国立天文台の成果と将来計画シンポジウム
2019.12.12. 13:40-14:20
国立天文台、三鷹

Comments to NAOJ from Japan Solar Physics Community

Takaaki Yokoyama
Japan Solar Physics Community (JSPC)
横山央明
太陽研究者連絡会（太陽研連）

スライド準備に、清水敏文・今田晋亮（Solar-C_EUVST）・
成影典之（PhoENiX）各博士にご提供・ご協力いただきました。
また一部図を、宇宙研提出用の「目標・戦略・工程表」から流用させていただいています。

Outlines

Overview of the strategy of the Japan Solar Physics Community (JSPC)

Comments on the NAOJ instruments

- Research performance
- Future prospections

1992/01/12

Why we study the Sun ?

Sun as itself

Flares, eruptions, steady heating, winds, dynamo ...

Sun as a plasma laboratory

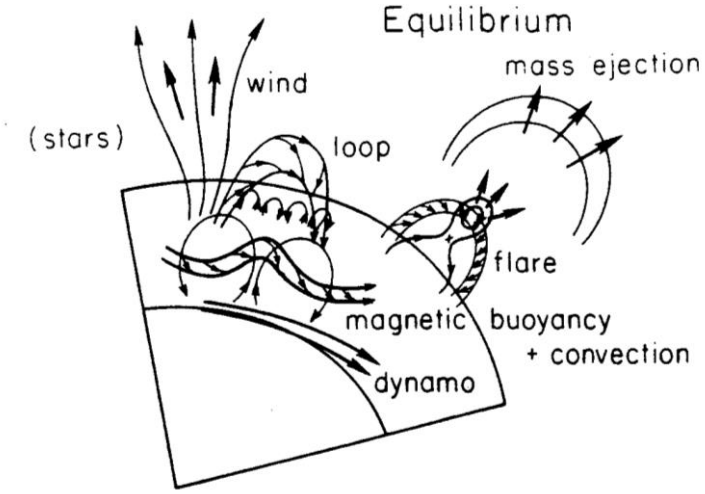
Magnetic reconnection, particle acceleration, MHD waves, turbulence ...

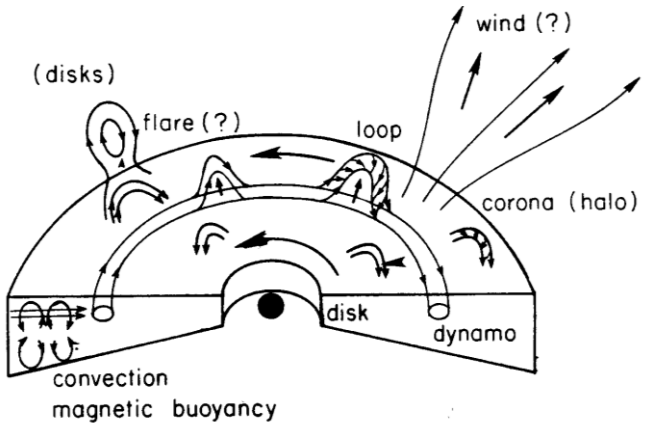
Sun as a star

A typical example of G-type main sequence star

Sun in a planetary system

Space weather, space environment, irradiance, cosmic rays



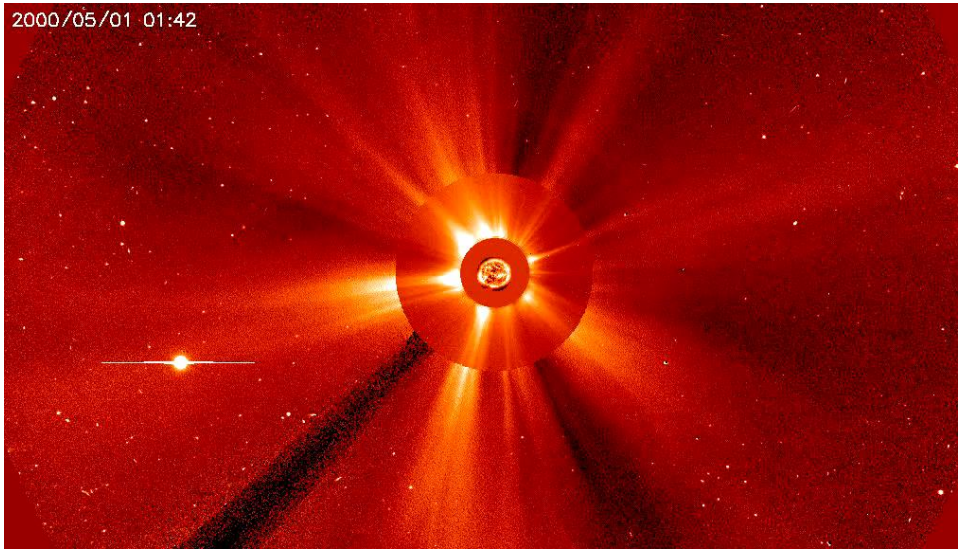


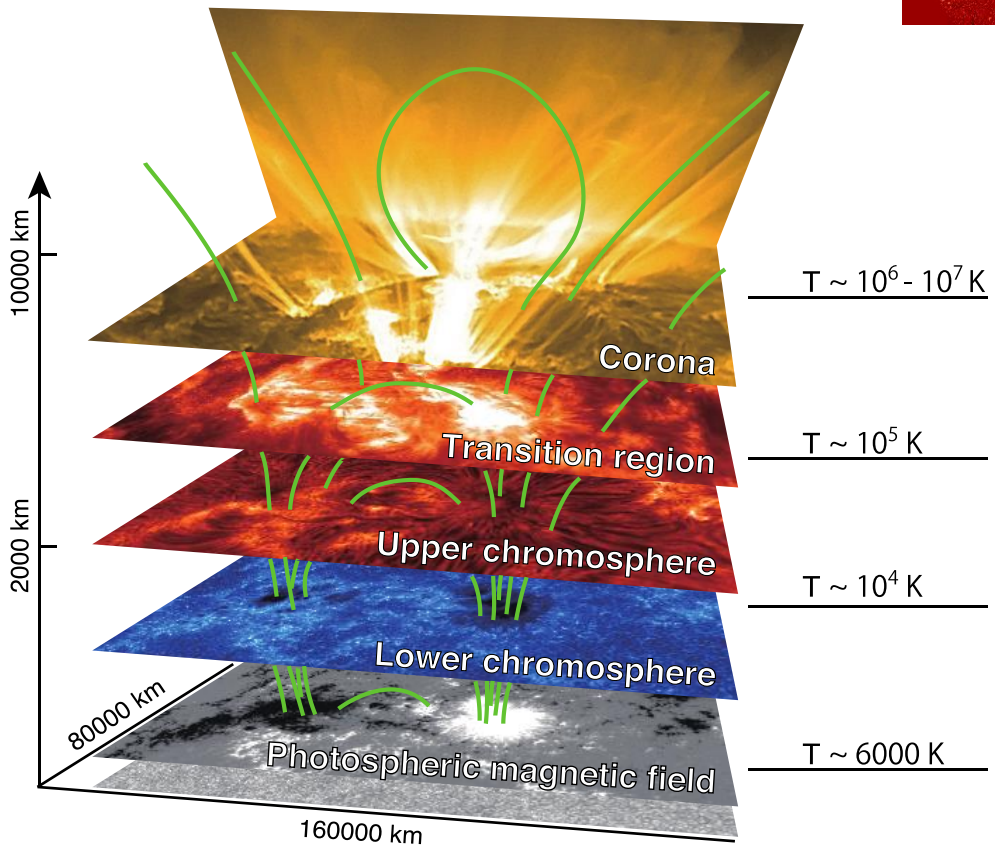
Tajima & Shibata (1997)

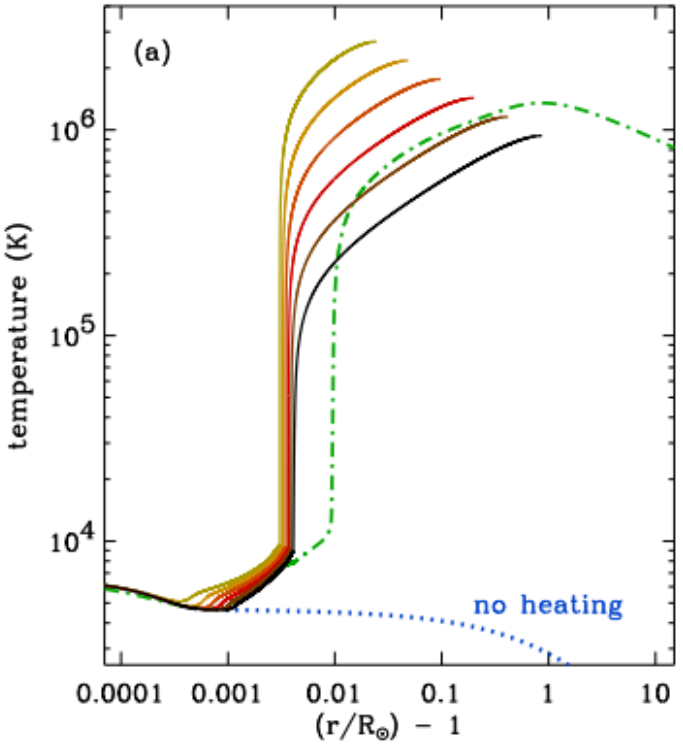
Coronal and chromospheric dynamics

Why hot ?

Why having winds ?





