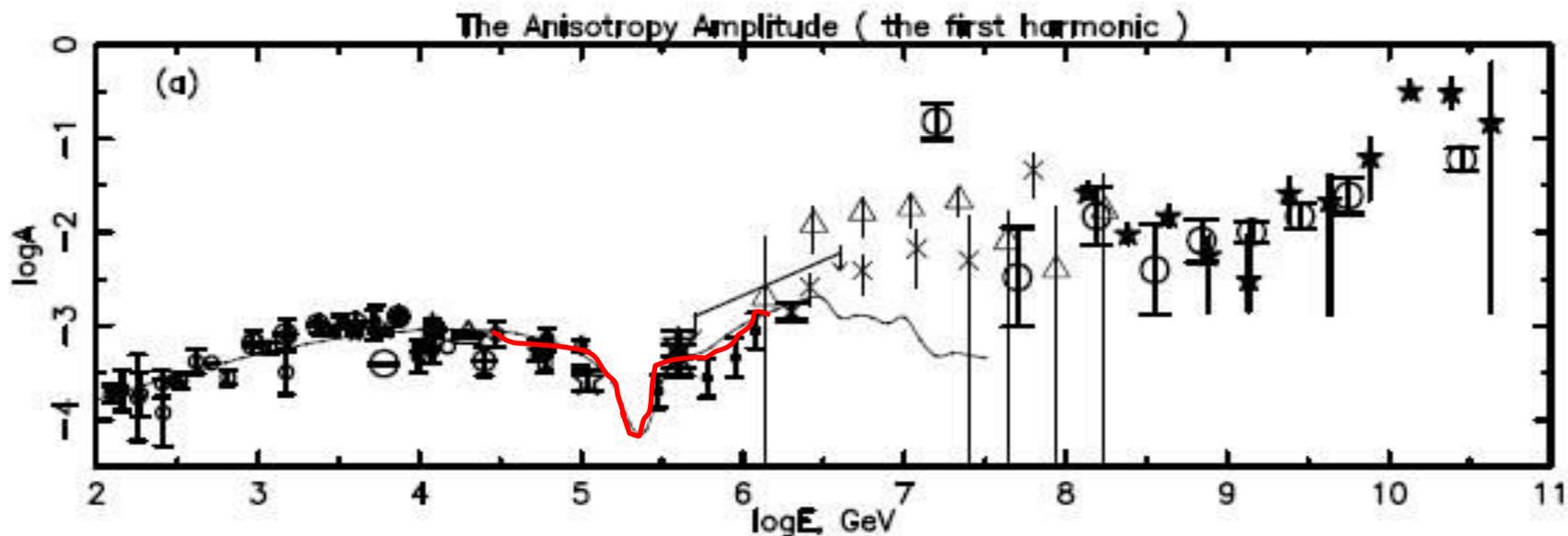


Age = 10^{10} y

Possible role of isotropic Halo and Single Source in the Outer Galaxy



Present time



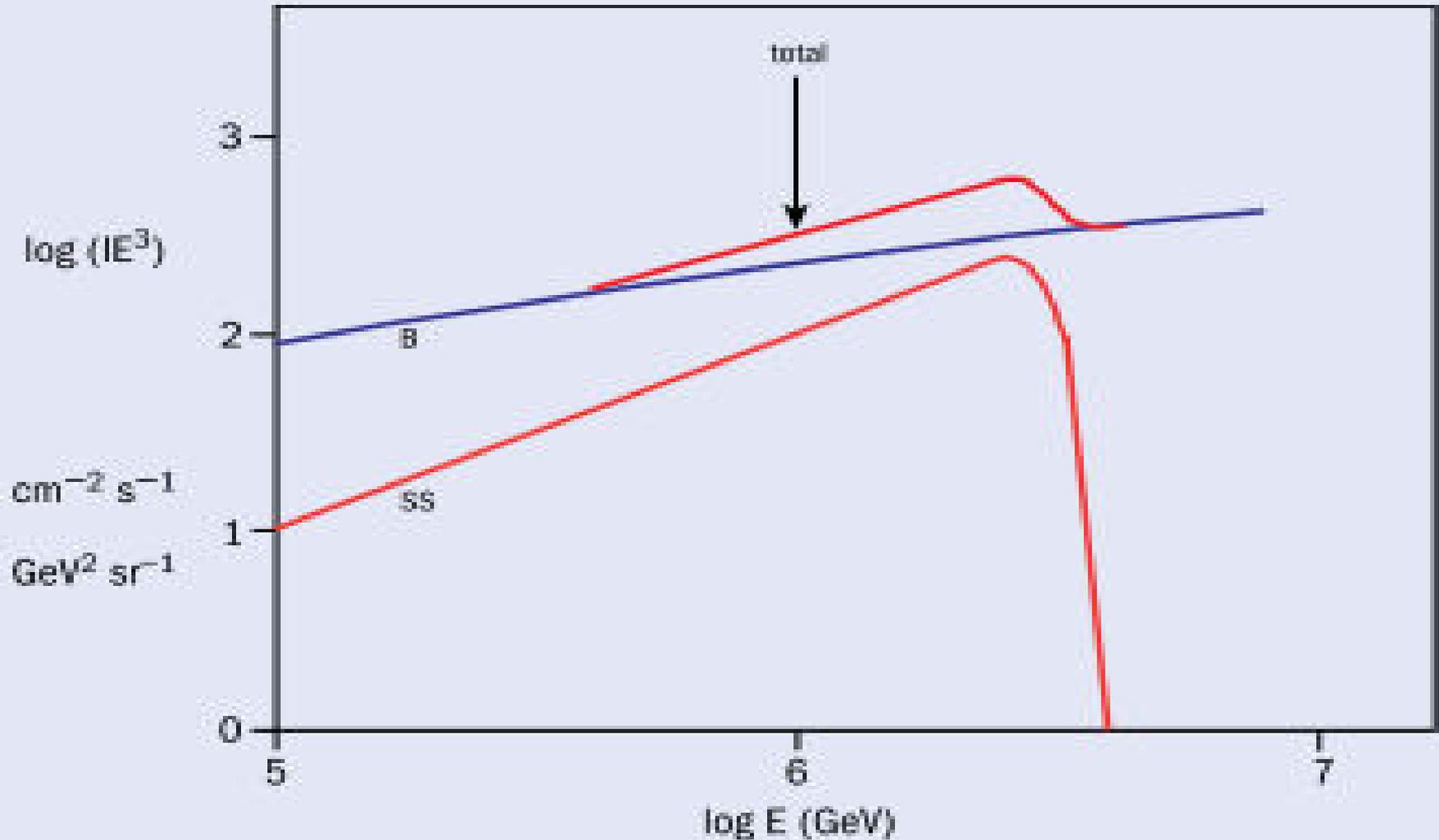
Questions:

- * Do the Halo and the Single Source really exist ?
- * Is the CR energy spectrum harder in the Halo than in the Disk ?
 - * To what extent are simplified assumptions, used in this scenario, reasonable ?

PUZZLE 3:

- What is the Single Source ?

