Next Generation Solar Physics Mission

Science Objectives Team

Overview/Progress

Lyndsay Fletcher

Charter

- JAXA/ESA/NASA are looking at a possible multi-lateral mission
- Primary role of SOT is to develop and document scientific priorities of such a mission *within resources to be specified by the Agencies**
- Scope – broad. All categories of mission currently under discussion
- Post-2024 launch
- Mission likely to be JAXA-led

**These have not been specified yet, apart from possible preference for JAXA Epsilon launcher*

NGSPM-SOT members

NASA-appointed Members

- David McKenzie, NASA, Marshall Space Flight Center
- Ted Tarbell, Lockheed Martin Solar and Astrophysics Laboratory
- John Raymond, Smithsonian Astrophysical Observatory
- Sarah Gibson, High-Altitude Observatory

ESA-appointed Members

- Luis Ramon Bellot Rubio - Instituto de Astrofisica de Andalucia, Spain
- Mats Carlsson - UiO Institute of Theoretical Astrophysics, Norway
- Lyndsay Fletcher - University of Glasgow, UK
- Sami Solanki - Max-Planck-Institut für Sonnensystemforschung, Göttingen

JAXA-appointed Members

- Kiyoshi Ichimoto, Kyoto University/NAOJ
- Kanya Kusano, Nagoya University
- Toshifumi Shimuzu, ISAS/JAXA, team chair
- Hirohisa Hara, NAOJ

NGSPM-SOT: Process

- Two phases of the team work
  - Phase 1: Review science objectives in solar physics [ongoing]
  - Phase 2: Prioritise the science objectives and assess mission design options to accomplish the objectives.
- Science objectives review
  - Starting with a review of the Solar-C science objectives in three categories, discussions have included ~20 topics of solar physics.
  - Three categories: I). Coronal heating, solar wind and dynamic atmosphere, II). Flares and space weather research for prediction, III). Solar cycle and irradiance variation that influence the climate change of the earth.
  - Details of science objectives greatly enhanced and informed by the input of 34 White Papers from the community. The SOT is immensely grateful for these contributions

NGSPM-SOT: future

- The report draft is requested by the agencies in April; the final report in July 2017.
- The SOT members continue to have email discussions, teleconferences and F2F meetings for documenting the report.
  - Polish up the descriptions of science objectives, such as science background, tasks, and key observations, in December-January.
  - Our discussions will be moving to Phase 2 (priority discussions). The ideas in the white papers are referred in assessing mission design options.
- Further community interaction opportunities
  - Japan Solar Physics Community (JSPC) meeting (ISAS, February 20-22, 2017)
  - A session in Joint Hinode-11/IRIS-8 science meeting (Seattle, May 30 – June 2, 2017) .

