

# Heliospheric physics by plan-A

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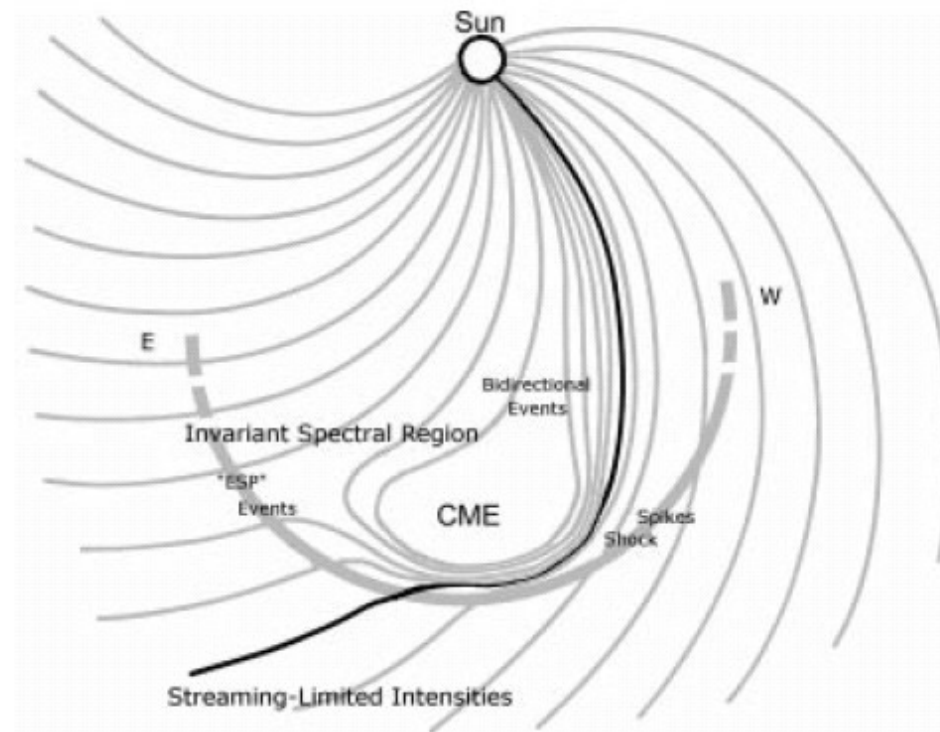
- Heliospheric imager and in-situ measurements have been in “option” list for plan-A. Little discussion so far, though.
- Heliospheric imager
- Cosmic ray

# Heliospheric imaging

by bringing STEREO/HI-like imager to high latitude

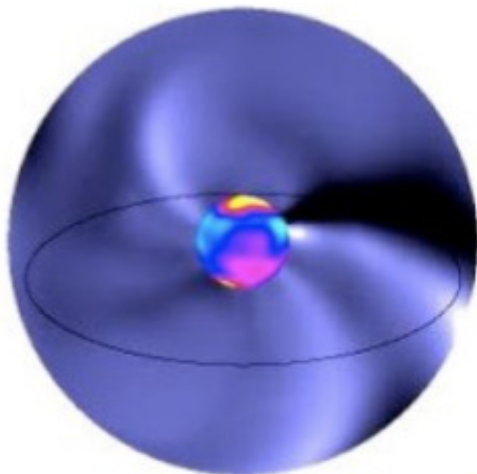
Interplanetary Coronal Mass Ejections (iCME) and Corotating Interaction Region (CIR) have been imaged by STEREO/Heliospheric Imager (HI)

# Top-view different from side-view



Reames 1999

CIR can be imaged by  
~6hour exposure  
(Hara-san's talk)



K. Hayashi

Figure 3.7. A map is shown of the location of various SEP population and phenomena with respect to the CME and shock. The observation of these phenomena at a particular energy will depend upon : width and speed of the CME, the strength of the shock, and the path of the spacecraft through the panning structure.

