太阳高能粒子事件的经度分布

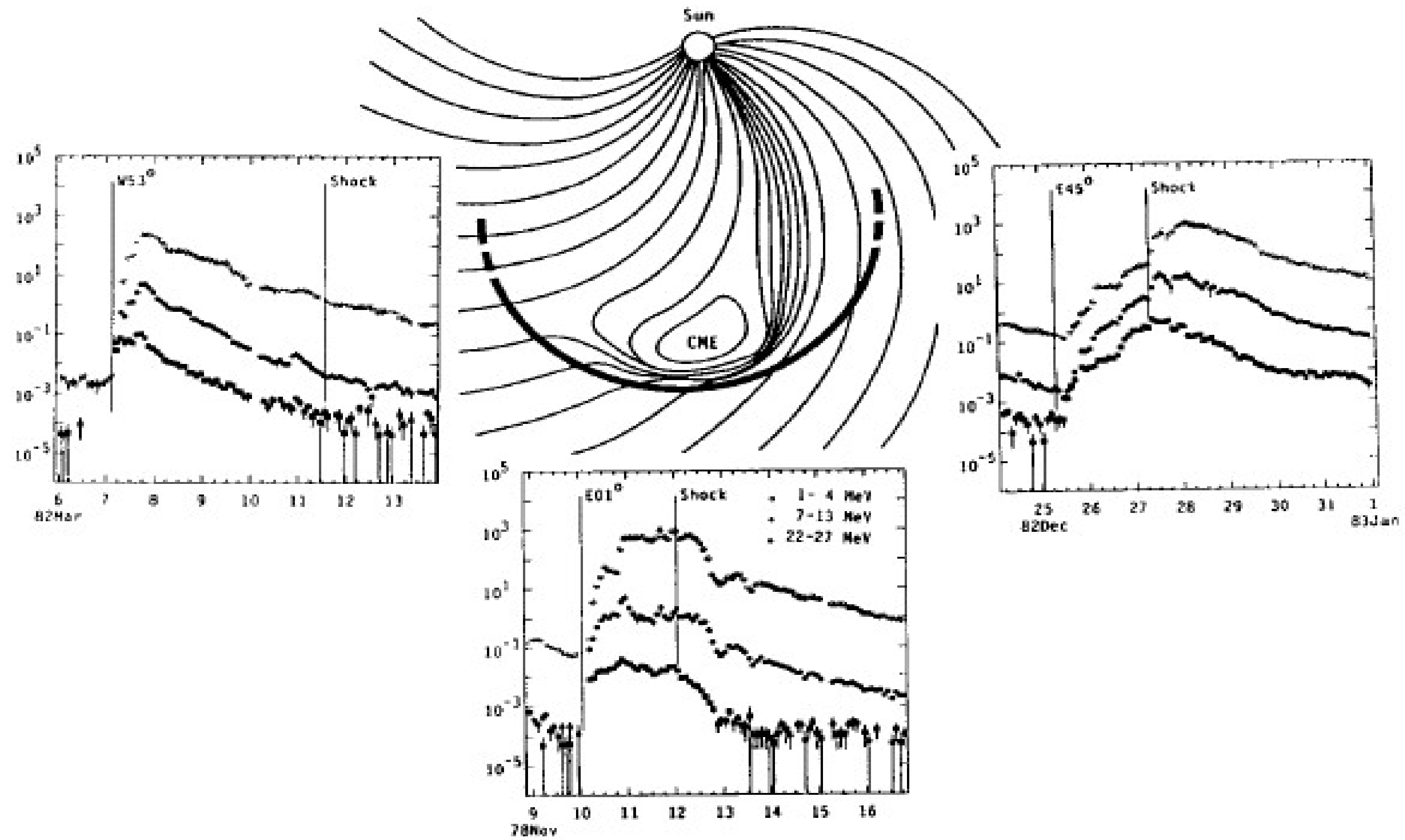


Figure 3.4. Typical intensity-time profiles are shown for 3 events viewed from different solar longitudes relative to the CME and shock.

思考题：为什么不同经度产生的太阳高能粒子事件曲线特点不一样？

预报CME的地磁效应

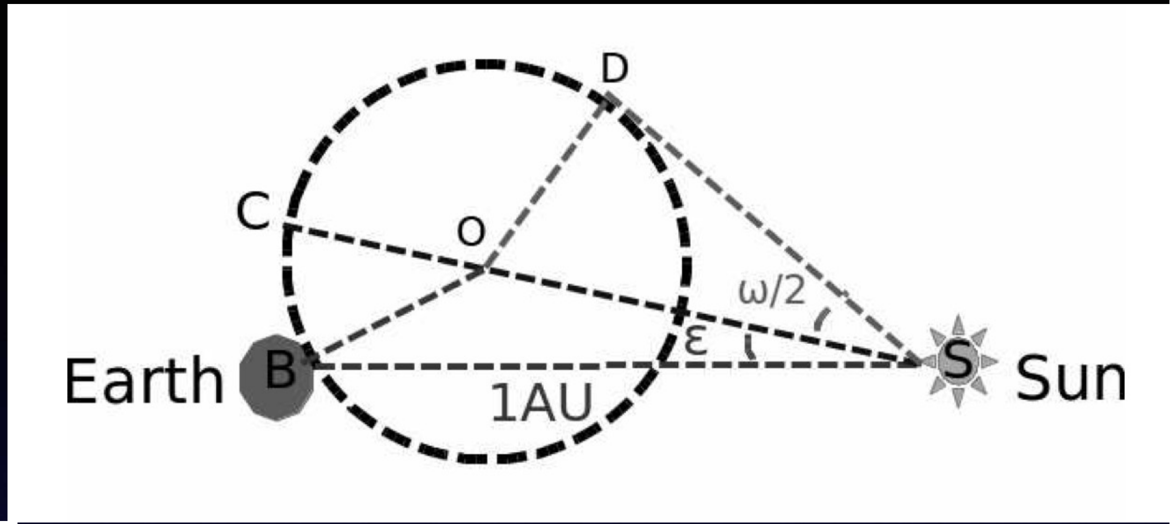
日冕物质抛射到达

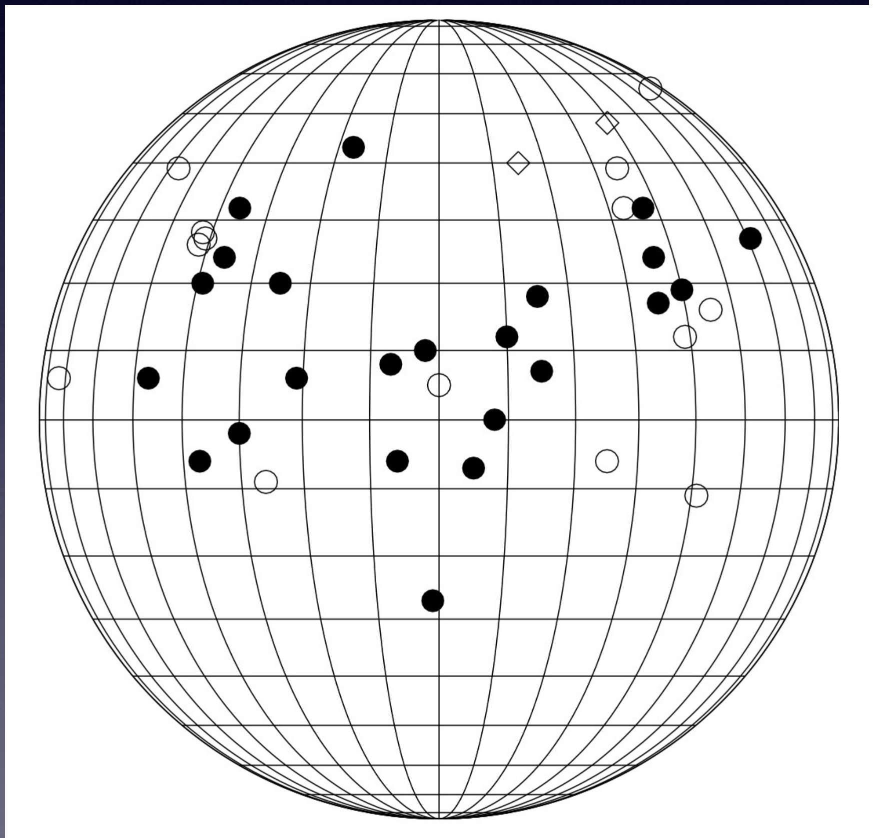
1. 能否达到地球?
2. 何时到达地球?
3. 地磁效应强度? → 南向磁场

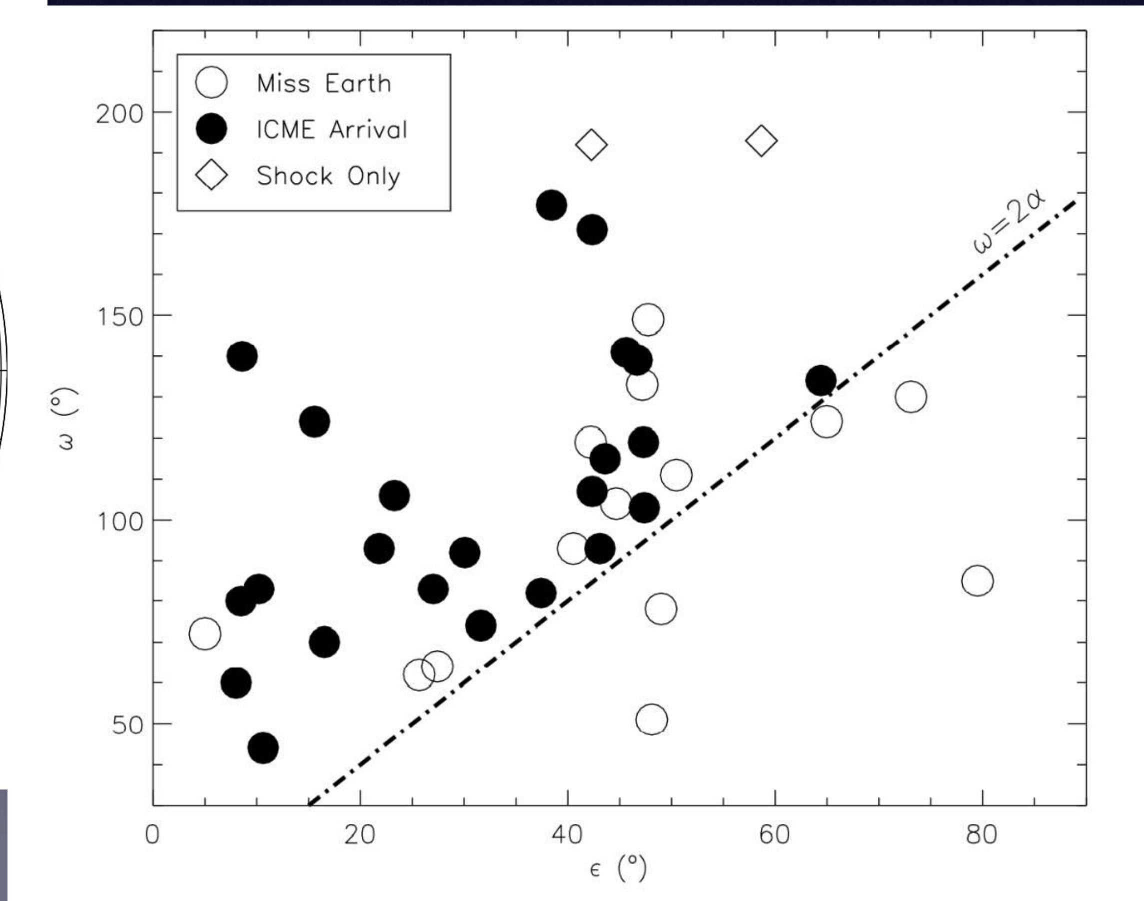
- ➢ 方向
- ➢ 大小
- ➢ 速度

Q1: 能否到达地球?

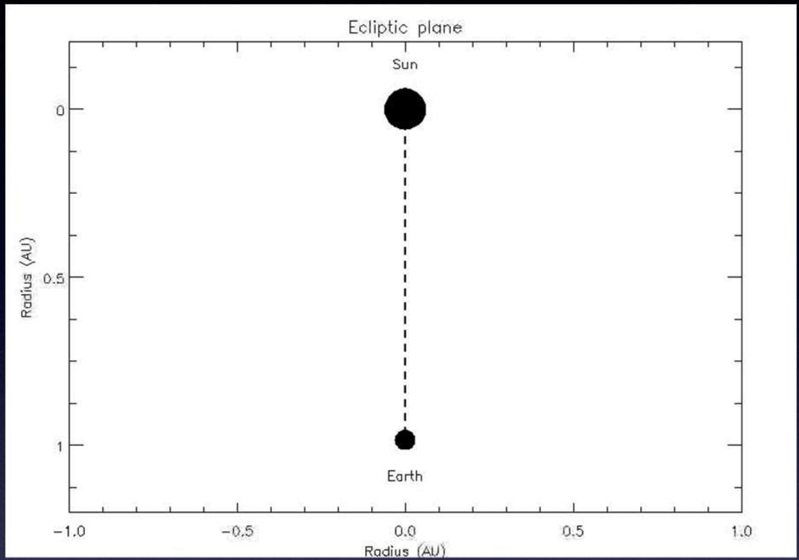
- 方向
- 大小

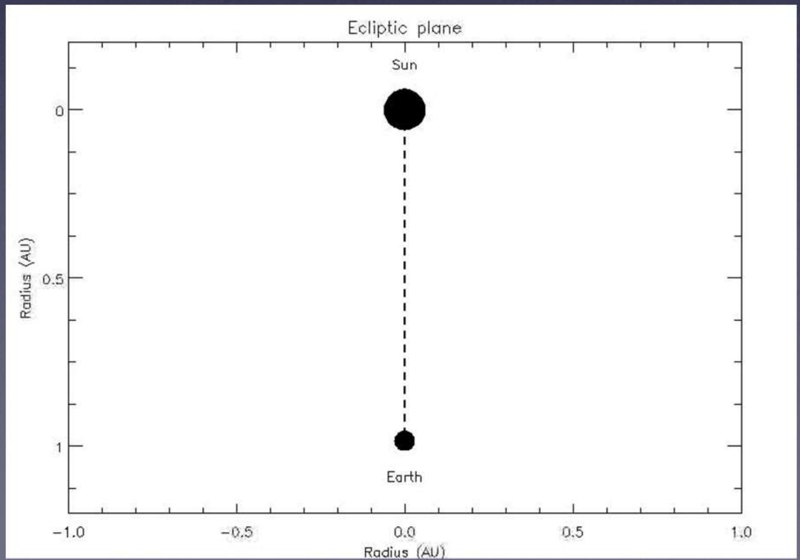


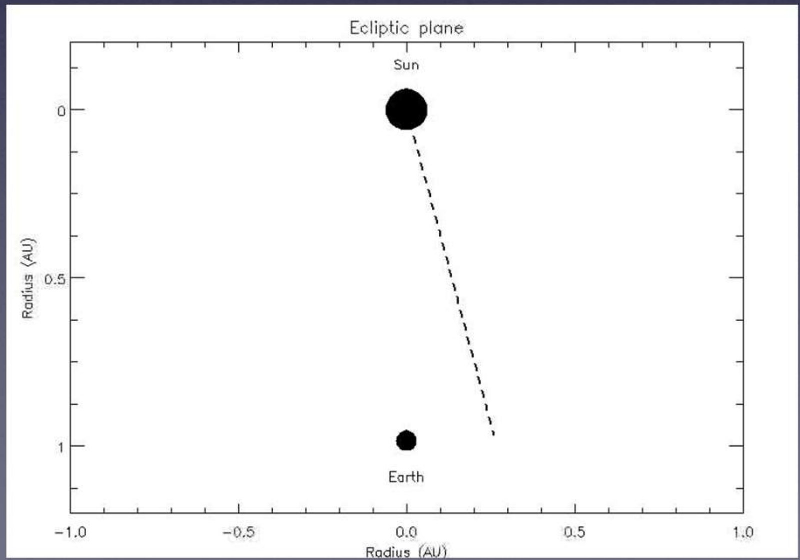




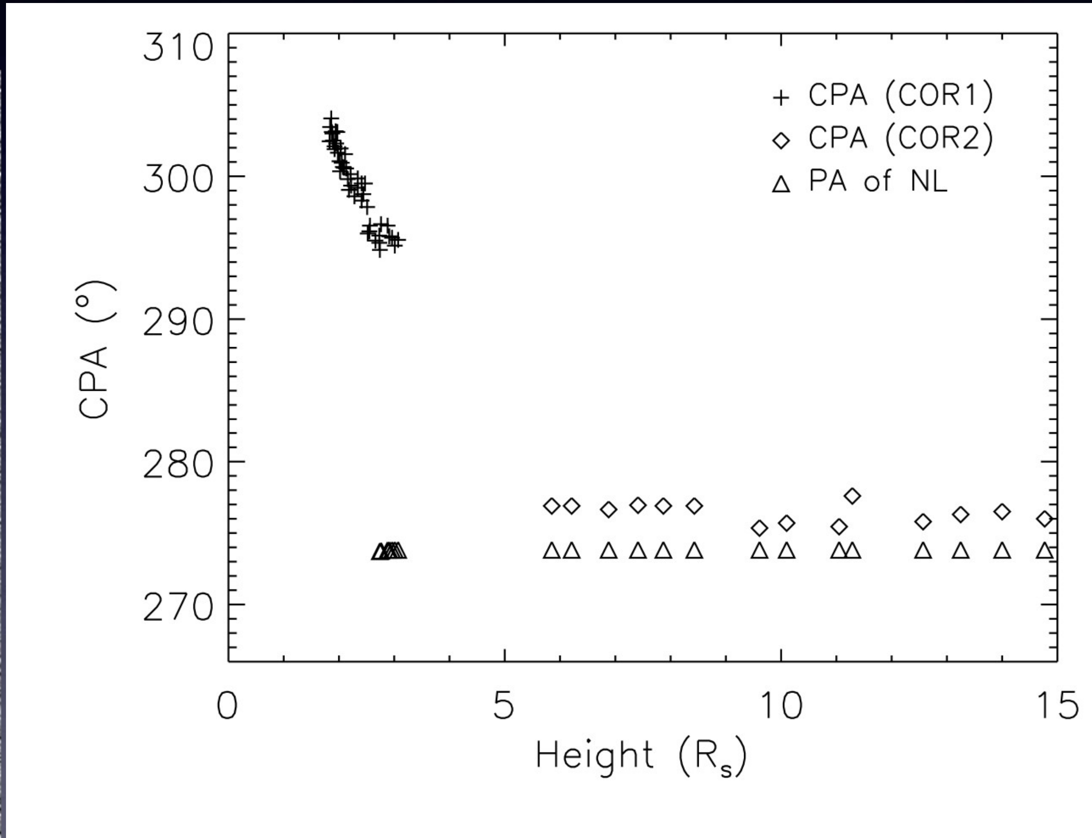
偏转对日冕物质抛射能否到达地球的影响？





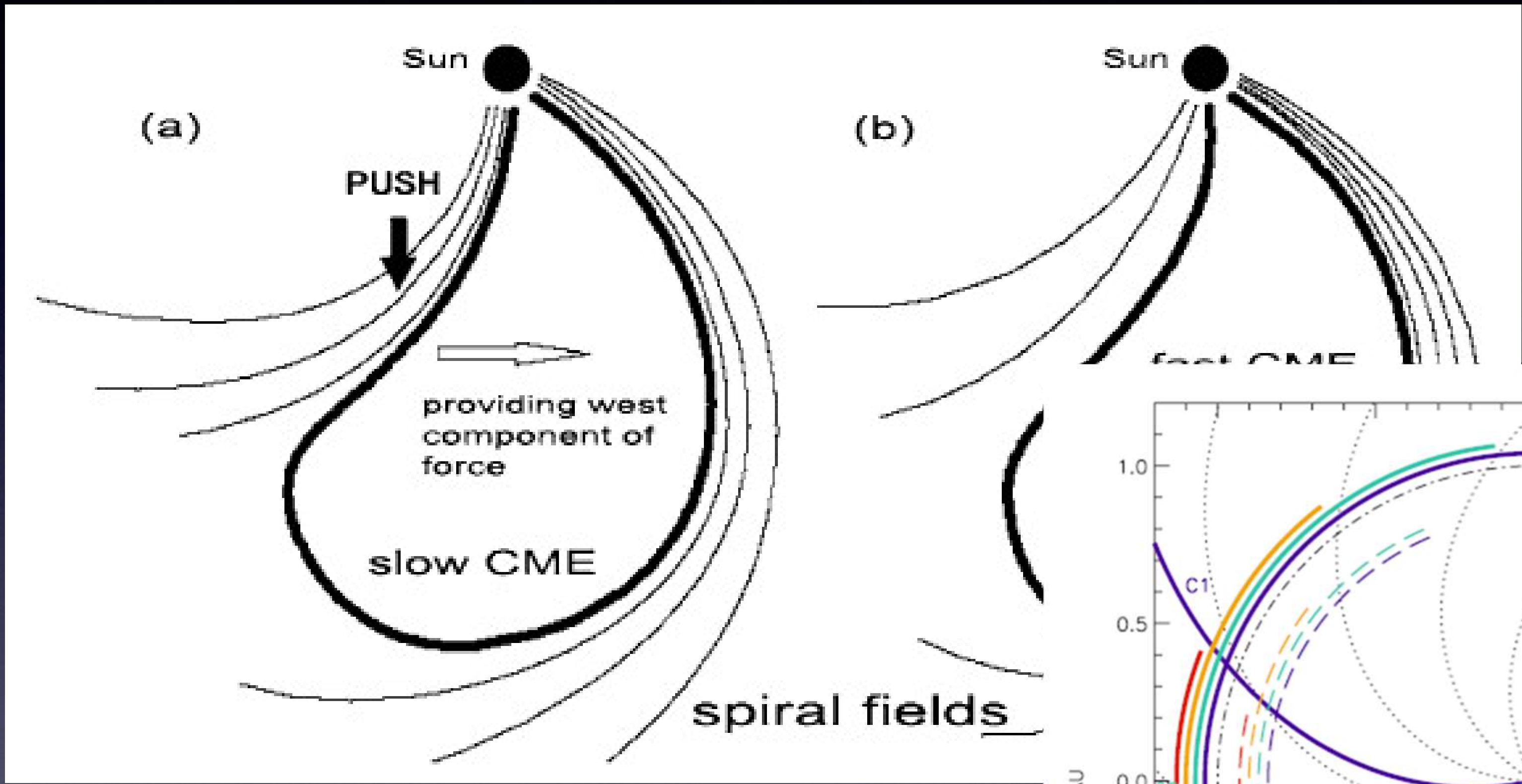


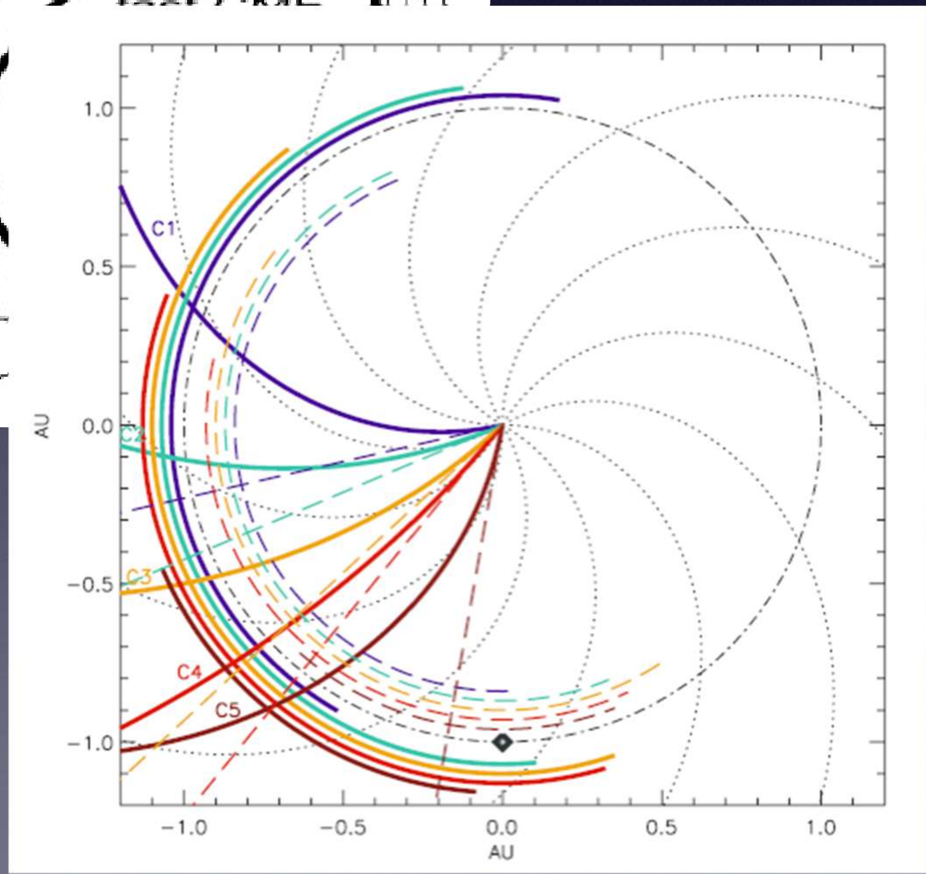
可能影响因素一：日冕中的偏转传播

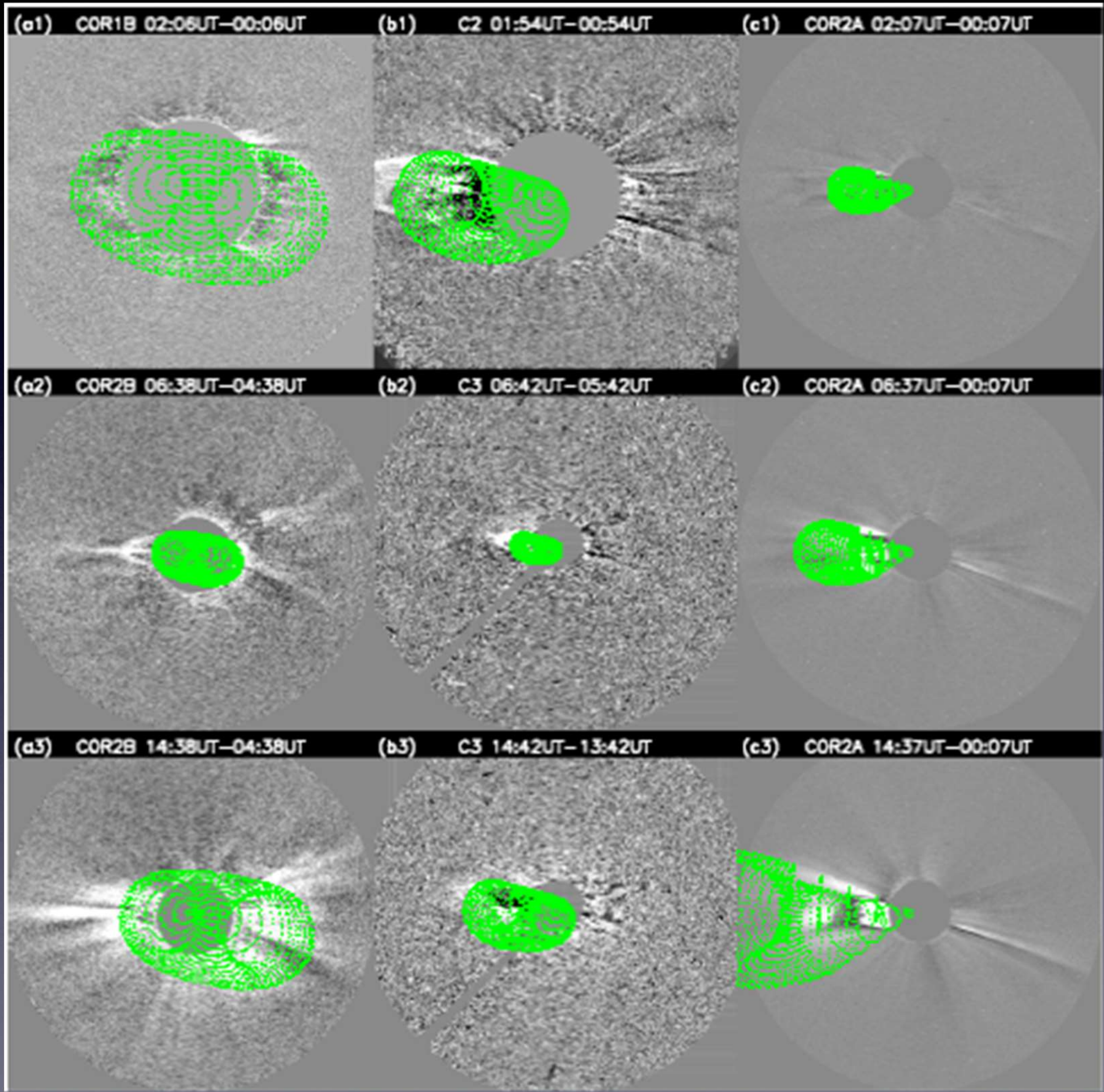


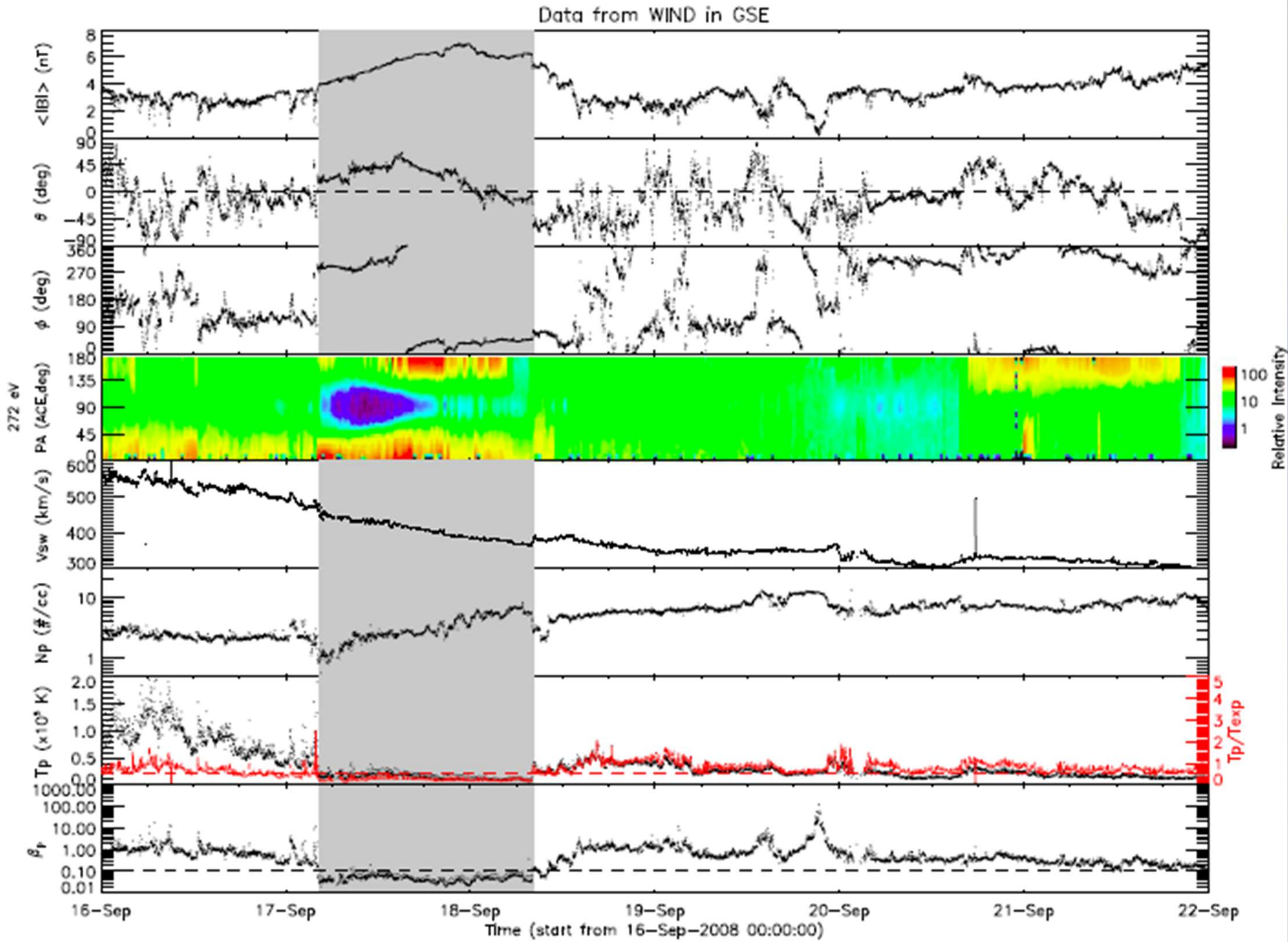
日冕物质抛射在传播过程中偏向电流片，后沿电流片传播

可能影响因素二：行星际空间中的偏转传播

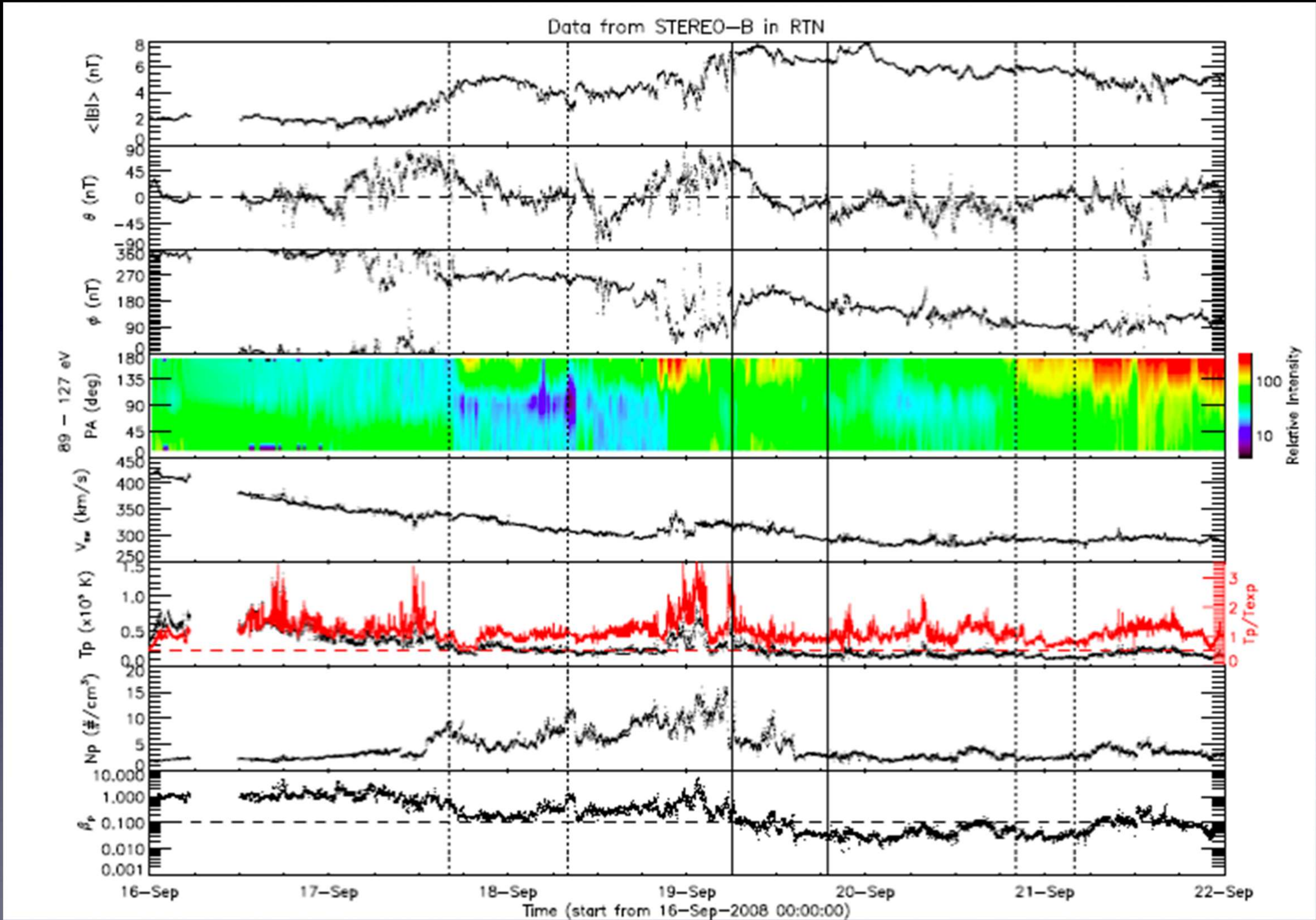




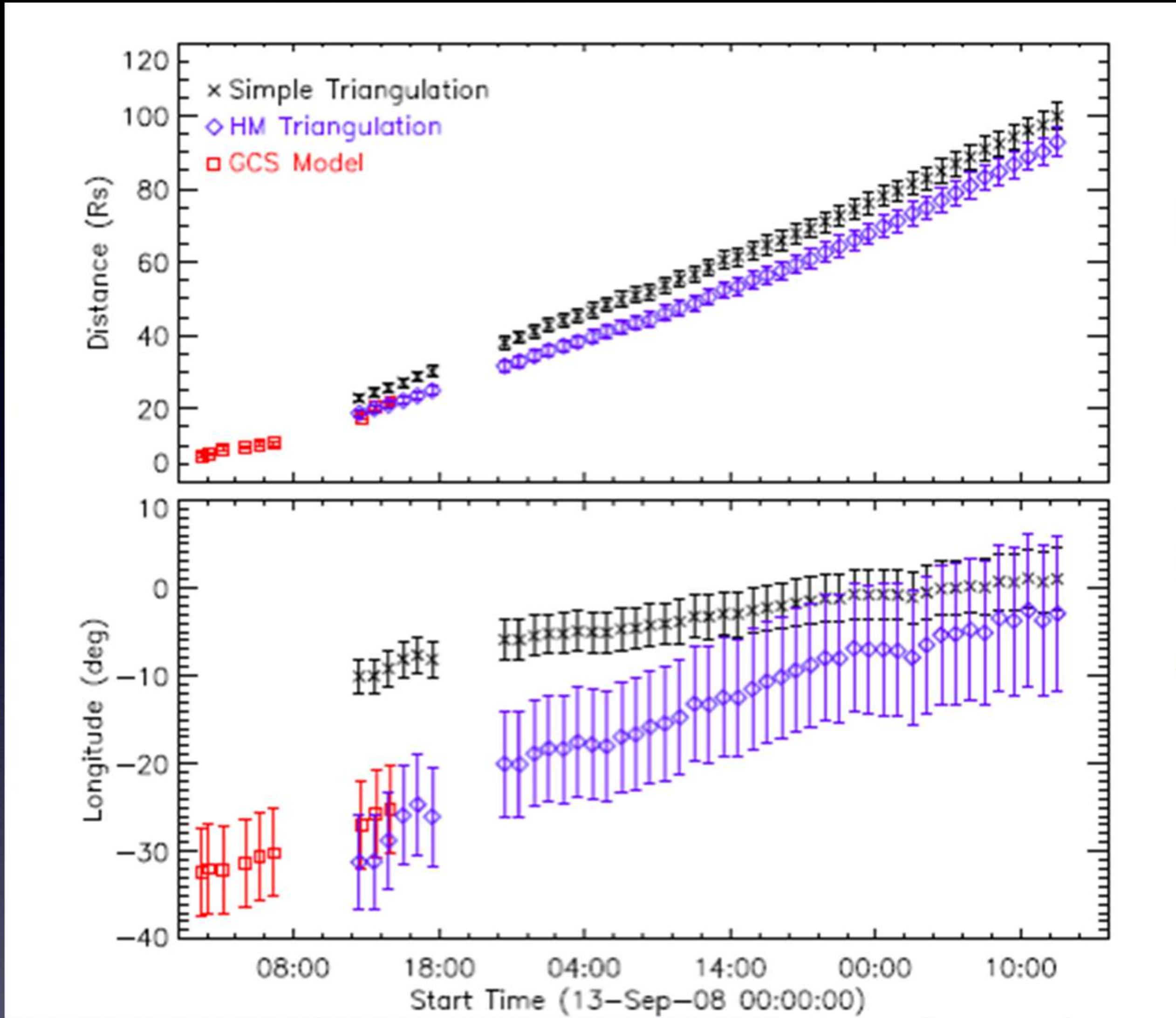

(a1) COR1B 02:06UT–00:06UT
(b1) C2 01:54UT–00:54UT
(c1) COR2A 02:07UT–00:07UT
(a2) COR2B 06:38UT–04:38UT
(b2) C3 06:42UT–05:42UT
(c2) COR2A 06:37UT–00:07UT
(a3) COR2B 14:38UT–04:38UT
(b3) C3 14:42UT–13:42UT
(c3) COR2A 14:37UT–00:07UT



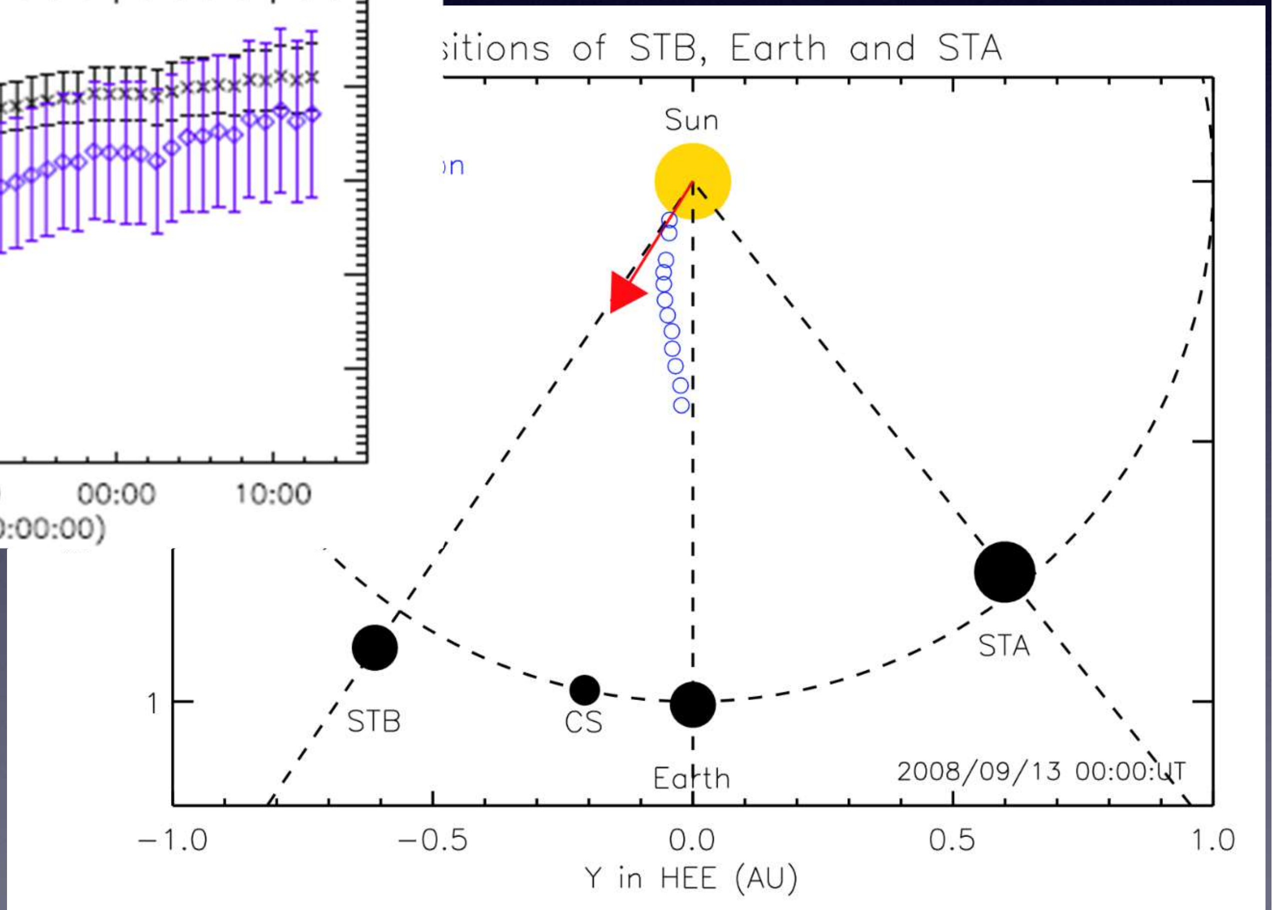
Data from WIND in GSE
<|B|> (nT)
θ (deg)
φ (deg)
272 eV
PA (ACE,deg)
Relative Intensity
Vsw (km/s)
Np (#/cc)
Tp (x10⁵ K)
Tp/Texp
βp
16-Sep
17-Sep
18-Sep
19-Sep
20-Sep
21-Sep
22-Sep
Time (start from 16-Sep-2008 00:00:00)



