Cosmic Rays in the Outer Heliosheath: How Local is the Local Interstellar Spectrum?

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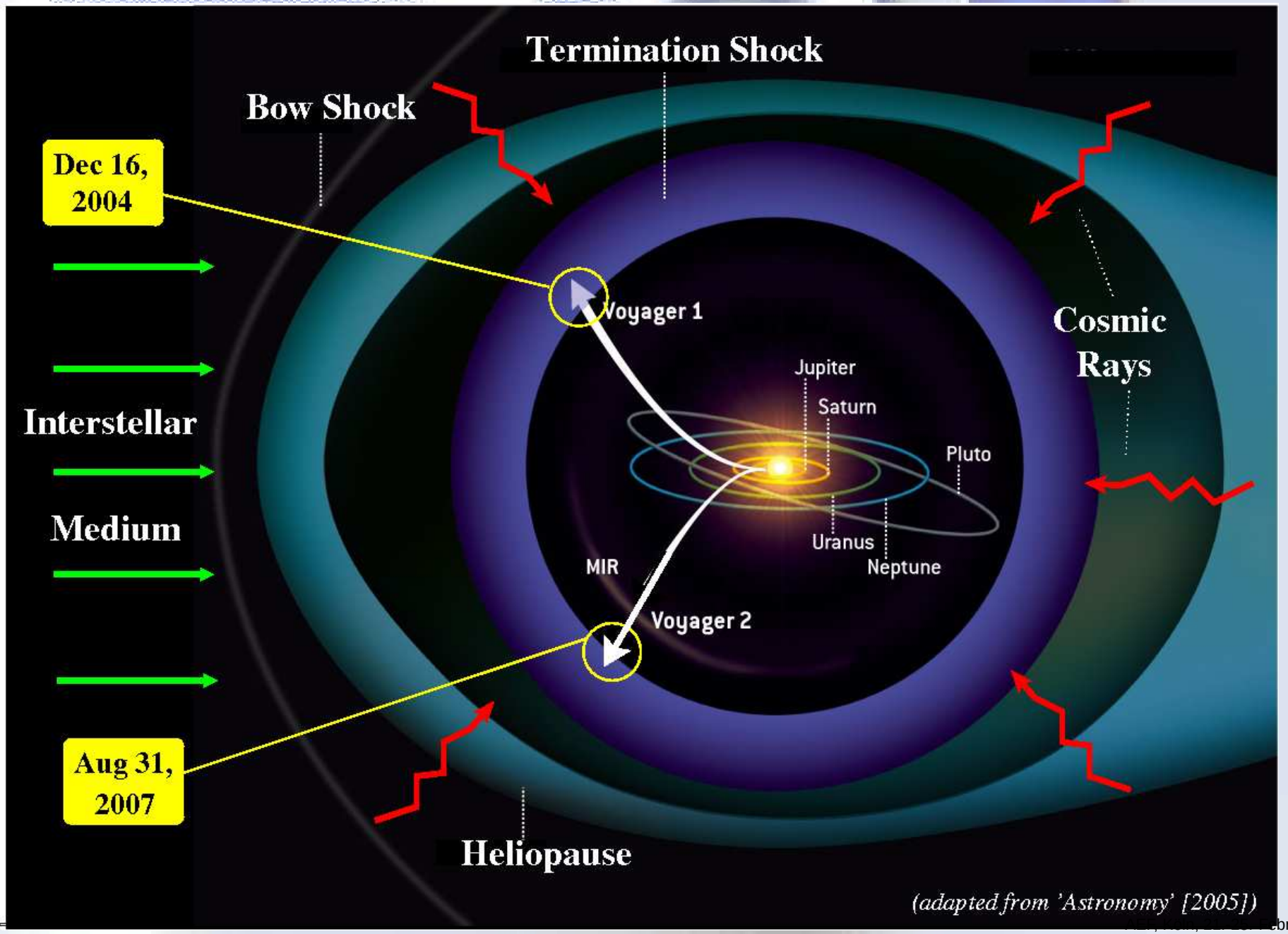
Cosmic Rays in the Outer Heliosheath:

How Local is the Local Interstellar Spectrum?