The White Papers

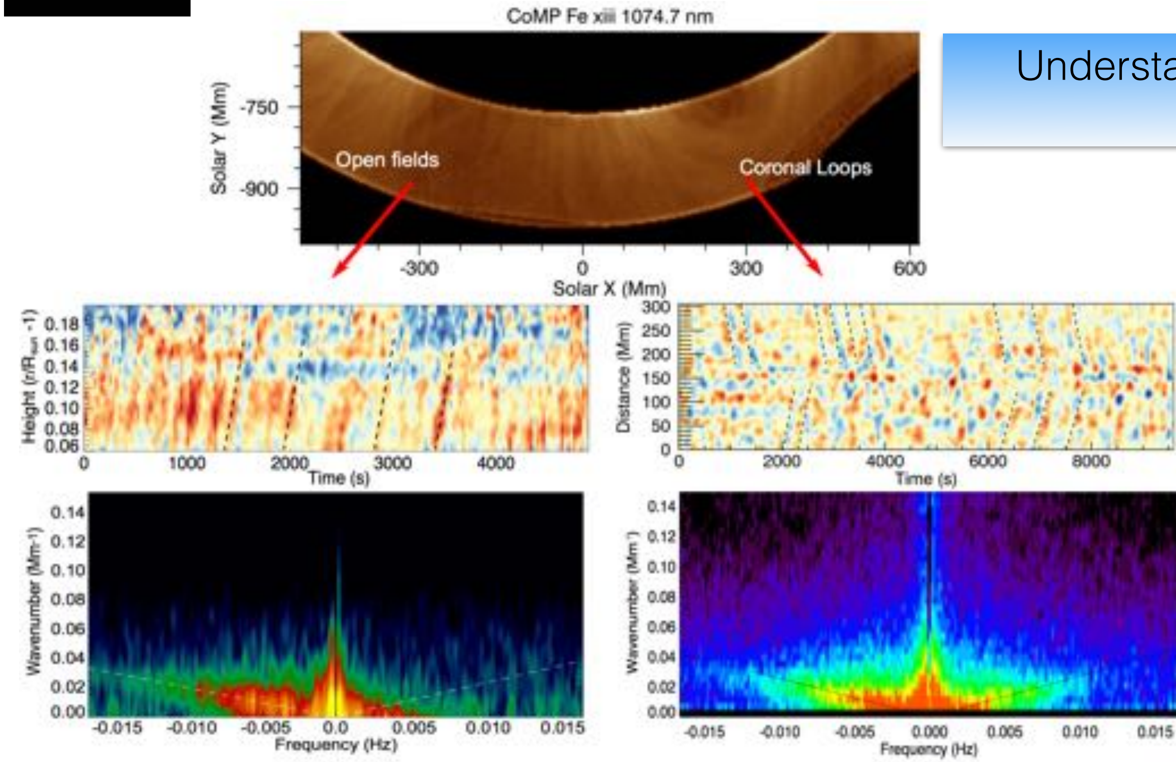
- 11 white papers (out of 34) with a UK involvement
- 1 slide per WP, 5 minute “advert”
- Running order:
  1. Morton
  2. Mathioudakis
  3. Del Zanna
  4. Hannah
  5. Matthews
  6. Russell
  7. Hudson
  8. Balikhin
  9. Harra
  10. Browning

Exploring coronal dynamics

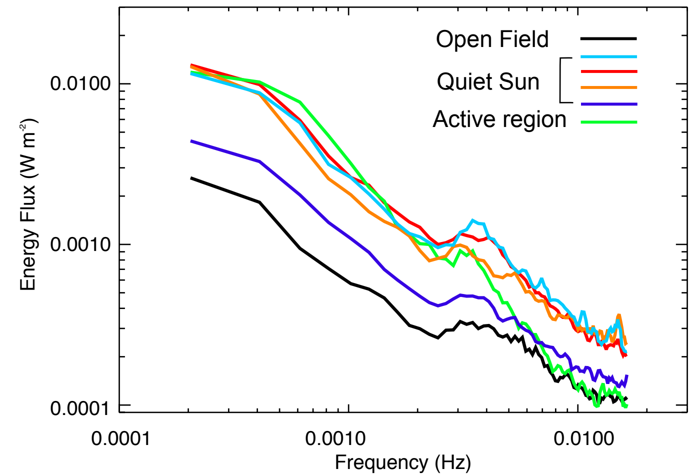
Morton, R. J.; Scullion, E.; Bloomfield, D. S.; McLaughlin, J. A.; Regnier, S.; McIntosh, S. W.; Tomczyk, S.; Young, P.