Data from STEREO–B in RTN
<|B|> (nT)
θ (nT)
φ (nT)
89 – 127 eV
PA (deg)
Relative Intensity
Tp (x10⁶ K)
Tp/Texp
Np (#/cm³)
16–Sep
17–Sep
18–Sep
19–Sep
20–Sep
21–Sep
22–Sep
Time (start from 16–Sep–2008 00:00:00)

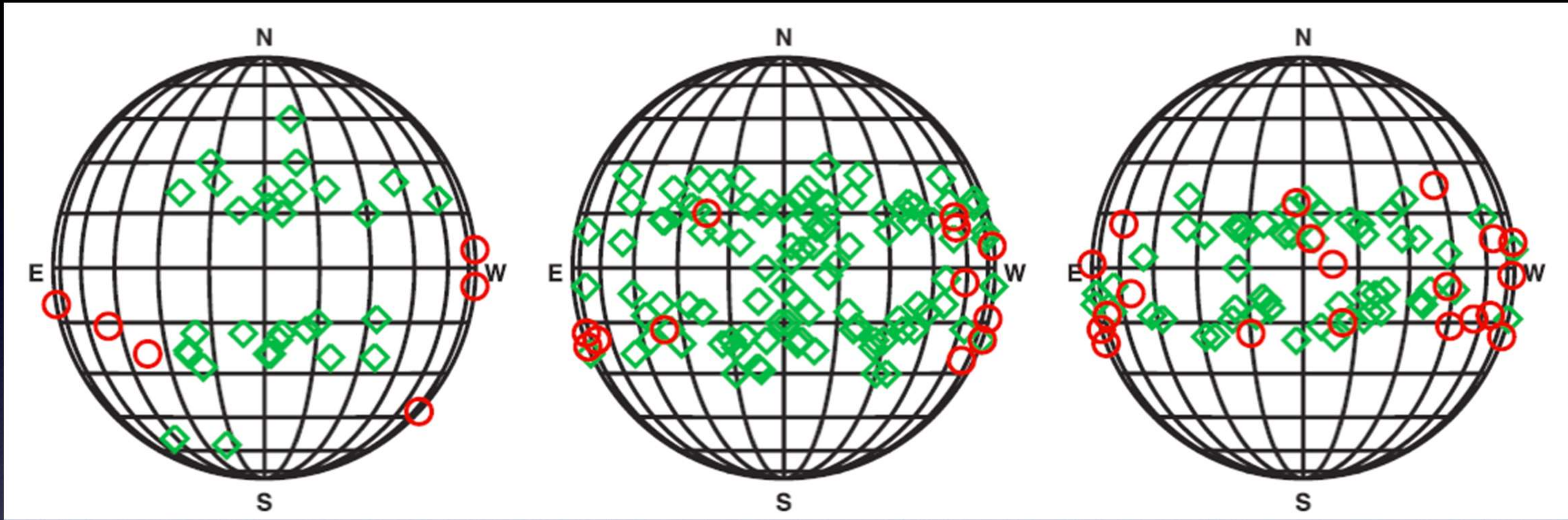


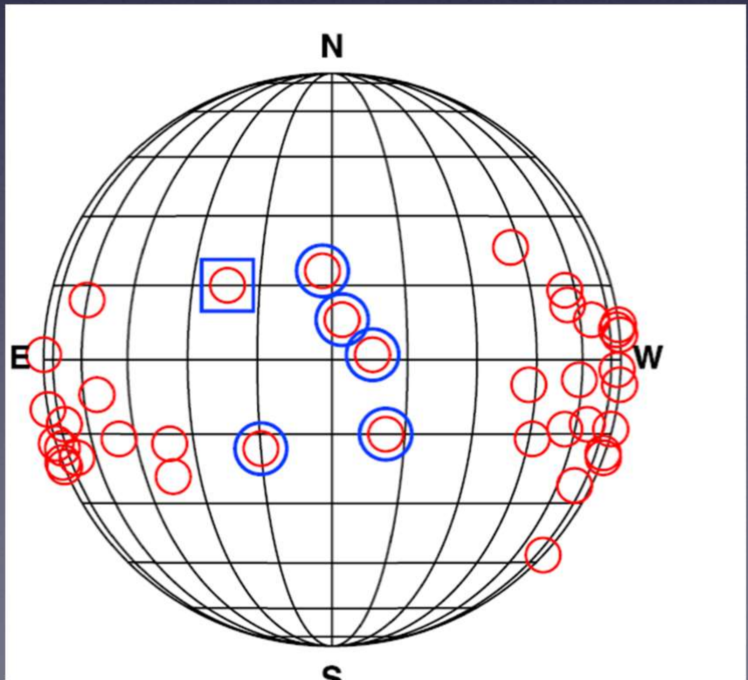
× Simple Triangulation
◇ HM Triangulation
□ GCS Model
Distance (Rs)
Longitude (deg)
08:00
18:00
04:00
14:00
00:00
10:00
Start Time (13-Sep-08 00:00:00)

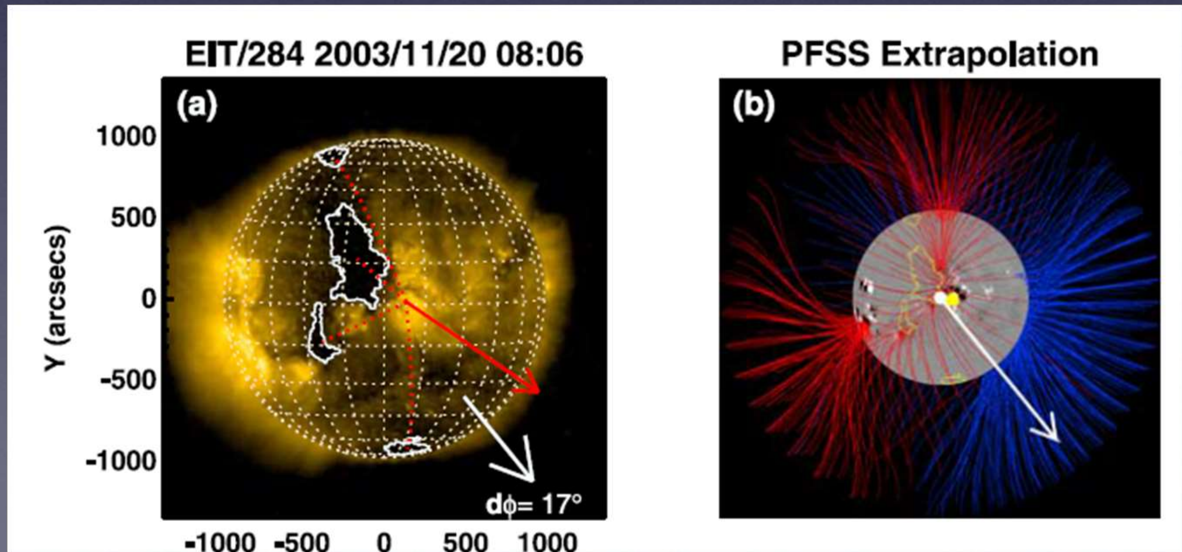


sitions of STB, Earth and STA
Sun
STB
CS
Earth
STA
2008/09/13 00:00:UT
Y in HEE (AU)

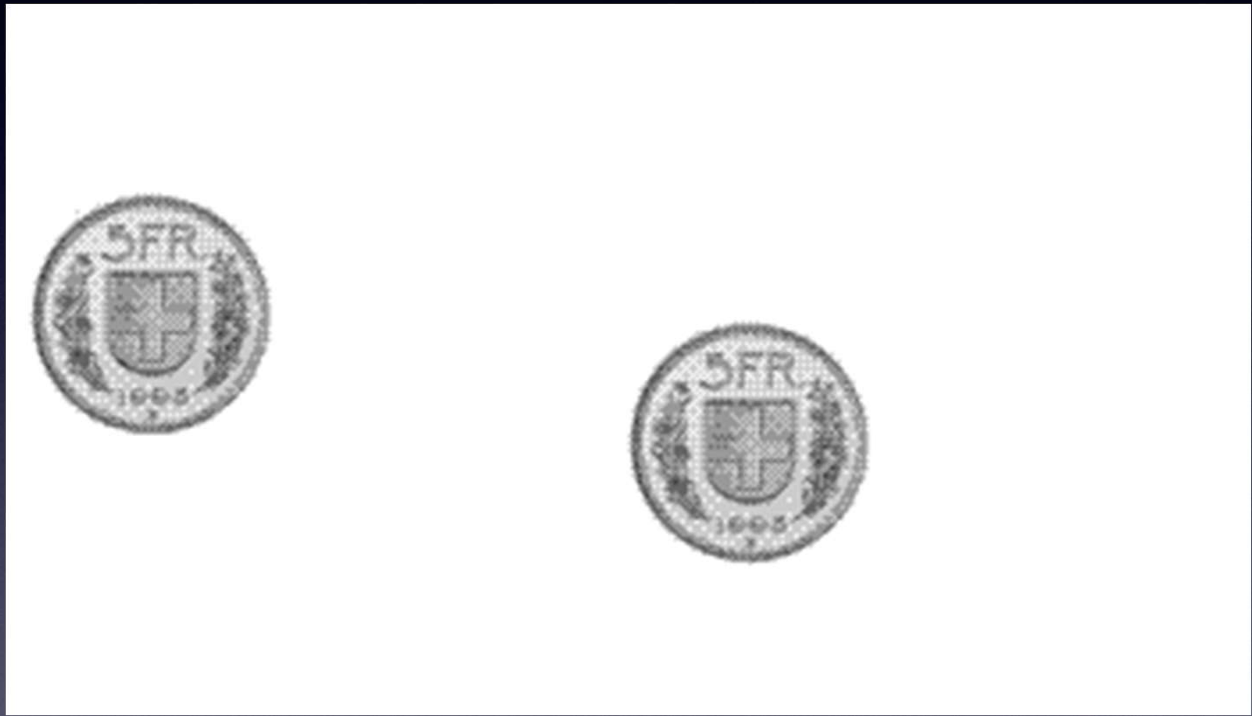
临近冕洞引起的日冕物质抛射的偏转





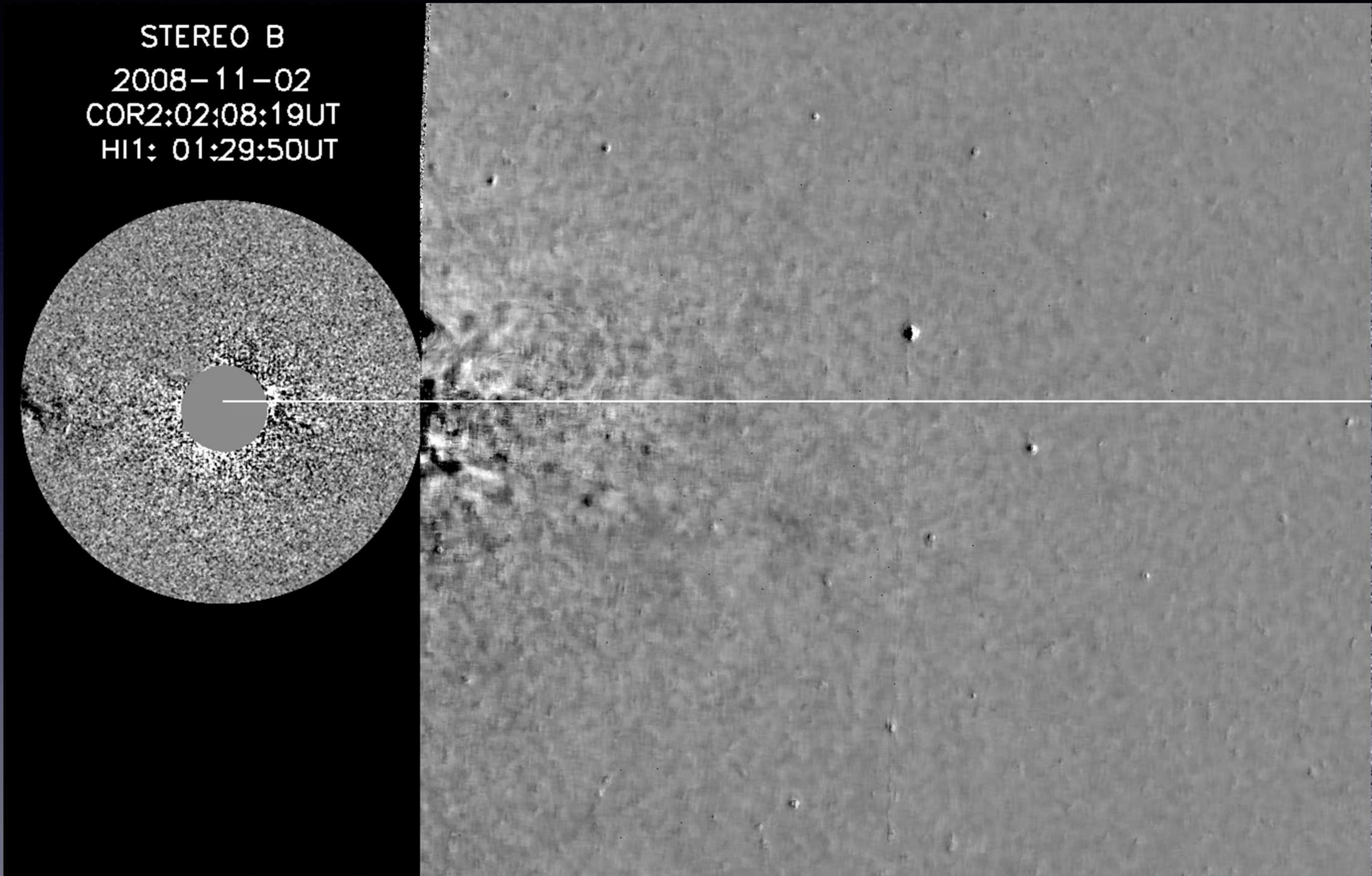


可能影响因素三：日冕物质抛射的相互作用

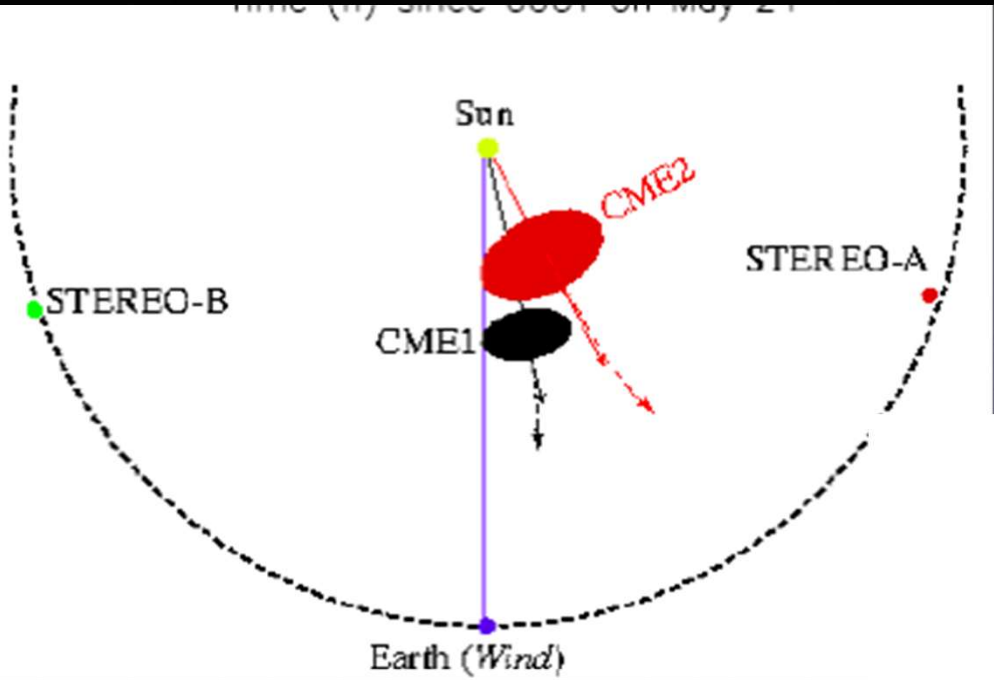


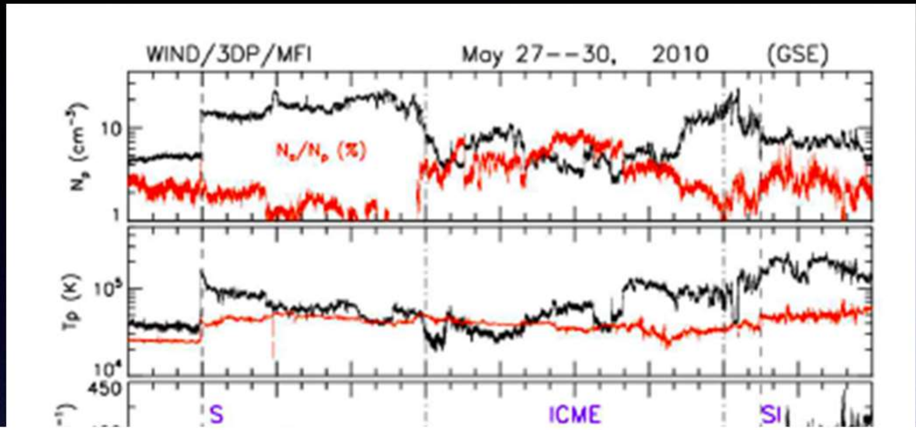
相互作用（碰撞）可能会显著改变CME的传播方向

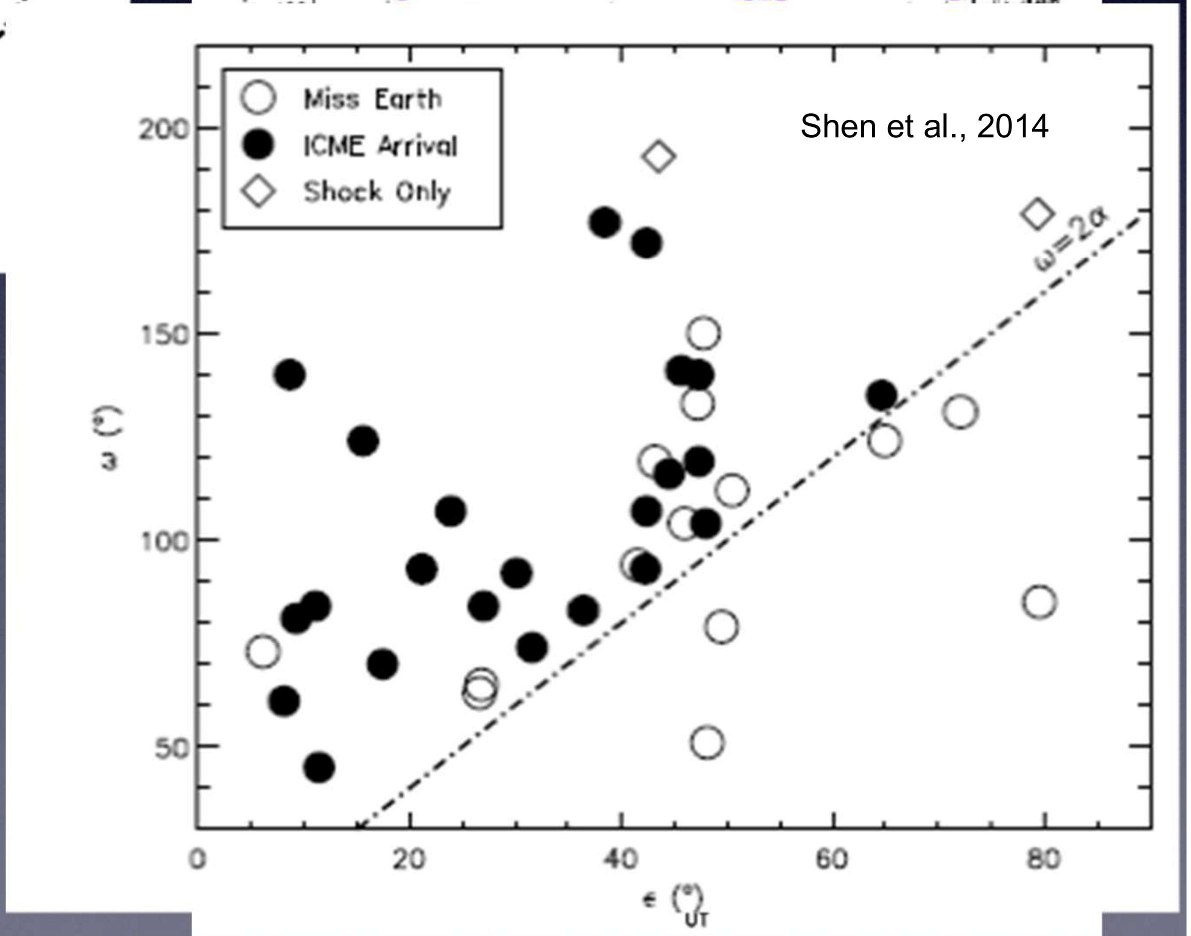
日冕物质抛射相互作用的成像观测



日冕物质抛射相互作用→改变方向[偏转]→对地日冕物质抛射离开地球



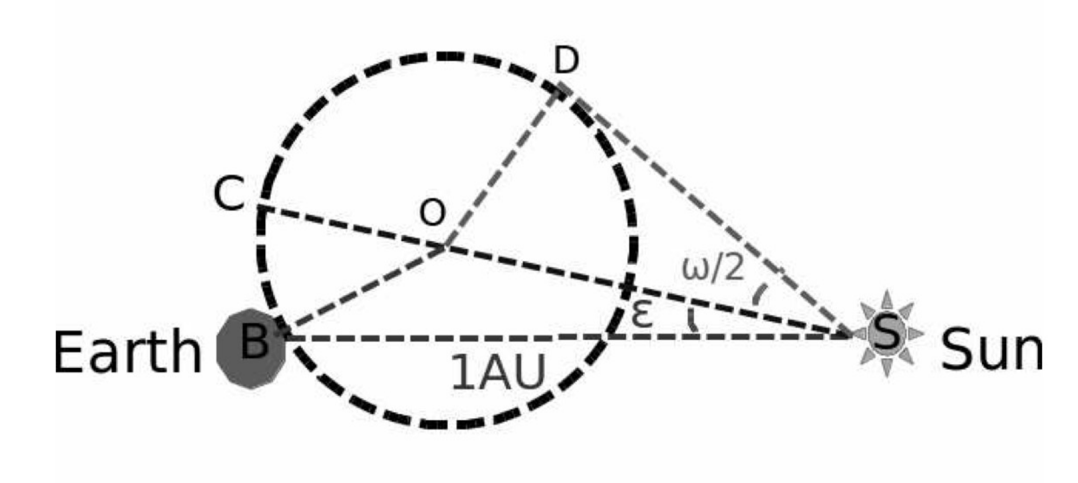


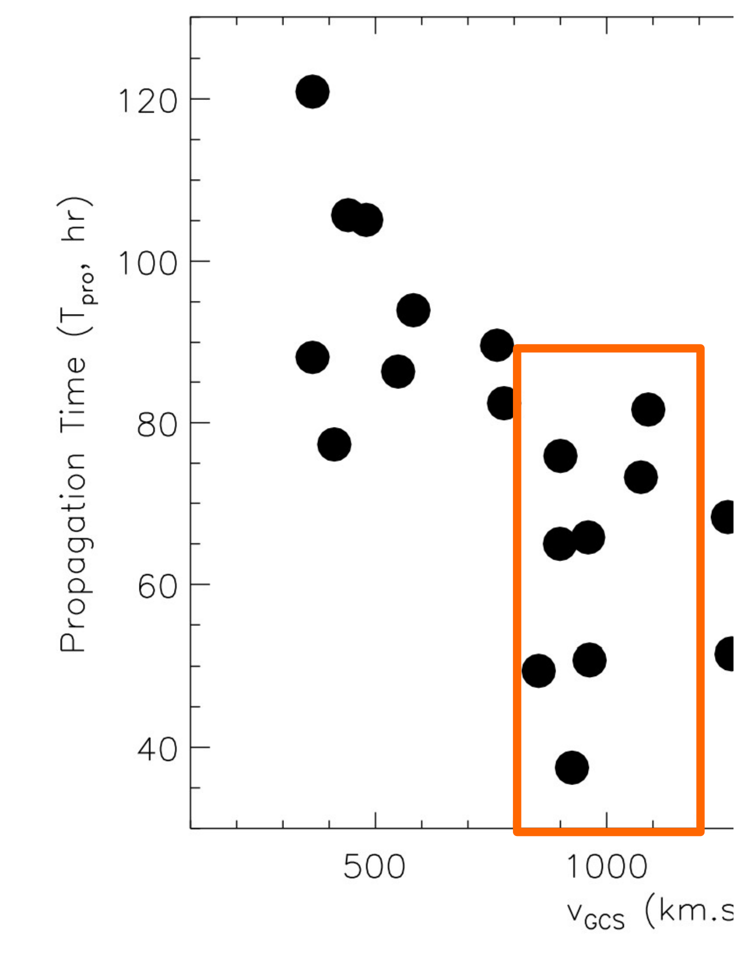


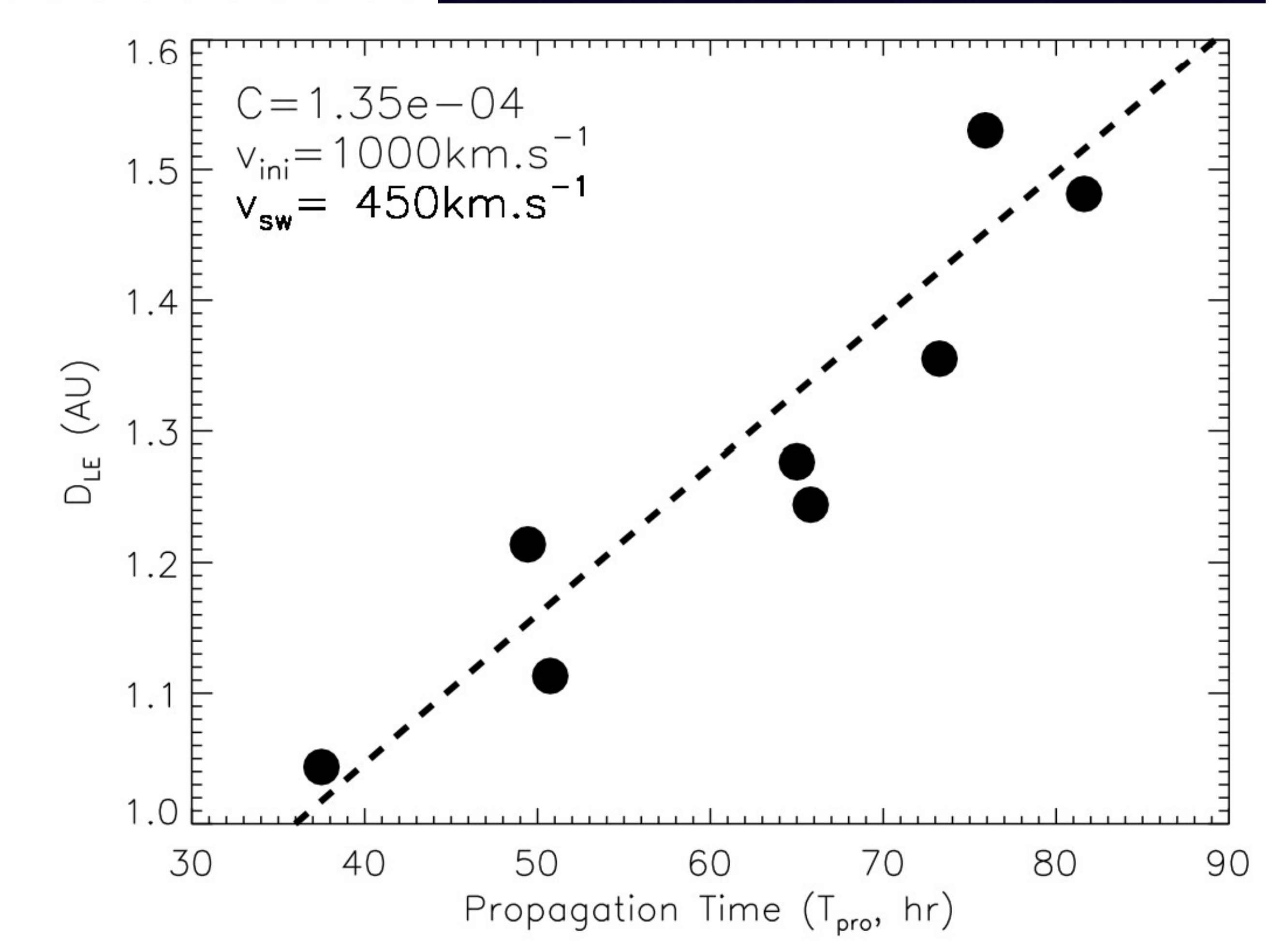
- 相互作用使得一个对向地球的CME离开了地球[Lugaz et al., 2013]
- 相互作用使得2（of 6）个爆发于日面中间的全晕状CME没有到达地球[Shen et al., 2014]

Q2: 何时到达地球?

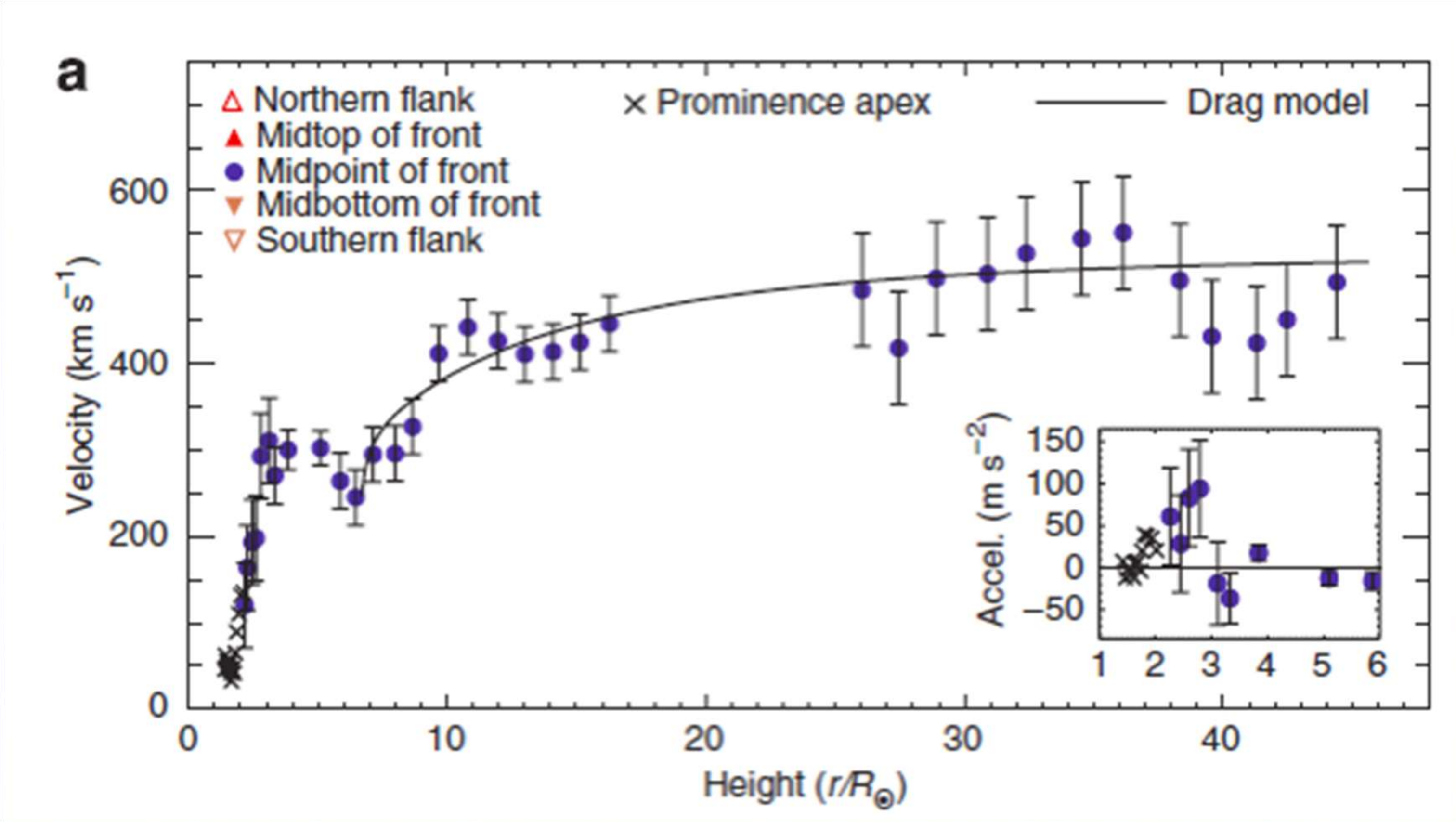
- ➢ 速度
- ➢ 方向







日冕物质抛射传播过程中的速度演化



传播的拖拽模型

$$\frac{dv_{\text{cme}}}{dr} = -\alpha r^{-\beta} \frac{1}{v_{\text{cme}}} (v_{\text{sw}} - v_{\text{cme}})^{\gamma}$$

$$\alpha r^{-\beta} = \frac{1}{2} \frac{A_{\text{cme}} C_{\text{D}} \rho_{\text{sw}}}{M_{\text{cme}}}$$

Q3: 需要的观测数据

- ➢ 大小

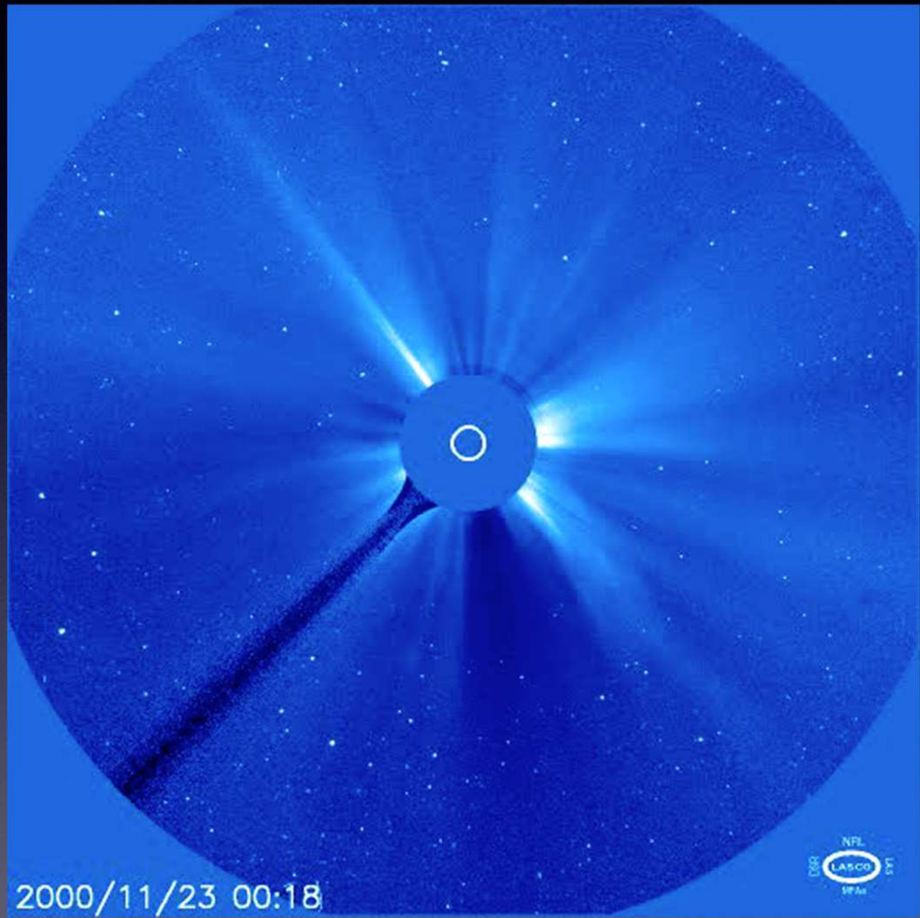
  角宽度

- ➢ 方向

  晕状、全晕状、源区信息

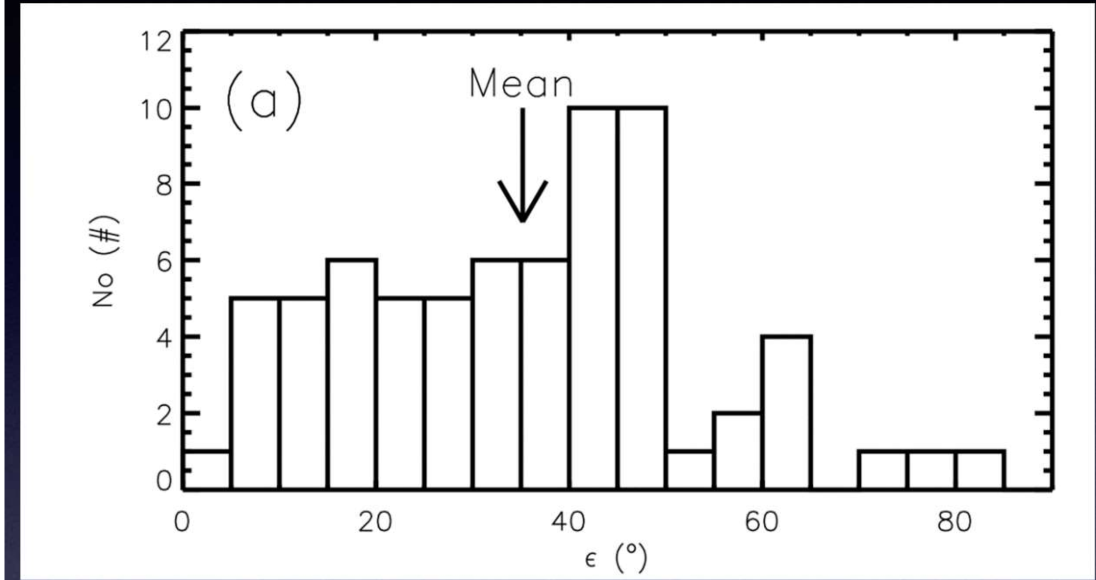
- ➢ 速度

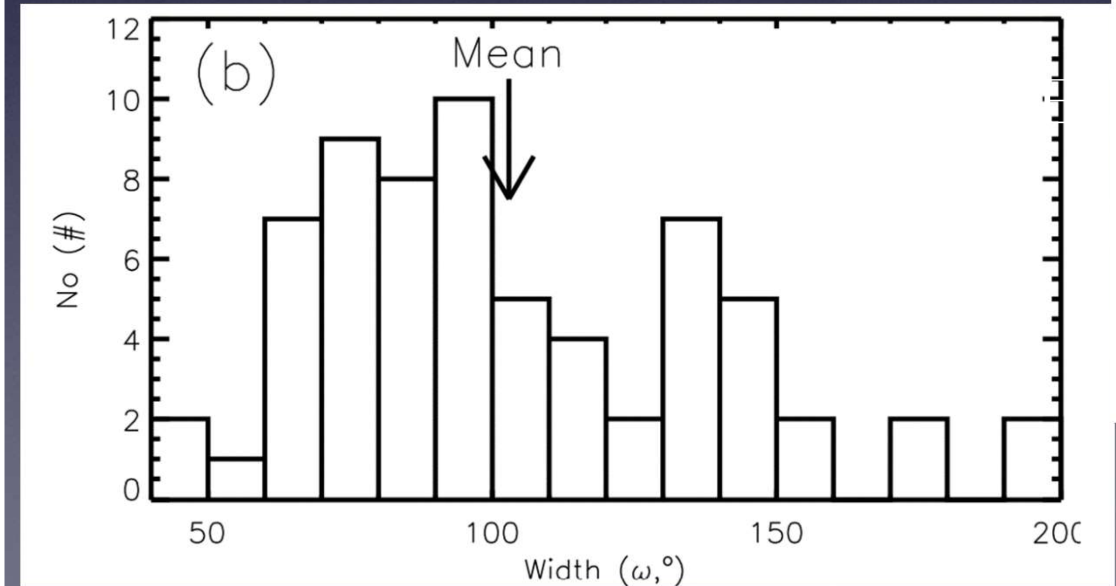
  速度

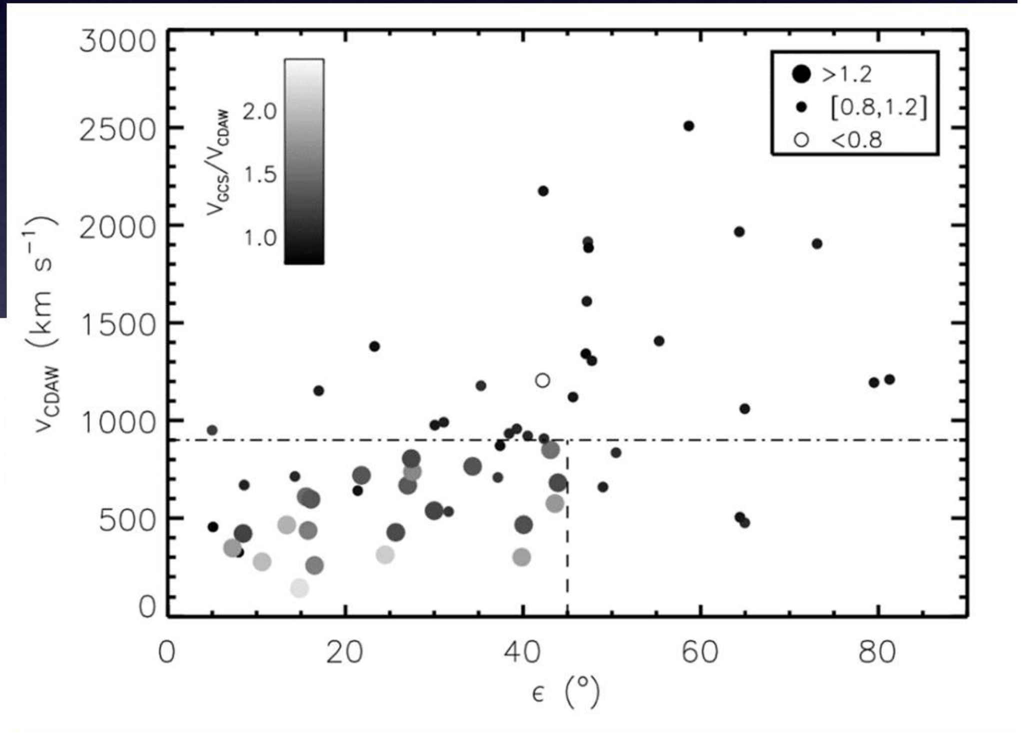


如果没有STEREO?

