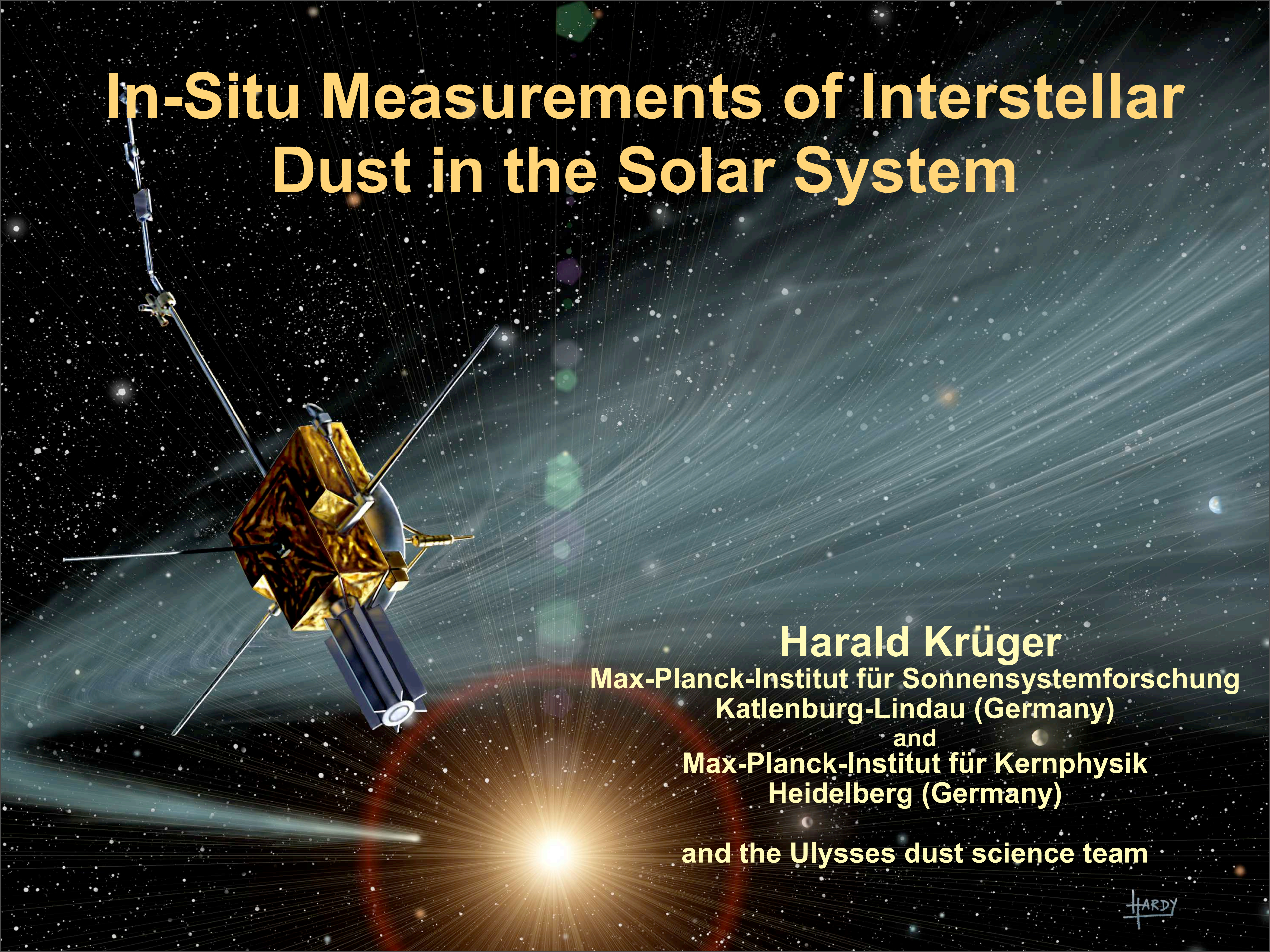
In-Situ Measurements of Interstellar Dust in the Solar System



