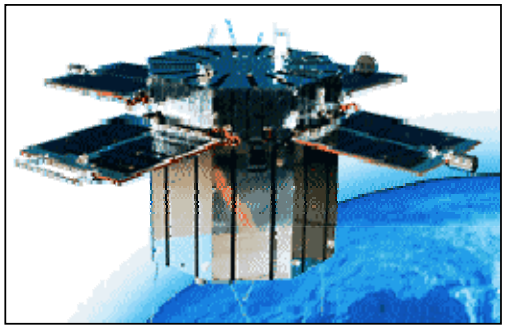
JAXA *SOLAR-C* mission

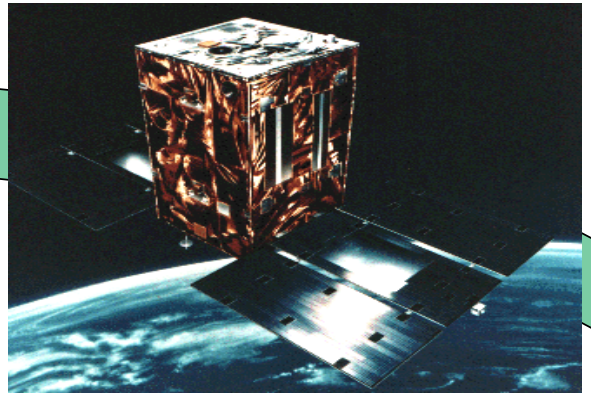
JAXA *SOLAR-C* Working Group
Saku Tsuneta (WG chair)

Solar physics from space in Japan

Yohkoh (1991- 2001)
With NASA/PPARC



Hinotori(1981-1982)



Hinode (2006-) with NASA/STFC/ESA

SOLAR-C
J-FY2016
(provisional)

Two *SOLAR-C* mission concepts under study

- *Plan A*: *Out-of-ecliptic magnetic/X-ray and helioseismic observations* of the polar and the equatorial regions to investigate properties of the polar region, meridional flow and magnetic structure inside the Sun to the base of the convection zone.
- *Plan B :*High spatial resolution, *high throughput, high cadence* spectroscopic (polarimetric) and X-ray observations *seamlessly from photosphere to corona* to investigate magnetism of the Sun and its role in heating and dynamism of solar atmosphere.
- *Launch Date*: Japanese fiscal year *2016 (provisional)*
  - Expects joint observations with highly complementary missions
  - *NASA SDO* (whole sun field of view)
  - *ESA&NASA Solar Orbiter* (Insitu and stereo obs with SOLAR-C)
  - *NASA Solar probe* (In-situ)

Plan-A: Exploration of polar region, internal structure and solar dynamo
The Sun as a star