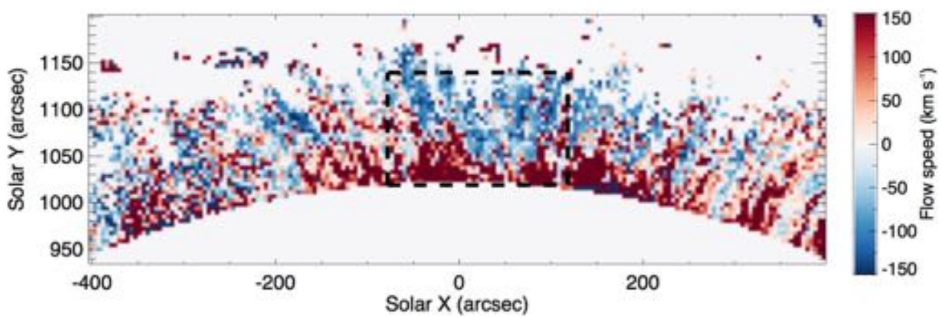
HAO High Altitude Observatory NCAR UCAR

northumbria UNIVERSITY NEWCASTLE



Understanding wave energy transfer through corona to solar wind





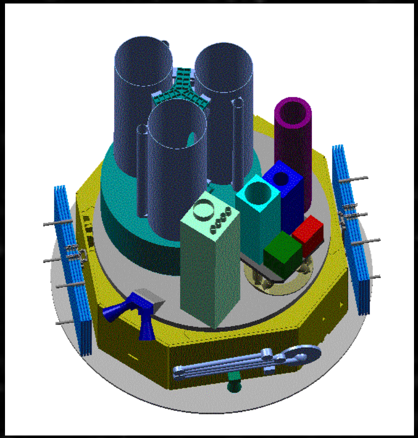
Measurement of coronal flow fields, e.g., low solar wind.

Space-based Imaging Spectrometer Coronagraph

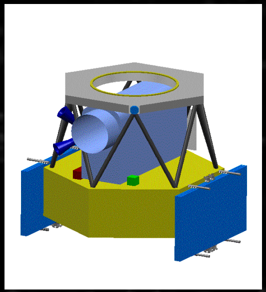
- 1074.7 nm (Fe XIII)
- Images at 3 λ's with a 0.13 nm FWHM filter.
- 30 s cadence
- Spatial sampling of 4.46"
- 1.05-1.3 R⊙ field of view
- Density diagnostics (1079.8 nm)
- Spectropolarimetric sensitivity

HiRISE

R. Erdélyi (UK), L. Damé (France), A. Fludra (UK), M. Mathioudakis (UK), S. Tomczyk (USA), F. Berrilli (Italy)



- **Resolution** (**0.02”**) chromosphere-corona interface characterization with a 1.4 m UV-FUV telescope equivalent (3 x 500 mm telescopes, independent or combined) and 3D imaging spectro-polarimetry

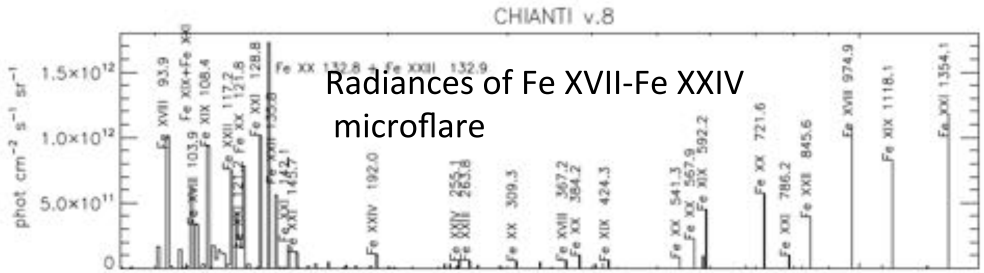


- Eclipse-like extreme coronagraphy of **inner corona** (up to **1.01 Rs – 10 arcsec**) in vis., UV, NIR by Formation Flying between 2 satellites 375 m apart (Fe XIV, He I D3 & 1083, Fe XIII 1075 & 1079, Lyman series & O VI)

The quest for the hot (5–10 MK) plasma in the solar corona

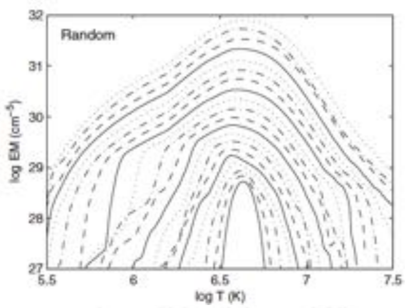
Giulio Del Zanna

To understand microflares and nanoflares we need high-resolution spectroscopy of 5-10 MK lines (Fe) which we never had.

