Solar-C A案 ヘリオスフィア研究

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- STEREO/Heliospheric Imager (HI) 程度の撮像装置とA案に載せたときに期待できる成果

- In-situ観測（cosmic ray）

STEREO/HI

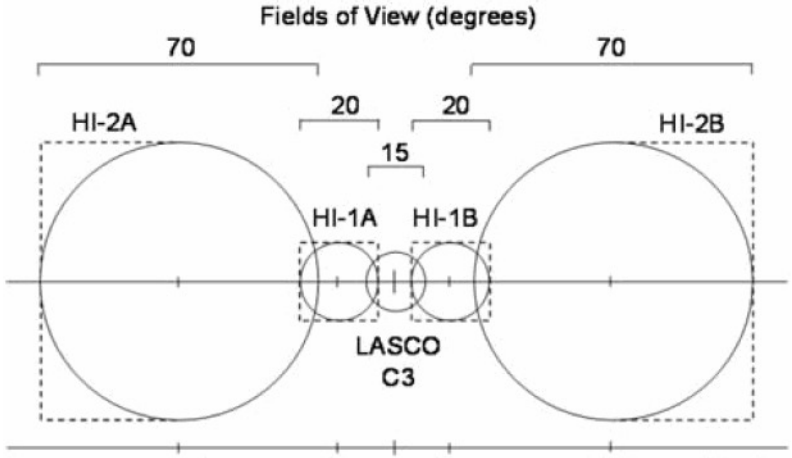
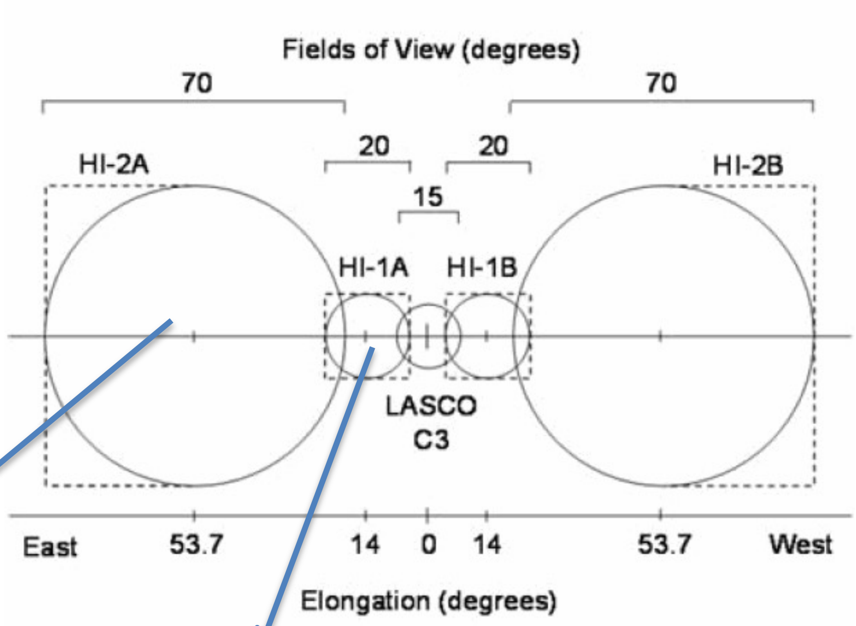
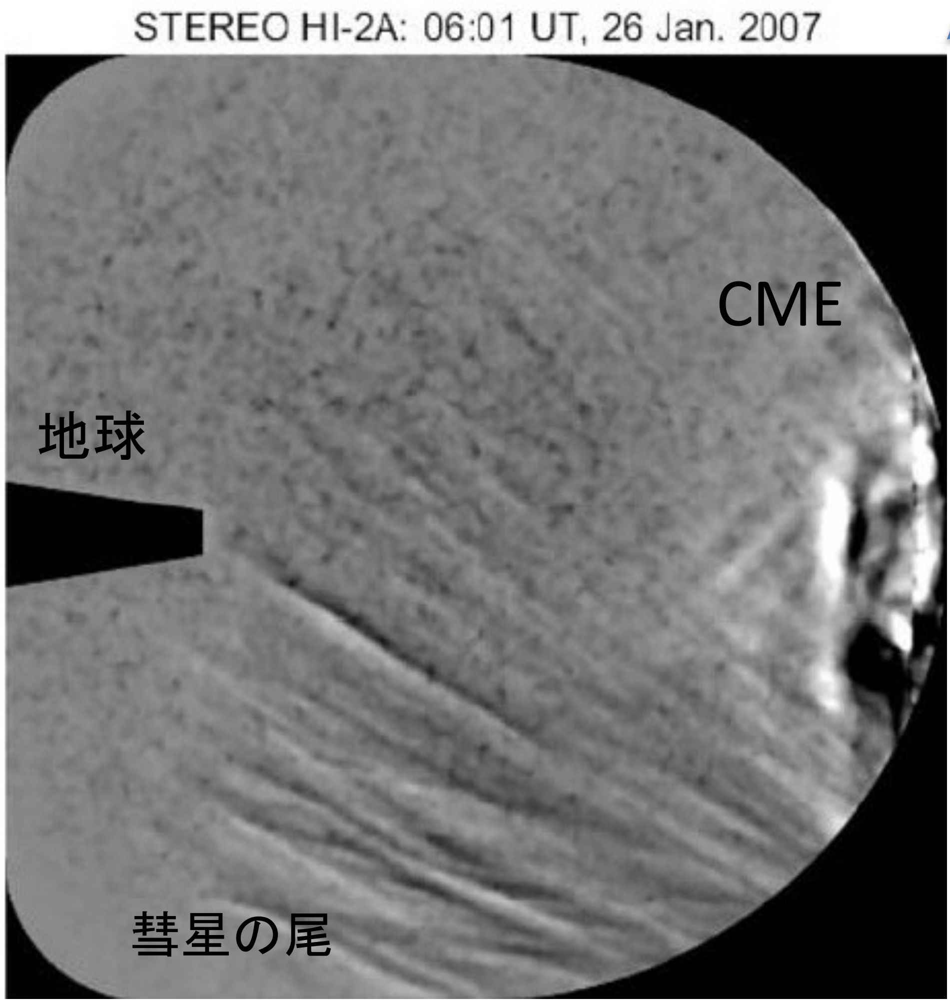


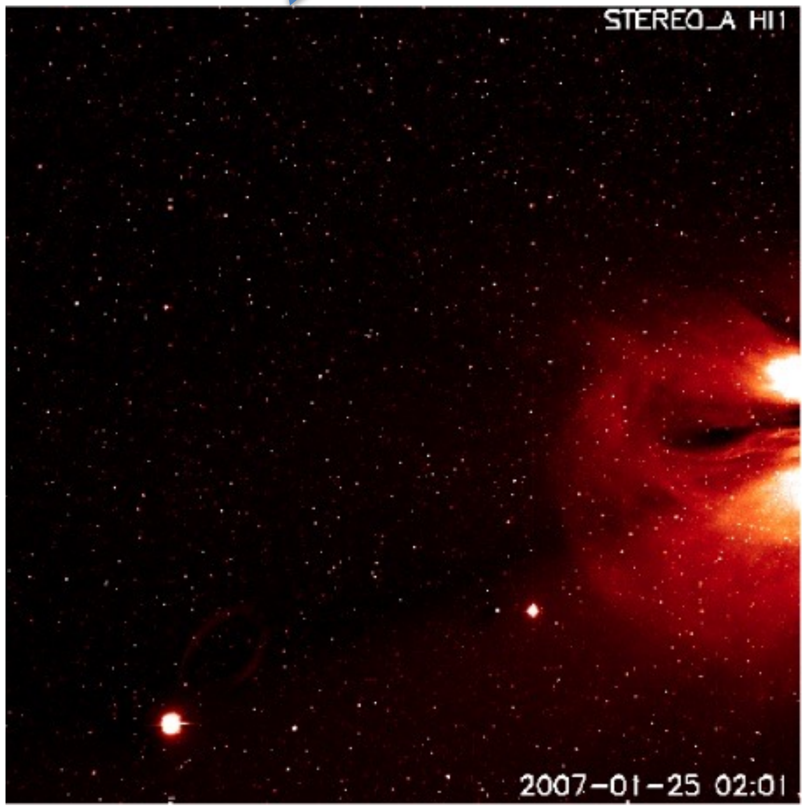
Table 6 Performance specifications of the HI telescopes

	HI-1	HI-2	Units
Direction of centre of FOV	13.98	53.68	Degrees
Angular field of view	20	70	Degrees
Angular range	3.98–23.98	18.68–88.68	Degrees
Image array (2 × 2 binning)	1024 × 1024	1024 × 1024	Pixels
Image pixel size	70 arcsec	4 arcmin	arcsec
Spectral bandpass	630–730 nm	400–1000 nm	nm
Nominal exposure time	12–20 s	60–90 s	sec
Typical exposures per image	150	100	
Nominal image cadence	60 min	120 min	min
Brightness sensitivity	3×10^{-15}	3 × 10−16	$B_\odot$
Straylight rejection (outer edge)	3×10^{-13}	10^{-14}	$B_\odot$

