Science Strategy of NAOJ
: Sun and Stars

Dec 3, 2025

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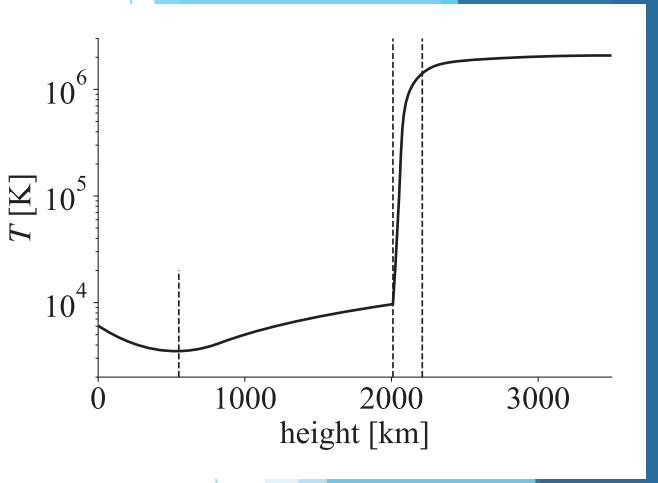
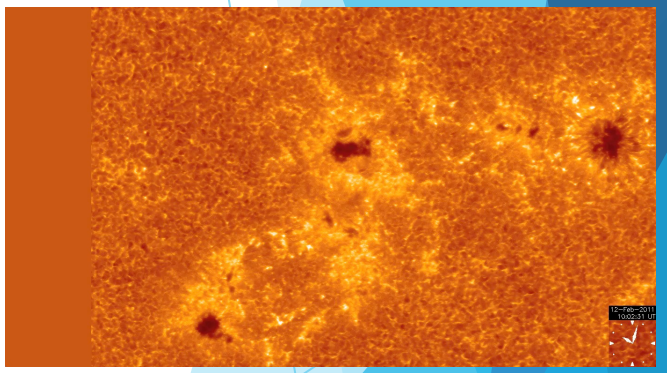
On behalf of Science Roadmap Committee of NAOJ

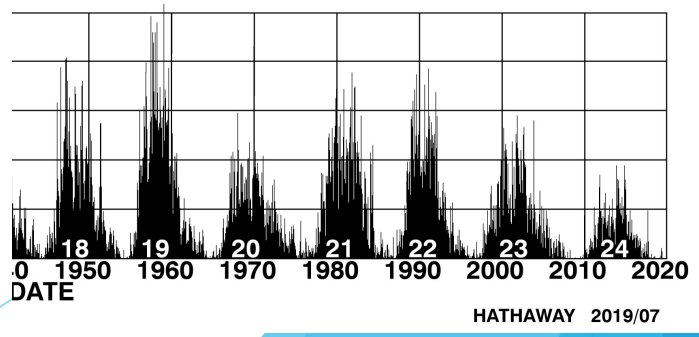
Current Trend in Sun and Stars
世界的な太陽と星研究の動向



- Ultimate Goal of Sun and Stars Study (当該分野の究極的な目的)
  - ✓ Solar physics aims to understand **the Sun as an astronomical object and to elucidate the mechanisms of diverse astrophysical and plasma** phenomena occurring on the Sun. Solar physics further provides the foundation for **space weather forecasting** and **understanding stellar atmospheres**.
- Goals in Sun and Stars (当該分野の目標)
  - ✓ **Atmospheric heating and Solar/Stellar wind acceleration**
    1 MK corona against the 6000 K solar surface. Supersonic plasma flow.
  - ✓ **Understanding and predicting plasma explosion**
    Main driver of space weather phenomena
  - ✓ **Origin of magnetism**
    11-year cycle of sunspots



