

Extraterrestrial Physics I

Energetic Particles in the heliosphere

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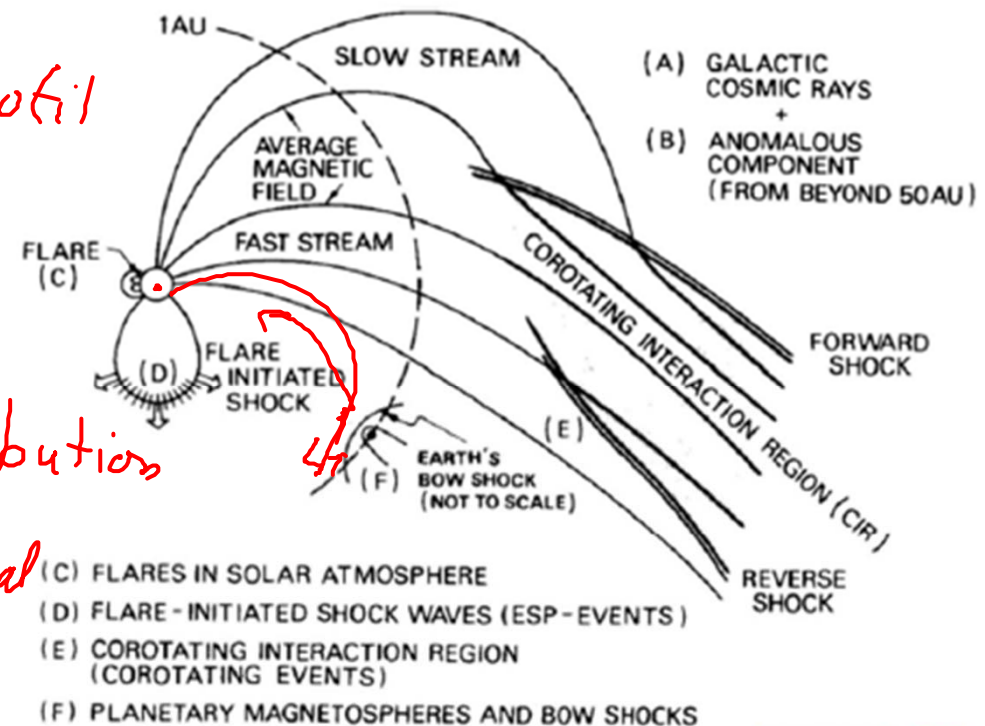
28 January, 2011



Overview (Sources)

Separate the particle:

- intensity-time profile
- Intensity energy spectrum
- Pitch-angle distribution
- composition, elemental as well as isotope
- Charge states



Kunow et al., 1991

Overview (Characteristics)

Sources

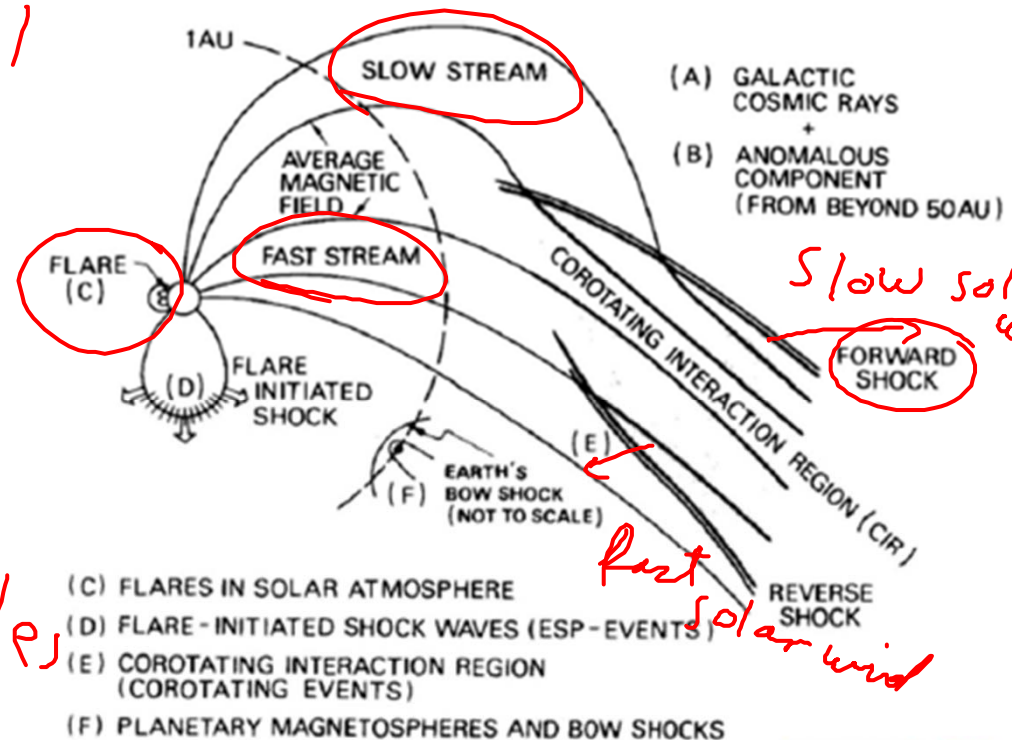
• Sun: flares, coronal shocks...

• interplanetary shocks

• Galaxy

• Heliospheric particles

• Magnetospheres of planets (Jupiter, Earth)



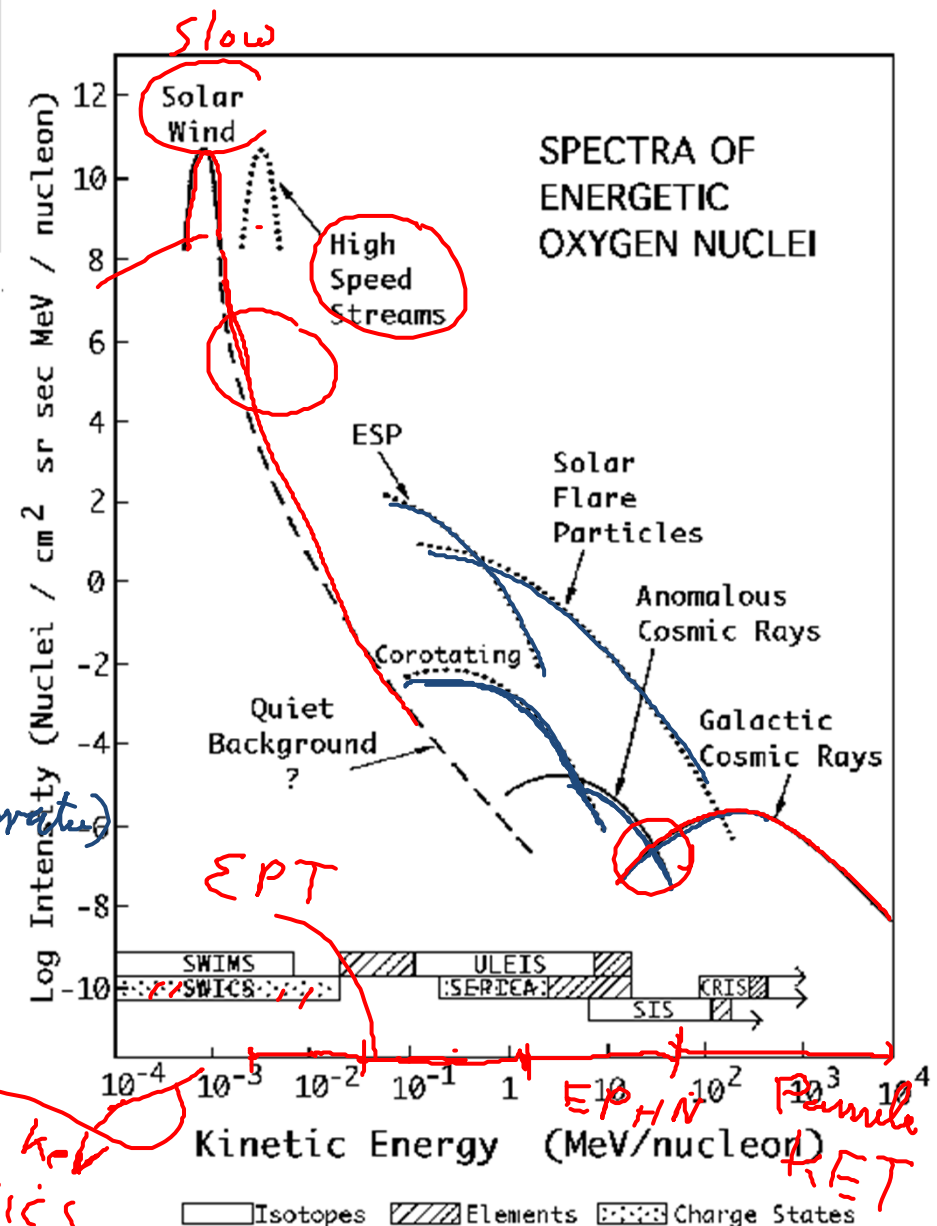
(C) FLARES IN SOLAR ATMOSPHERE
(D) FLARE-INITIATED SHOCK WAVES (ESP-EVENTS)
(E) COROTATING INTERACTION REGION (COROTATING EVENTS)
(F) PLANETARY MAGNETOSPHERES AND BOW SHOCKS

Kunow et al., 1991

Energy spectra of Oxygen (I)

Kappen-distribution of the solar wind

- exponential or power law like energy distribution (shock acceleration)