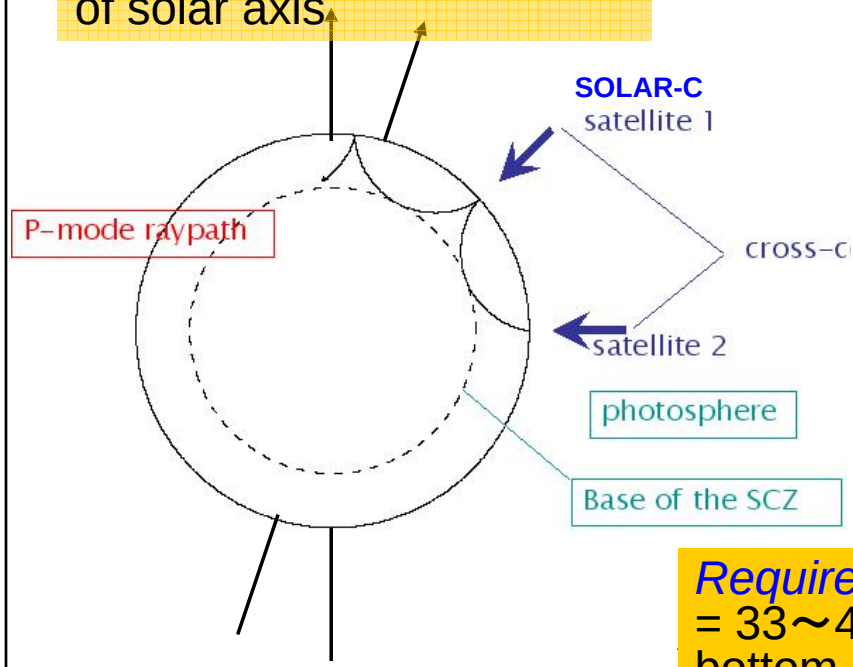
- *Scientific objective*
  - Measure meridional flow at high latitudes, and see where it turns downwards
  - Detect magneto-sound speed anomaly located in the tachocline region (*flux tube/sheet imaging in tachocline*)
  - Observe the vector magnetic fields of photosphere and chromosphere and coronal imaging in X-ray/EUV
  - Obtain acoustic speed and angular rotation speed distribution in the polar region
  - Understand acceleration mechanism of fast solar wind
  - Monitor total irradiance (optional)
  - Study influence of the Sun to heliosphere
- *Model payload*
  - Photospheric and chromospheric dopplergram
  - Stokes-polarimeter for photosphere and chromosphere
  - X-ray/EUV imager
  - Optional: total irradiance monitor, in-site instruments, and coronagraph

Plan-A: A new possibility
Imaging of flux tubes in tachocline

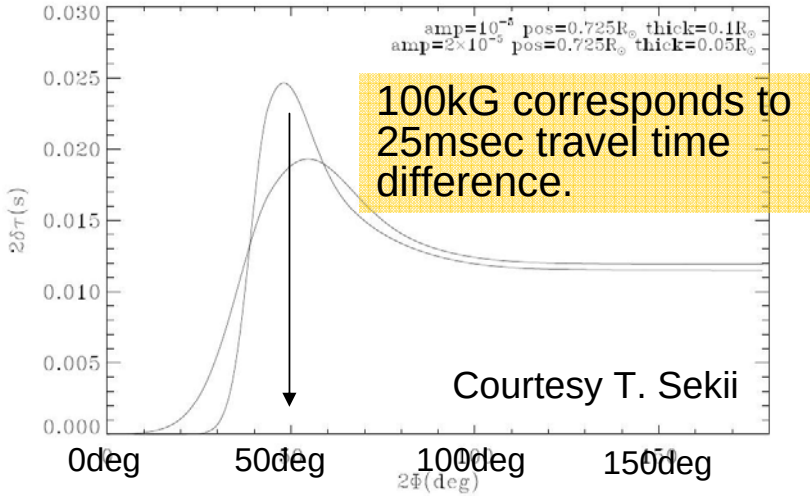
A high-inclination orbit and dual observations

- Observe Doppler velocity at high latitudes without undesired projection
- Observe waves penetrating deep into the sun with dual stations.

By choosing launch timing, use precious 7 degree tilt of solar axis



Skip angle versus travel-time perturbation due to flux sheet at tachocline



100kG corresponds to 25msec travel time difference.

Courtesy T. Sekii

Required inclination : 40～50 minus 7 degree = 33～43 degree: Optimum angle to reach bottom of CZ

Plan A Orbit and Engine Trade-off

Case 1: Ion engine + Earth swing-by

Case 2: Ion engine + Earth swing-by + Venus swing-by

Case 3: Chemical engine + Jupiter swing-by

Case 4: Chemical engine + Jupiter swing-by + Earth swing-by

<Trade-off items>

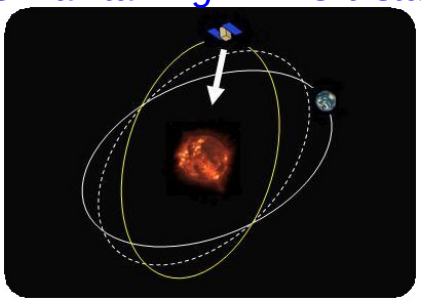
flight time until starting observation, achievable inclination, observational timing, payload mass, thermal design, tele-communication link, etc.

ex.) One possible solution of *Case 1* assumes,

- JAXA H2A launch
- Initial mass = 1200kg.
- Payload mass = 100kg.