CME imaging by STEREO/HI

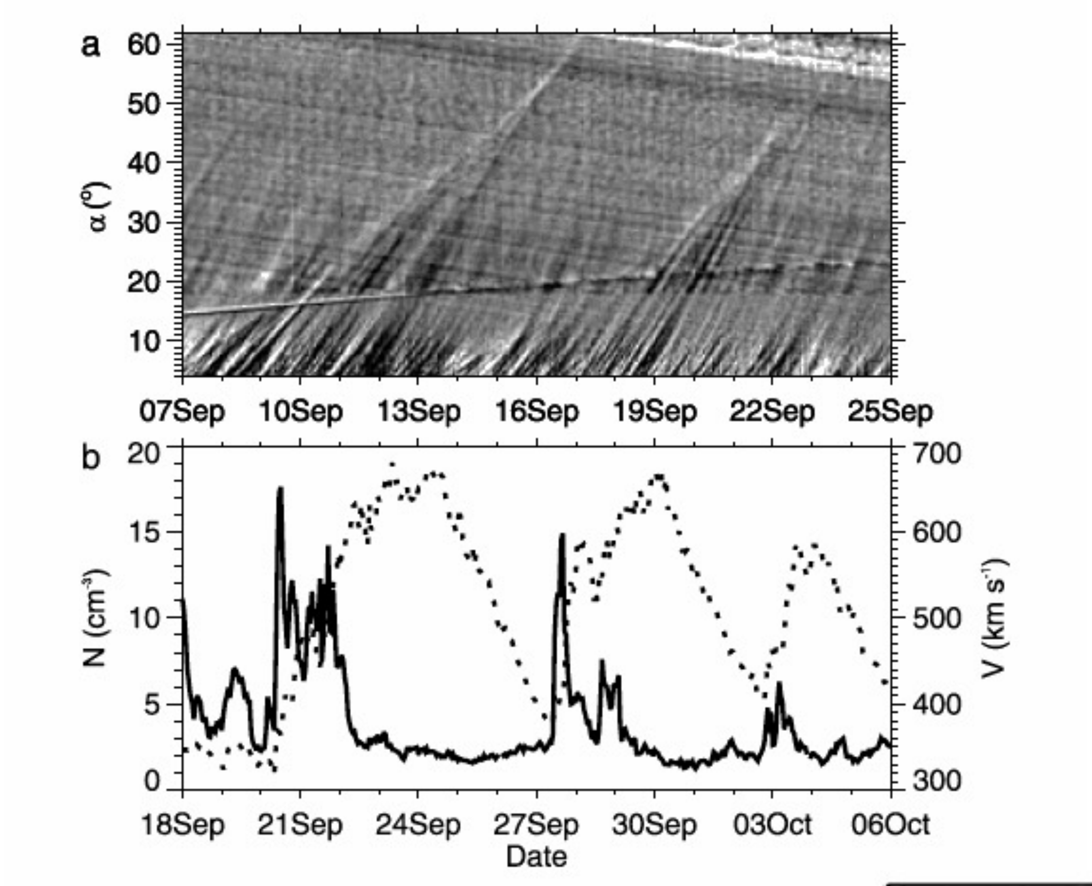






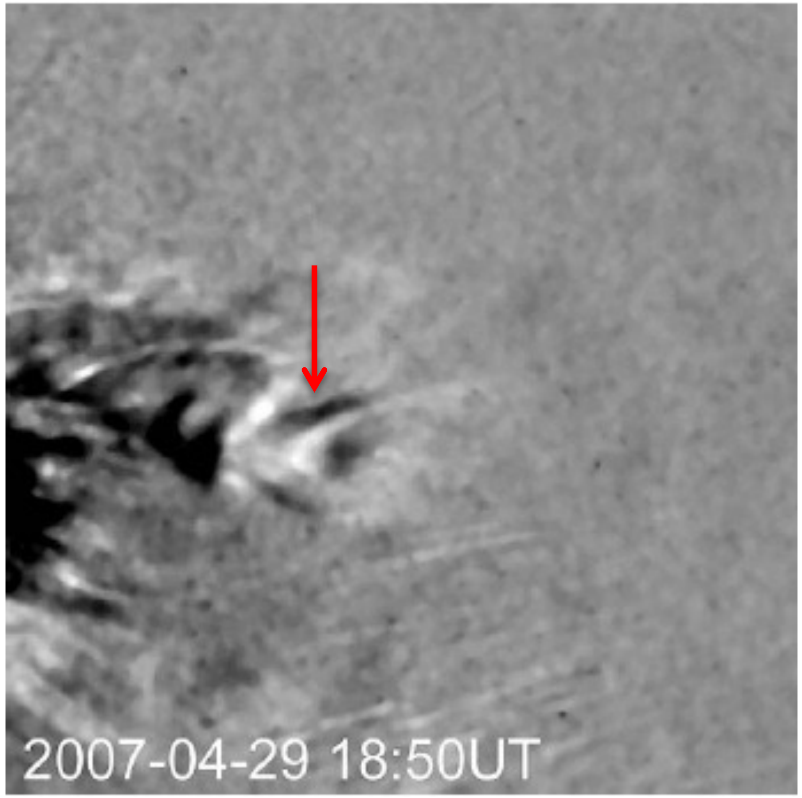
Harrison+ 08

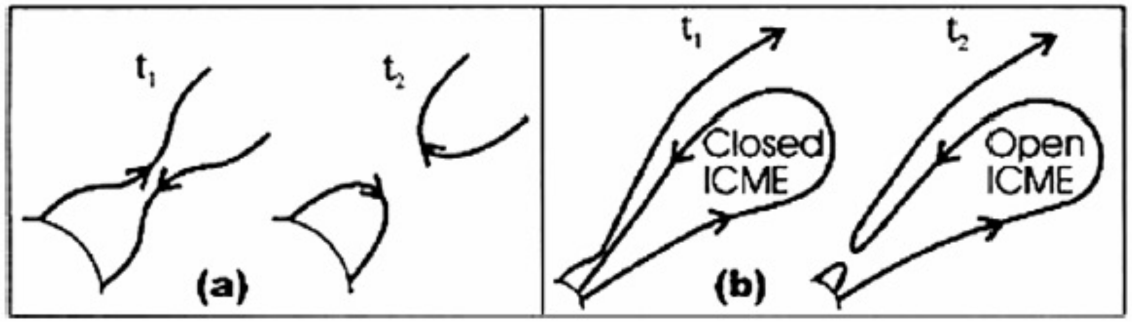
Corotating Interaction Region (CIR)のイメージング



