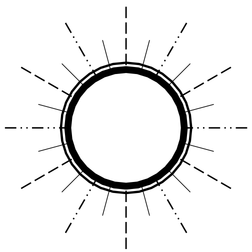
PhoENiX

Physics of Energetic and Non-thermal plasmas in the X (= magnetic reconnection) region



Noriyuki Narukage (NAOJ)

Mitsuo Oka, Yasushi Fukazawa, Keiichi Matsuzaki, Shin Watanabe, Taro Sakao, Kouichi Hagino, Ikuyuki Mitsuishi, Tsunefumi Mizuno, Iku Shinohara, Masumi Shimojo, Shinsuke Takasao, Tomoko Kawate, Takafumi Kaneko, Seiji Zenitani, Hiroshi Tanabe, Munetaka Ueno, Tadayuki Takahashi, Takeshi Takashima, Masayuki Ohta and PhoENiX WG member

Science Goal

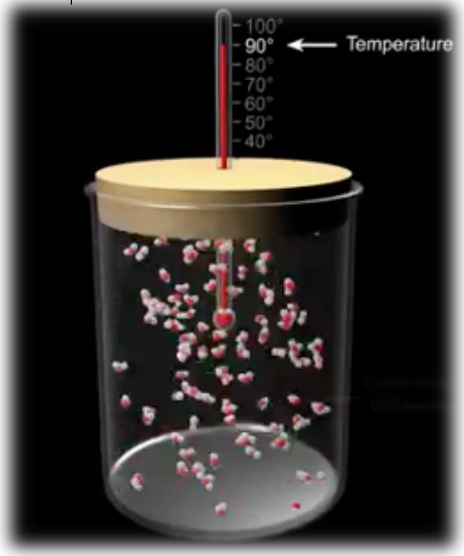
Understanding of particle acceleration during magnetic reconnection

- **Science Objectives**

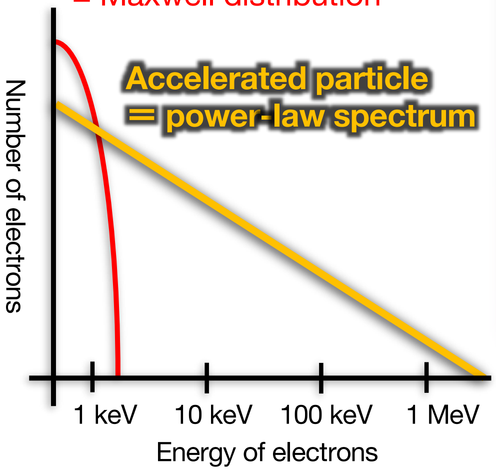
1. To identify
   particle acceleration sites
   in reconnection-associated structures in solar flares
2. To investigate
   the timing of particle acceleration
   during reconnection-associated phenomena in solar flares
3. To characterize
   the properties of accelerated particle populations in solar flares

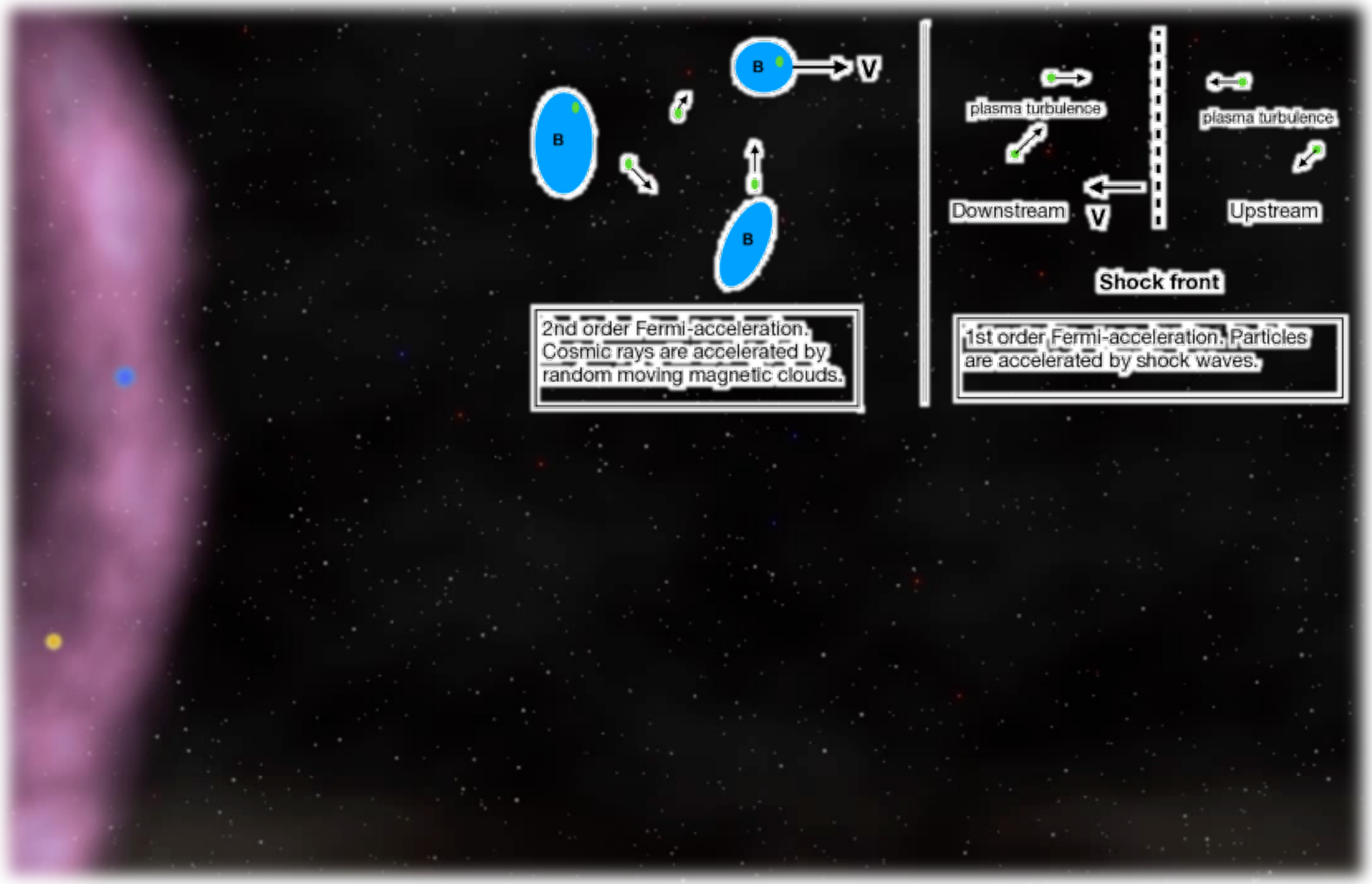
Particle acceleration

Accelerated particles are deviated from equilibrium.



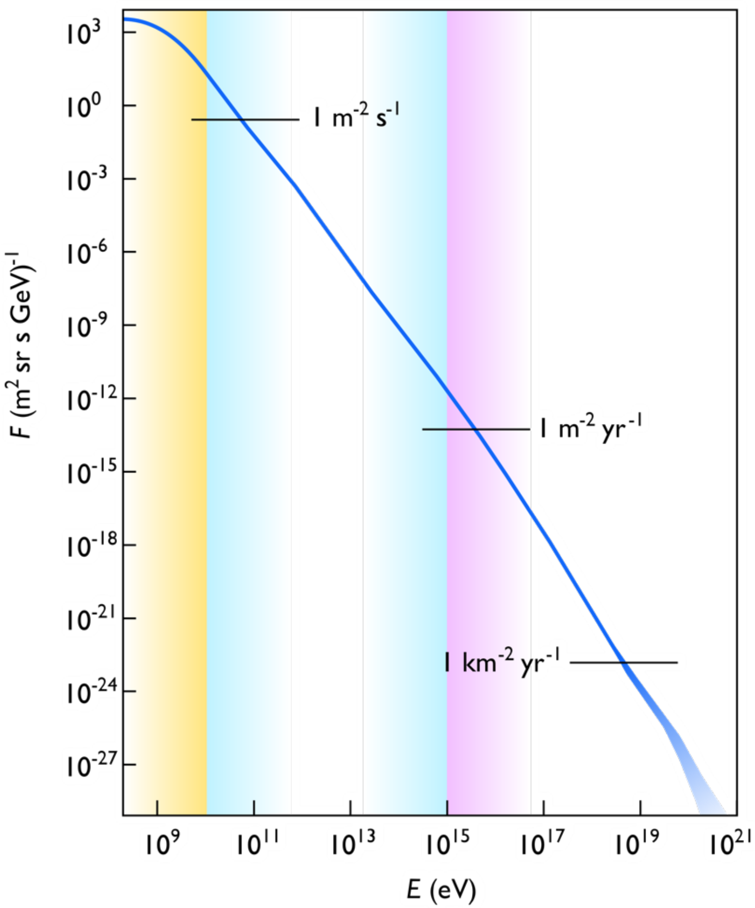
Thermal equilibrium
= Maxwell distribution

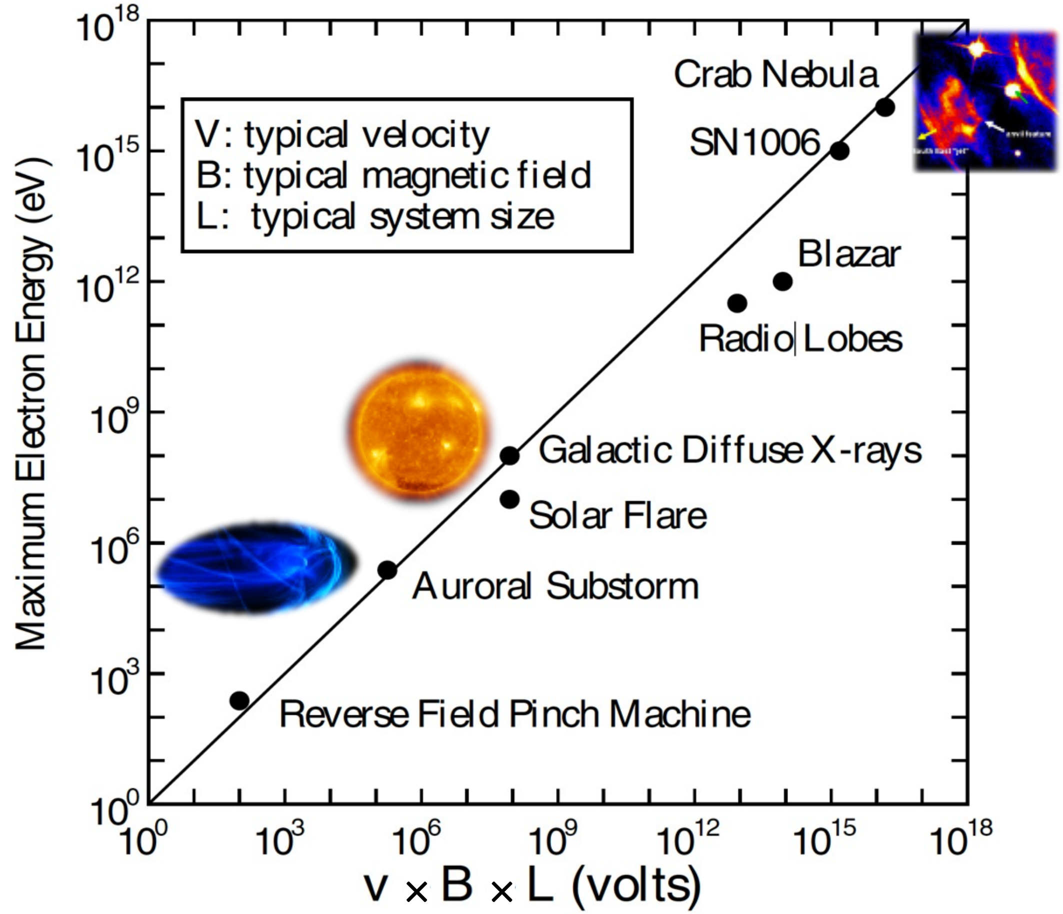




Particle acceleration

The energy of accelerated particles achieves up to 10^{20} eV.
Accelerated particles are ubiquitously detected in the universe.