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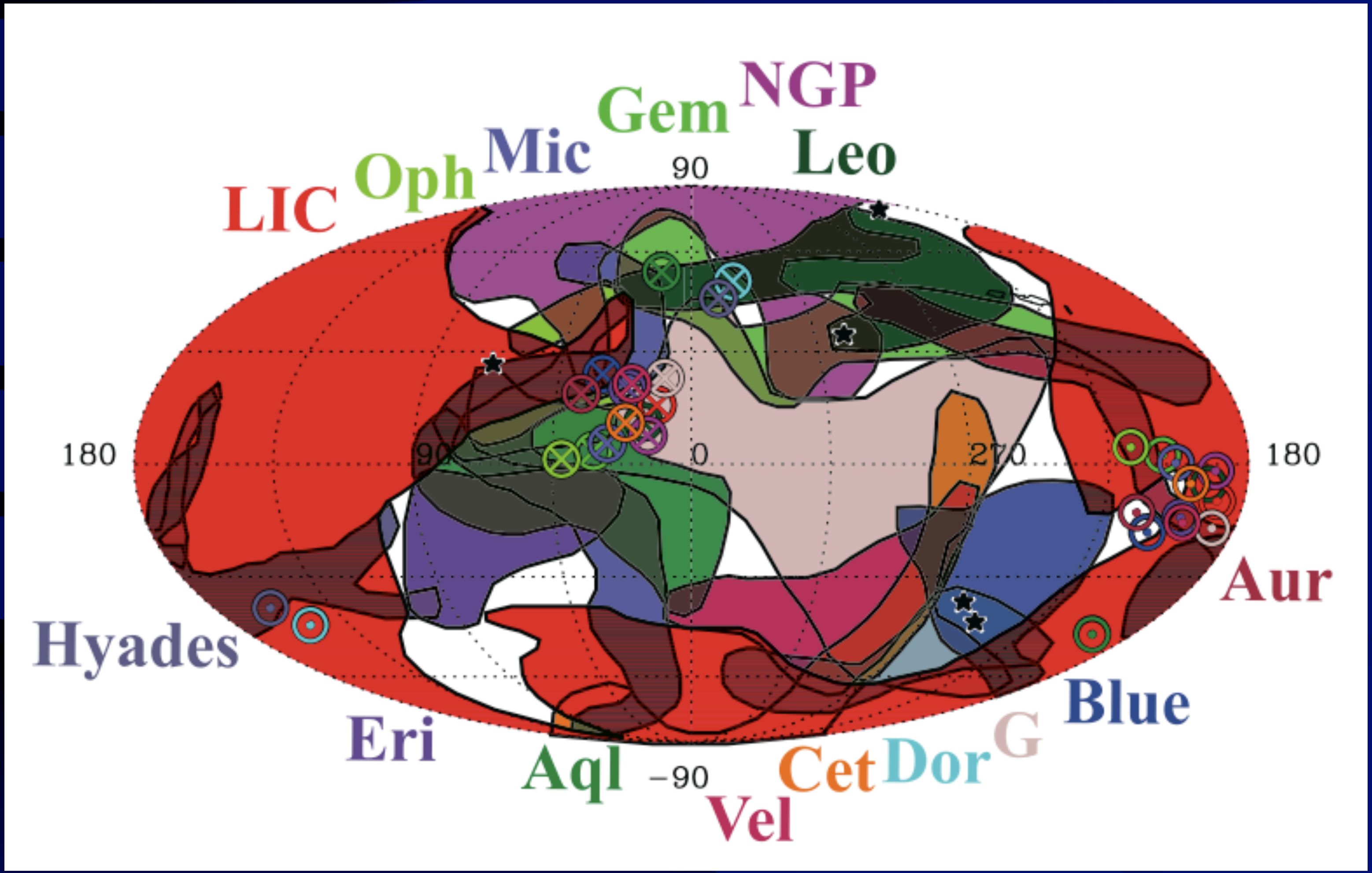
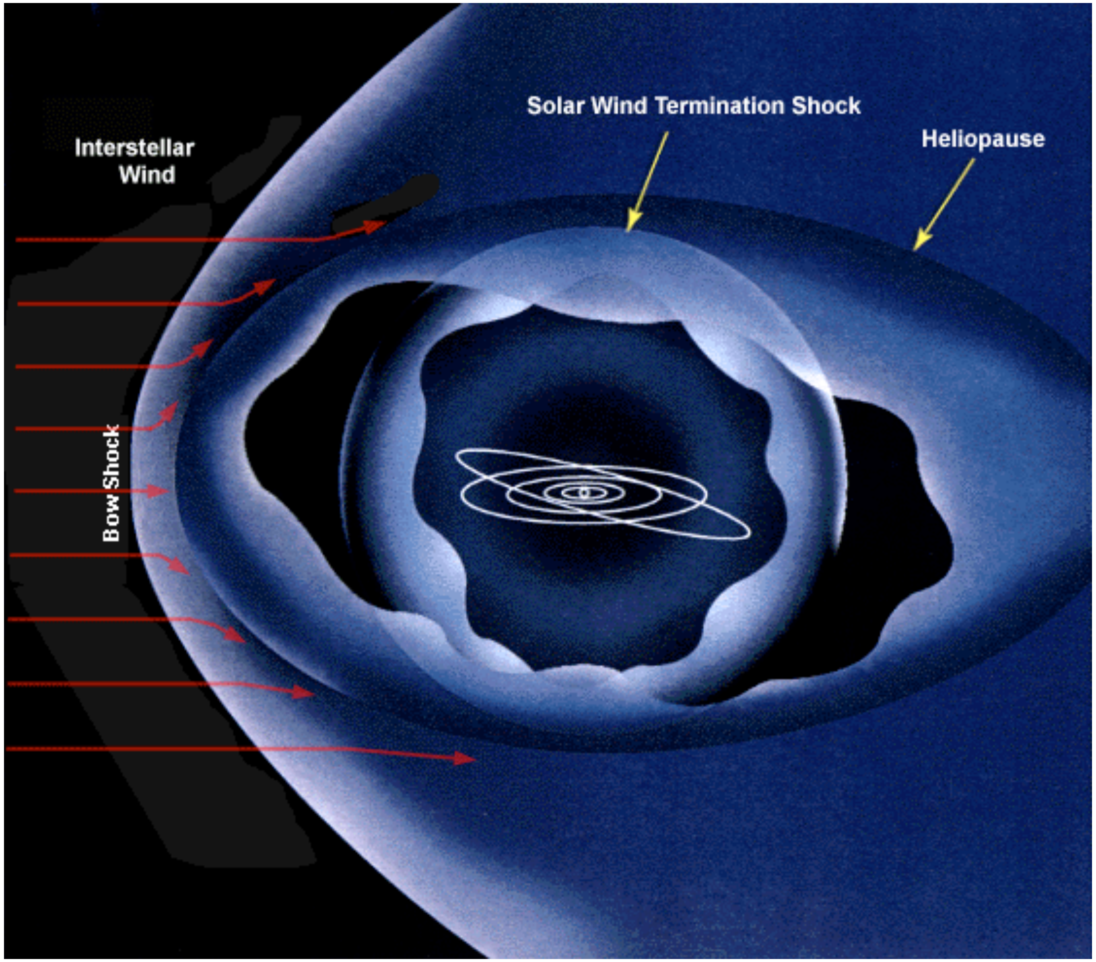
and the Ulysses dust science team

Our Galactic Environment
(in Galactic Coordinates)