- The heliosphere
- Cosmic ray transport paradigms
- Anomalous cosmic rays
- Galactic cosmic rays

The heliosphere



General modeling

Continuity-, momentum-, and energy equations including the magnetic field

$$\frac{\partial}{\partial t}\begin{bmatrix}\rho\\ \rho\vec{v}\\ e\\ \vec{B}\end{bmatrix} + \nabla\cdot\begin{bmatrix}\rho\vec{v}\\ \rho\vec{v}\vec{v}+\rho\hat{\vec{I}}-\frac{\vec{B}\vec{B}}{4\pi}\\ (e+p_0)\vec{v}-\frac{\vec{B}(\vec{B}\cdot\vec{v})}{4\pi}\\ \vec{v}\vec{B}-\vec{B}\vec{v}\end{bmatrix} = \begin{bmatrix}S^c_{p-H}\\ \vec{S}^m_{p-H}\\ S^e_{p-H}\\ 0\end{bmatrix}$$

Transport equation

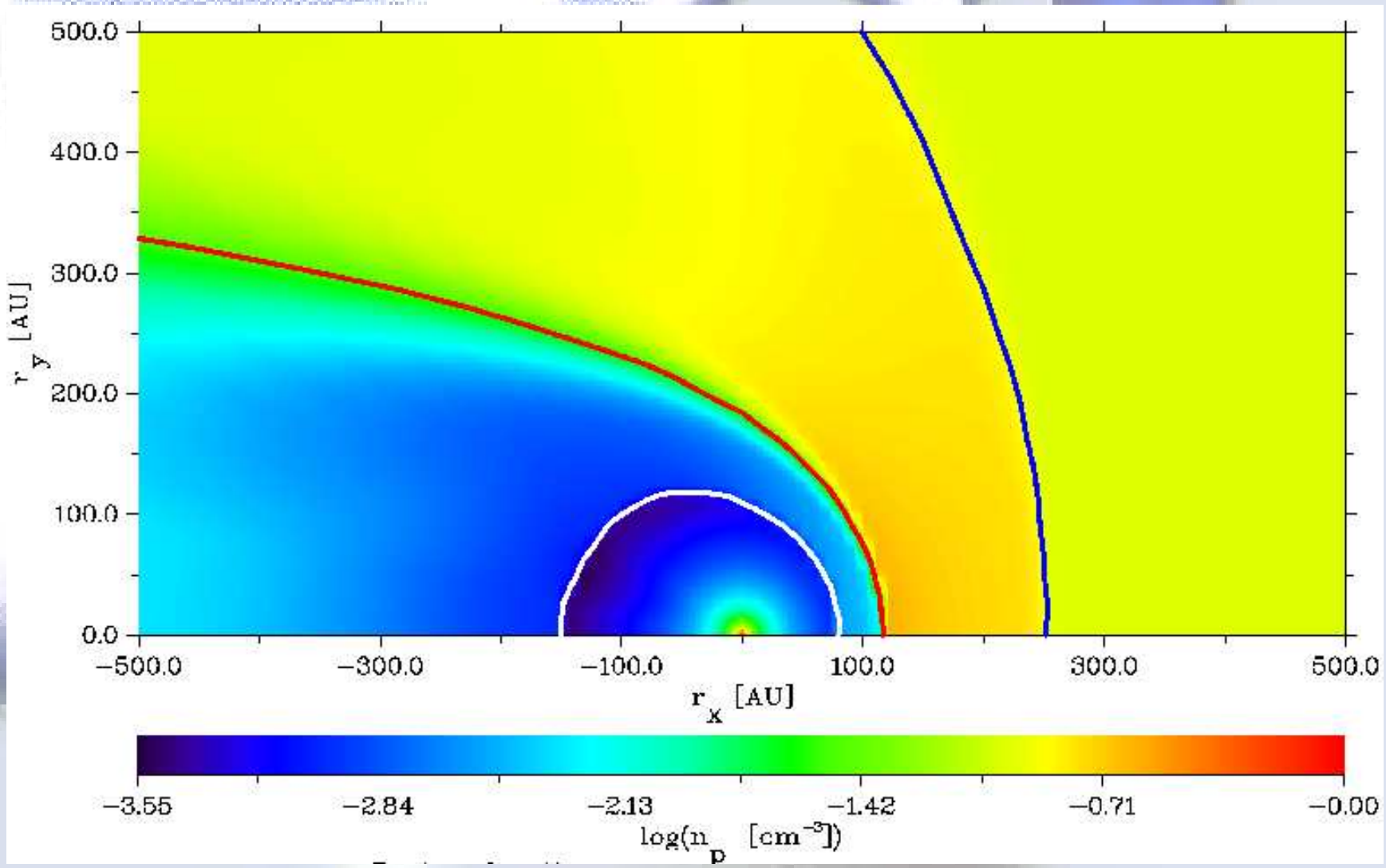
$$\frac{df}{dt} = -(\vec{v}+\vec{v}_D)\cdot\nabla f + \nabla\cdot(\overleftrightarrow{\kappa}\cdot\nabla f) + \tfrac{1}{3}(\nabla\cdot\vec{v})\frac{\partial f}{\partial \ln P} +$$