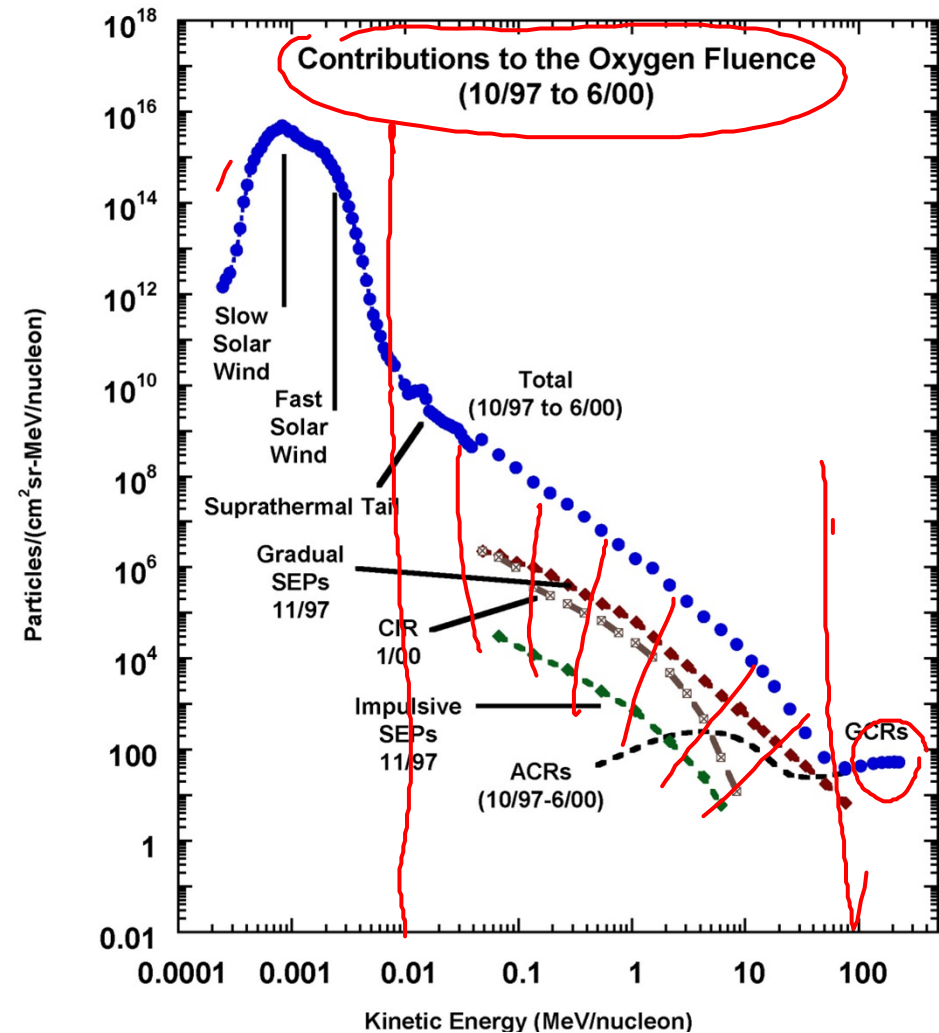
SWICS

EPHN

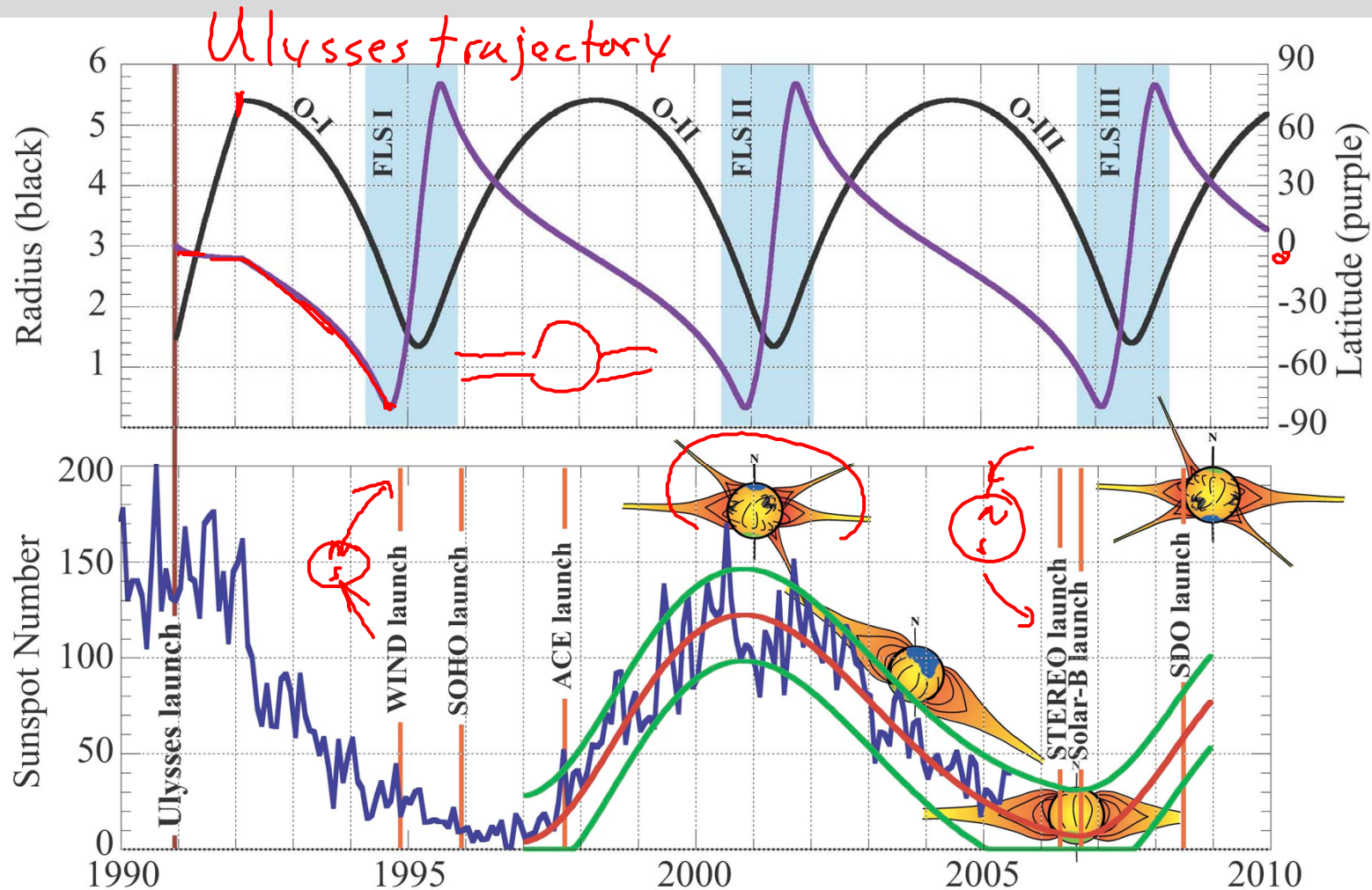
Formula

KET

Energy spectra of Oxygen (II)



The solar cycle



Solar Wind (I)

Composition $96\% \text{H}^+$, $4\% \text{He}^{++}$ e^- , ...

@ Earth 5 p/cm^3

$V_p = U_e$ $v = 400 \text{ km/s}$ Slow solar wind

$v = 800 \text{ km/s}$ fast solar wind.

Temperatur $T = 70^5 \text{ K}$

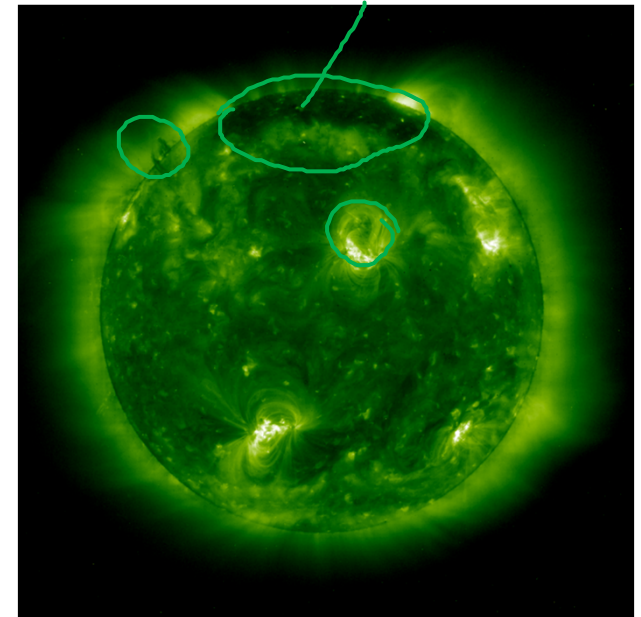
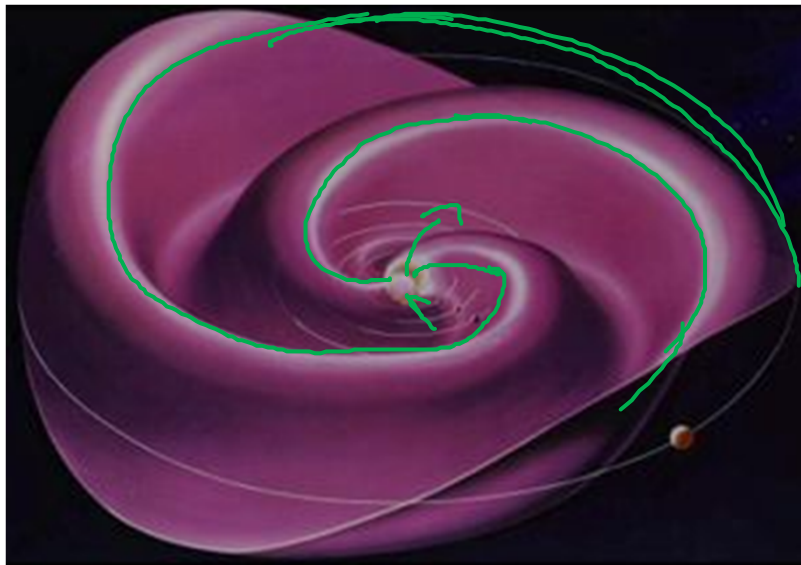
3 classes of solar wind, Slow solar wind @ Minimum
 " " " @ Maximum,
 fast solar wind

Solar Wind (II)

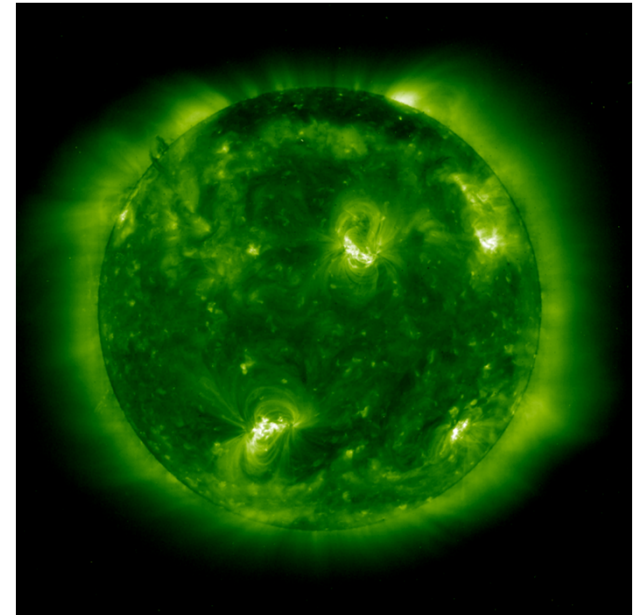
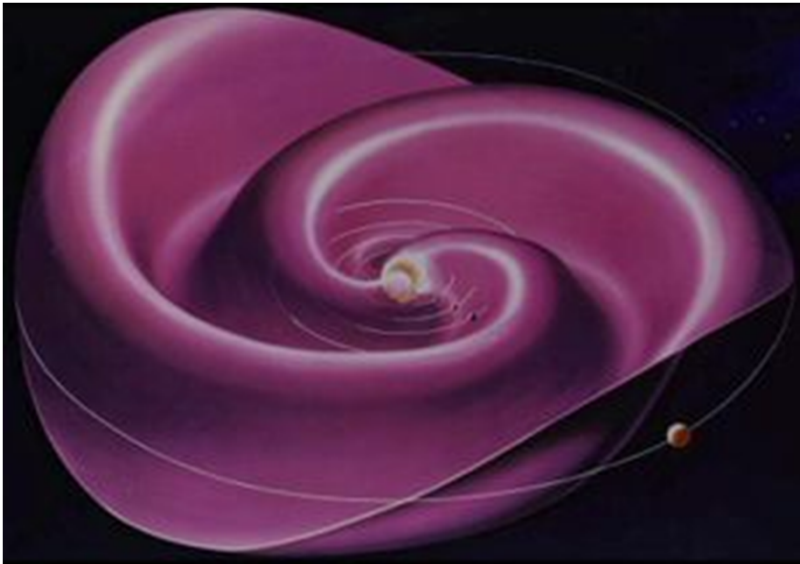
fast solar wind from the coronal holes