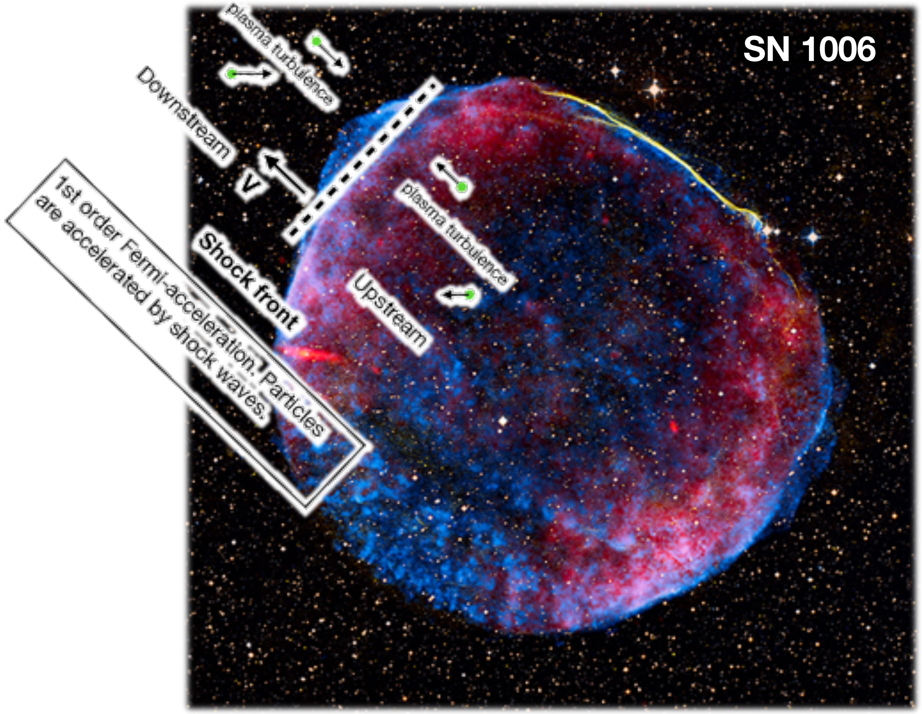


Makishima (1999)

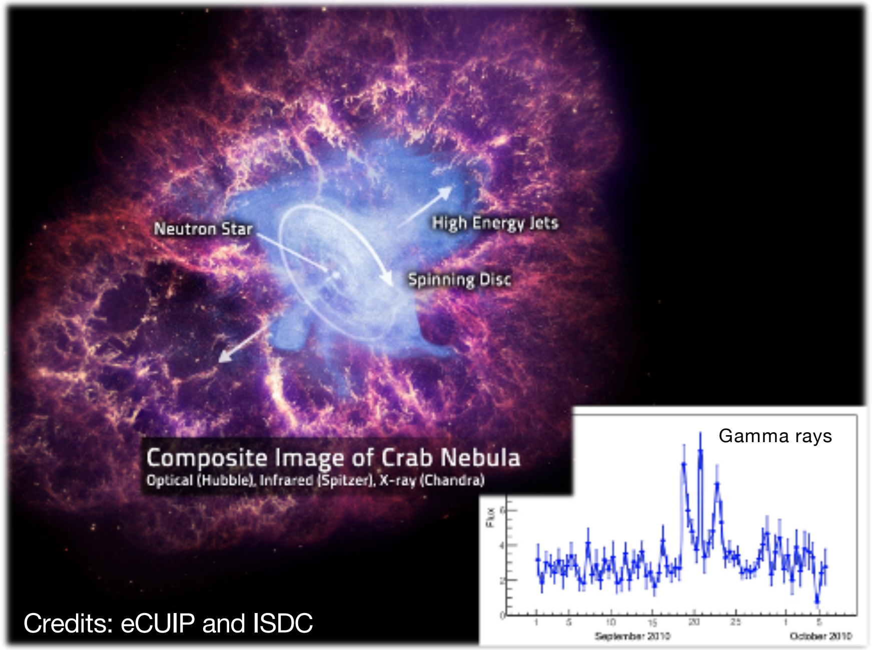
Particle acceleration

How are particles accelerated? It is not fully understood.

Super Nova Remnant
(long time acceleration)



Gamma-ray Burst
(short time acceleration)



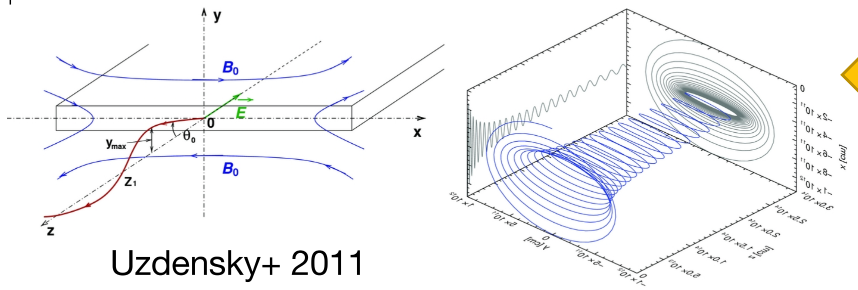
Balbo+ 2011

1st order Fermi-acceleration
Statistical acceleration

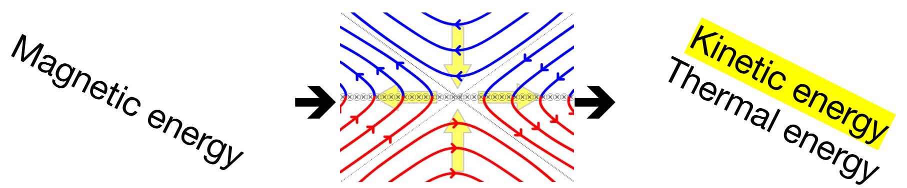
How are particles accelerated
in very short time?

Particle acceleration

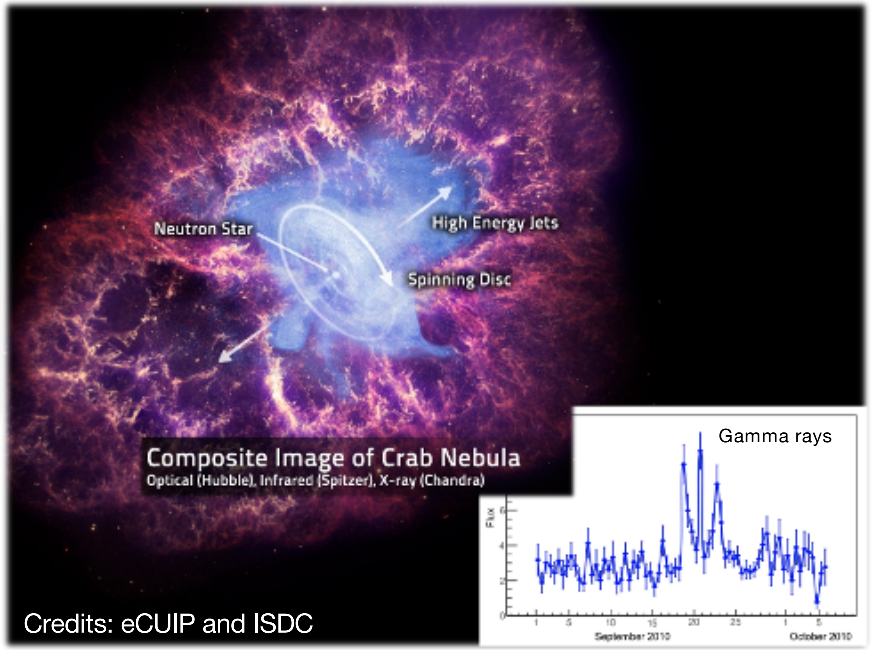
Magnetic reconnection is a key.



Uzdensky+ 2011



Gamma-ray Burst
(short time acceleration)



Balbo+ 2011

How are particles accelerated
in very short time?

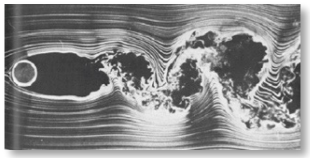
Magnetic Reconnection

MR is fundamental plasma process and ubiquitously occurs in the universe.

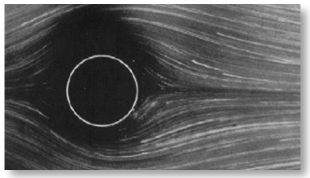
Lundquist number

$$S \equiv \frac{\mu_0 V_A L_{CS}}{\eta}$$

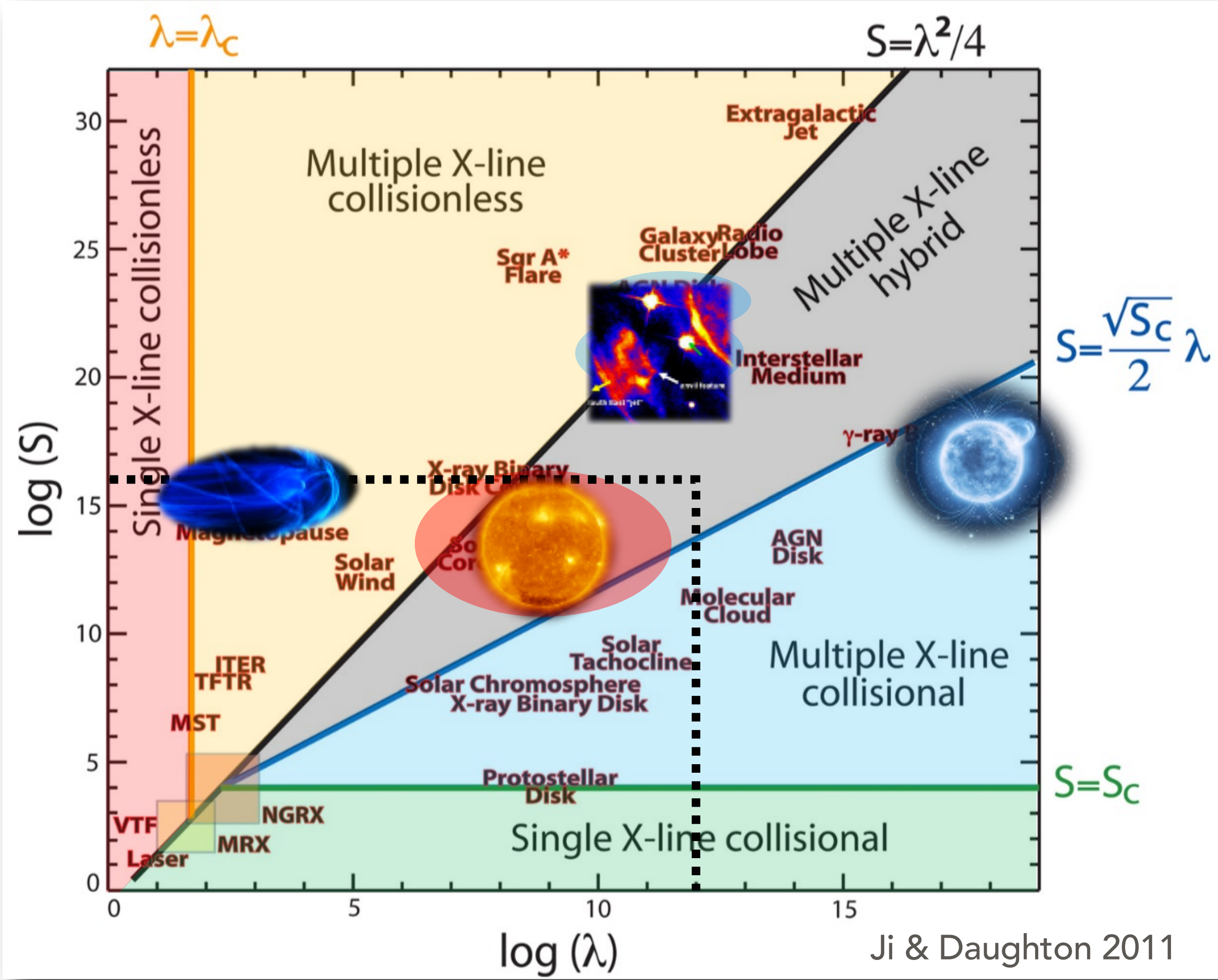
Cf. Reynolds number

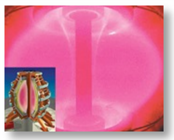


$R_e = 10^4$



$R_e = 1.54$

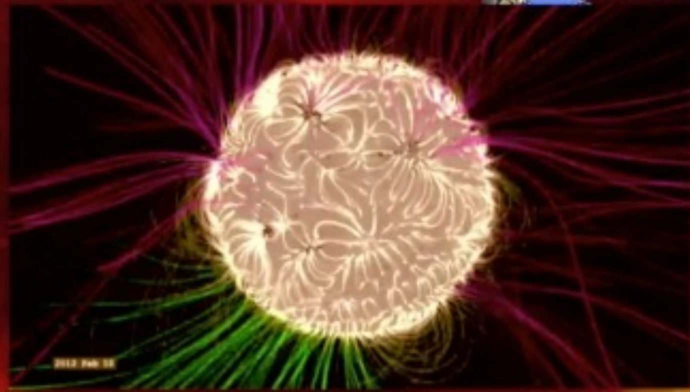




Effective plasma size $\lambda \equiv \frac{L}{d_i}$

Significance of solar flare study

ひので XRT



[Plasma physics]