Rouillard+ 08

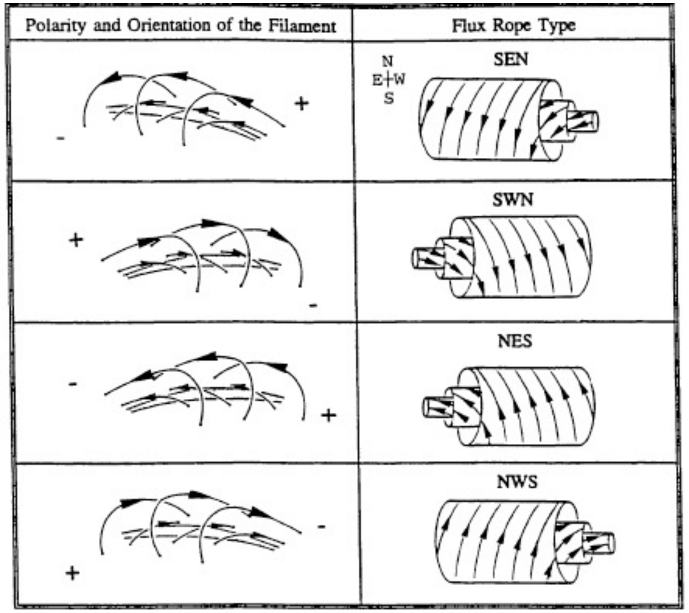
CMEの太陽表面からのdisconnection

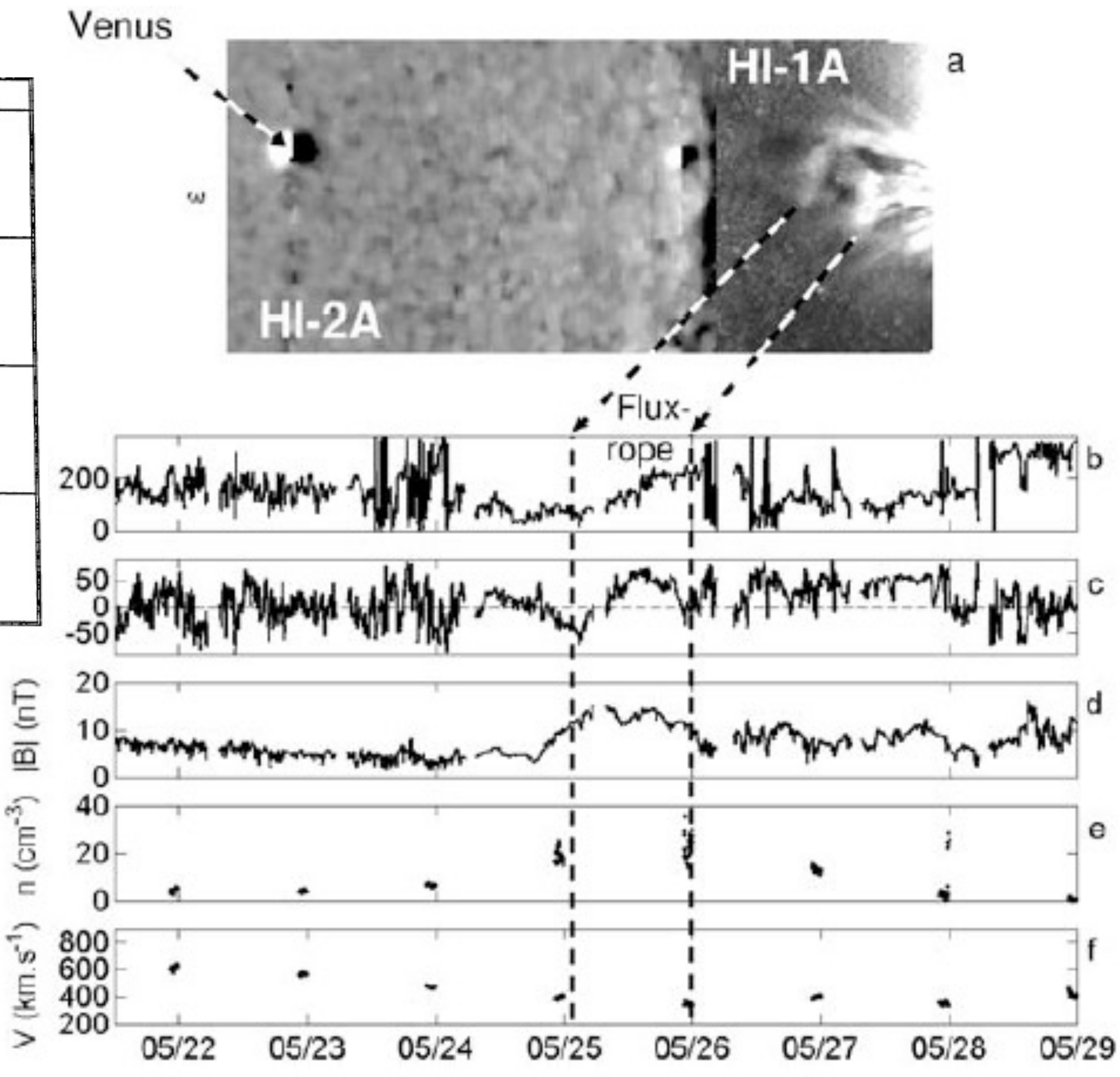




Flux rope構造の同定

Bothmer & Schwenn 1993



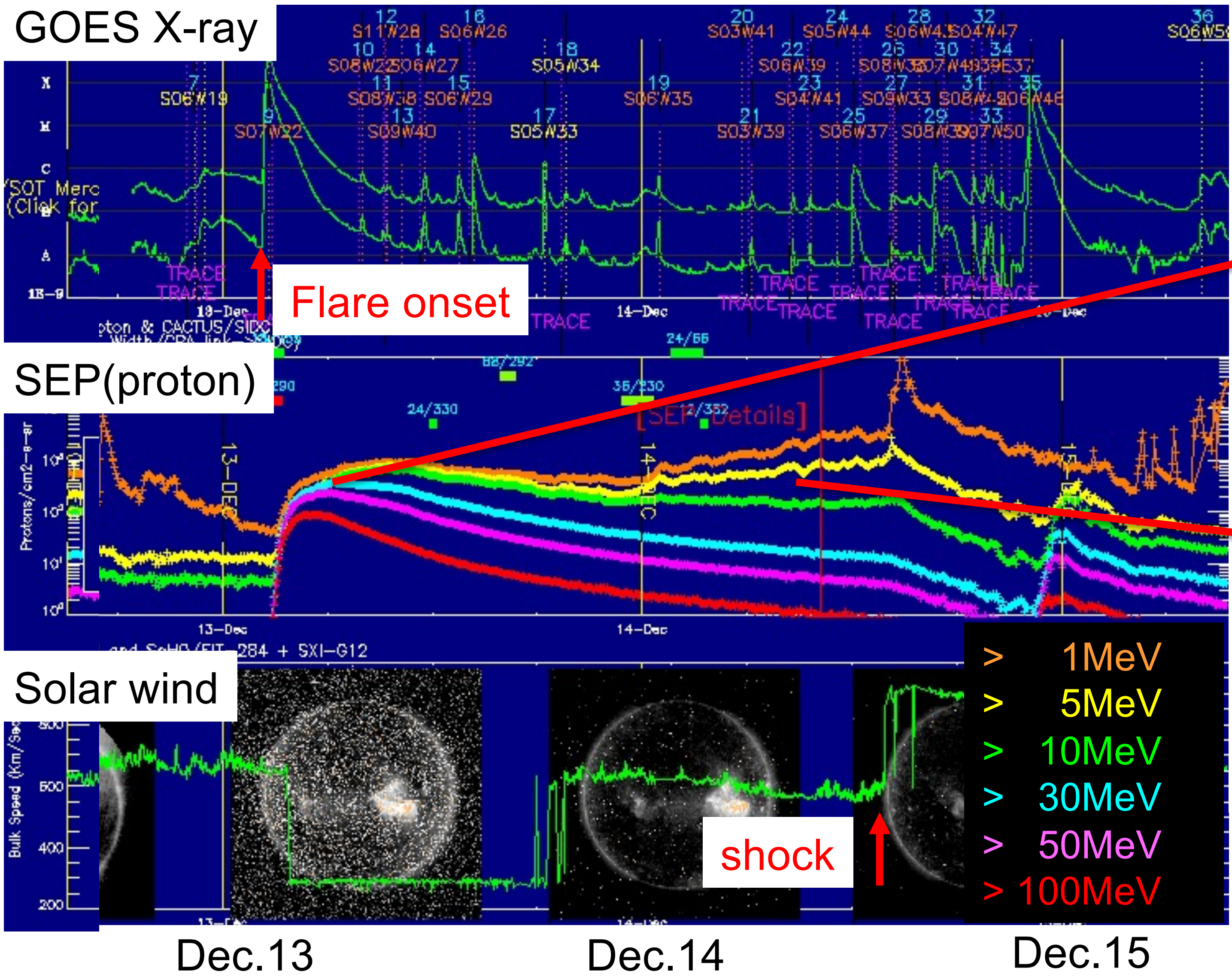


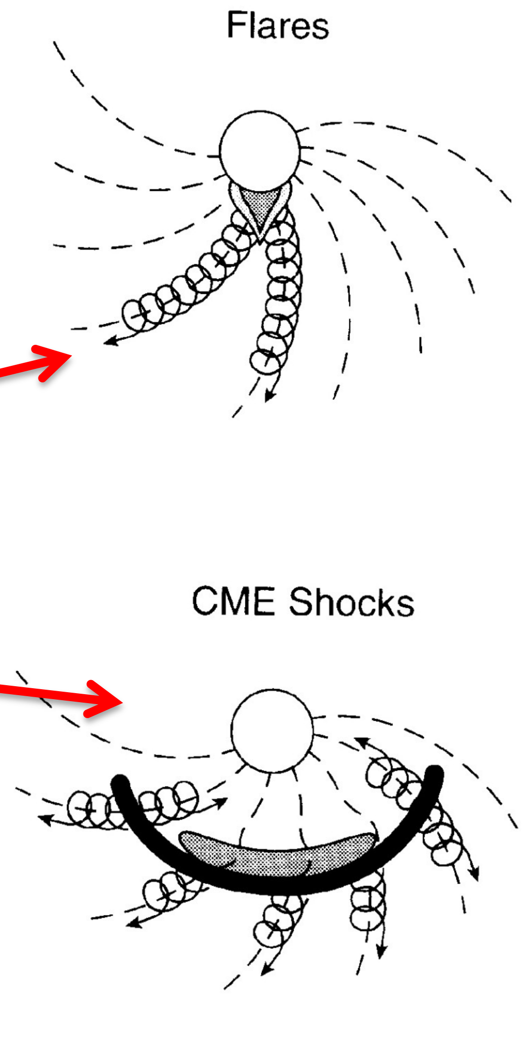
ただしICMEの半分くらいは
きれいなflux rope構造は
見えず、もっと複雑

Rouillard+09

Solar Energetic Particles (SEP)