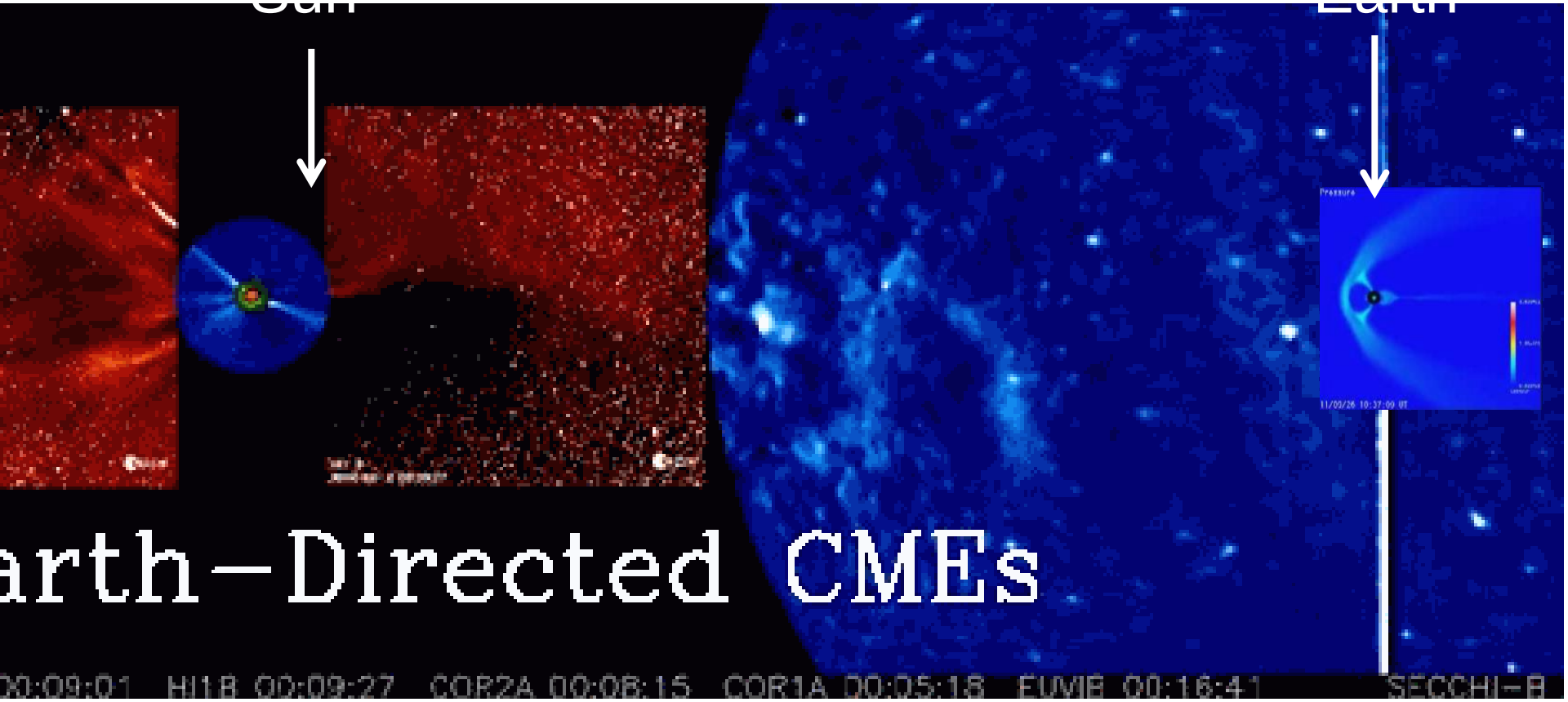


(Cranmer & Winebarger 2018)

Fundamental physics of space weather and climate

What are the conditions for eruptions like flares and CMEs ?

What are the mechanisms driving the magnetic cycles and their irregular variations like the Manunder minimum ?



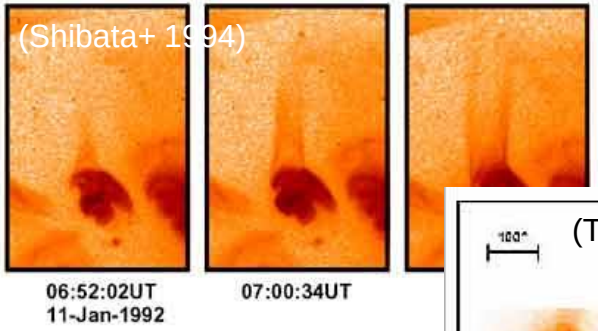
(credit; S. Imada, Solar-C_EUVST team)

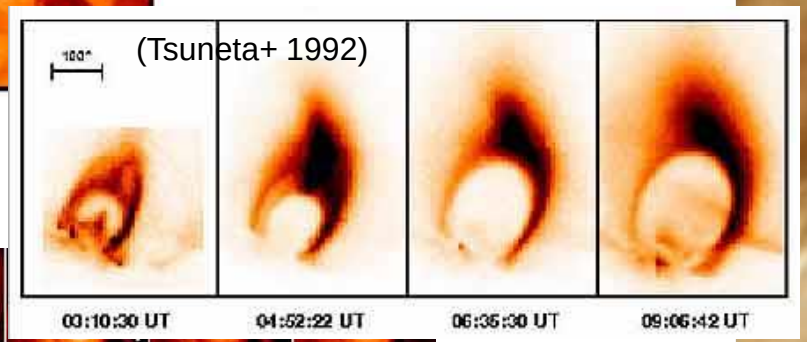
What is known and what is not known ? 1/3

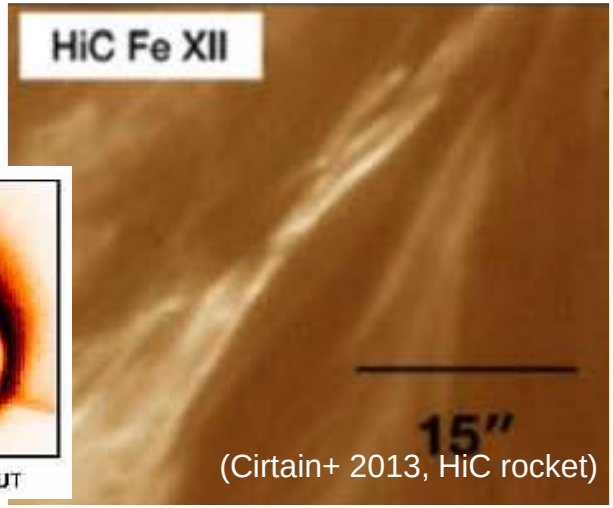
On the heating of the solar corona and chromosphere

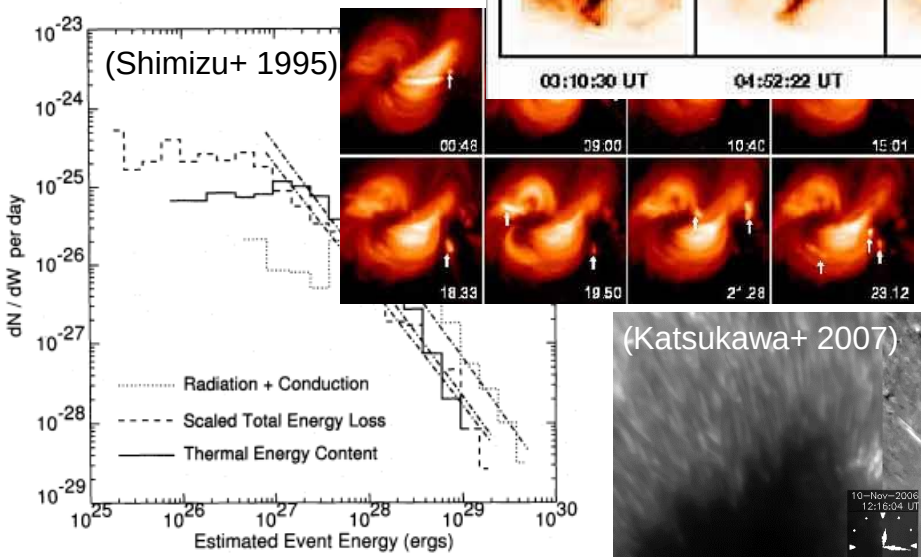
Ubiquitousness of magnetic reconnection in magnetically dominant environments with various scales

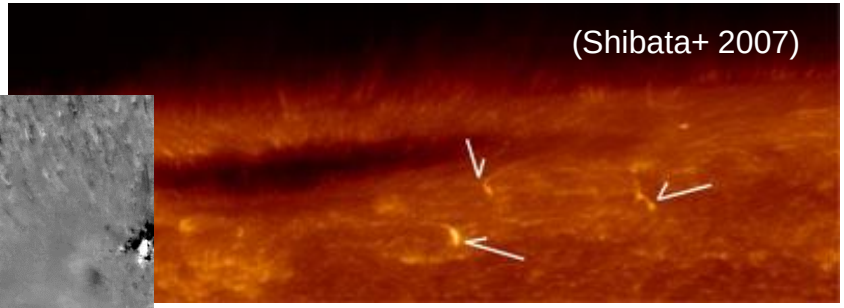
It is unknown to what extent contribution by reconnection to the heating is.