slow solar wind " the Streamer Belt

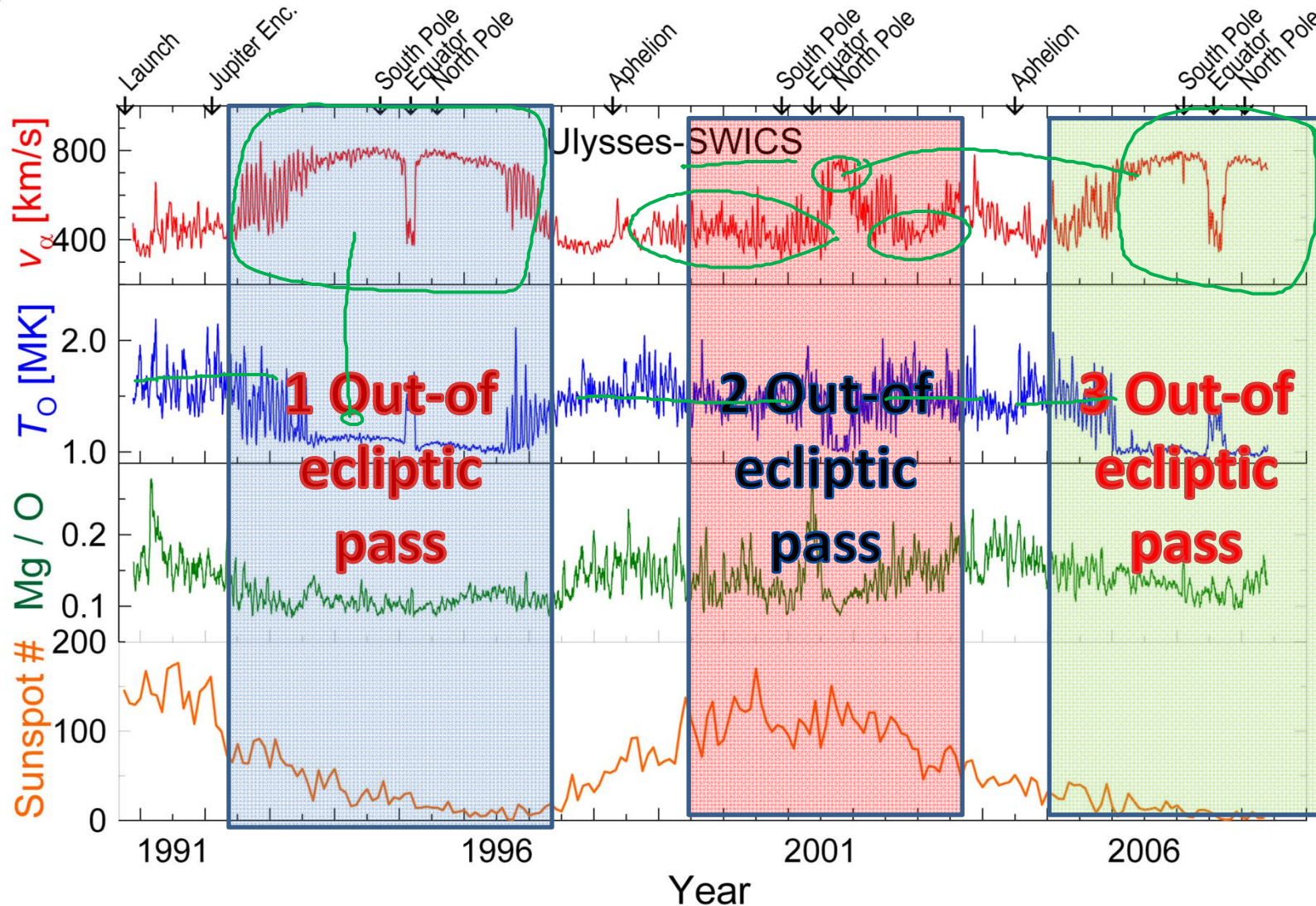
coronal
holes



Solar Wind (II)



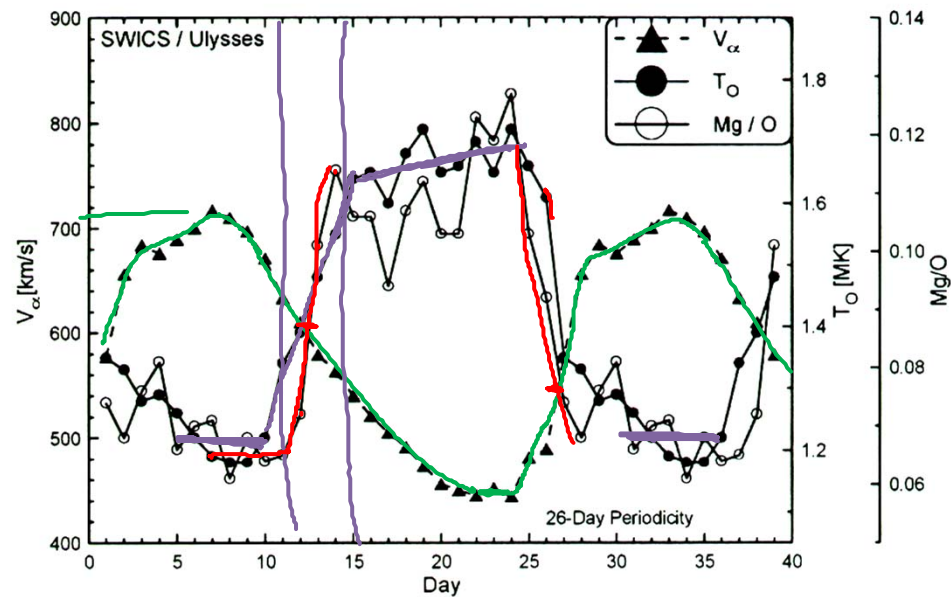
Ulysses-Solar-Wind Overview (SWICS)



Ulysses' First Southern Excursion

McComas, et al., GRL, 2000

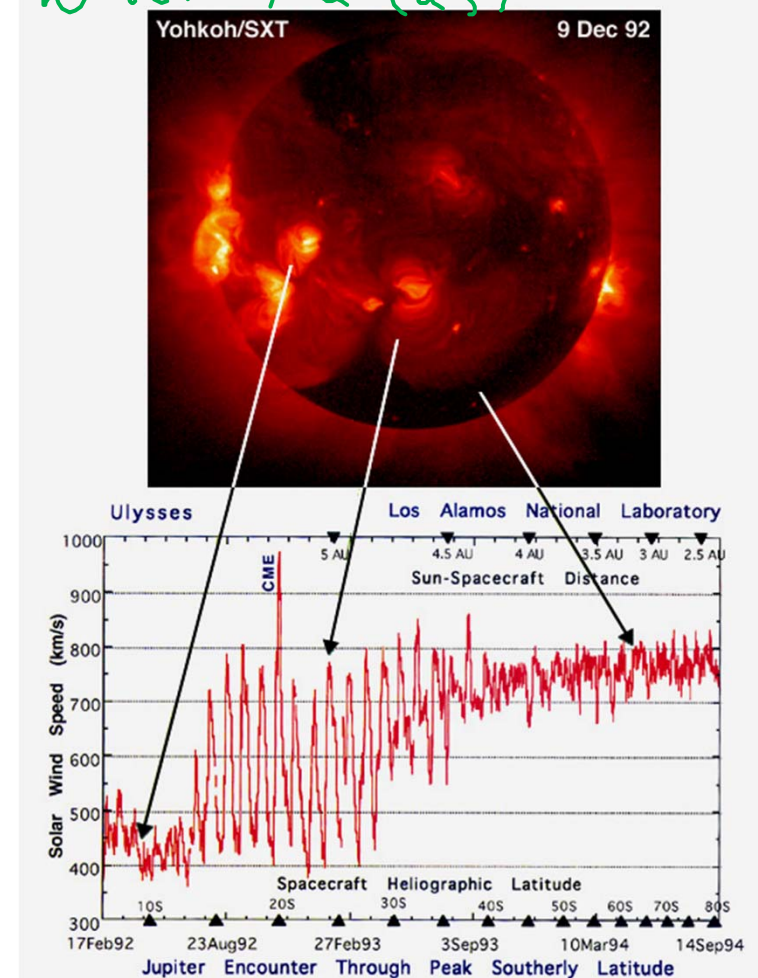
Where is the slow wind Where the fast



Geiss et al., 1995

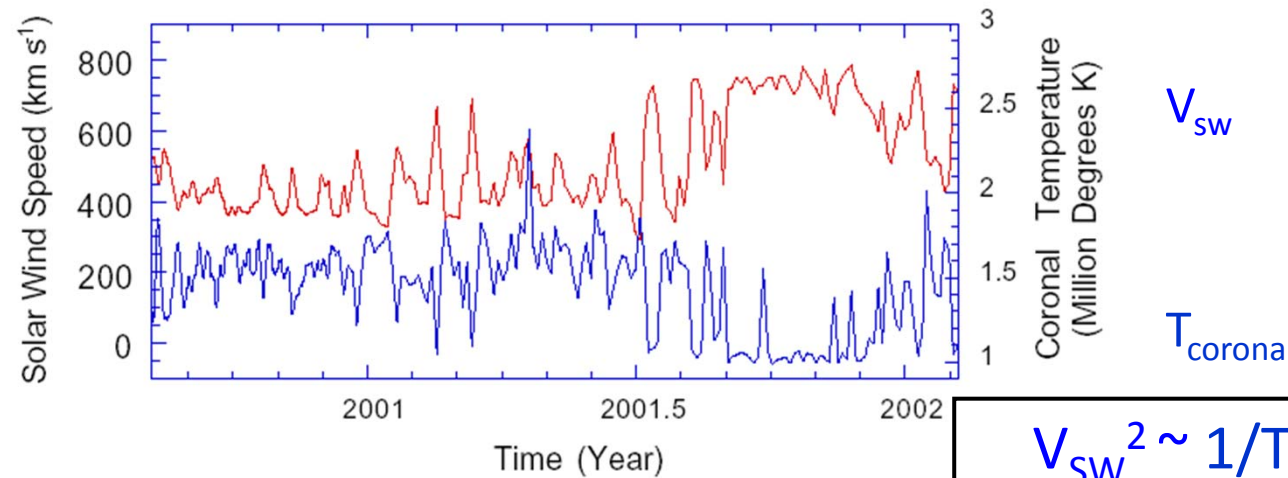
Inside Fast Streams

- Easily ionized material (low-FIP) depleted
- Low ion freezing-in temperatures (T_{FI})