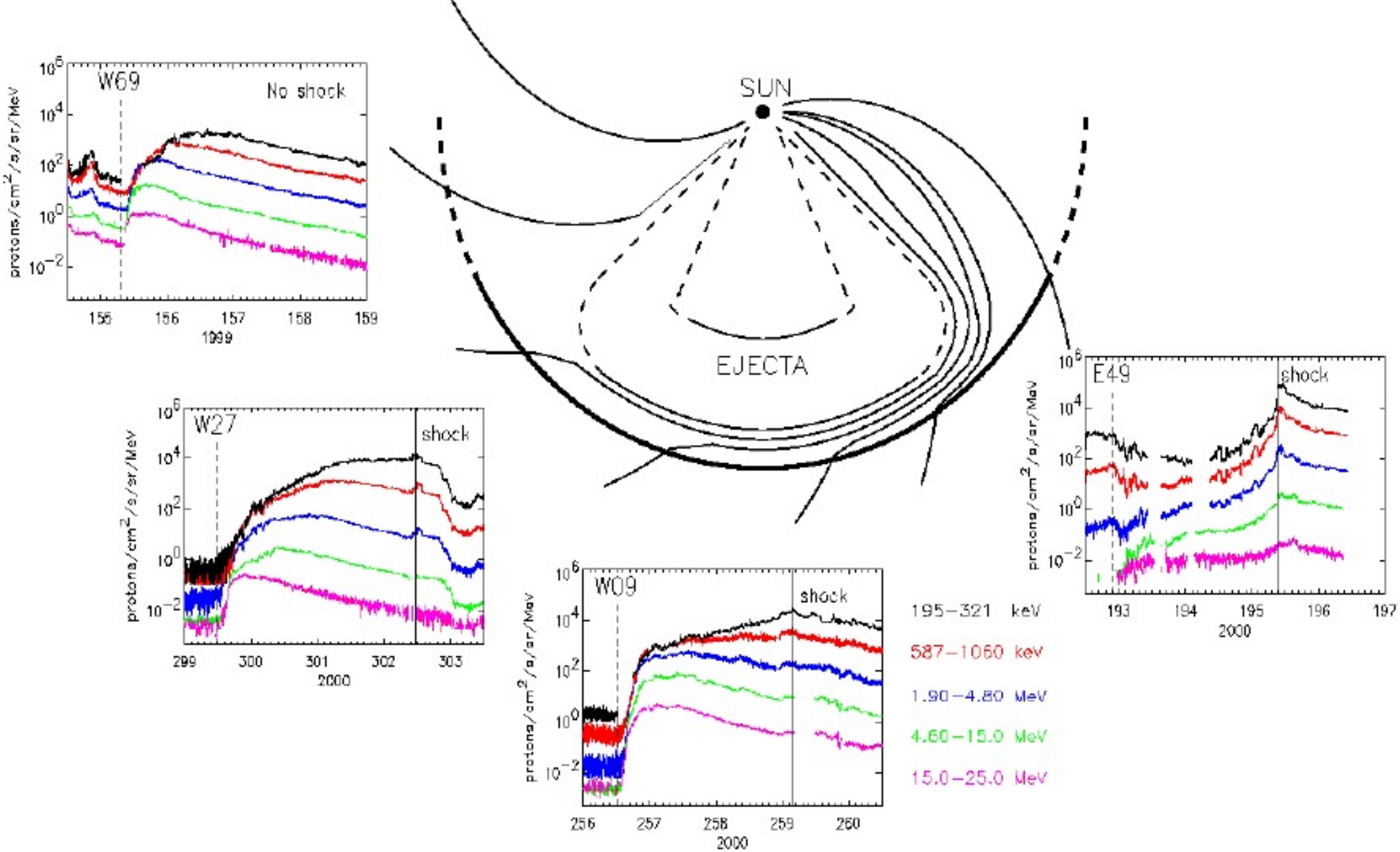
2006, Dec.13 X class flare event





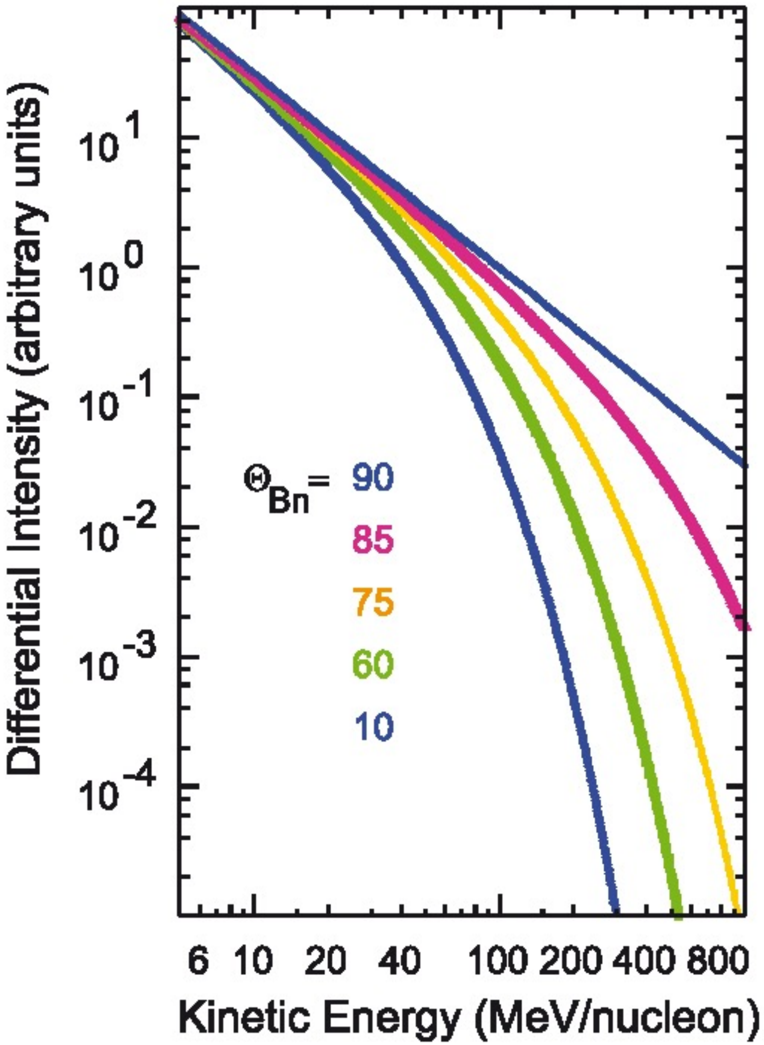
Courtesy of D. Shiota

CMEの位置とSEP

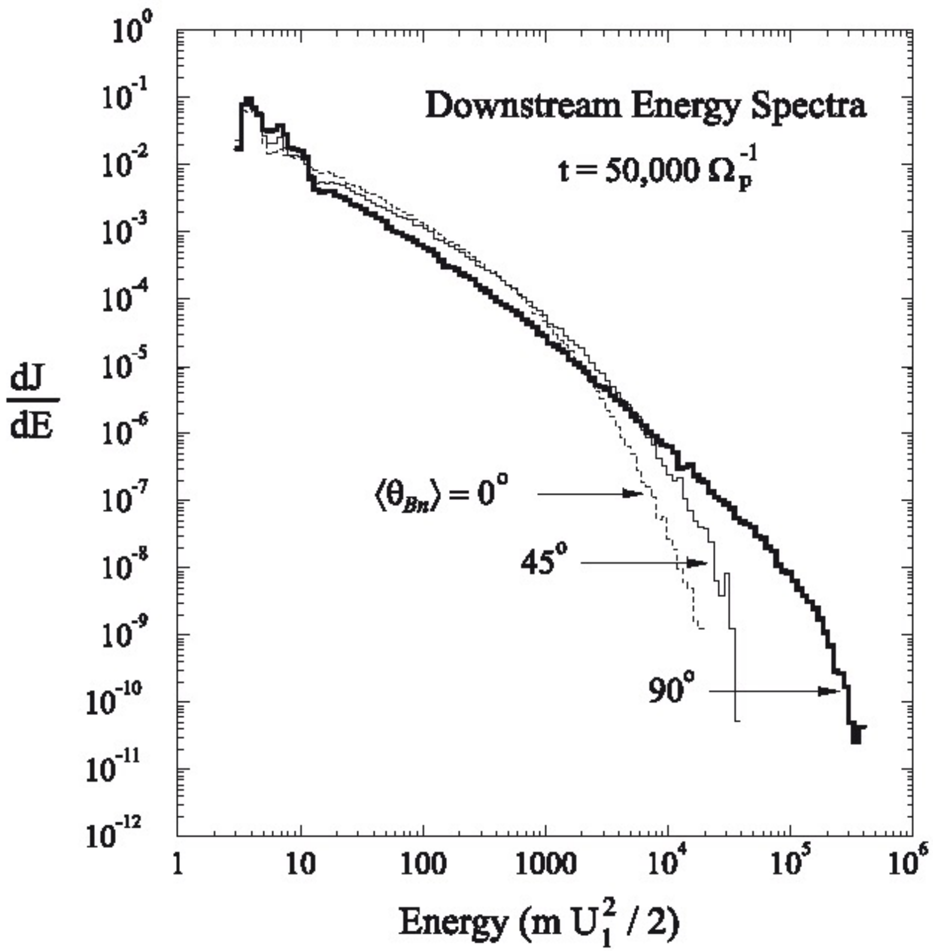


From R. Vainio

衝撃波面の磁場の角度がショック加速には重要



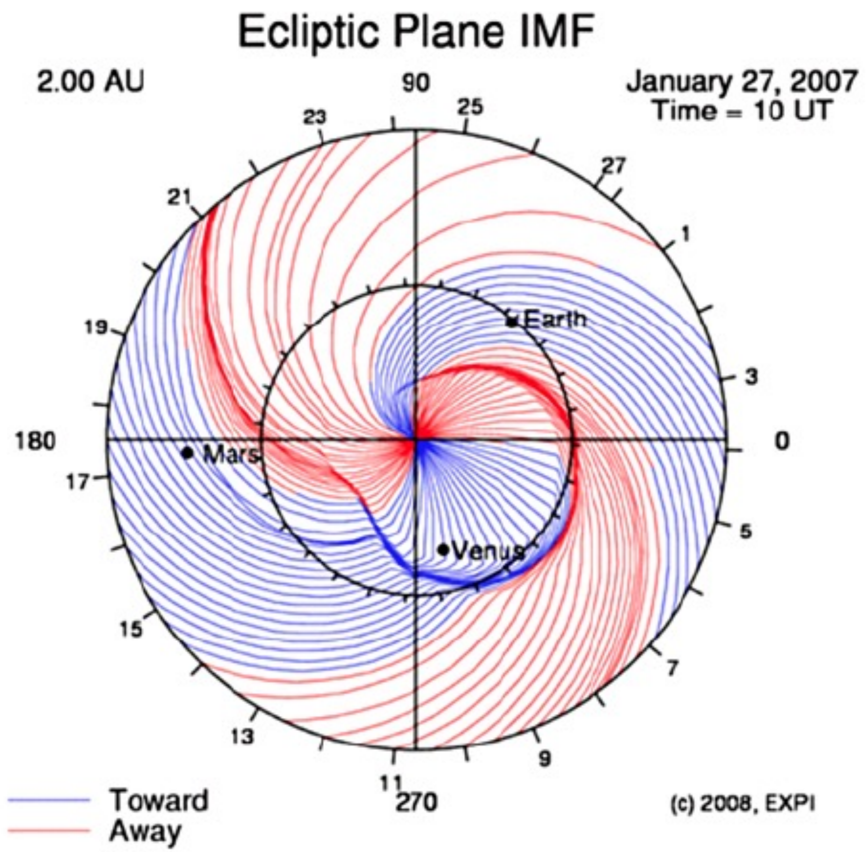
Analytical derivation
(Lee 2005)



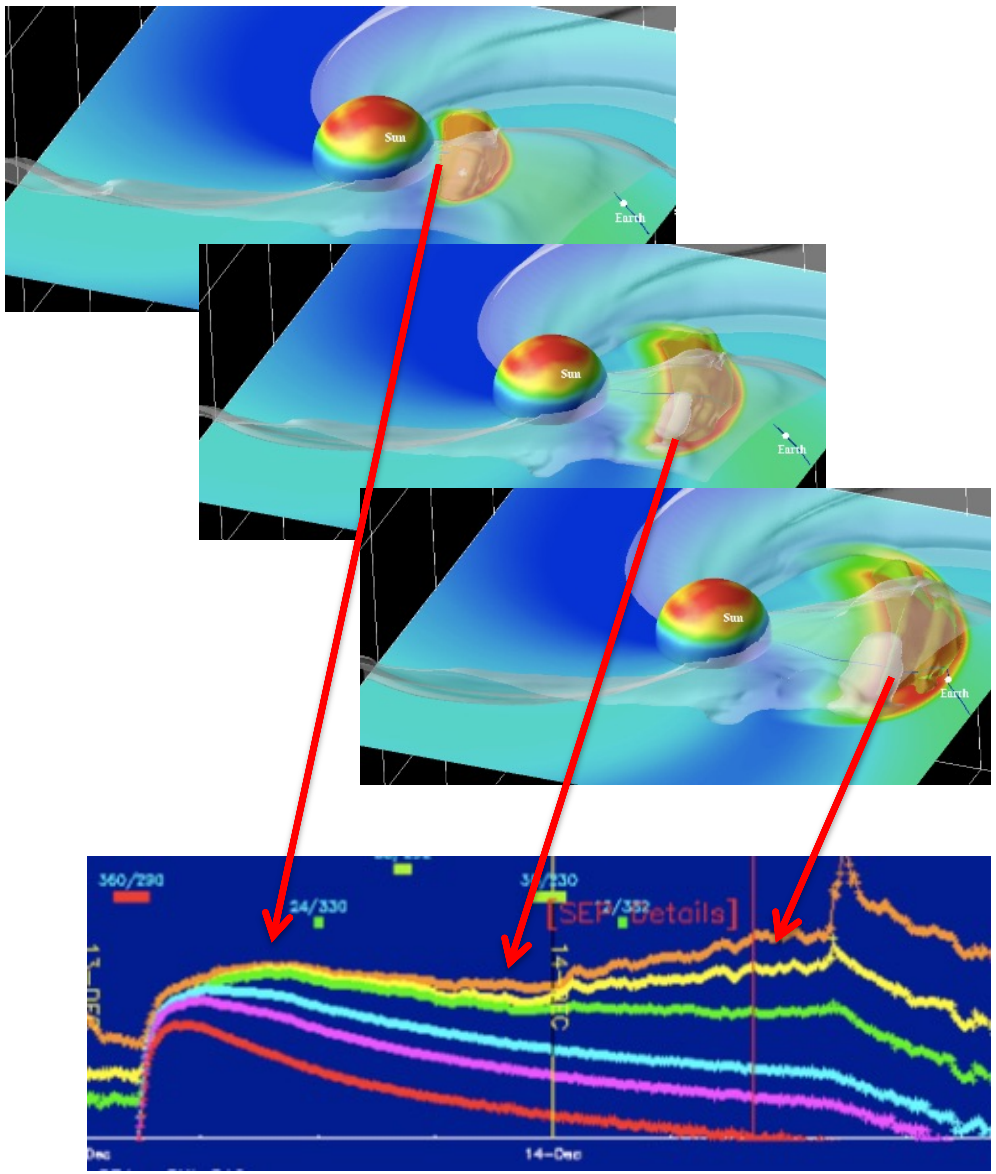
Test particle calculations with upstream
turbulence (Giacalone 2005)