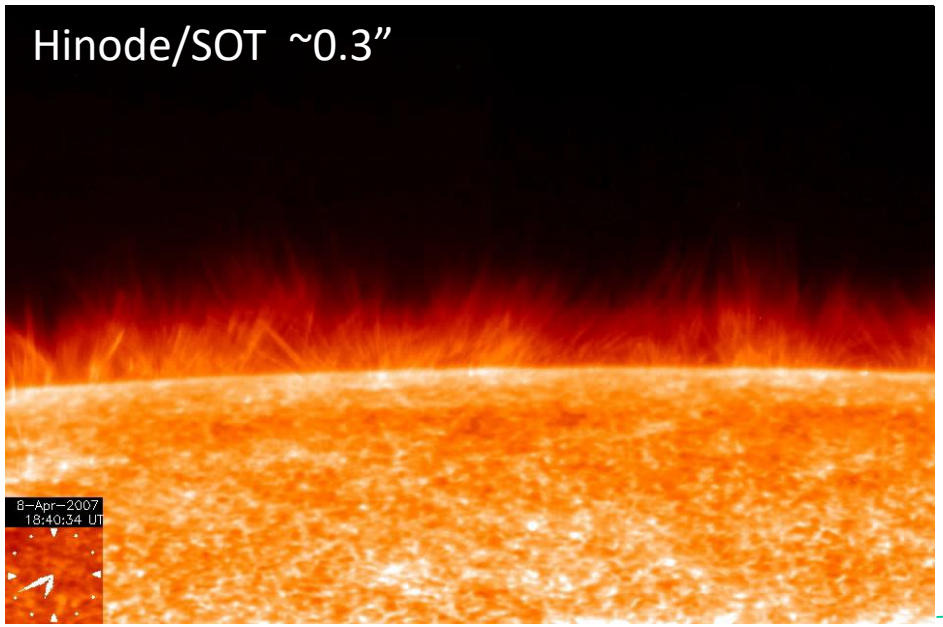


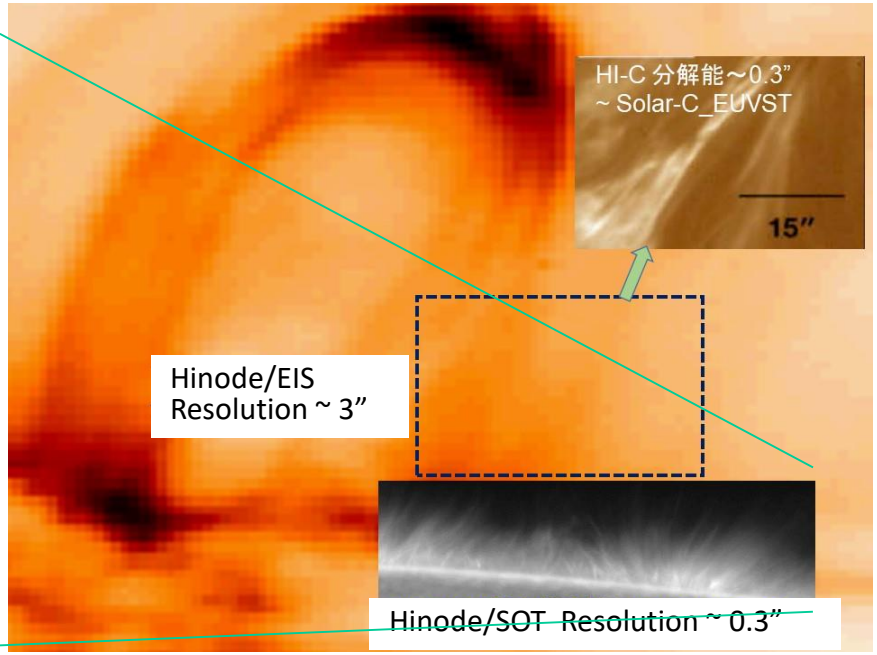
What is known and what is not known ? 2/3

MHD waves

Identification of Alfven and magnetoacoustic waves was successful

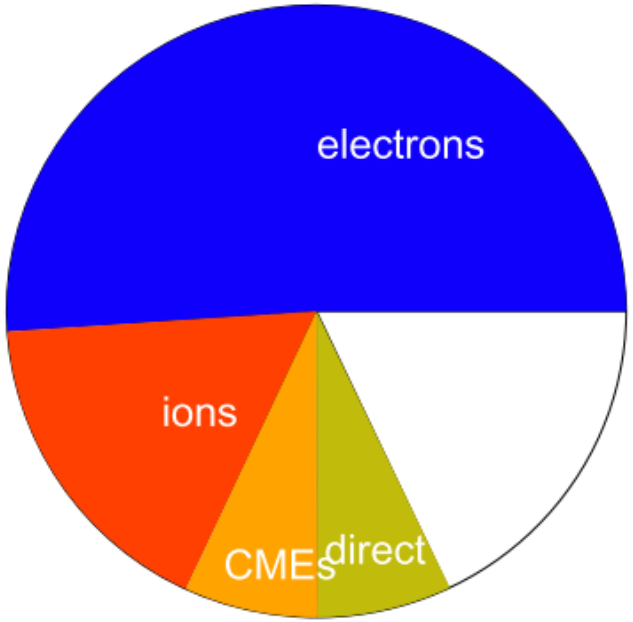
Quantitative study, e.g. of energy flux, spectral density, is necessary. The interconnection among corona, transition region, and chromosphere is required.





What is known and what is not known ? 3/3

Aschwanden+ (2017)

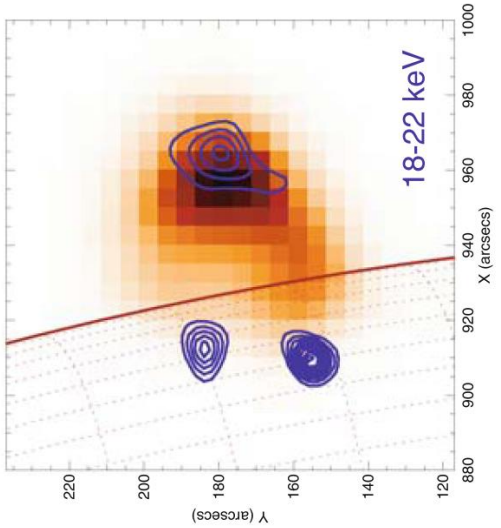


Elec/magnetic energy = 0.51+0.17
Ions/magnetic energy = 0.17+0.17
CME/magnetic energy = 0.07+0.14
direct/magnetic energy= 0.07+0.17

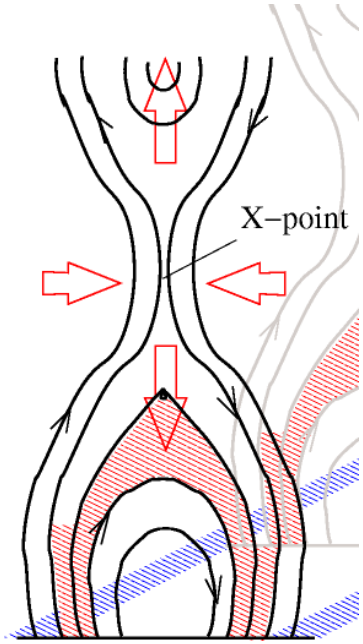
ENERGY CLOSURE :
Sum/magnetic energy = 0.87+0.18

Widely accepted that the central engine of flares is the magnetic reconnection.

70% of the released energy was converted to the non-thermal acceleration. The mechanisms are elusive yet.



RHESSI HXR (contours) and SXR (color)
(Battaglia & Benz 2006; Krucker+ 2008)



NGSPM-SOT

International team organized by JAXA/NASA/ESA

Next Generation Solar Physics Mission Science Objectives Team (2017/7)

Higher priority of notional instruments

0.3” coronal/TR spectrograph (T-9)

seamless plasma diagnostics through the atmosphere

0.2”-0.6” coronal imager (T-7)

0.1” – 0.3” chromospheric imager and magnetograph (T-4)
0.1” photospheric magnetograph (T-1)
0.1” chromospheric spectrograph (T-5)

Magnetic and velocity fields at chromosphere

Constellation of small/med-class missions around 2025.

Solar-C_EUVST
as JAXA competitive M-class mission

Expect a NASA MiDEX mission

Spectro-polarimetry:
CLASP (UV), Sunrise-3 balloon(1m)
→ Closely coordinated observations with ground-based 4m (DKIST)
→ 1m-class telescope for a launch in 2030’s

Decadal strategy of Japan Solar Phys. Com.

Science target

- ✓ Coronal and chromospheric dynamics
- ✓ Fundamental physics of space weather and climate

Strategy

- ✓ Current top priority: Solar-C_EUVST mission
- ✓ Scientific planning, technological development, and demonstration experiments for post-Solar-C projects

Cooperation with surrounding fields

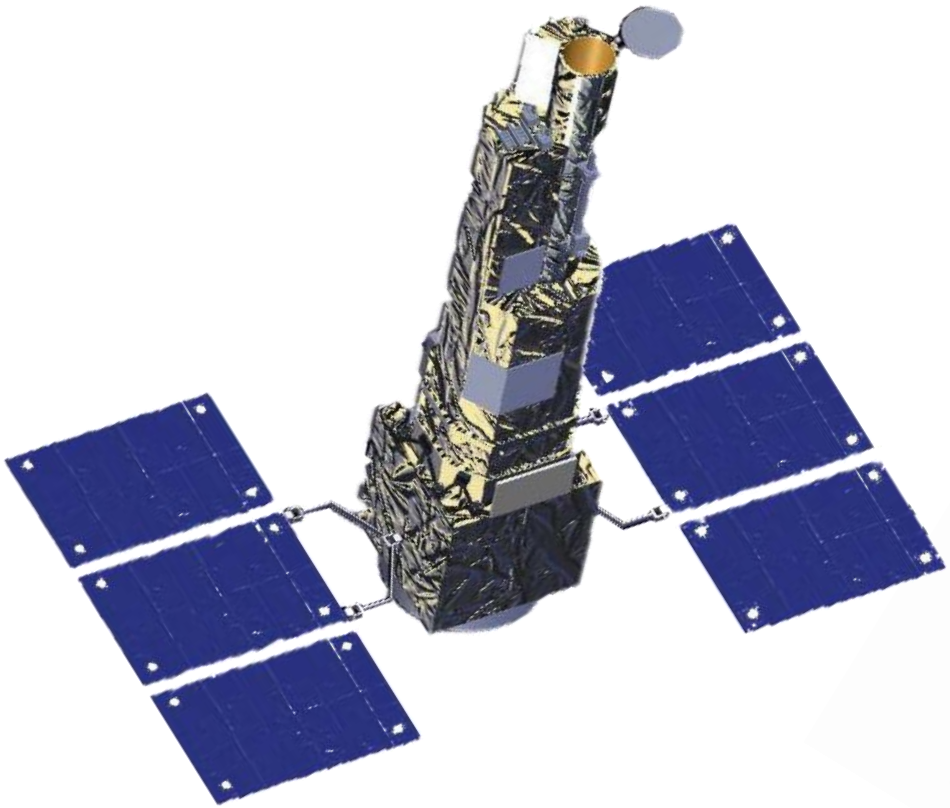
- ✓ Future extension of solar physics
  - ✓ Heliospheric / space plasma
  - ✓ Plasma physics
  - ✓ Stellar & astrospheric physics