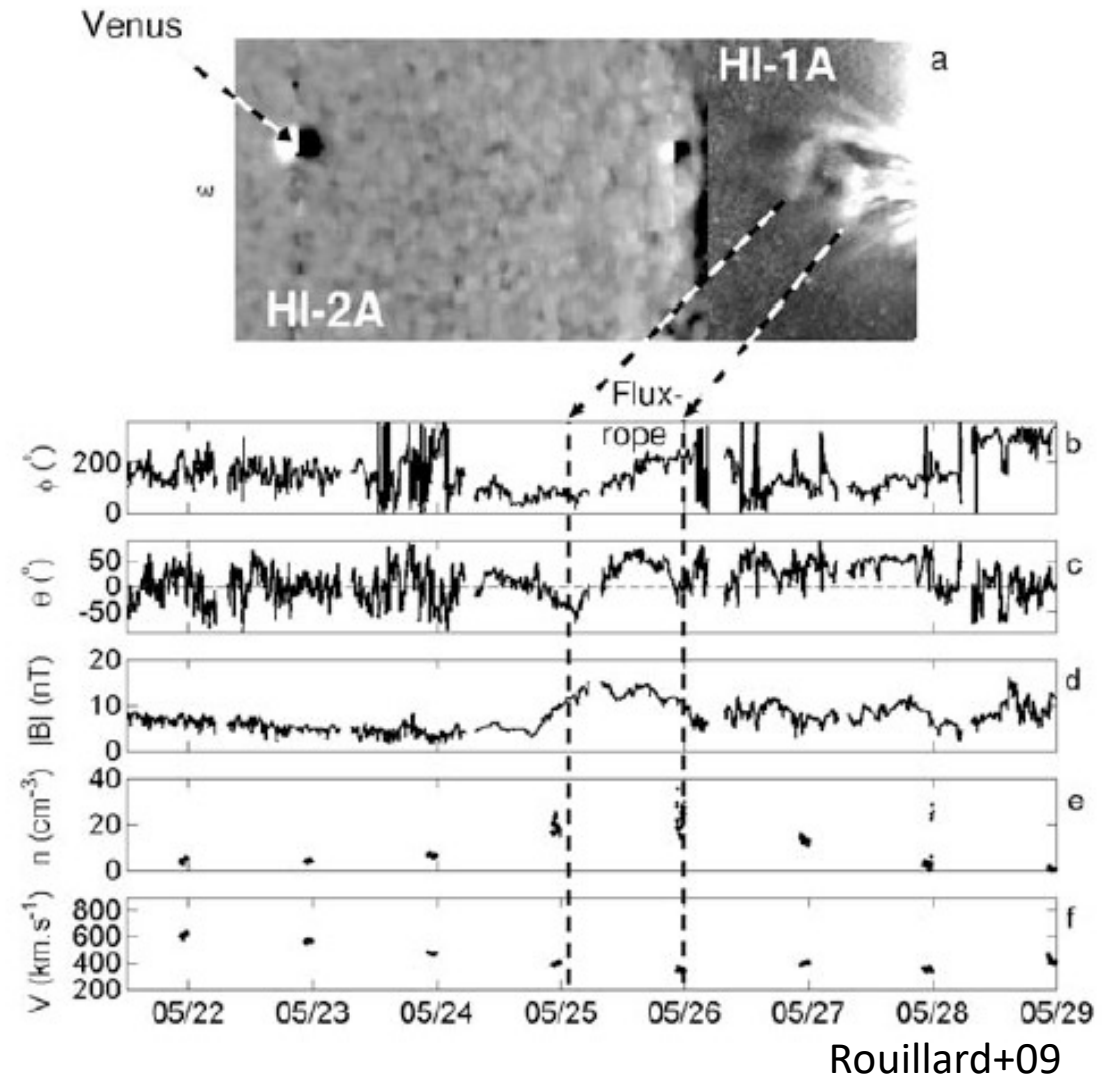
- CME-CIR interaction
- Magnetic connection of Earth and CME