Natural laboratory of plasma

- **Magnetic reconnection**
- **Particle acceleration**

[Unique observation target]

The closest star

- **Solar phenomenon can be observed with wide field of view and with spatial and temporal resolutions**

[Impacts on the Earth and social environments]

The mother of the Earth

- **Evolution of life (cosmic rays)**
- **Space weather**

[As a star]

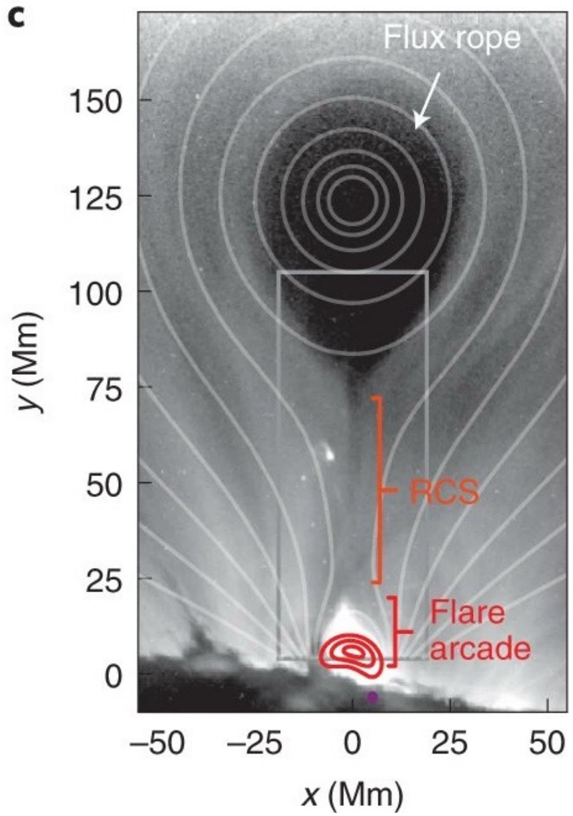
- **Reference of other astrophysical objects**

2011-09-12 05:34:16 UT

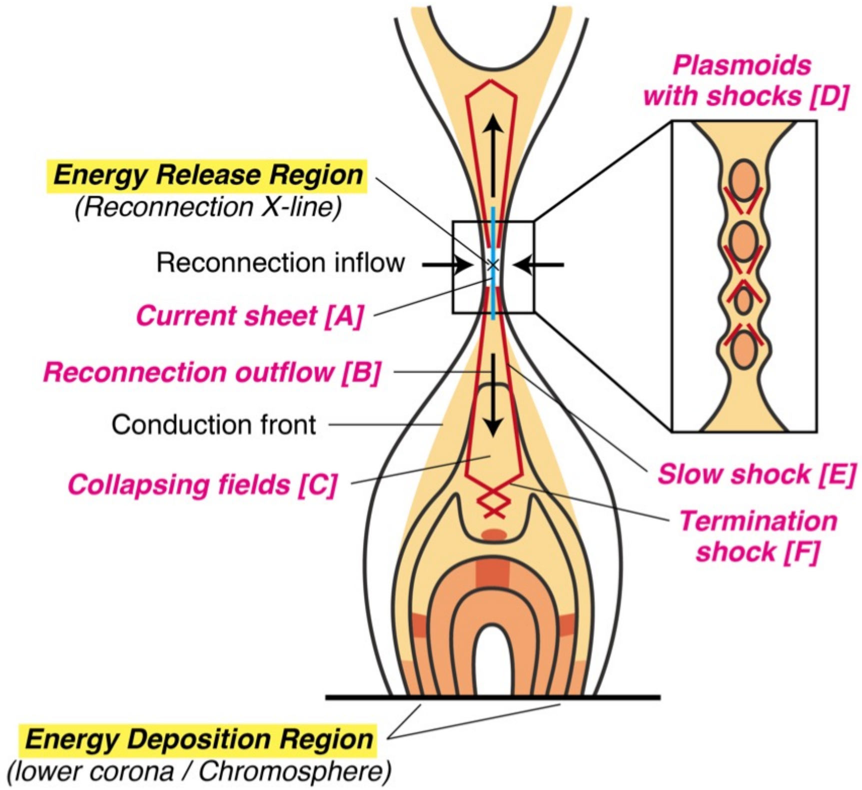
Magnetic Reconnection Picture in Solar Flare

has been established by both observation and theory.

Observation



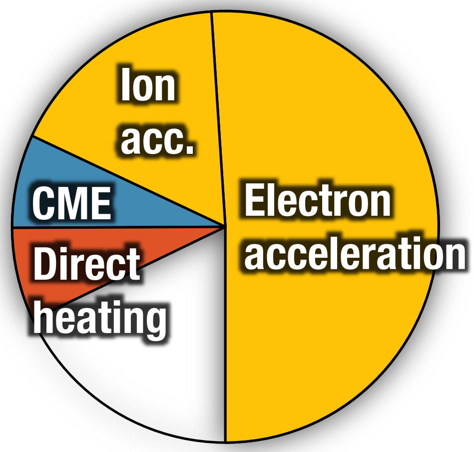
Model



Magnetic reconnection & Particle acceleration in solar flare

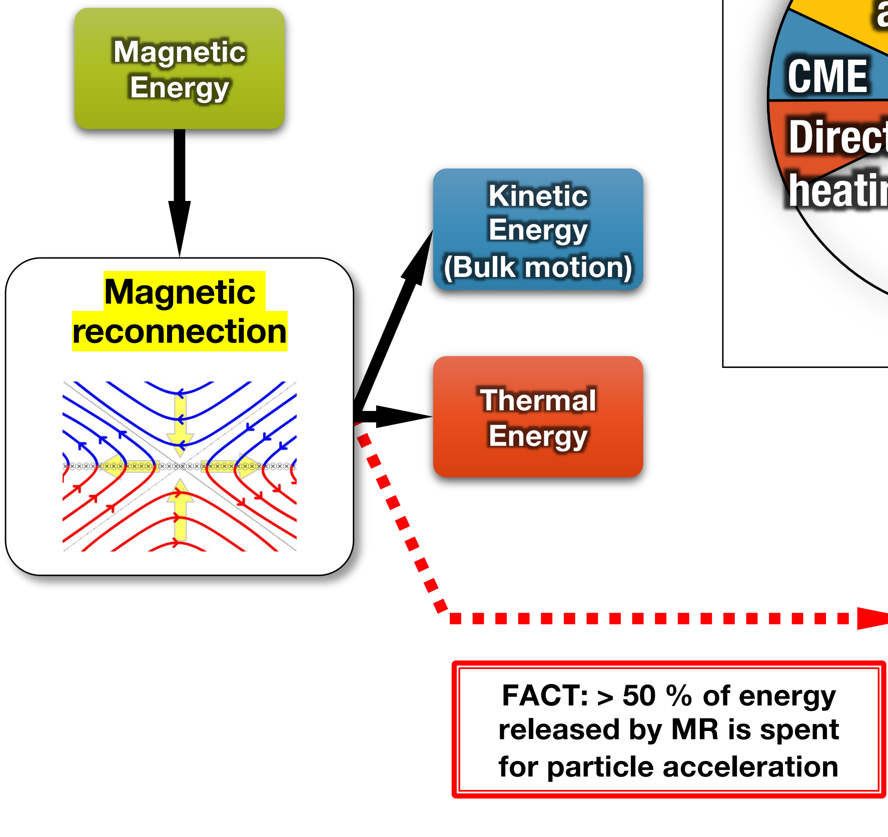
1. A solar flare is an efficient accelerator.

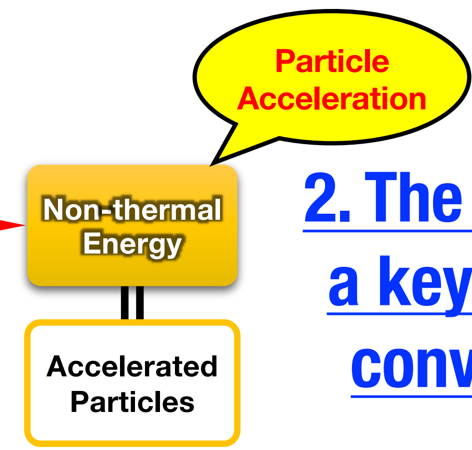
Aschwanden et al. (2017)



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

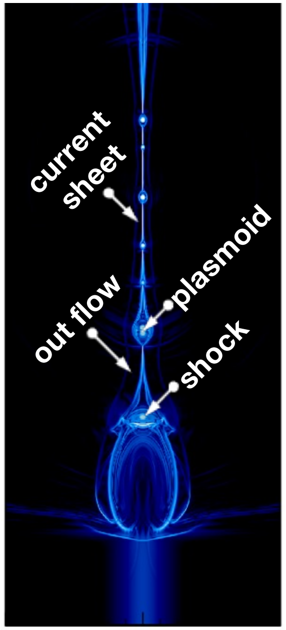
ENERGY CLOSURE :
Sum/magnetic energy = 0.87+0.18