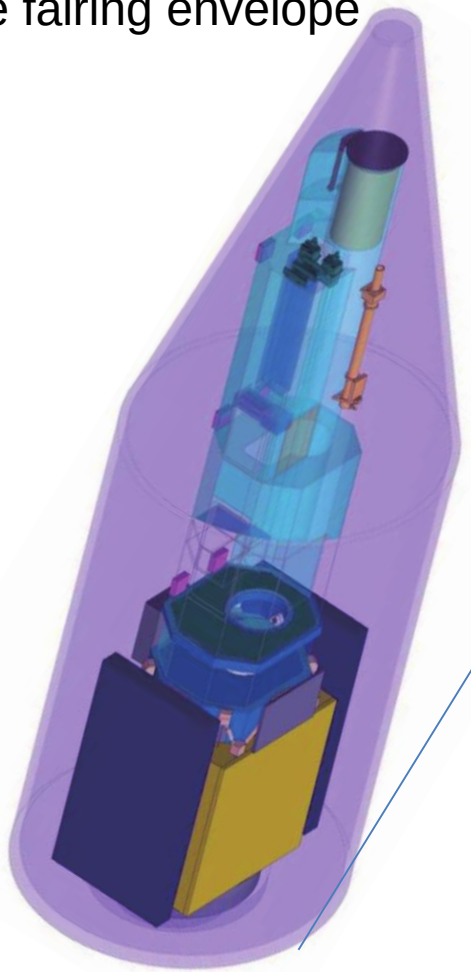
Solar-C_EUVST

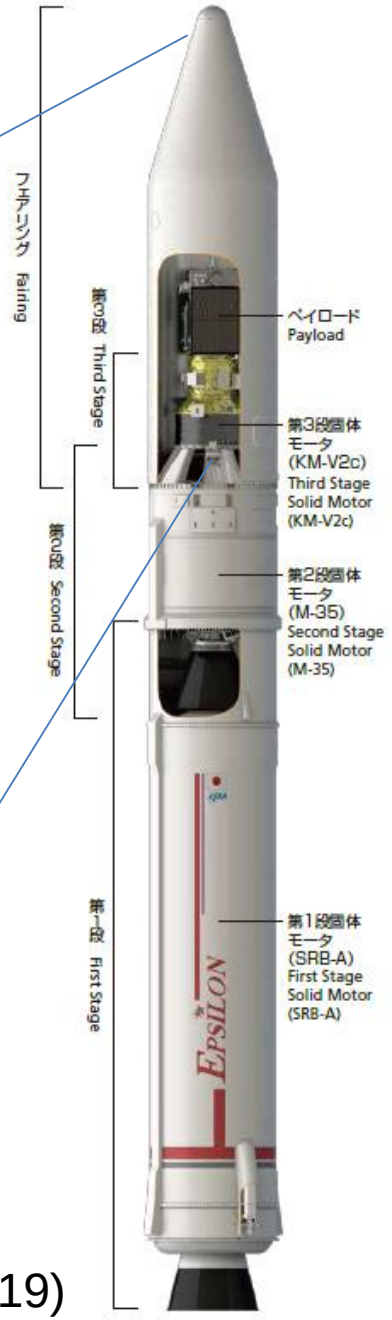
JAXA Epsilon vehicle

Spacecraft installed
in the fairing envelope

Weight 520-550 kg







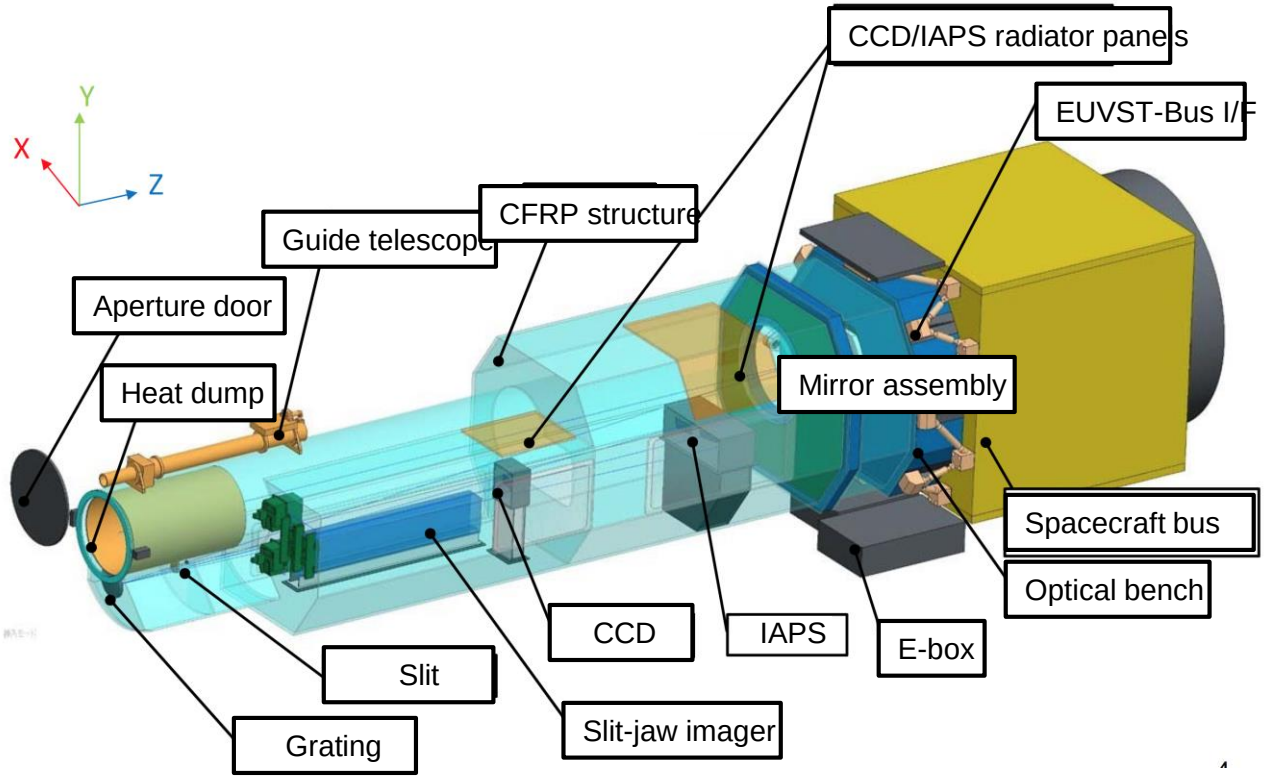
Sun synchronous polar orbit (>600 km)

High pointing stability, based on Hinode knowledge

（credit; Shimizu 2019)

EUVST

EUV High-throughput Spectroscopic Telescope



- The instrument: length 3.8 m, weight ~200 kg

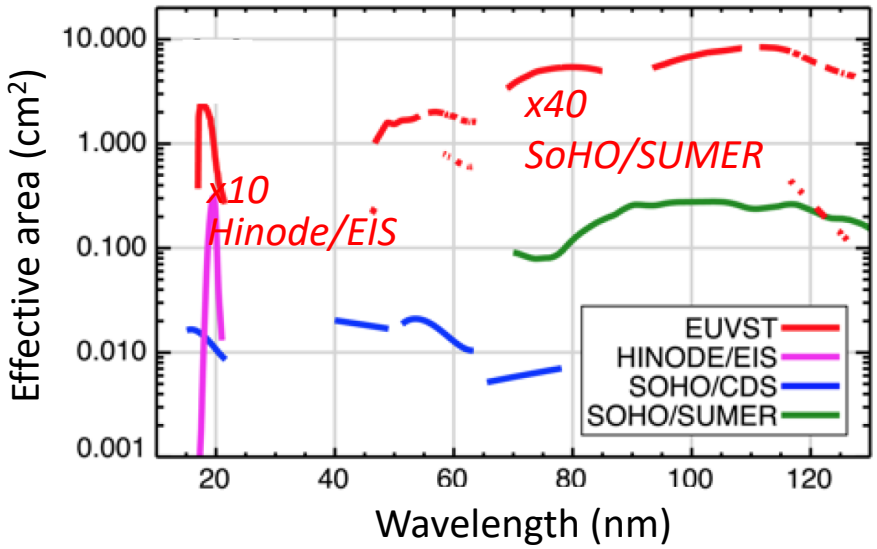
（credit; Shimizu 2019）

Performance

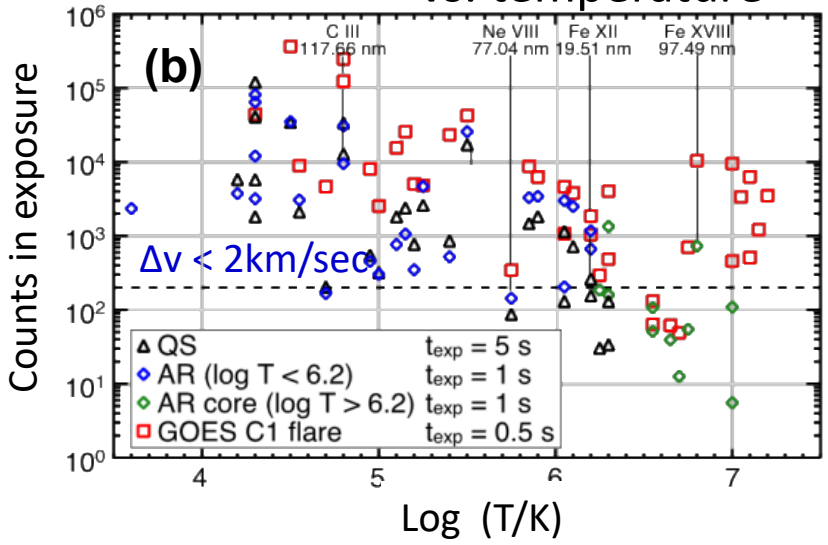
- Peak efficiencies is a factor of 10 improvement in Hinode/EIS and 40 over SoHO/SUMER