# Combination with in-situ observation

Bothmer & Schwenn 1993

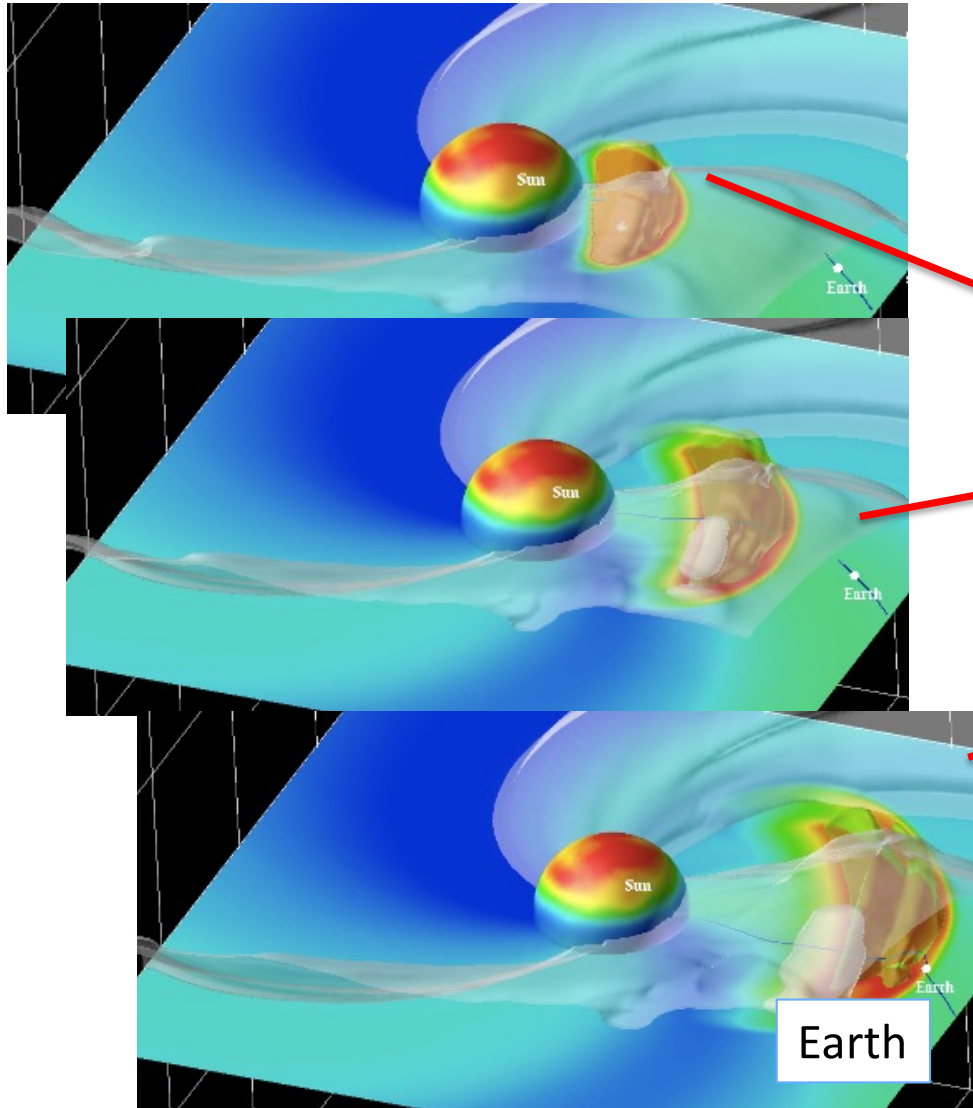
Polarity and Orientation of the Filament	Flux Rope Type
	SEN 
	SWN 
	NES 
	NWS 

Identification of low-corona and on-disk counterpart of interplanetary CME



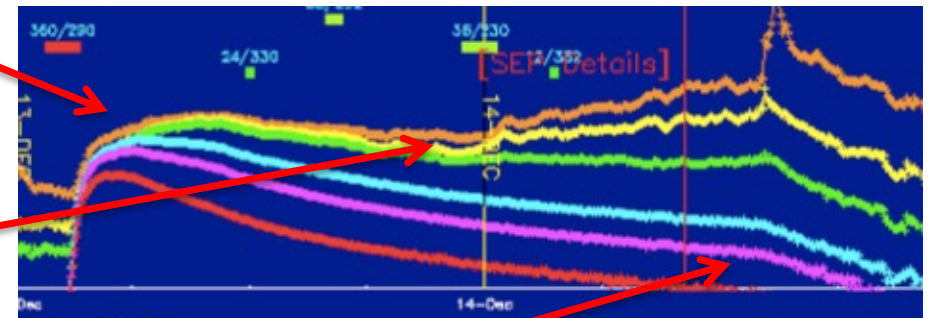
# Solar energetic particles (SEP)

Heliospheric imaging



3D MHD simulation  
Kataoka+ 09

Proton flux (GOES)