上から見ればショック角がわかる
=>SEP加速メカニズムの定量的評価

Courtesy of R. Kataoka, D. Shiota



Webb+09



In-situ観測（地球軌道他）、
モデリングとの協同が必須

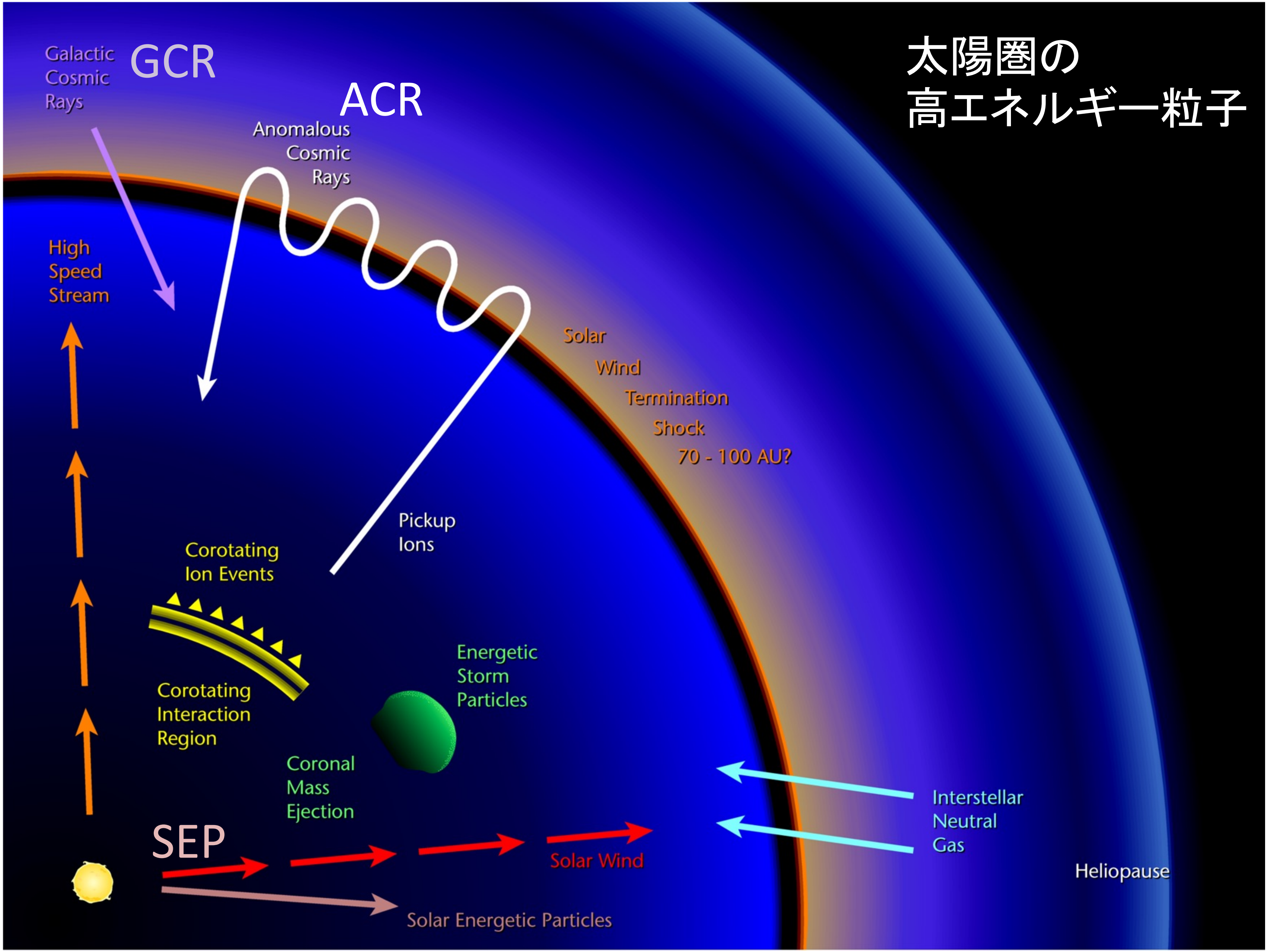
Cross-scale observation of space plasma

- 太陽風中のイオン慣性長 100~1000 km
- STEREO/HI 2's pixel size 70"... 50000km/pix for 1AU (5000km/pix for 0.1AU)
- 撮像で分解できるマクロスケールと、in-situ観測で見えるミクロスケールのギャップが「それほど」大きくない。
- 運動論的スケールとマクロなMHD構造を同時に観測できる可能性はコロナや磁気圏より高い
- 太陽風速度~400km/s. 10000kmを分解するには露出は30s以下＝＞STEREO/HIより3-4桁感度がよくないといけない。

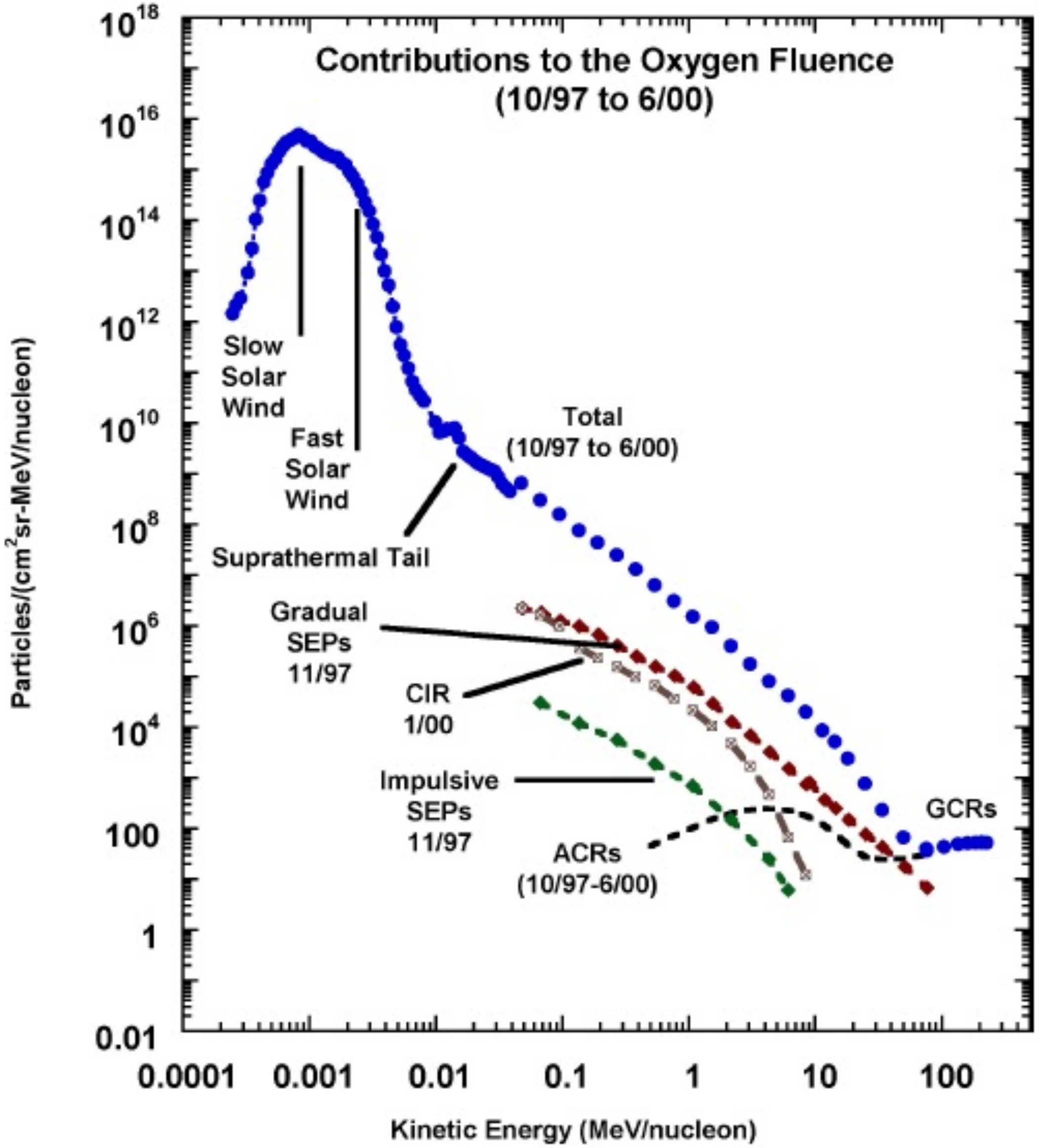
In-situ measurements

- 太陽風
  - 極域からの太陽風の太陽活動依存性をモニターする意義はある
  - 極域からの高速太陽風は高緯度でなくても測れているし、観測可能な物理量の制限（回転しないで分布関数測れる？イオンエンジンついてて磁場測れる？）もあり、それほど魅力的とは言えない