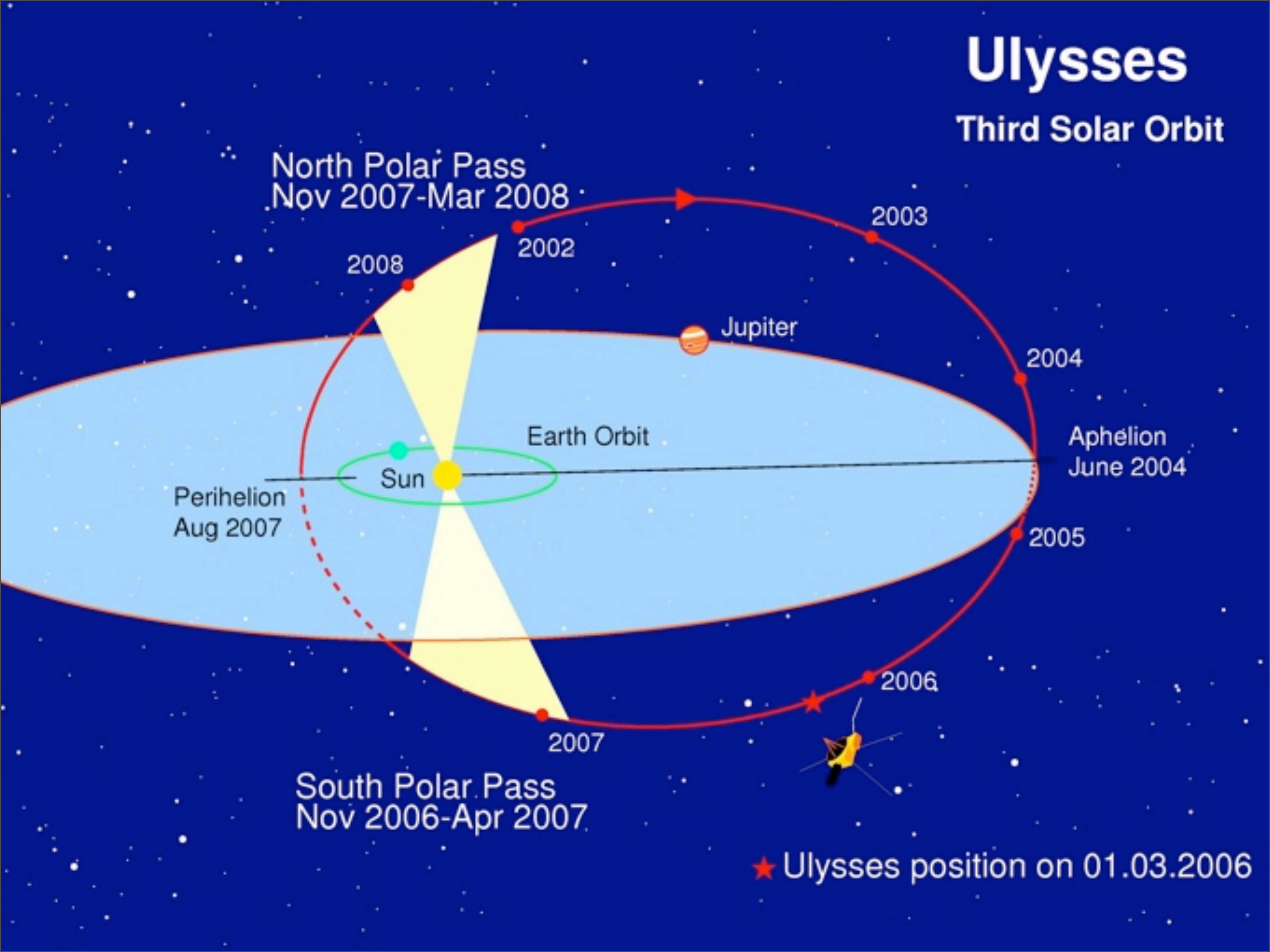


At least 15 clouds identified within 15pc of the Sun (Redfield & Linsky 2008).
Our Sun located at the transition zone of the LIC and the G cloud.

The Heliosphere



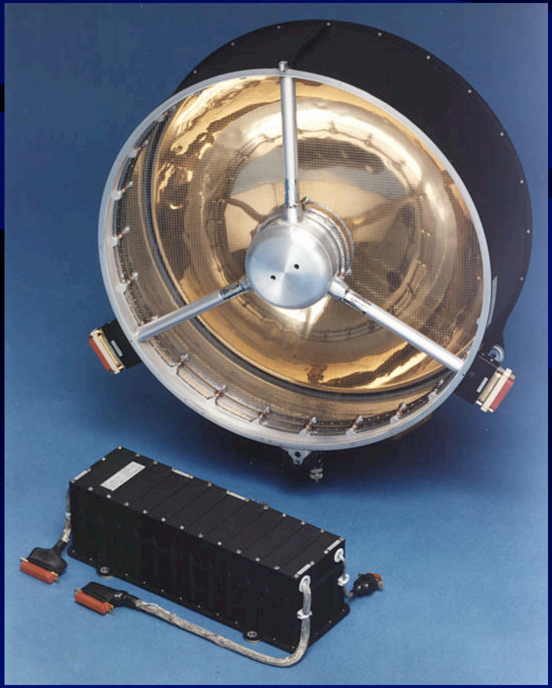
The Sun (and the helisophere) moves with ~ 26 km s^{-1} through our local interstellar environment.

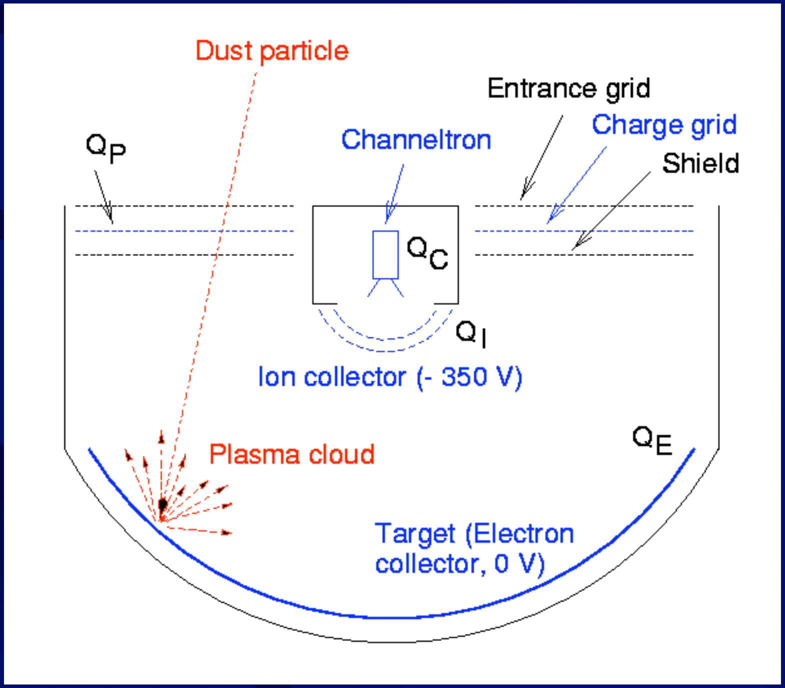


Ulysses
Third Solar Orbit
North Polar Pass
Nov 2007-Mar 2008
2002
2003
2008
Jupiter
2004
Earth Orbit
Aphelion
June 2004
Sun
Perihelion
Aug 2007
2005
2006
2007
South Polar Pass
Nov 2006-Apr 2007
Ulysses position on 01.03.2006

Ulysses/Galileo In-Situ Dust Detectors

- Multi-coincidence impact ionization detector
- 0.1 m^2 sensitive area
- 140° field of view
- Measurement of mass, speed and impact direction
- Mass range: 10^{-19} - 10^{-9} kg (~ 0.1 - 10 μm radii)
- Speed range: 2 - 70 km s^{-1}