显著的投影效应

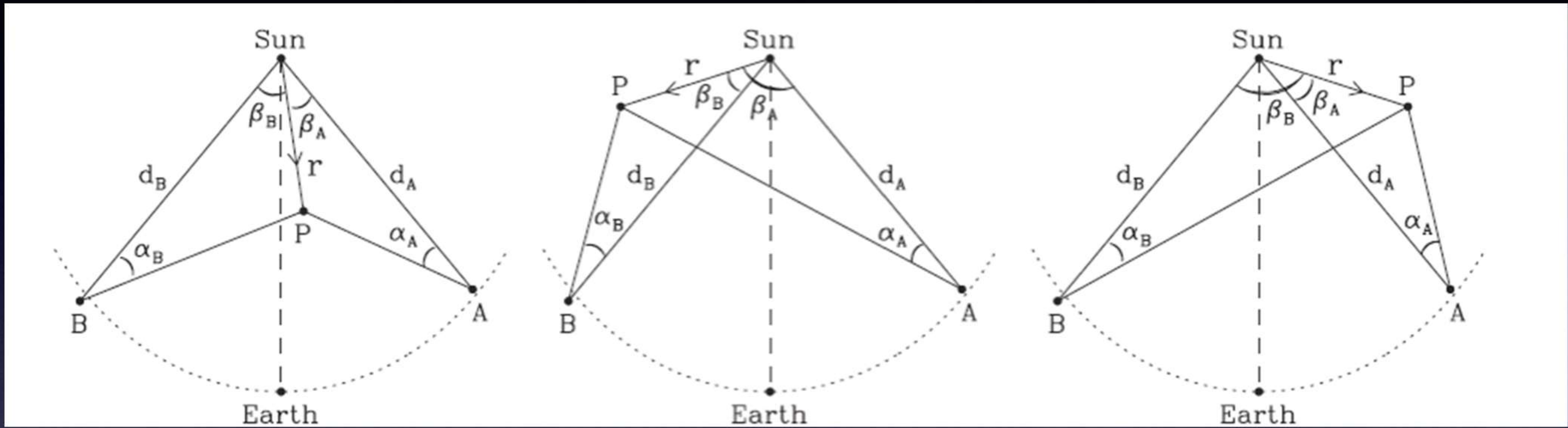

(a)
Mean
No (#)
ϵ (°)
0
20
40
60
80
0
2
4
6
8
10
12

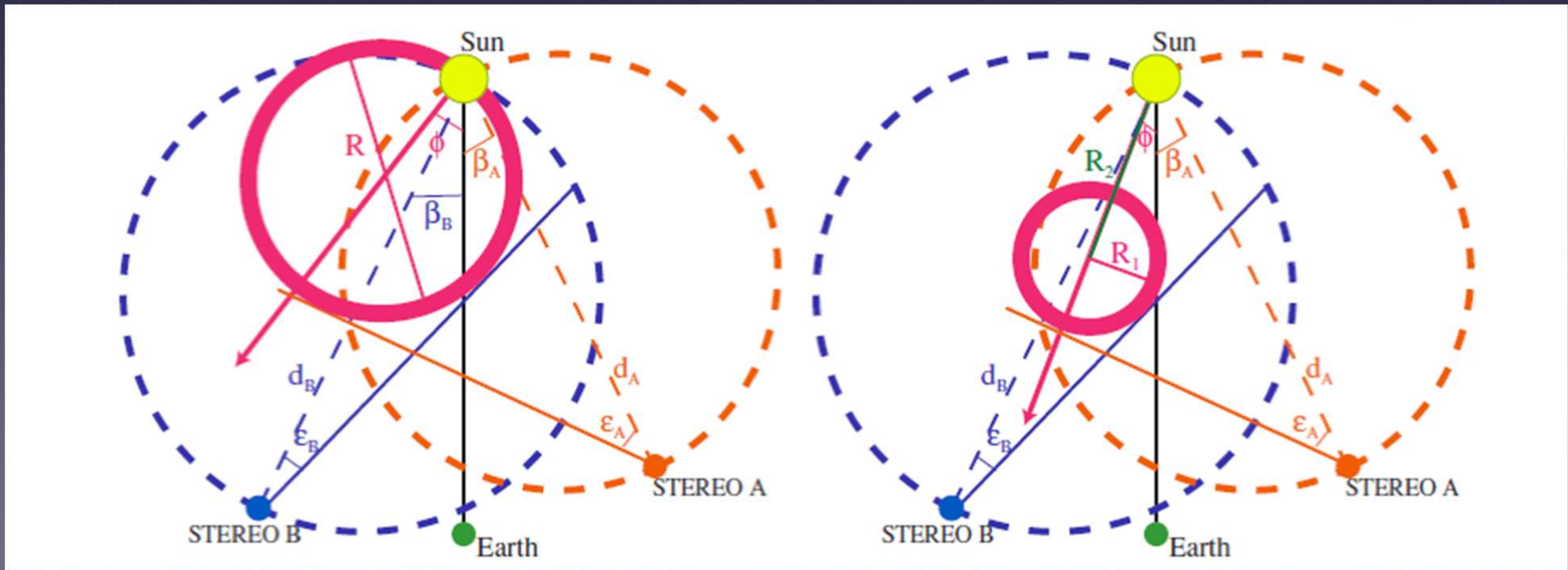

(b)
Mean
No (#)
Width (ω,°)
50
100
150
200
0
2
4
6
8
10
12


V_{CDAW} (km s^{-1})
ϵ (°)
V_{GCS}/V_{CDAW}
2.0
1.5
1.0
>1.2
[0.8,1.2]
<0.8
0
500
1000
1500
2000
2500
3000
0
20
40
60
80

利用STEREO数据获取三维参数的问题

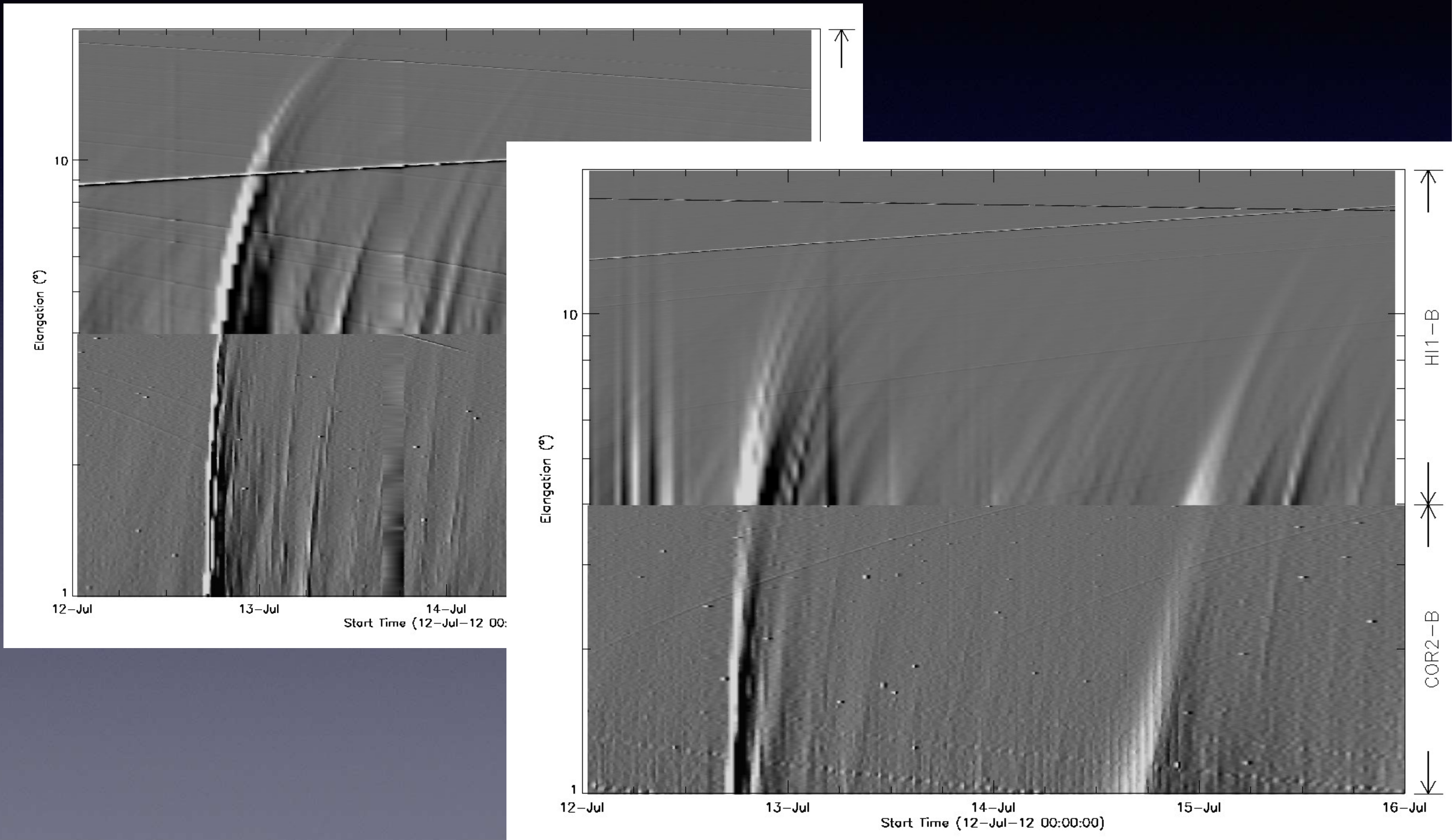
1. 各种方法假设太强





利用STEREO数据获取三维参数的问题

2. 多星结构之间对应不确定



Q4: 如何得到这些数据

可能的模型(没有STEREO的情况下)

➢大小

--- 锥模型[e.g. Xue et al. 2005]

GCS模型[Thernisien et al., 2006; 2011]

➢方向

--- 锥模型 +偏转模型[e.g. Shen et al., 2011, Wang et al., 2004, 2013]

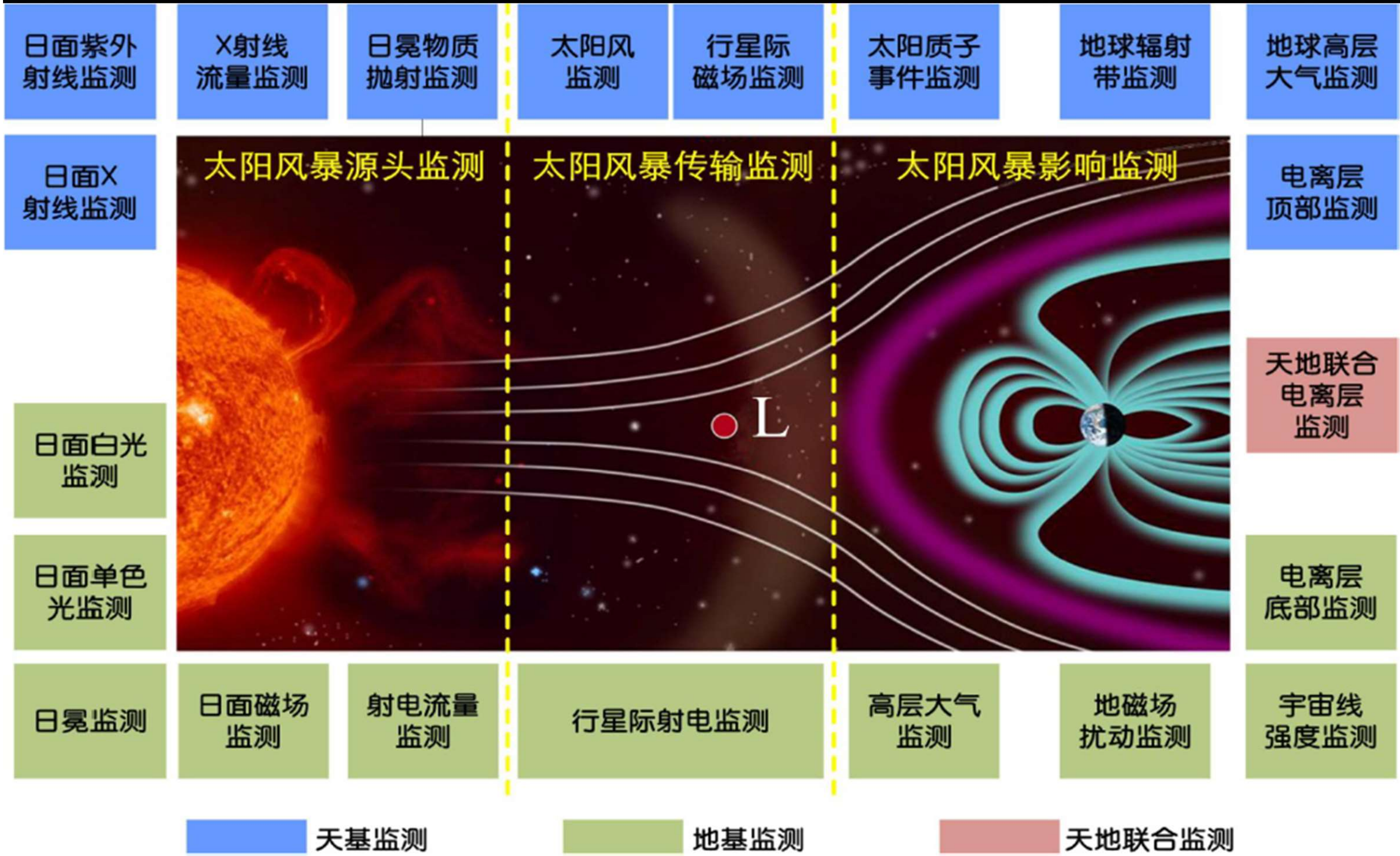
（需要参数：背景磁场、背景太阳风速度）

➢速度

--- 锥模型+拖拽模型[e.g. Chen et al., 1993,1996]

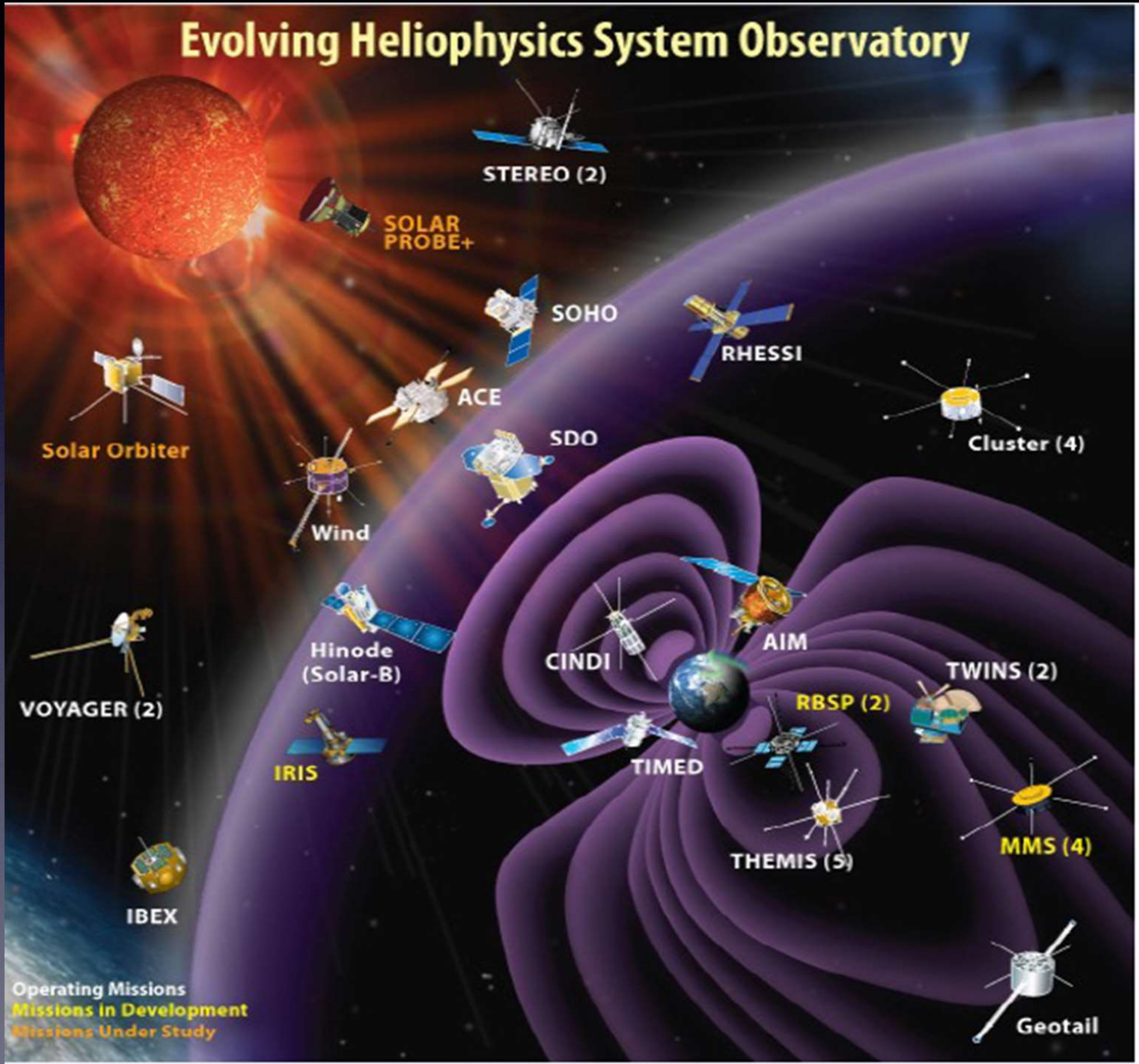
（需要参数：CME质量、大小、截面积、拖拽系数）

2.6 空间天气预报中的日地监测卫星



▲ 太阳风暴监测体系示意图

太阳风暴天基监测



Evolving Heliophysics System Observatory
STEREO (2)
SOLAR PROBE+
SOHO
RHESSI
Solar Orbiter
ACE
SDO
Cluster (4)
Wind
Hinode (Solar-B)
CINDI
AIM
TWINS (2)
VOYAGER (2)
RBSP (2)
IRIS
TIMED
MMS (4)
THEMIS (5)
IBEX
Geotail
Operating Missions
Missions in Development
Missions Under Study

卫星轨道参数(卫星轨道根数)

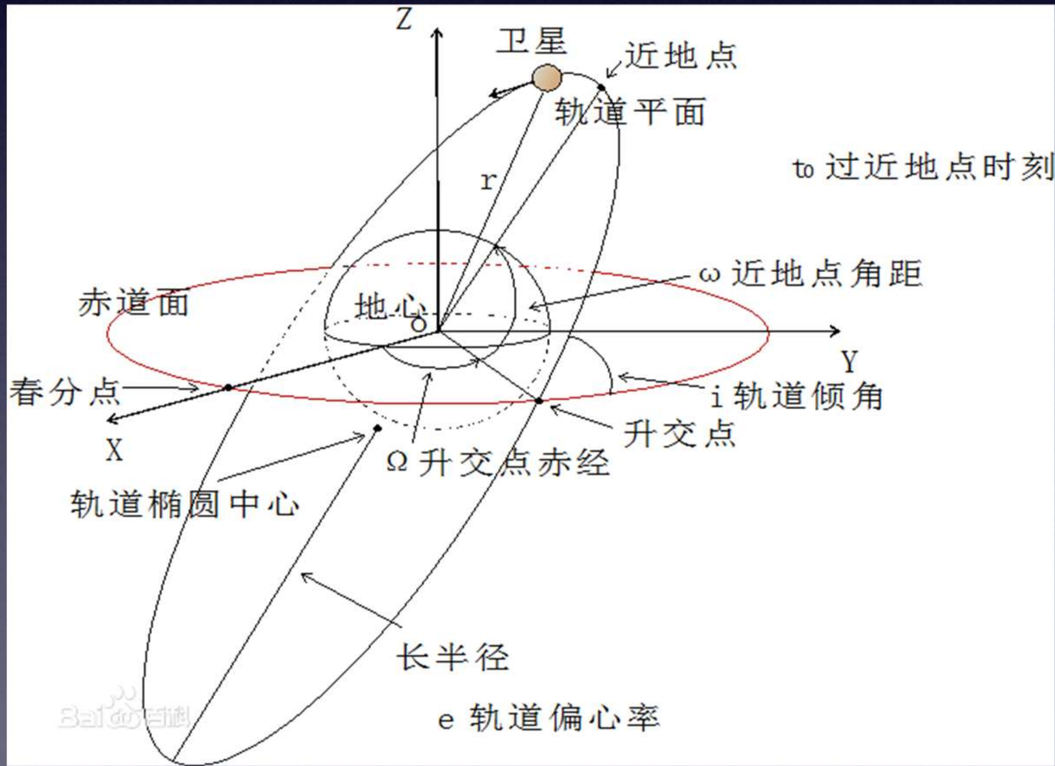
周期：卫星绕地球一周需要的时间。

截距：卫星绕地球一周，地球转过的度数。

偏心率：焦距与轨道半长轴之比

近地点角：在轨道平面内升交点和近地点与地心连线间的夹角。

平均近点角：若卫星通过近地点的时刻为t_p，卫星的平均角速度为 n，则任一时刻的平均近点角 $M=n(t-t_p)$



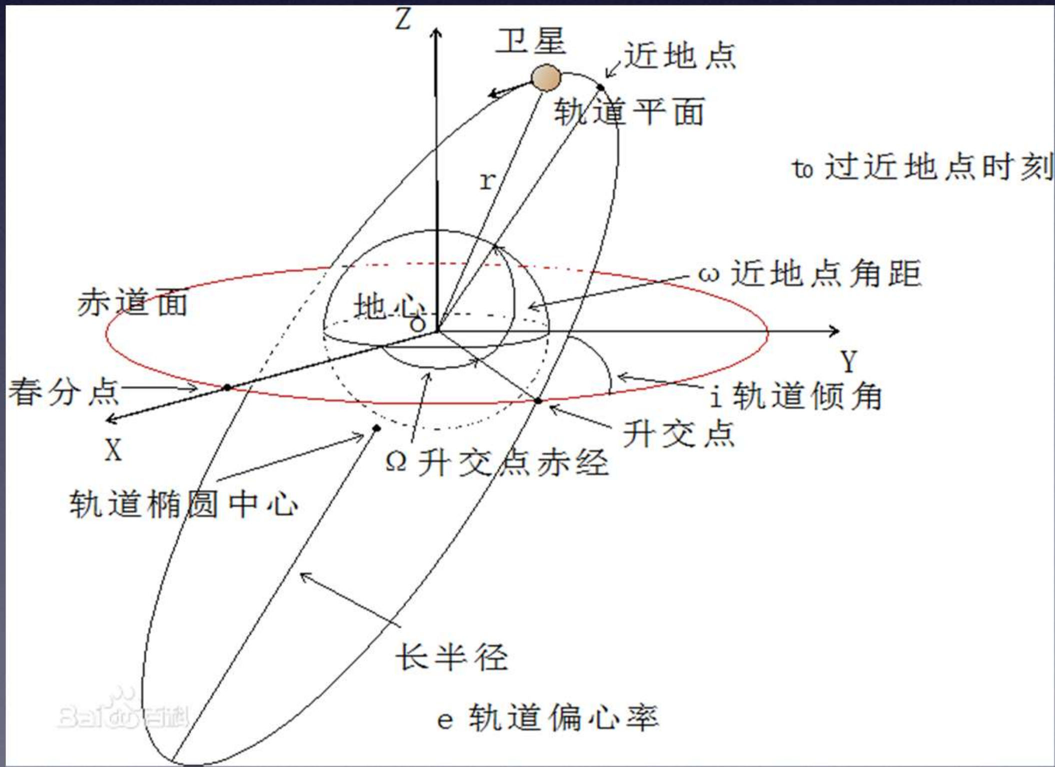
卫星轨道参数(卫星轨道根数)

倾角：赤道平面与卫星轨道平面间的夹角，具体计算是在卫星轨道升段时由赤道平面反时针旋转到轨道平面的夹角。

高度：卫星离地球表面的距离。

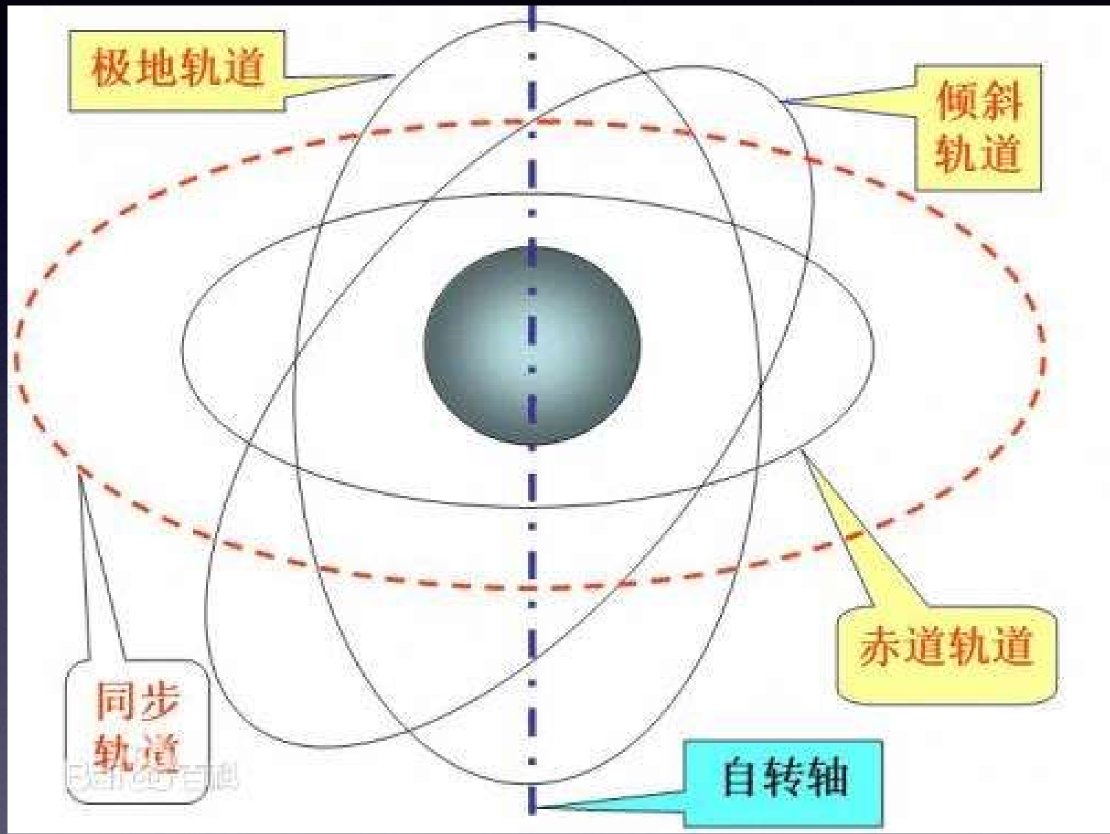
星下点：卫星与地球中心连线在地球表面的交点。

升交点：卫星由南往北飞行轨迹在赤道上的交点。



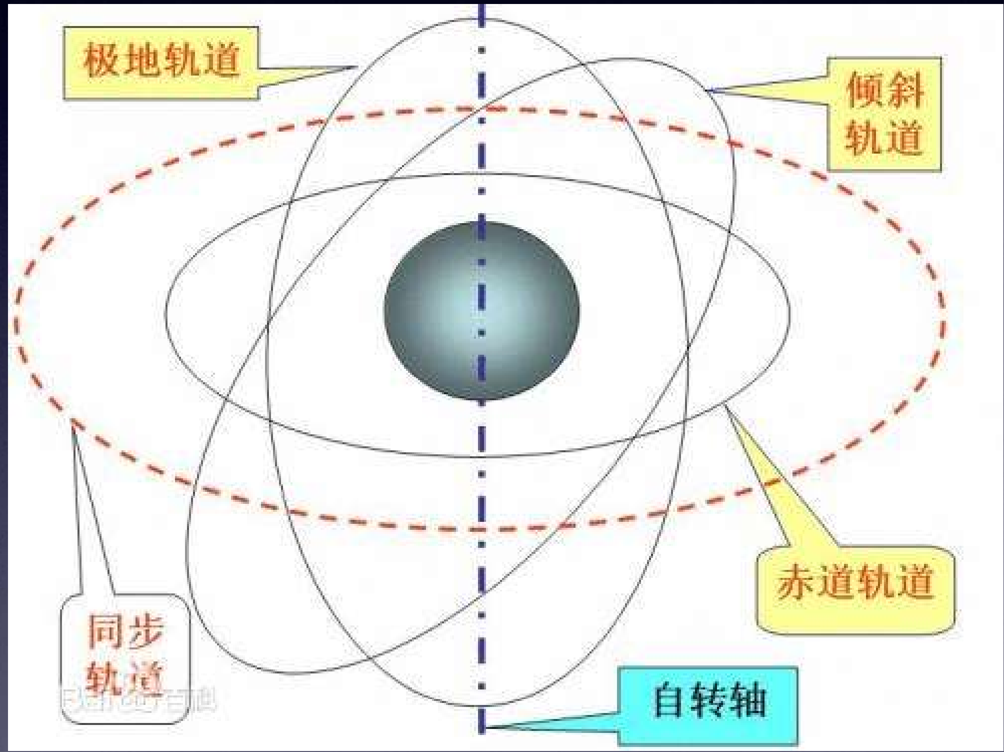
常见卫星轨道

赤道轨道：轨道倾角为零，轨道平面与地球赤道平面重合，这种轨道叫赤道轨道。



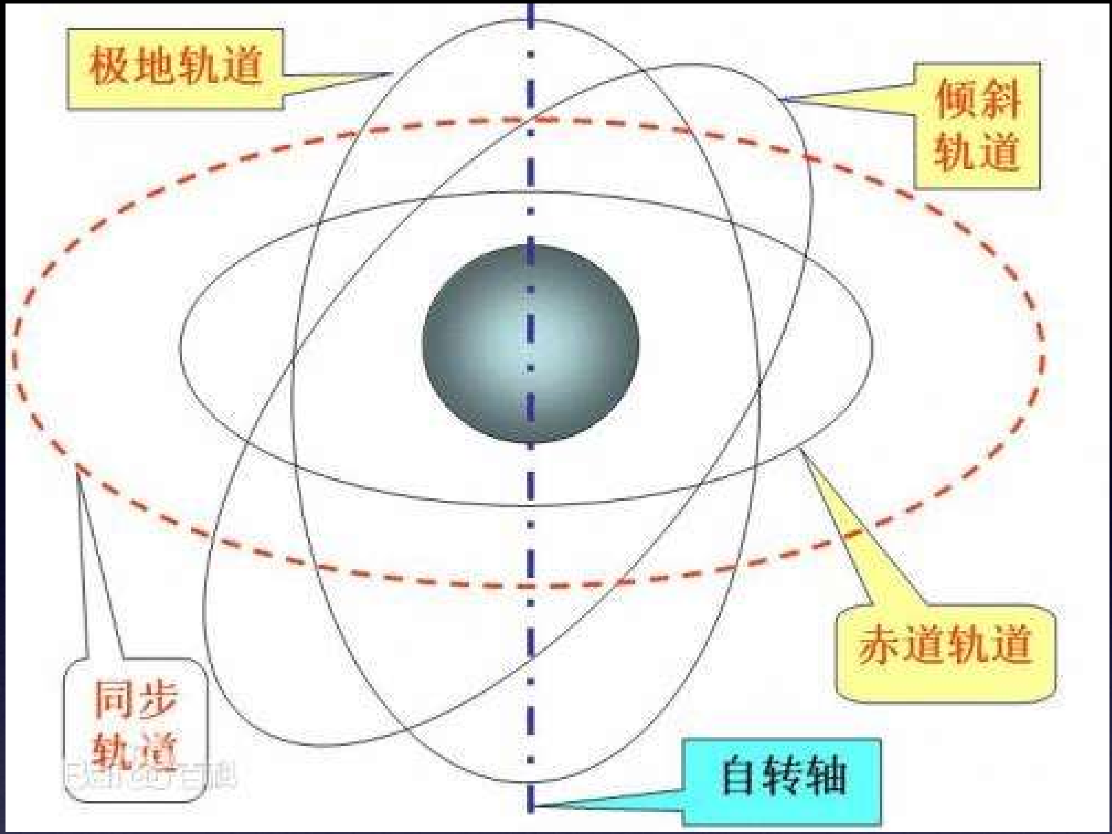
常见卫星轨道

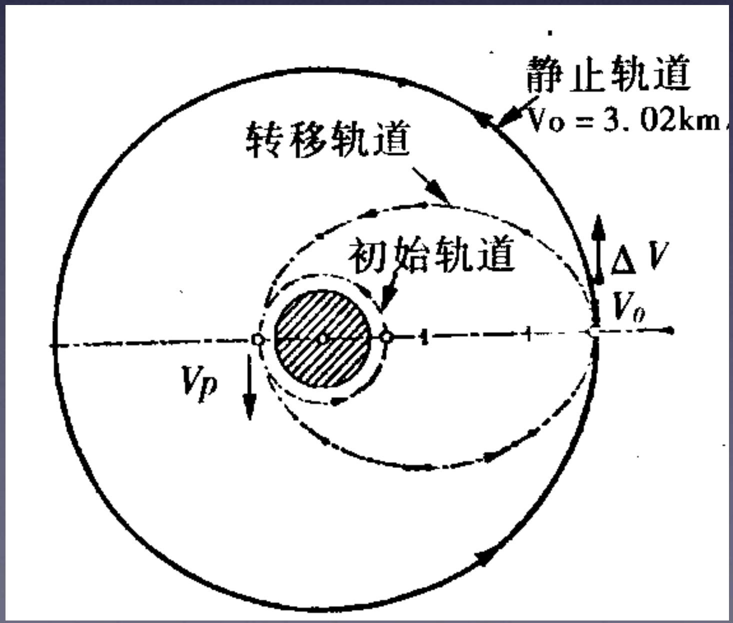
地球同步轨道：卫星的轨道周期等于地球在惯性空间中的自转周期（23小时56分4秒），且方向亦与之一致，卫星在每天同一时间的星下点轨迹相同。



常见卫星轨道

地球静止轨道：倾角为零的圆形地球同步轨道称为地球静止轨道。



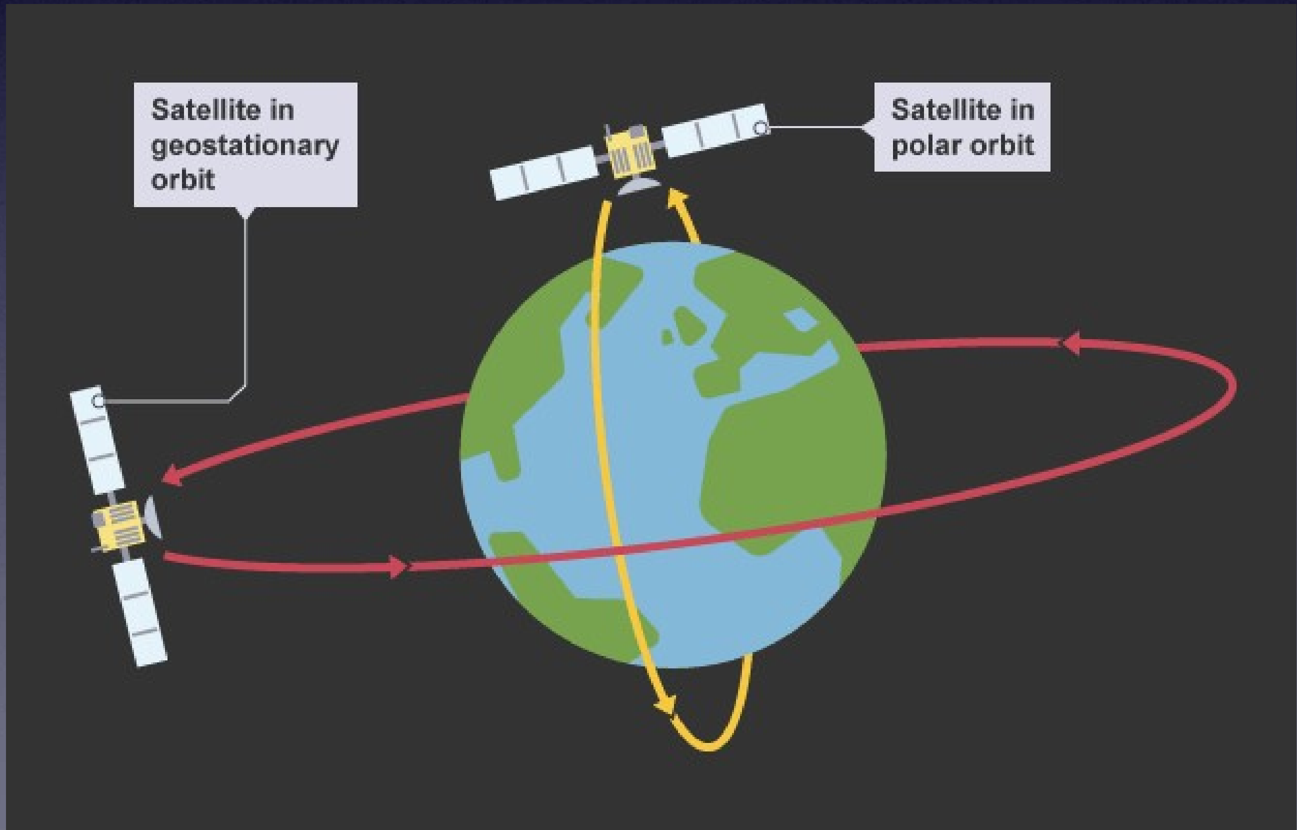


- 卫星运行方向与地球自转方向相同
- 轨道倾角为0°；
- 轨道偏心率为0，即轨道是圆形的；
- 轨道周期等于等于地球自转周期。静止卫星的高度为35786公里

常见卫星轨道

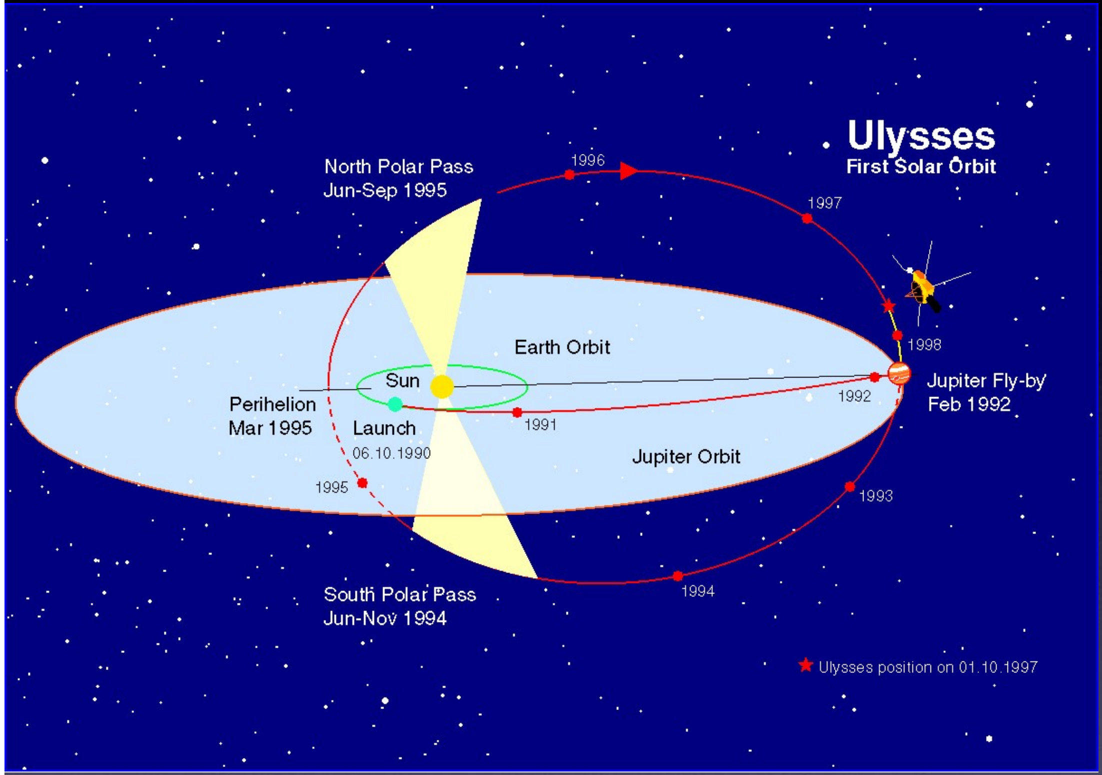
太阳同步轨道（polarorbit）：卫星的轨道平面和太阳始终保持相对固定的取向，轨道倾角（轨道平面与赤道平面的夹角）接近90度，卫星要在两极附近通过，因此又称之为近极地太阳同步卫星轨道。

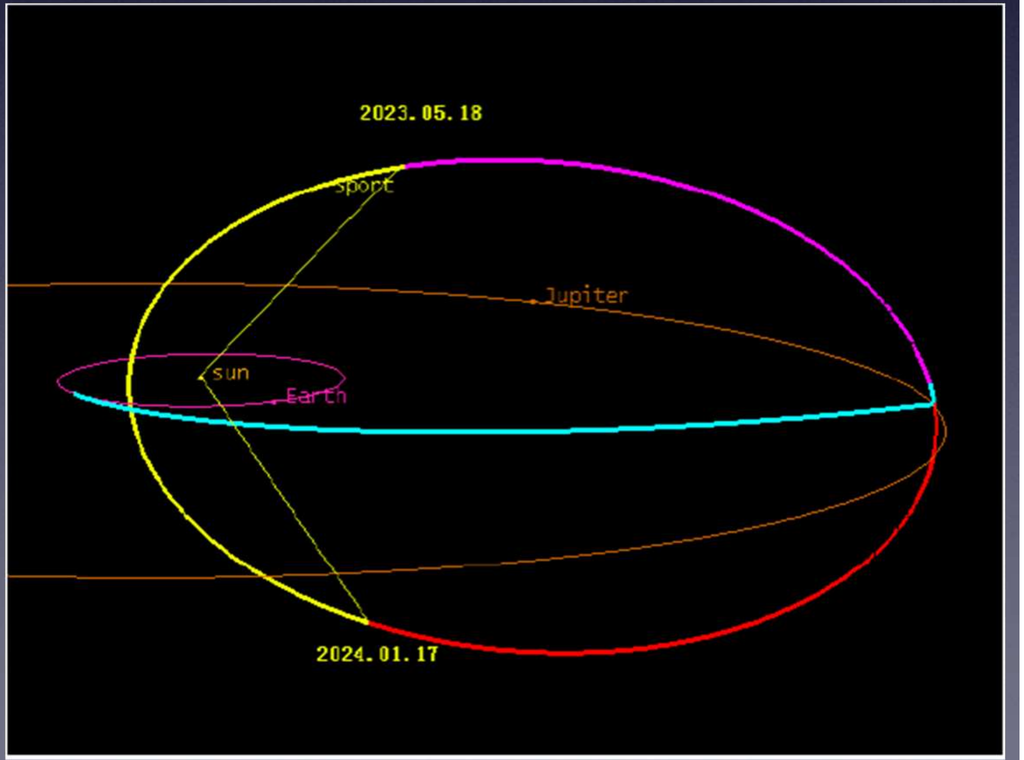
为使轨道平面始终与太阳保持固定的取向，因此轨道平面每天平均向地球公转方向（自西向东）转动0.9856度（即360度/年）。