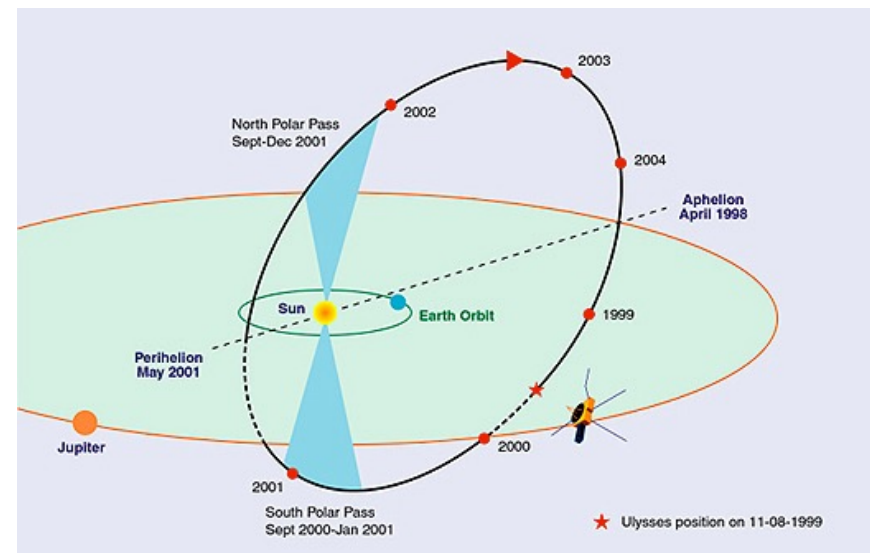
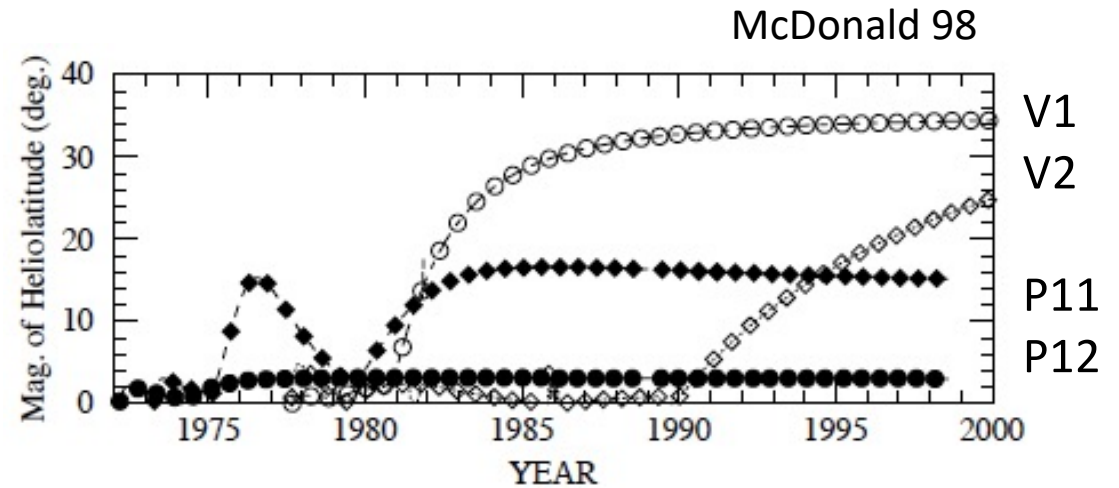
- Combining the heliospheric imaging and in-situ observation will enable to study:
  - CME-earth magnetic connectivity
  - dependence of SEP acceleration on CME speed and shock angle etc.

# Cross-scale observation of space plasma

- Ion inertia length 100~1000 km in solar wind
- STEREO/HI 2's pixel size 70''... 50000km/pix for 1AU
- Scale gap not desperately huge
- Cross-scale observation from global MHD to kinetic scales in space plasma is most likely to happen by heliospheric imaging (+ in-situ).
- Solar wind speed ~400km/s. Exposure should be <30 s to resolve 10000km. Need 3-4 orders of magnitude increase in sensitivity from STEREO/HI...