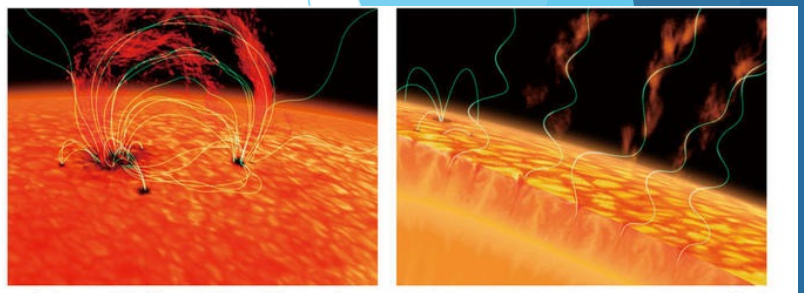
Hinode



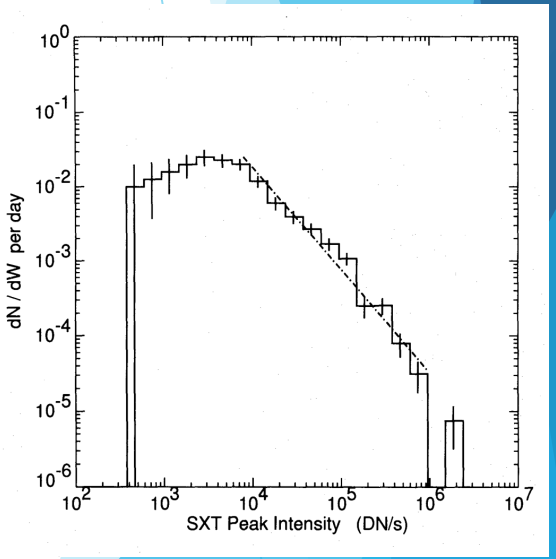
Current Status of Sun and Stars Study
現在までの到達点

- Atmospheric heating and Solar/Stellar wind acceleration
  - ✓ Wave heating
    - There may be Alfvenic waves (Okamoto+2007; De Pontieu+2007, 2014) Energy is not enough for heating the corona.(?)
    - Dissipation mechanism is unknown (Tomczyk+2007)
  - ✓ Nanoflare heating
    - Small-scale flare. Power-law distribution is well investigated (e.g., Shimizu+1995). Still not enough to heat the corona.
    - High resolution (Chitta+2023) and in situ observation (Raouafi+2023) suggest the importance of the jet.

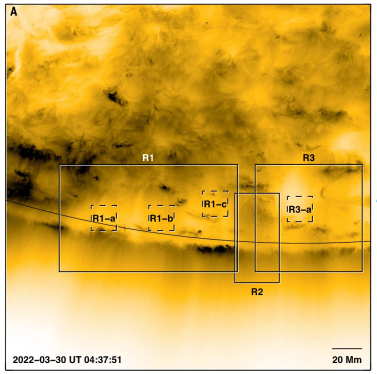
Nanoflare　　Wave heating



JAXA/ISAS



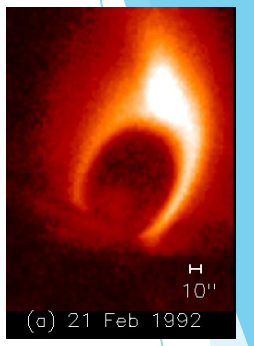
Shimizu, 1995



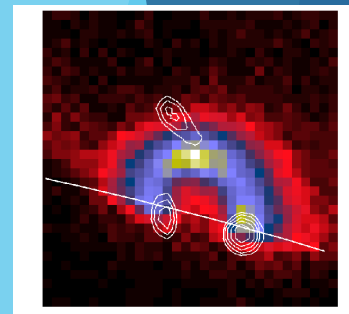
Chitta+2023

Current Status of Sun and Stars Study
現在までの到達点

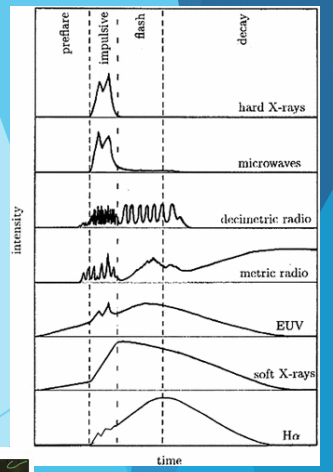
- Understanding and predicting plasma explosion
  - **Understanding**
    - ✓ The standard solar flare model (CSHKP model) has been established. Thanks to the YohKoh satellite (Tsuneta+1992, Masuda+1994).
    - ✓ Solar Flare causes strong emission of many different wavelengths, white light, EUV, X-ray, gamma (e.g., Benz+2017), which is partly caused by high-energy particles.
    - ✓ Significant influence from CME (Coronal Mass Ejection) and SEP (Solar Energetic Particle) (Salas-Matamoros et al. 2015)
    - ✓ The acceleration mechanism for the high-energy particle has not been fully understood yet.
  - **Prediction**
    - ✓ Flare prediction study is significantly improved (Kusano+2012, 2020), even including machine learning techniques (Nishizuka+2012).
    - ✓ Superflare may also occur in the Sun (Maehara+2012, Miyake+2012)