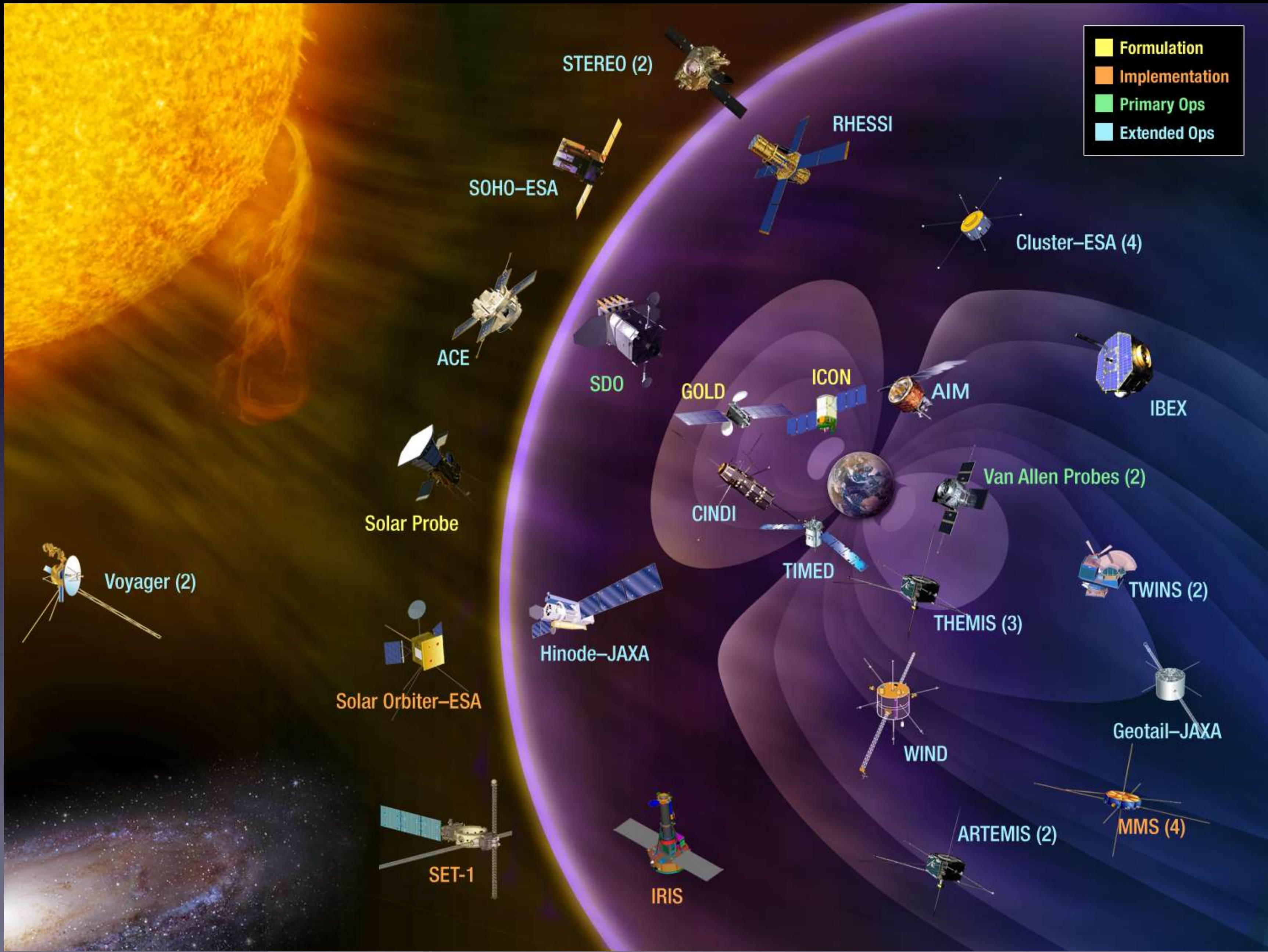
常见卫星轨道

太阳极轨(solar polar orbit)



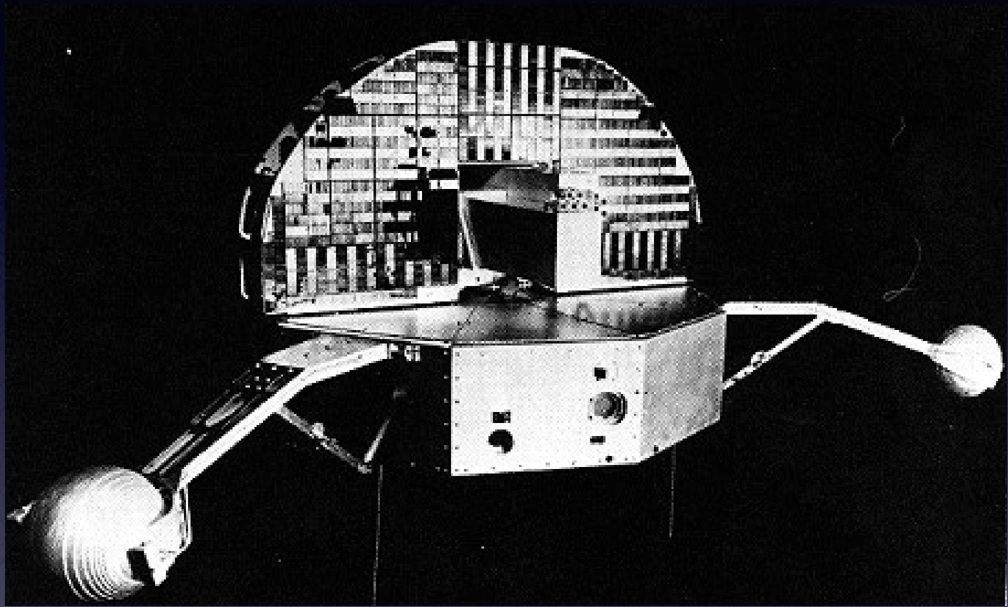


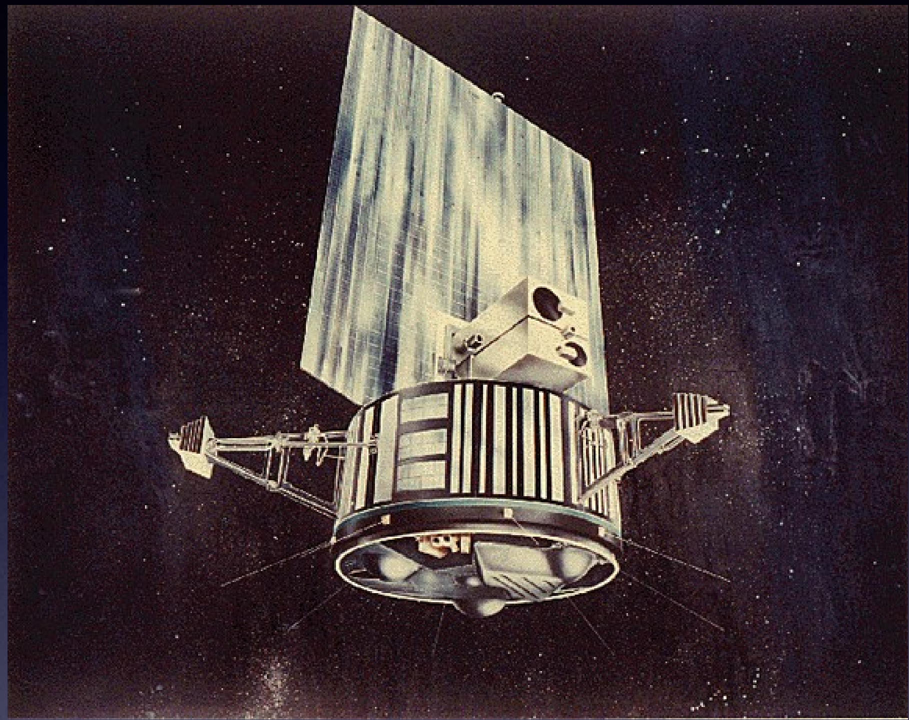
日地空间监测卫星



Formulation
Implementation
Primary Ops
Extended Ops
STEREO (2)
RHESSI
SOHO–ESA
Cluster–ESA (4)
ACE
SDO
ICON
GOLD
AIM
IBEX
Van Allen Probes (2)
Solar Probe
CINDI
TIMED
Voyager (2)
TWINS (2)
THEMIS (3)
Hinode–JAXA
Solar Orbiter–ESA
Geotail–JAXA
WIND
MMS (4)
ARTEMIS (2)
SET-1
IRIS

ORBITING SOLAR OBSERVATORIES (OSO’s)[美国]





- OSO’s 是第一部稳定的面对太阳的空间观测平台
- OSO’s 观测对象是flares和X-ray, gamma, 远紫外波段的日面活动现象 . 观测精度 30 arc sec -1 arc min
- OSO’s 由Delta火箭发射,它的轨道距离地球 565 km, 每96分钟围绕地球一周

OSO 年代表

Designation	Launch Date	Re-entry date	Notable results
OSO 1	7 March 1962	7 October 1981	
OSO 2	3 February 1965	8 August 1989	
OSO 3	8 March 1967	4 April 1982	Observed solar flares from the sun, as well as a flare from Scorpius X-1
OSO 4	18 October 1967	14 June 1982	
OSO 5	22 January 1969	2 April 1984	Measured diffuse background X-ray radiation from 14-200 keV
OSO 6	9 August 1969	7 March 1981	Observed three instances of hard X-ray coincidences with gamma ray bursts.[
OSO 7	29 September 1971	8 July 1974	Observed solar flares in the gamma ray spectrum. Collected data allowed for identification of Vela X-1 as a High-mass X-ray binary.
OSO 8	21 June 1975	8 July 1986	Found an iron emission line in the X-ray spectrum of a galaxy cluster.

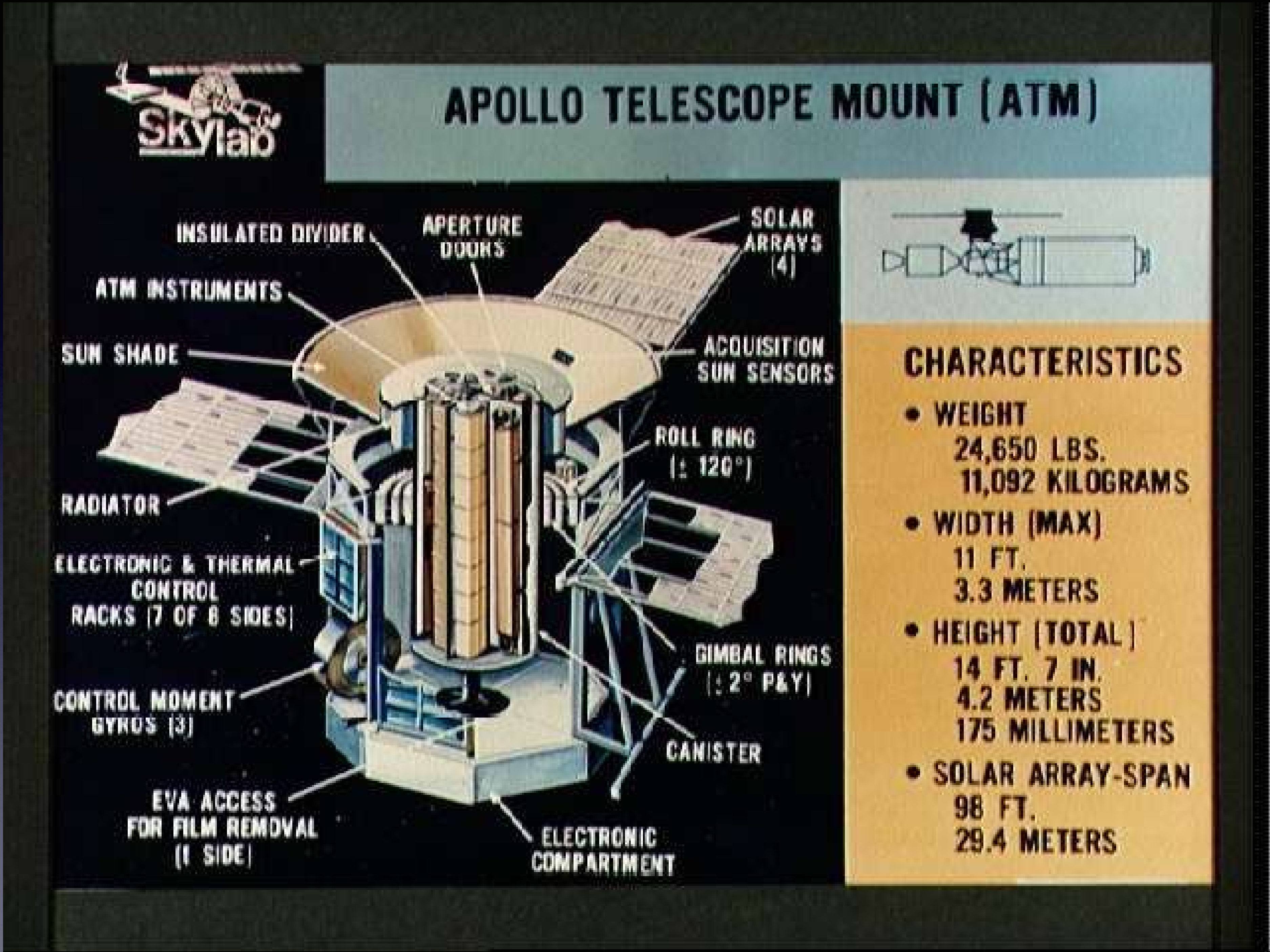
Skylab Mission[美国]

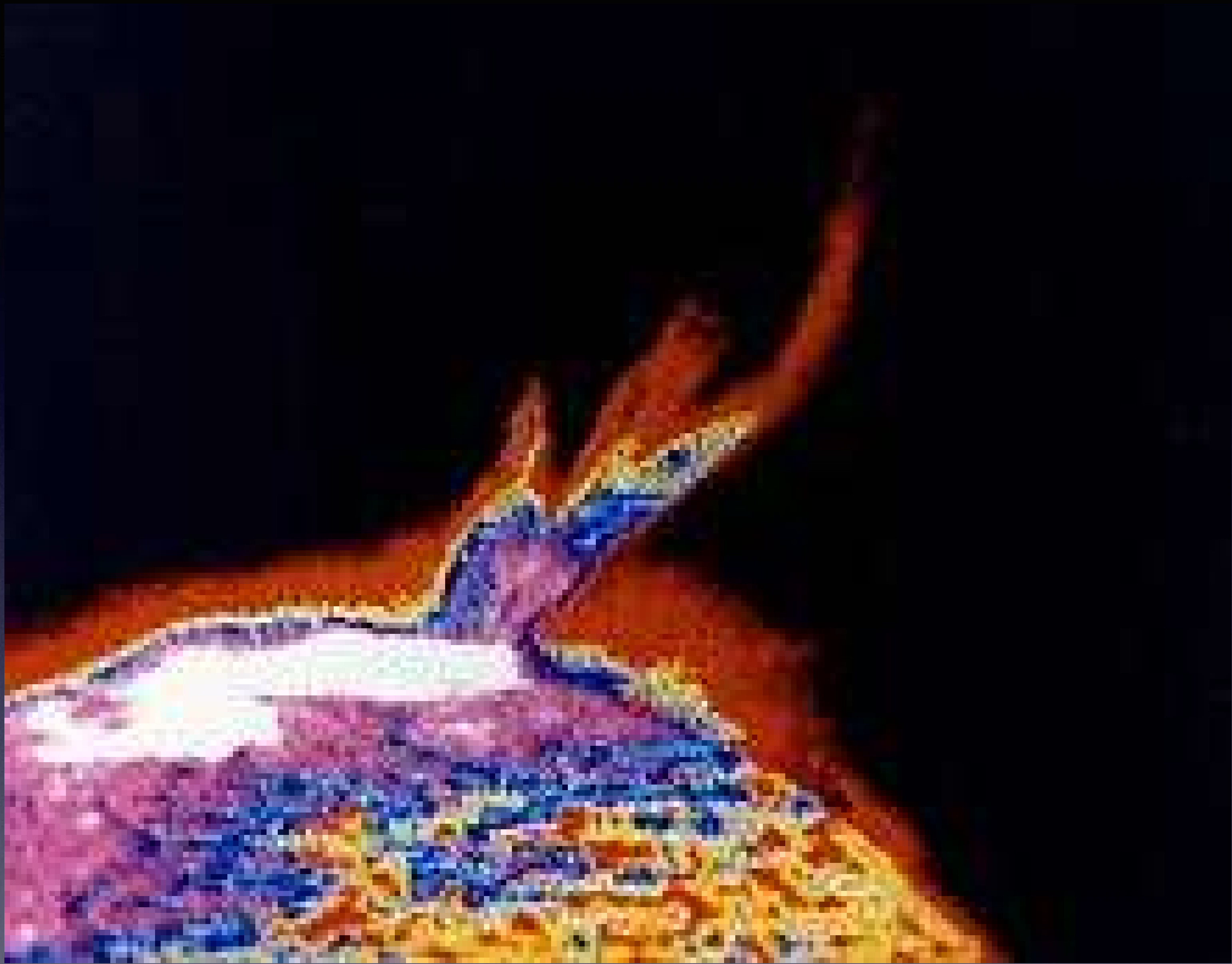
Skylab 1 通过无人Saturn V 运载火箭发射

Skylab 2 首次载人, 固定的太阳电池板, 太阳监视屏幕, 执行周期1个月, 太阳观测的接收和传输

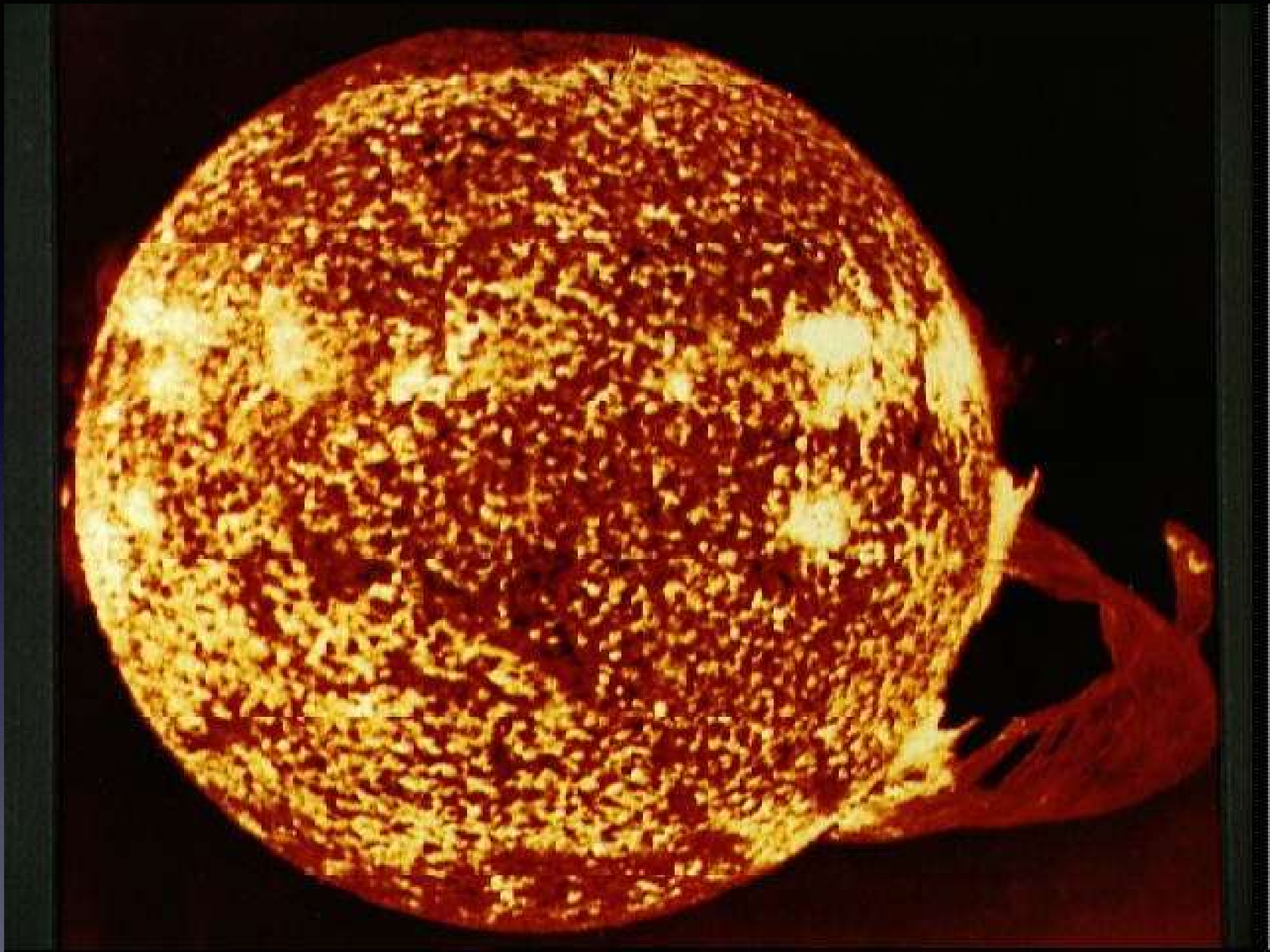
Skylab 3 载人, 扩展观测数据, 执行周期2月

Skylab 4 载人, 扩展观测数据(包括彗星数据)，执行周期3月


Skylab
APOLLO TELESCOPE MOUNT (ATM)
INSULATED DIVIDER
APERTURE DOORS
SOLAR ARRAYS (4)
ATM INSTRUMENTS
SUN SHADE
ACQUISITION SUN SENSORS
ROLL RING (± 120°)
RADIATOR
ELECTRONIC & THERMAL CONTROL RACKS (7 OF 8 SIDES)
GIMBAL RINGS (± 2° P&Y)
CONTROL MOMENT GYROS (3)
CANISTER
EVA ACCESS FOR FILM REMOVAL (1 SIDE)
ELECTRONIC COMPARTMENT
CHARACTERISTICS
• WEIGHT
24,650 LBS.
11,092 KILOGRAMS
• WIDTH (MAX)
11 FT.
3.3 METERS
• HEIGHT (TOTAL)
14 FT. 7 IN.
4.2 METERS
175 MILLIMETERS
• SOLAR ARRAY-SPAN
98 FT.
29.4 METERS



Solar prominence recorded by Skylab on August 21, 1973



SO82 A Photo of December 1973 Solar Eruption In He II λ304

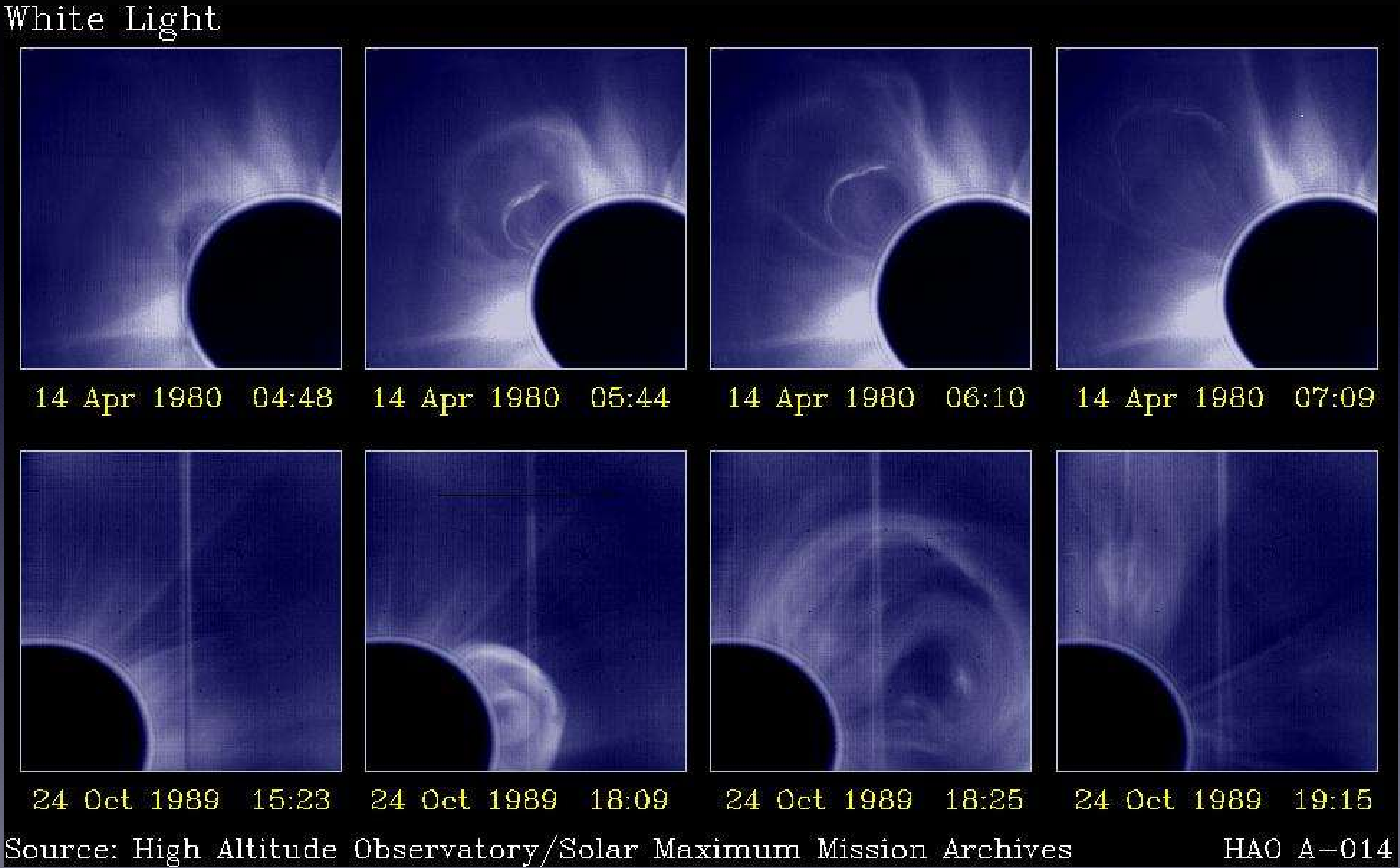
Solar Maximum Mission　(SMM)

Strong KT, Saba JLR, Haisch BM, Schmelz JT, ed. (1999). The many faces of the sun : a summary of the results from NASA's Solar Maximum Mission. New York: Springer.

SMM卫星上搭载的仪器

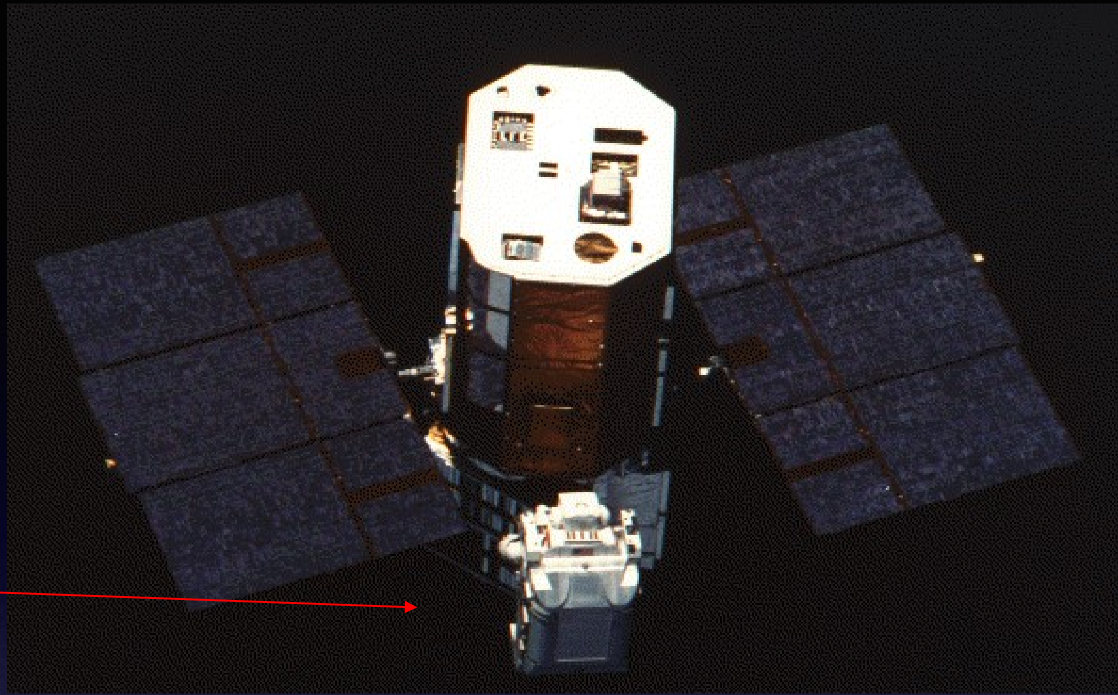
Name	Target	Principal Investigator
Active Cavity Radiometer Irradiance Monitor: 0.001-1000 micrometer solar flux	solar irradiance	Willson, Richard C, NASA Jet Propulsion Laboratory
Coronagraph/Polarimeter: 446.5-658.3 nm, 1.5- 6 sq.solar radii fov, 6.4 arcsec res.	Solar corona, prominences, and flares	MacQueen, Robert M., High Altitude Observatory
Gamma-ray Spectrometer: NaI(T1),0.01-100 MeV in 476 channels, 16.4 s per spectrum	solar gamma-rays	Chupp, Edward L, University of New Hampshire
Hard X-ray Burst Spectrometer: CsI(Na), 15 energy channels covering 20-260 keV	Solar flares and active regions	Frost, Kenneth J., NASA Goddard Space Flight Center
Hard X-ray Imaging Spectrometer: fov 6.4 arcmin, 8 or 32 arcsec res, 3.5-30 keV	Solar active regions and flares	de Jager, Cornelis, University of Utrecht
Soft X-ray Polychromator: raster imager, crystal spectrom. in parts of 0.14-2.25 nm	Solar flares, active solar regions	Acton, Loren W., Lockheed Palo Alto, Culhane, J University College, London, Leonard, Gabriel, Alan-Henri, Rutherford Appleton Laboratory
Ultraviolet Spectrometer and polarimeter 175.0-360.0 nm raster imager, 0.004 nm sp.res.	Solar UV, Earth's atmosphere	Tandberg-Hanssen, Einar A., NASA Marshall Space Flight Center

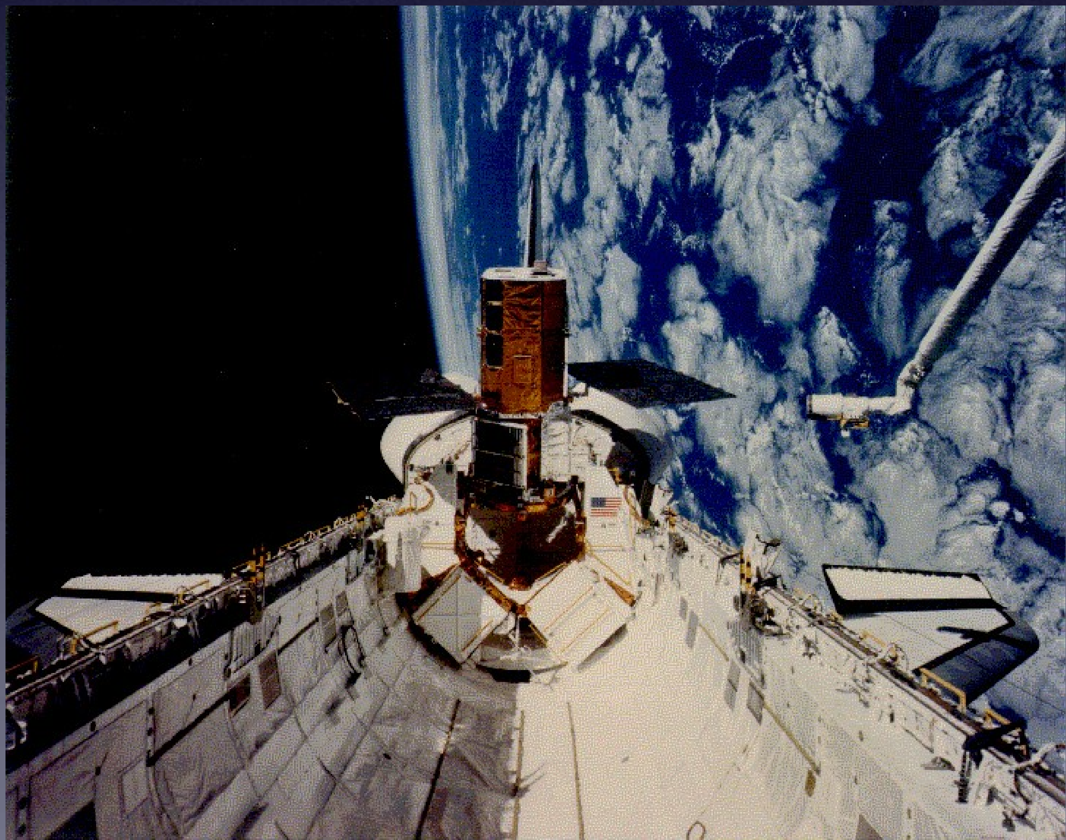
SMM 白光日冕仪观测图像

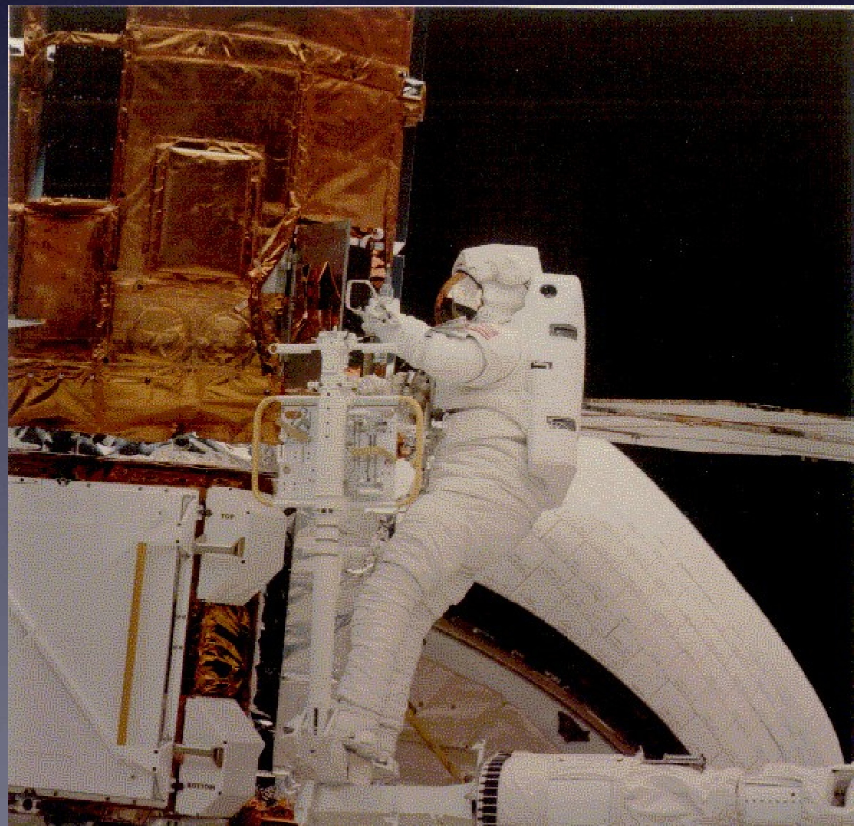


SMM 在1984被维修(Space Shuttle *Challenger* mission).

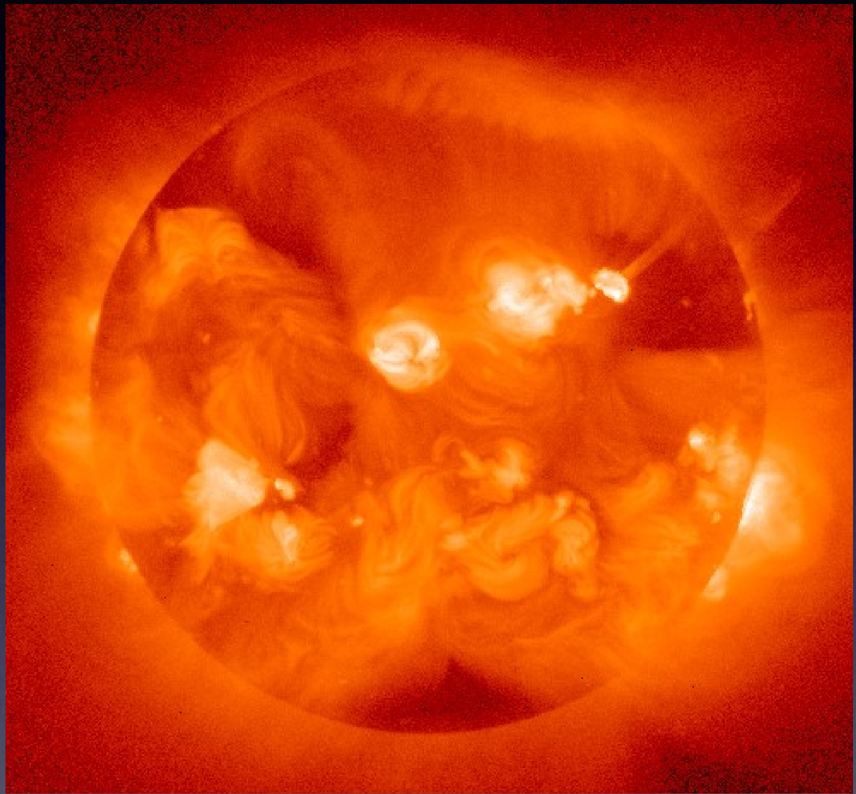
Astronaut in maneuvering unit

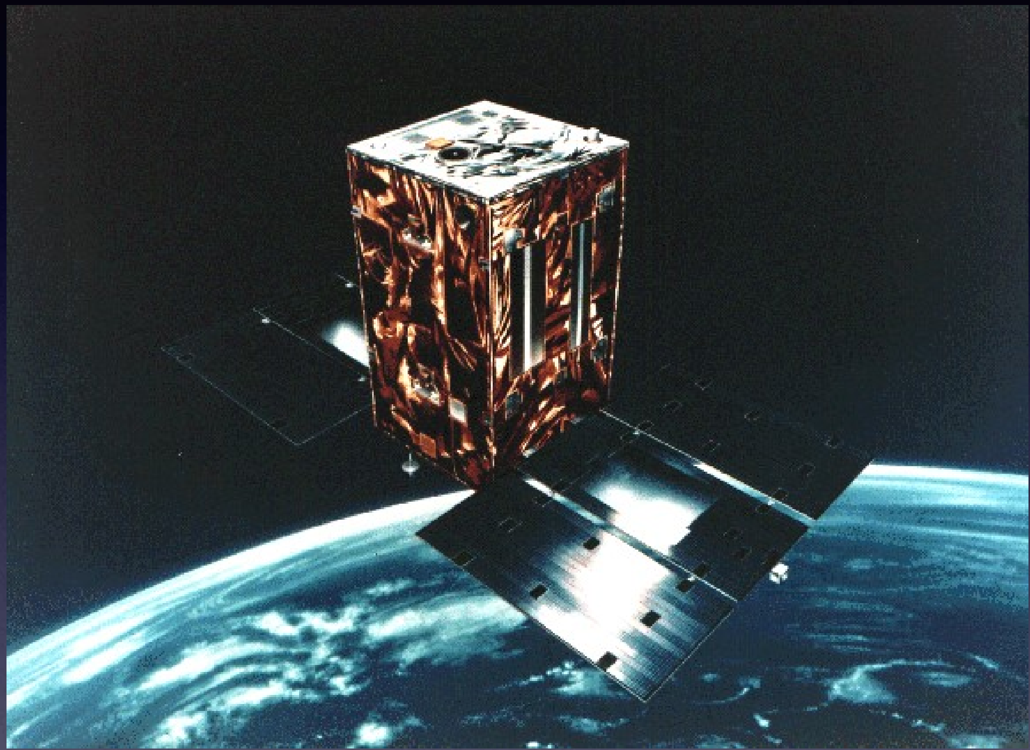






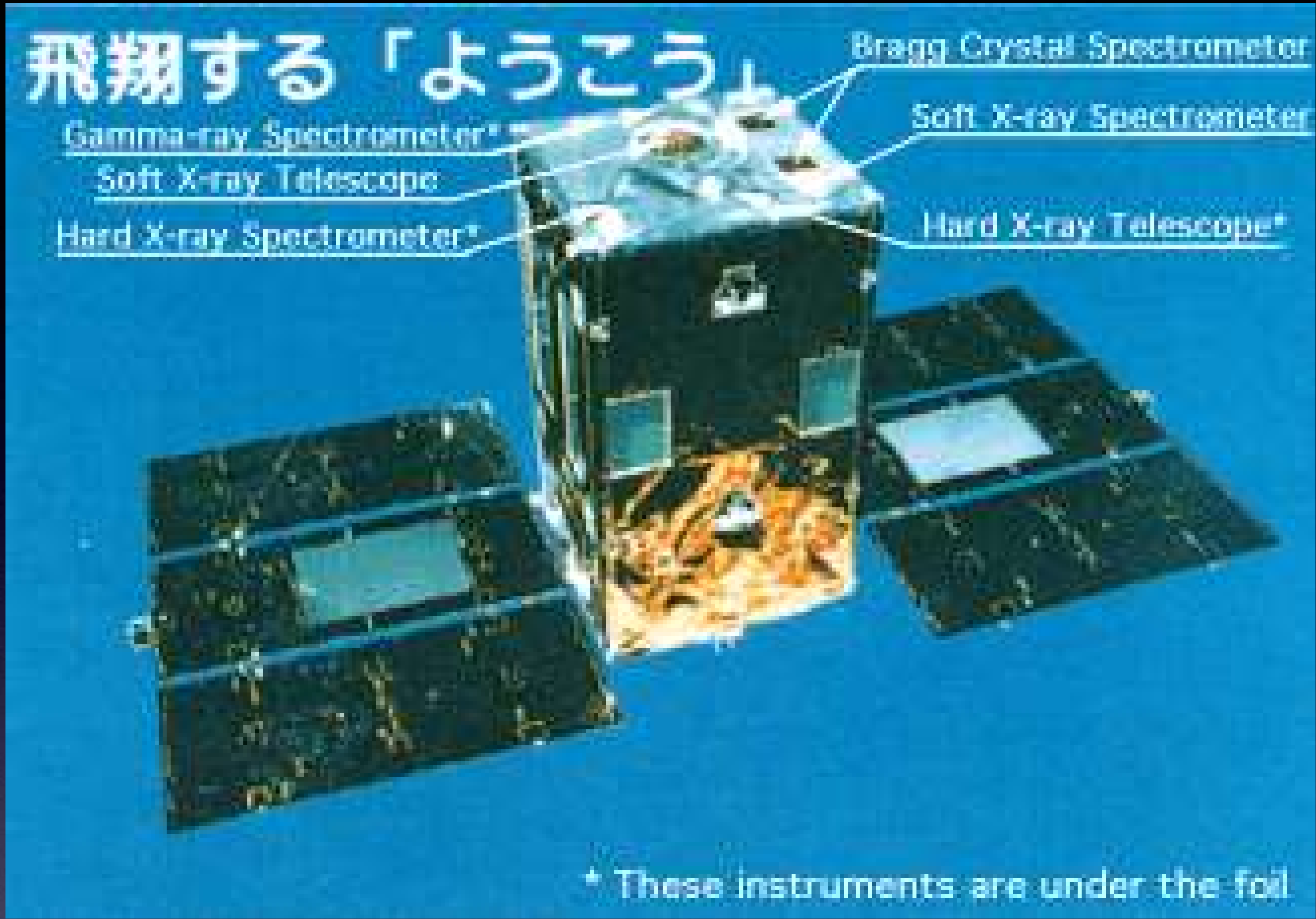
Yohkoh (‘Sunbeam’ Solar-A)





发射时间： August 30, 1991, 工作10年(December 2001)