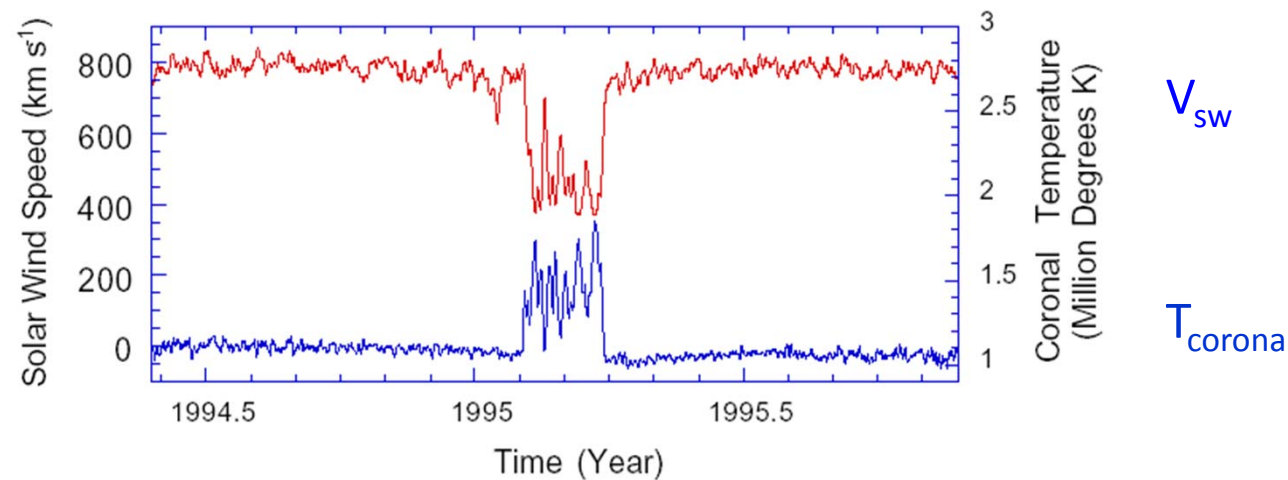
Solar wind origin

Solar
Maximum

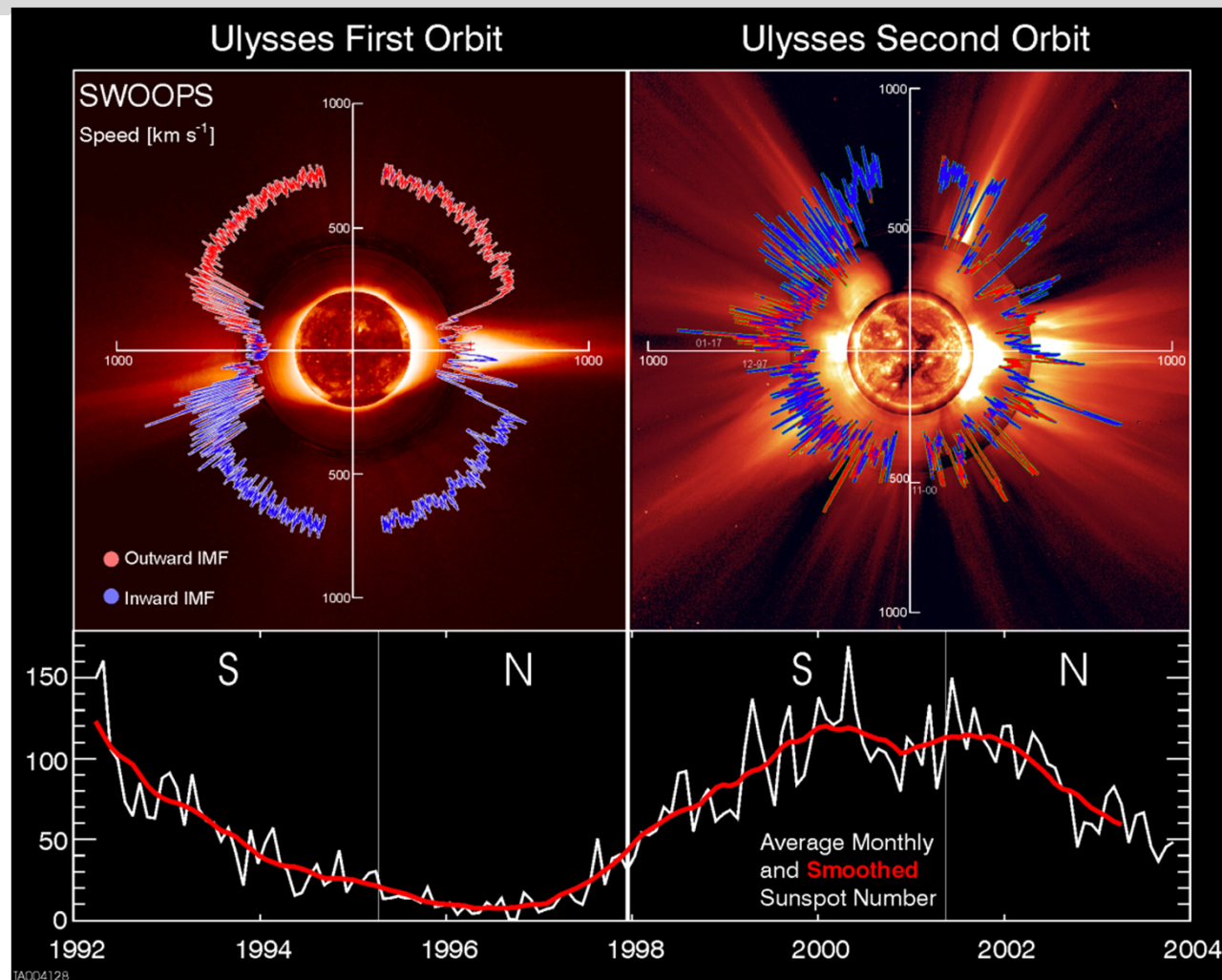


$$V_{sw}^2 \sim 1/T$$

Solar
Minimum

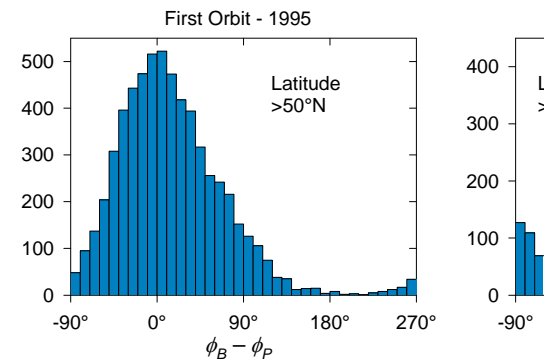
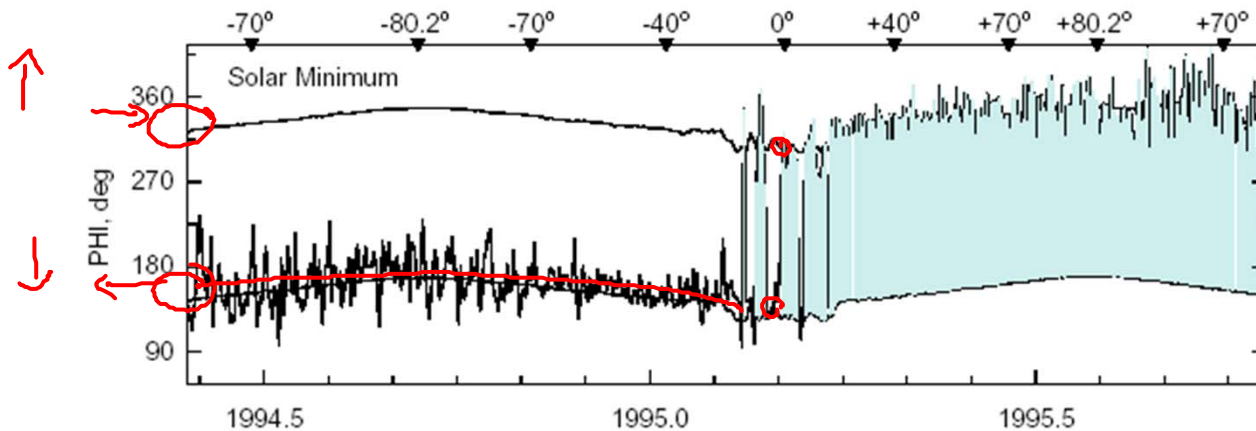
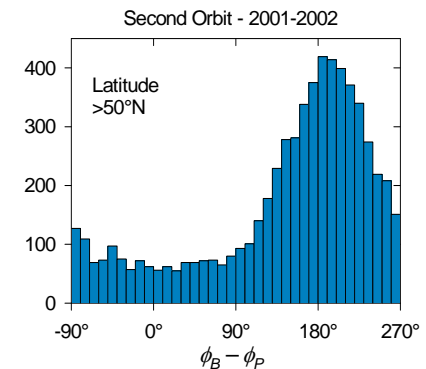
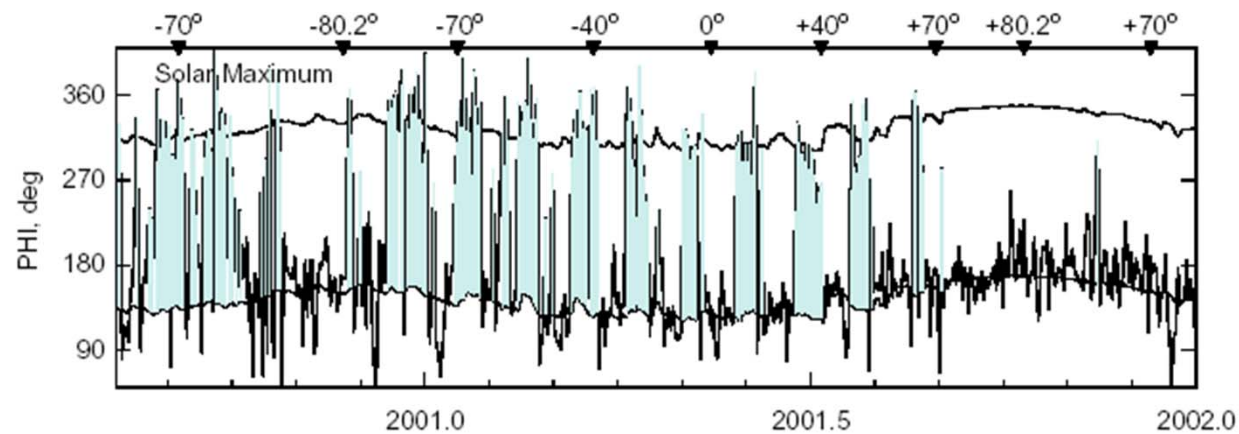