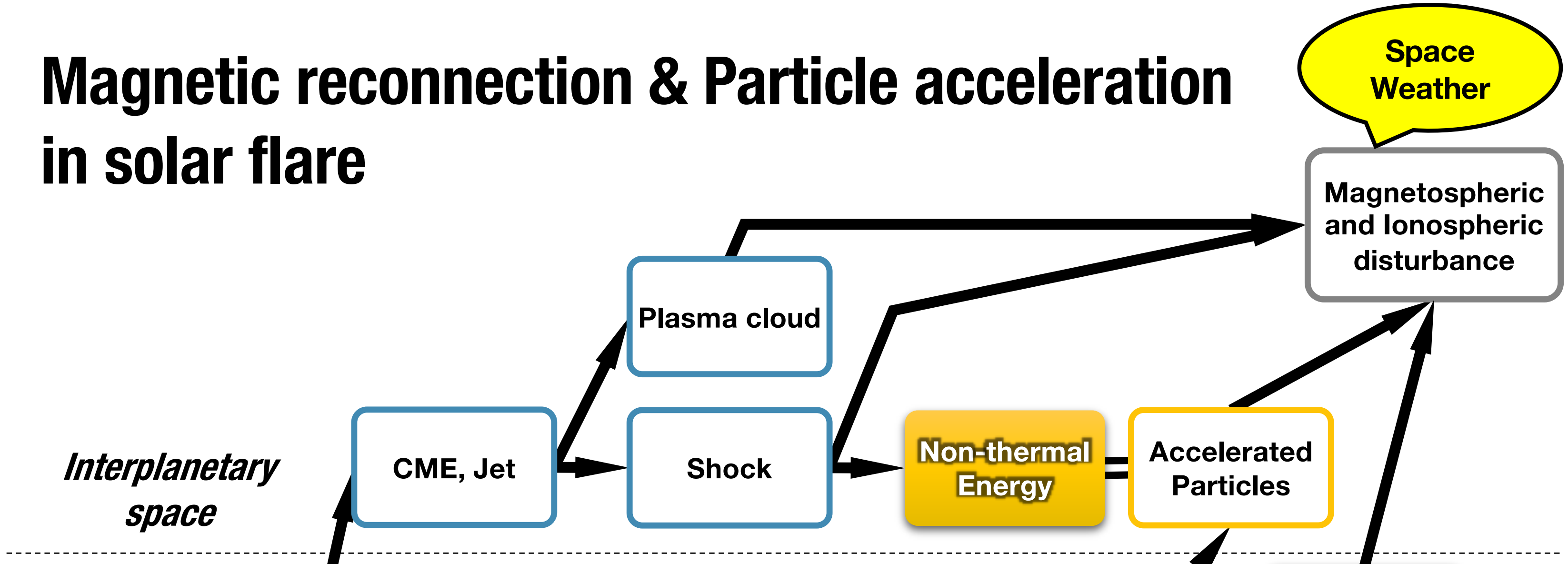


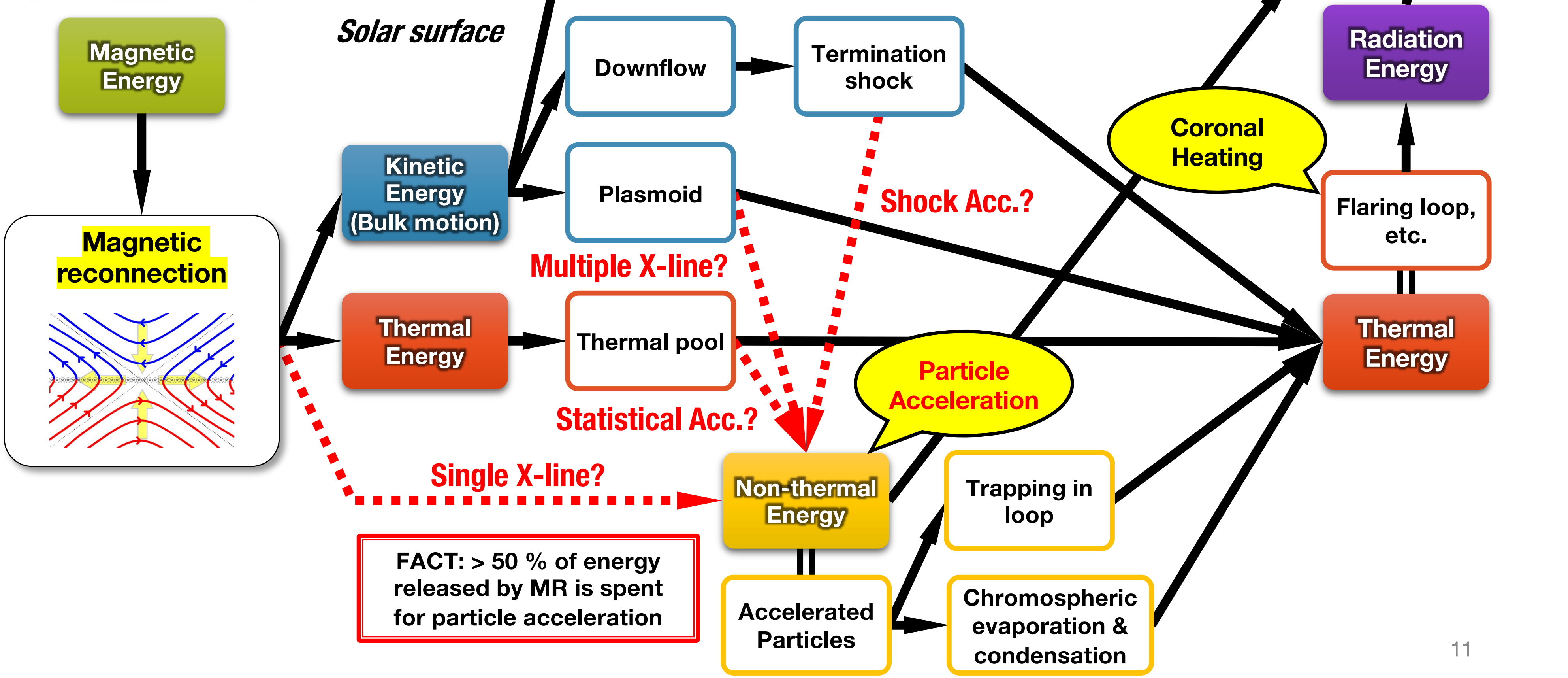


2. The particle acceleration is a key to energy release and conversion in solar flares.

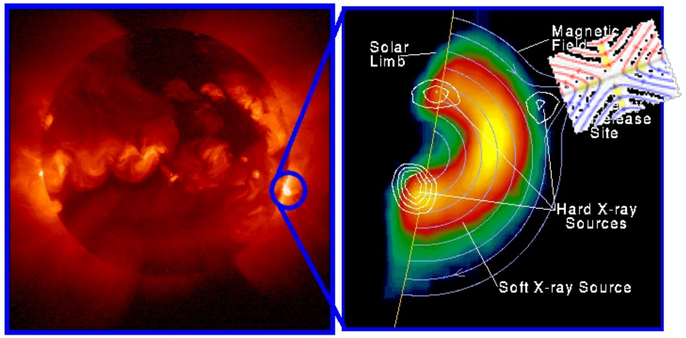
Magnetic reconnection & Particle acceleration in solar flare







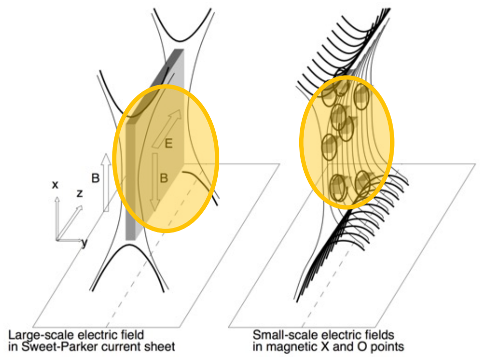
Particle Acceleration is one of the long-standing major puzzles in solar physics



By hard X–ray observations, it is known that the particles are accelerated by solar flares.
But even particle acceleration site is still puzzle.

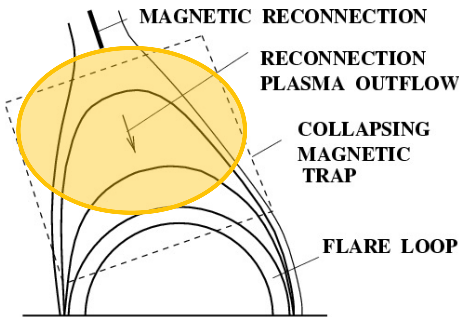
[Reason 1] Poor observations, especially for the energy release region (around the X-point)

DC acceleration?



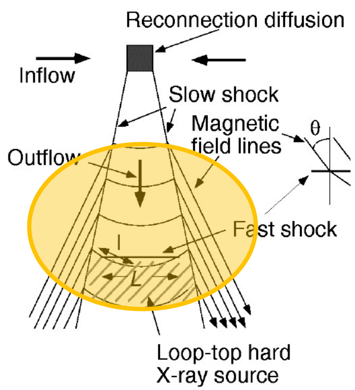
Aschwanden (2002)

Collapsing magnetic traps?



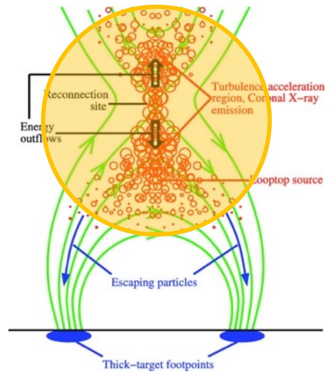
Karlicky & Kosugi (2004)

Shocks?



Tsuneta & Naito (1998)
Takasao & Shibata (2016)

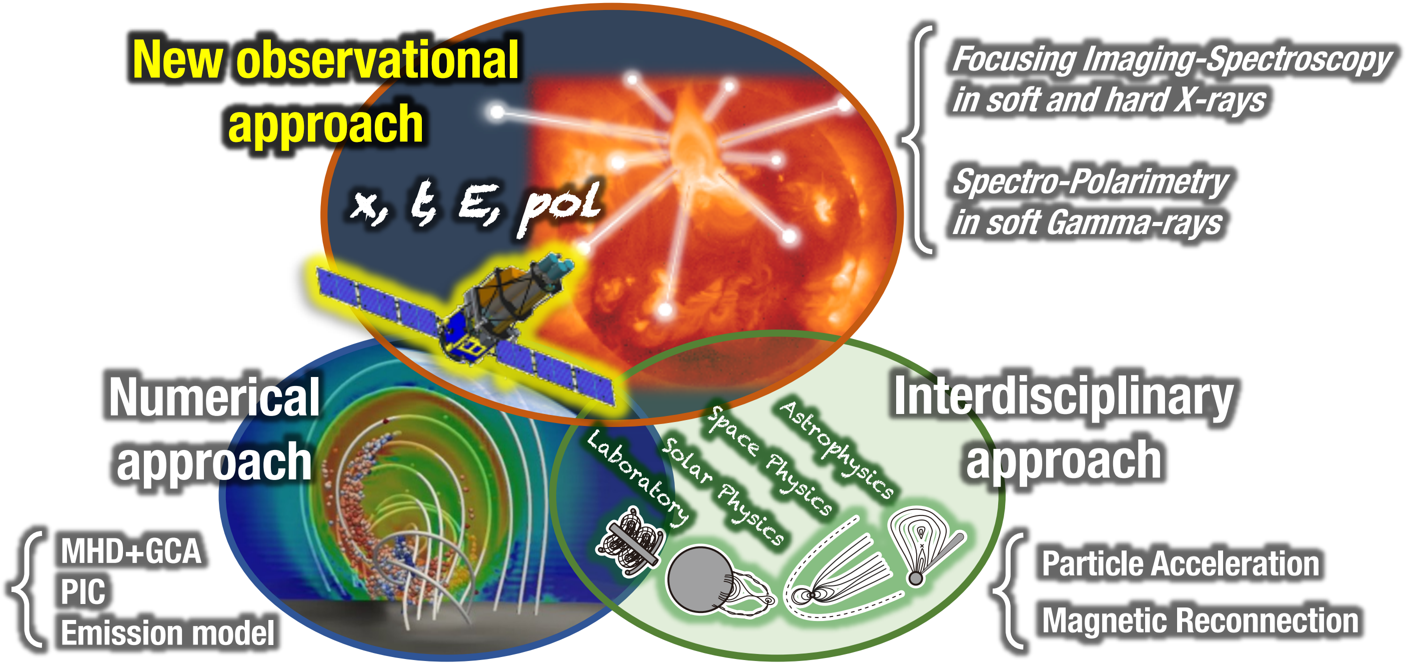
Turbulence?



Liu et al. (2008),
Petrosian, (2012)

Accelerator	**MHD scale**	**~ 10^7 - 10^{10} cm (Size of plasma structures)**	**~ 10 sec (Alfven time)**
Accelerated Particles	**Particle scale**	**~ 10^0 - 10^2 cm (Electron - Ion Larmor radius)**	**<< 1 sec**

[Reason 2] Huge scale gap in both space and time!!



Science Objectives of *PhoENiX* mission

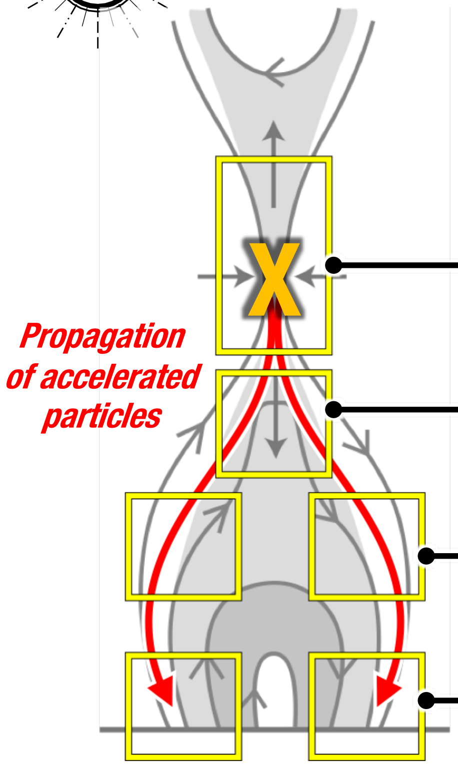
1. Identify particle acceleration sites in solar flares [where]
2. Investigate temporal evolution of particle acceleration [when]
3. Characterize properties of accelerated particles [how]

PHYSICS OF ENERGETIC AND NON-THERMAL PLASMAS IN THE X-REGION
PHOENIX

planned to be realized in Solar Cycle 26 (2030')

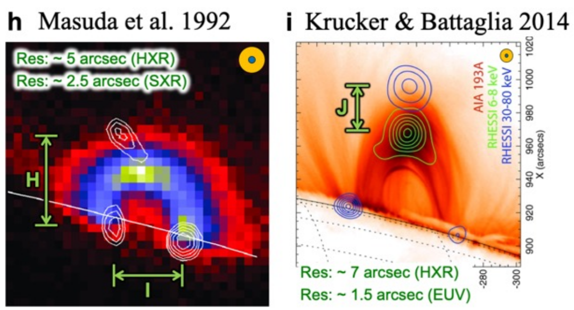
Required measurements to trace the accelerated particles in MHD-scale solar flare system

(Update from past or existing observations)

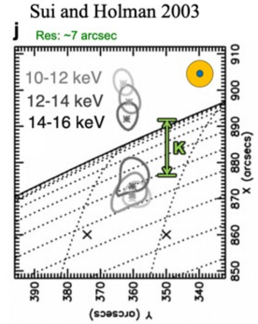


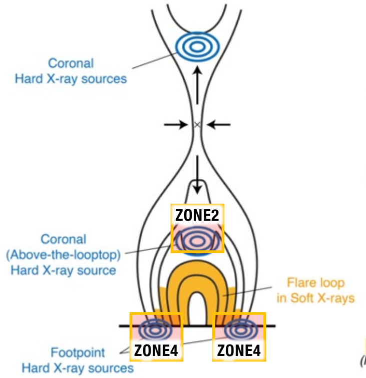
ZONE	Structural characteristic	Property in particle acceleration point of view	Observational capability	
			Past or existing obs.	Requirements for new obs.
ZONE1	Around reconnection site	• Energy release region ➔ Possible acceleration site	Few samples in X-ray obs.	Plasma diagnostic capability for both thermal and non-thermal plasmas in all the ZONEs and capability to track the propagation of accelerated particles
ZONE2	Above-the-loop-top	• Boundary between rare and dense plasmas ➔ Possible acceleration site	Sometimes observed as hard X-ray coronal sources	
ZONE3	Flare loop	• Transit area (• Trapping area ➔ Possible acceleration site)	Few samples in hard X-ray obs.	
ZONE4	Foot points of the flare loop (Solar surface)	• Energy deposition region (• Mirroring region)	Observed in many flares as the brightest hard X-ray source	