科学目标： 用软X射线和硬X射线观测太阳上发生的能量事件



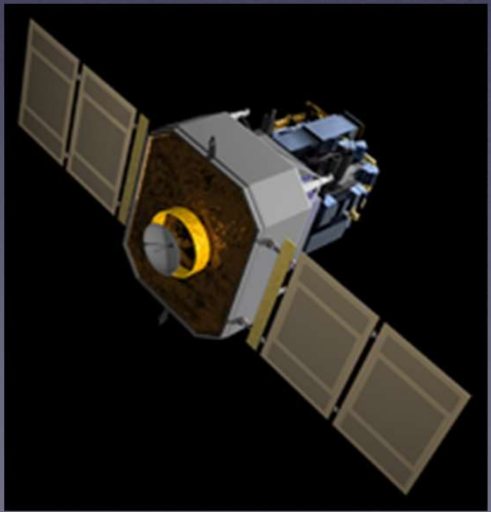
Instruments:

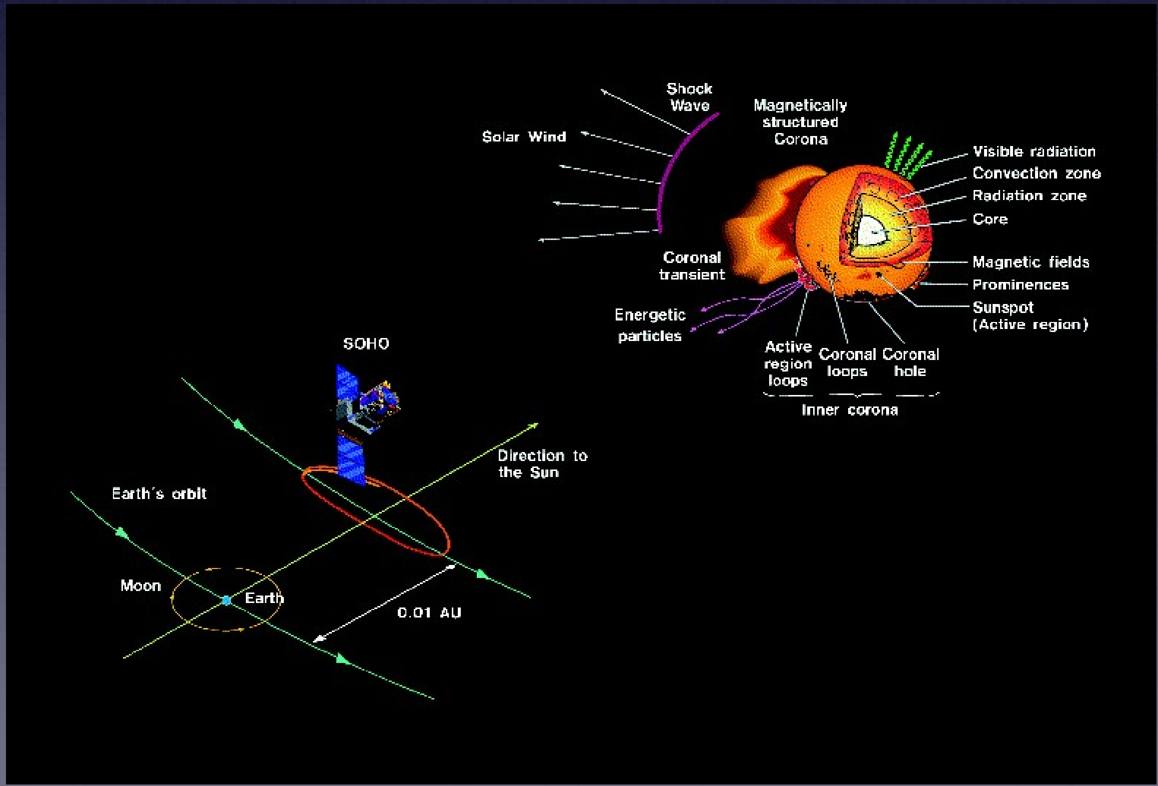
–Bragg Crystal Spectrometer (BCS)	US and GB
–Wide Band Spectrometer (WBS)	Japan
–Soft X-Ray Telescope (SXT)	U.S.
–Hard X-Ray Telescope (HXT).	Japan

Yohkoh Soft X-ray Images

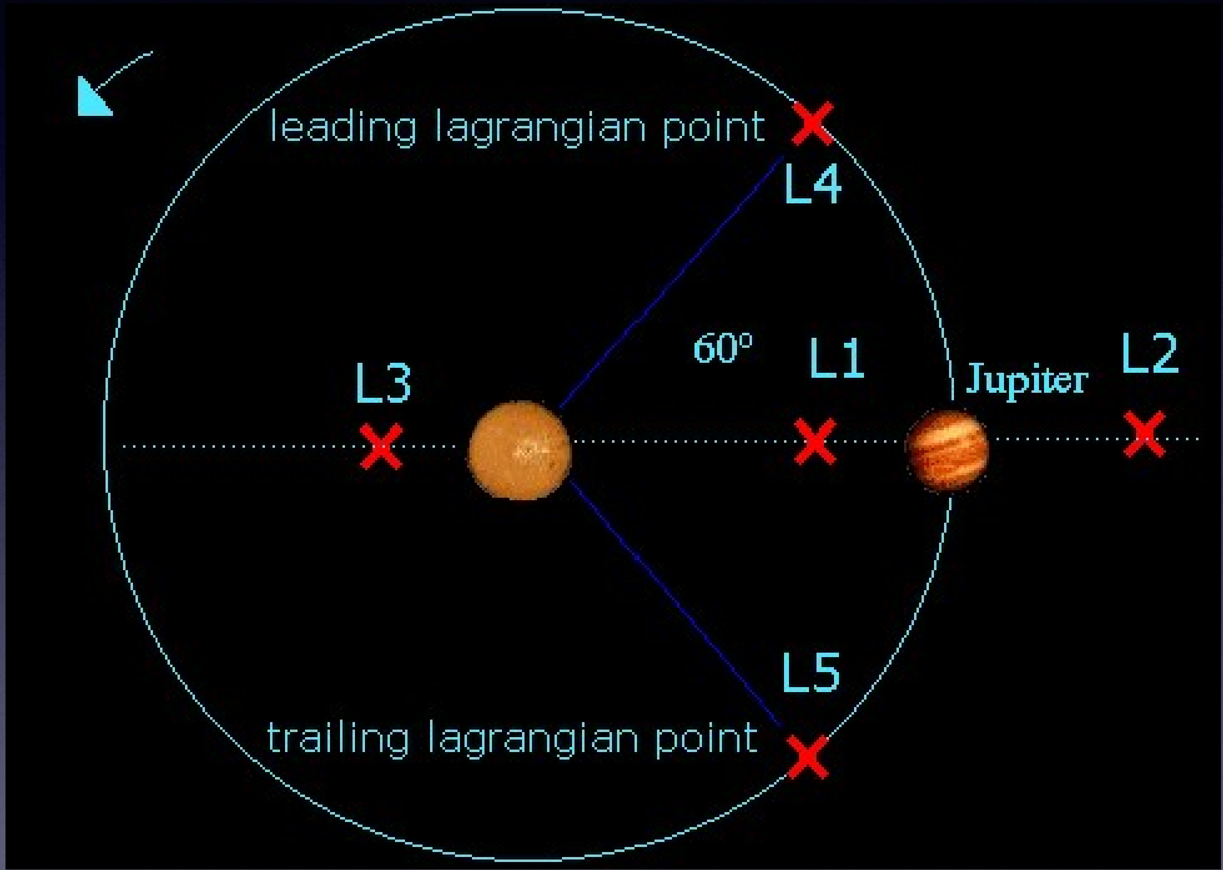
Solar and Heliospheric Observatory (SOHO)

- ★ 1982年：ESA提出
- ★ 1986年：与CLUSTER仪器被批准，并和NASA合作
- ★ 1995年12月2日发射
- ★ 1996年2月定点成功
- ★ 1998年夏天失控，后挽救回来





SOHO飞船的空间位置



为什么选择日地平衡点：

(1) 可以连续对日观测；

(2) 在光学波段，可避免地球大气散射和吸收；

(3) 出于地球磁层之外，适合局地观测太阳风。

图片来源：http://map.gsfc.nasa.gov/m_mm/ob_techorbit1.html

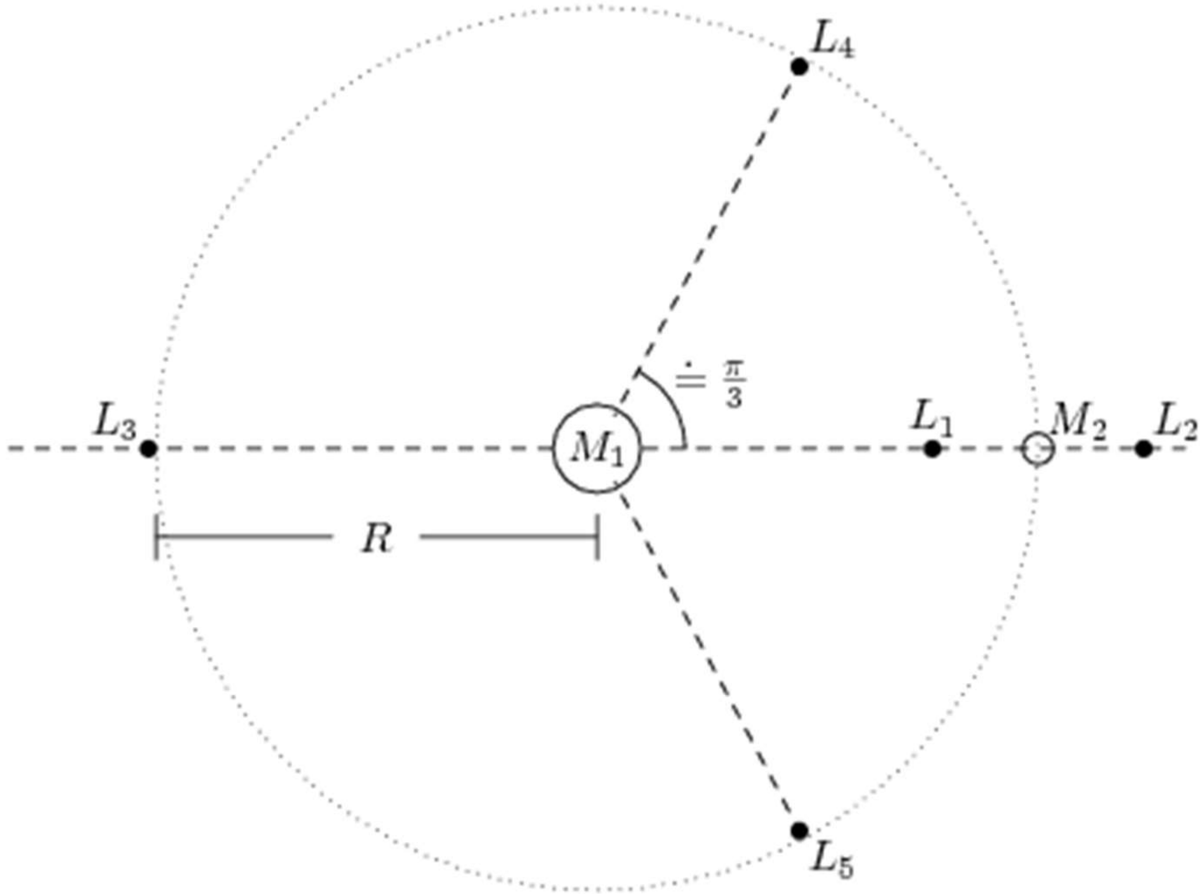
$$L_1 = \left(R \cdot \left(1 - \sqrt[3]{\tfrac{\alpha}{3}}\right), 0\right) \qquad \alpha = \frac{M_2}{M_1 + M_2}$$

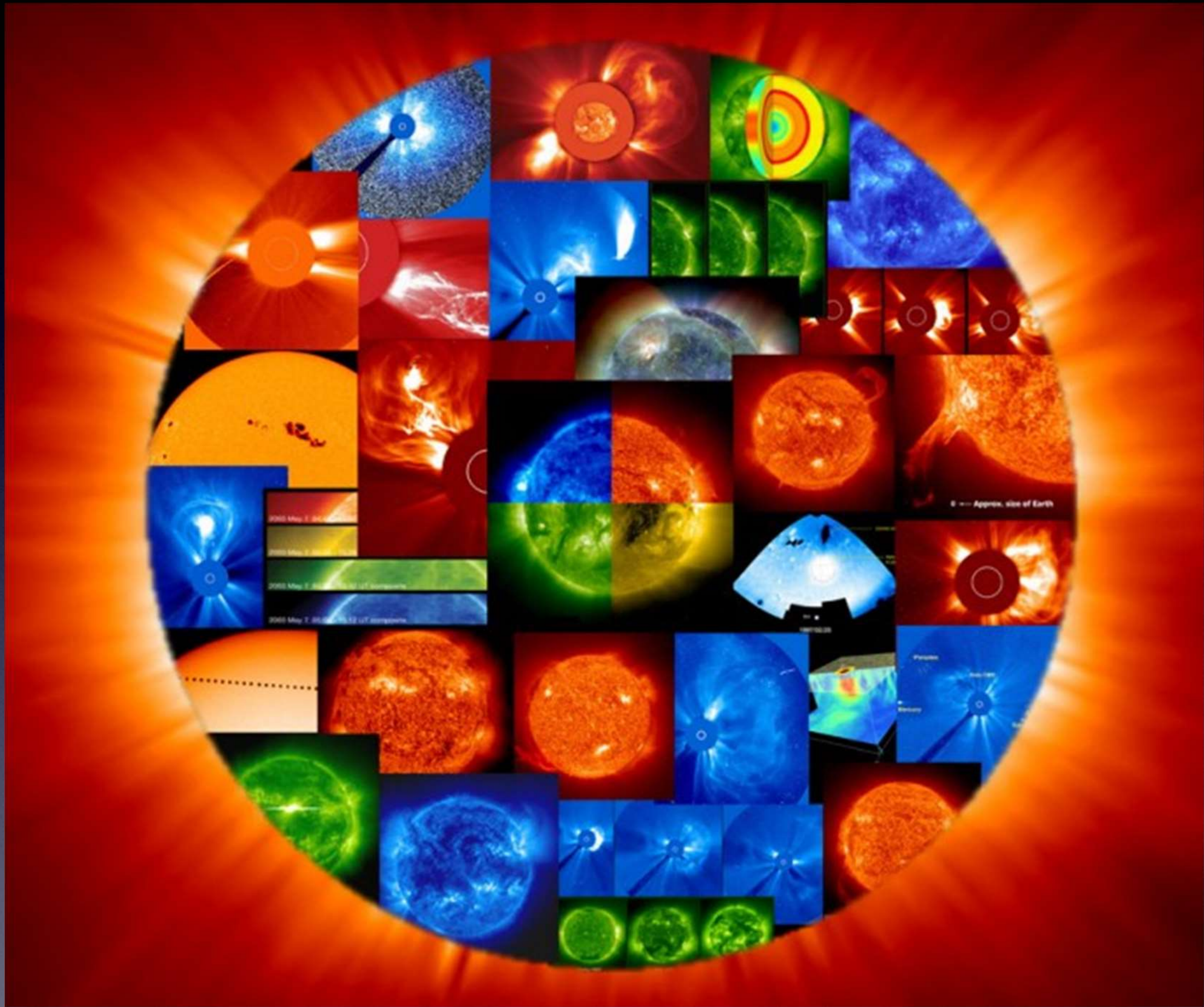
$$L_2 = \left(R \cdot \left(1 + \sqrt[3]{\tfrac{\alpha}{3}}\right), 0\right)$$

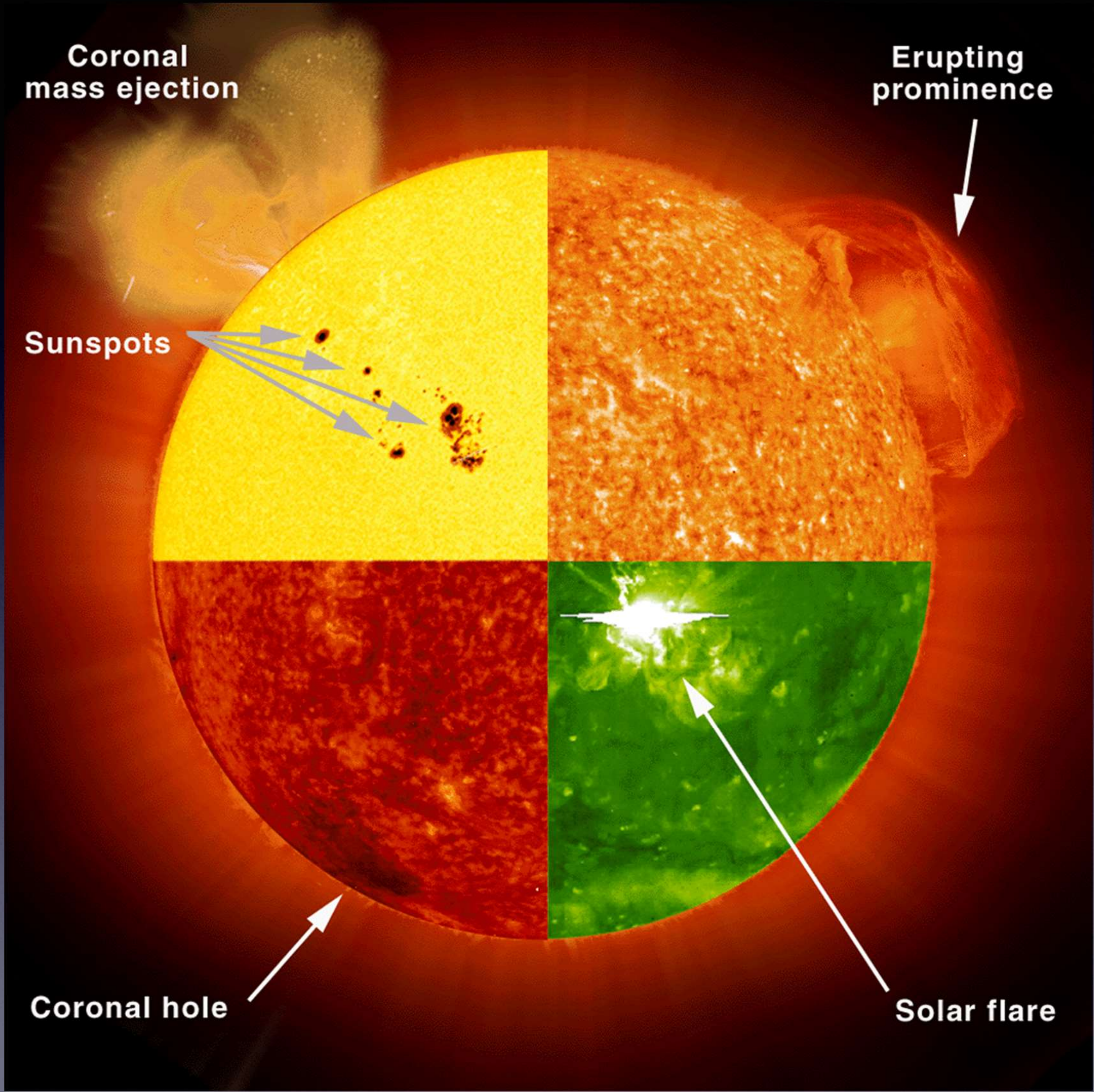
$$L_3 = \left(-R \cdot \left(1 + \tfrac{5\alpha}{12}\right), 0\right)$$

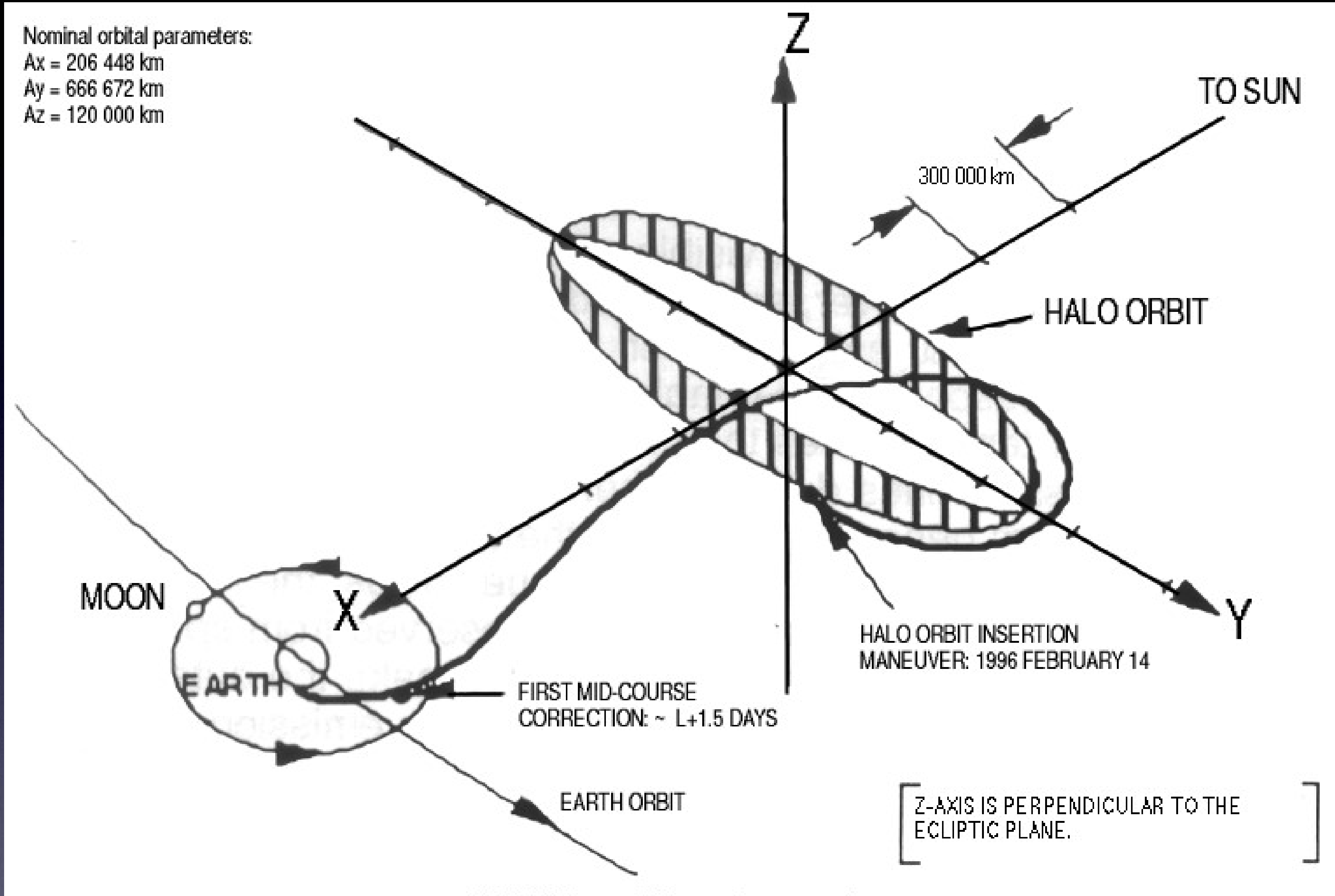
$$L_4 = \left(\frac{R}{2} \cdot \frac{M_1 - M_2}{M_1 + M_2}, \quad \frac{\sqrt{3}}{2} R\right)$$

$$L_5 = \left(\frac{R}{2} \cdot \frac{M_1 - M_2}{M_1 + M_2}, -\frac{\sqrt{3}}{2} R\right)$$




← Approx. size of Earth


Coronal
mass ejection
Erupting
prominence
Sunspots
Coronal hole
Solar flare



SOHO orbit schematic

SOHO轨道示意图：http://sohowww.estec.esa.nl/

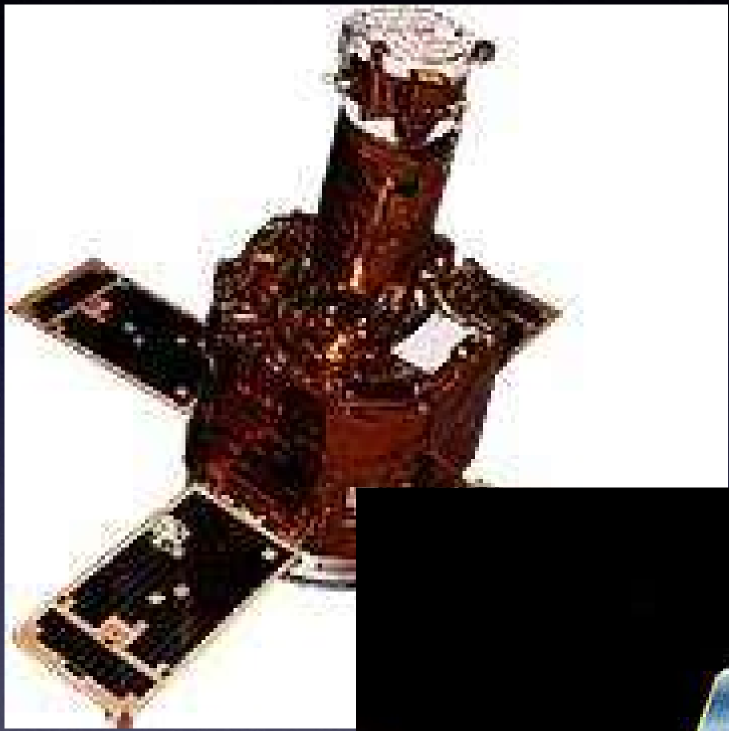
说明：飞船将围绕 L1 点的环状轨道运行，其原因：(1) 易于飞船定点；(2) 避免通讯天线直接面对太阳。

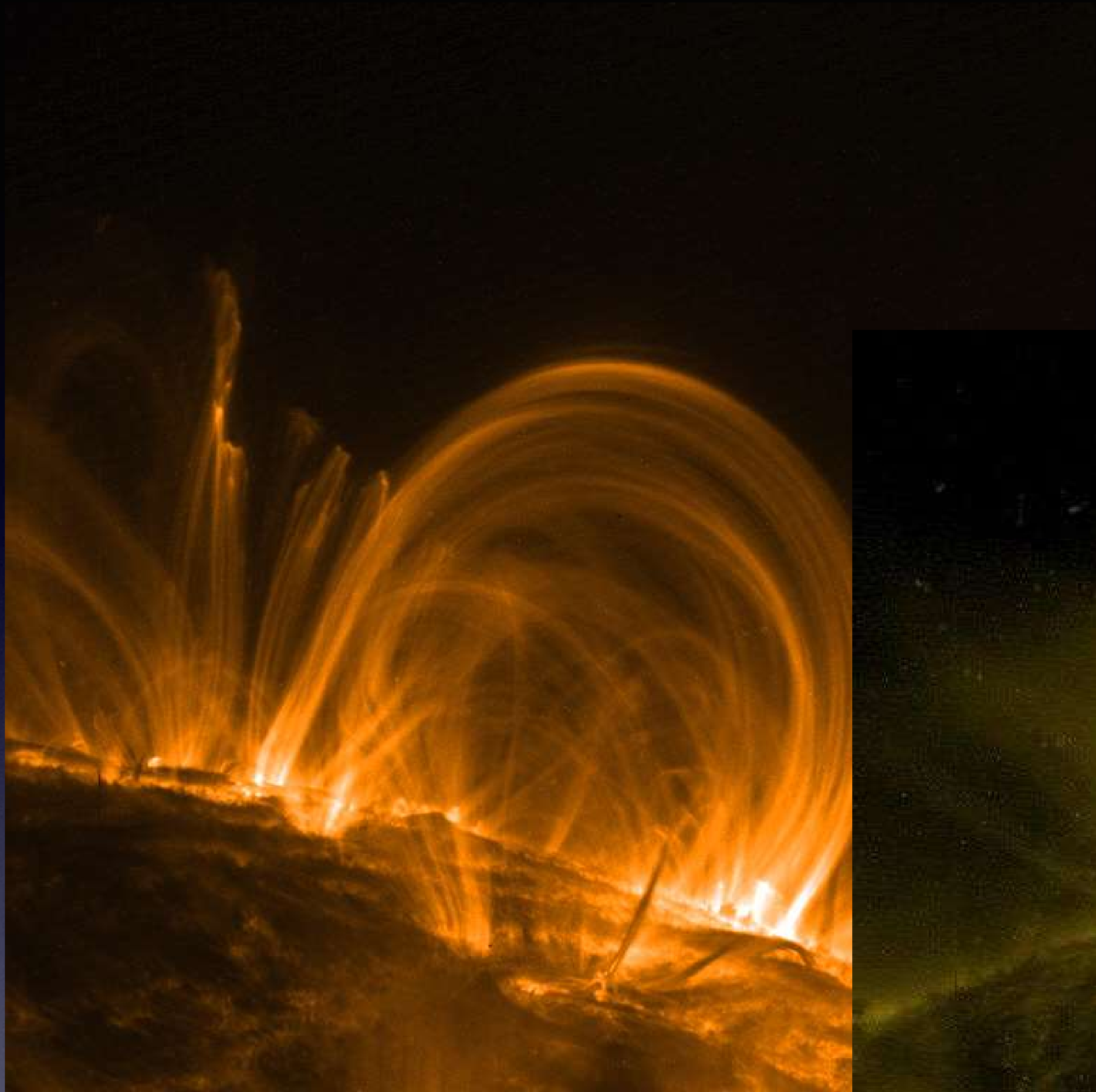
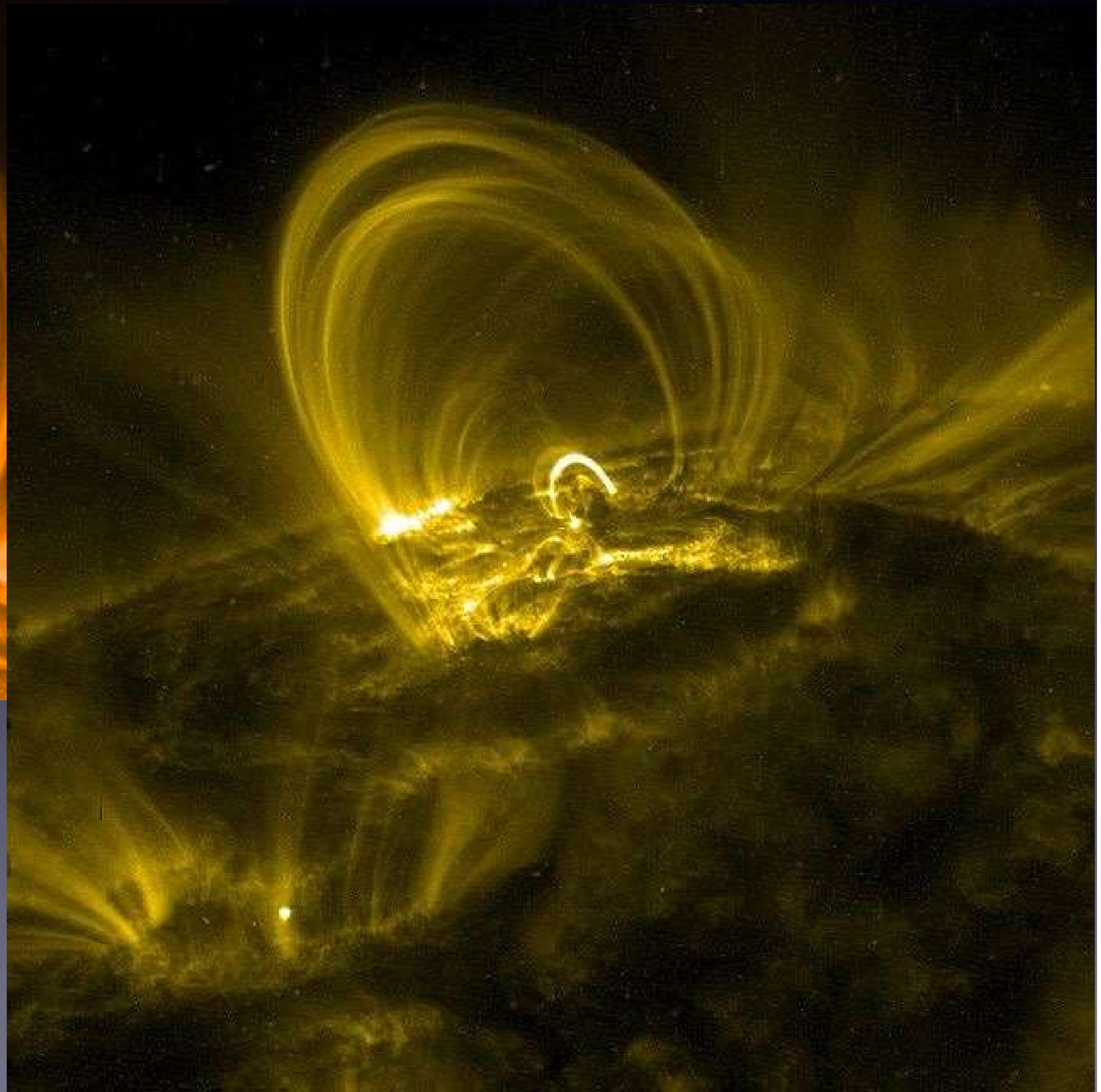
Transition Region and Coronal Explorer (TRACE)[美国]

TRACE 用来探测太阳大气磁场:

- 3-D磁场结构
- 磁场在光球入流影响下的时间演化.
- 日冕精细结构的时间演化
- 日冕和过渡区的热拓扑结构

运行时间：1998 - 2010



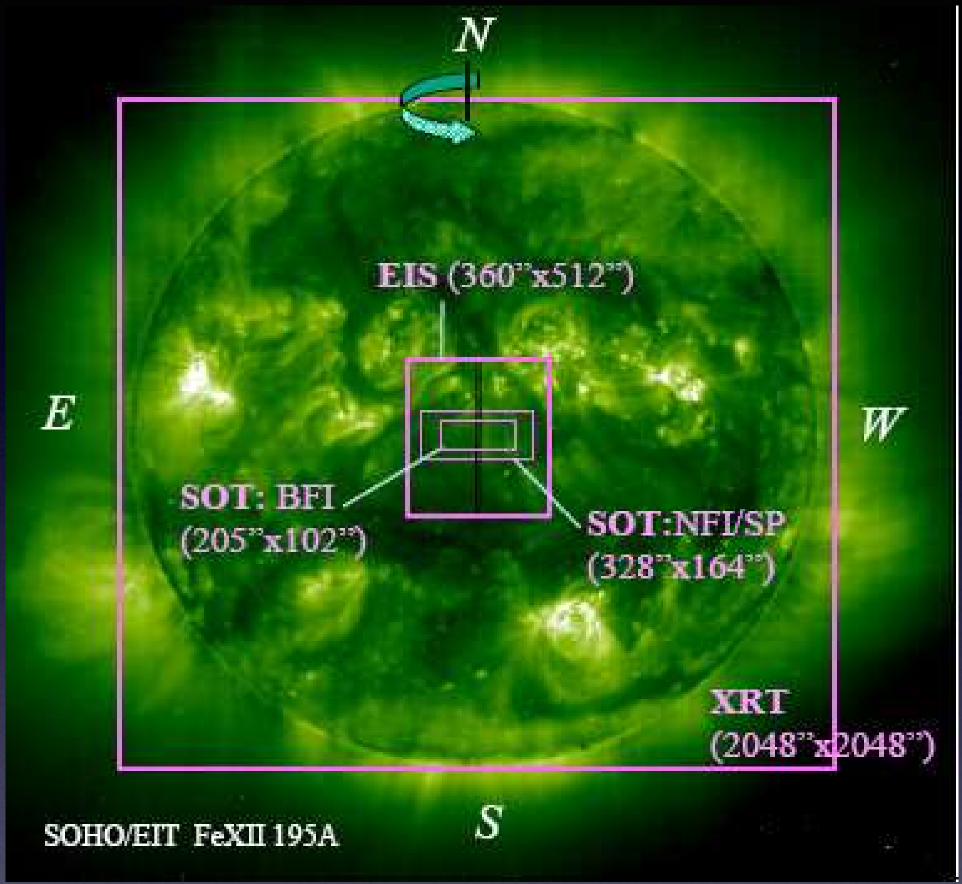



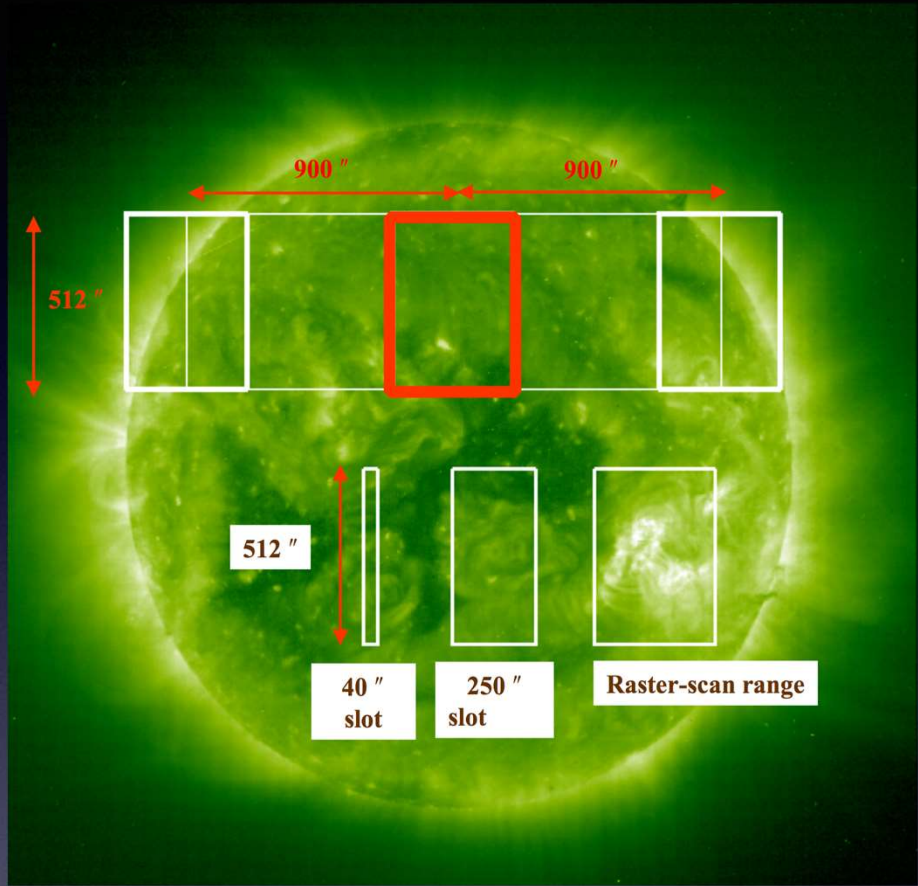
Hinode's (Solar-B)

科学目标：探测太阳大气更加精细磁场结构,用来深入理解太阳各种活动现象的爆发机制

发射时间：日本本土时间2006年9月22日4:36pm

Field of view





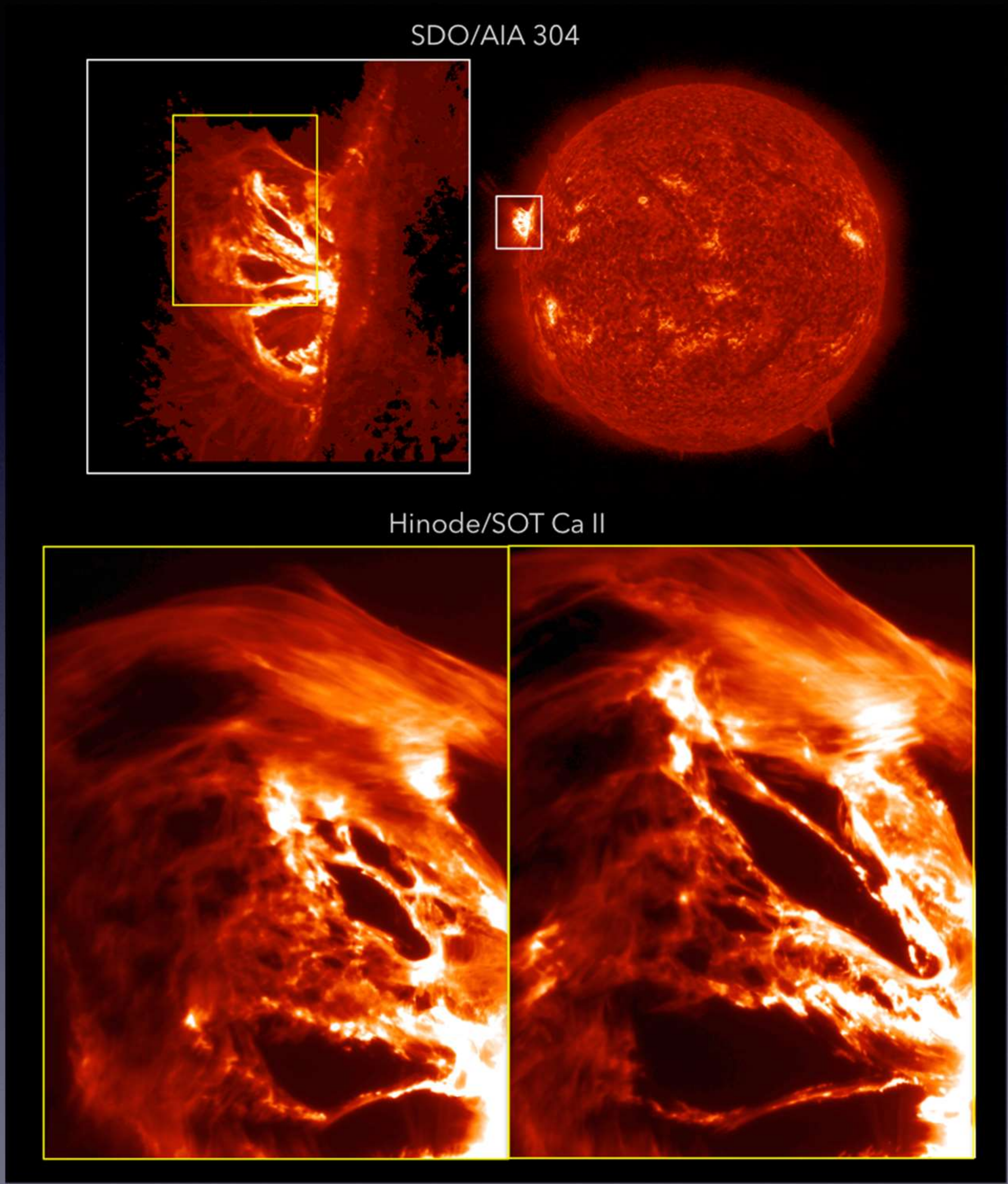
EIS can independently offset along the EW axis.