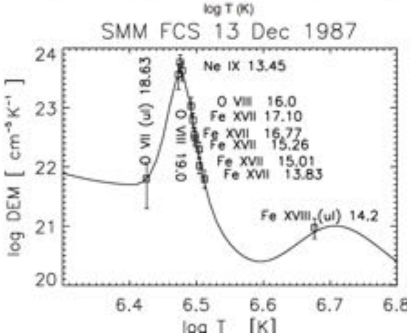


Radiances of Fe XVII-Fe XXIV microflare

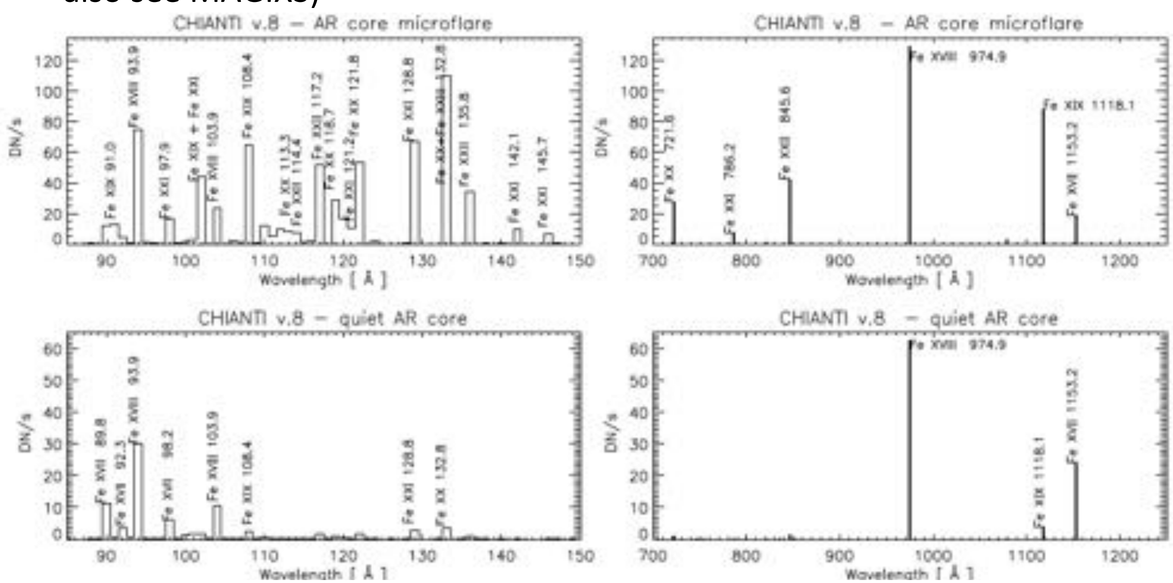
AIA ! EIS CDS SUMER/IRIS



EM of random nanoflares with varying frequency (Cargill 2014)



DEM AR core (X-ray spectroscopy from SMM: Del Zanna & Mason 2014; also see MAGIXS)



Modified Solar-C LEMUR spectra with a soft X-ray channel.

Exploring impulsive solar magnetic energy release & particle acceleration with focused Hard X-ray imaging spectroscopy

PI: Christe (GSFC), UK: Hannah, Kontar (Glasgow)

FOXSI – Focusing Optics X-Ray Solar Imager

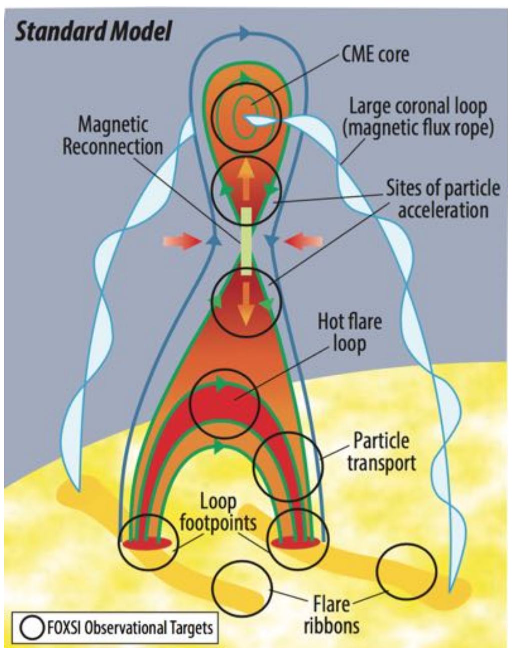
Directly focused Hard X-ray (HXR) imaging spectroscopy to explore:

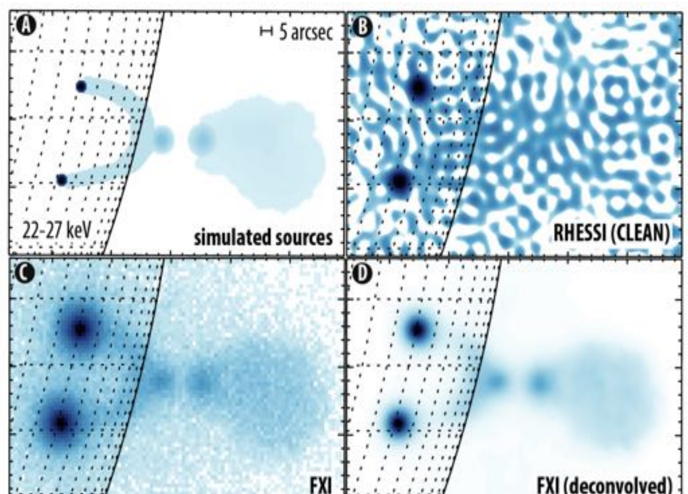
1. How are particles are accelerated at the Sun?
2. How does magnetic energy release on the Sun lead to flares and eruptions?

HXR imaging spectroscopy = direct & accurate info about energetic electrons

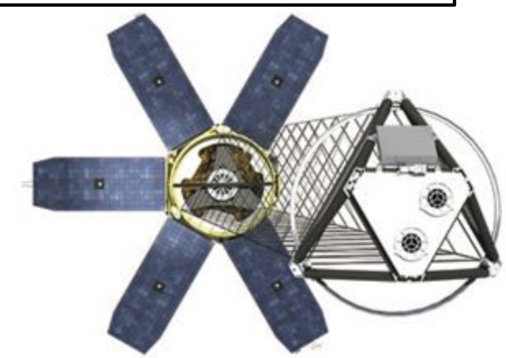
FOXSI/FXI = Higher sensitivity & dynamic range than RHESSI

- Simultaneously observe HXR coronal + footpoint sources, as well as smaller events
- Heritage: FOXSI sounding rockets, HERO Balloon, HEXITEC (RAL) detectors





Sims & specs of proposed FOXSI-SMEX/FXI instrument

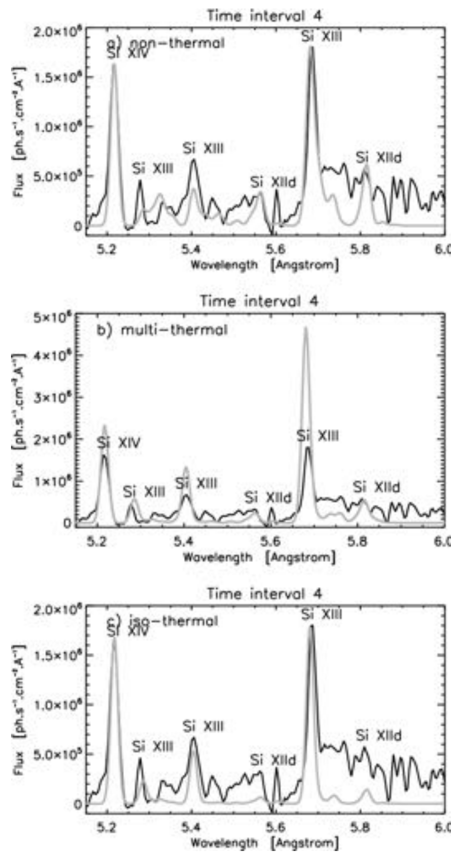


FXI: HXR Spectroscopic Imager

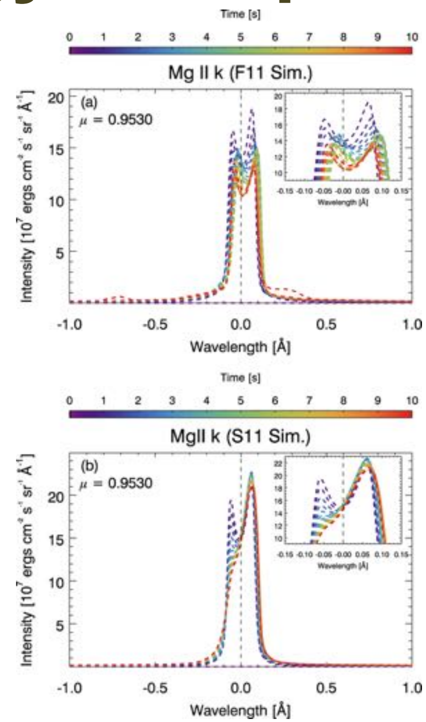
- **Energy Range:** 3 - 50 keV
- **Energy Resolution:** 0.8 keV FWHM
- **Time Resolution:** 0.1 s
- **Field of View:** 9 x 9 arcmin
- **Dynamic Range:** 20:1 at 20″, 1000:1 at 45″
- **Effective Area:** 55 cm^2
- **Angular Resolution:** 8″ FWHM over 300″