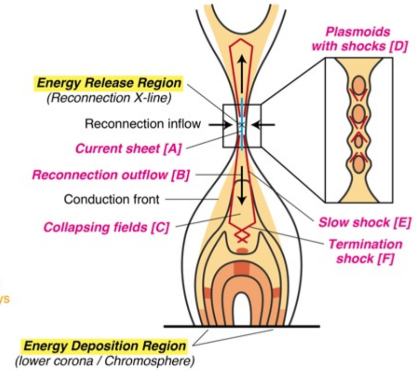
Above-the-looptop & footpoint sources



Double coronal source

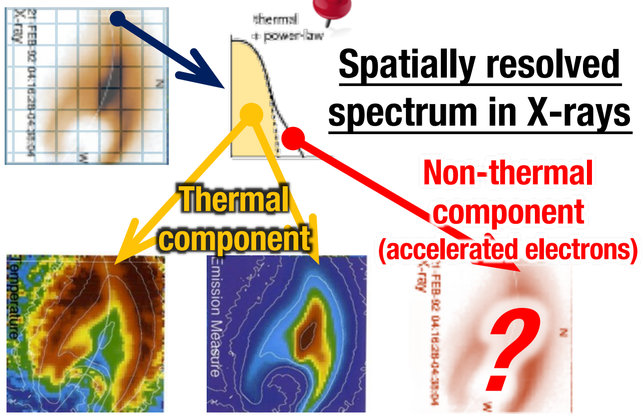




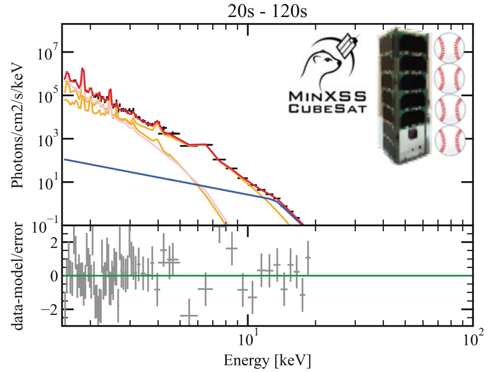


Observational Approach for Scientific Objectives

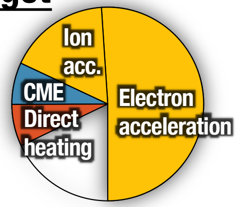
Spatially resolved spectrum in X-rays



Temporal evolution of spectrum



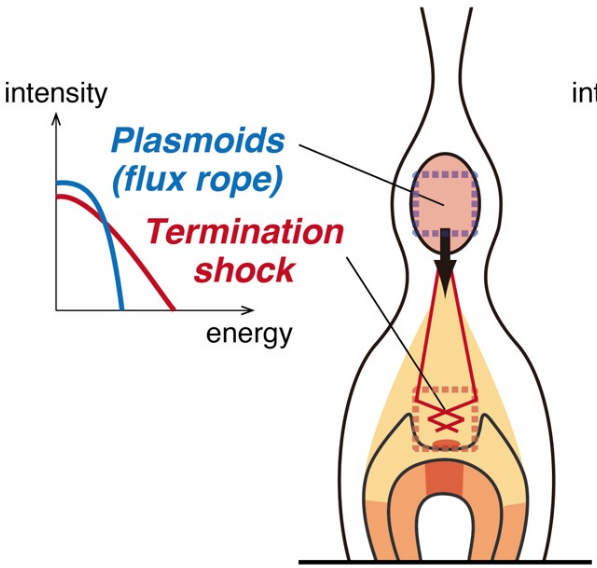
Energy transportation & budget



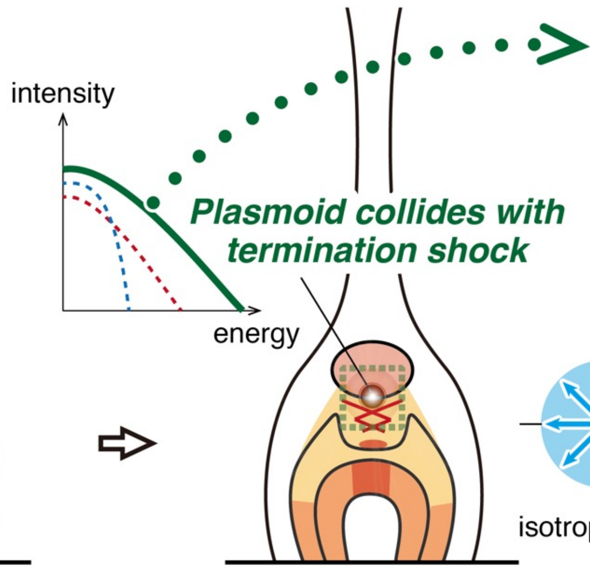
- Released magnetic energy $= E_{B\_pre\text{-}flare} - E_{B\_post\text{-}flare}$

- Kinetic energy of bulk plasma $= 1/2\ N_p\ m_p\ v^2$
- Thermal energy $= \int 3/2\ N\ k_B\ T\ \underline{dT}$
- Energy of accelerated particles $= \int N_{NT}\ E_{NT}\ \underline{dE}$

Scientific Objective 1 where?



Scientific Objective 2 when?



Parameters obtained from spectroscopy

Power-Law Index
Relative Intensity
Lower/Higher Energy Cut-off
Break Energy

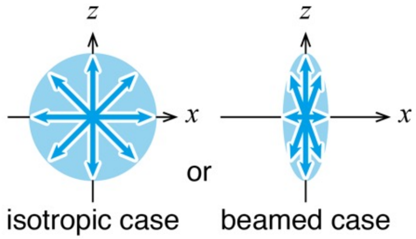
Theory / Model

Numerical Simulation

Laboratory Experiment

Comparison with other observations than solar

Scientific Objective 3 how?



Parameters obtained from polarimetry

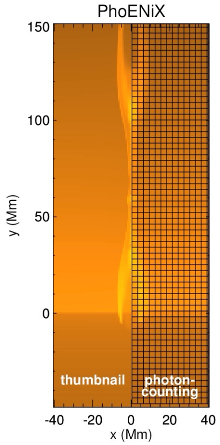
Direction of polarization
Degree of polarization

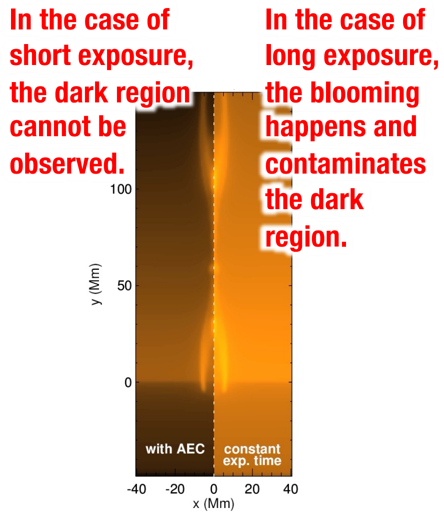
Why X-rays and Gamma-rays?

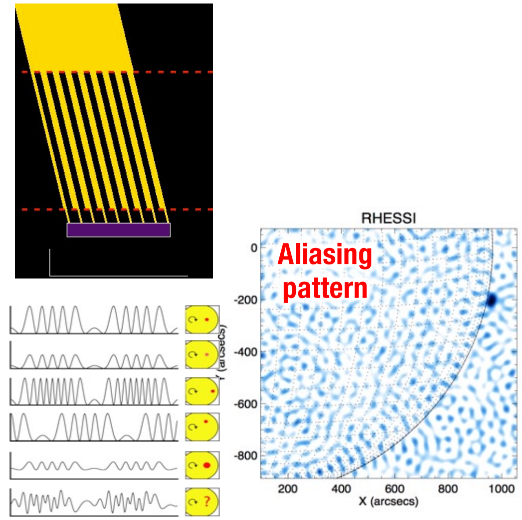
– comparison with spectroscopy in other wavelengths

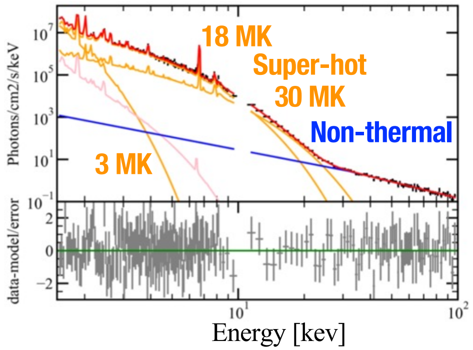
Significant	New by PhoENiX	Collaboration

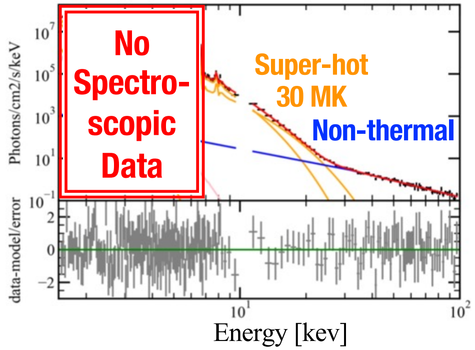
Wavelength	EUV	Soft X-rays	Hard X-rays	Gamma-rays	Radio
Energy	< 0.1 keV	0.1 – 10 keV	10 – 100 keV	0.1 – 1 MeV	0.1 – 1 MeV
Common properties					
Dynamic range	✅✅	✅✅✅	✅✅✅		✓
Field of view	✅✅	✅✅✅	✅✅✅		✅✅✅
Spatial sampling	✅✅✅	✅✅	✅✅		✓
Temporal sampling	✅✅	✅✅✅	✅✅✅	✅✅✅	✅✅✅
For investigation of thermal plasmas (possible agents of particle acceleration)					
Temperature diagnostic capability	✅✅✅	✅✅✅	✅✅		
Response speed to temperature change	✓	✅✅✅	✅✅✅		
Velocity measurement of bulk plasma	✅✅✅	✅✅	✅✅		✓
For investigation of non-thermal plasmas (particle acceleration)					
Accelerat<u>ing</u> electrons	(✓)	✅✅✅	✓		
Accelerat<u>ed</u> electrons	(✓)	✓	✅✅✅	✅✅✅	✅✅✅
Low energy cutoff		✅✅	✓		
Maximum energy				✅✅	
Electron anisotropy				✅✅	✓
Magnetic field measurement					
Magnetic field measurement					✓

<table>
<tr><th>Capability</th><th>PhoENiX</th><th colspan="2">Other (past or existing) X-ray missions</th></tr>
<tr>
<td><u>Dynamic Range</u>
To observe entire ZONEs</td>
<td>

[SXR & HXR]
Focusing optics (mirror)
+ CMOS or CdTe</td>
<td>

[SXR]
Focusing optics (mirror)
+ CCD</td>
<td>

[HXR]
with modulation collimator</td>
</tr>
<tr>
<td><u>Imaging Spectroscopy</u>
SXR:
• Thermal plasma
• Accelerating e⁻
• Low energy cutoff
HXR:
• Accelerated e⁻</td>
<td>