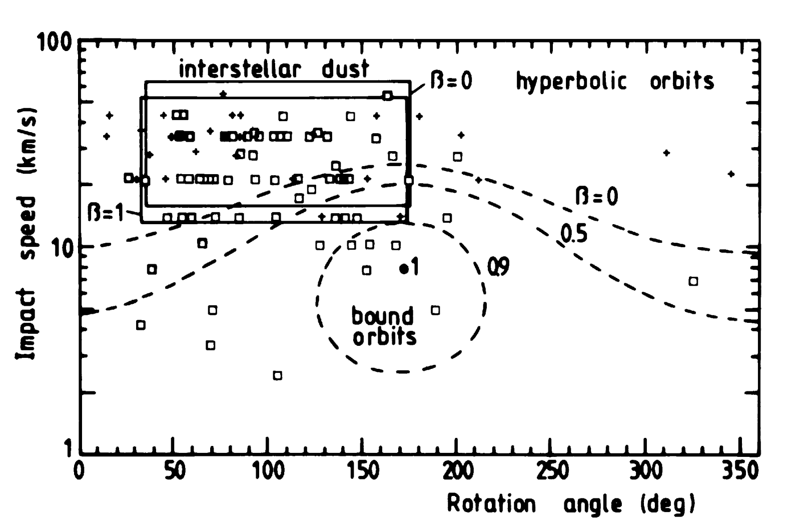




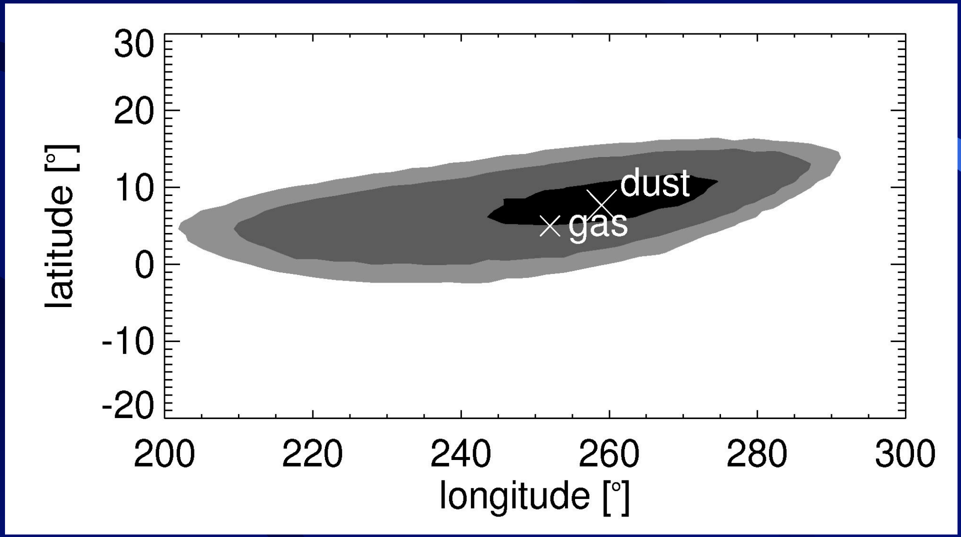
Grün et al. 1992

Identification of Interstellar Grains in the Solar System

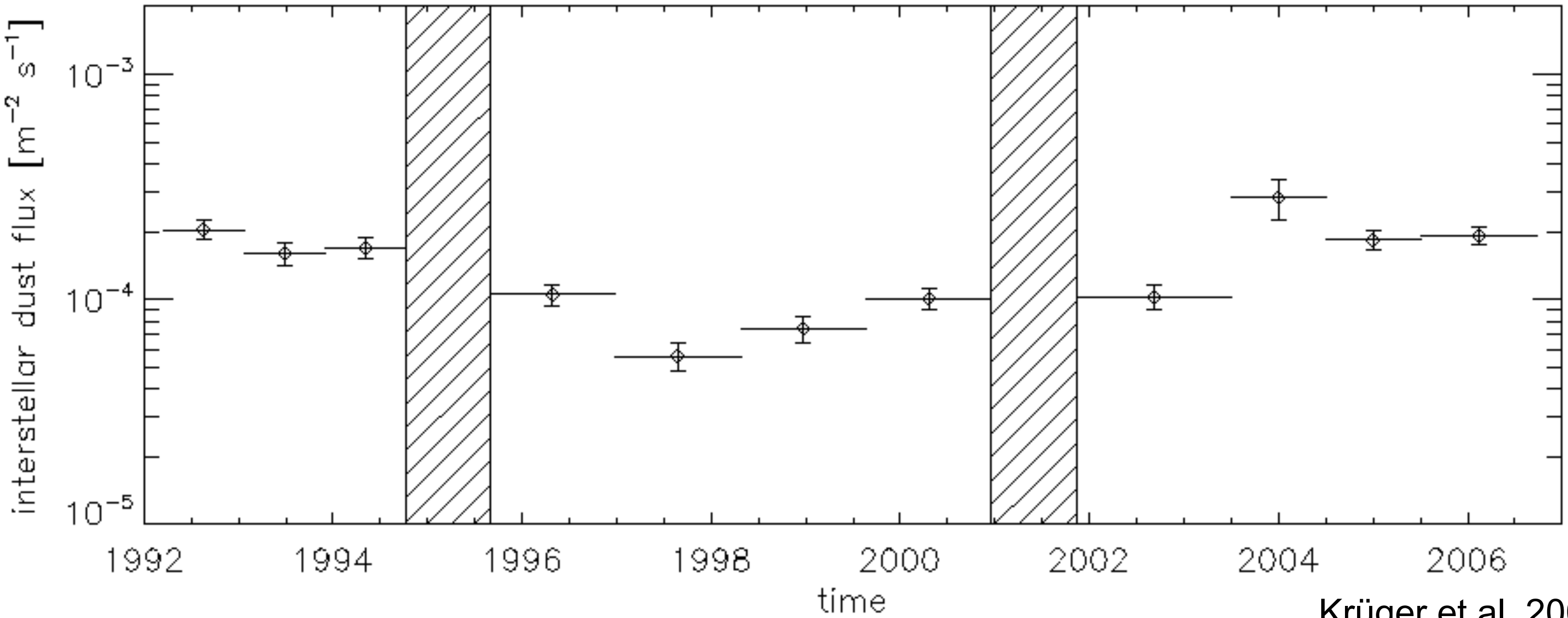
- Ulysses (3-5 AU) identified dust grains on retrograde hyperbolic orbits: speed > 26 km s^{-1} (Grün et al. 1994)
- Flow direction coincides with interstellar helium gas flow (Witte et al. 1996, 2004)



- Flux is independent of ecliptic latitude.
- Very small intrinsic velocity dispersion: stream very well collimated (Altobelli et al., 2003)
- Confirmed by Galileo and Cassini