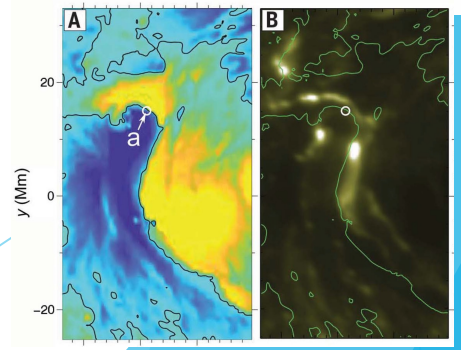
Tsuneta+1992



Masuda+1995

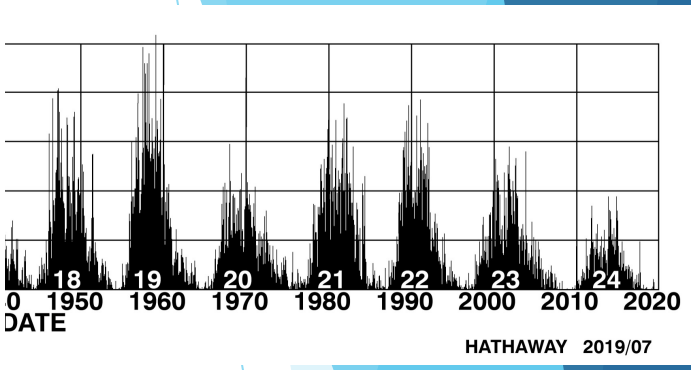


Benz+1992

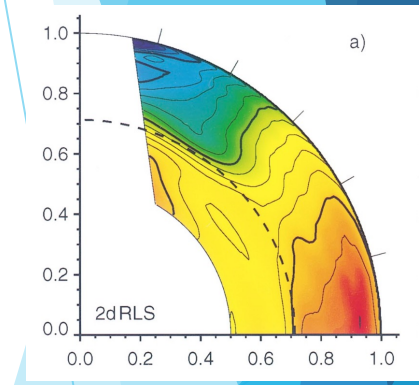


Kusano+2020

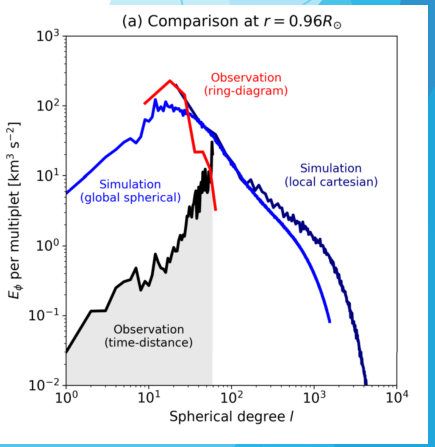
Current Status of Sun and Stars Study
現在までの到達点



- Origin of magnetism
  - ✓ Long-term observation has been continued even from the Galileo era.
  - ✓ The solar interior (especially the convection zone) is key.
    - Detailed interaction between convection, rotation, and magnetic field may lead to the sunspot cycle.
    - Differential rotation
      Detailed structure has been revealed by global helioseismology
    - Meridional flow
      Structure is controversial, but some results are available.
    - Convection
      Significant difference between simulation and observation.
  - ✓ Theory and simulation are also significantly improved in the last seven decade.



Schou+1998



Hotta+2023

Future Trends
今後の世界的動向

- Atmospheric heating and Solar/Stellar wind acceleration
  - ✓ Pasma motion from photosphere to chromosphere (CLASP, SUNRISE, DKIST)
  - ✓ Magnetic energy transport and dissipation (Solar Orbiter, Paker Solar Probe, Solar-C, MUSE)
- Understanding and predicting plasma explosion
  - ✓ Mechanism → High resolution Microwave and Xray (FASR, FOXSI, Solar-C, MUSE)
  - ✓ Continuous monitor for flare occurrence (ngGONG, CMEx, Vigil, Korea-L4)
- Origin of magnetism
  - ✓ Multi-vantage point observations for pole and interior evaluation are targeted. (SPO, China mission, Japan mission)
- Solar-Stellar connection
  - ✓ Kepler, TESS, XRISM, JWST, ARIEL, LAPYUTA