[SXR & HXR]
Imaging spectroscopy</td>
<td colspan="2">

[SXR]
Mainly Imaging only
[HXR]
Imaging spectroscopy</td>
</tr>
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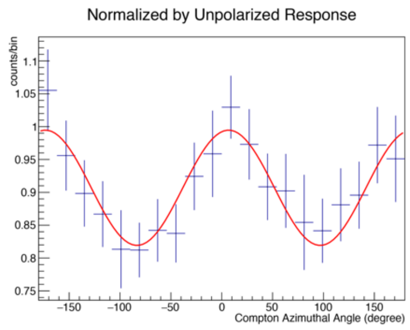
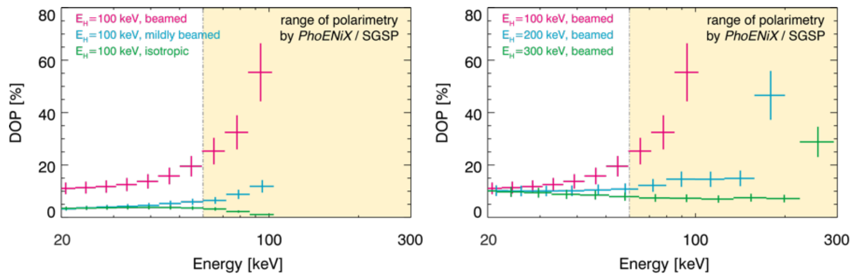
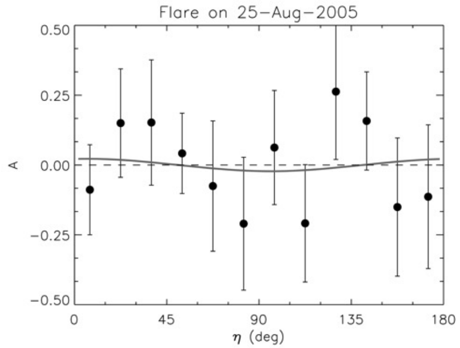
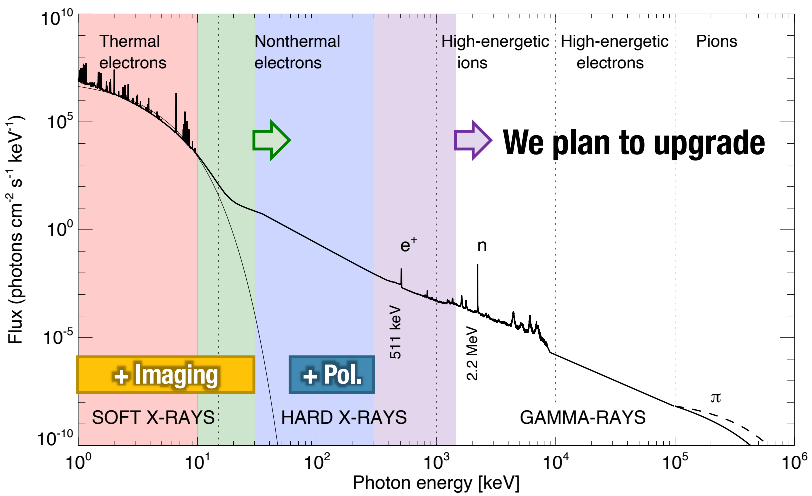
Capability	PhoENiX	Other (past or existing) X-ray missions
Polarization • **Electron anisotropy** (velocity angle to the guiding magnetic field) • **High energy cutoff** (highest energy electrons produced by the acceleration conditions: mechanism, spatial extent, and time)	 **Minimum detectable polarization degree < 10%** **🡐 Expected modulation polarization with PhoENiX for 60 – 300 keV in an M3.4 flare. Assumed polarization degree is 20%.**  Jeffrey et al. (2020)	**Polarization = 6 ± 25% for 100 – 350 keV in M7 flare**  Suarez-Garcia et al. (2006) There are some studies to estimate the polarization in solar flares with RHESSI. But <u>RHESSI is not designed (calibrated) to derive the polarization.</u>
Energy Coverage		

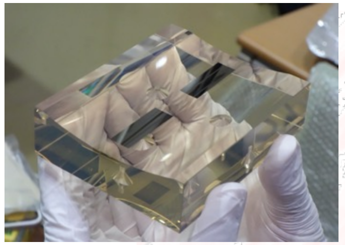
Specification of the PhoENiX instruments

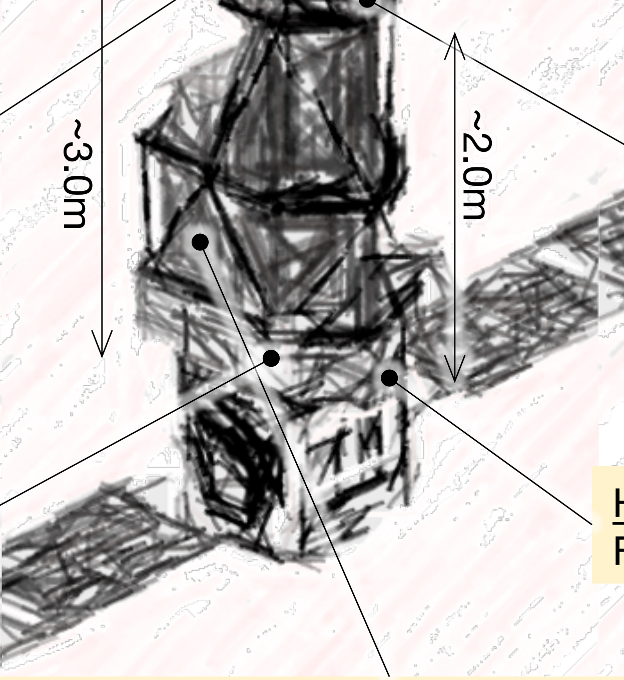
observational capability	Requirement	Rationale
Requirements for observing solar flares (common requirements for observations in all energy bands)		
FOV	**> 360×360 arcsec^2**	The entire flare area must fit in the field of view.
Observation time	**> 10 minutes**	At least, to observe from pre-flare to the peak of flare.
Temporal resolition	**< 10 sec per spectrum** **< 1 sec per light curve**	For the spectrum, it is specified by the Alfvén time; For the light curve, it is specified by the propagation time of accelerated electrons.
Requirements for investigating the plasma structure produced by flare systems and the electron population during acceleration: Soft X-ray imaging spectroscopy		
Energy coverage	**0.5 keV – 10 keV**	To obtain the temperature of the plasma structure (thermal spectrum) and information about the electrons under acceleration (spectrum deviating from the thermal distribution).
Energy resolution	**< 0.2 keV (FWHM)**	To distinguish the emission line group and the continuum component
Spatial resolution	**< 2 arcsec (FWHM)**	Since the structures produced by magnetic reconnection contain scale-free ones, we set the requirements for spatial resolution as follows: For large scale flares (~10^5 km ~ 140"), plasma structures should be identified by resolving each Zone. For small flares (~10^4 km ~ 14"), at least the flare region can be resolved into Zones 1 to 4.
Dynamic range	**> 10^4**	To observe all the Zones even when the flare loops increase in intensity
Photon number per spectrum	**> 1600 photons**	To suppress the measurement error of temperature and density to 10% or less
Requirements for detecting accelerated electron populations and tracking their propagation: Hard X-ray imaging spectroscopy		
Energy coverage	**5 keV – 30 keV**	To obtain information on accelerated electrons (power spectrum deviating from thermal distribution)
Energy resolution	**< 1 keV (FWHM)**	To detect components with different acceleration states (broken power law spectrum)
Positioning accuracy	**< 2 arcsec**	It is crucial to determine the position of the accelerating electrons in the spatially resolved plasma structure (candidate acceleration source). The accuracy of this determination should be the same as the spatial resolution required to investigate the plasma structure. To achieve this accuracy, the spatial resolution should be twice as high as that required to the positioning accuracy.
Spatial resolution	**< 4 arcsec (FWHM)**	
Dynamic range	**> 10^3**	To observe all the Zones even when the foot point of loop increase in intensity
Photon number per spectrum	**> 3200 photons**	To suppress the measurement error of the total number of accelerated electrons to a factor of 2 or less
Requirements for investigating the anisotropy of accelerated electron motion and the maximum energy: Soft gamma-ray spectropolarimetry		
Energy coverage	**20 keV – 300 keV, a few MeV**	To obtain information on electrons accelerated to higher energies
Energy resolution	**< 10 % (FWHM)**	To detect components with different acceleration states (broken power law spectrum)
Lower limit of detectable polarization	**< 10 % in >M5 class flares**	To evaluate the anisotropy of the accelerated electron motion. Note that due to the measurement method, the energy range of the polarization measurement is 60 keV - 300 keV.
Photon number per spectrum	**> 500 photons**	To achieve the above polarization measurement accuracy

Instruments and Key technologies of PhoENiX

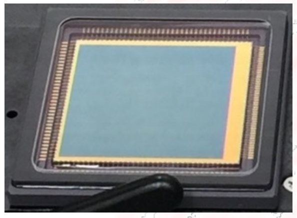
The basic developments of these technologies have been completed.

Soft X-ray Imaging Spectrometer (0.5 keV ~ 10 keV)



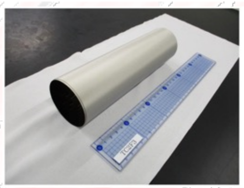


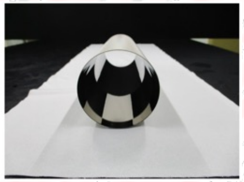
High-precision X-ray mirror
Resolution: < 2 arcsec
Low scatter: 10^{-4} @ 20 arcsec

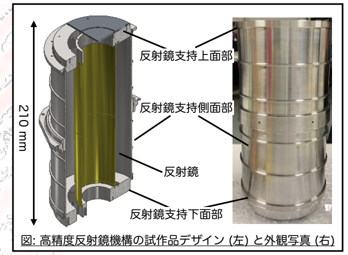


High-speed soft X-ray camera
Back-illuminated CMOS sensor

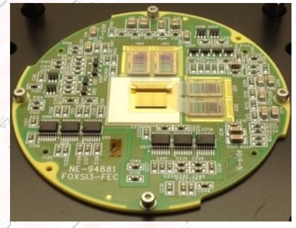
Hard X-ray Imaging Spectrometer (5 keV ~ 30 keV)







Large effective area X-ray mirror
Resolution: < 4 arcsec (FWHM)

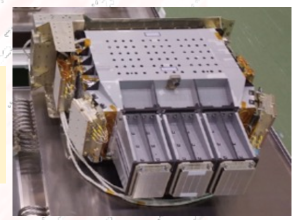


High-sensitivity hard X-ray camera
Fine-pitch CdTe detector

Soft Gamma-ray SpectroPolarimeter

(20 keV ~ > 300 keV (> 1 MeV))

Si/CdTe Compton camera with active shield
Polarization measurement: > 60 keV



FOXSI sounding rocket series

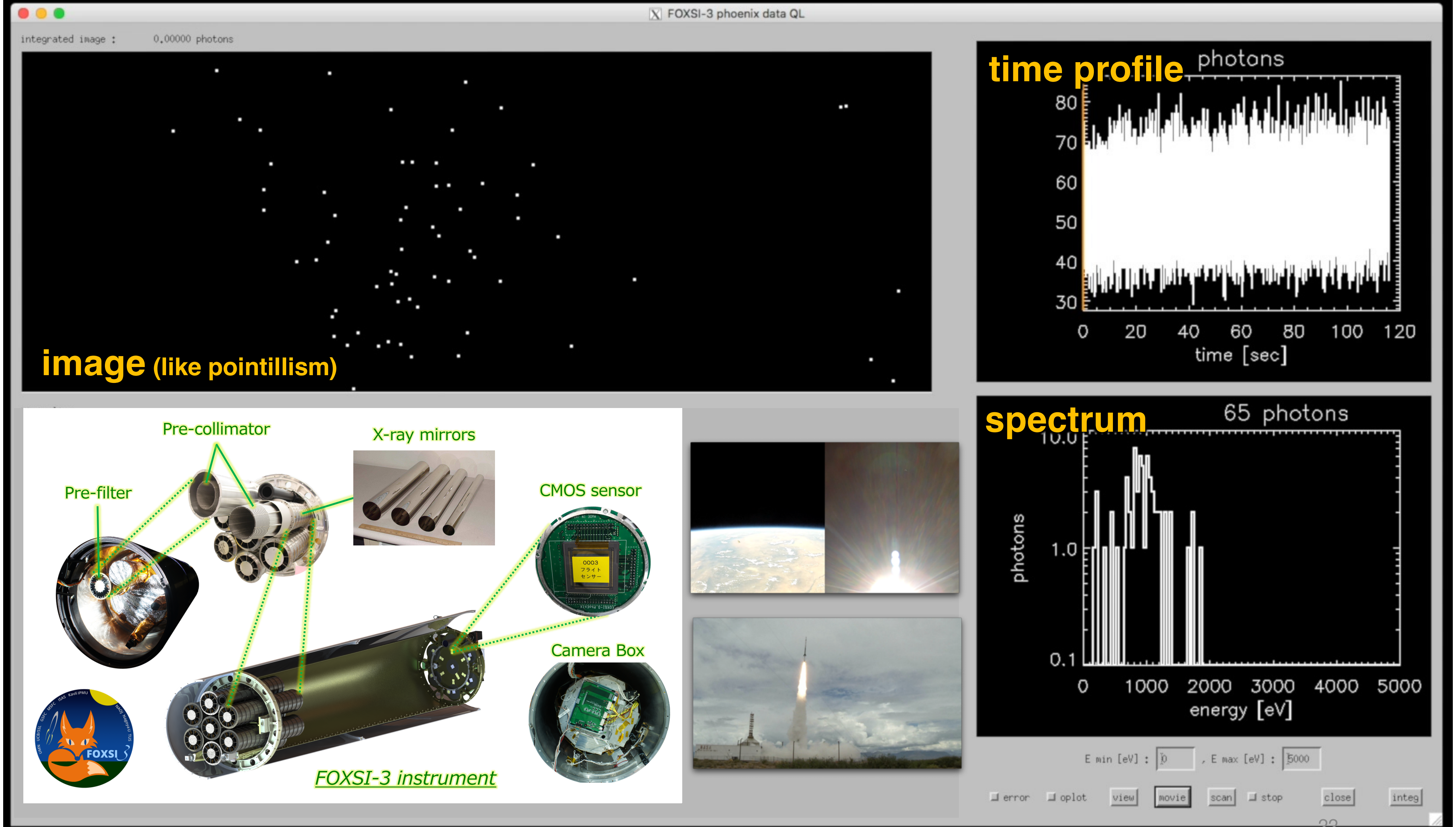
– Demonstration of SXIS & HXIS of PhoENiX