Achieves Inclination (to the Solar equator) of
30 deg. in 2 years from the launch,
45 deg. in 5 years from the launch.

Observe both polar and equatorial Regions maintaining ~1AU distance



Plan-B brings new discovery space though enhanced spectroscopic capability *seamlessly covering entire atmosphere*

Hinode discoveries

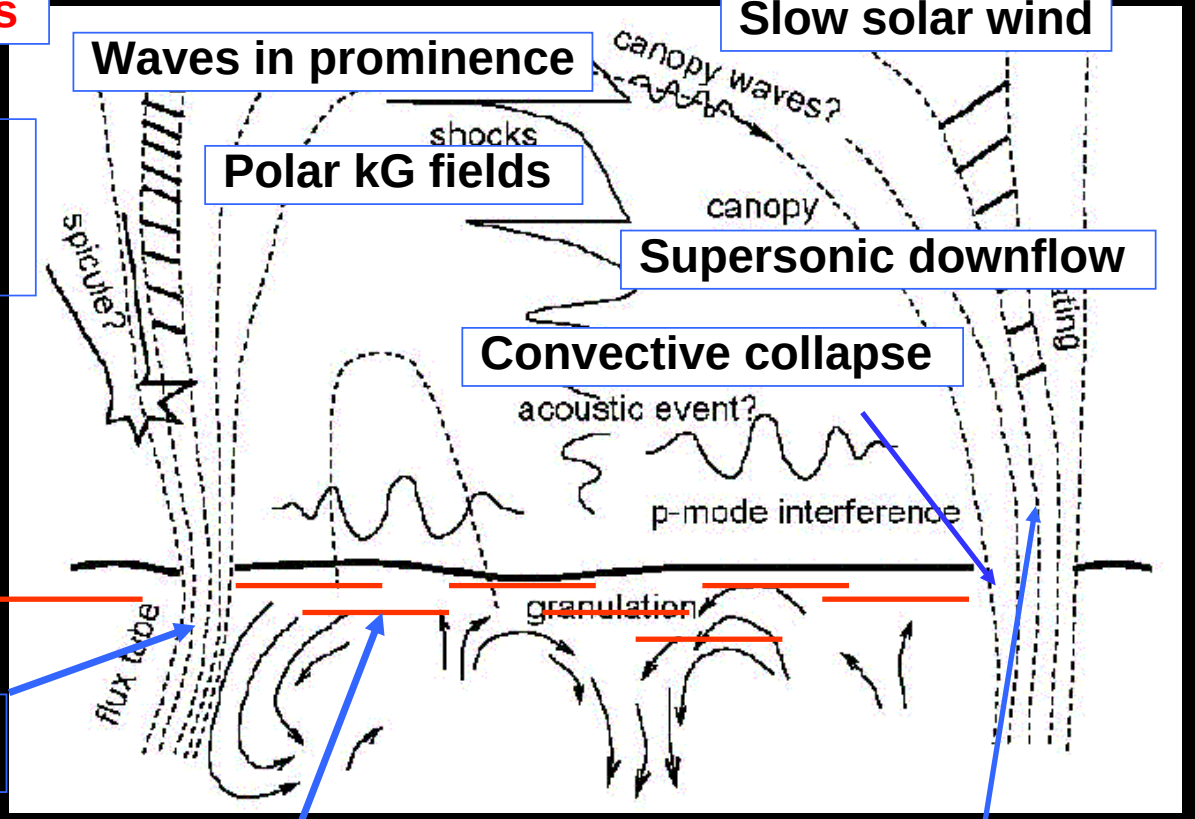
Chromospheric transition region jets due to reconnection