・High throughput → High temporal resolution

Effective area vs. wavelength



Count rate of spectral lines vs. temperature



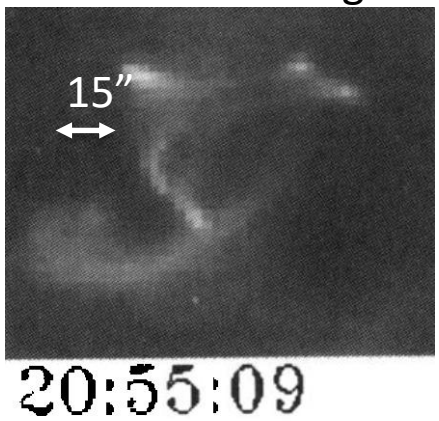
・A variety of spectral lines, seamless access to plasma temperatures from 0.01 MK to 20MK

(credit; Shimizu 2019)

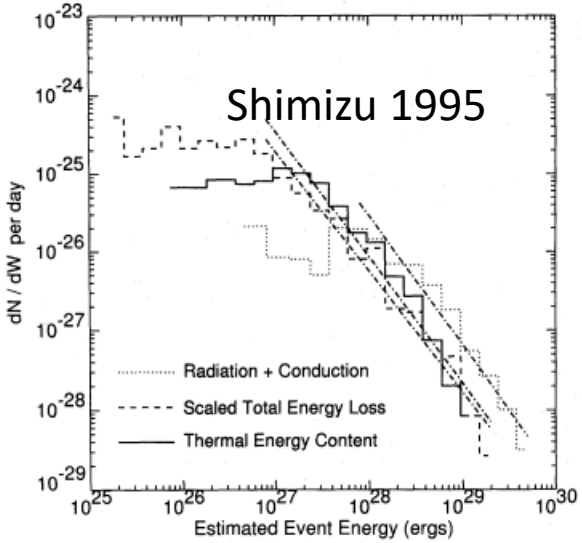
Scientific objectives

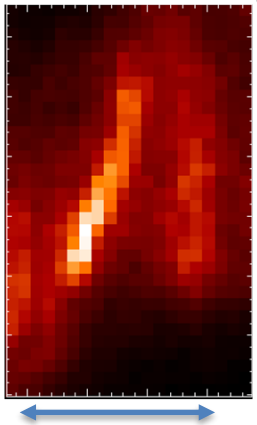
I-1: Quantify the Contribution of Nanoflares to Coronal Heating

I-1-1: Measure the energy of small-scale heating events in the transition region and the corona in the energy range of ~10^{24} - 10^{27} erg.

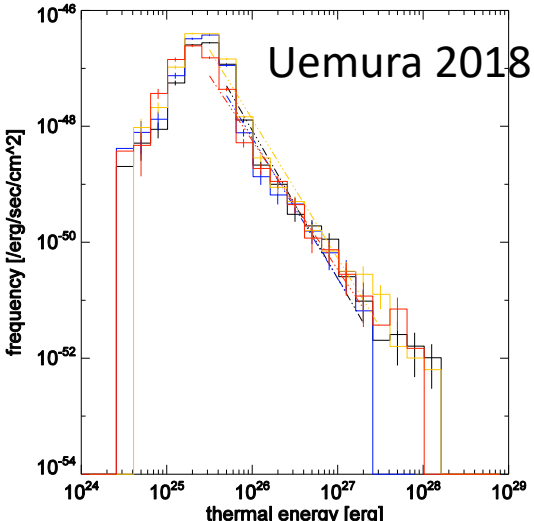


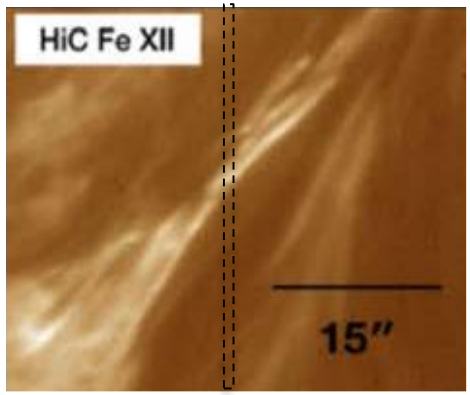
Yohkoh/SXT ~3” ~10^{27}erg





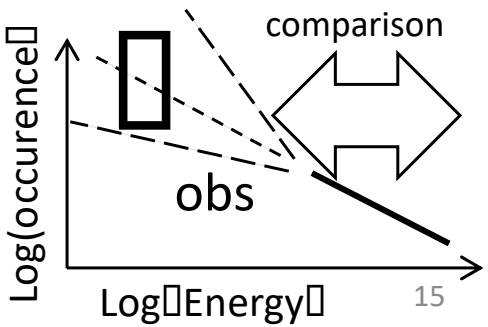
Hinode/XRT 1.5” ~10^{25}erg





Spatial Resolution 0.4”
Temporal Resolution 5s

~10^{24}erg Testa et al. 2013



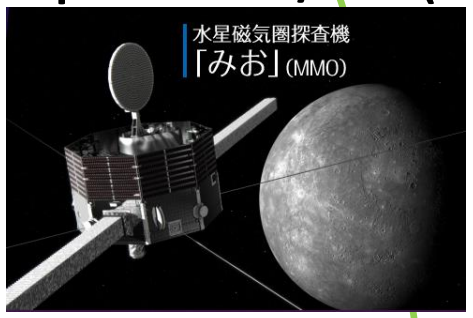
Near future projects of solar/heliospheric physics

Solar-C_EUVST
(2025~)

8.9Rs (closest @ 2025~)

"in situ" measurements

BepiColombo/Mio (MMO)



65Rs – 100 Rs @Mercury
(2025~)

"in situ" measurements

DKIST (2020~) 4m solar telescope
<0.1arcsec photo/chromosphere

60Rs (closest), 25 deg. solar latitude
(2026~)

Coronal image/spectra,
photospheric magnetogram

(low resolution/telemetry)

Decadal strategy of Japan Solar Phys. Com.

Science target

- ✓ Coronal and chromospheric dynamics
- ✓ Fundamental physics of space weather and climate

Strategy

- ✓ Current top priority: Solar-C_EUVST mission
- ✓ Scientific planning, technological development, and demonstration experiments for post-Solar-C projects

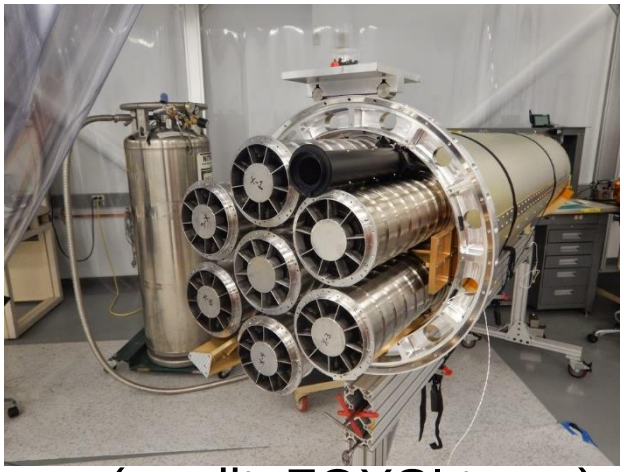
Cooperation with surrounding fields

- ✓ Future extension of solar physics
  - ✓ Heliospheric / space plasma
  - ✓ Plasma physics
  - ✓ Stellar & astrospheric physics

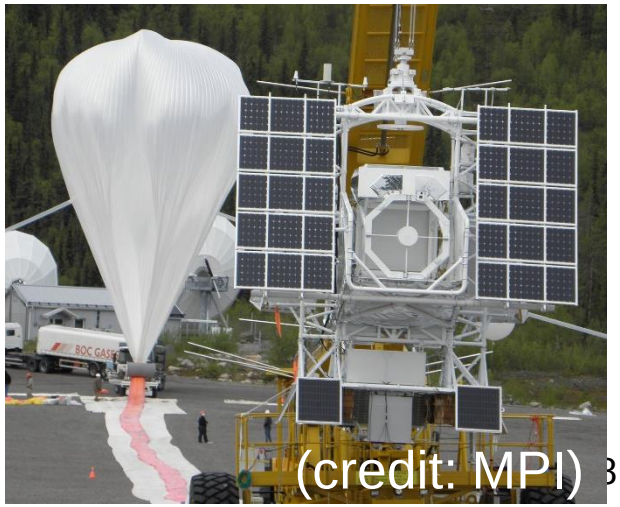
next after Solar-C_EUVST

- ✓ CLASP（2015）、CLASP2（2019） rocket experiments
  - Successful detection of scatter polarization and the signature of the Hanle effect from the chromosphere
- ✓ FOXSI-3 rocket experiment (2018 lead by NASA)
  - Successful observation of SXR 2D imaging. A step to PhoENiX.
- ✓ 1mΦ telescope Sunrise-3 balloon experiment (2021 Japan, Germany, Spain, US) Spectropolarimetry of the chromosphere
- ✓ Space-based 1mΦ UV/Vis/IR telescope
- ✓ Out-of-ecliptic mission, solar poles