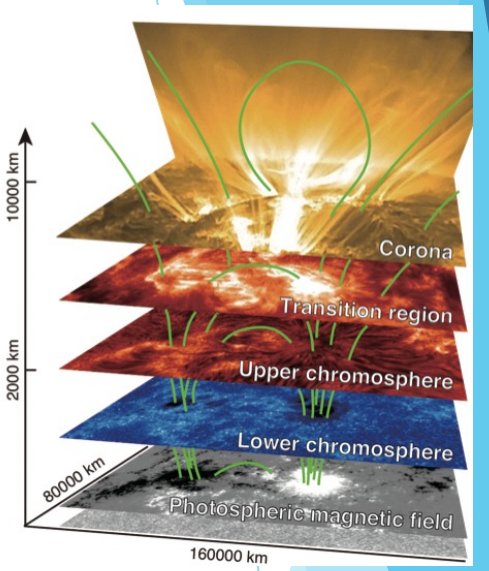
Science Strategy of NAOJ
国立天文台の科学戦略

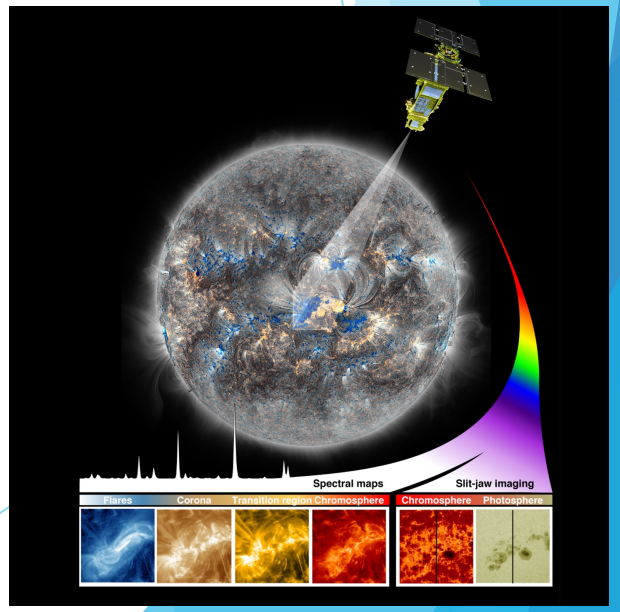
Scientific Goals and Methods for “Sun and Stars”
「太陽と星」の科学目標と手法

- Atmospheric heating and Solar/Stellar wind acceleration
- Understanding and predicting plasma explosion
- Origin of magnetism

Atmospheric heating and solar/stellar wind acceleration

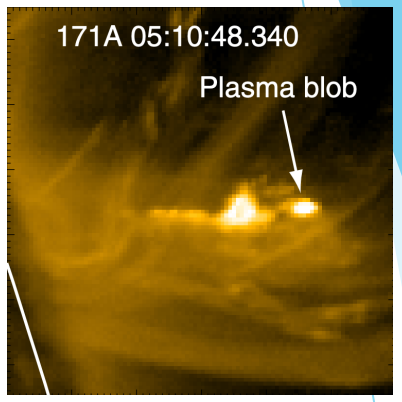
- Solar-C_EUVST (FY 2028)　NAOJ Solar-C Project
  - ✓ High resolution: sub-arcsec resolution (1 arcsec ~ 700 km at the surface)
    Necessary for resolving “magnetic element”.
  - ✓ Multi-temperature observations
    Chromosphere (10,000 K) – Corona (1 MK) – Flare (10 MK)
    Necessary for detecting transport and dissipation of B energy.
- CLASP (rocket), SUNRISE (balloon)
  - ✓ Evaluate the magnetic field in the chromosphere
    Support for understanding the atmospheric dynamics