Single Source Model of the Knee



Difference Method

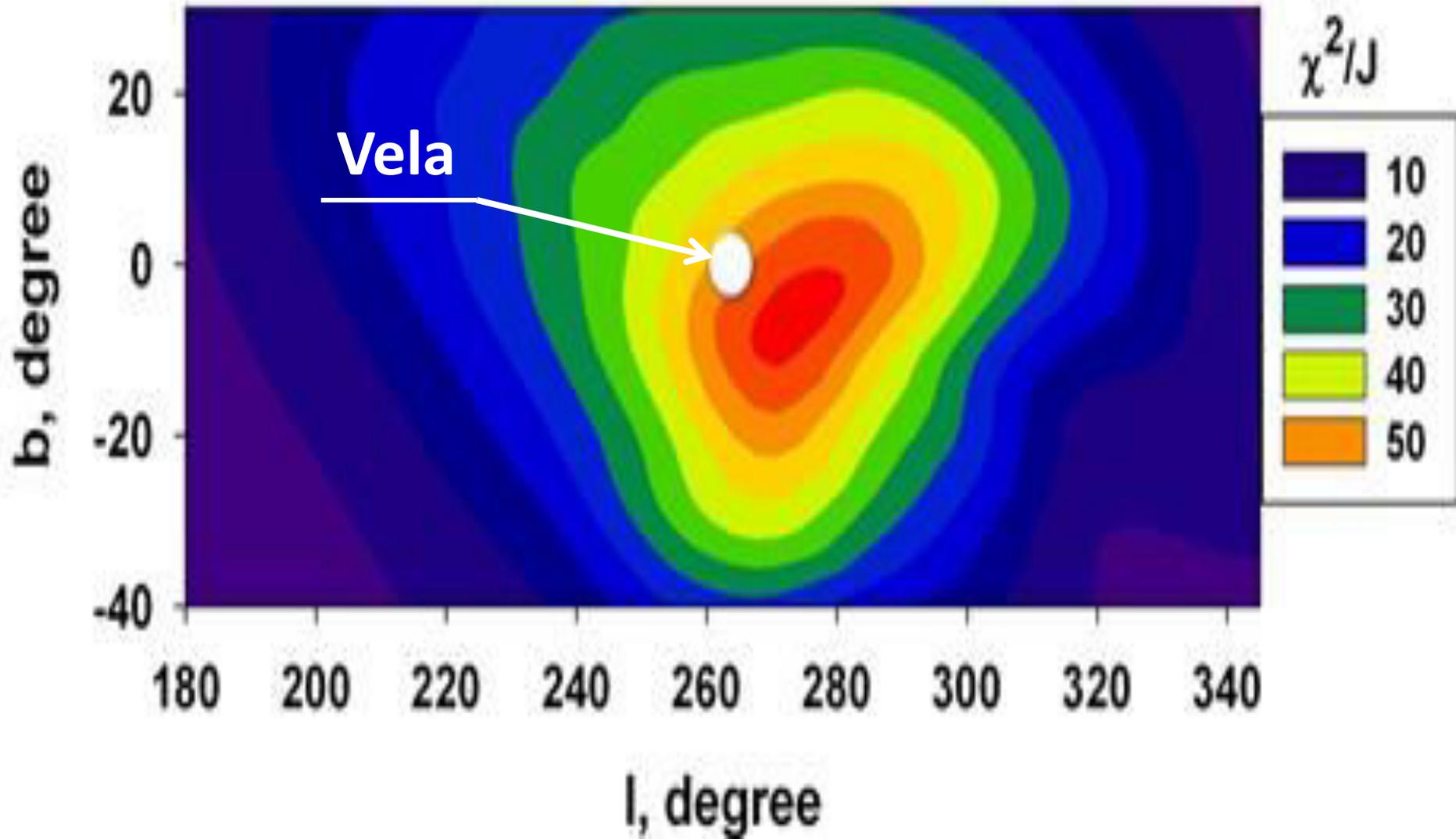
(Pavlyuchenko V.P. , 2014, Bull. Lebedev Phys. Inst., 3, 3)

One does NOT look in the sky for a direction of the maximum cosmic ray intensity , but that of the maximum difference in the characteristics of extensive air showers coming from the opposite directions.