Solar minimum vs. maximum



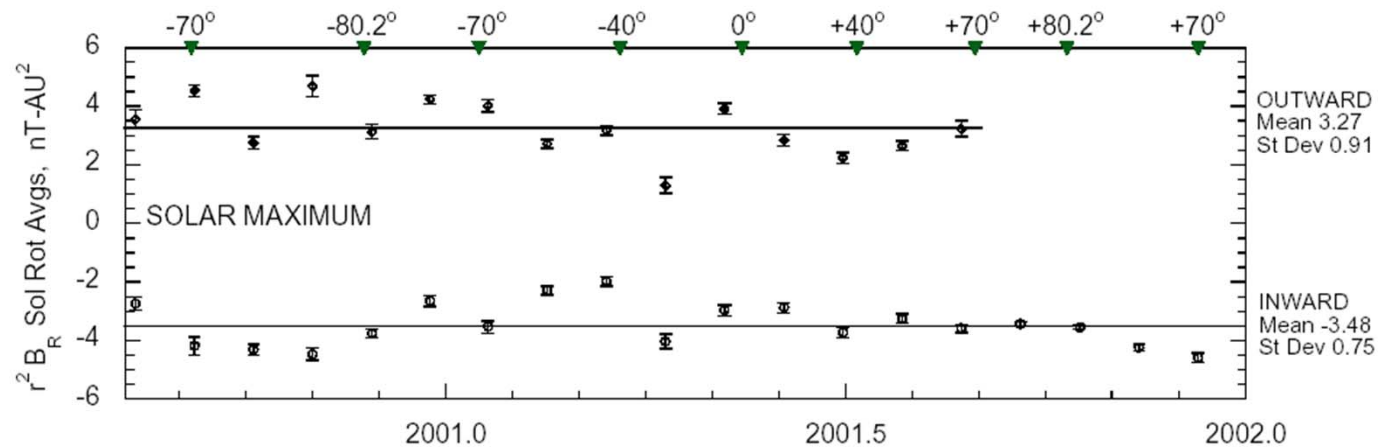
McComas et al., GRL, 2002

The heliospheric magnetic field

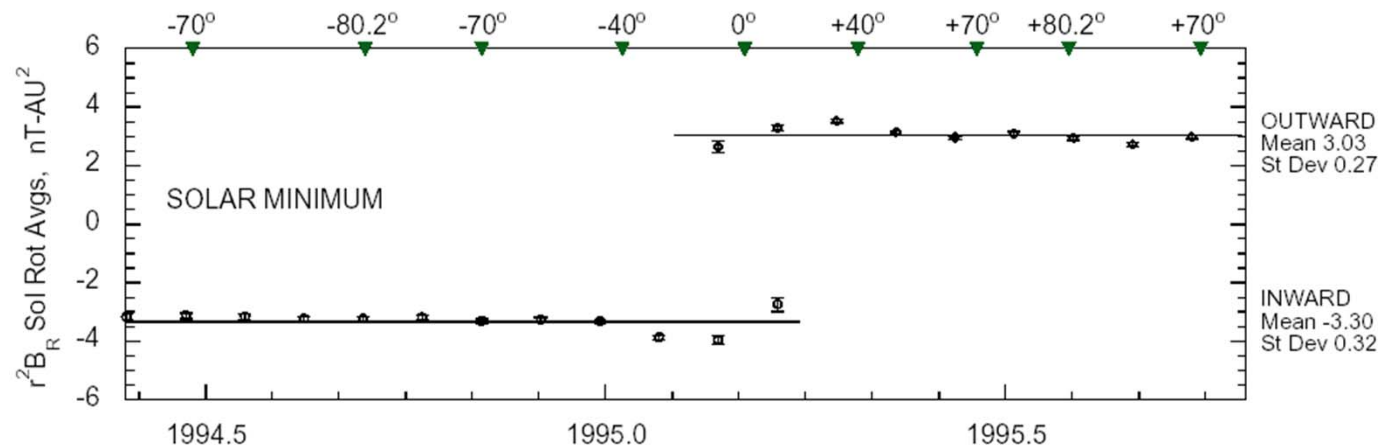


Magnetic field

Solar
Maximum



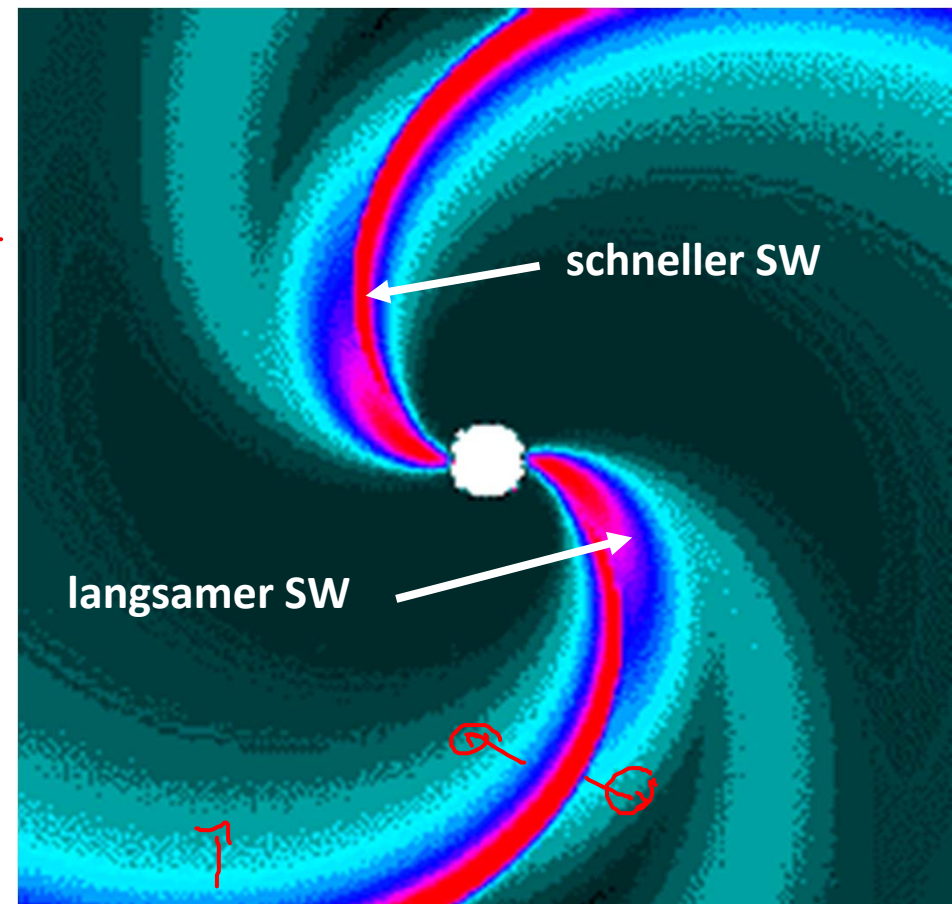
Solar
Minimum



Corotating Interaction Regions

Co-rotating particle events
Protons, helium composition
 $>10\text{ MeV}$ like the solar
electrons wind.
 $\sim 100\text{ keV}$

HS $\sim 3\text{ keV/m}$



Galactic Cosmic Rays (I)

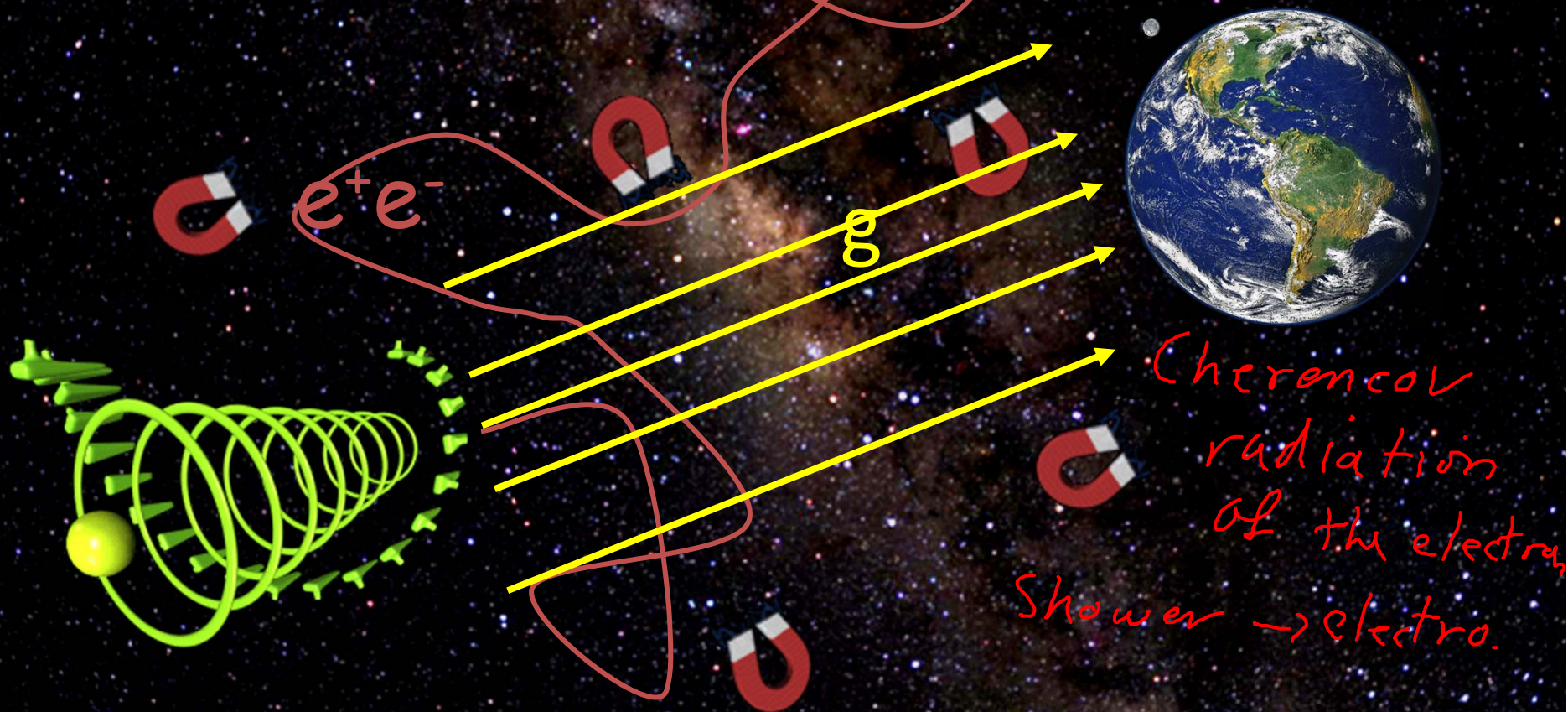
- Supernova remnant shock acceleration
~ relativistic \Rightarrow high 10^{15} eV
- Active galactic nuclei - γ -ray source
bursting
- Wolf Rayet stars
- Composition } acceleration process / B, C
Isotopes } propagation / \uparrow overabundant.
electron capture \rightarrow acceleration time