# Out-of-ecliptic observation of cosmic rays (CR)

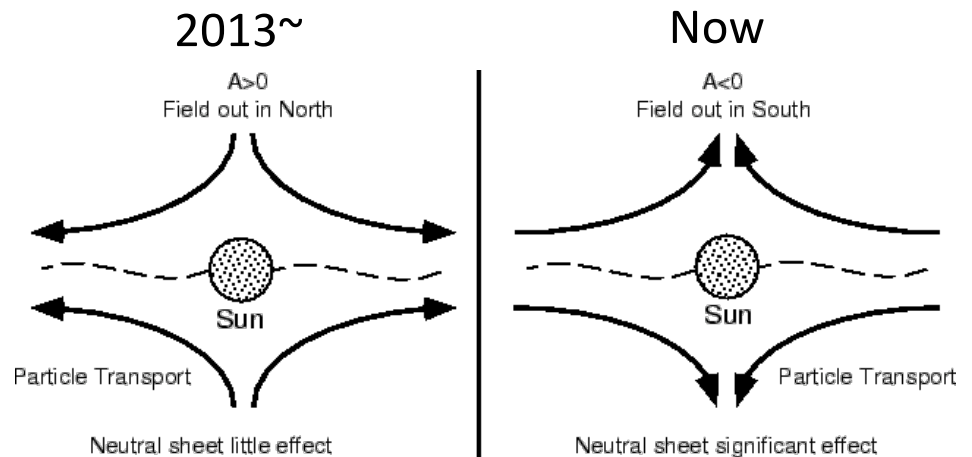
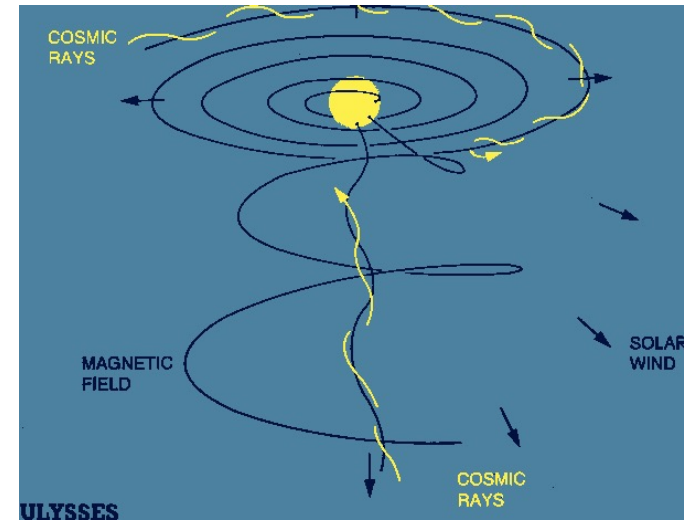
- Data available from  
Voyager1 ( $<40^\circ$  ),  
Voyager2 ( $<30^\circ$  ),  
Pioneer 11 ( $<20^\circ$  ),  
Ulysses ( $>80^\circ$  )





# Ulysses result

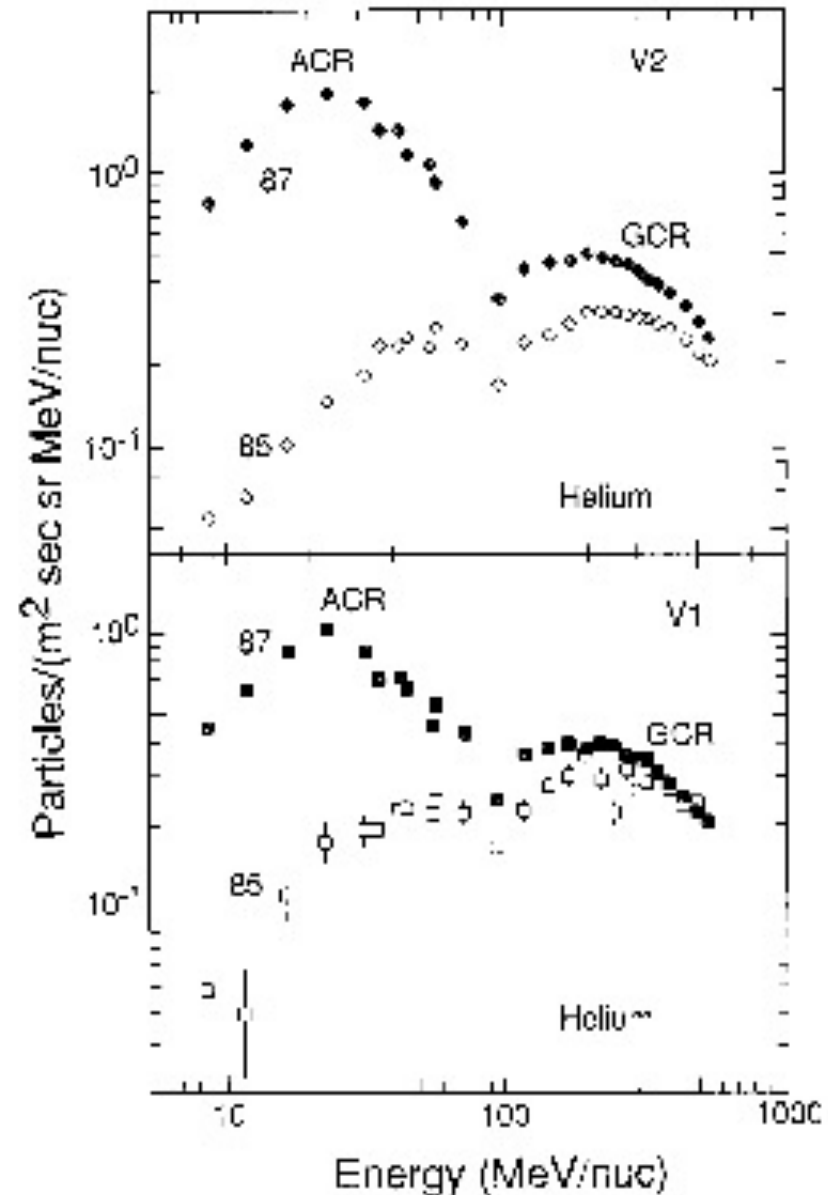
- CR intensity increases  $\sim 30\%$  from ecliptic to high latitude, despite the theoretical prediction of factor  $>10$  increase
- Challenge to transport theory.
- More data definitely necessary to see the latitudinal gradient as a function of 11- and 22-cycle
- Fast, continuous, and long-term latitudinal scans by plan-A will be of great advantage