Waves along spicules

Penumbral micro-jets

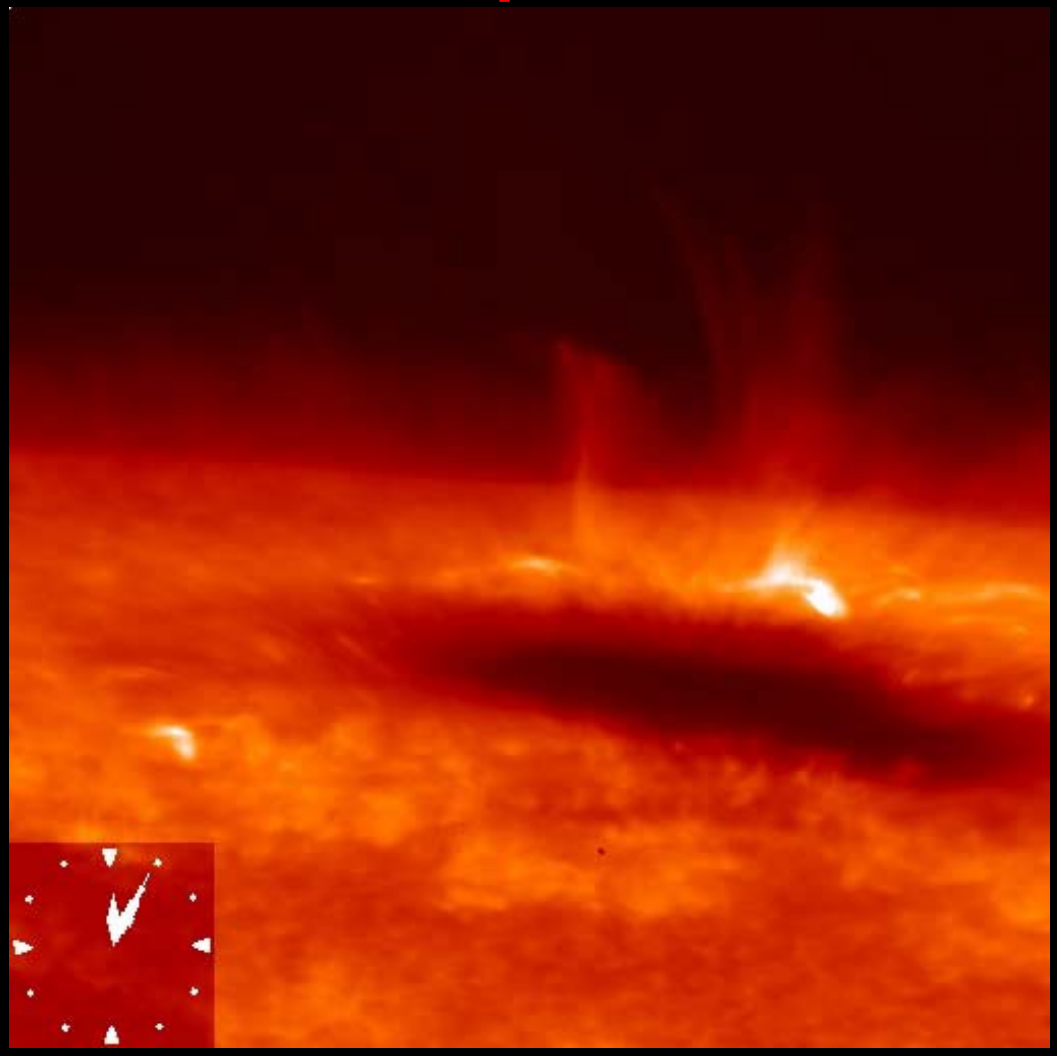
Magnetic velocity Fluctuation

Local dynamo process



Rutten, R., ASP-CS, 184, 181, 1999

Chromosphere more dynamic than expected!