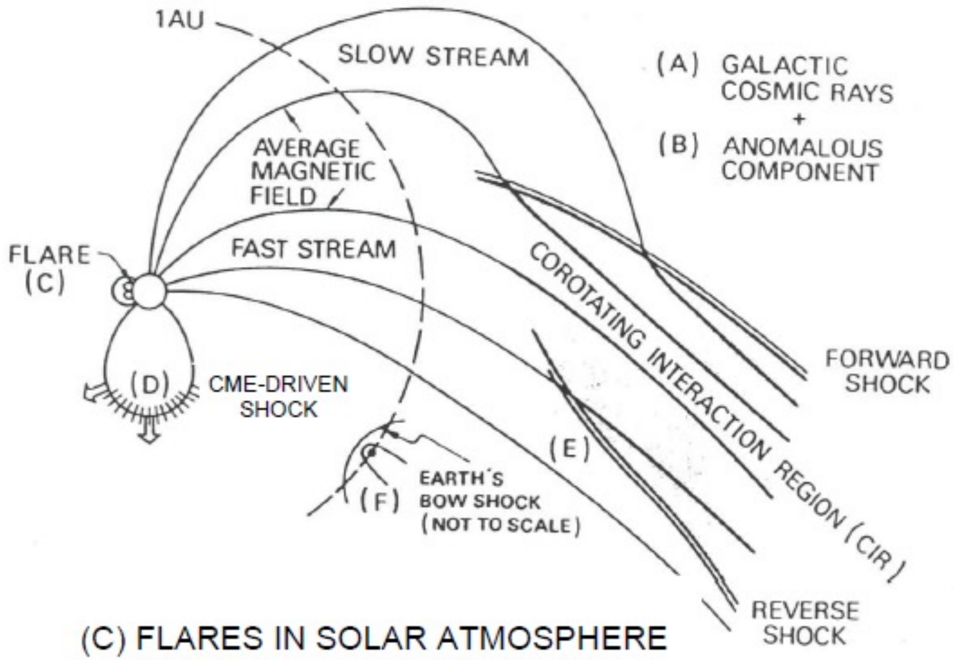
- Cosmic Ray (CR)


太陽圏の
高エネルギー粒子
Galactic
Cosmic
Rays
GCR
ACR
Anomalous
Cosmic
Rays
High
Speed
Stream
Solar
Wind
Termination
Shock
70 - 100 AU?
Pickup
Ions
Corotating
Ion Events
Energetic
Storm
Particles
Corotating
Interaction
Region
Coronal
Mass
Ejection
Interstellar
Neutral
Gas
SEP
Solar Wind
Heliopause
Solar Energetic Particles

Energetic Particles in heliosphere



Mewaldt et al. (2001)

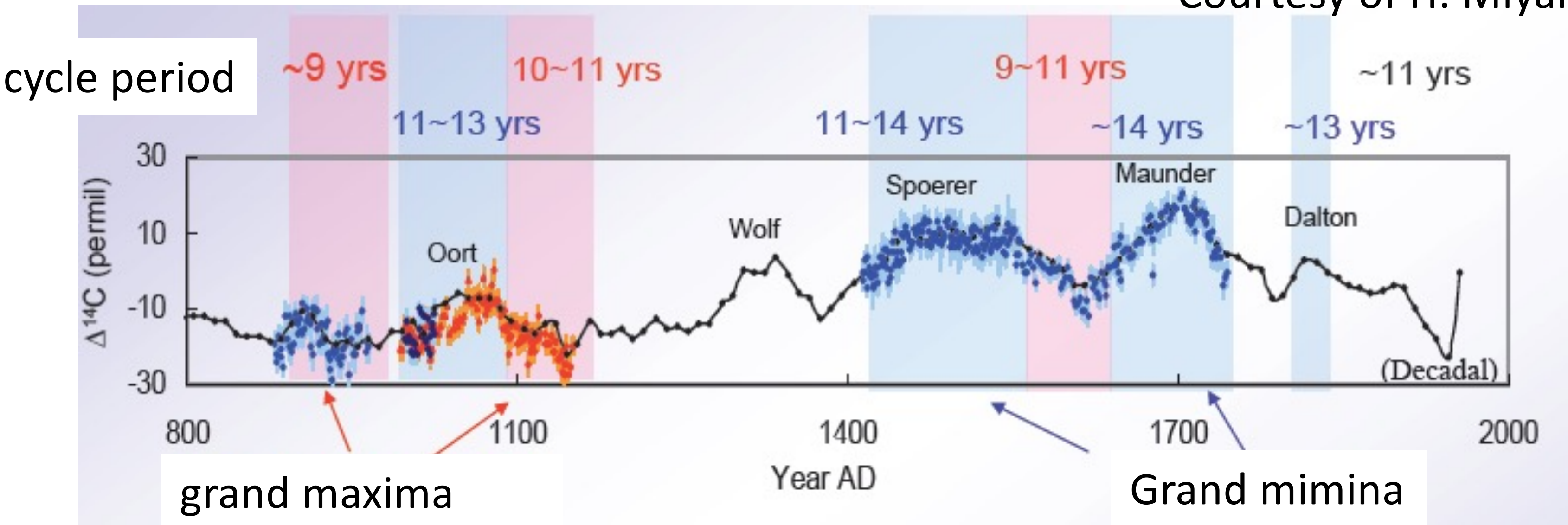


(C) FLARES IN SOLAR ATMOSPHERE
(D) CME-DRIVEN SHOCK WAVES
(E) COROTATING INTERACTION REGION (COROTATING EVENTS)
(F) PLANETARY MAGNETOSPHERES AND BOW SHOCKS

Original figure: Kunow et al. (1991)