TODAY

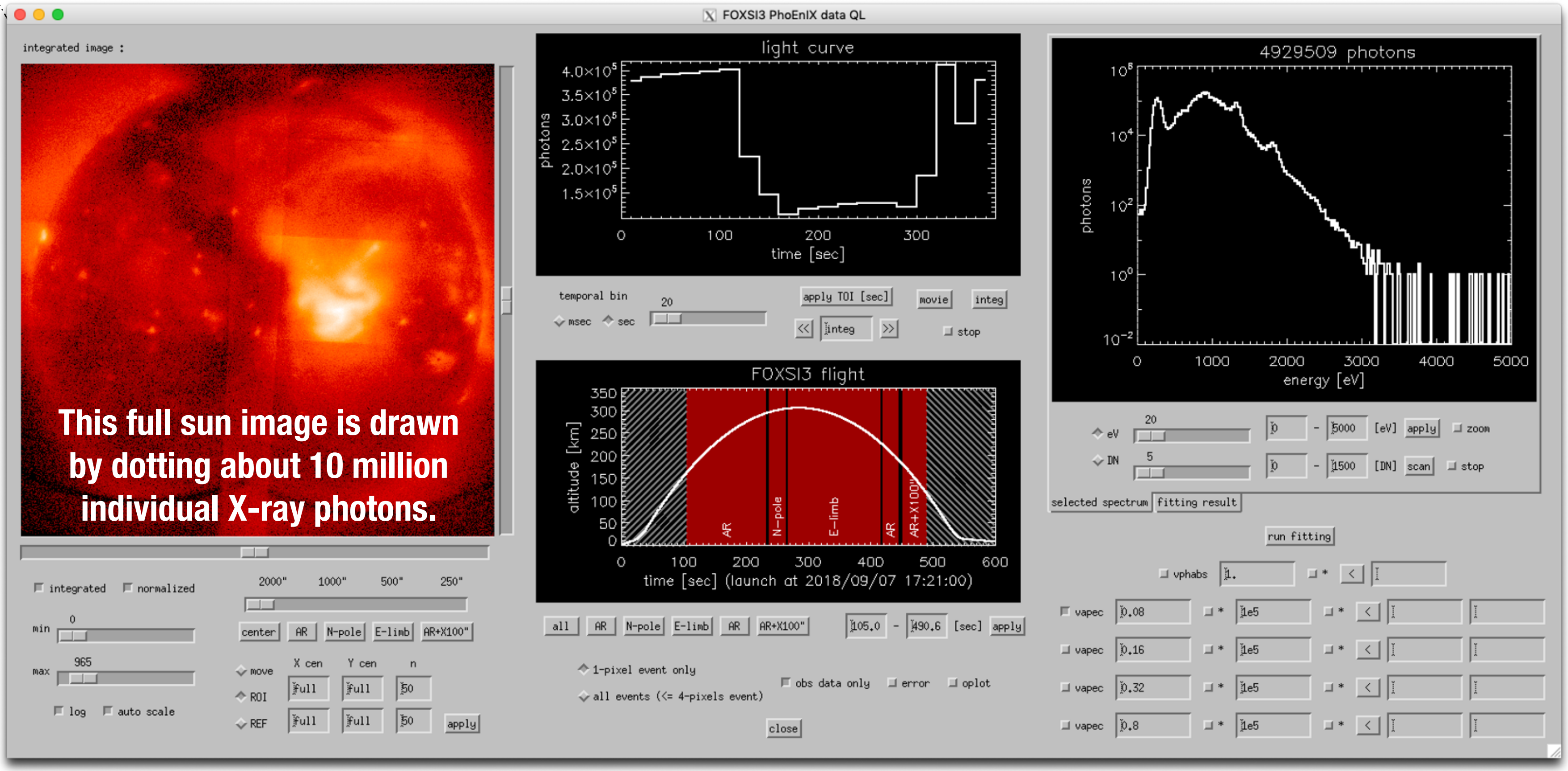
	FOXSI-1 in 2012	*FOXSI-2 in 2014*	*FOXSI-3 in 2018*	*FOXSI-4 in 2024*
Obs. target	Quiet sun	Active region and Quiet sun	Full sun including Active region	**Solar flare**
Energy range	**Hard X-rays 5〜30 keV** (→)	(→)	**Soft X-rays 0.5〜10 keV** (→) / (→)	(→) / (→)
Telescope	**7 shells x 7 modules**	**10 shells x 2 modules** 7 shells x 5 modules	(10 shells + **blocker**) x 1 (7 shells + **collimator**) x 2 10 shells x 3 modules 7 shells x 1 modules	**high resolution optics x 5** 10 shells x 2 modules
Detector	**Si (7.7 arcsec) x 7** **[for hard X-rays]**	**CdTe (6.7 arcsec) x 2** Si (7.7 arcsec) x 5 [for hard X-rays]	CdTe (6.7 arcsec) x 2 Si (7.7 arcsec) x 4 [for hard X-rays] + **CMOS (1.1 arcsec) x 1** **[for soft X-rays]**	CdTe (6.7 arcsec) x 5 [for hard X-rays] + CMOS (1.1 arcsec) x 2 [for soft X-rays]

FOXSI-3 Soft X-ray data

250 FPS data (4 ms continuous exposure)



Data analysis software

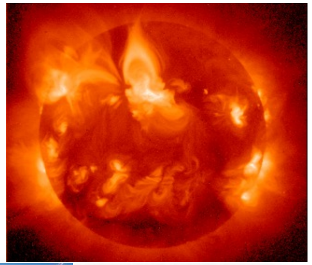


Data analysis software (GUI tool) for FOXSI-3

1. Selection of area, timing and energy range
2. Adjustment of binning for space, time and energy
3. Spectral fitting with *Xspec*

This version is developed with IDL, which is widely used in solar physics community.

FOXSI-4 sounding rocket project :
It's time to observe a flare!!



First sounding rocket to observe a solar flare

Science objectives:

1. Determine how much particle acceleration occurs in the gradual phase of a flare
2. Produce images and spectra of flare footpoints from thermal to non-thermal energies
3. Determine where non-thermal sources and heated plasma are located in a given coronal configuration
4. Measure the spatial distribution of superhot sources in a flare
5. Identify locations of energetic electrons in an erupting CME

- Method: Focusing imaging spectroscopy in X-rays (update of FOXSI-3 observation)

OVERALL GRADE (mark panel overall score with "X")

	Excellent	E/V G	Very Good	VG/ G	Good	G/F	Fair	F/P	Poor
'X': Overall grade.	X								

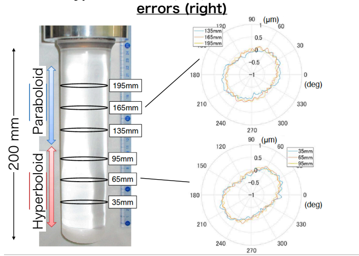
	July, 2020	2021	2022	2023	2024
Schedule	Proposal was accepted by NASA	Design & Development	Fabrication & Test	Integration & Test	Launch!!

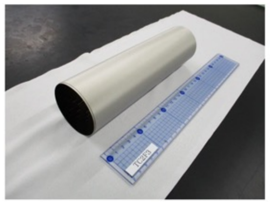
FOXSI-4 sounding rocket project

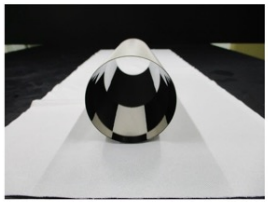
High-precision electroformed X-ray mirror

Goal (cf. FOXSI-3)
- <10" HPD (← 25" HPD)
- <4" FWHM (← 5" FWHM)

Wolter type I mandrel (left) and circumferential errors (right)







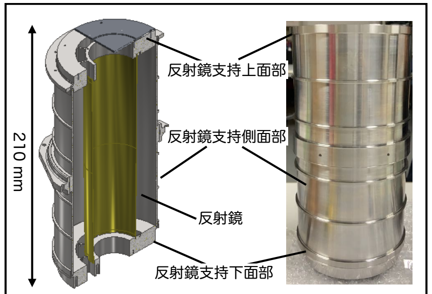
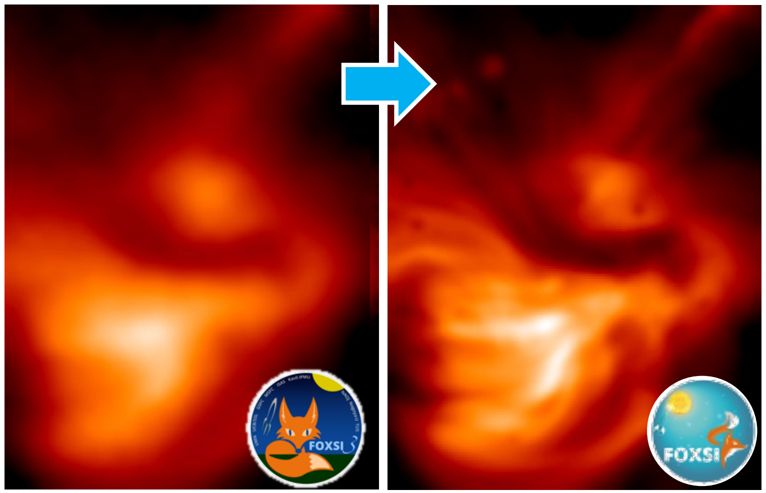


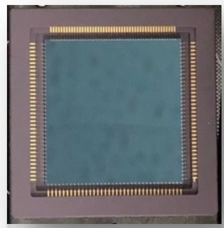
図: 高精度反射鏡機構の試作品デザイン (左) と外観写真 (右)

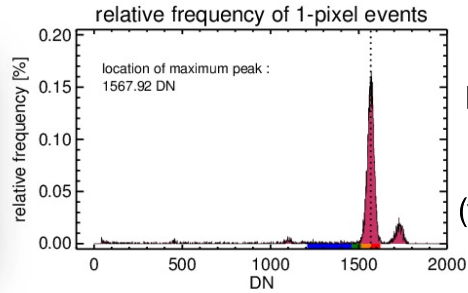


Updated CMOS (for soft X-rays) & CdTe (for hard X-rays) detectors

CMOS detector (cf. FOXSI-3)

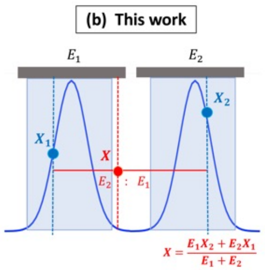
25 um depletion layer thickness (← 4 um) for
- Higher sensitivity to high-energy X-rays
- Higher robustness against X-rays

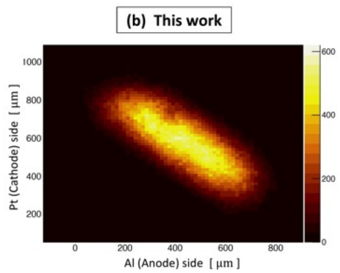




Photon counting capability of CMOS (with ^{55}Fe source)

CdTe detector (cf. FOXSI-3)
- Position resolution (~30 μm ← 60 um)
- High Count Rate (~5 k events / s / detector ← 500 events / s / detector)

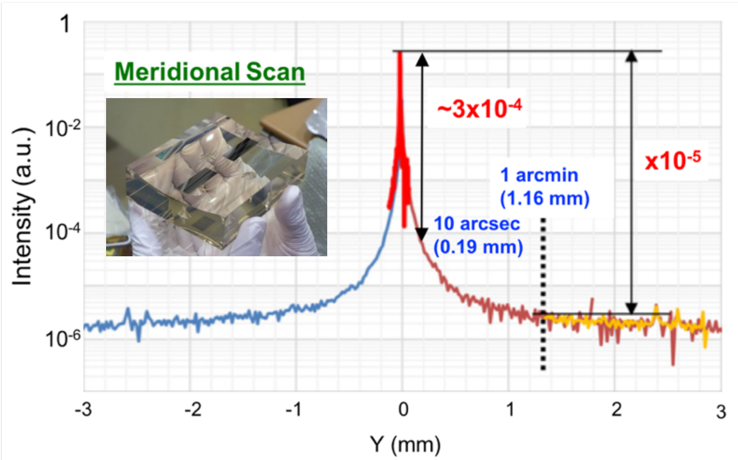


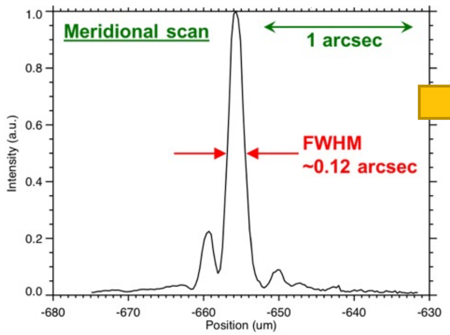


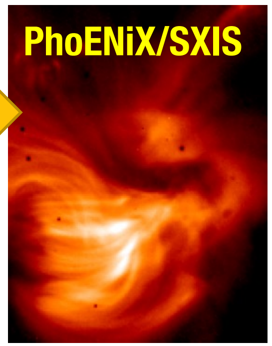
Sub-strip resolution (Furukawa et al., 2020)