$$\frac{1}{P^2}\frac{\partial}{\partial P}\left(P^2 D\frac{\partial f}{\partial P}\right) + Q$$

Turbulence equations

$$F(\lambda, T, v, ...)$$

The heliosphere

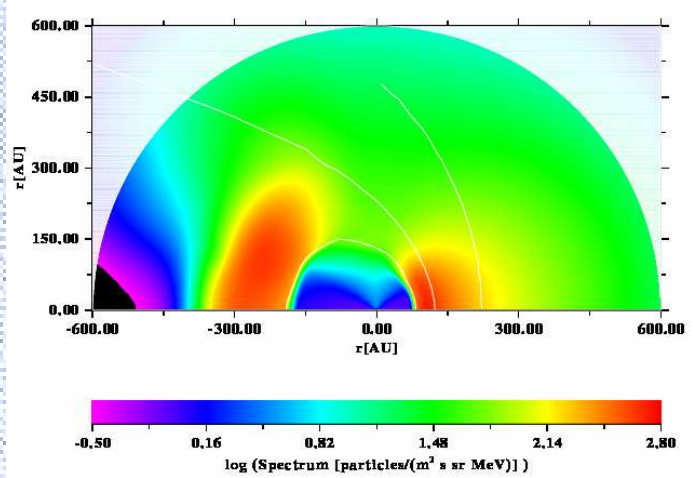


Cosmic Ray paradigms

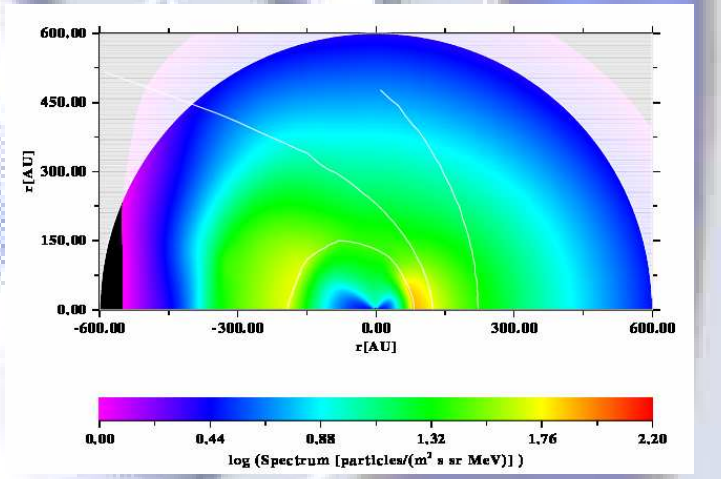
1.) No ACRs beyond HP
2.) No GCRs modulation beyond HP