Ulysses Interstellar Dust Flux Monitoring

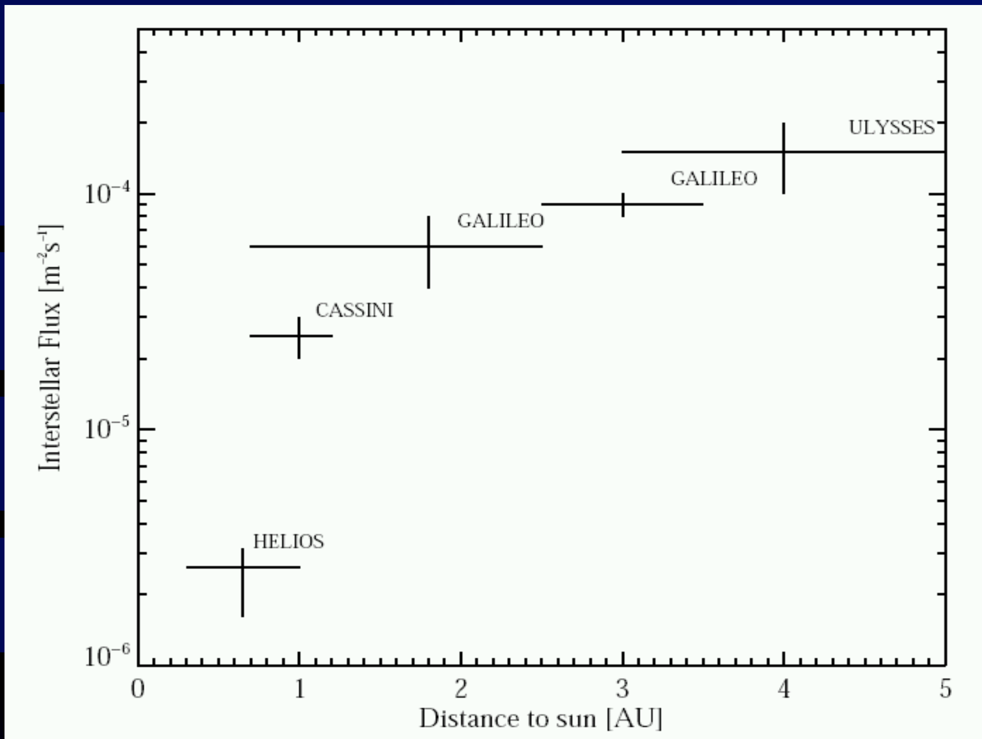


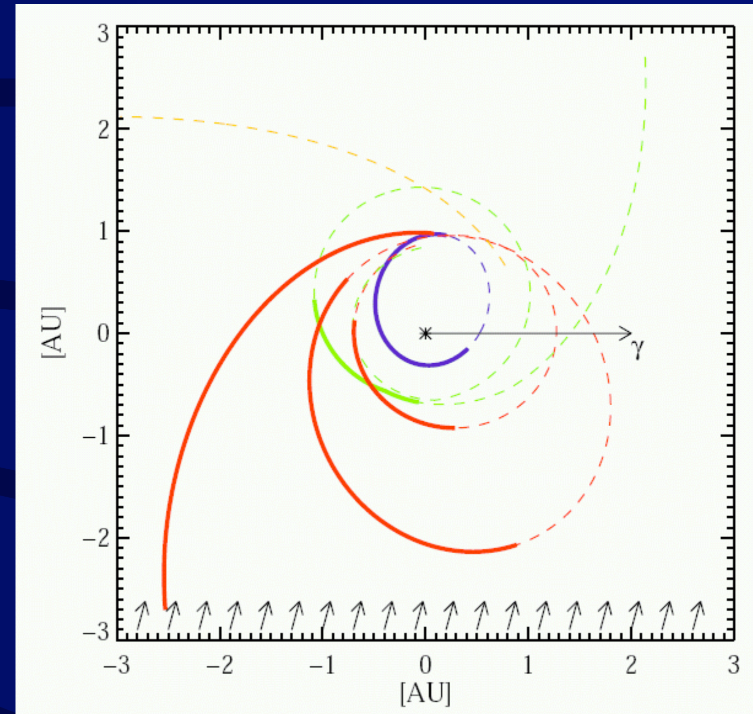
Krüger et al, 2007

Model with solar gravity, radiation pressure and Lorentz force due to IMF explains flux variation until 2003; β=1.1, corresponding to ~ 0.3 μm grains gives best agreement (Landgraf 2000, Landgraf et al. 2003).

Minimum in 1997-99 explained by reversal in IMF polarity (~6 years delay due to grain motion through heliosphere)

The Heliosphere: A Giant Mass Spectrometer





Altobelli et al, 2005

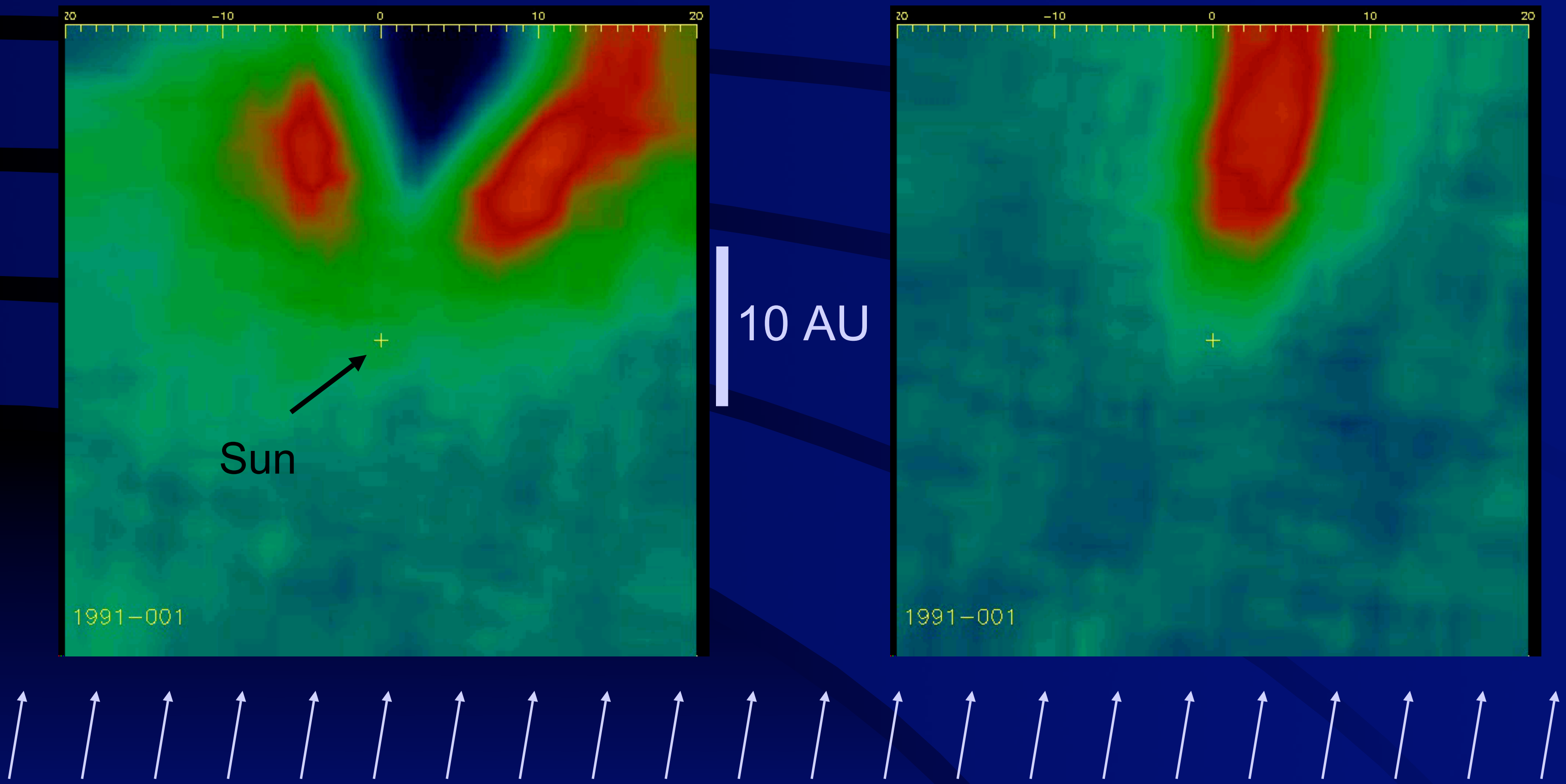
Helios Galileo Ulysses Cassini

- Interstellar dust flux is modified due to radiation pressure filtering in the heliosphere ⇒ β spectroscopy (Altobelli et al. 2005)
- β depends of grain size and material properties
- Best agreement with particle dynamics for astronomical silicates