Non-thermal distributions and energy transport

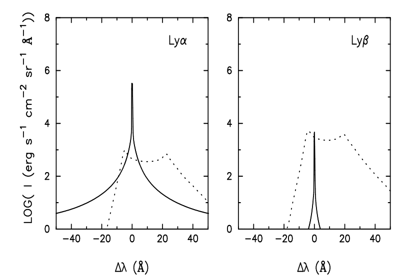
- What are the roles of particles and/or waves in flare energy transport?
- What are the limits of the low energy non-thermal electron distribution?
- Can we detect < 1 MeV proton beams?



Dzifcáková et al., 2008



Kerr et al., 2016



Zhao et al., 1998

How?

- X-ray imaging spectroscopy

- Heritage from MaGIXS and FOXSI

- UV imaging spectroscopy

- Image slicer technology for simultaneous coverage of large FOVs

- Spectropolarimetry for photospheric and vector magnetic field

- Imager slicers for high temporal resolution

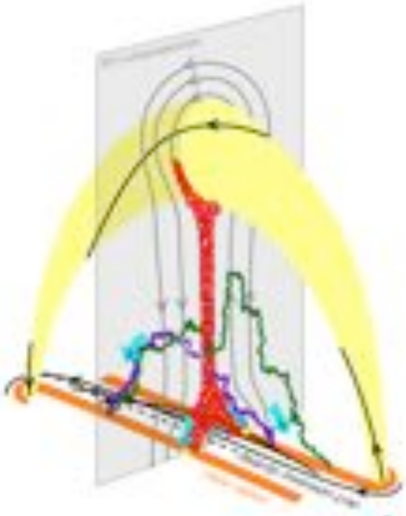
Understanding Energy Transport by Alfvénic Waves in Flares

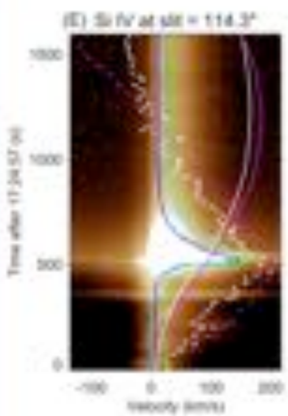
J.W. Reep, H.P. Warren, J.E. Leake, L.A. Tarr, A.J.B. Russell, G.S. Kerr & H.S. Hudson. arXiv:1702.01667

Field aligned transport:

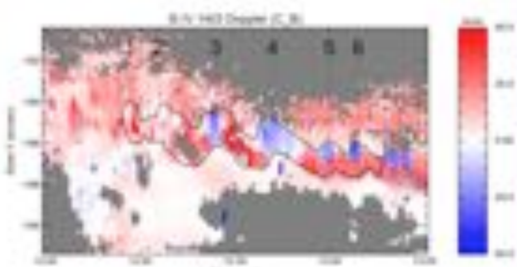
Particles.
Conduction.
Poynting flux.

<u>What mix?</u>



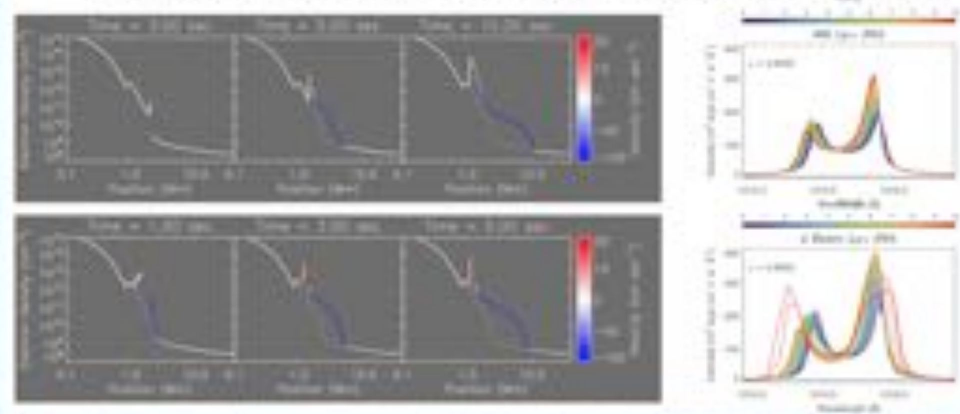


Tian et al. 2015



Brannon et al. 2015

EB and AW models – similarities and differences



What mission would crack this?