Propagation in the Galaxy

Photons: direct connection

Charged particles: Reflection in galactic magnetic fields

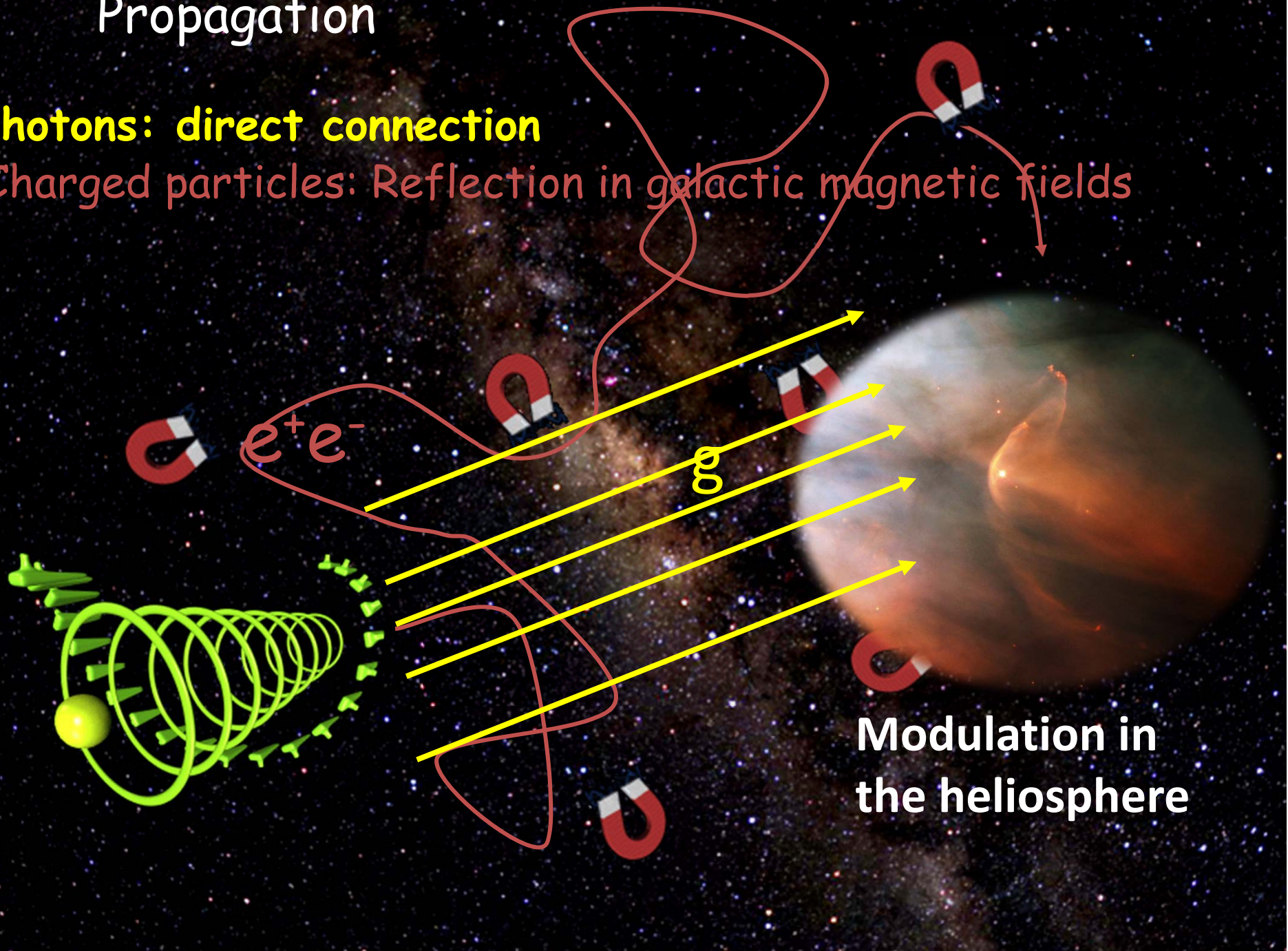
HSS, Magic



Propagation

Photons: direct connection

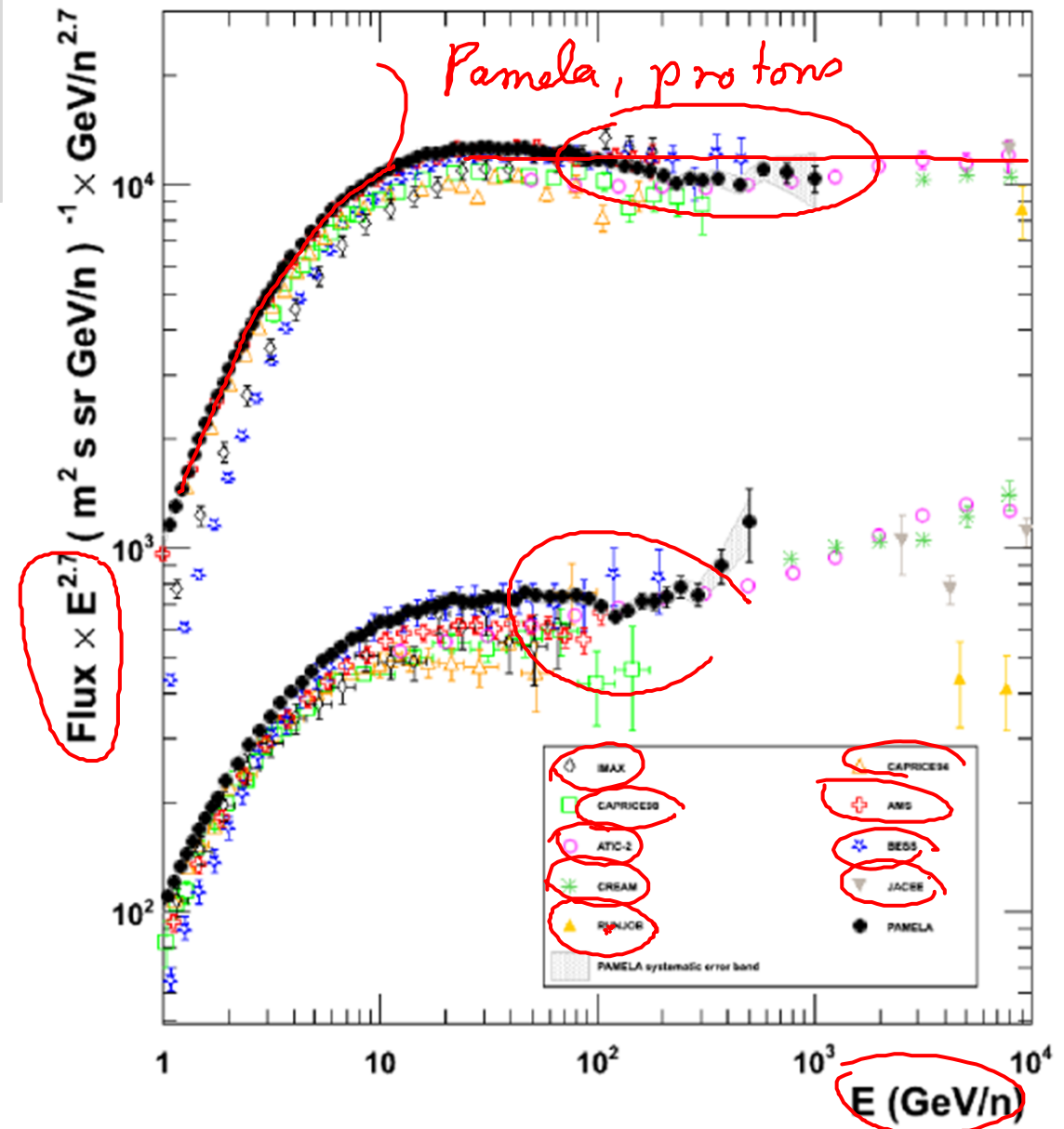
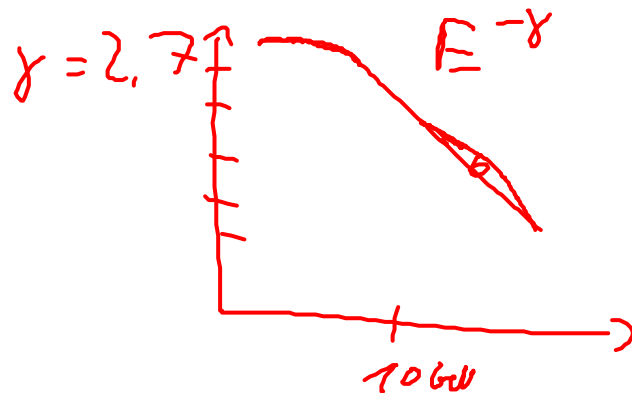
Charged particles: Reflection in galactic magnetic fields