Flow of Interstellar Grains Through the Solar System

s = 0.2 µm

s = 0.9 µm

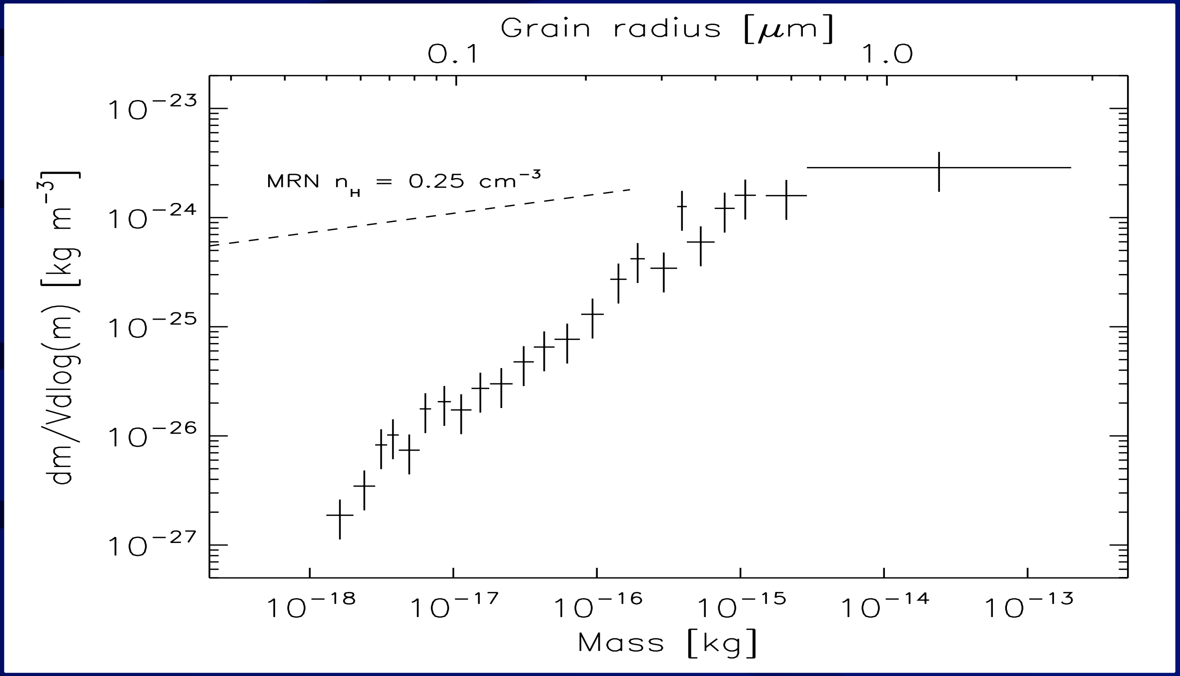


Interstellar dust flow

Landgraf, 2000

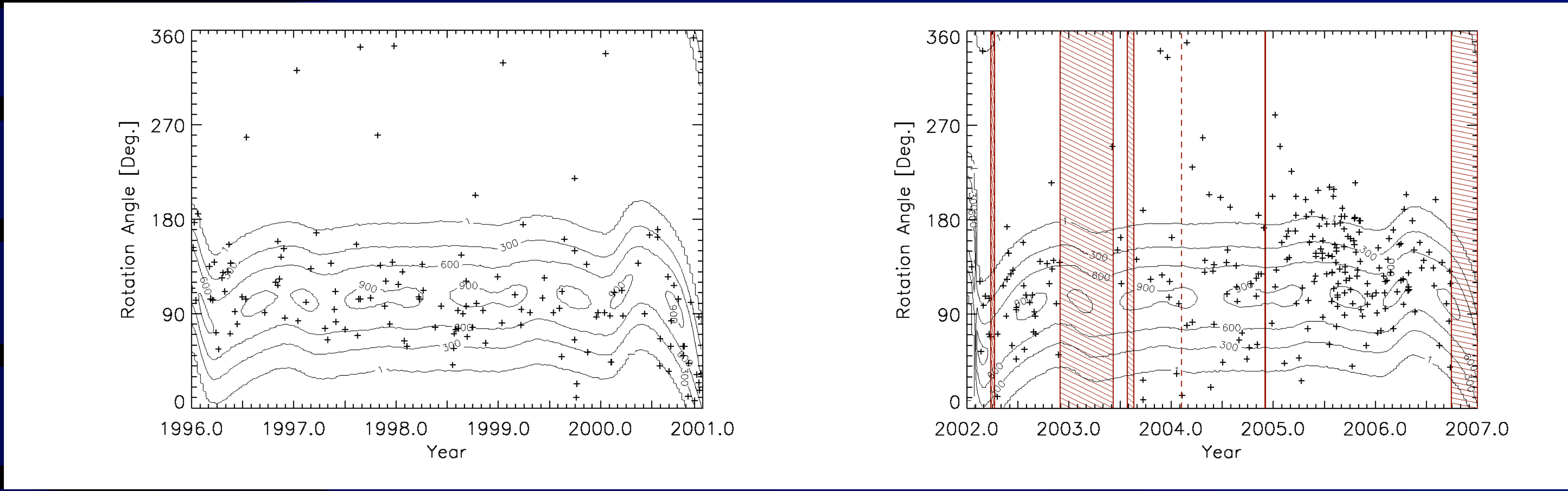
Size Distribution of Interstellar Particles

Insterstellar dust data set from entire Ulysses mission (Krüger et al. 2008)