Hinode and *SOLAR-C Plan-B*

- Hinode/***SOLAR-C***
  - Demonstrates power of spectro-polarimetry from space
    - ***Significantly enhance spectro-polarimetric capabilities to UV and near-IR***
  - Dynamism of chromosphere is a major Hinode discovery. Chromospheric dynamics may generate disturbance to corona: new implication to coronal heating (Isobe et al 2008)
    - **High time resolution, high throughput spectrometer**
  - Little diagnostic capability for chromosphere and transition regions
    - **Seamless observations from photosphere to corona**
- *Scientific Objective*
  - Obtain precise *chromospheric* and, if possible, *coronal vector magnetic field* maps in addition to photospheric magnetic maps with high spatial and temporal resolution
  - Obtain *coronal 3-D magnetic field* map from chromospheric vector field, predict location and evolution of neutral-sheets, dicontinuities for transient and stationary coronal heating and eruption
  - Reveal *causal relationship* of photosphere-chromosphere-transition region-corona to understand coronal/chromospheric heating and dynamism
  - Understand the nature of *hidden magnetism*: Is the observed B tip of the iceberg?
  - Deepen Hinode discoveries with quantitative analysis: *waves, turbulence, magnetic reconnection*
  - Study influence of the Sun to heliosphere

Plan B model payload

- *General*
  - From imaging to spectroscopy
    - *Concentrate best possible lines to represent each layer of atmosphere*
  - High resolution, high S/N, and high time resolution
    - *High throughput multi-object-spectrograph or equivalent needed*
  - From visible to visible+UV+near IR
    - *Seamless coverage of photosphere, chromosphere, TR and corona*
- *Model payload*
  - *Near IR-Visible-UV* telescope（TBD-1.1 micron）
    - ＞50cm diffraction-limited telescope（0.1-0.4arcsec）
  - *Ultra-high resolution* EUV/X-ray telescope
  - High resolution high throughput coronal spectroscopic capability
- ***Key point1 : Chromospheric, and if possible coronal spectro-polarimetry for vector magnetic field observations***
  - Needs He10830 or equivalent with *Zeeman+Hanle* sensitivity
  - Evaluate potentiality of UV and EUV lines for *Hanle-effect* diagnostics of chromosphere and corona
  - Closer to force-free layer: provide better BC for coronal field extrapolation: concern on the adequacy on photospheric BC
- ***Key point 2: High spatial and temporal resolution chromospheric and transition region spectroscopy for dynamics***

Development of *SOLAR-C* concept

- JAXA *SOLAR-C* WG refines both plans, compare science, technology, and other constraints, and prioritize the two plans with international partners.
- ***International SOLAR-C science definition meeting***
  - **week of November 10 2008 at JAXA/ISAS-JSPEC**
- Purpose of meeting
  - Refine science cases for plans A and B
  - Determine option for Plan-A orbit and engine for further study
  - Propose model science instruments and identify key technology issues
  - Discuss consistency and synergy with NASA and ESA plans
  - Form international sub working groups for specific critical issues
  - Establish connection with space weather

SOLAR－C development schedule (provisional)

- FY2016 Launch
- FY2015 S/C tests
- FY2011～14 Flight and proto model
- FY2010 Phase-A
- FY2008～9 Concept study
- FY2007 JAXA SOLAR-C WG

(FY: Japan fiscal year starting April 1.)

Summary

- Solar physics community in Japan has so far developed 3 solar missions over past 25 years.
- We recognize that success of Hinode and Yohkoh is due to strong international support.
- Solar physics community and related-disciplines in Japan strongly desire and endorse one of the SOLAR-C mission concept to be realized in mid-2010s.
- *The JAXA SOLAR-C working group invites US and European participation to the SOLAR-C program, following our remarkable history of collaboration.*