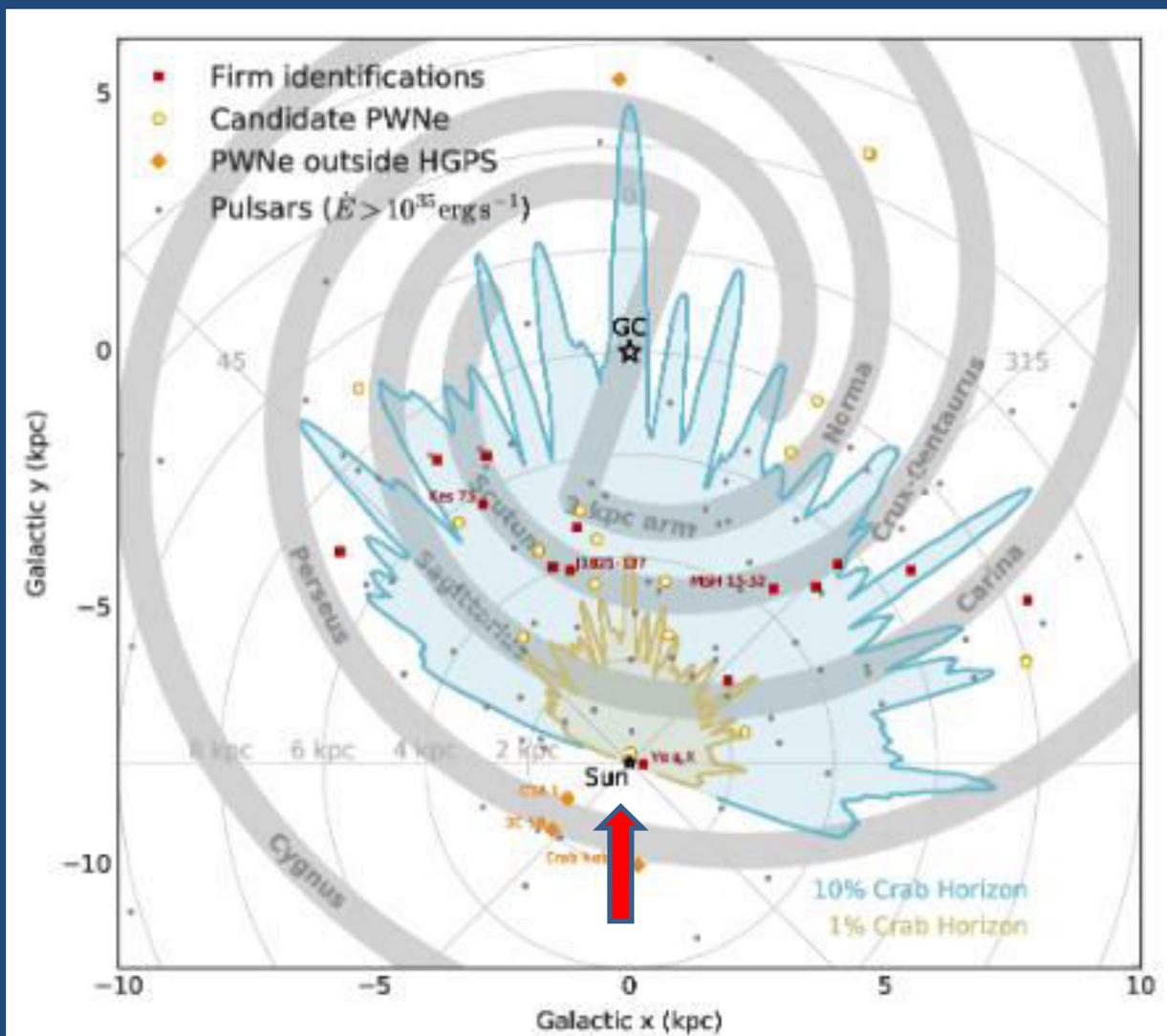
Sunrise or Sunset



Search of the Single Source

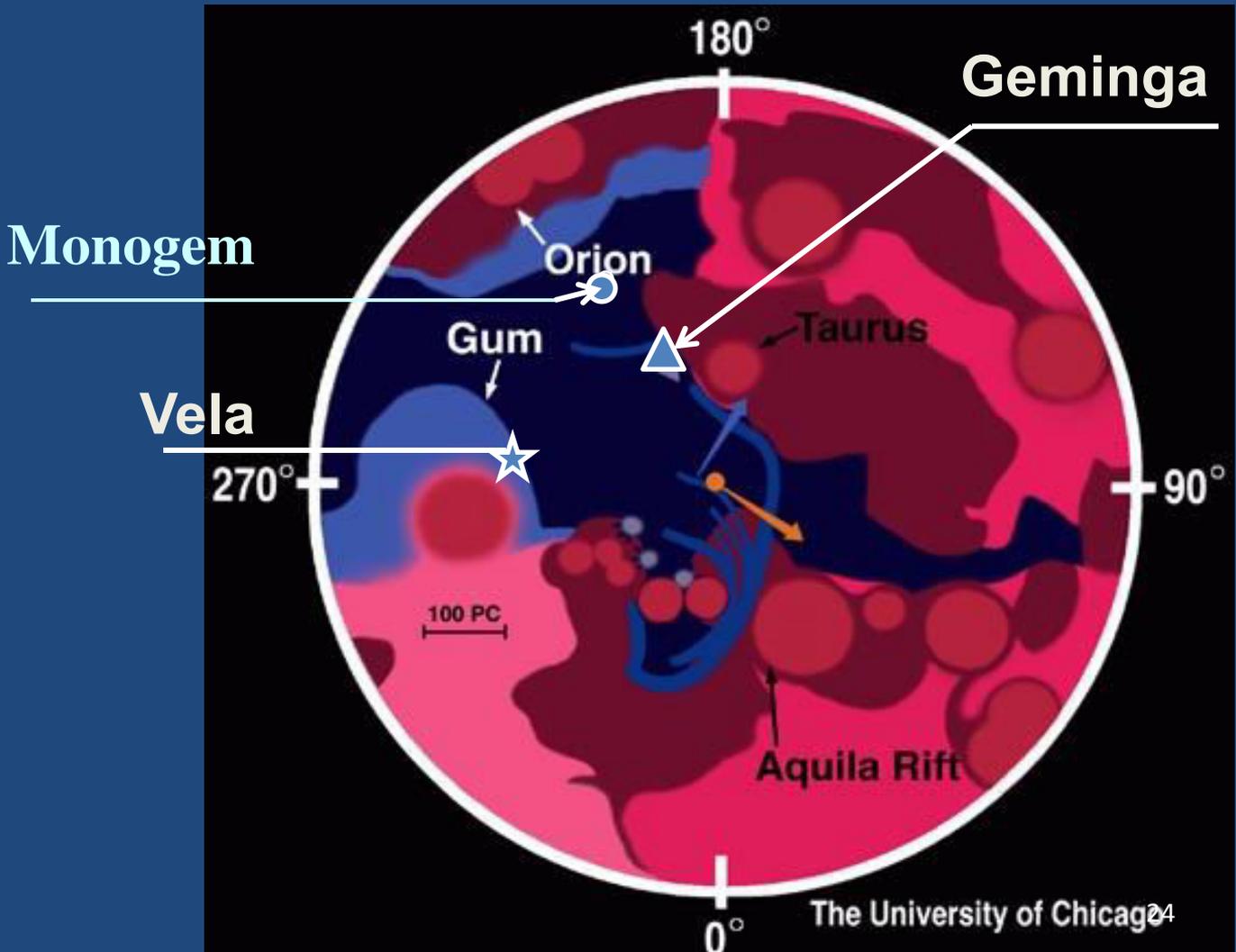


Location of the Vela cluster in the Galaxy

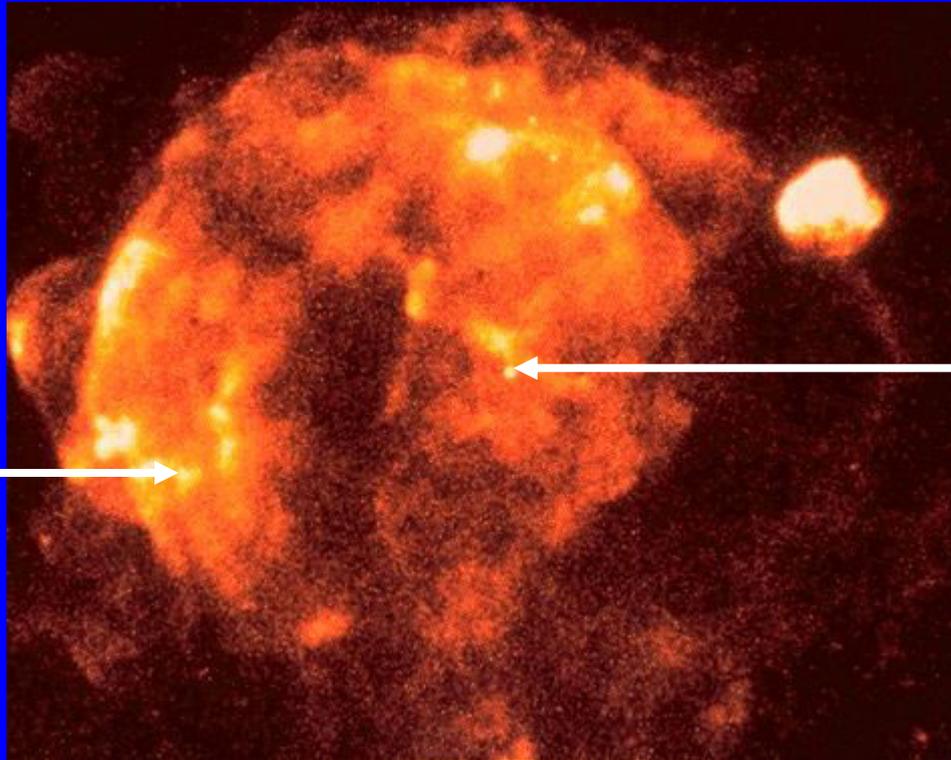


Environment of the Solar System

(nearby 500 pc)



Morphology of the Vela Cluster



Vela Jr



pulsar B0833-45 & Vela X PWN



Minimum of the anisotropy amplitude in the PeV region can be caused by the contribution of the Single Source. The most likely candidate for the Single Source is the **Vela** Cluster

CONCLUSIONS

**There are more things in heaven and earth,
Horatio, than are dreamt of in your philosophy**

W.Shakespeare, Hamlet