Duldig 2000

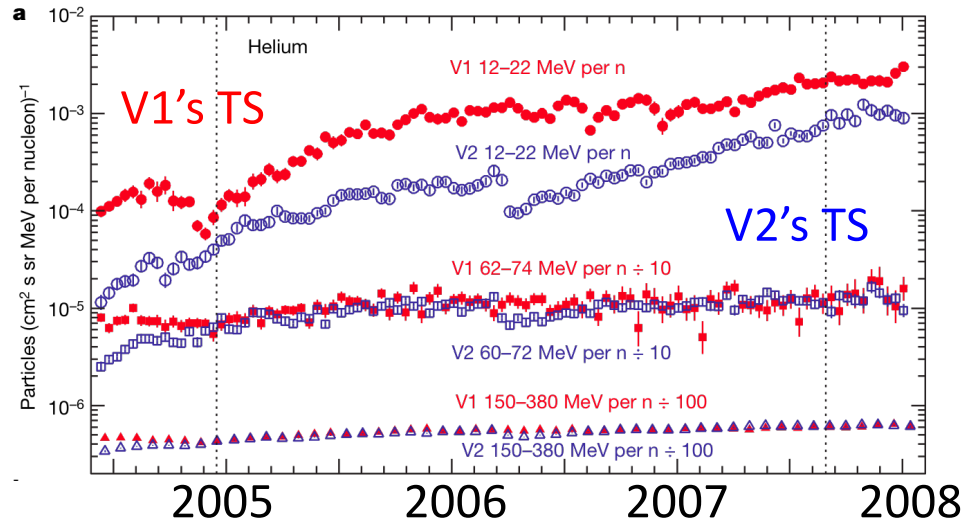
# Anomalous Cosmic Ray

- 1-100MeV/nucleon
- Origin has been believed to be pick-up ions accelerated by the heliospheric termination shock
- Probe for local interstellar medium (LISM)



# Voyager observations of termination shock

Stone et al. 2008, Nature

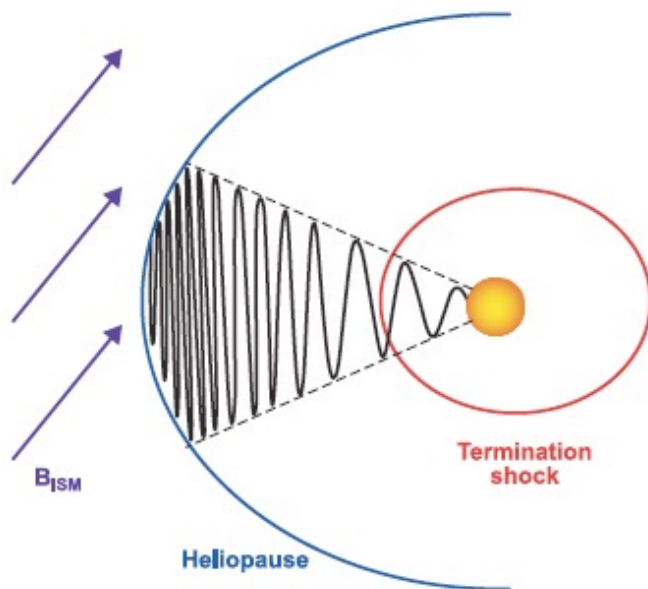


- ACR intensity doesn't peak at TS by keeps increasing monotonically
- Inconsistent with theoretical prediction of shock acceleration

- Acceleration by magnetic reconnection in heliospheric current sheet? (Lazarian & Opher 2009, Drake et al. 2010)