Aim: Record atmospheric response to infer depths of energy deposition & travel times.

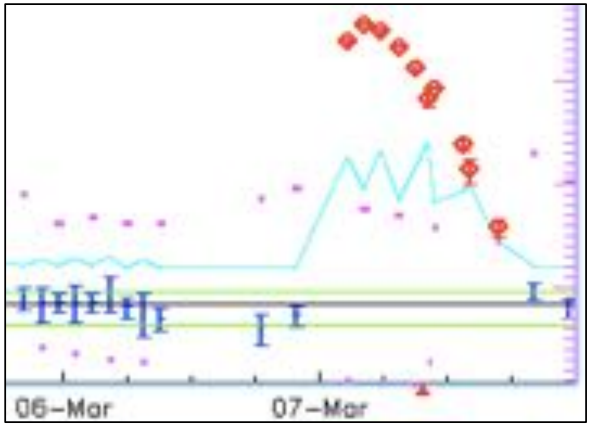
Mission type: Improved EUV slit spectrograph.

Wishlist: Cadence ~0.1 sec; Wide coverage of depths & ionisation stages alongside DKIST & EST; Spatial resolution at or beyond IRIS; Slitjaw images (context).

University of Glasgow | School of Physics & Astronomy

Ion Acceleration in Solar Eruptive Events:
New and interesting solar messengers

- Gamma rays
- High-energy gamma rays
- Neutrons
- Energetic neutral atoms
- Relativistic ions

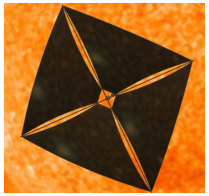


We have heritage in many of these areas, but often not from the solar community. Particle acceleration represents a fundamental problem in space weather.

The LAT long-duration events have no solar identification yet!

A. Y. Shih (NASA/GSFC), N. Vilmer (Paris Observatory), A. MacKinnon (University of Glasgow), M. Pesce-Rollins (INFN-Pisa), R. Vainio (University of Turku) , H. Hudson (University of Glasgow) , P. J. A. Simões (University of Glasgow), C. M. S. Cohen (Caltech)

Misha Balikhin



Polar Investigation of the Sun: POLARIS+

	Remote sensing					In situ
Scientific Objectives	DSI	TSI	EUVI	COR	EUS	TBD
What is the 3D structure of convection and circulation flows below the surface, and how does it affect solar activity?	x	x				
What is the 3D structure of the solar magnetic field, and how does is vary over a solar cycle?	x	x	x	x		
How does the spectral and total solar irradiance vary with latitude?	x	x	x		x	
What advantages does the polar perspective provide for space weather prediction?			x	x	x	

Science orbit: Circular orbit with a 75° inclination at 0.48 AU

Feature: Solar sail with a 50-kg payload

All Around the Sun

An inter-space agency effort to study the Sun-Earth system as a whole

by A.S Brun et al. (*provided by M. Browning*)

It is essential to have a full 3-D view of the Sun-Earth system in order to understand our star, to predict and to anticipate its activity, and to protect ourselves from its potentially dangerous impact on our society.

A mother ship at L1 (L5) with large passband (for relay for far away probes) and storage capacity seconded by a swarm of simpler (cheaper) probes that will be coordinated and provided by partner space agencies. This space system will provide a full 3-D (including farside and poles) view of the Sun-Earth system as budget and planning in the various agencies allow.

Other White Papers:

ADAHELI PLUS (R. Erdelyi, Sheffield) Led by F. Berrilli

- *Long duration, high cadence (5fps) IR multi-line spectropolarimetry in near IR, for chromospheric fields*
- *X-ray polarimetry of flares*