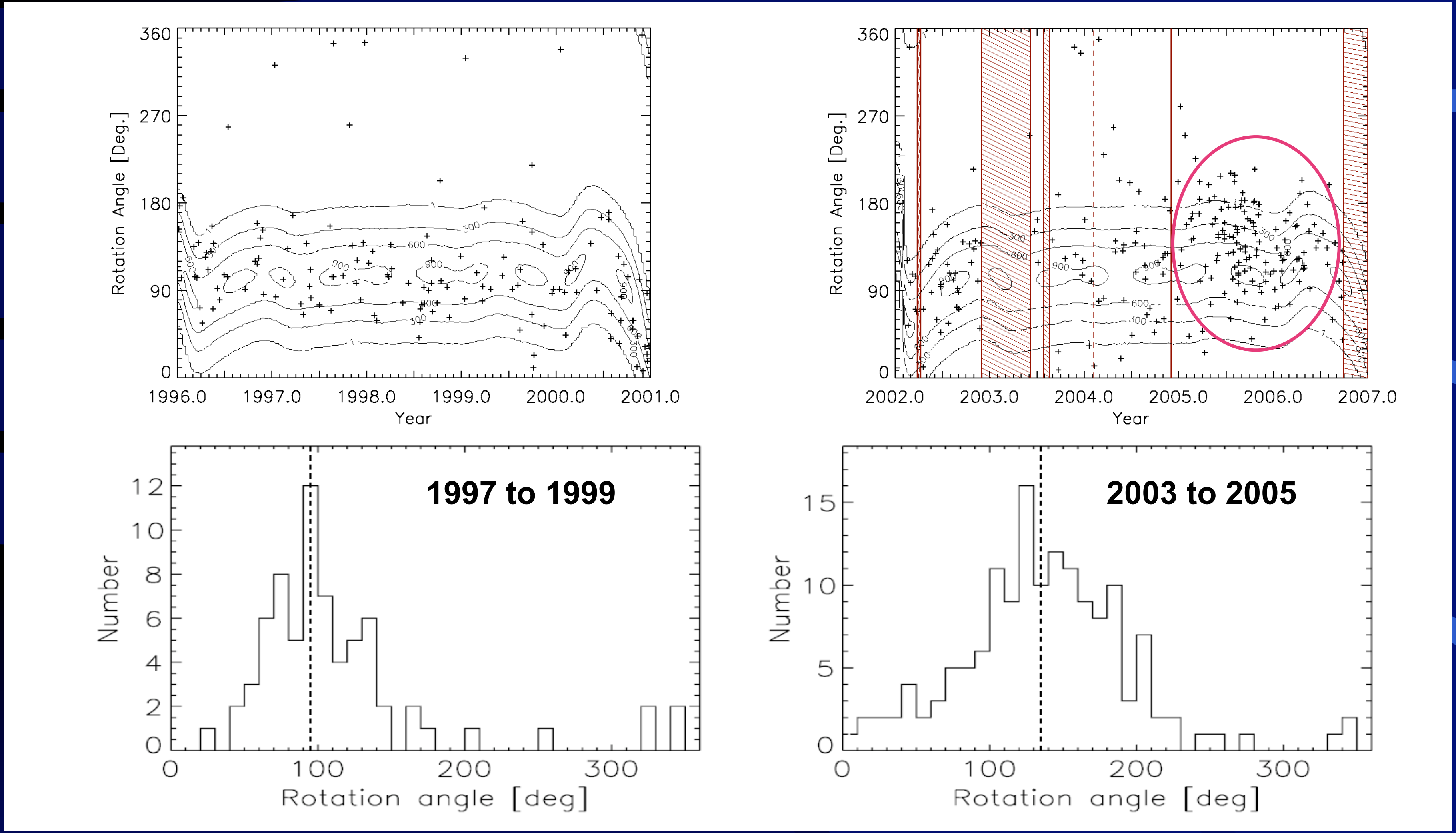


- MRN distribution derived from astronomical observations (interstellar extinction curves), cutoff at ~0.3 μm (Mathis 1977).
- Size distribution extends to bigger grains than is accessible with astronomical observations;
- Gas-dust mass ratio $R_{g/d}$ = 116-127 in LIC (Landgraf et al. 2000, Altobelli et al. 2004).
- $R_{g/d}$ = 149-217 in ISM (from astronomical observations; Slavin & Frisch 2008).
- ⇒ LIC enriched in dust by factor 1.5 - 2 compared to mean cosmic abundances.

Interstellar Dust Flow Direction

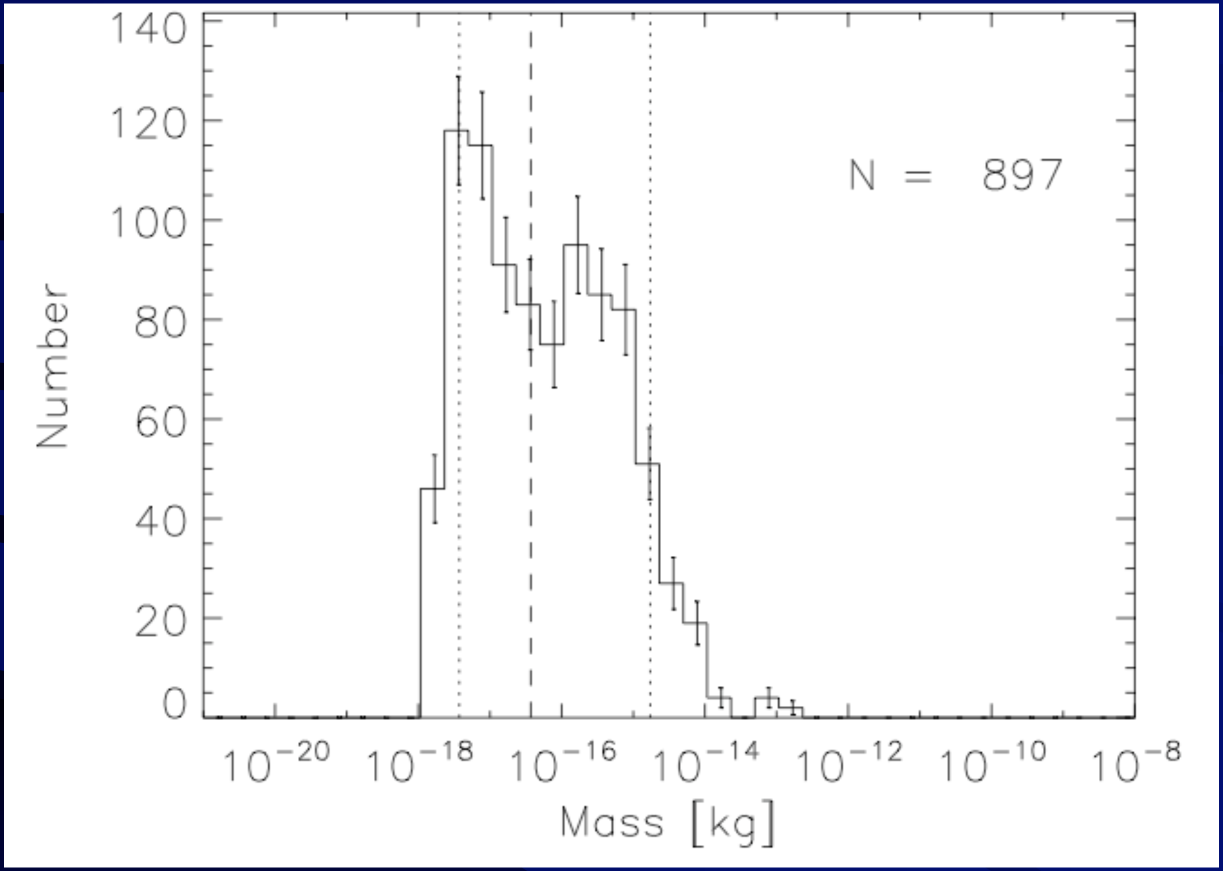


Interstellar Dust Flow Direction



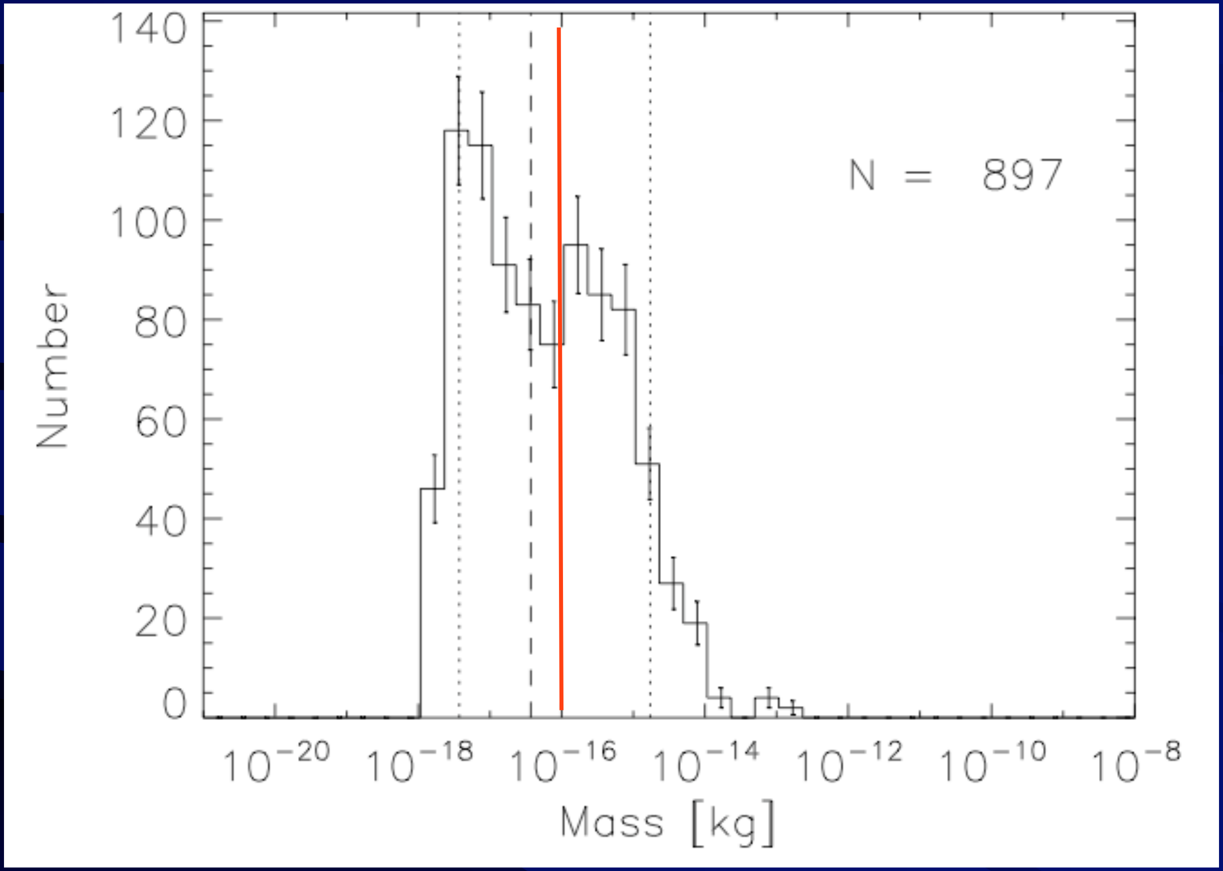
- **2005/2006: ~30° shift of interstellar dust flow direction from neutral helium flow (indicated by red circle). No such deviation seen six years earlier (Krüger et al., 2007).**