(credit: CLASP team)



(credit: FOXSI team)



(credit: MPI)

PhoENiX (Physics of Energetic and Non-thermal Plasmas in the X-region)

Science Goal

Understanding particle acceleration in magnetic reconnection

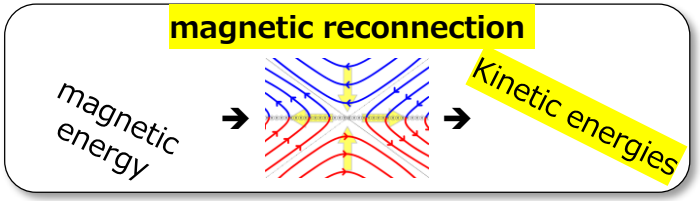
https://www.phoenix-project.science/

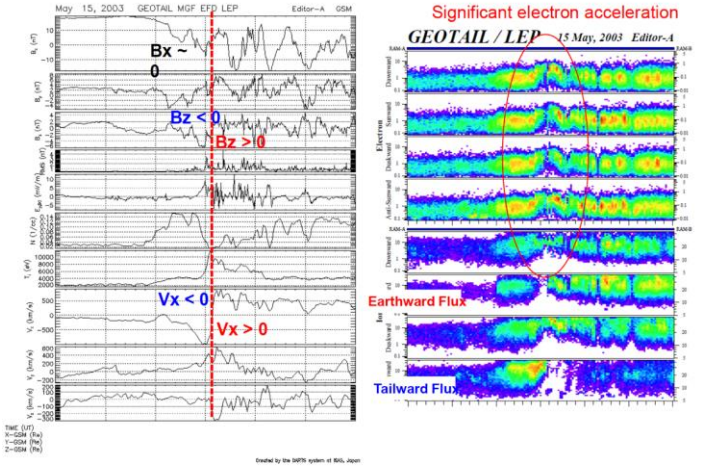
Science Objectives: Specification in flares of

[where] location of particle acceleration,

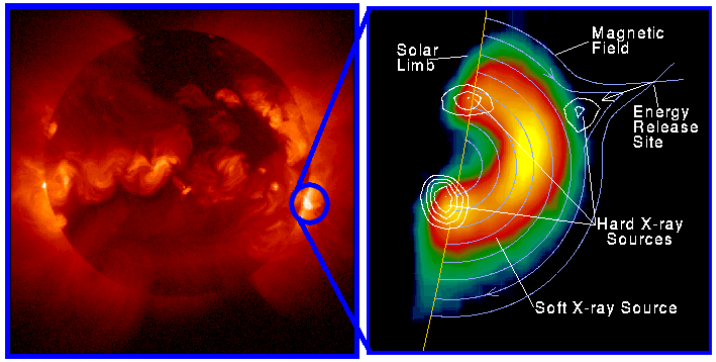
[when] temporal evolution of non-thermal emission, and

[how] characteristics of particles.

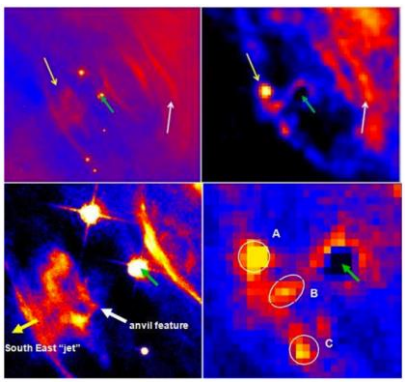




Magnetspheric X-lines



Solar flares



γ-ray flare in crab nebula

Roadmap to 2030's

観測はより上空大気へ、磁場診断(偏光分光)かつ温度シームレスに(分光)

光球での磁場診断

ひので 2006 –(2021)

FOXSI3観測ロケット実験 (2018)
軟X線コロナ分光技術開拓

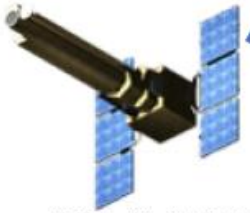
SUNRISE-3気球実験 (2021)
光球～彩層の3D診断

海外大型望遠鏡(DKIST等)への科学的参加 (2020~)
超高解像度光球・彩層磁場

上空大気の磁場診断
UV域彩層上部・遷移層での手法開拓
CLASP1観測ロケット実験 (2015)
CLASP2観測ロケット実験 (2019)

現在

観測協働



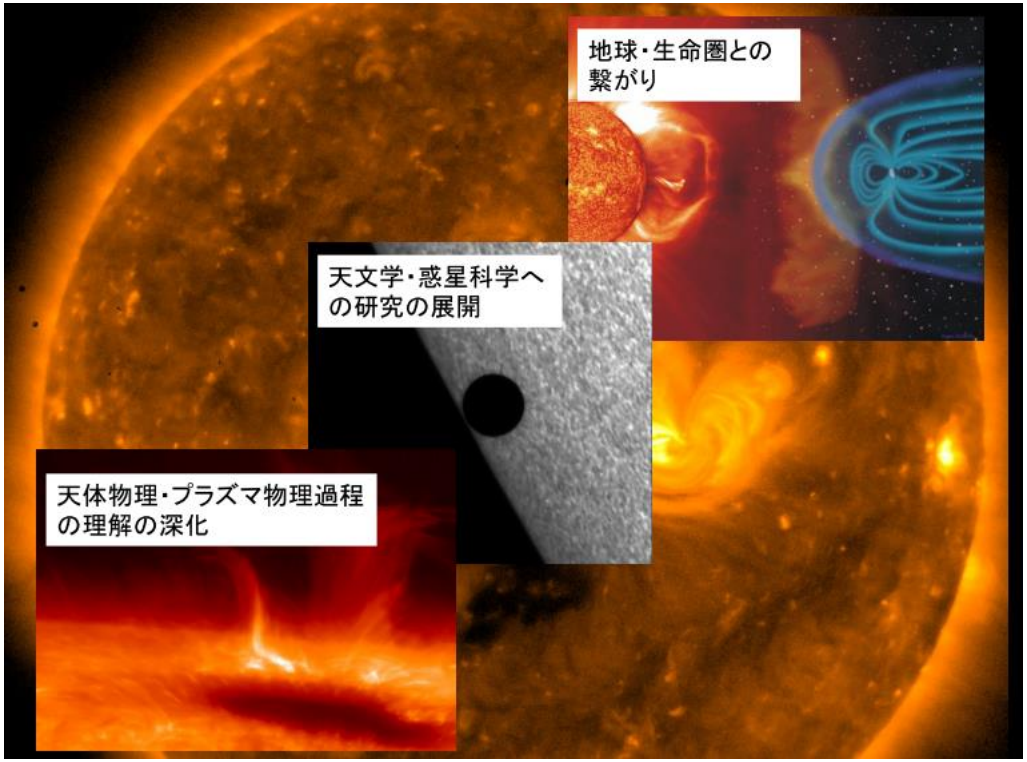
上空大気の紫外線分光診断
公募型小型衛星
Solar-C_EUVST (2025)
彩層～コロナ・フレアの温度間隙のない高解像度の紫外線分光観測の実現

Solar-C_EUVST以降: 多様な方向可能性
(優先付けは検討課題)

- 宇宙からの1m望遠鏡 (2030以降)
  上空大気磁場精密計測
- 黄道面脱出による太陽極域観測 (2030以降)
  太陽磁場周期活動の理解
- 公募型小型PhoENiX (2027~)
  MRにおける粒子加速の理解・分野連携