近年の銀河宇宙線(GCR)への興味の増大

Courtesy of H. Miyahara

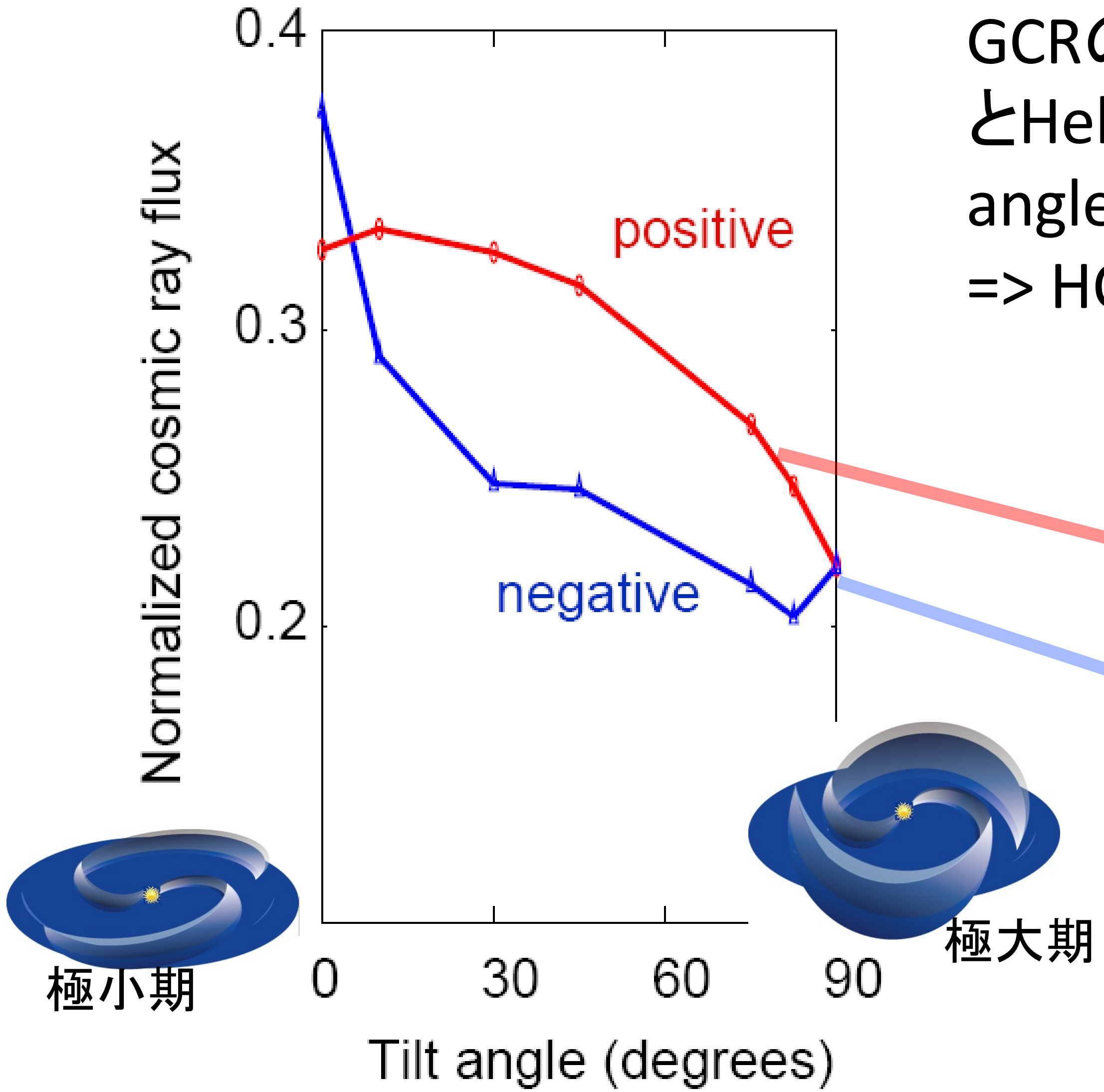


- 気候変動との関係（Svensmark効果）

- 過去の太陽活動の指標＝＞ダイナモ機構

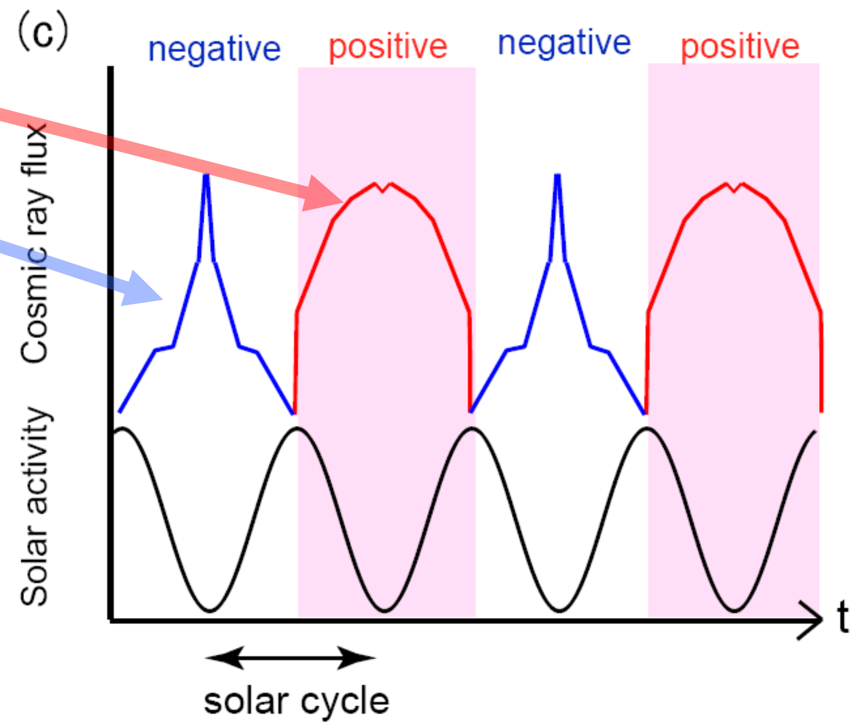
- GCRの変動をもたらすのは太陽圏中の輸送
- 輸送モデルの精緻化が鍵。黄道面を出たCR観測はこのための基礎データを与える

GCRのプロファイルは磁場の極性とHeliospheric current sheetのtilt angleに大きく依存
=> HCSの外と中でGCRを測りたい



Kota&Jokipii, 2003

2. Waviness

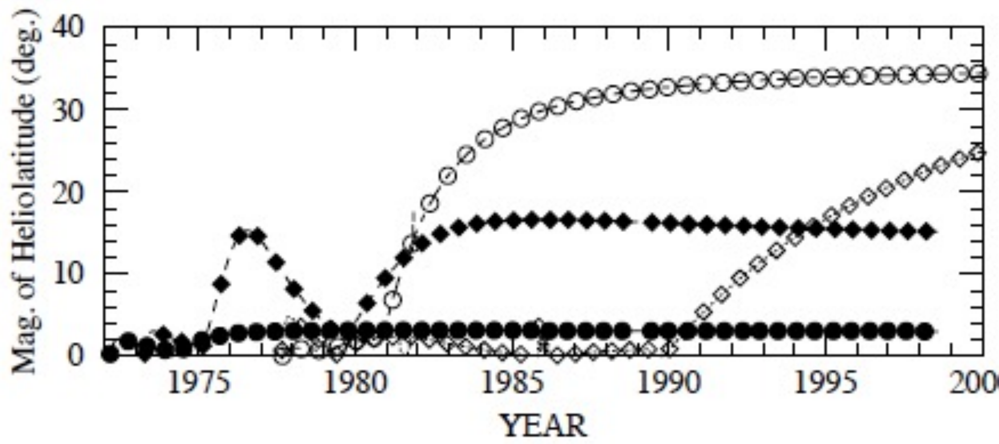


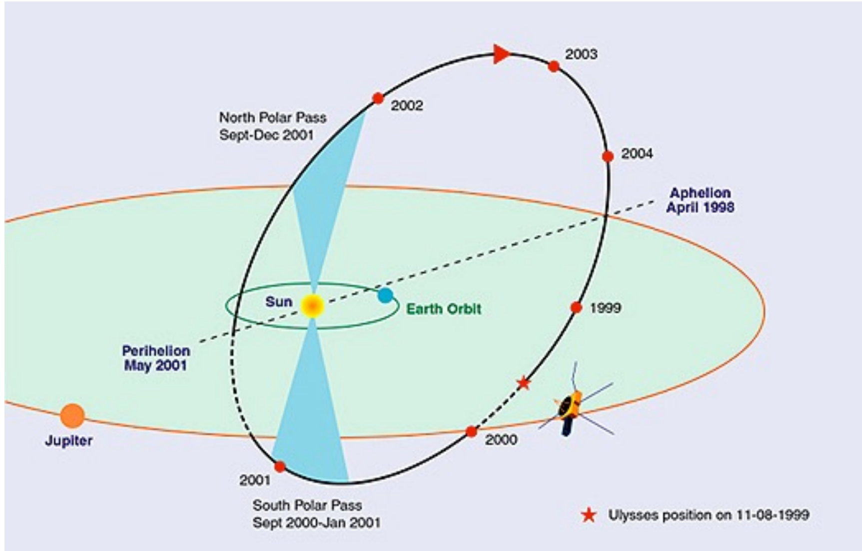
Courtesy of H. Miyahara

黄道面を出たCRの観測

- Data available from Voyager1 (<40°), Voyager2 (<30°), Pioneer 11 (<20°), Ulysses (>80°)

McDonald 98

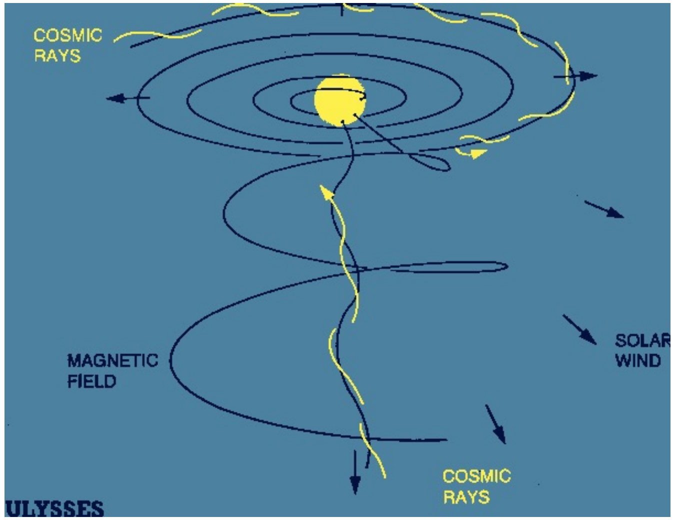




Ulysses orbit

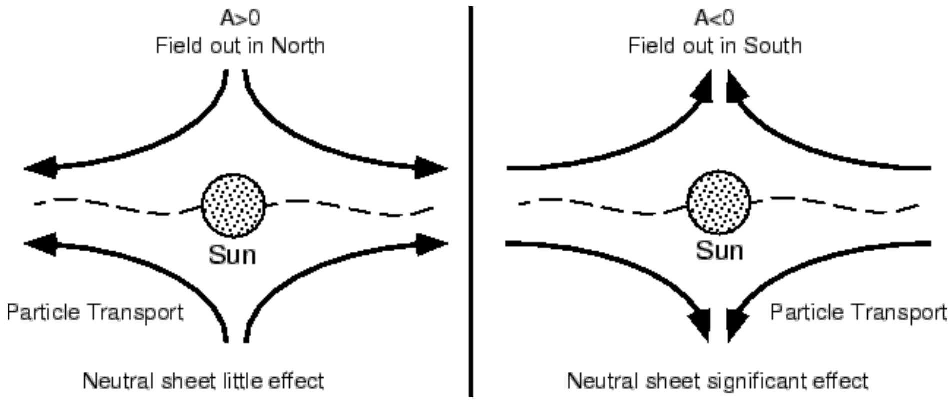
Ulysses result

- 黄道面に比べ、極域(~80°)のCR密度は ~30% 増加
- 一方CR輸送モデルの予想では10倍以上合わない。輸送モデルに問題？



- 太陽活動の変動と緯度分布を切り分けるために、~1AUの軌道をとるSolar-Cでの速い緯度スキャンは有用。（Ulyssesのfast scanでは1(2?)度だけ）

2013~　　　Now

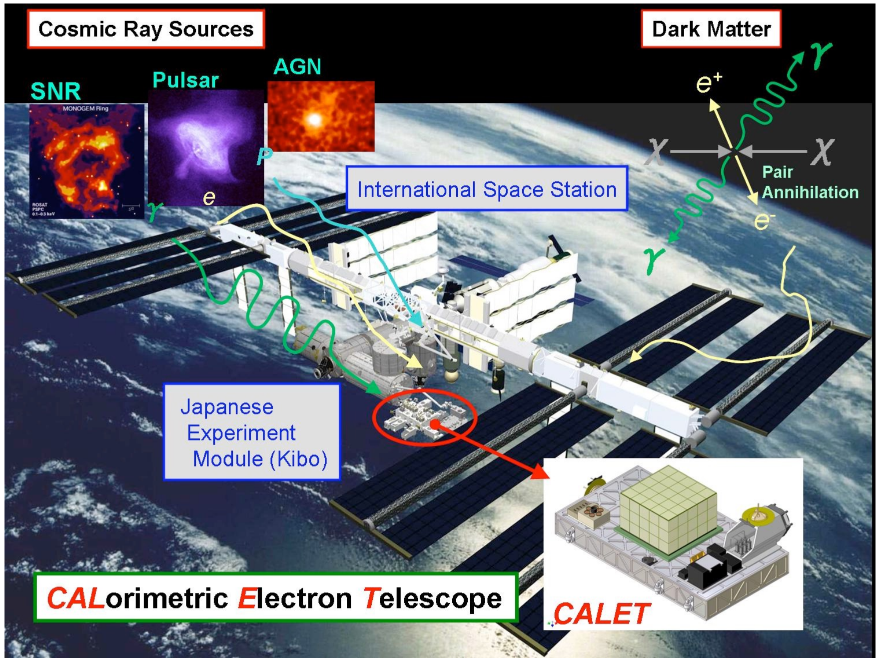


Duldig 2000

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°　allows measurement outside the tilted heliospheric current sheet
- Data rate negligible