No Boundary - BoPo

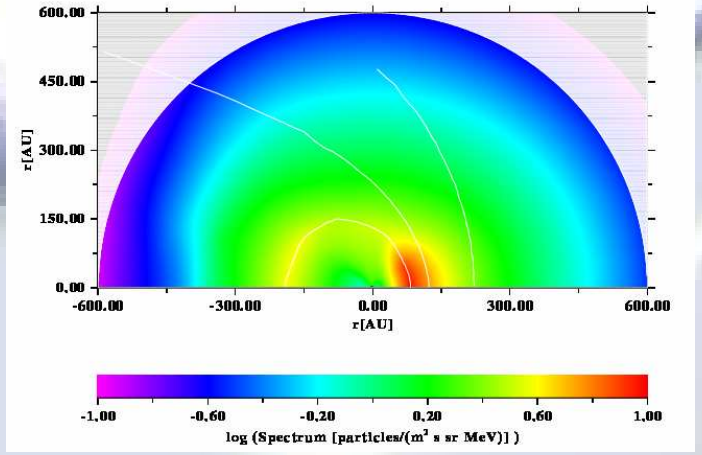
10 MeV



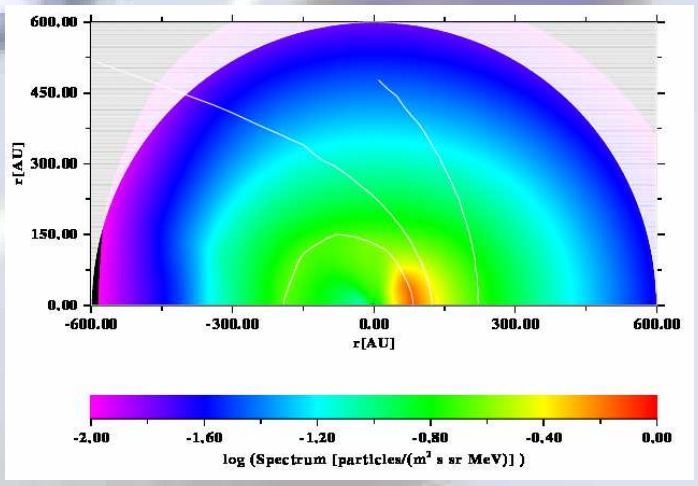
100 MeV



500 MeV



1 GeV



ACRs and LIS

Integration in the range < 300 MeV

over 10^{11} F,G and K stars leads to a

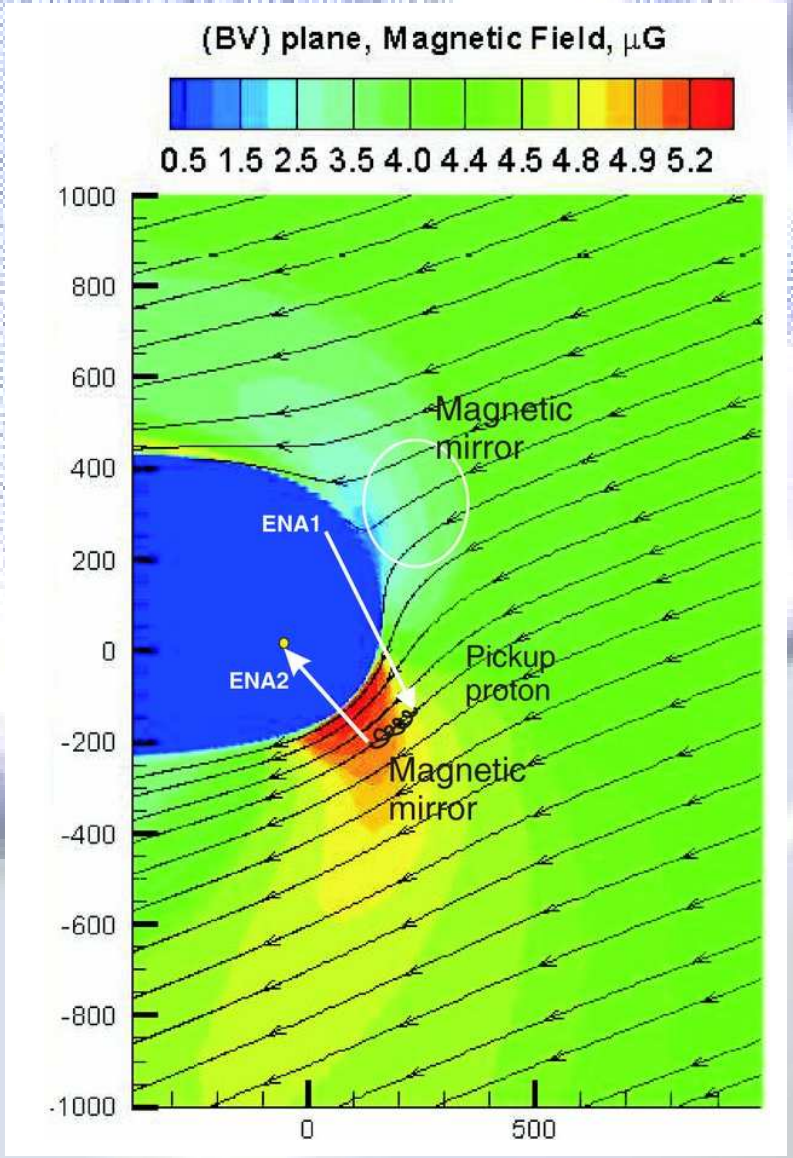
total energy in region 1 of

$e_{\mathrm{astro}}(ACR) \approx 7.6 \cdot 10^{-2}$ eV cm^{-3}.

$e_{\mathrm{helio}}(ACR) = 3.2 \cdot 10^{-3}$ eV cm^{-3}

About 50% and 2.5% of the total energy in that range contribute to the total LIS.

The Outer Heliosheath (OHS)



taken from Chalov et al. (2010)