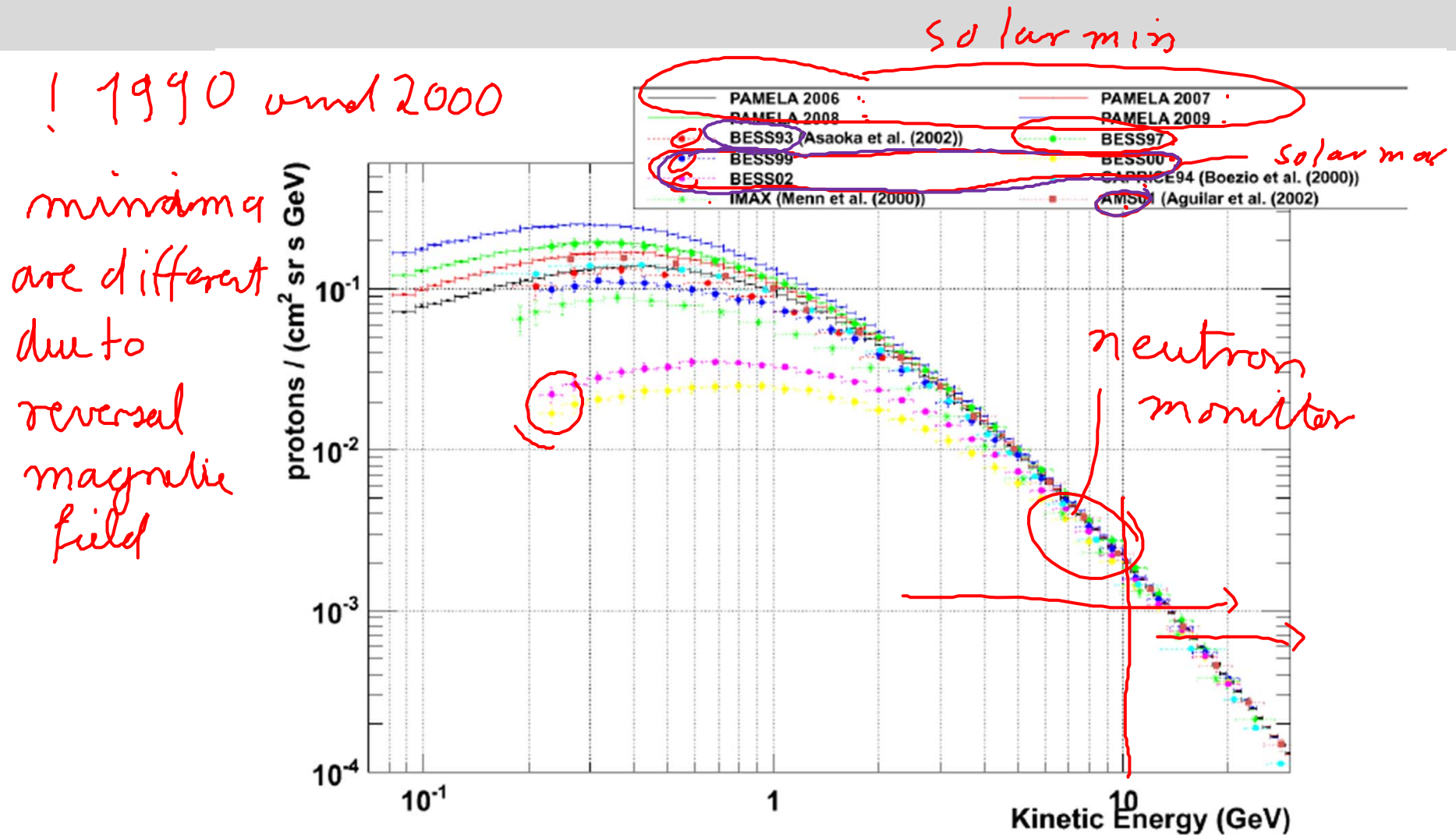
**Modulation in
the heliosphere**

Galactic Cosmic Ray Spectrum (III)

Results from Pamela

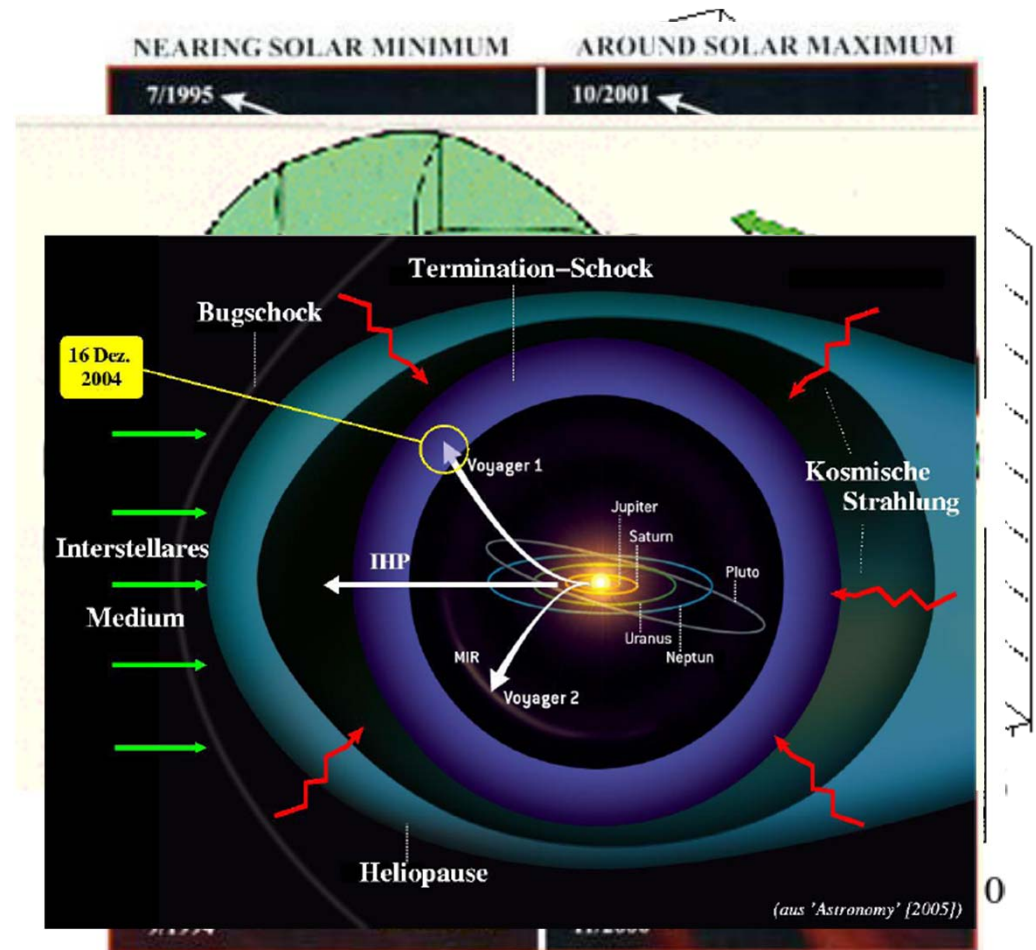


Galactic Cosmic Ray Spectrum (II)



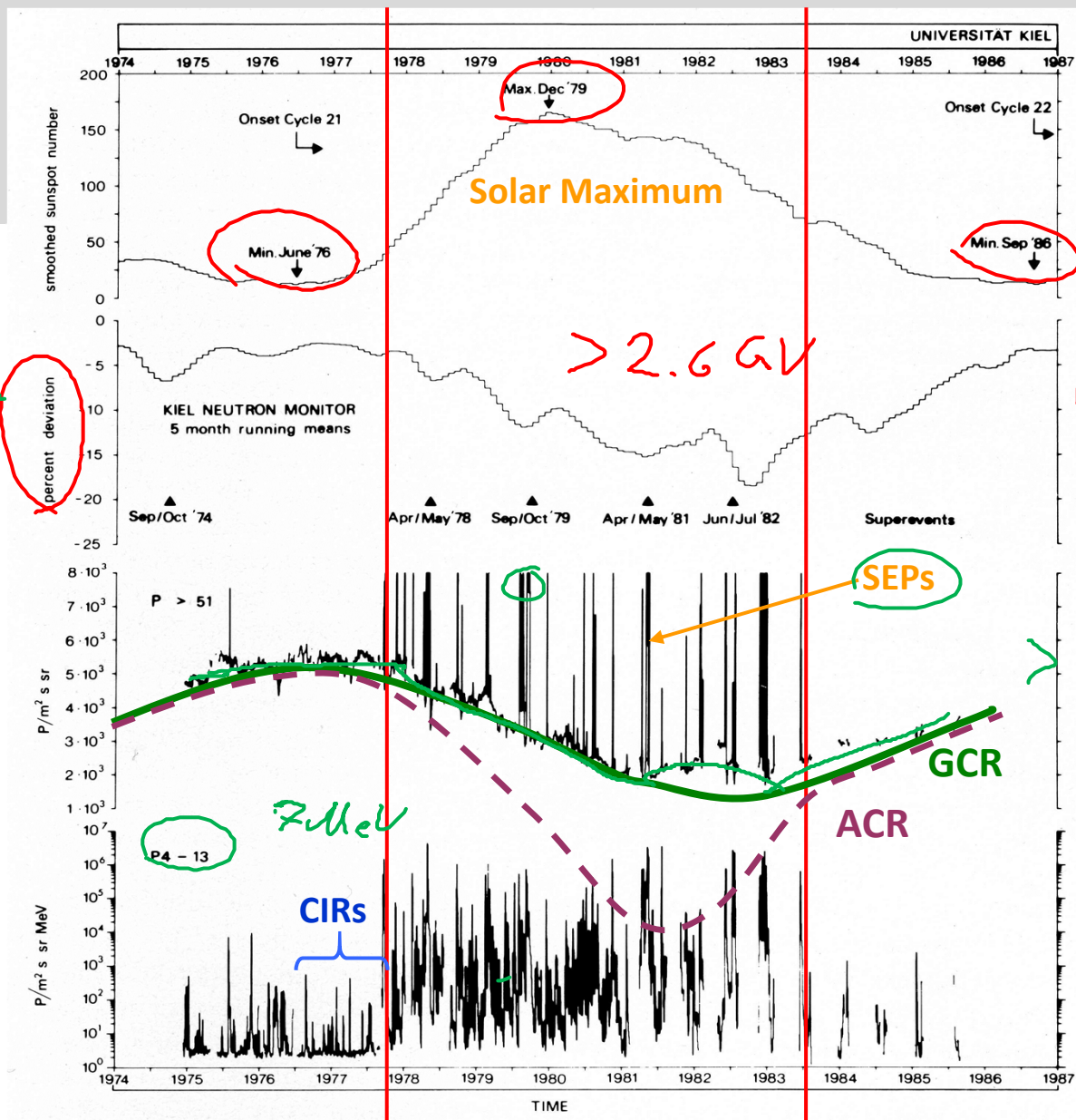
Heliospheric Propagation

1. Diffusion coefficients
2. The local Interstellar Spectrum
3. Solar wind speed
4. Heliospheric magnetic field
5. Modulation volume