Size Distribution and Flow Direction of Interstellar Particles



Data set from entire mission (897 particles).

Size Distribution and Flow Direction of Interstellar Particles



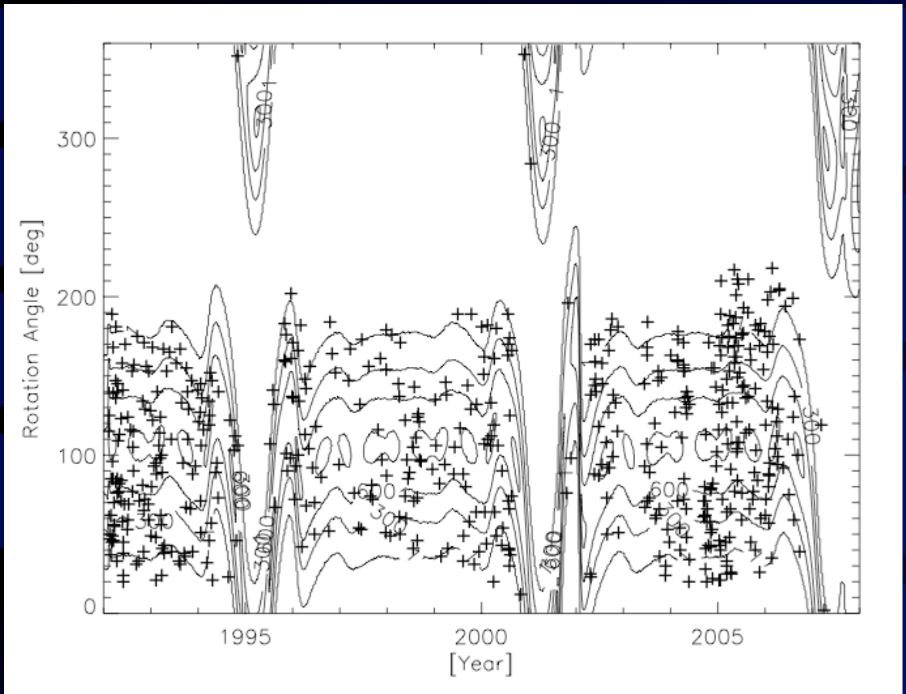
Data set from entire mission (897 particles).

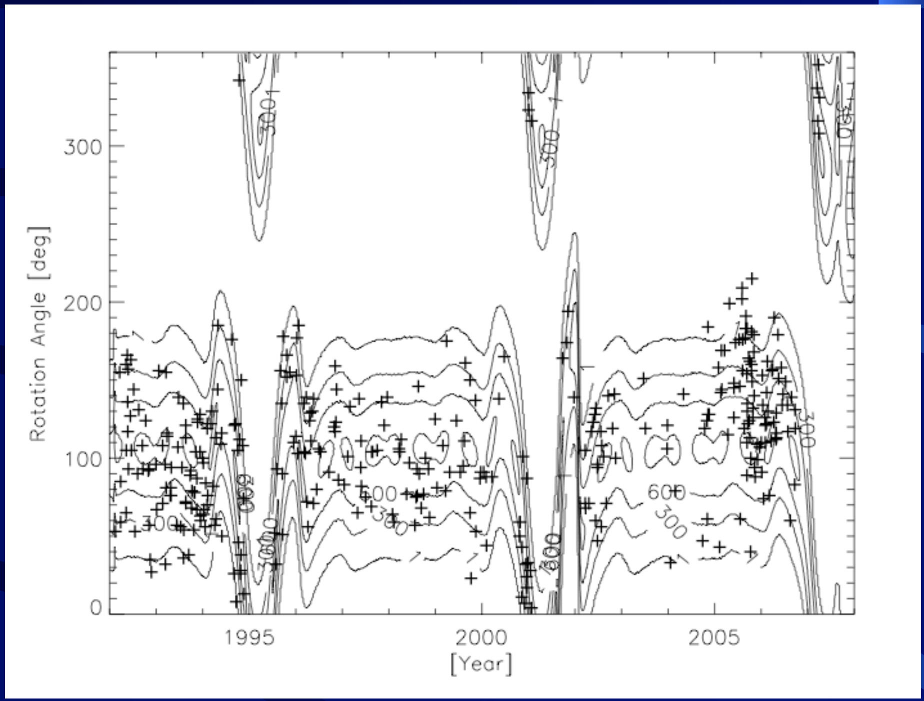
Size Distribution and Flow Direction of Interstellar Particles

m < 10^{-16} kg

m > 10^{-16} kg

MRN distribution





- Shifted population dominated by ‘big’ particles > 0.2 µm.

Conclusions

- Interstellar dust penetrates deeply into the heliosphere (measured from 0.3 to 5.3 AU).
- Flux modulation due to interaction with interplanetary magnetic field and radiation pressure filtering.
- Interstellar dust mass distribution can be inferred at sizes which are inaccessible to usual optical observations.
- Data from entire mission confirm mass distribution, in particlular the existence of ‘big’ interstellar grains discovered by Landgraf et al. (1998).
- 30^{o} shift in impact direction of particles > 10^{-16} kg in 2005/06. Reason unclear. Due to IMF or intrinsic in interstellar dust approach direction?
- Dust-gas mass ratio in local interstellar cloud (LIC) enriched by factor 1.5 - 2 compared to mean cosmic abundances (Slavin & Frisch 2008).

Ongoing work!