Solar Optical Telescope (SOT): 0.2 arcsec, 5 min; vector B

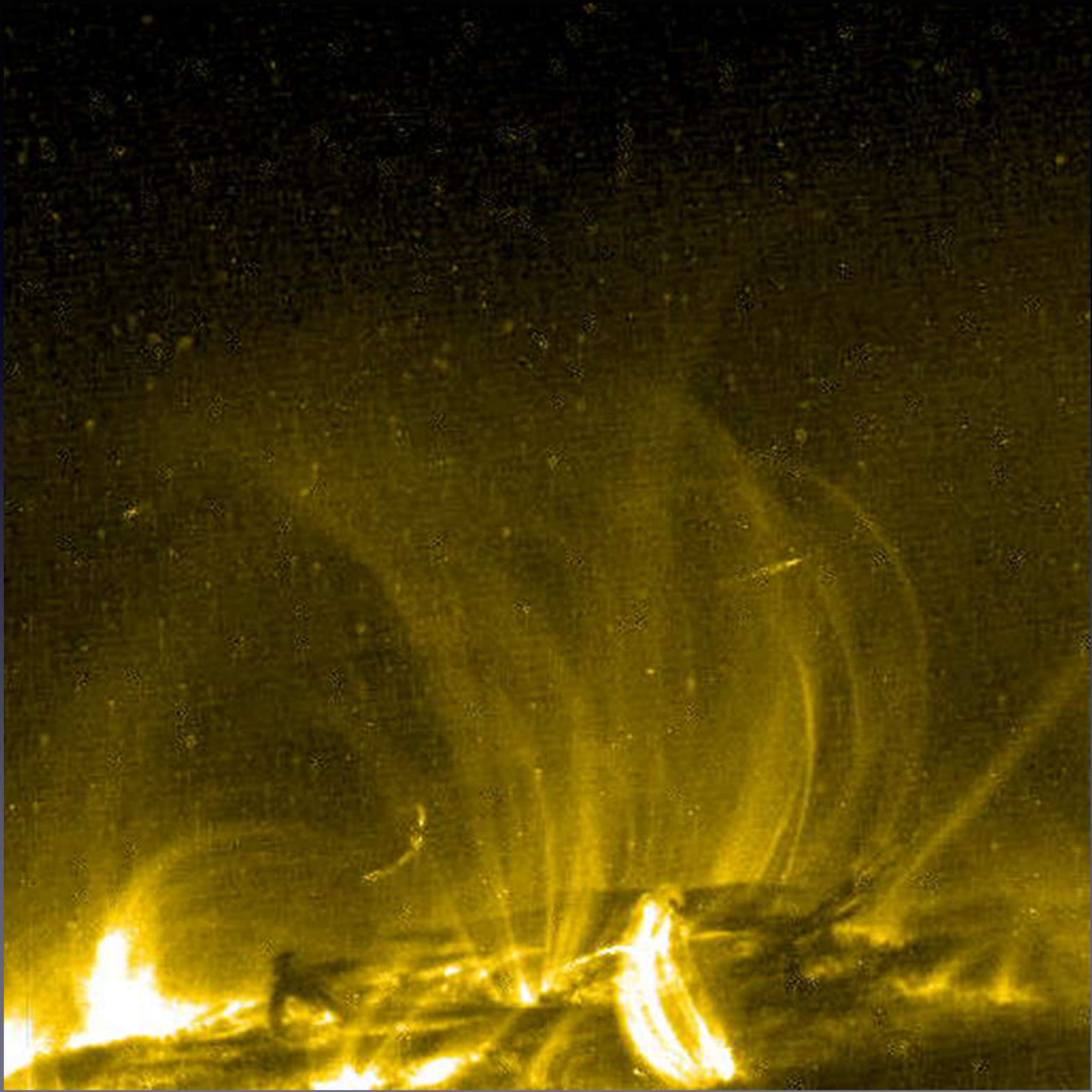
EUV Imaging Spectrometer (EIS): 2 arcsec; two λ ranges -> 0.1 – 20 MK

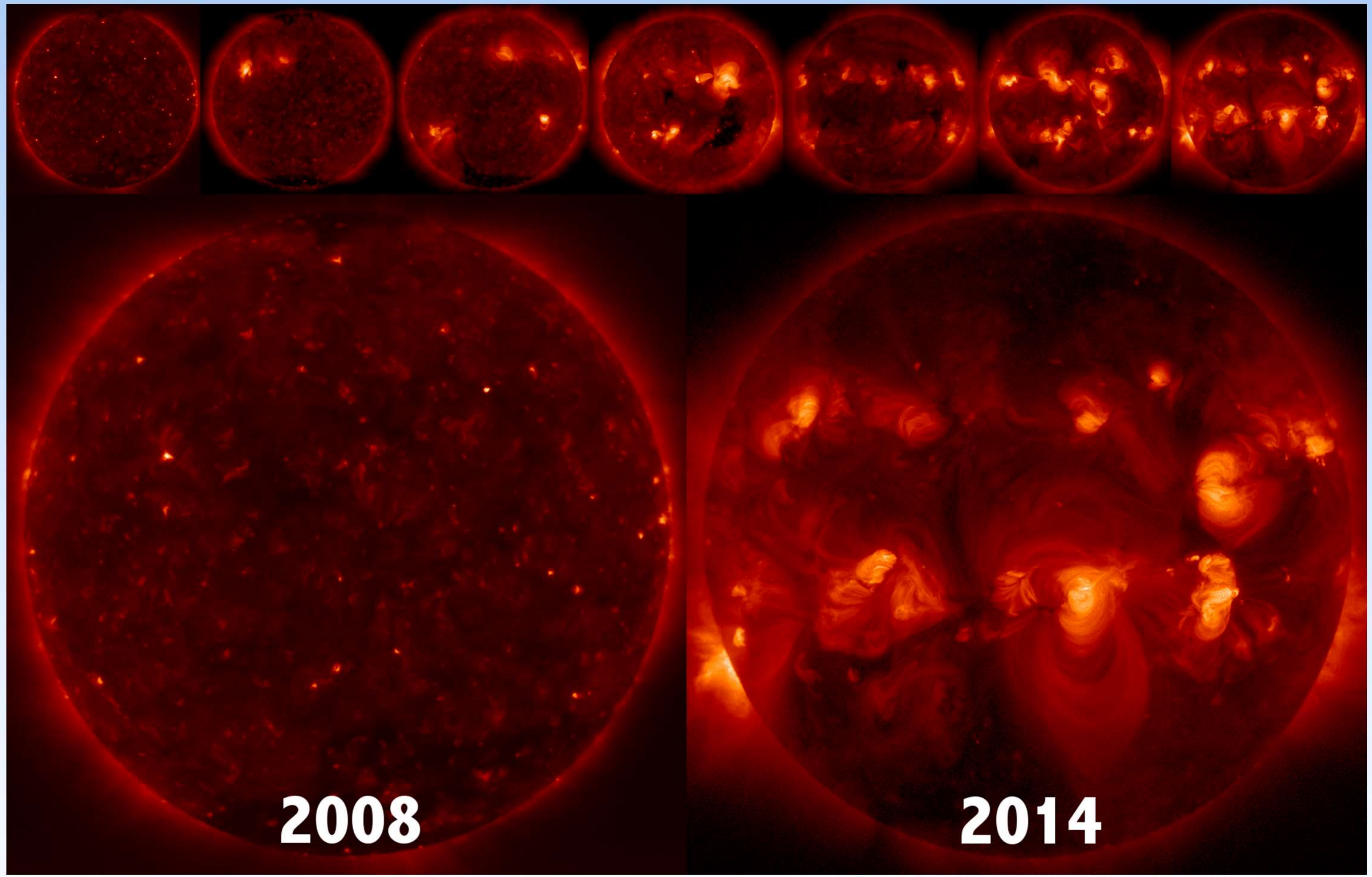
X-Ray Telescope (XRT): 2 arcsec, 2 sec; full field of view

Hinode高探测精度



Hinode高探测精度

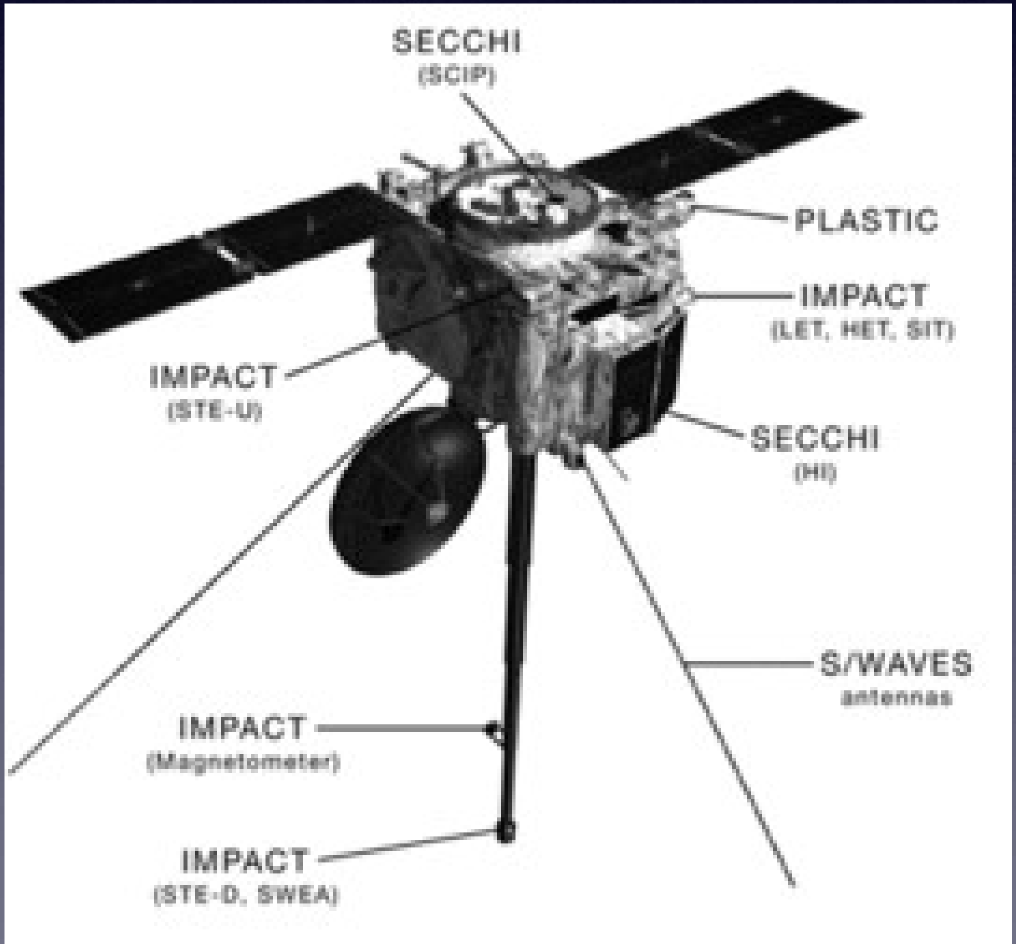


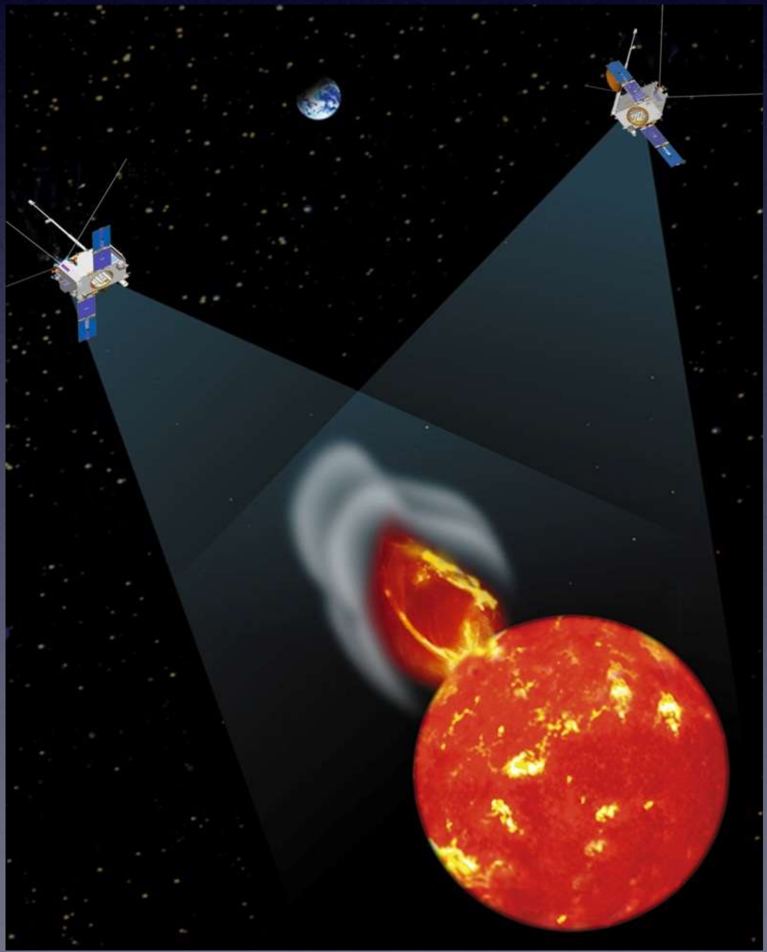

2008
2014

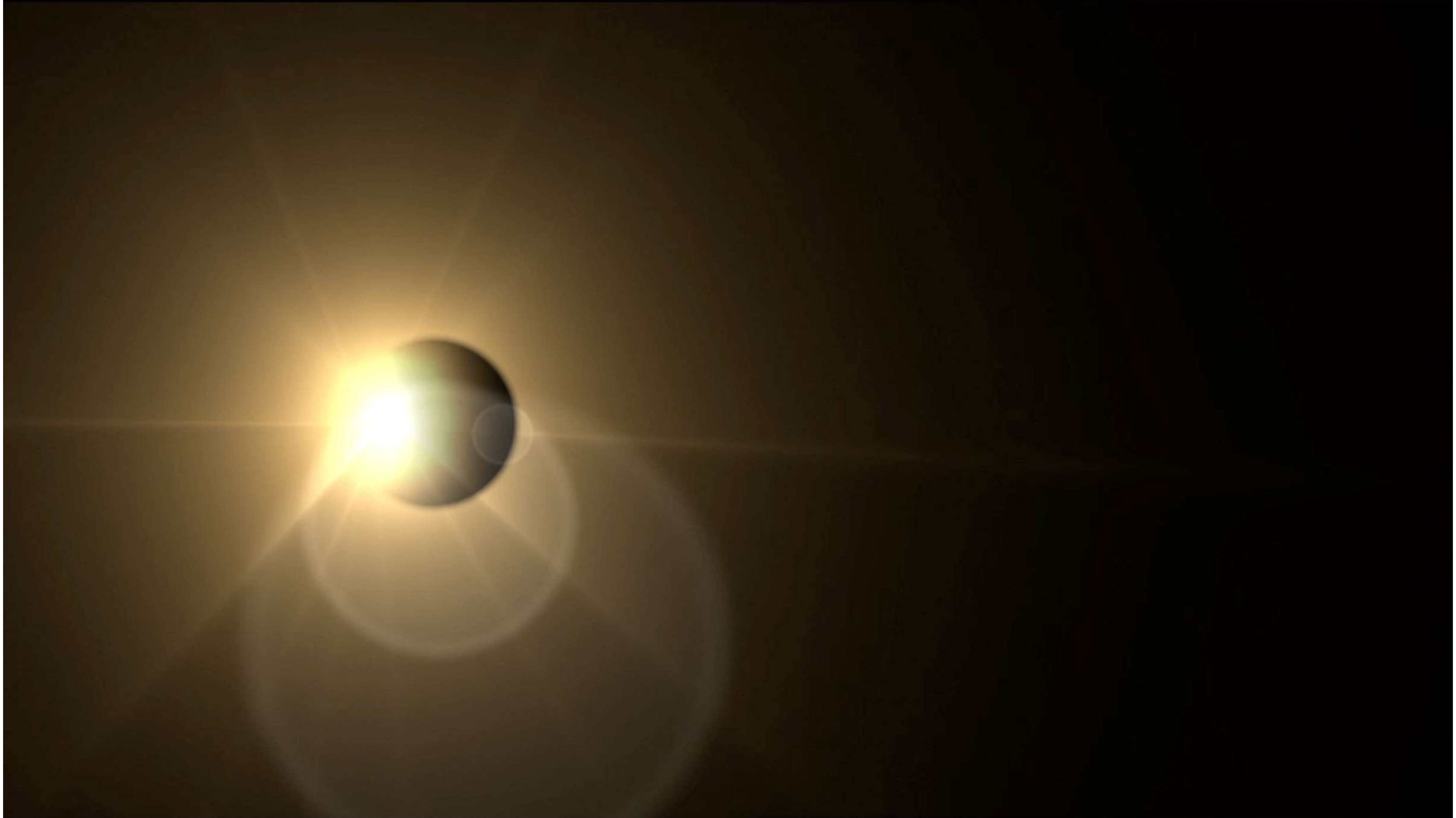
STEREO (Solar TErrestrial RElations Observatory)[美国]

科学目标：两个完全相同的卫星观测太阳, 用于研究太阳和日冕物质抛射.

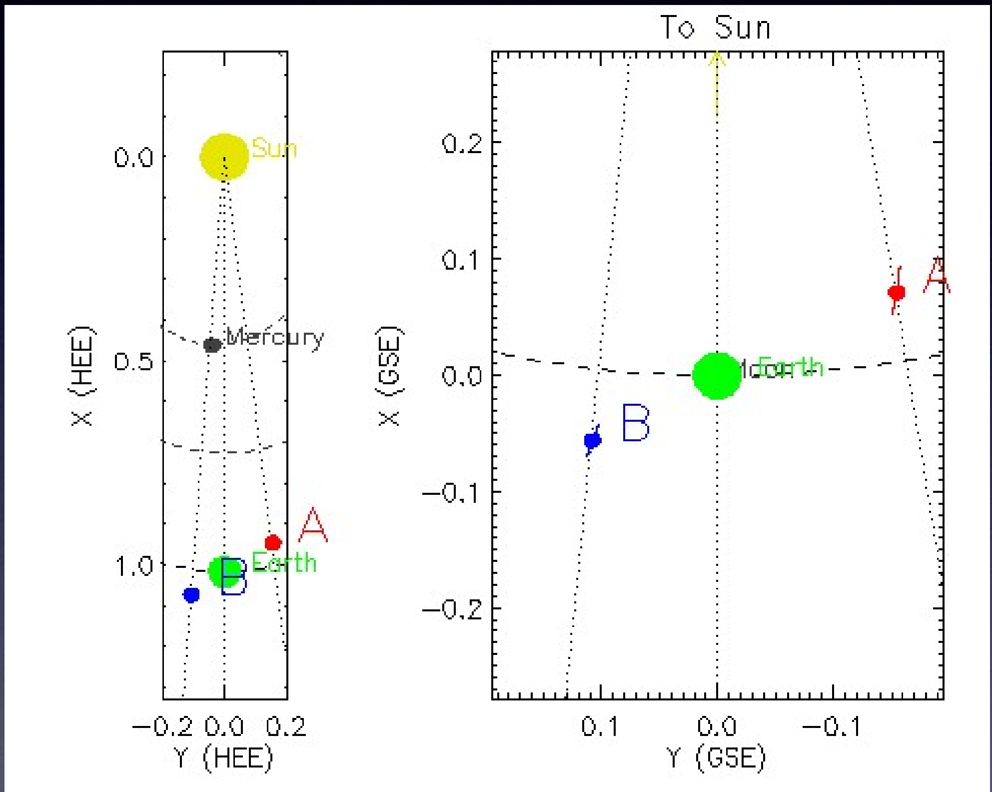
发射时间：2006年10月25日8:52 p.m

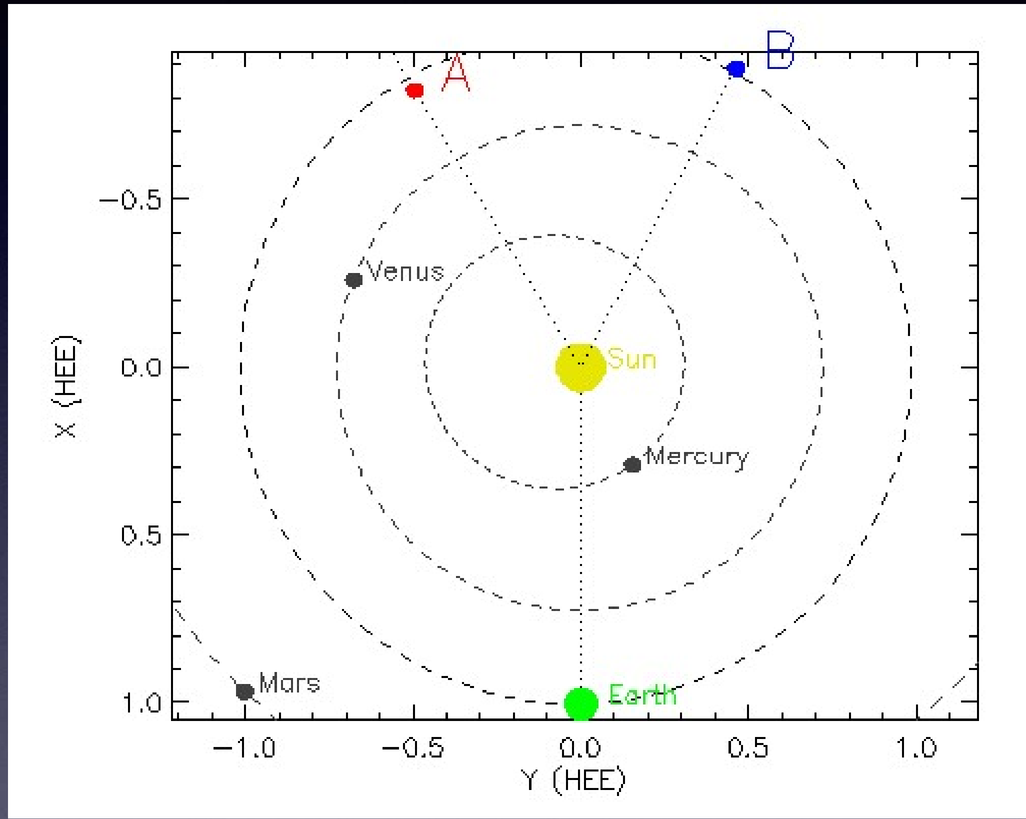






STEREO位置变化图

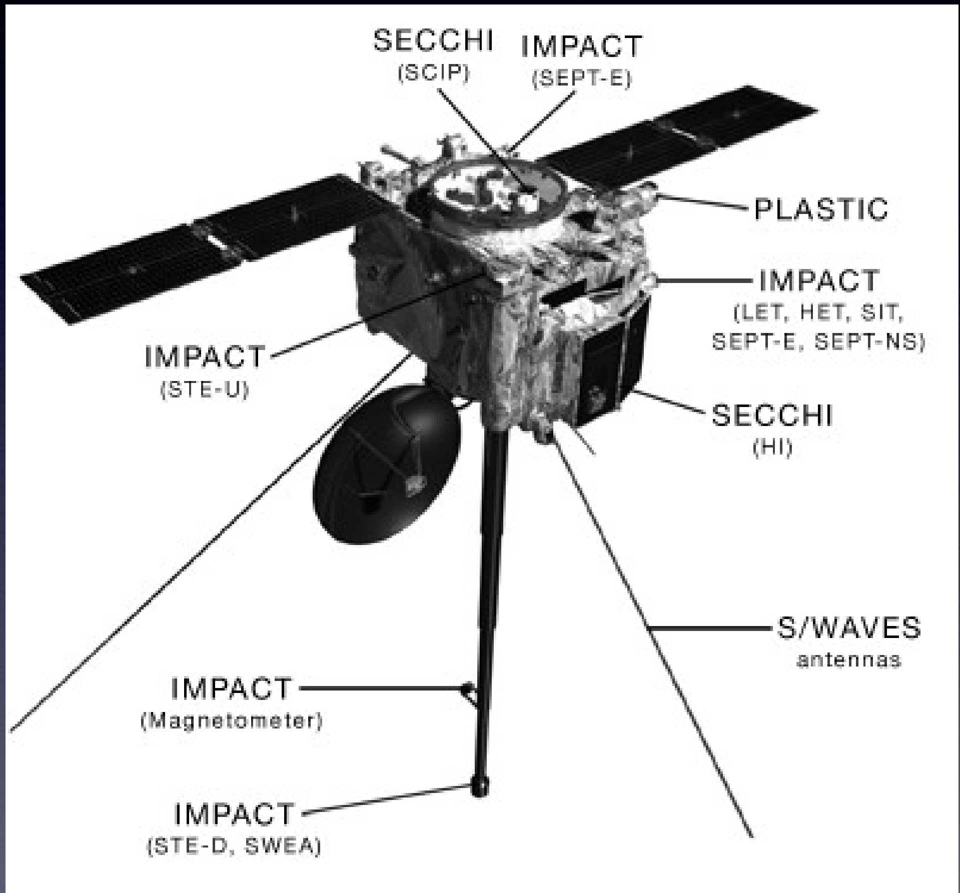


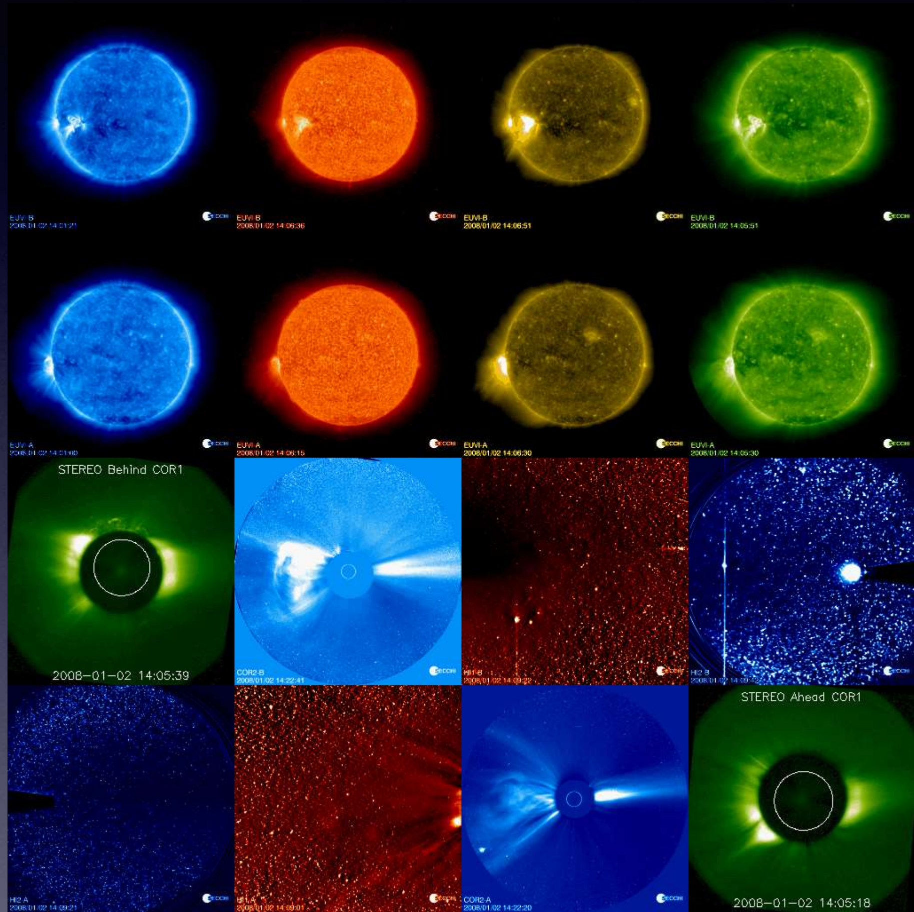


2007-06-26 00:00

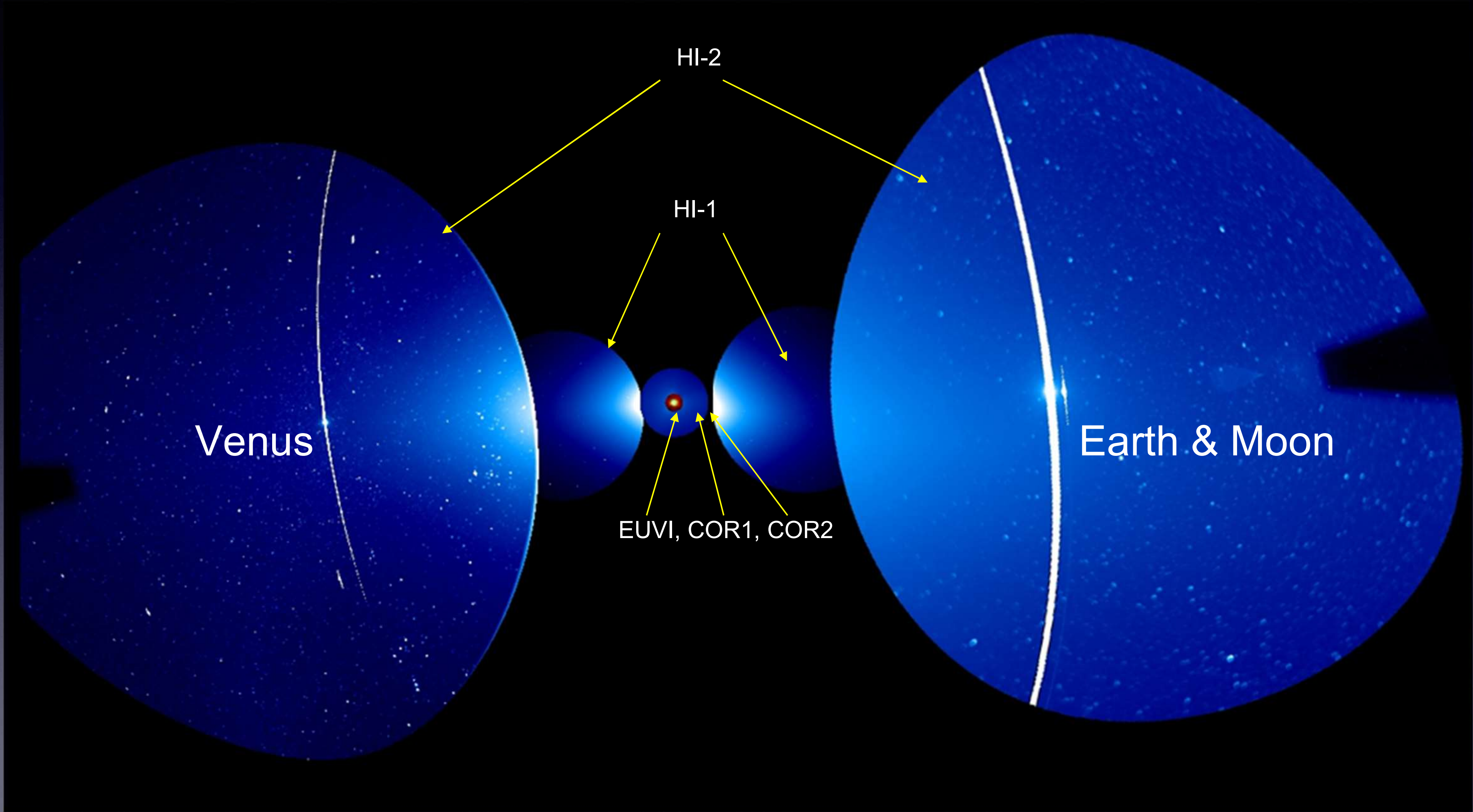
2016-09-20 00:00

STEREO卫星搭载仪器





EUVI: 4 波段 (304,171,195,284)
日冕仪：COR1, COR2
日球层成像仪：HI1, HI2


HI-2
HI-1
Venus
Earth & Moon
EUVI, COR1, COR2

SECCHI仪器拍摄的CME传播过程

Propagation of an Earth-directed coronal mass ejection in three-dimensions

Jason P. Byrne, Shane A. Maloney, R. T. James McAteer, Jose M. Refojo & Peter T. Gallagher

Trinity College Dublin

Fondúireacht Eolaíochta Éireann

Science Foundation Ireland

STEREO

SOLAR TERRESTRIAL RELATIONS OBSERVATORY

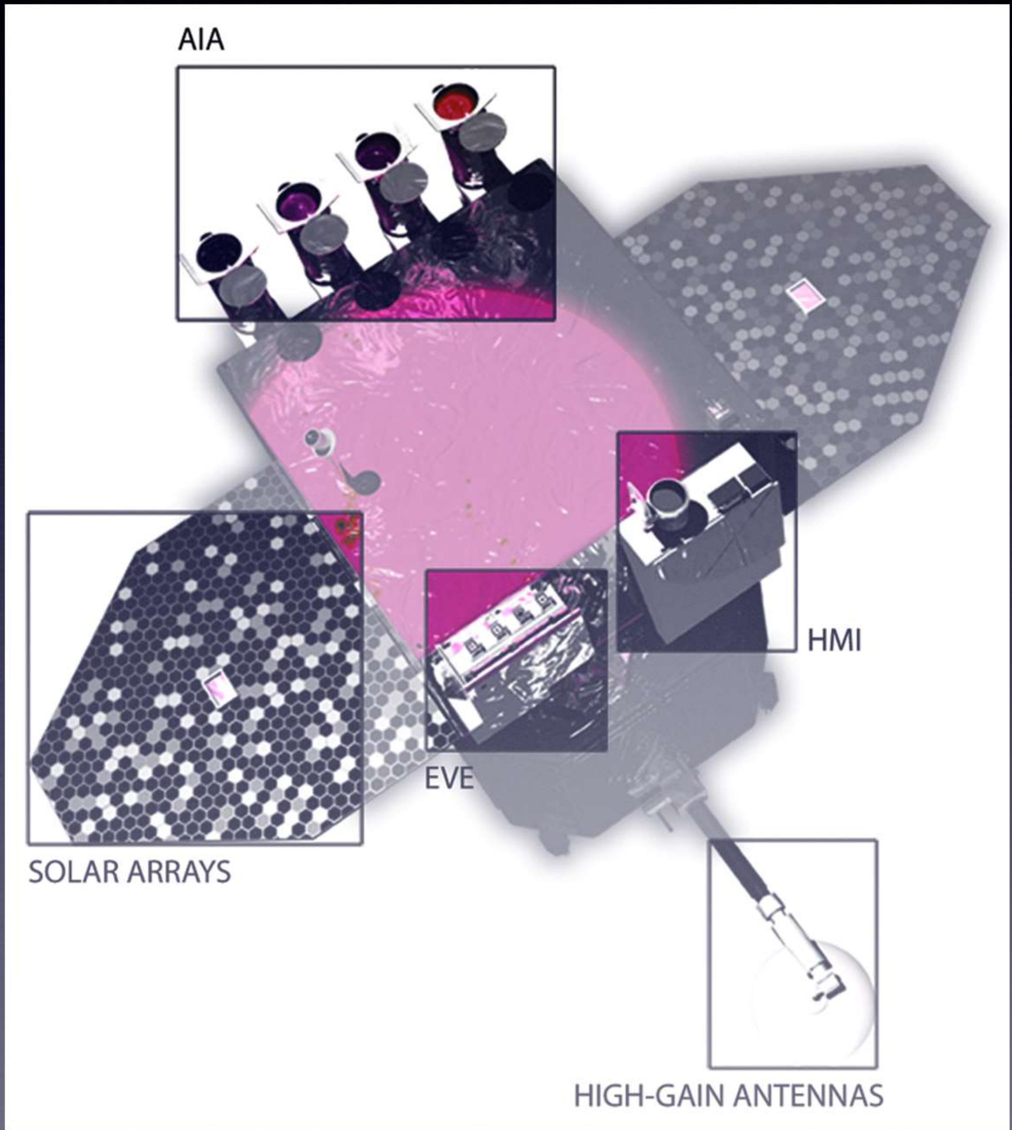
STEREO-A

STEREO-B

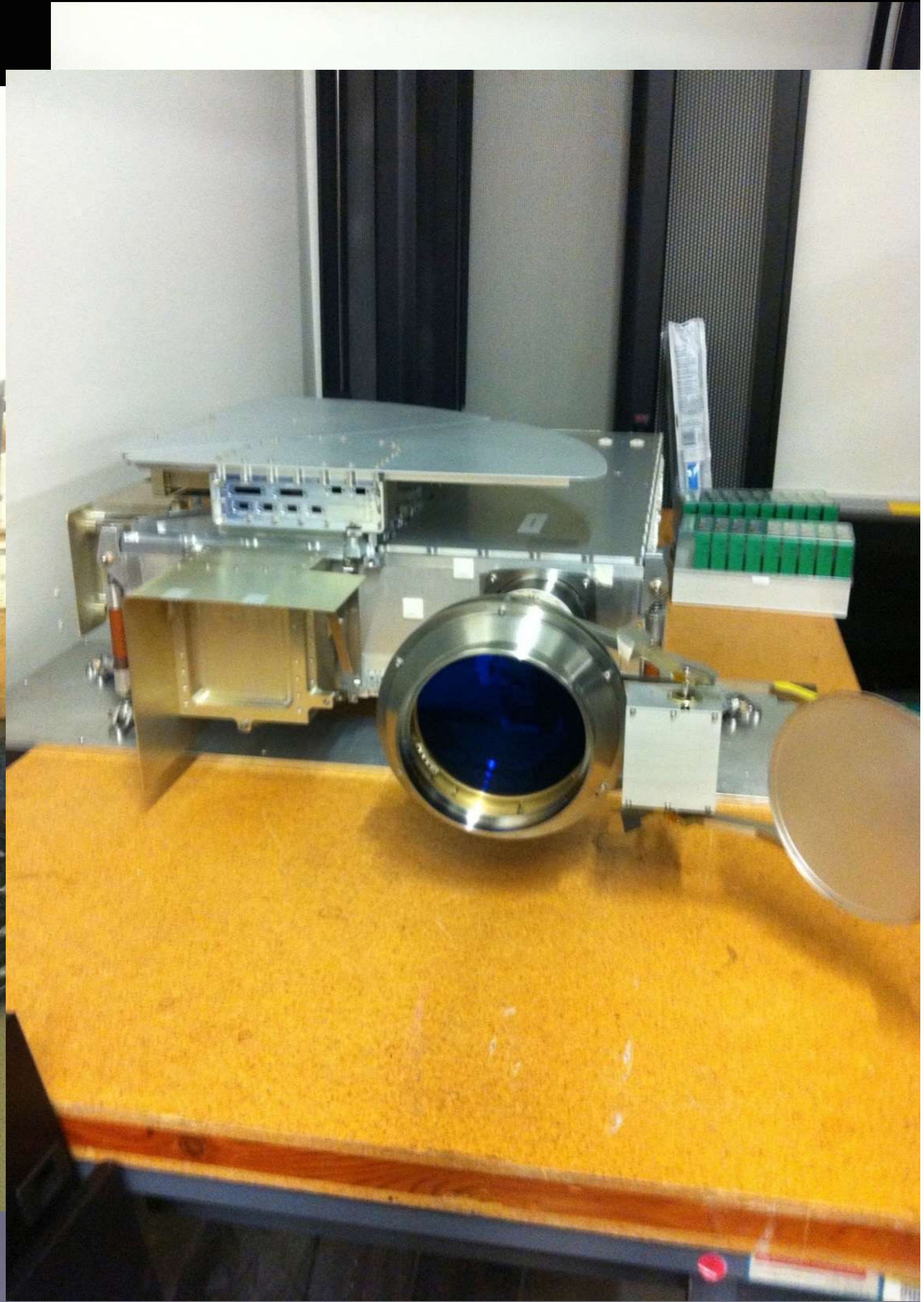
12 December 2008 06:05 UT

Instrument: COR1

Solar Dynamic Observatory (SDO)

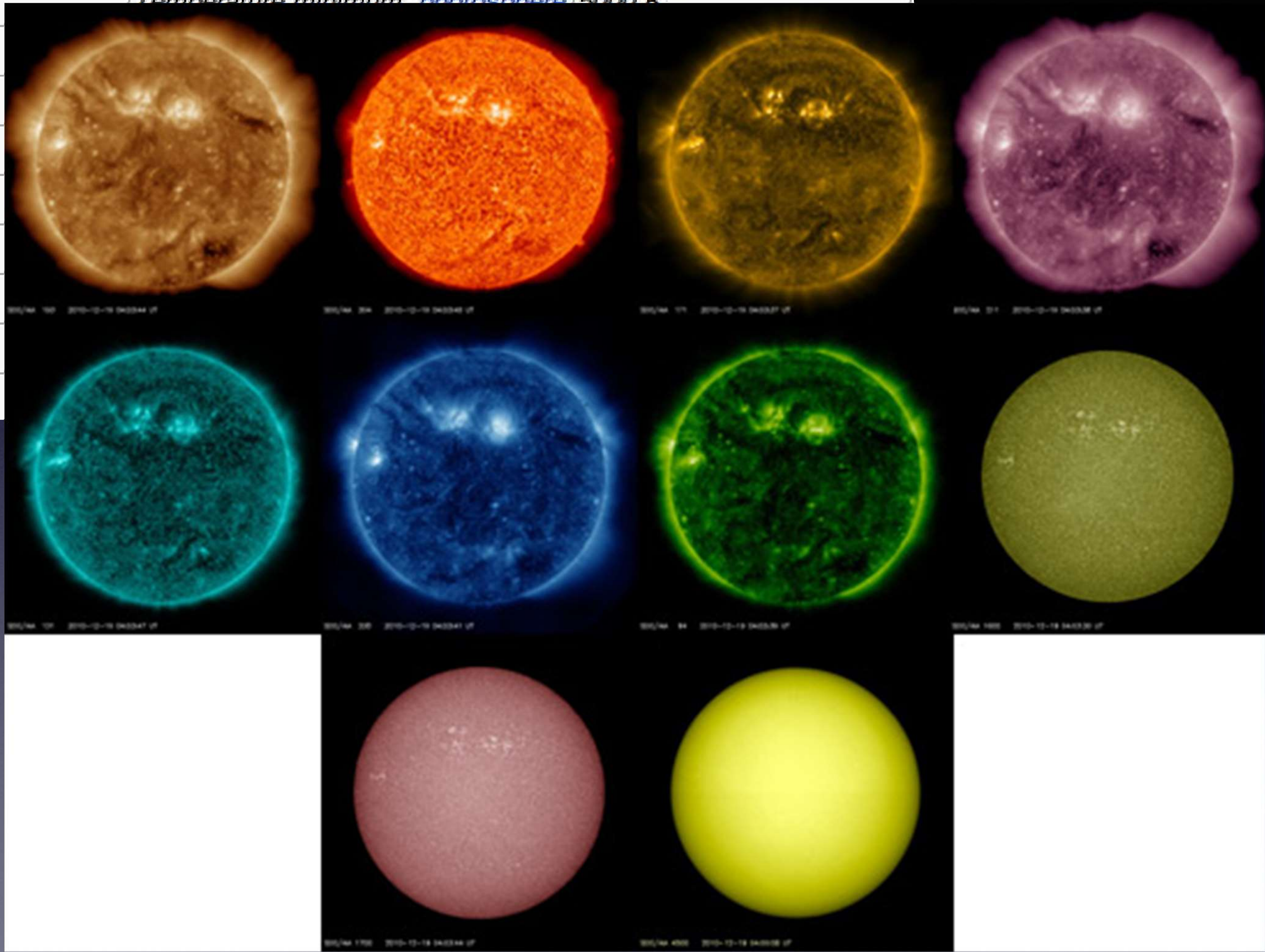


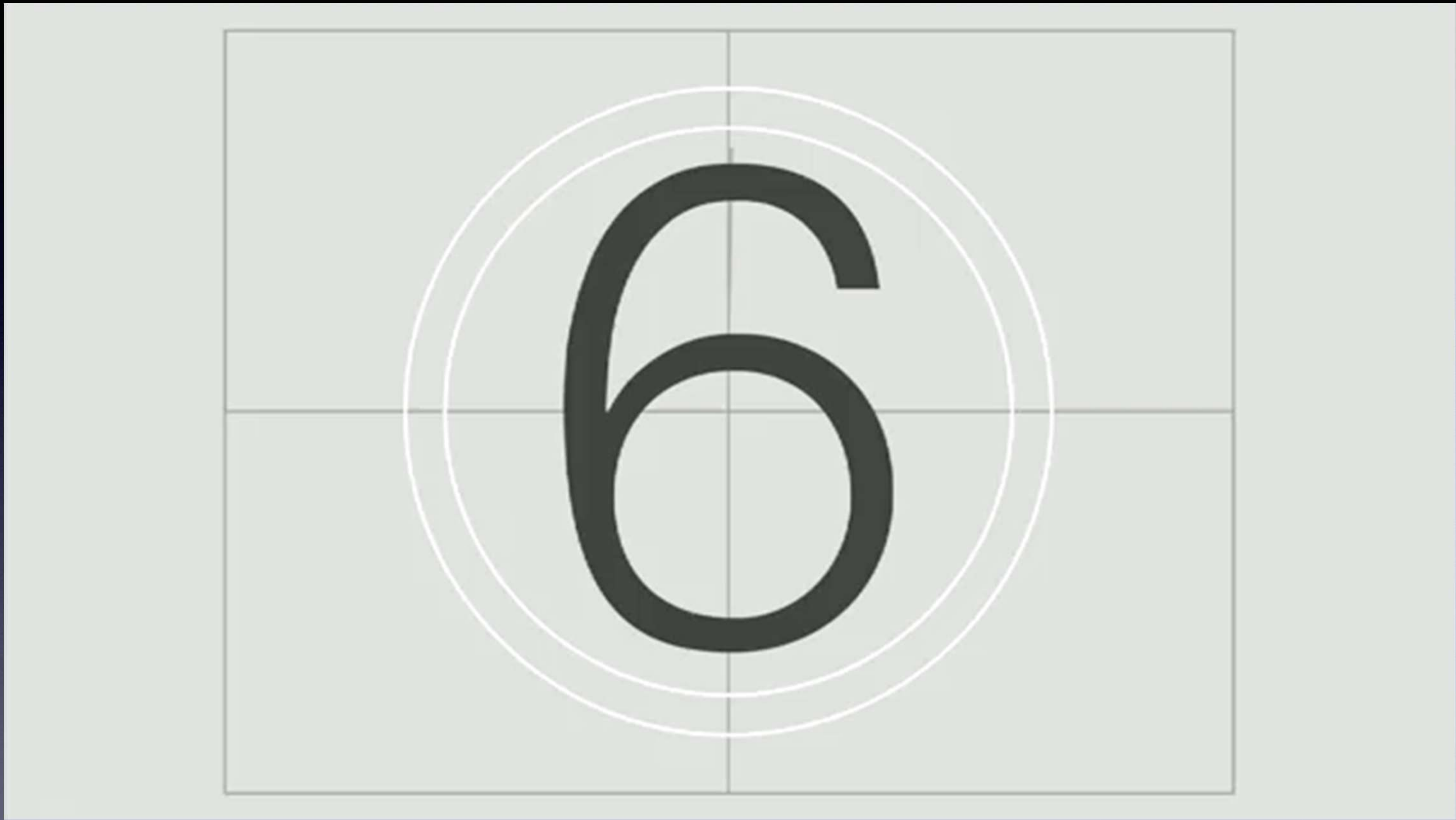
- First mission of NASA's Living With a Star (LWS) program
- Designed to study the dynamic behaviors of the Sun
- AIA: Atmospheric Imaging Assembly
- EVE: Extreme-ultraviolet Variation Experiment
- HMI: Helioseismic and Magnetic Imager