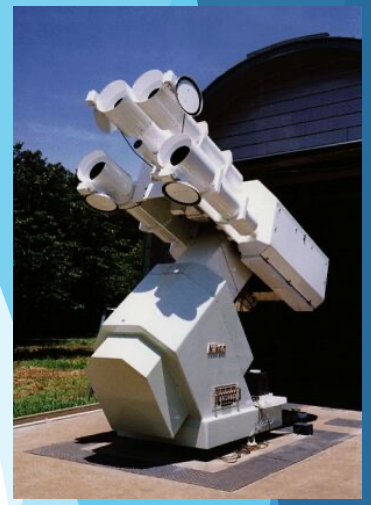


Understanding and predicting plasma explosion

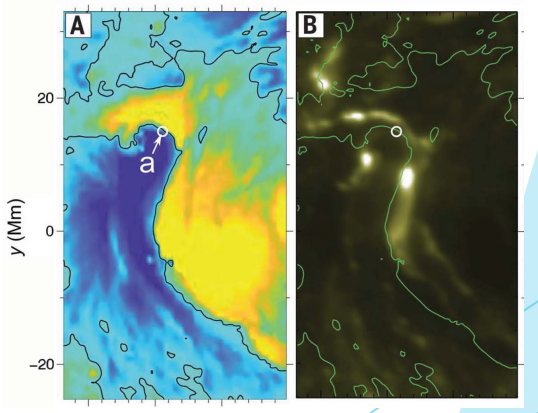
- Solar-C_EUVST
  - ✓ High-resolution and High-cadence observation leads to a question: Why is the solar flare “fast”?
    - ➢ Plasmoid? Shock wave?
  - ✓ Understand the precursor of triggering flare in chromosphere, corona
- Mitaka Solar Flare Telescope
  - ✓ Flare occurrence distribution obey Power-Las.
  - ✓ There is events once 100 – 1000 year.
  - ✓ Continuous observation is critical to observe such events.
- FOXSI(rocket)/PhoENiX(satellite)
  - ✓ X ray high resolutiopn imaging leads to further understanding of flare mechanism and high-energy particle.



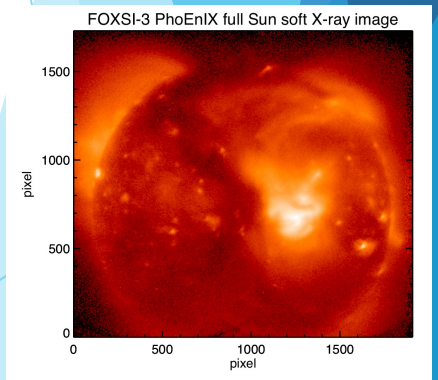
Takasao+2012



Solar Flare Telescope



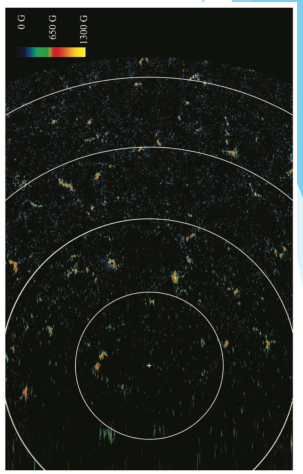
Kusano+2020



FOXSI-3 Website

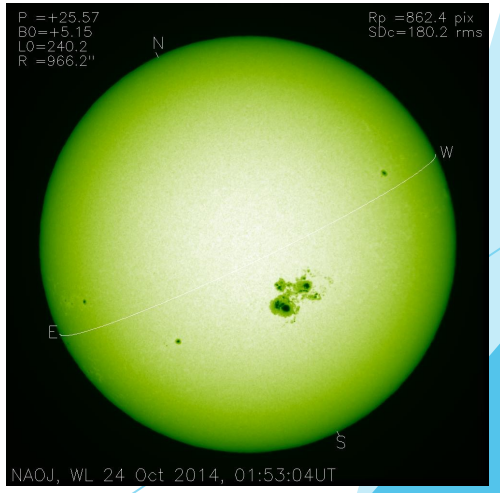
Origin of magnetism

- Hinode (~2006) Observation
  - ✓ Unique observation of the polar magnetic field
    (good correlation with the sunspot number in the next cycle)
  - ✓ Hinode Observation should be extended at least to next minimum (~2030)
    also for overlap with the Solar-C
- Sunspot observation at Mitaka -> ngGONG
  - ✓ ~ A 100-year record of the sunspot is precious.
  - ✓ participation in ngGONG is an option.



Tsuneta+2008

Mitaka White
Light Telescope



Summary and further remarks

- Goals in Sun and Stars (当該分野の目標)
  - ✓ **Atmospheric heating and Solar/Stellar wind acceleration**
    1 MK corona against the 6000 K solar surface. Supersonic plasma flow.
    - Solar-C_EUVST, CLASP, SUNRISE
  - ✓ **Understanding and predicting plasma explosion**
    Main driver of space weather phenomena
    - Solar-C_EUVST, Mitaka Solar Flare Telescope,
  - ✓ **Origin of magnetism**
    11-year cycle of sunspots
    - Hinode, Mitaka sunspot observation, ...
- Sun-Star connection is essential task.
  - ✓ Kepler, TESS, JWST, XRISM, LAPYUTA