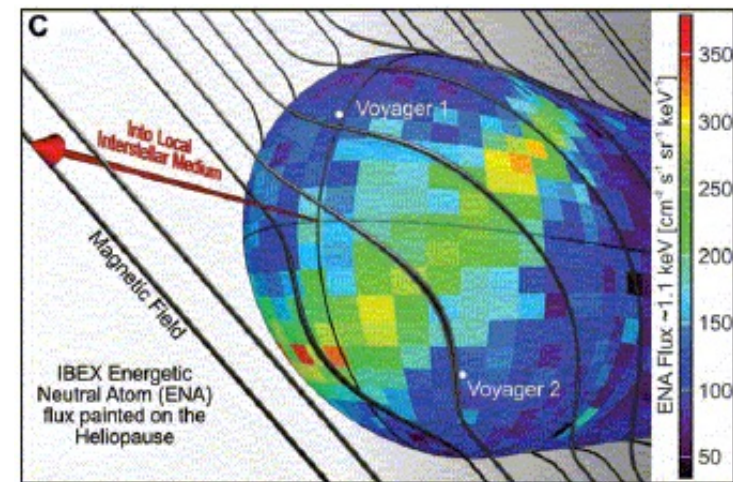
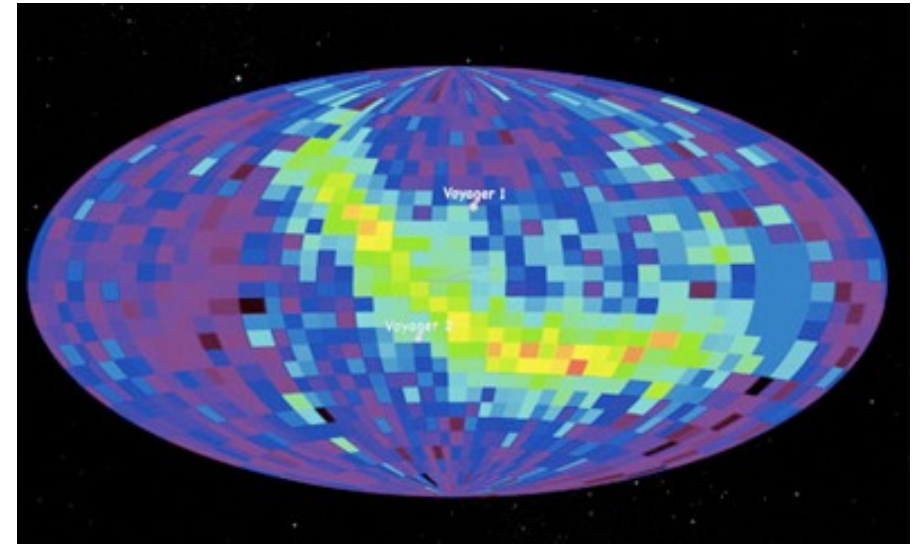
- Similar to pulsar wind

- Different latitudinal /longitudinal dependence from TS?