Solar Dynamics Observatory

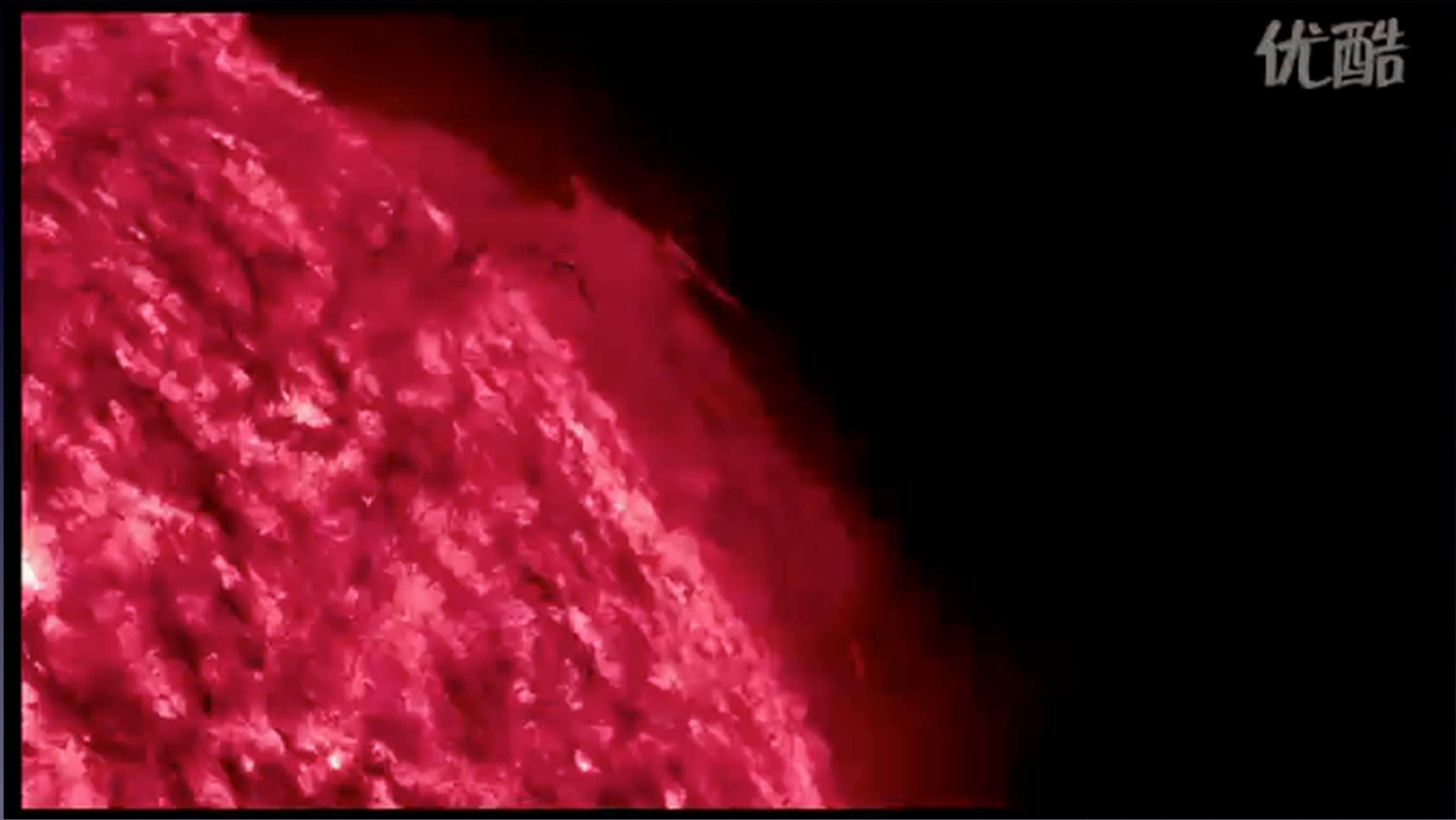
AIA Wav	on of solar atmosphere	Characteristic Temperature
White Light	Photosphere	5000 K
1700 Å	Temperature minimum, photosphere	5000 K
1600 Å		
304 Å		
171 Å		
193 Å		
211 Å		
335 Å		
94 Å		
131 Å		



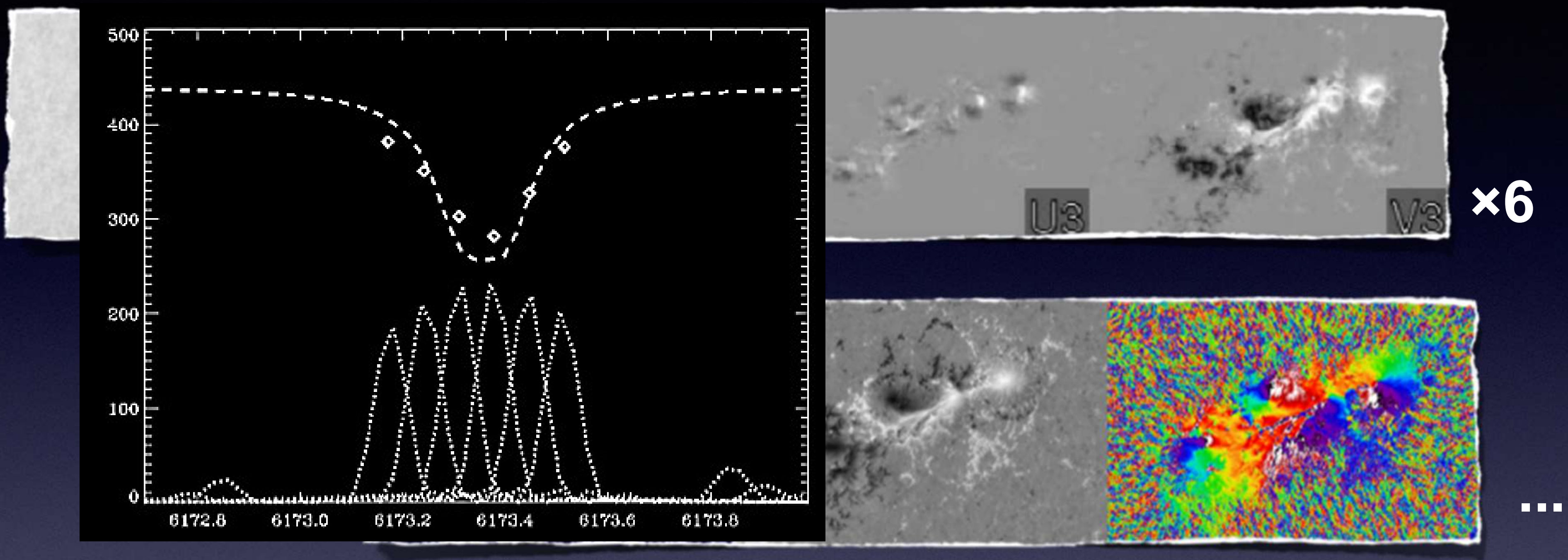

6


优酷

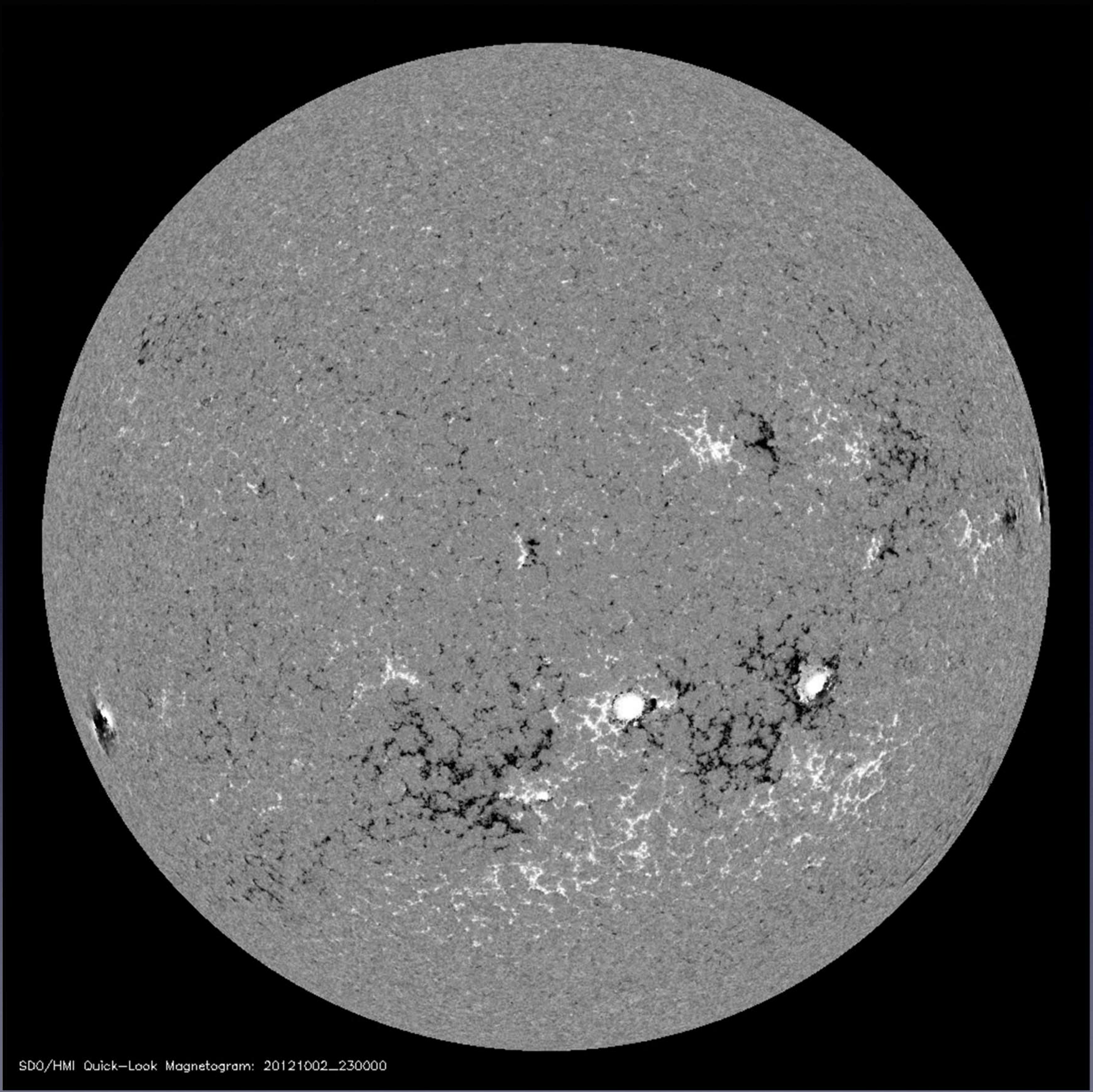

优酷

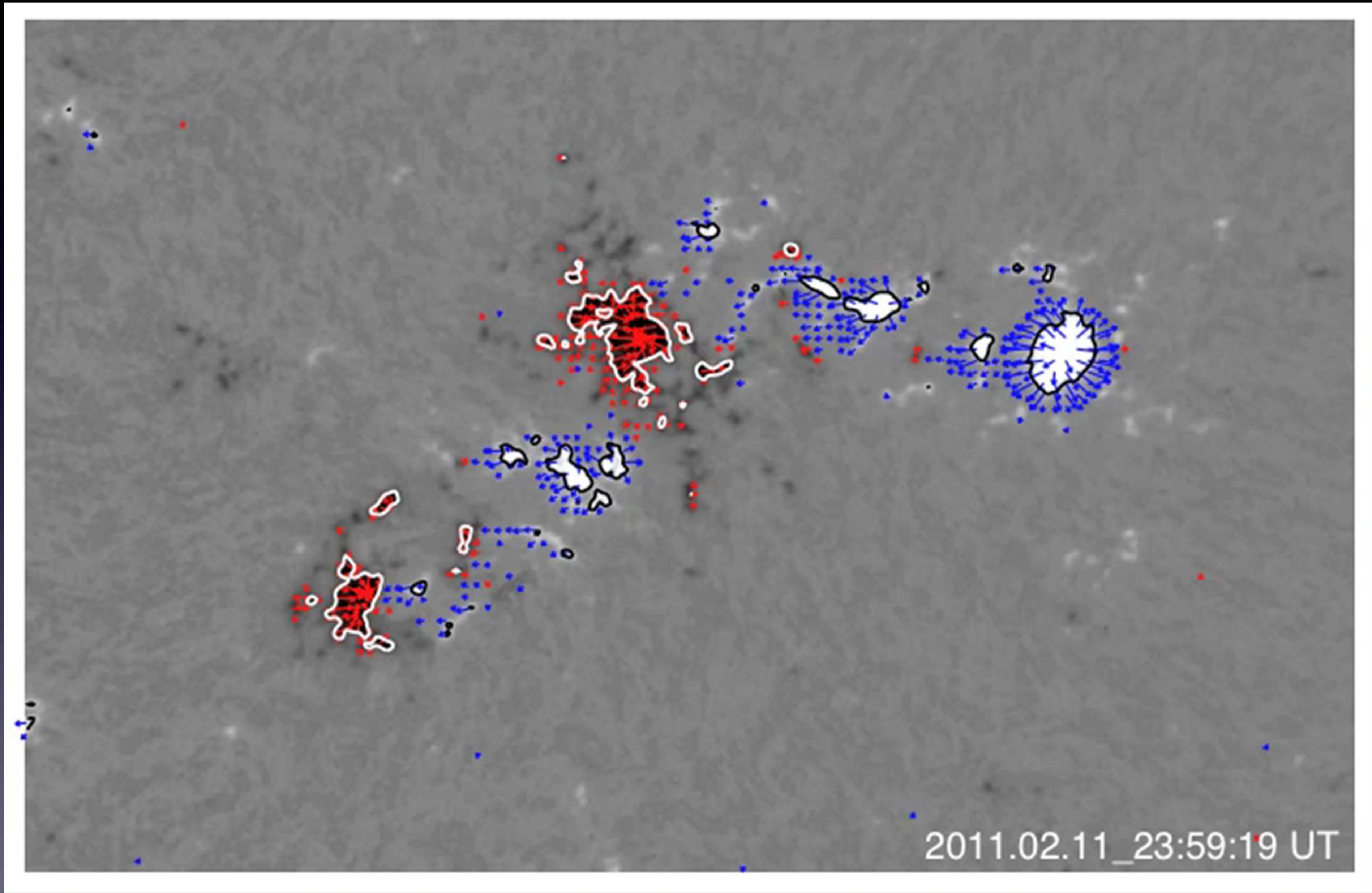

优酷

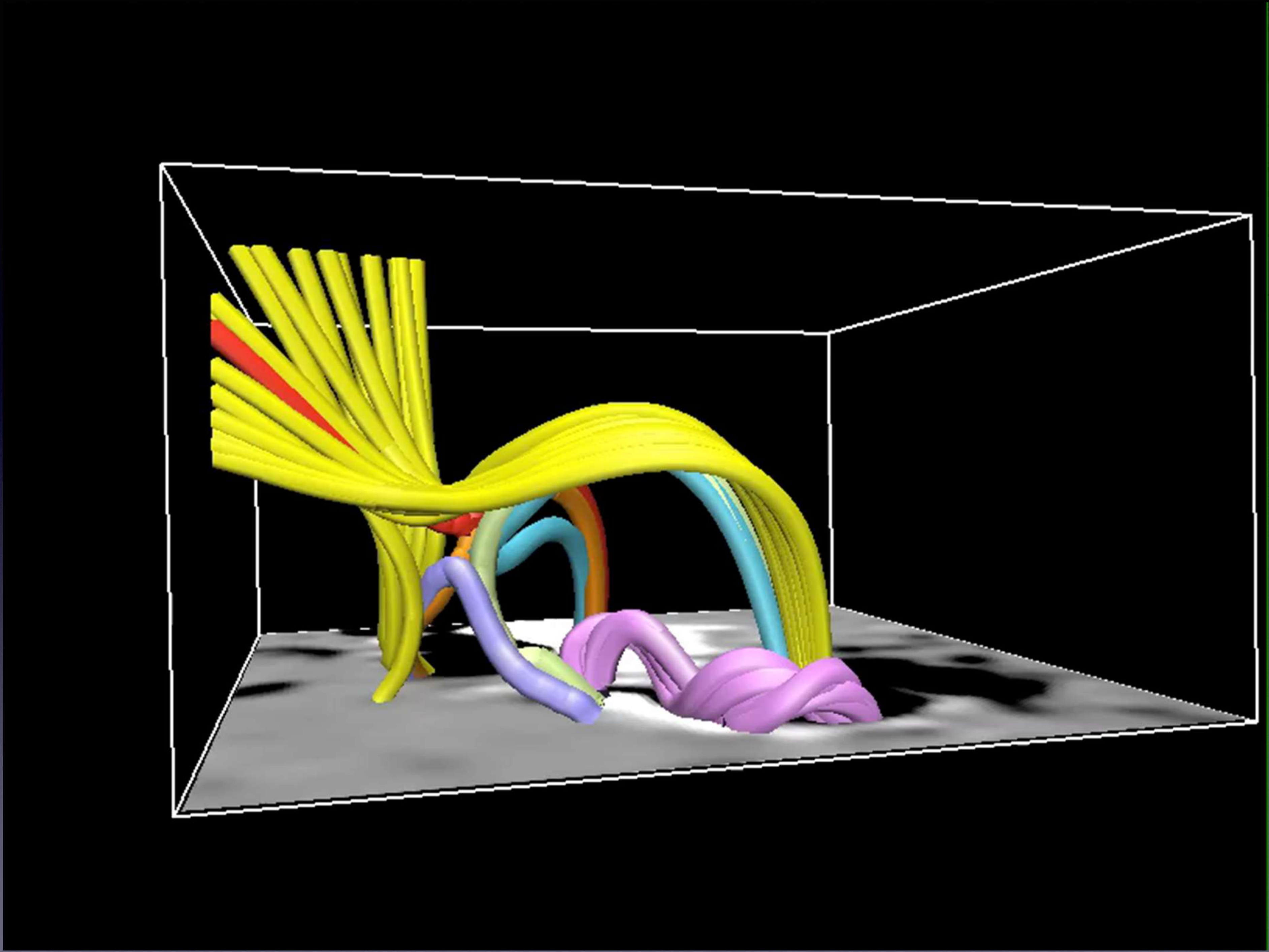
光球层观测: HMI



- ★ Spectropolarimetry observation: Fe I 6173 Å, 6 wavelengths
- ★ High cadence (12 min); moderate resolution (0.5” pix)
- ★ Fast Milne-Eddington inversion (VFISV, Borrero et al. 2010)
- ★ Minimum-energy azimuthal disambiguation (e.g. Metcalf 1994)
- ★ Automated feature tracking & extraction (Turmon et al. 2010)


SDO/HMI Quick-Look Magnetogram: 20121002_230000


2011.02.11_23:59:19 UT

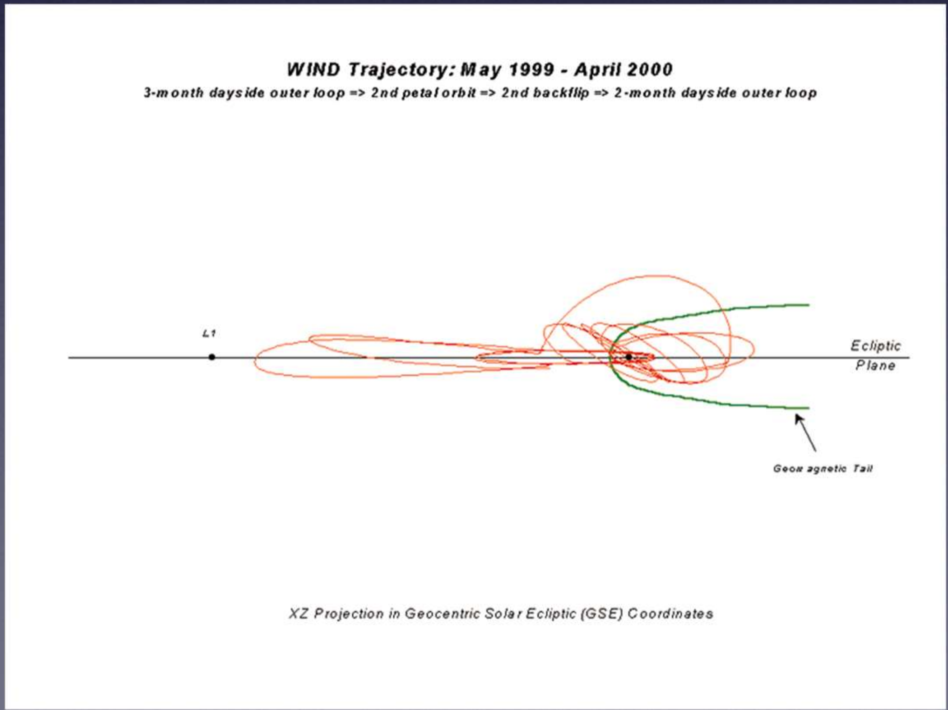


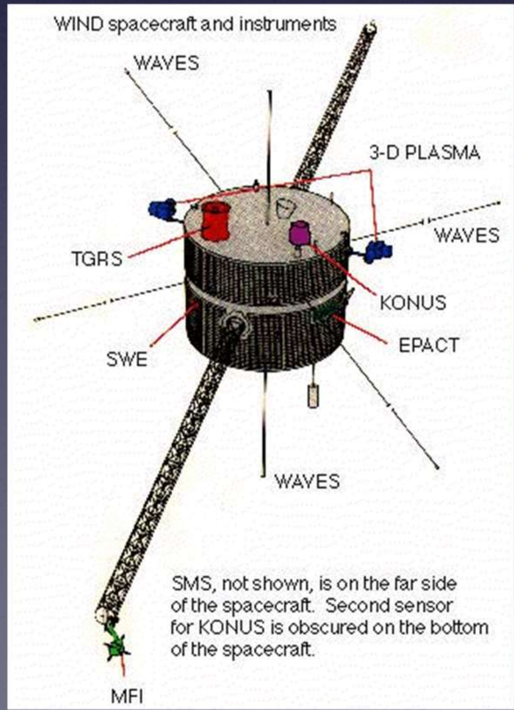
WIND卫星

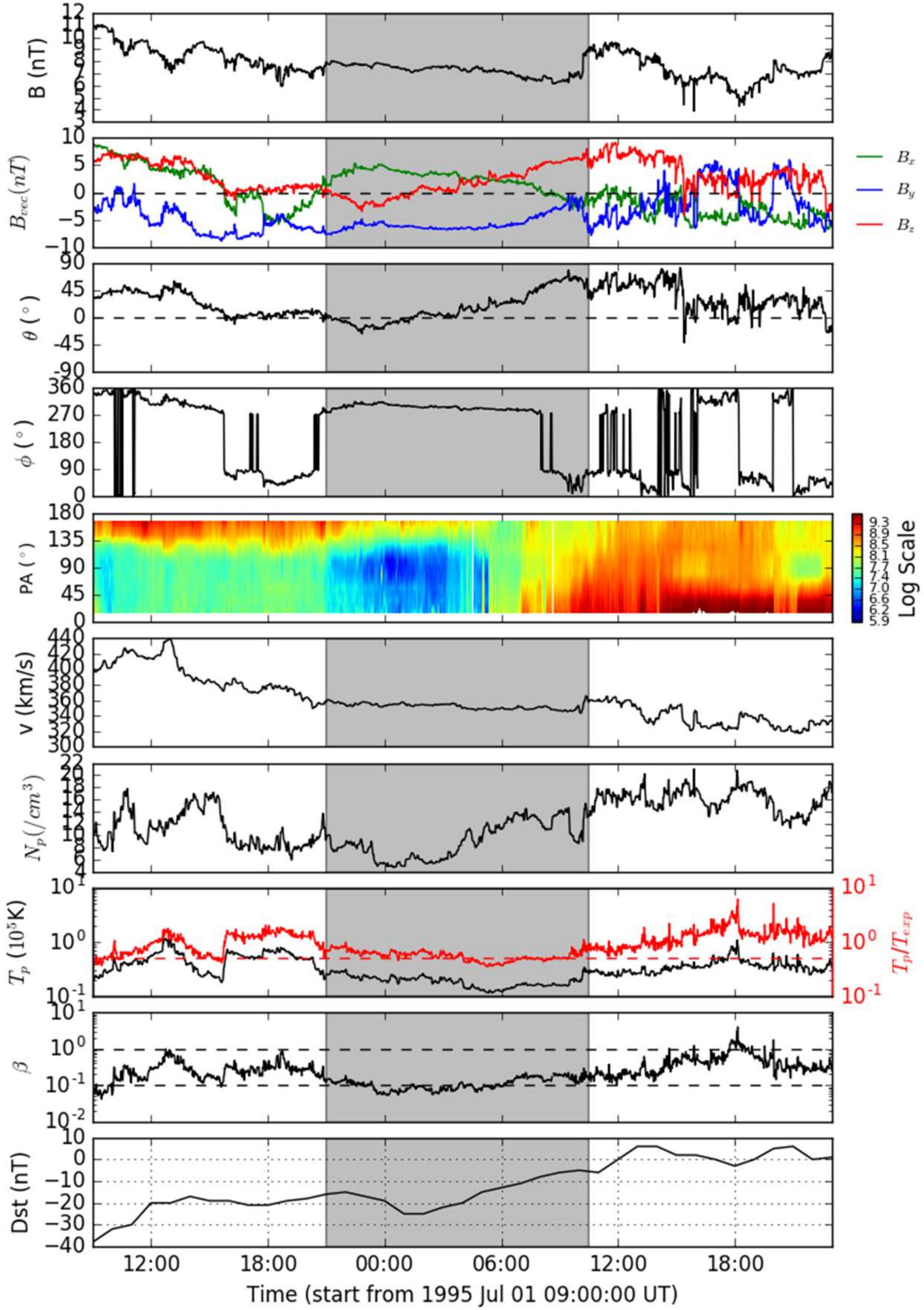
发射时间：November 1, 1994

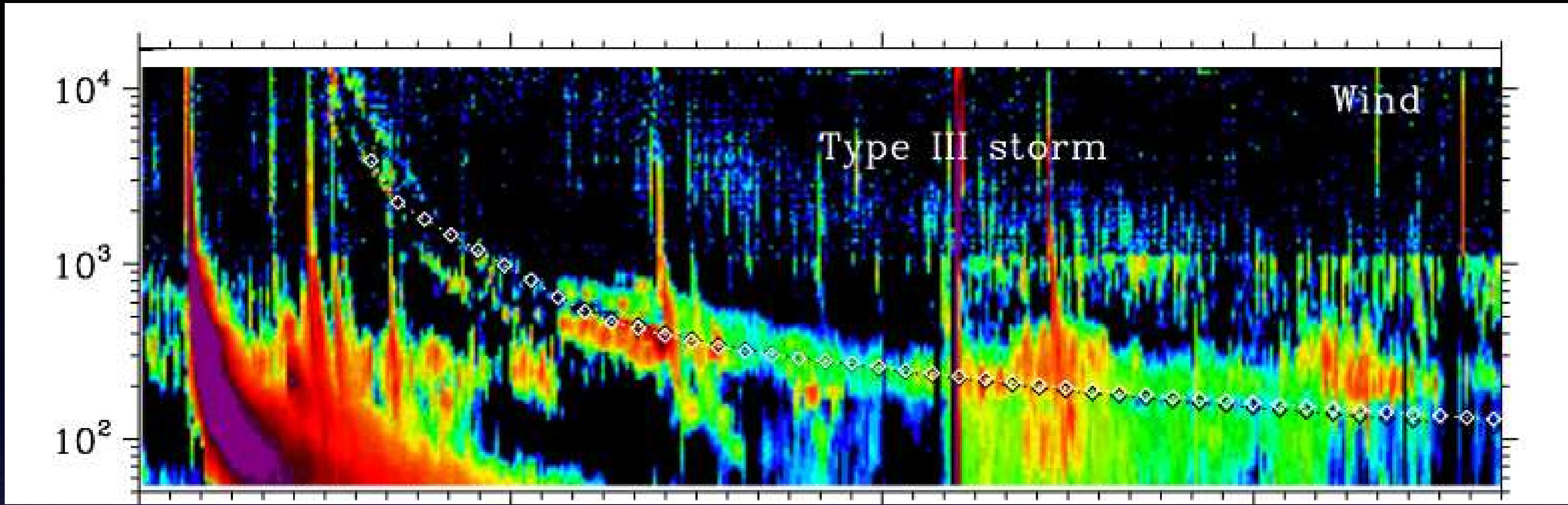
科学目标：

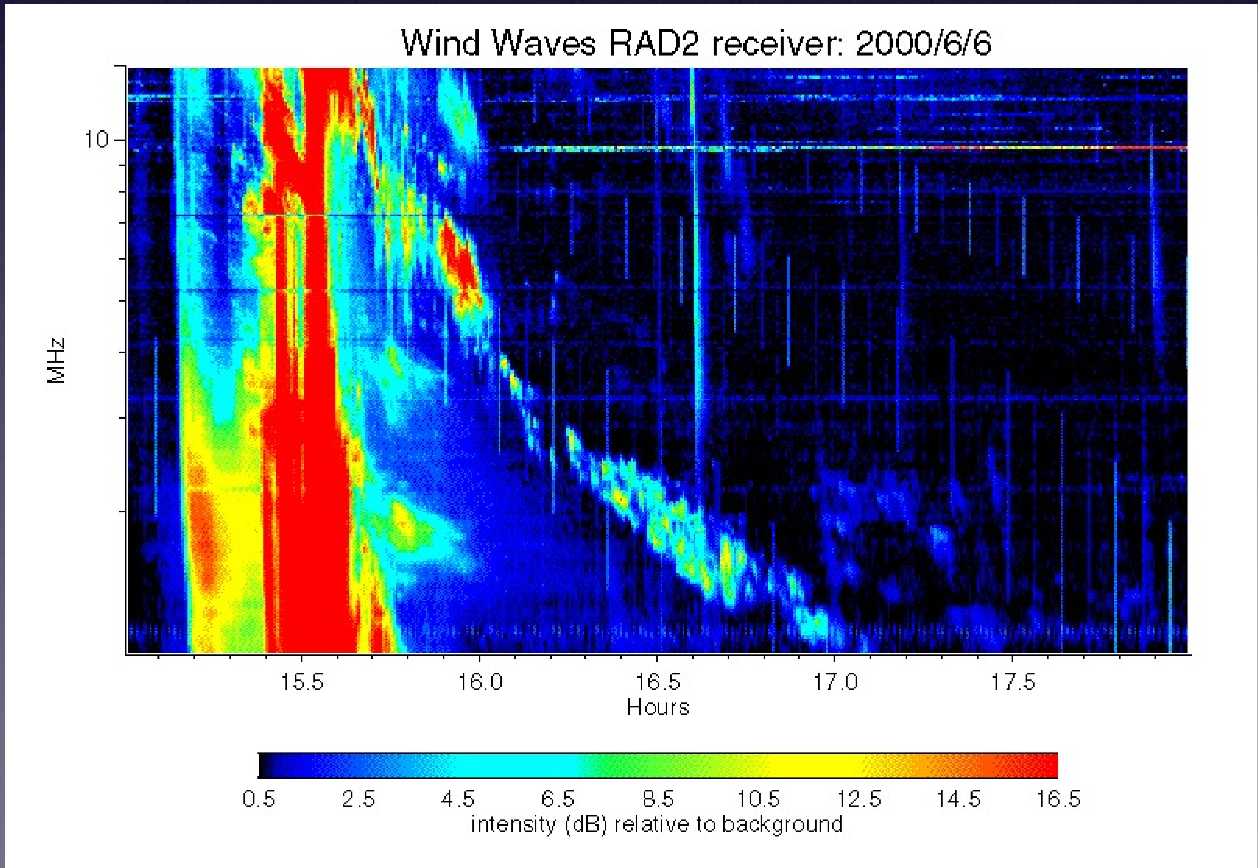
- ★ 提供完成的等离子体和磁场数据, 用于行星际响应研究.
- ★ 探测磁层顶区域向行星际的能量输出
- ★ 探测近地球附近太阳风的基本等离子体过程
- ★ 提供给ULYSSES卫星黄道面观测基准






B (nT)
$B_{vec}(nT)$
B_x
B_y
B_z
θ (°)
ϕ (°)
PA (°)
Log Scale
v (km/s)
$N_p(/cm^3)$
T_p (10^5K)
T_p/T_{exp}
β
Dst (nT)
12:00
18:00
00:00
06:00
12:00
18:00
Time (start from 1995 Jul 01 09:00:00 UT)


Type III storm
Wind
10^4
10^3
10^2

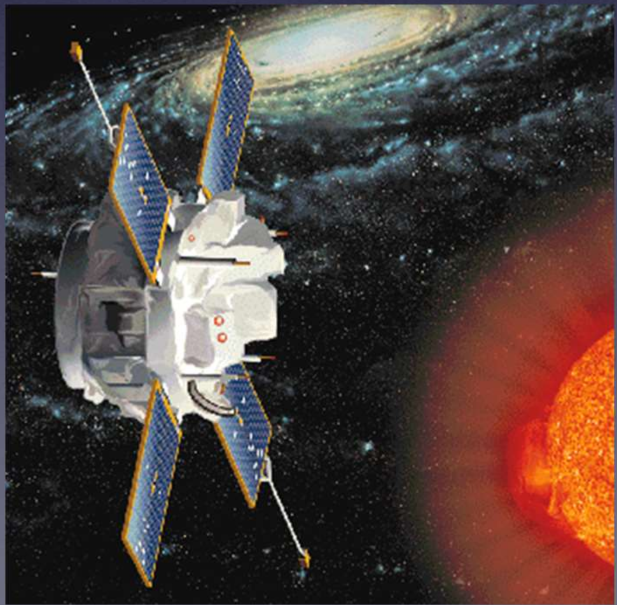

Wind Waves RAD2 receiver: 2000/6/6
MHz
10
15.5
16.0
16.5
17.0
17.5
Hours
0.5
2.5
4.5
6.5
8.5
10.5
12.5
14.5
16.5
intensity (dB) relative to background

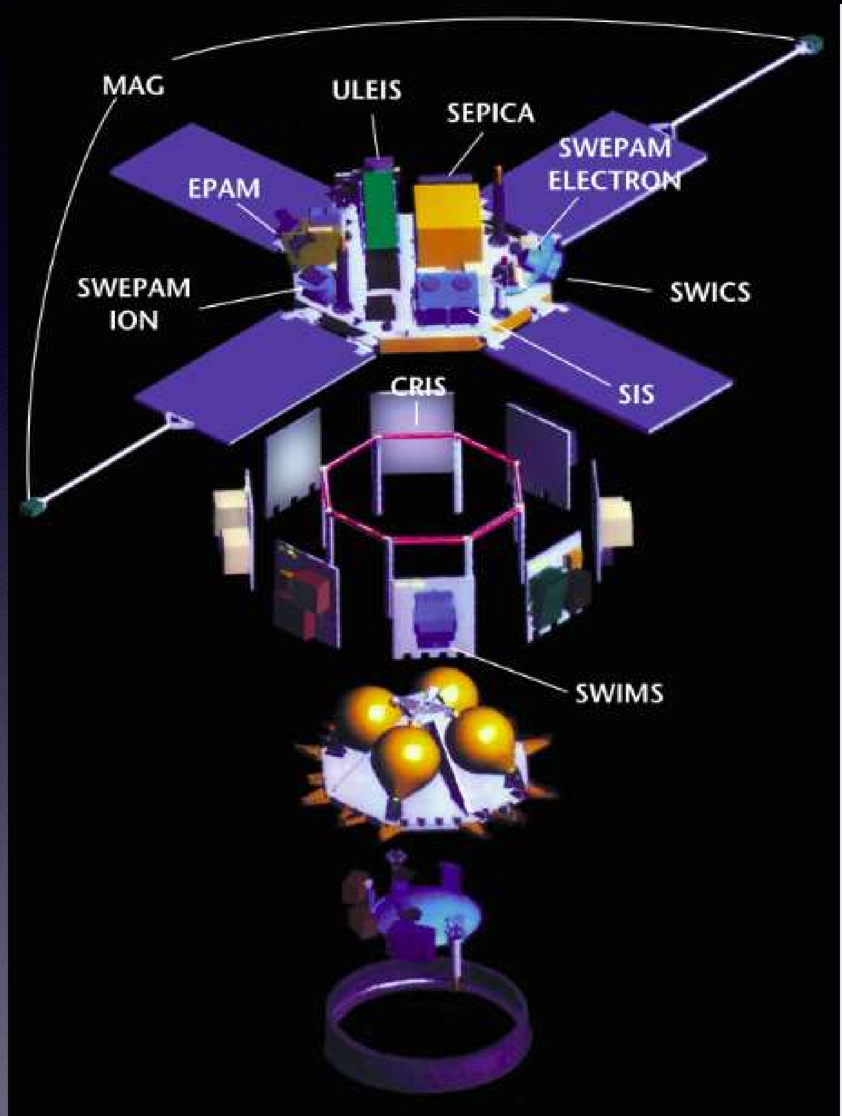
Advanced Composition Explorer (ACE)