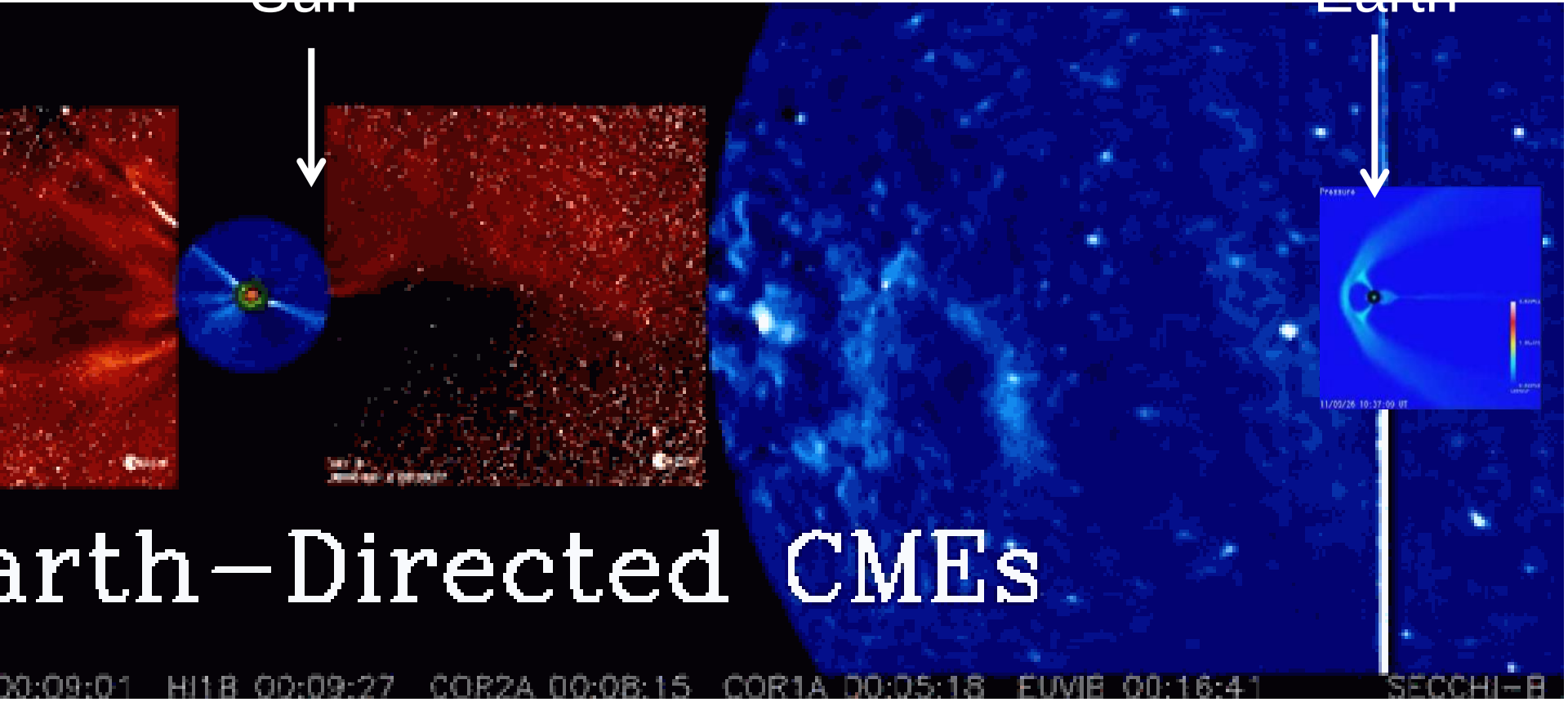
Expected outcomes

- Understanding the fundamental plasma physics
  - magnetic reconnection
  - MHD turbulence
  - partially-ionized plasmas
- Contribution to the astronomy and planetary science
  - heliosphere
  - astrosphere
- Effect on life and society
  - space weather impacts
  - habitability



Disturbance to the planetary environment

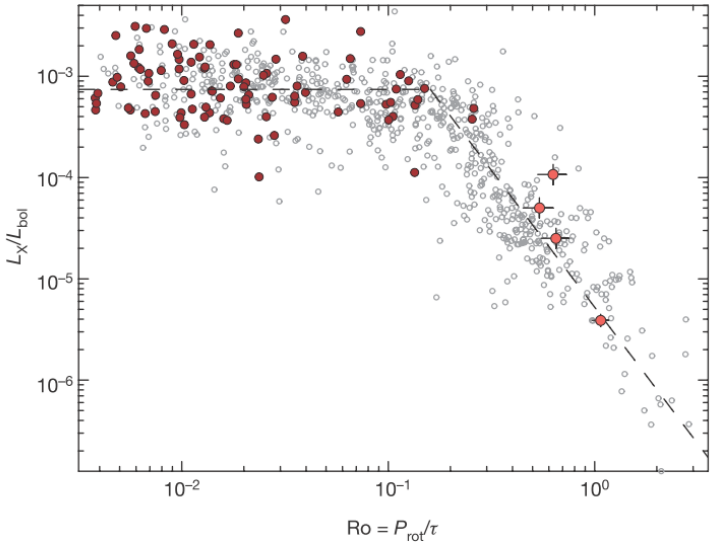
Plasma eruptions, high-energy particles, and EUV/X-ray irradiance give strong impact on the plasma environment around planets.



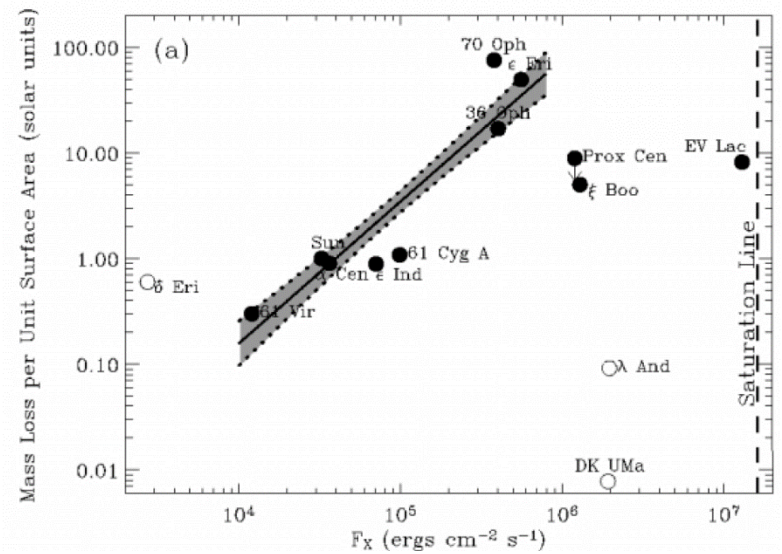
(credit; S Imada, Solar-C_EUVST team)

Comprehensive understanding of the Sun and stars with their surrounding environment

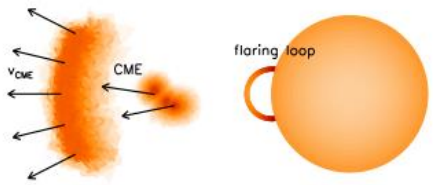
age(rotation) vs Xray luminocity (Wright & Drake 2016)

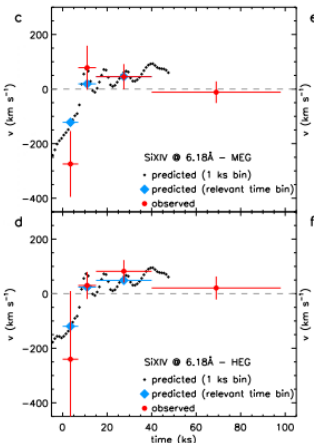


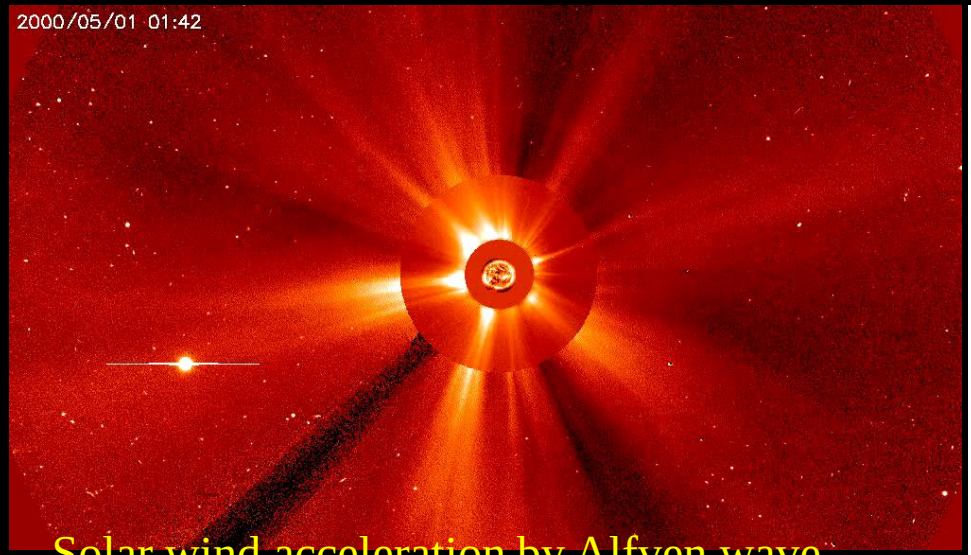
age(rotation) vs mass loss rate (Wood et al. 2005)



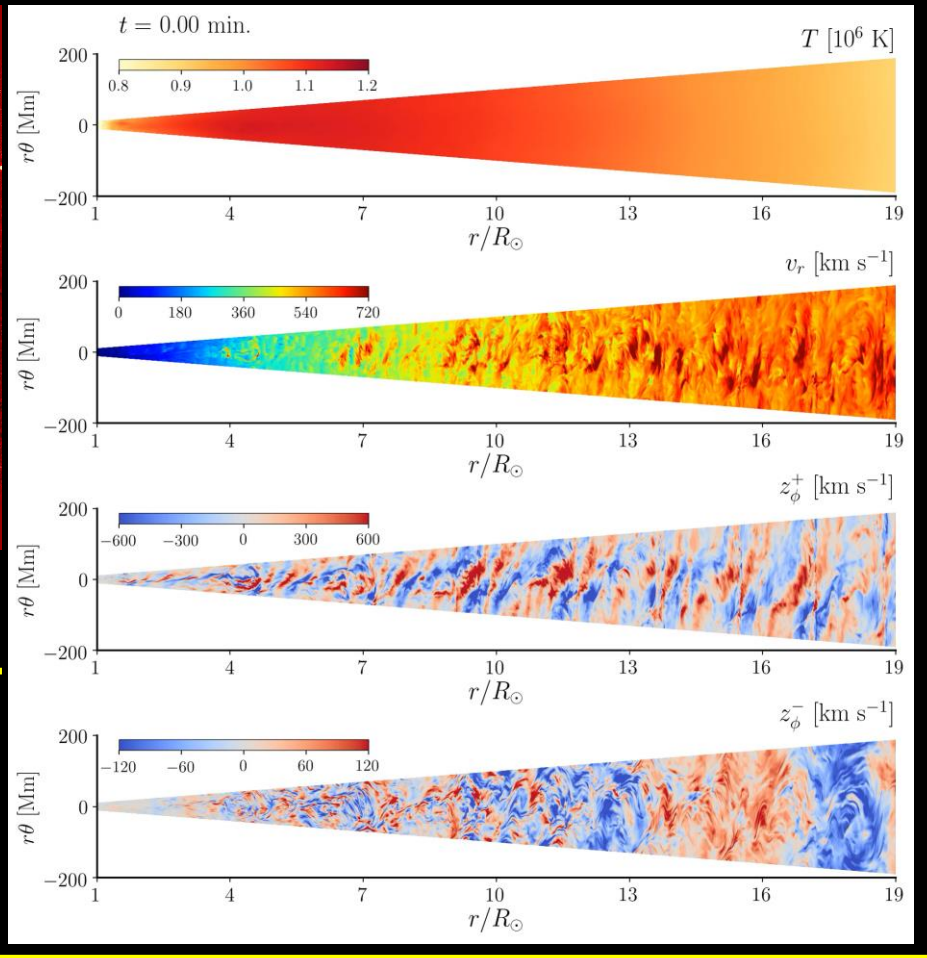
CME of a G1III giant (Argiroffi et al. 2019)