Helias

Solar
Emergent
Particles



Kiel neutron
monitor

> 1.2 GV

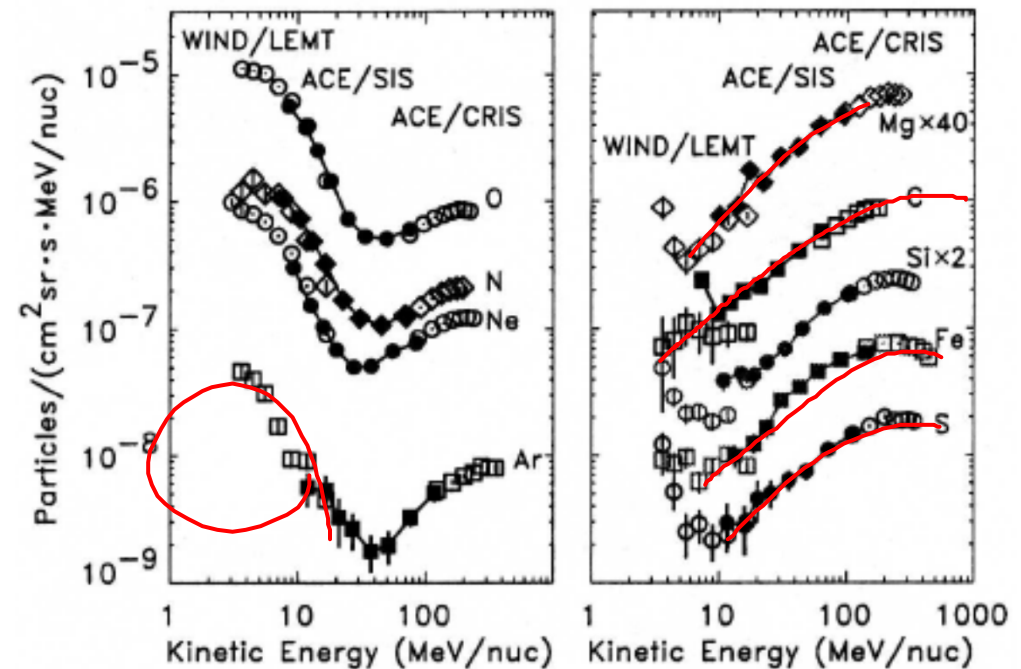
Anomalous Cosmic Rays (I)

- Galaxy has neutral Particles
- move into the heliosphere
- Ionized by EUV, collision by solar wind ions
- Picked up by the solar wind and taken with
- accelerated in the outer heliosphere

Anomalous Cosmic Rays (II)

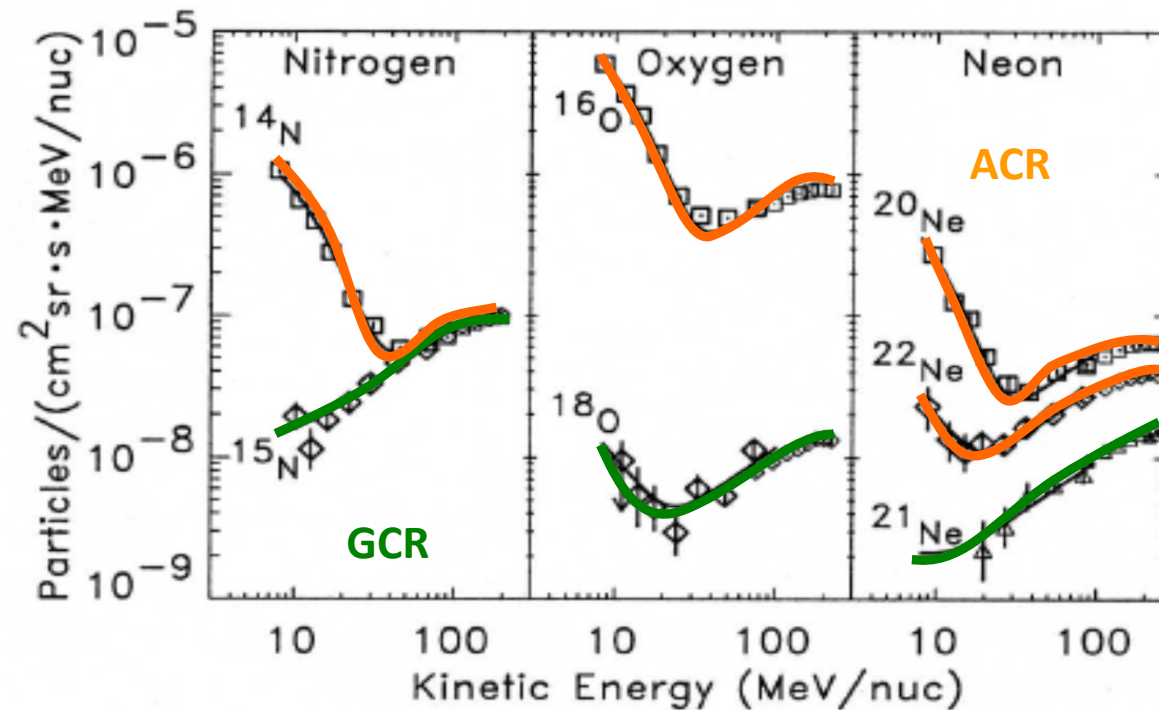
Pickup Ions

Spectral
Shape

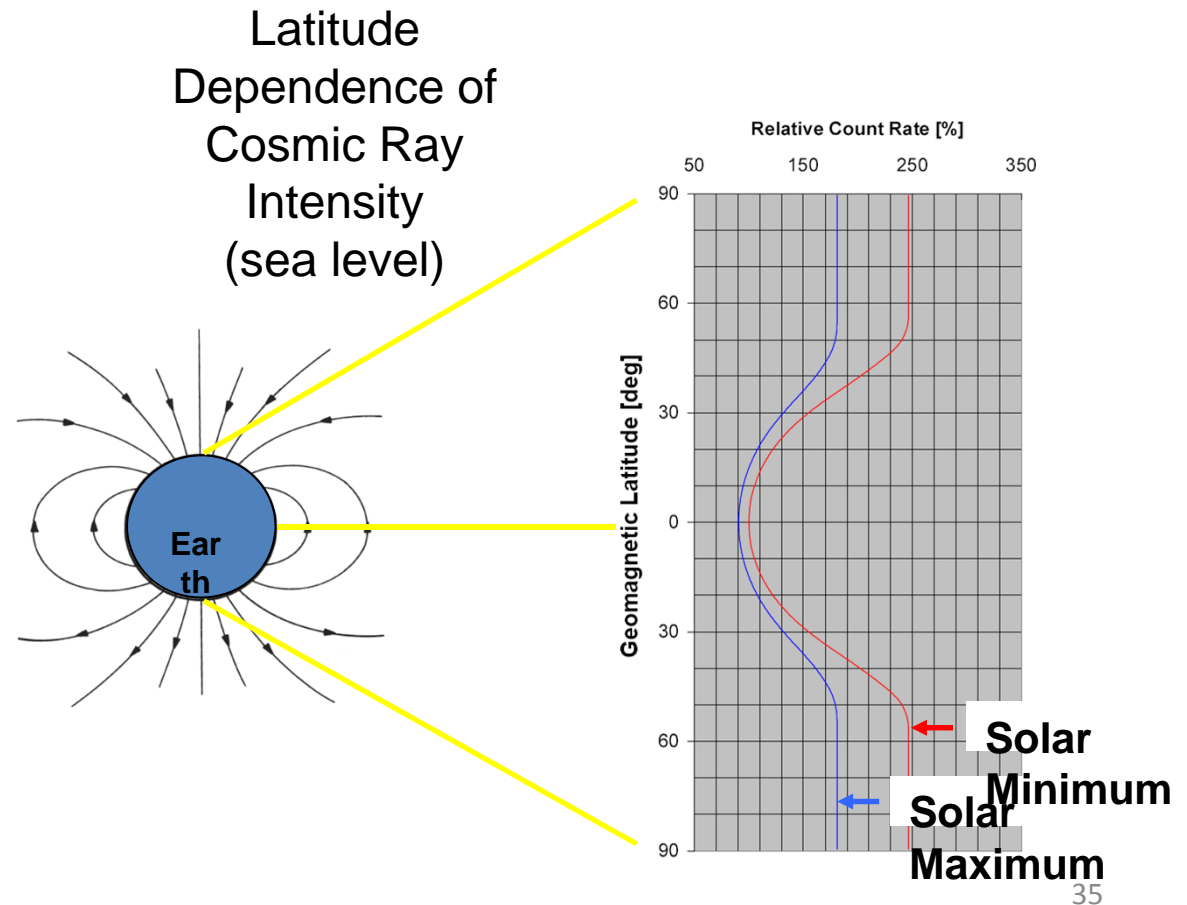


Anomalous Cosmic Rays (III)

isotopes

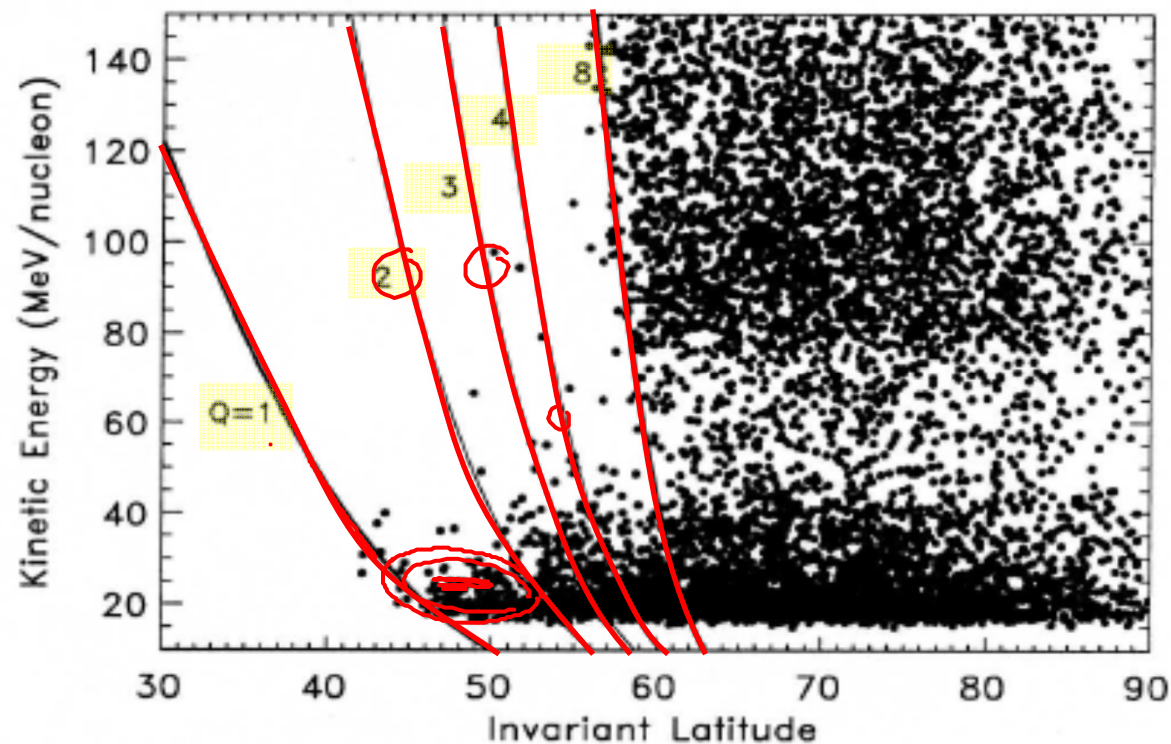


Anomalous Cosmic Rays (IV)



Anomalous Cosmic Rays (V)

acceleration time / SDE



Temporal variation with the solar cycle