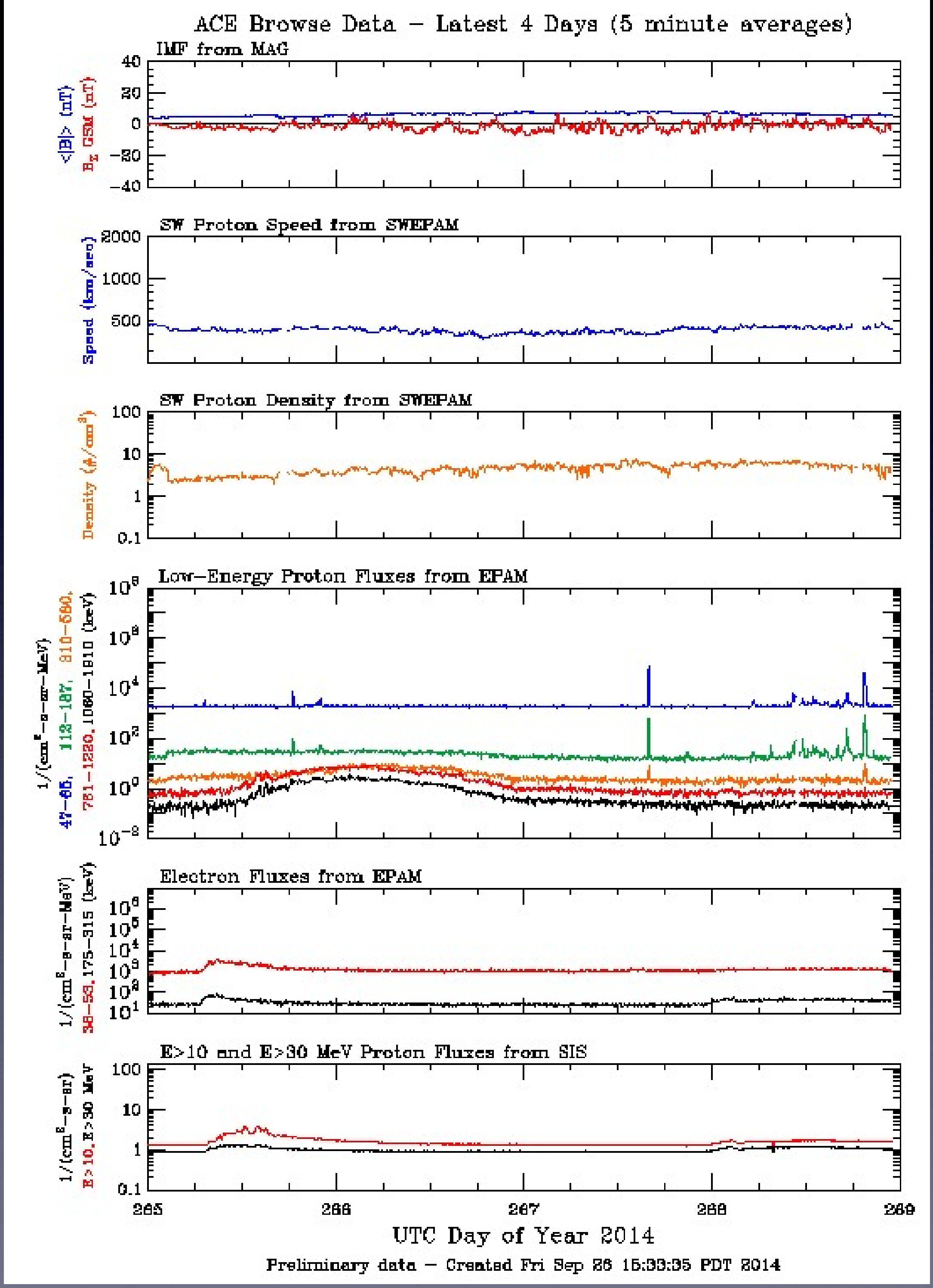
发射时间： 1997年8月

卫星特点：

★全面的物质成分确定
★宽广的观测范围
★观测太阳物质的演化

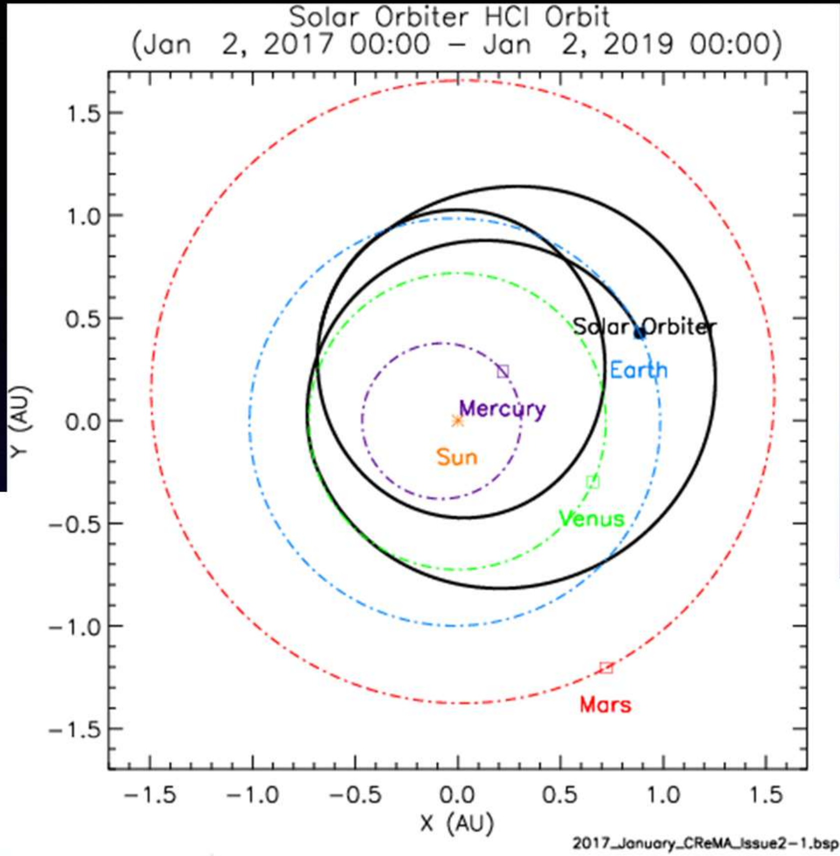


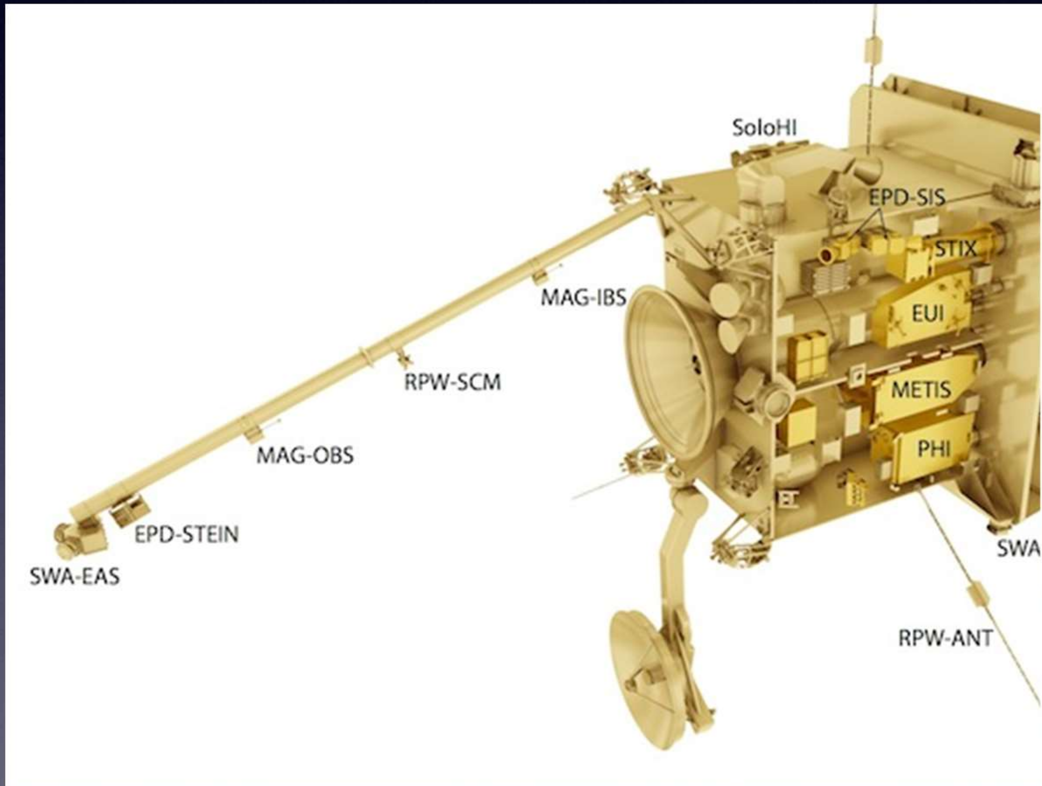


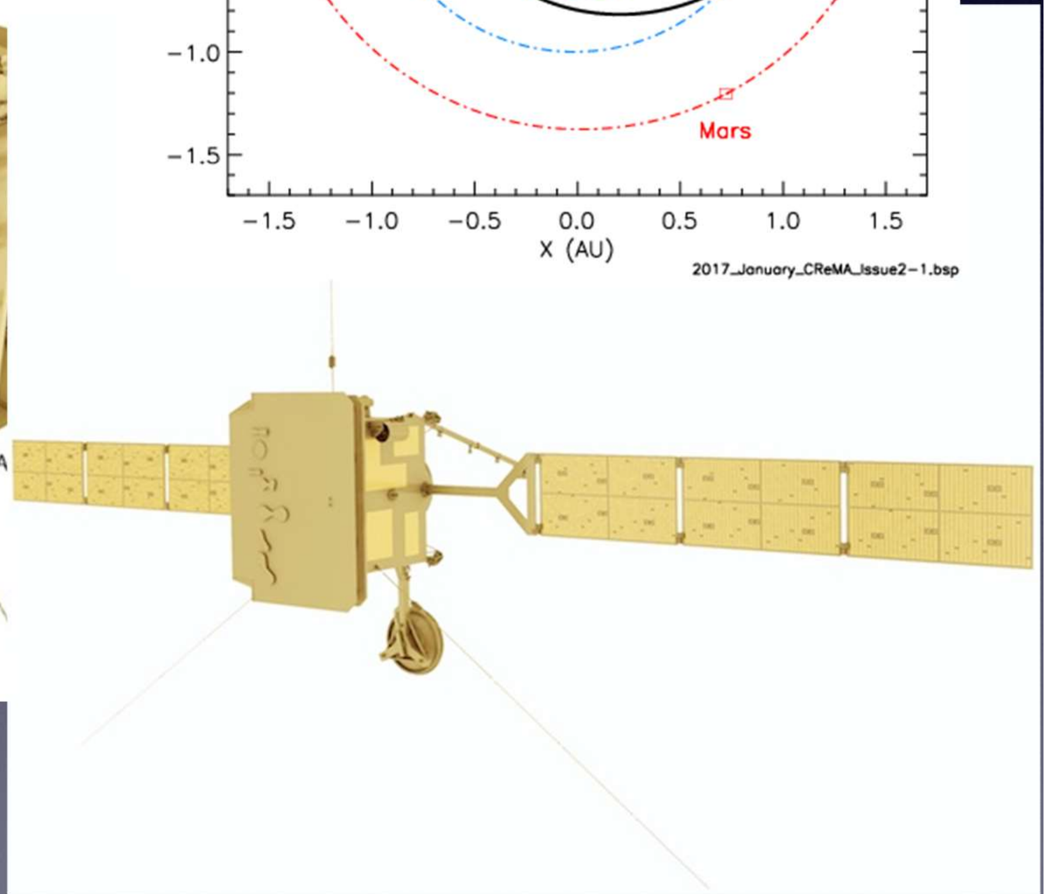

ACE Browse Data – Latest 4 Days (5 minute averages)
IMF from MAG
<|B|> (nT)
Bz GSM (nT)
SW Proton Speed from SWEPAM
Speed (km/sec)
SW Proton Density from SWEPAM
Density (#/cm3)
Low-Energy Proton Fluxes from EPAM
1/(cm2-s-sr-MeV)
47-65, 112-187, 310-580, 761-1220, 1060-1910 (keV)
Electron Fluxes from EPAM
1/(cm2-s-sr-MeV)
38-53, 175-315 (keV)
E>10 and E>30 MeV Proton Fluxes from SIS
1/(cm2-s-sr)
E>10, E>30 MeV
265
266
267
268
269
UTC Day of Year 2014
Preliminary data – Created Fri Sep 26 15:33:35 PDT 2014

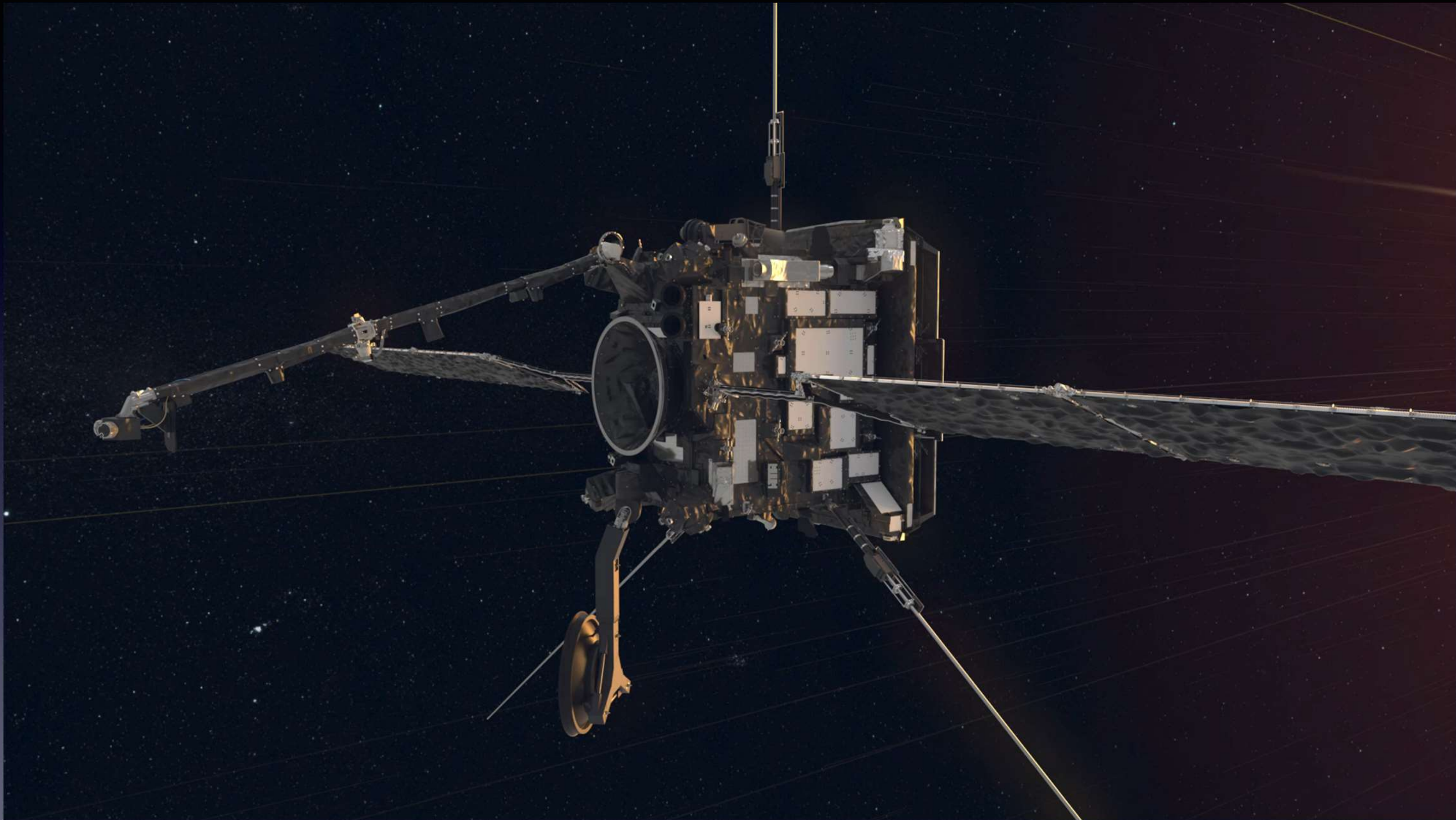
Solar Orbiter

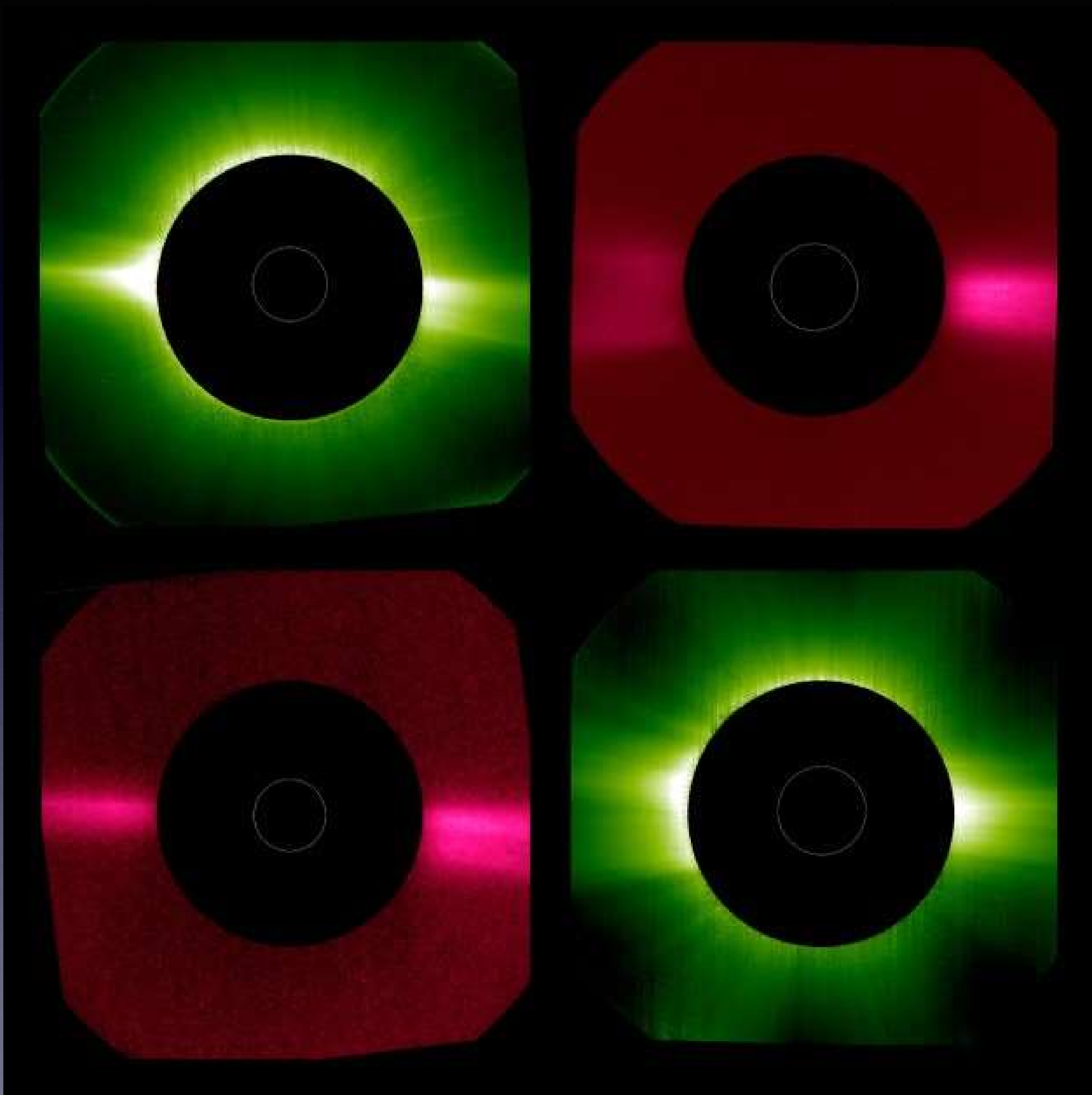
距离太阳最近：0.28 AU
发射时间：February 2020









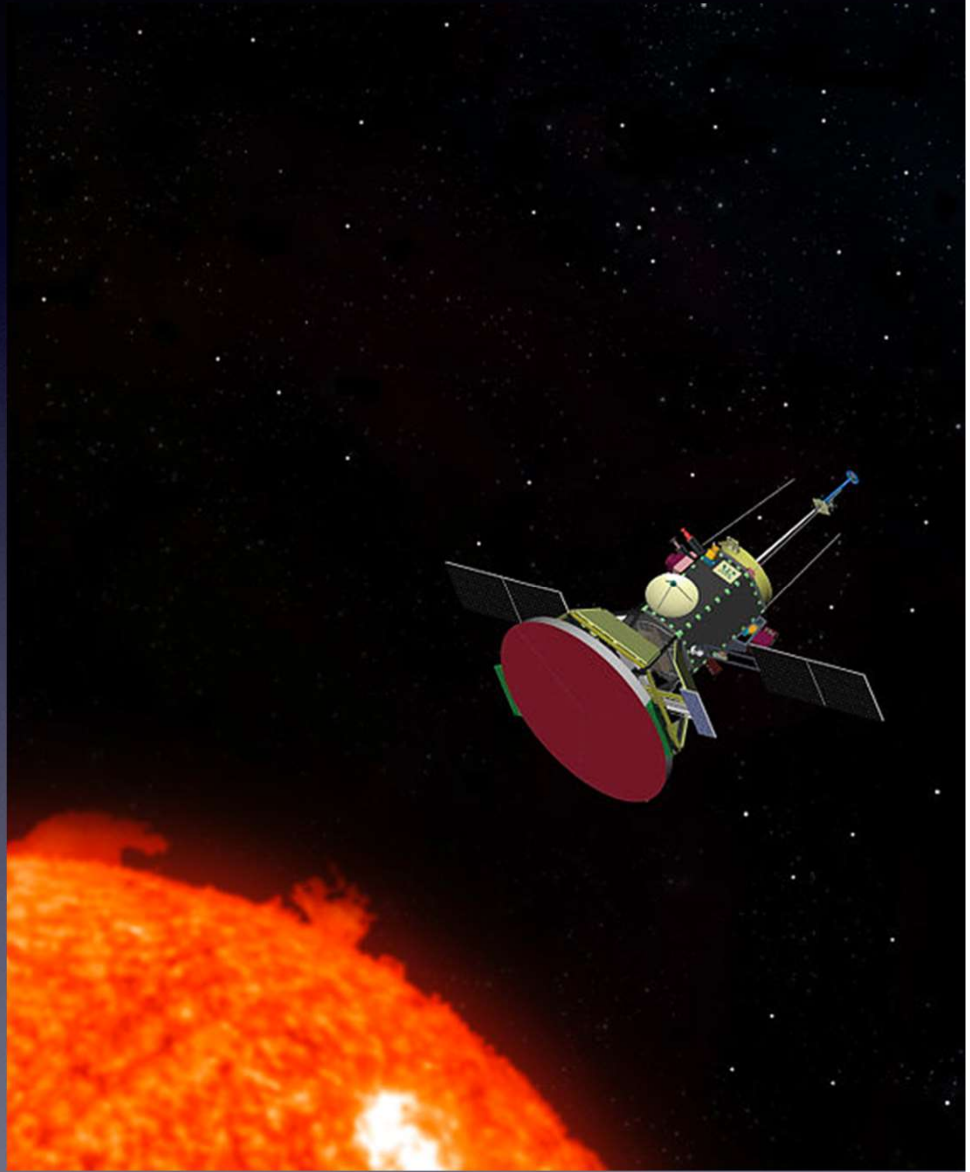


Parker Solar Probe

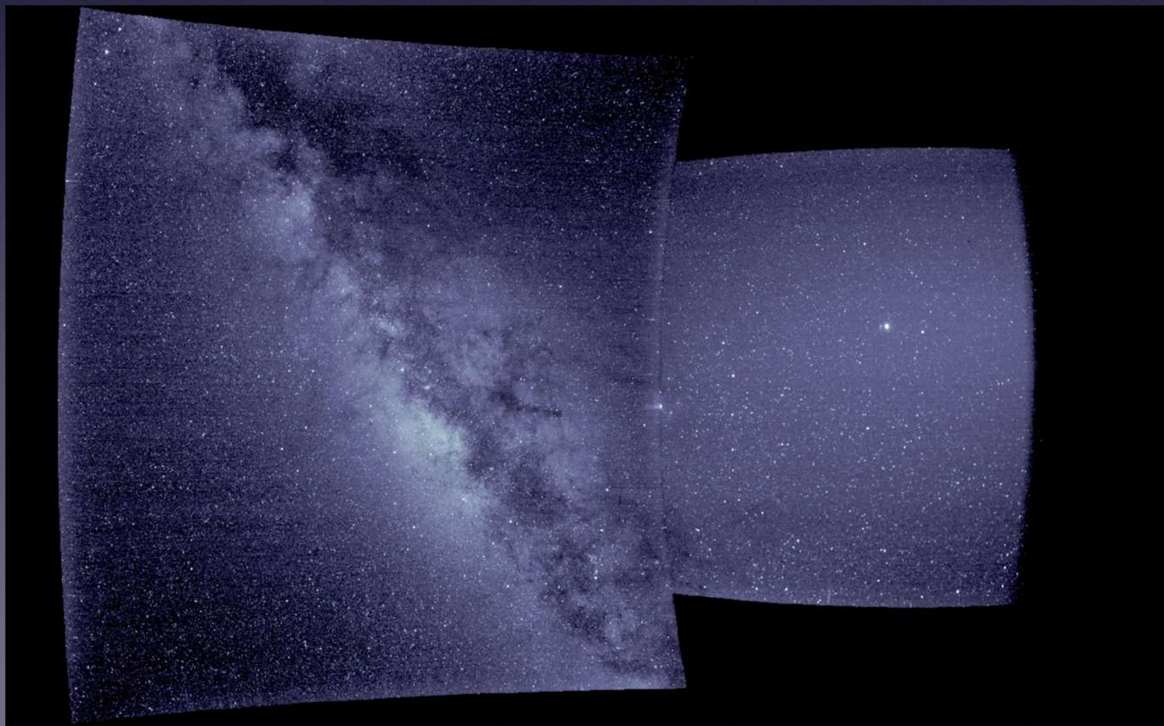
研究目标：探测太阳日冕

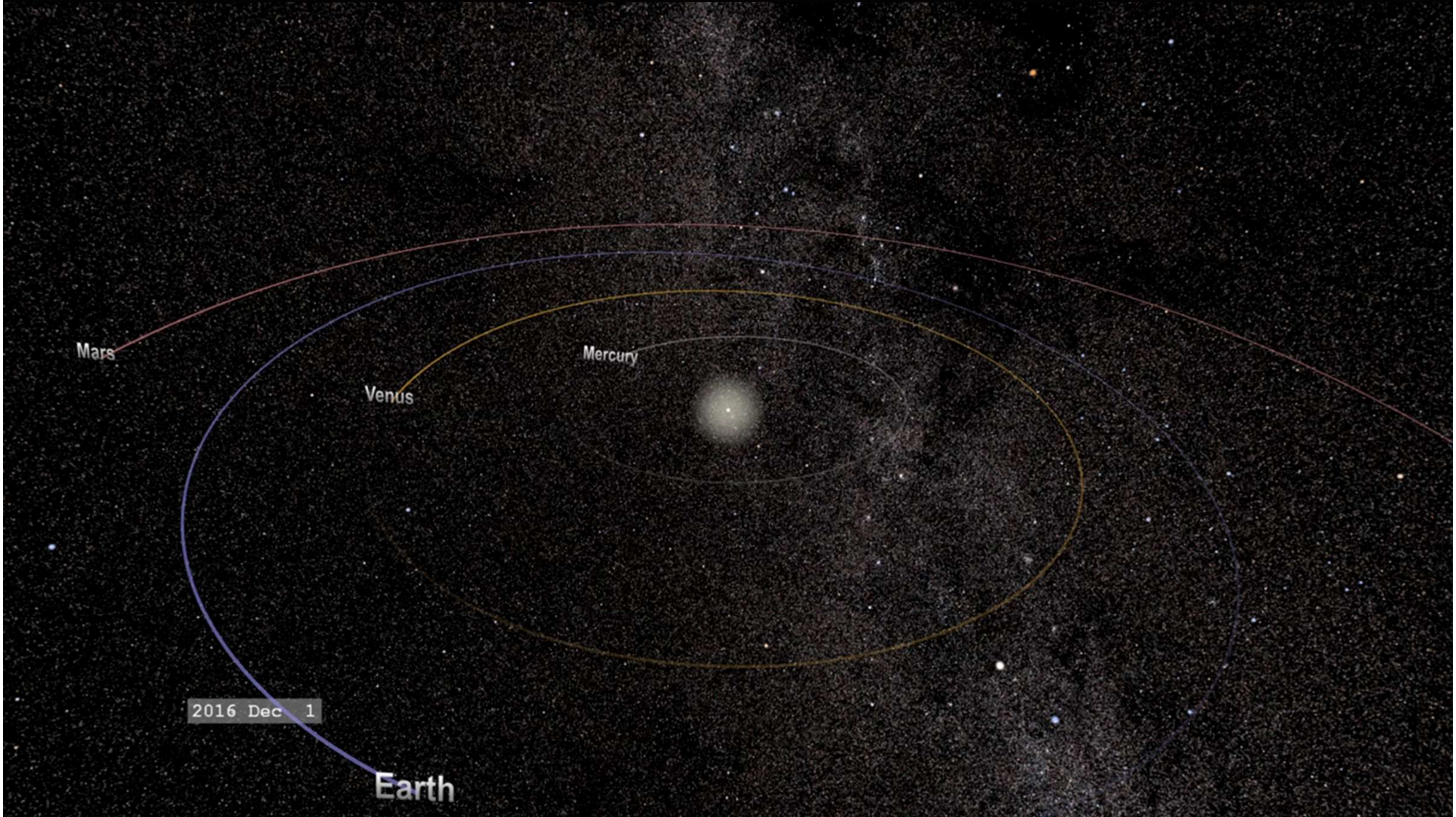
最近离太阳距离：$8.5R_s$

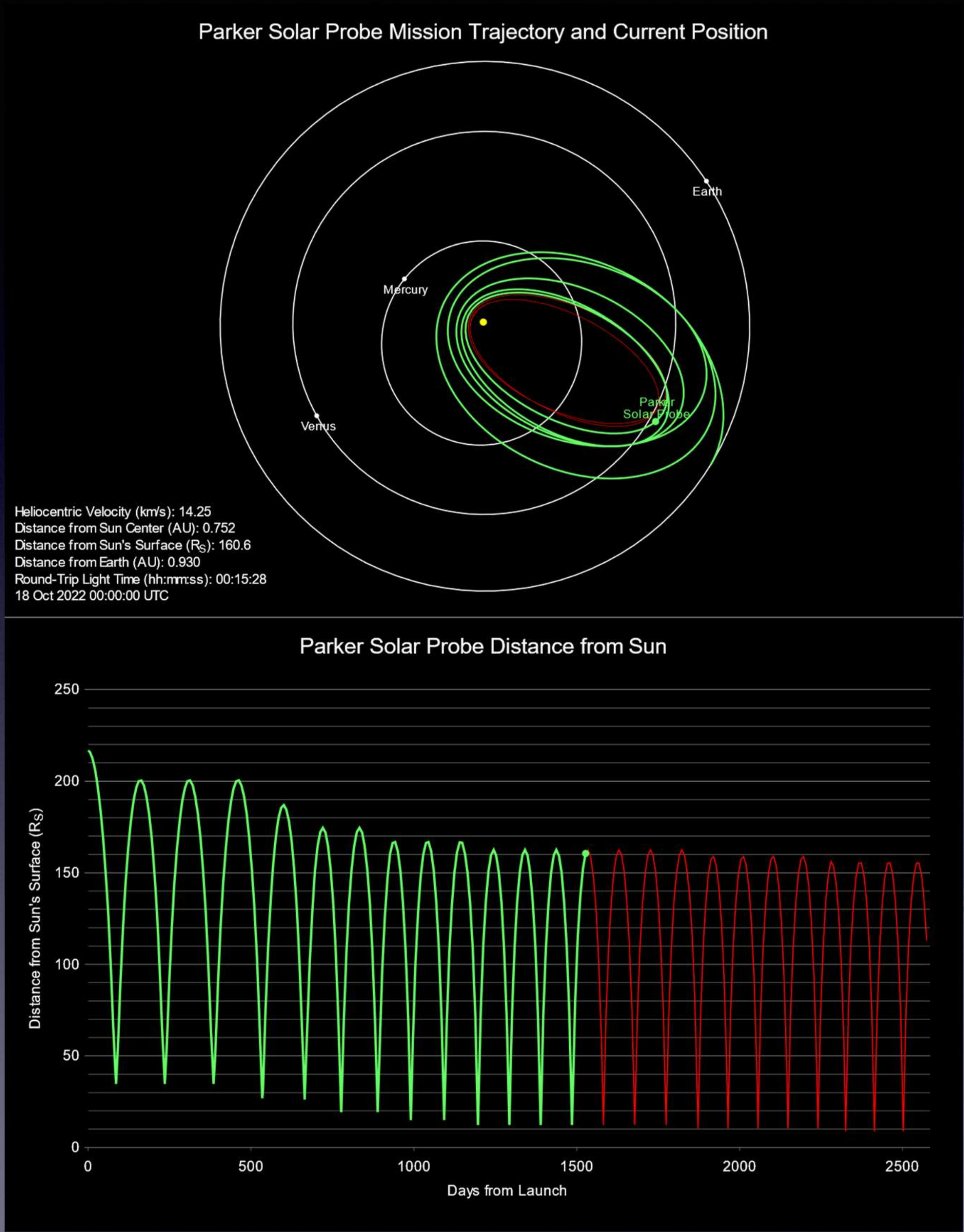
发射时间：2018年8月12日15:31，“帕克”太阳探测器发射成功



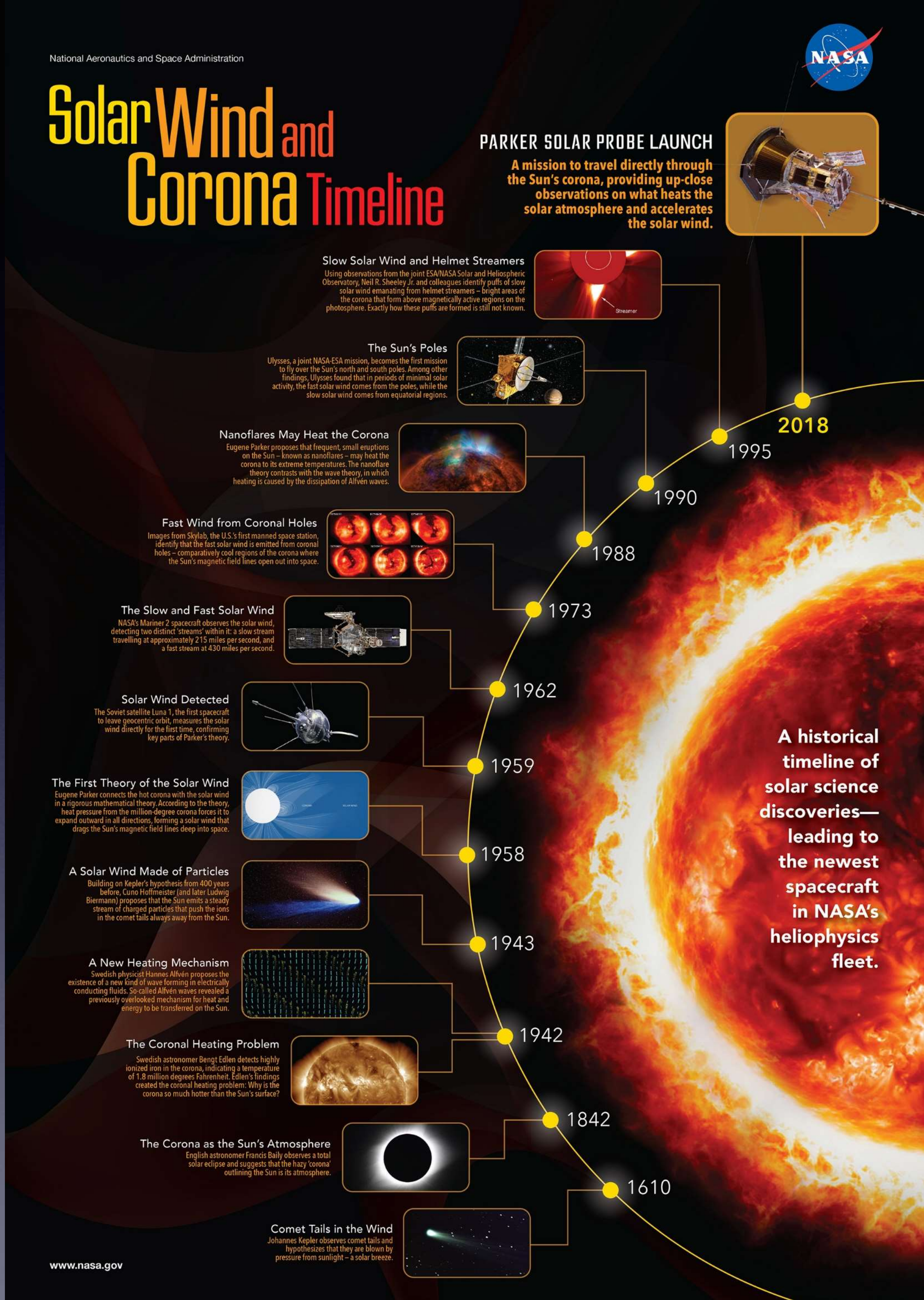

NASA




Mars
Mercury
Venus
2016 Dec 1
Earth

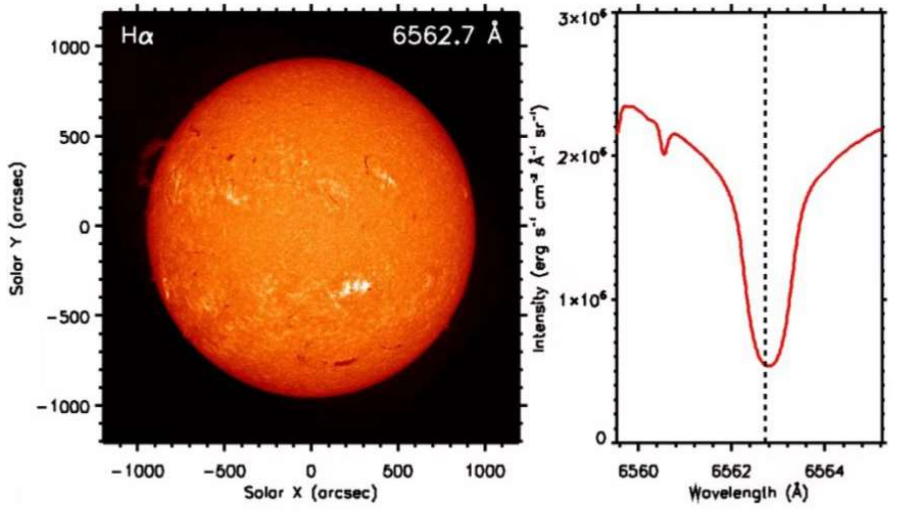


Parker Solar Probe Mission Trajectory and Current Position
Earth
Mercury
Venus
Parker Solar Probe
Heliocentric Velocity (km/s): 14.25
Distance from Sun Center (AU): 0.752
Distance from Sun's Surface (RS): 160.6
Distance from Earth (AU): 0.930
Round-Trip Light Time (hh:mm:ss): 00:15:28
18 Oct 2022 00:00:00 UTC
Parker Solar Probe Distance from Sun
Distance from Sun's Surface (RS)
250
200
150
100
50
0
0
500
1000
1500
2000
2500
Days from Launch



National Aeronautics and Space Administration
NASA
Solar Wind and Corona Timeline
PARKER SOLAR PROBE LAUNCH
A mission to travel directly through the Sun's corona, providing up-close observations on what heats the solar atmosphere and accelerates the solar wind.
2018
Slow Solar Wind and Helmet Streamers
Using observations from the joint ESA/NASA Solar and Heliospheric Observatory, Neil R. Sheeley Jr. and colleagues identify puffs of slow solar wind emanating from helmet streamers – bright areas of the corona that form above magnetically active regions on the photosphere. Exactly how these puffs are formed is still not known.
Streamer
1995
The Sun's Poles
Ulysses, a joint NASA-ESA mission, becomes the first mission to fly over the Sun's north and south poles. Among other findings, Ulysses found that in periods of minimal solar activity, the fast solar wind comes from the poles, while the slow solar wind comes from equatorial regions.
1990
Nanoflares May Heat the Corona
Eugene Parker proposes that frequent, small eruptions on the Sun – known as nanoflares – may heat the corona to its extreme temperatures. The nanoflare theory contrasts with the wave theory, in which heating is caused by the dissipation of Alfvén waves.
1988
Fast Wind from Coronal Holes
Images from Skylab, the U.S.'s first manned space station, identify that the fast solar wind is emitted from coronal holes – comparatively cool regions of the corona where the Sun's magnetic field lines open out into space.
1973
The Slow and Fast Solar Wind
NASA's Mariner 2 spacecraft observes the solar wind, detecting two distinct 'streams' within it: a slow stream travelling at approximately 215 miles per second, and a fast stream at 430 miles per second.
1962
Solar Wind Detected
The Soviet satellite Luna 1, the first spacecraft to leave geocentric orbit, measures the solar wind directly for the first time, confirming key parts of Parker's theory.
1959
The First Theory of the Solar Wind
Eugene Parker connects the hot corona with the solar wind in a rigorous mathematical theory. According to the theory, heat pressure from the million-degree corona forces it to expand outward in all directions, forming a solar wind that drags the Sun's magnetic field lines deep into space.
1958
A Solar Wind Made of Particles
Building on Kepler's hypothesis from 400 years before, Cuno Hoffmeister (and later Ludwig Biermann) proposes that the Sun emits a steady stream of charged particles that push the ions in the comet tails always away from the Sun.
1943
A New Heating Mechanism
Swedish physicist Hannes Alfvén proposes the existence of a new kind of wave forming in electrically conducting fluids. So-called Alfvén waves revealed a previously overlooked mechanism for heat and energy to be transferred on the Sun.
1942
The Coronal Heating Problem
Swedish astronomer Bengt Edlen detects highly ionized iron in the corona, indicating a temperature of 1.8 million degrees Fahrenheit. Edlen's findings created the coronal heating problem: Why is the corona so much hotter than the Sun's surface?
1842
The Corona as the Sun's Atmosphere
English astronomer Francis Baily observes a total solar eclipse and suggests that the hazy 'corona' outlining the Sun is its atmosphere.
1610
Comet Tails in the Wind
Johannes Kepler observes comet tails and hypothesizes that they are blown by pressure from sunlight – a solar breeze.
A historical timeline of solar science discoveries—leading to the newest spacecraft in NASA's heliophysics fleet.
www.nasa.gov

“羲和号”：太阳Hα光谱探测与双超平台科学技术试验卫星



“羲和号”全日面Hα波段光谱扫描成像（2022年8月3日）

2021年10月14日发射，成为国首颗太阳探测科学技术试验卫星

Insight into Science
科技短视频大赛
展现科学之美，促进科学传播
《中国科学》杂志社
SCIENCE CHINA PRESS

先进天基太阳天文台(ASO-S)

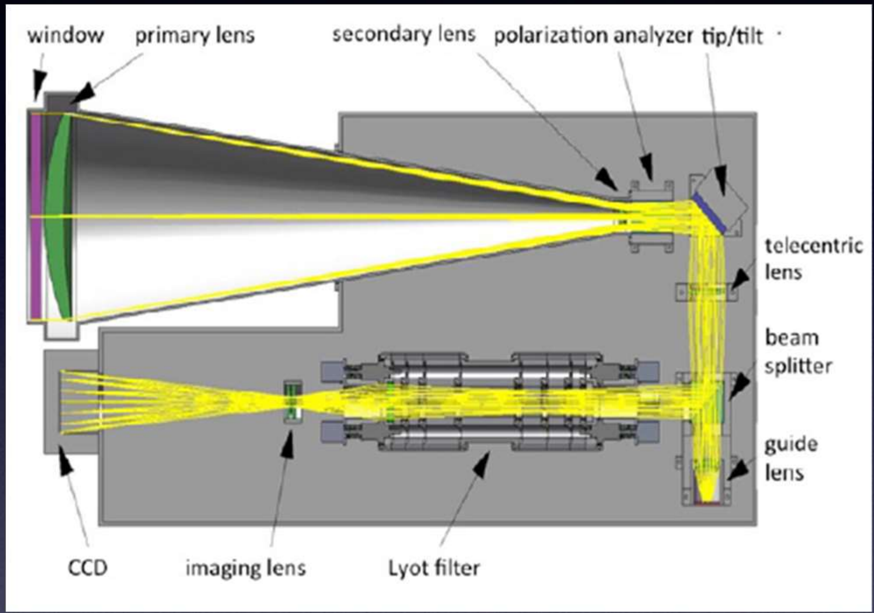
发射时间：2022年10月9日

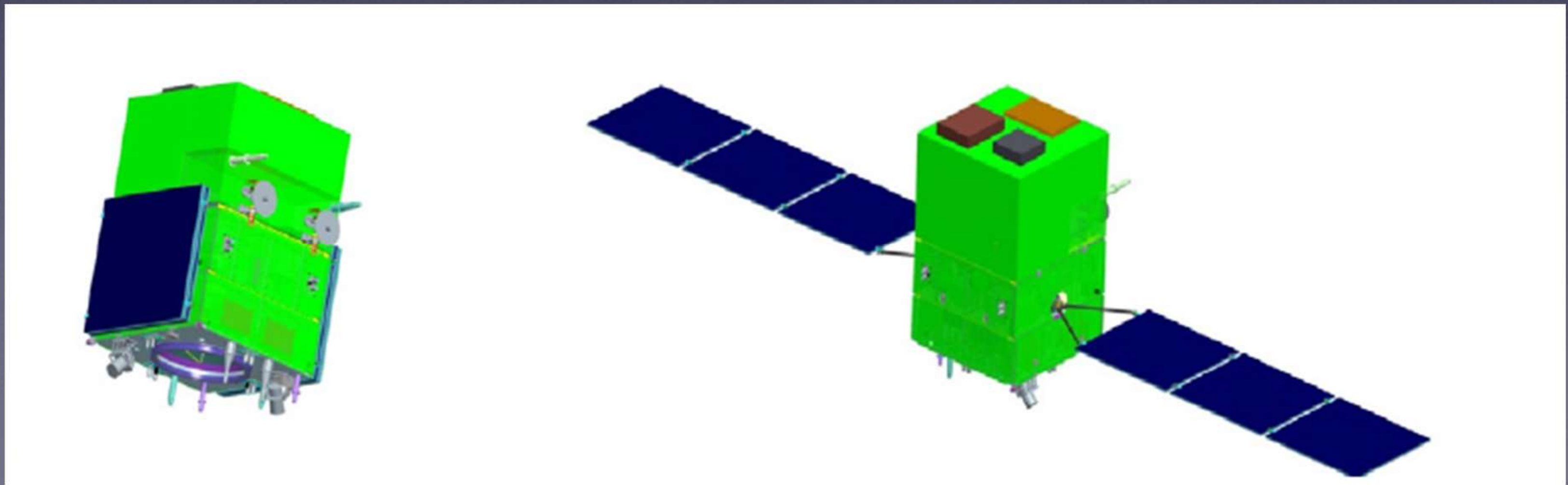
搭载仪器：

★全日面太阳矢量磁像仪(FMG)

★莱曼阿尔法太阳望远镜(LST)

★太阳硬X射线成像仪(HXI)





提供太阳观测数据图像查看

- http://www.solarmonitor.org
- http://jhelioviewer.org/mac.html
- http://space.ustc.edu.cn/dreams/shm/