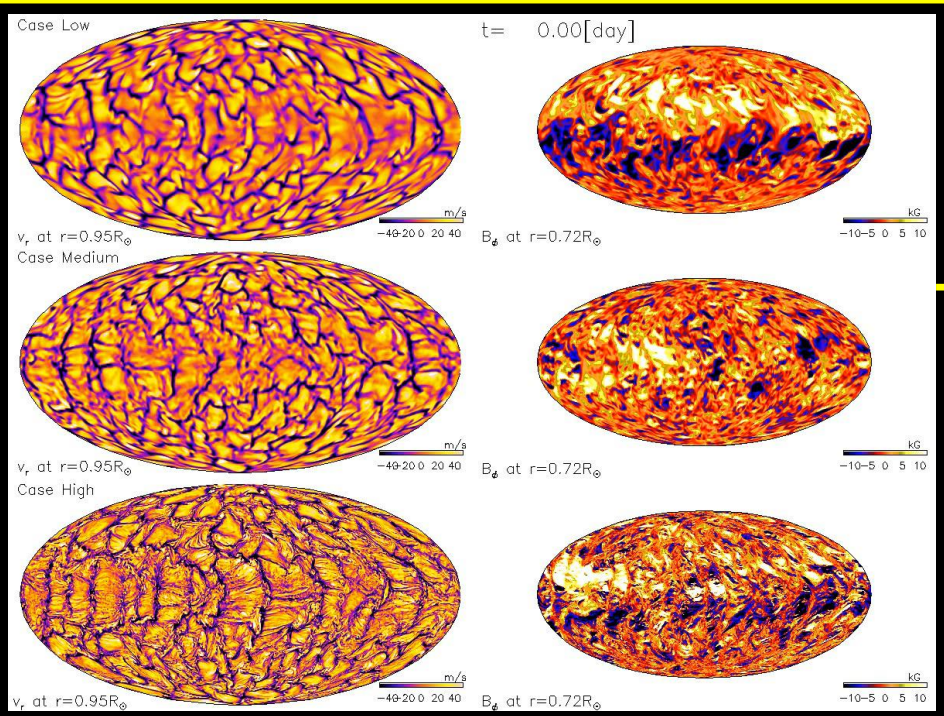


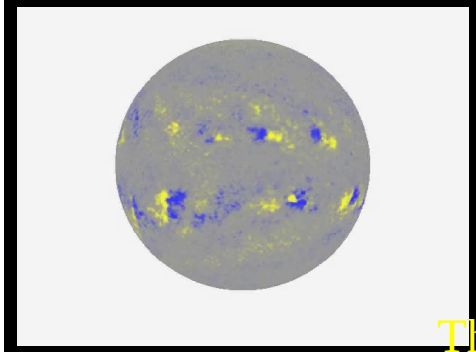




Solar wind acceleration by Alfven wave turbulence (M. Shoda)







Thermal convection in the solar interior (H. Hotta)

Decadal strategy of Japan Solar Phys. Com.

Science target

- ✓ Coronal and chromospheric dynamics
- ✓ Fundamental physics of space weather and climate

Strategy

- ✓ Current top priority: Solar-C_EUVST mission
- ✓ Scientific planning, technological development, and demonstration experiments for post-Solar-C projects

Cooperation with surrounding fields

- ✓ Future extension of solar physics
  - ✓ Heliospheric / space plasma
  - ✓ Plasma physics
  - ✓ Stellar & astrospheric physics

Comments on the NAOJ instruments 1/6

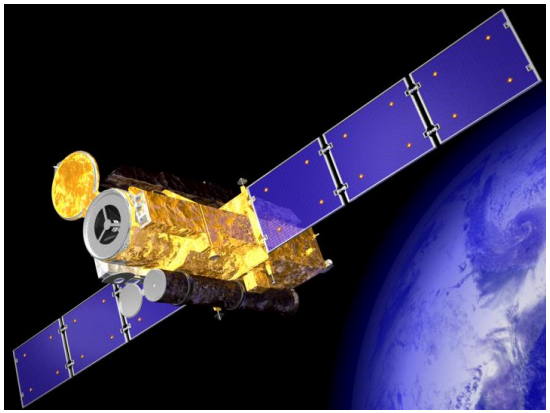
Hinode

It is still be a unique and Japan solar physics community's flag-ship instrument. The photospheric spectro-polarimetric data is unreplaceable by any other instruments even now.

It is producing substantial results by collaborations with the newly appeared projects like SDO and IRIS (NASA).

e.g. flare trigger mechanism by Kusano +

We are expecting further collaborations with the new instruments such as Parker Solar Probe (NASA, on orbit approaching the Sun), Solar Orbiter (ESA, 2020 launch), and DKIST(NSO, 2020 first light).



(© NAOJ/JAXA, Hinode team)

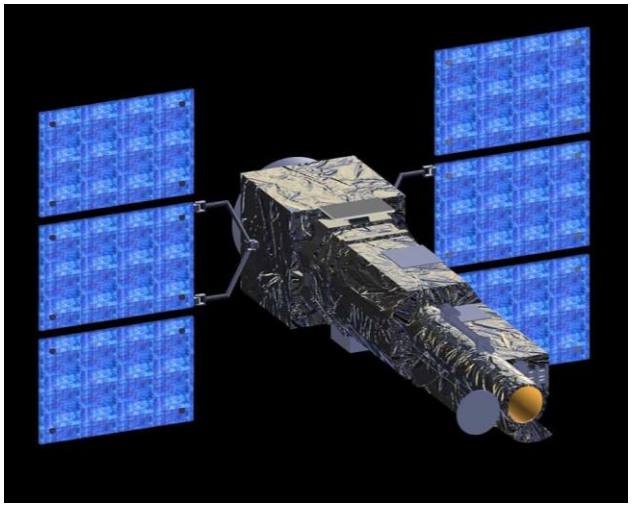
Comments on the NAOJ instruments 2/6

Solar-C_EUVST

It is regarded as THE next flag-ship project of Japan solar physics community to be realized in this coming decade.

NAOJ is currently playing a important key role for the design of the telescope and the spacecraft system under a collaboration with JAXA/ISAS, Nagoya U. ISEE, Kyoto U., other domestic universities and international partners including NASA and European countries' agencies.

The next down-selection process at JAXA will be conducted in January, 2020. It is highly important to make the Solar-C project stronger from human-resource and budget points of view.



(© NAOJ/JAXA, Solar-C WG)

Comments on the NAOJ instruments 3/6

CLASP

The successful launch of the 2nd flight was highly appreciated. The first preliminary results of the polarization data of the MgII lines were impressive giving us an expectation of near-future scientific outputs.

It is also highly appreciated that the project was conducted mainly by the young-generation scientists.

Note that the study of the solar chromospheric dynamics and inter-relationship with the upper atmosphere are the main subjects of the world-wide solar community,

(© NAOJ, CLASP team)

Comments on the NAOJ instruments 4/6

FOXSI and PhoENiX

The successful launch of the 3rd flight was highly appreciated. The first preliminary results shown in the Hinode-13 meeting of the soft X-ray imaging spectroscopy was impressive.

It is also highly appreciated a project conducted mainly by the limited number of young-generation scientists' effort.

The science activities for the future PhoENiX project is supported by the community. High-energy physics, i.e. the non-thermal acceleration of particles in flares is one of the remained frontiers for the solar physics.

Inter-discipline activities based on the key science, i.e. magnetic reconnection by the project are appreciated.

(© NASA, FOXSI-3 team)

Comments on the NAOJ instruments 5/6

ALMA solar

The effort by the NAOJ member for the solar observations by ALMA is highly appreciated. Without his contribution, the realization of the solar observation may not be achieved.

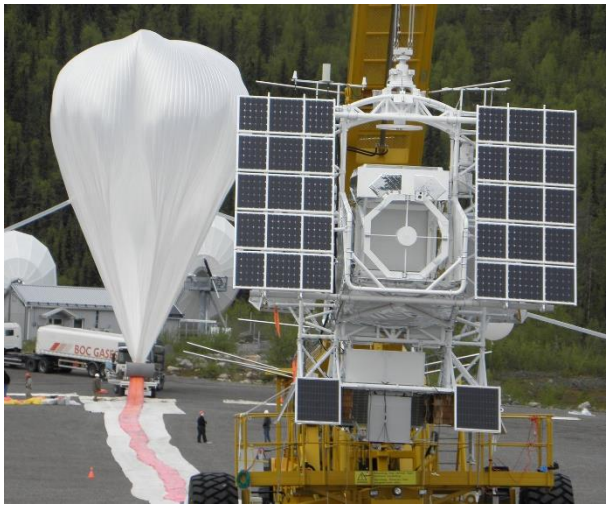
Although there still appeared a few solar papers by using ALMA, the performance of the instruments for the solar observations is improving so that the number of papers should be increased in the near future.

(© NAOJ)

Comments on the NAOJ instruments 6/6

Sunrise-3

Substantial contribution to the project is conducted by providing one of the instruments, i.e. SCIP. The target science, i.e. chromospheric polarization is consistent with the strategy of the JSPC.



(© MPS, Sunrise team)

DKIST

It is regarded as one of the most important projects for the world-wide solar community. Now the collaboration with Hinode is under an effort to organize. More substantial contribution by NAOJ, e.g. providing an instrument etc. is expected under a collaboration with the international/domestic communities.

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