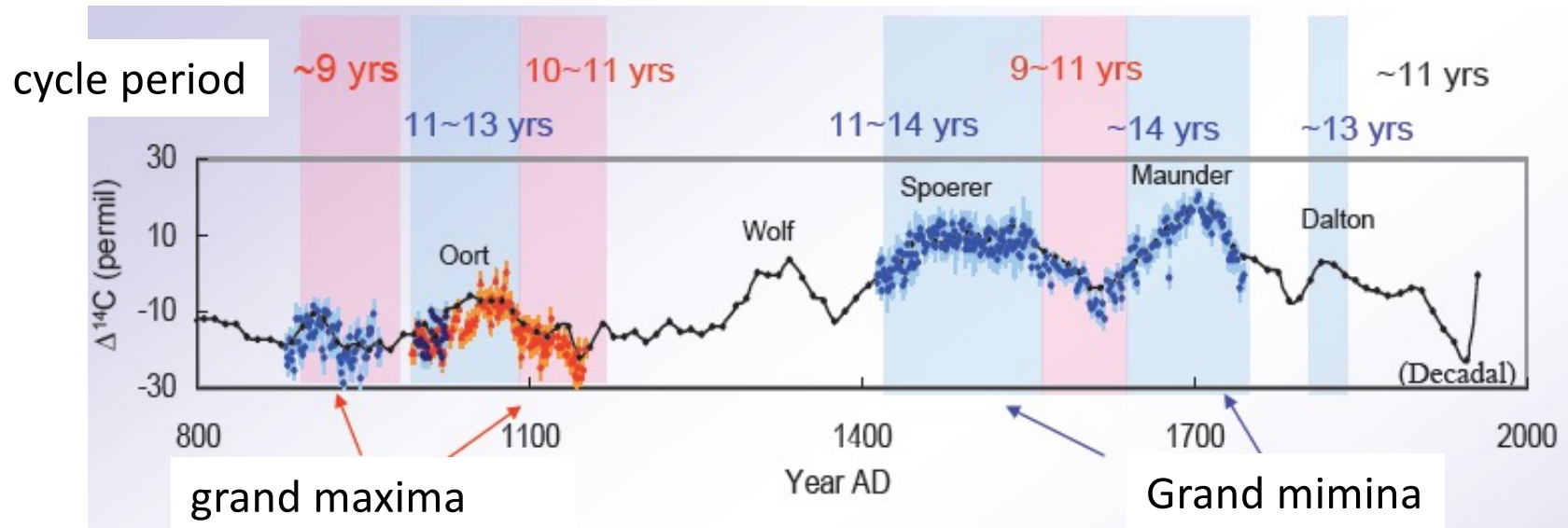


# Probing local interstellar medium (LISM)

- Interstellar Boundary Explorer (IBEX) obtained all-sky map of Energetic Neutral Atoms (ENA).
- ENAs are (believed to be) pick-up ions that are heated ( $\sim 1\text{keV}$ ) near termination shock and then exchange the charge with surrounding plasma
- Strange ribbon-like structure found... effect of interstellar B?



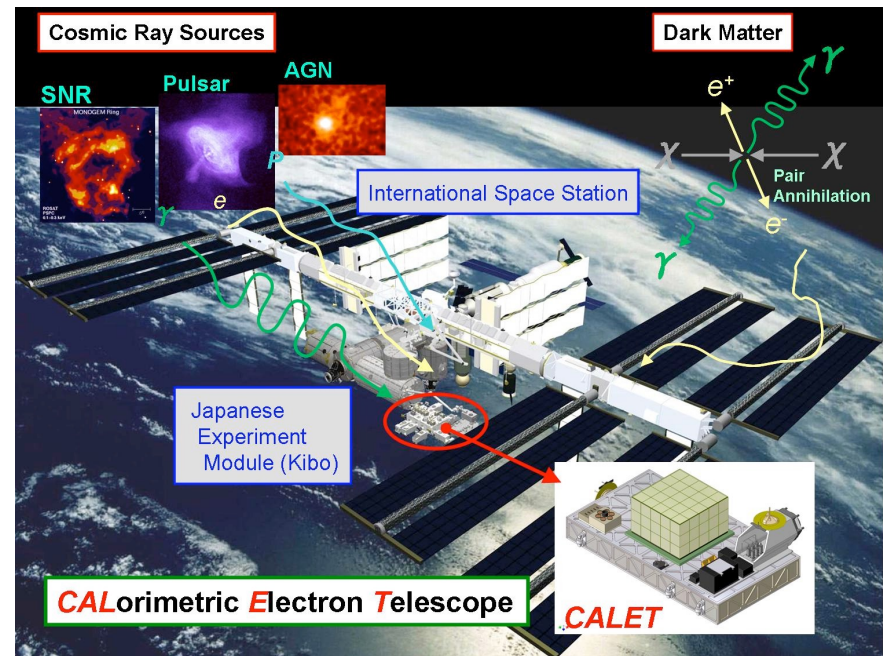
# CR and dynamo



- GCR-origin isotopes ( $\text{C}^{14}$ ,  $\text{Be}^{10}$  etc) are the most direct proxy for long-term (>400 year) solar activity and cyclic behavior during grand minima
- Understanding and precise modeling of CR transport in heliosphere is essentially important to reconstruct the past solar activity from isotope recodes

# Required instrument and trajectory

- Ulysses/COSPIN.... 5kg/detector
- Measurements of solar wind plasma and magnetic field are desired. Jupiter option preferred.
- Higher is better, but  $>40^\circ$  allows measurement outside the tilted heliospheric current sheet
- Data rate negligible
- Synergy with other projects
  - Solar Orbiter / Energetic Particle Detector (EPD)
  - ISS / Calorimetric Electron Telescope (CALET, 2014~)



# Summary

- Heliospheric imager
  - Ultimate observation for space weather
  - only practical possibility to directly observe from global MHD to kinetic scales in space/astrophysical plasmas
- Cosmic ray measurement
  - still too little data... any new information, particularly latitudinal dependence, useful to improve the CR production and modulation models
  - reconstruction past solar activity from CR-related isotopes  
=> Dynamo

# Personal view

- If we go for plan A, HI and CR could have priority over coronal observation
  - polar corona already seen from side
  - jets, waves and fast wind... can be studied in disk coronal hole
- They are not the option for “someone”. There are young Japanese scientists (incl. myself) who are willing to do this