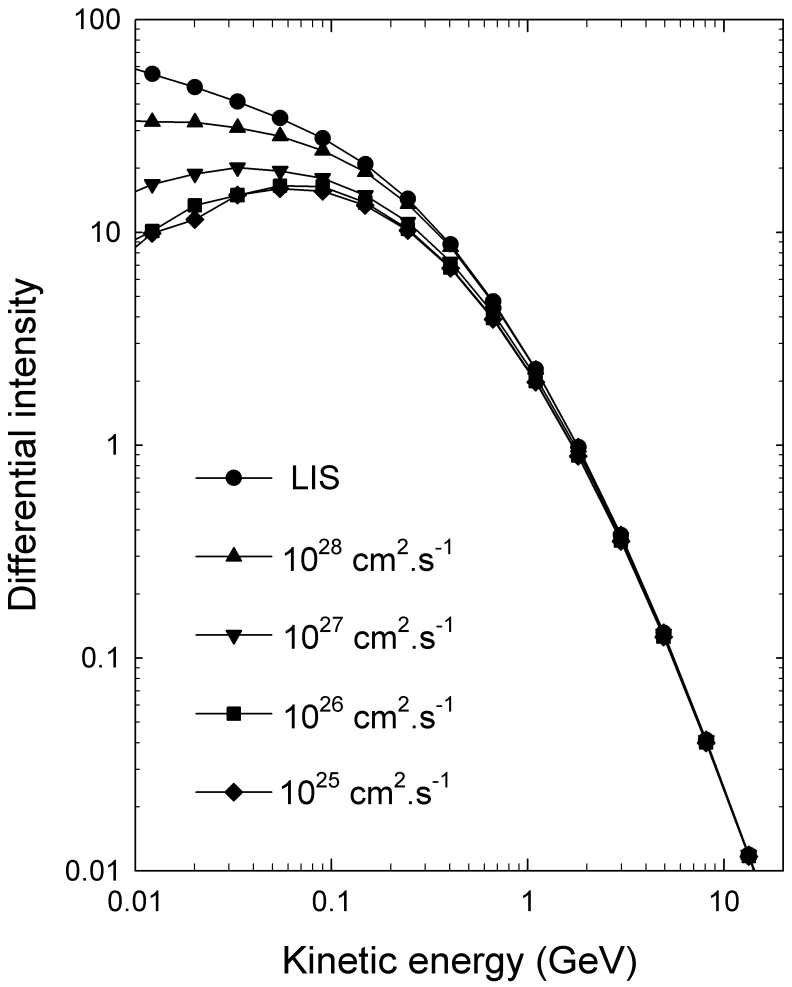
(No) Bow shock

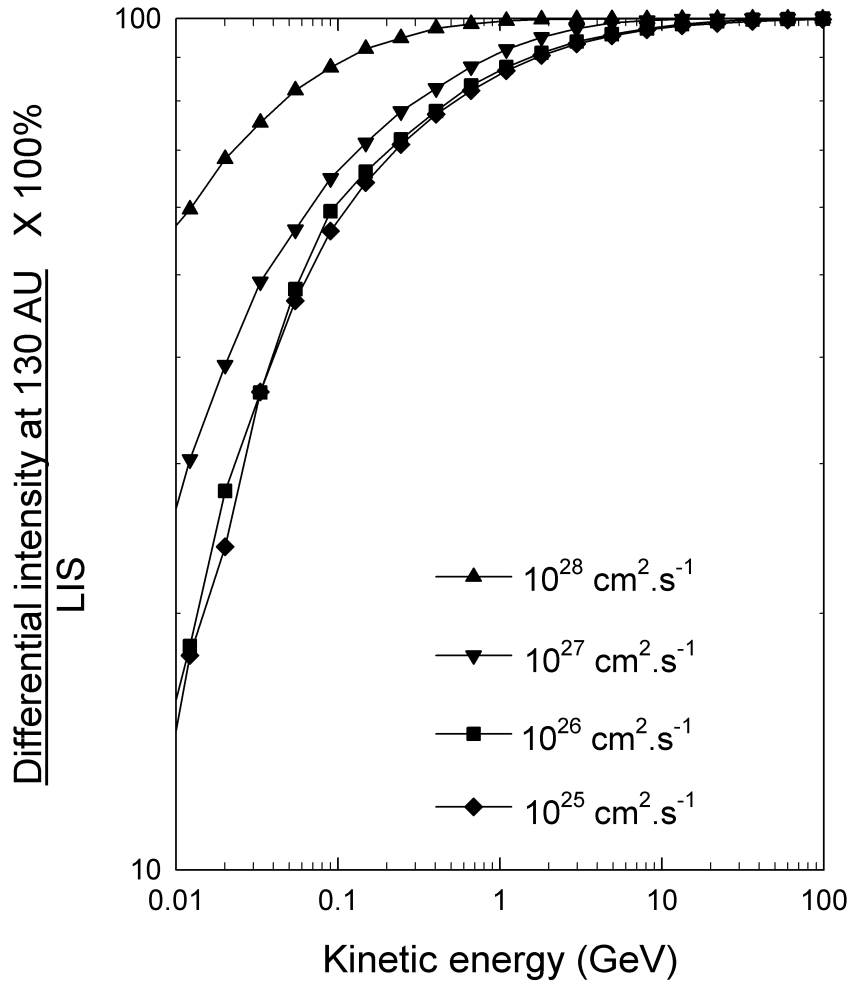
- 100 AU scales no isotropic diffusion
- magnetic field not homogeneous
- enhanced turbulence
- trapping

Assumptions:

- spheric symmetric outer heliosphere (BS = 250 AU, HP = 130 AU)
- isotropic diffusion tensor in OHS, tensor inside HP
- LIS at 250 AU, Webber & Higbie 2003

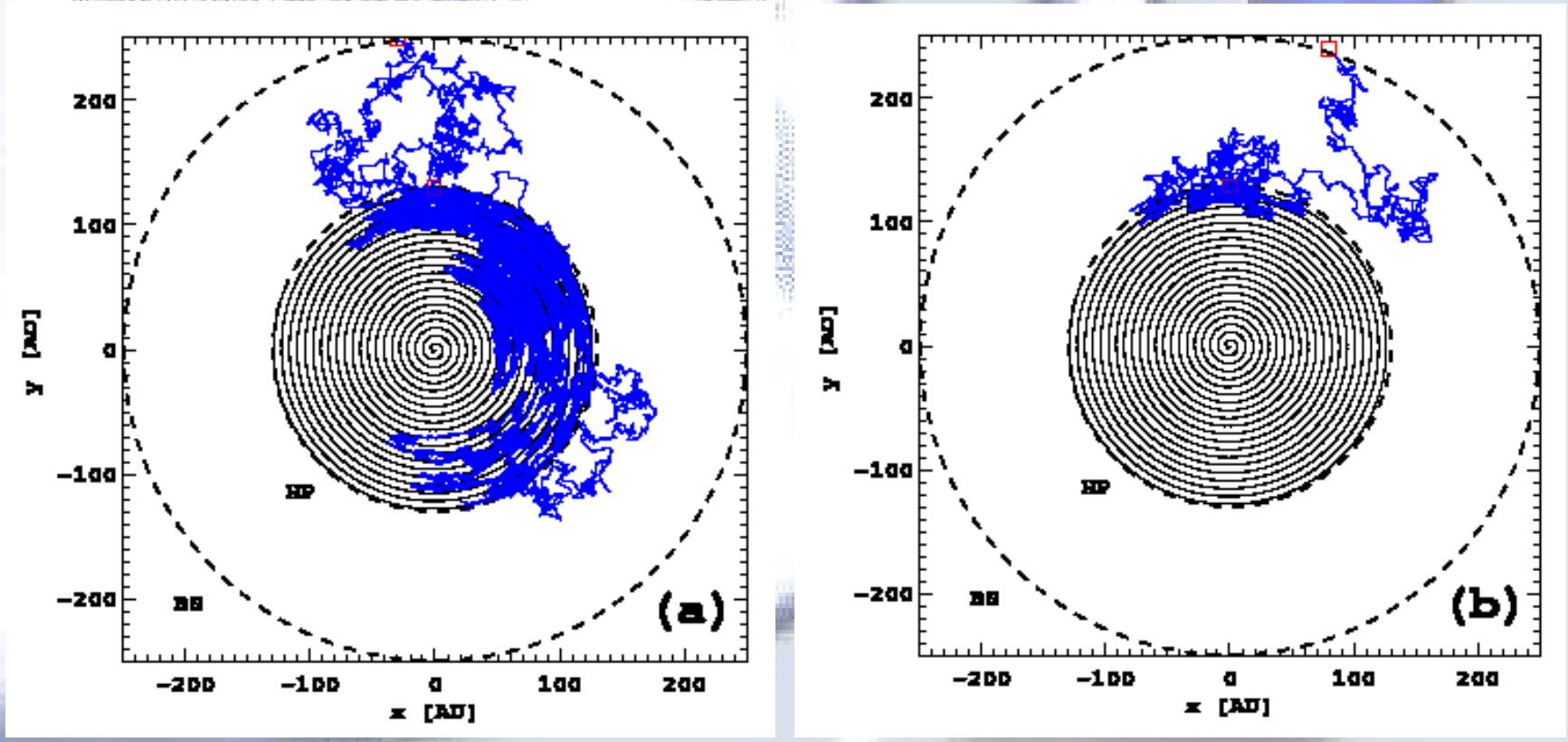
Spetcra at HP





Left: Spectra at HP (130 AU), right: ratio to LIS

Trajectories



Trajectories for 100 MeV particles and $\kappa = 10^{25}\text{cm}^2/\text{s}$

inner dashed circle: heliopause at 130 AU

outer dashed circle: bow shock at 250 AU