- Synergy with other projects
  - Solar Orbiter / Energetic Particle Detector (EPD、ただし<100MeV)
  - ISS / Calorimetoric Electron Telescope (CALET, 2014~)

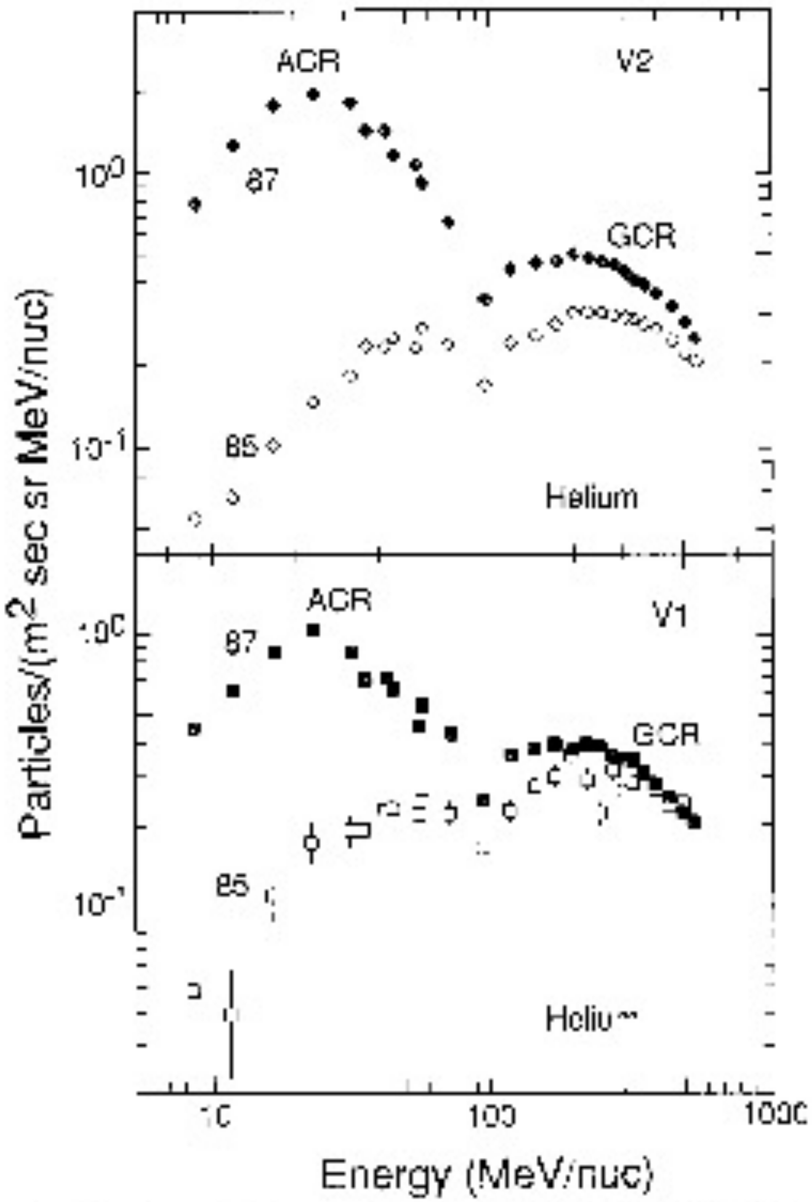


Summary

- Heliospheric imager
  - 宇宙天気研究にとって間違いなく有用
  - In-situ観測との協同で衝撃波の粒子加速に迫れる
  - 撮像で運動論的スケール（~1000km）に迫れるとしたらここ
- Cosmic ray measurement
  - 気候変動、過去の太陽活動（ダイナモ）の観点から興味大
  - 輸送モデルの精緻化が鍵。Heliospheric current sheet外でのCRが測れるとステキ

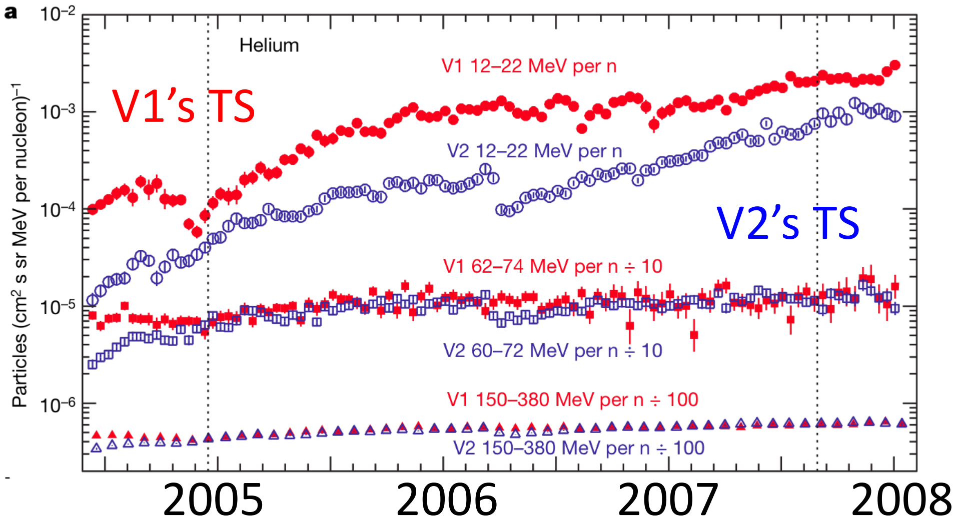
Anomalous Cosmic Ray

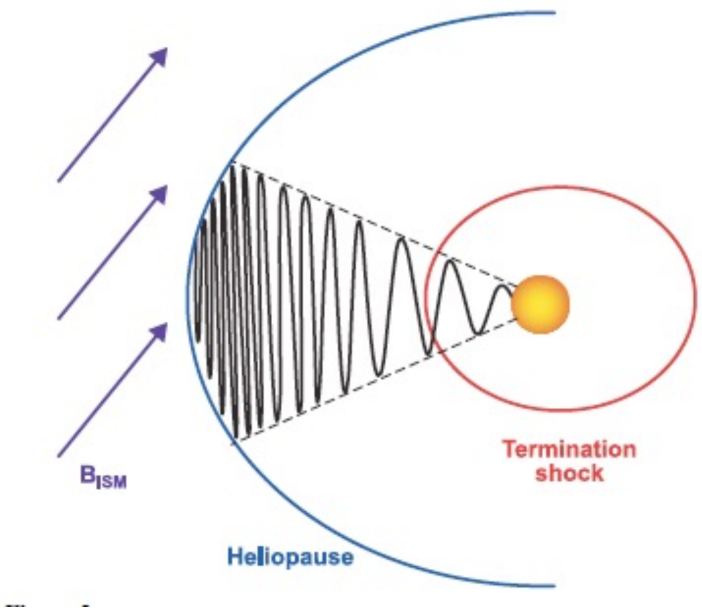
- 1-100Mev/nucleon
- Origin has been believed to be pick-up ions accelerated by the heliospheric termination shock
- Prove for local interstellar medium (LISM)



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

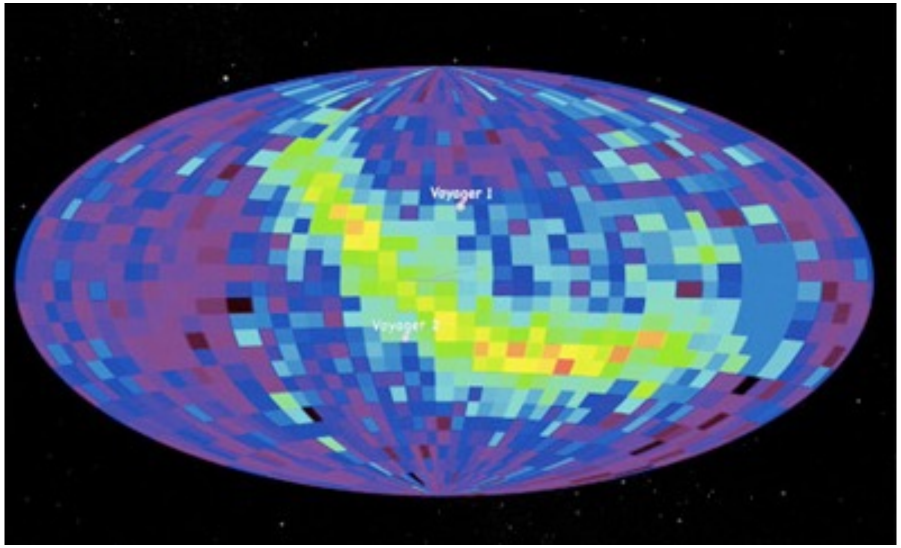
- Different latitudinal /longitudinal dependence from TS?

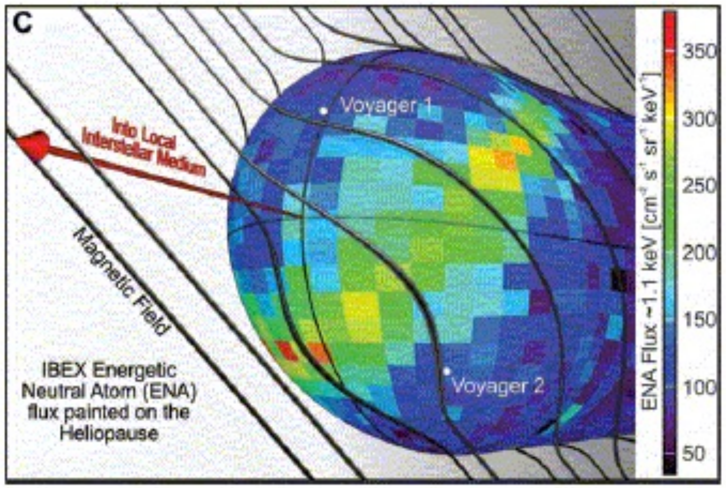
Probing local interstellar medium (LISM)

•Interstellar Boundary Explorer (IBEX) obtained all-sky map of Energetic Neutral Atoms (ENA).

•ENAs are (believed to be) pick-up ions that are heated (~1keV) near termination shock and then exchange the charge with surrounding plasma

• Strange ribbon-like structure found... effect of interstellar B?





McComas+ 2009, Science