Conclusion I

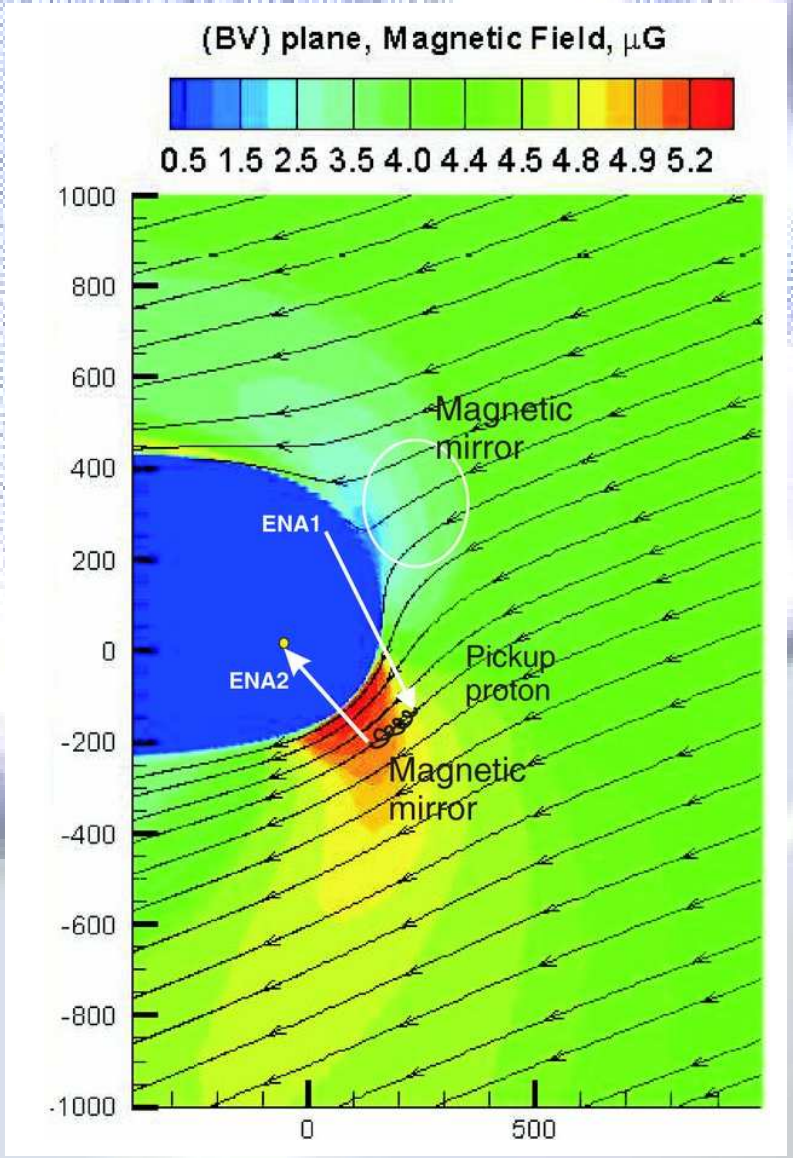
Cosmic Rays in the Outer Heliosheath:

How Local is the Local Interstellar Spectrum?

- Paradigm 1 ☹: ACRs diffuse into LISM
- Paradigm 2 ☹: Modulation in the OHS

LIS not yet understood

Conclusion II



taken from Chalov et al. (2010)

Future work:
(No) Bow shock

- realistic heliospheric shape
- realistic anisotropic diffusion tensor
- heliospheric trapping
- undisturbed LIS