Development of key technologies
– Soft X-ray mirror, Soft Gamma-ray spectropolarimeter

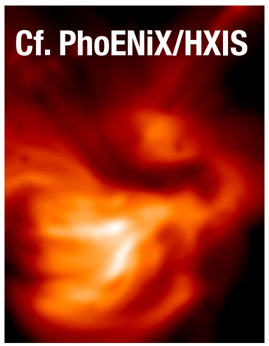
High precision soft X-ray glass-polished mirror





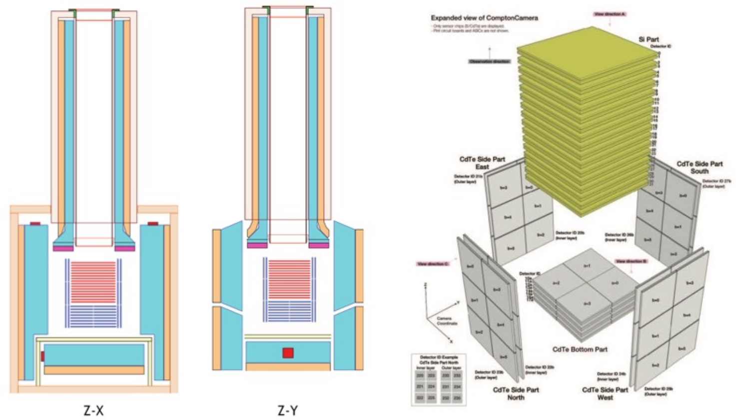


< 2” FWHM
(Hinode/XRT)

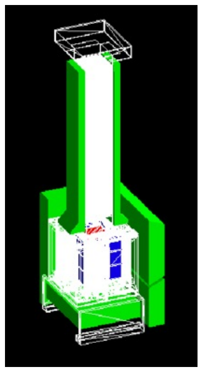


< 4” FWHM
(previous page)

Si/CdTe Compton camera with active shield

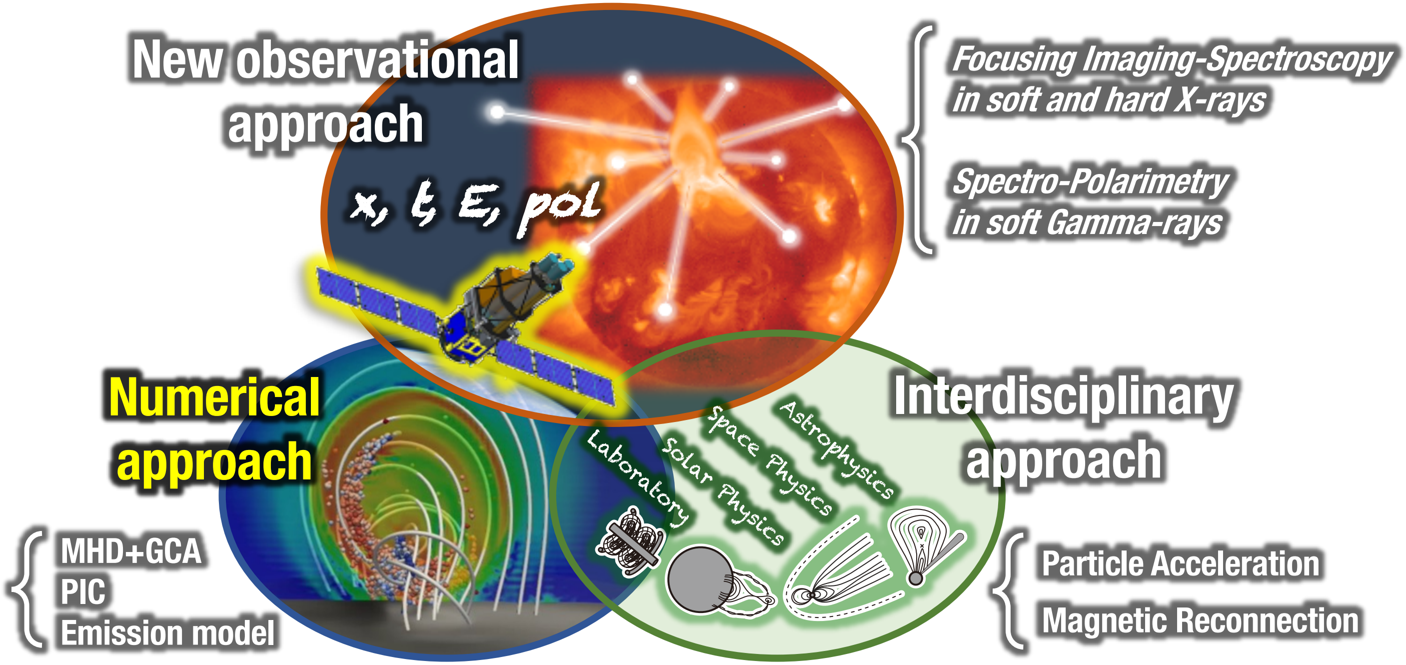


Design for PhoENiX: 1CC



BGO design as

- Active shield for **polarimetry**
- Detector to evaluate **maximum energy** (for above MeV detection)



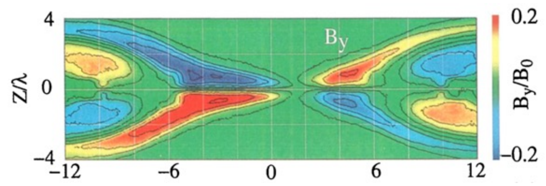
Science Objectives of *PhoENiX* mission

1. Identify particle acceleration sites in solar flares [where]
2. Investigate temporal evolution of particle acceleration [when]
3. Characterize properties of accelerated particles [how]

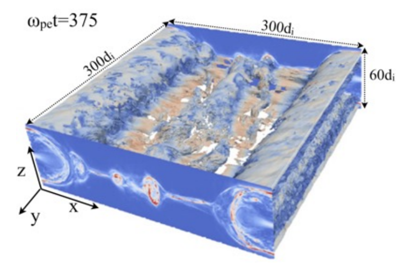
PhoENiX: Physics of Energetic and Non-Thermal Plasmas in the X-region

planned to be realized in Solar Cycle 26 (2030')

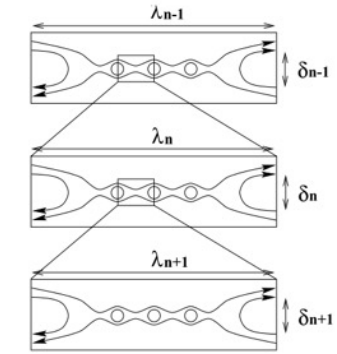
Numerical Approach



λ ~ 10 (Hoshino et al. 2001)



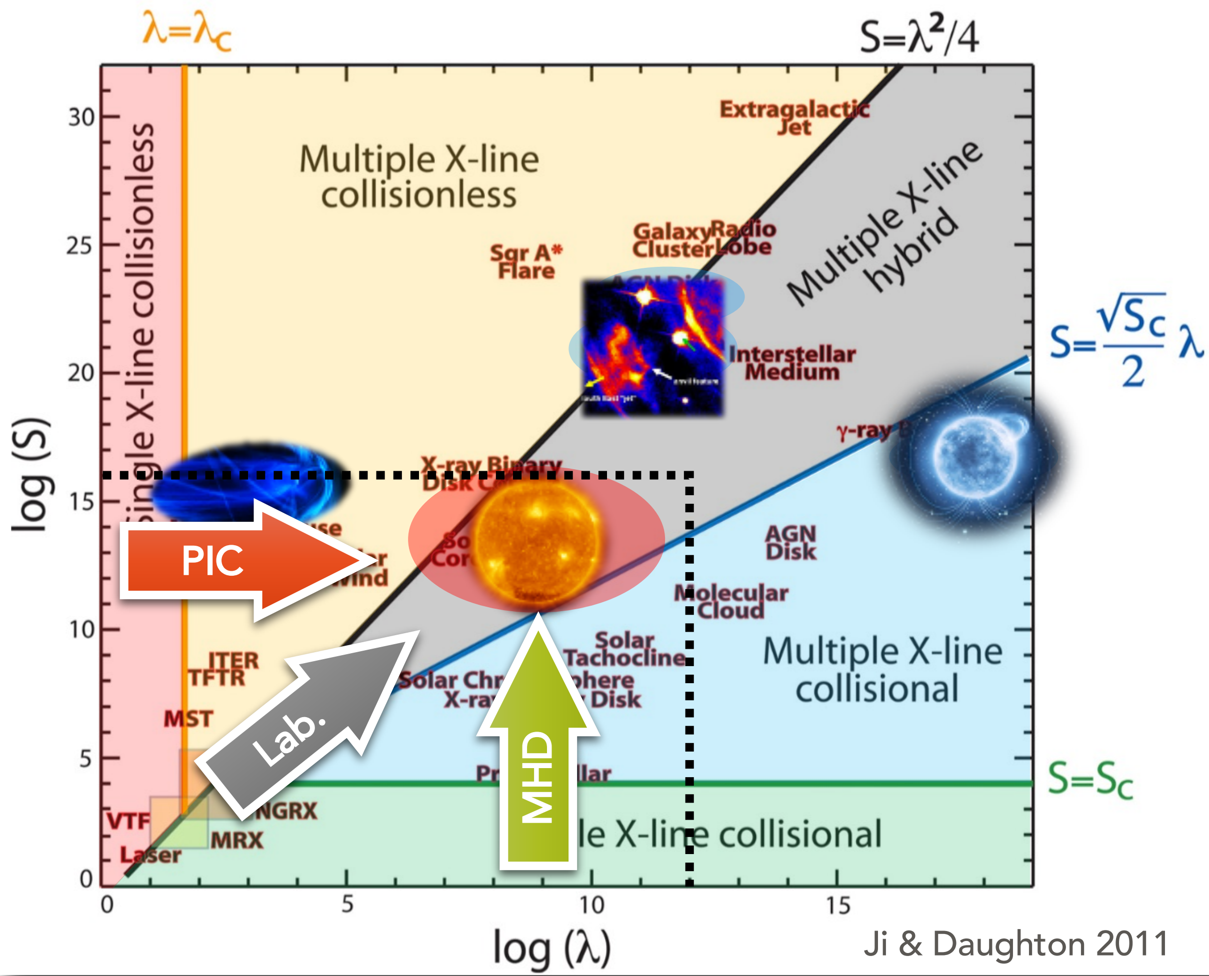
λ ~ 100 (Guo et al. 2015)

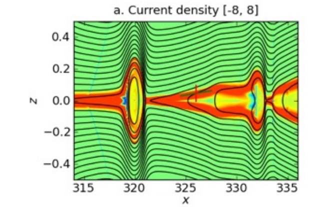


Model of Shibata & Tanuma 2001

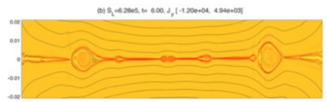
Lundquist number

$$S \equiv \frac{\mu_0 V_A L_{CS}}{\eta}$$

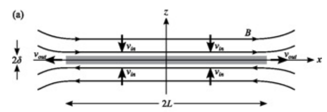




Dynamical Petschek
S < 10^6
(Shibayama et al. 2015)

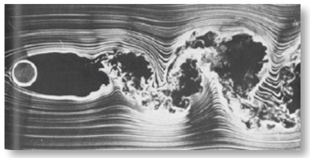


Plasmoid chain MR
10^4 < S < 10^6

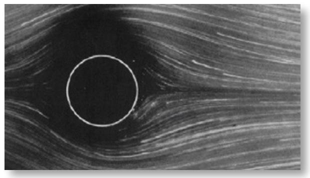


Sweet-Parker model
S < 10^4

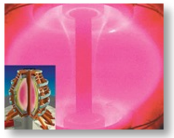
Cf. Reynolds number



R_e = 10^4

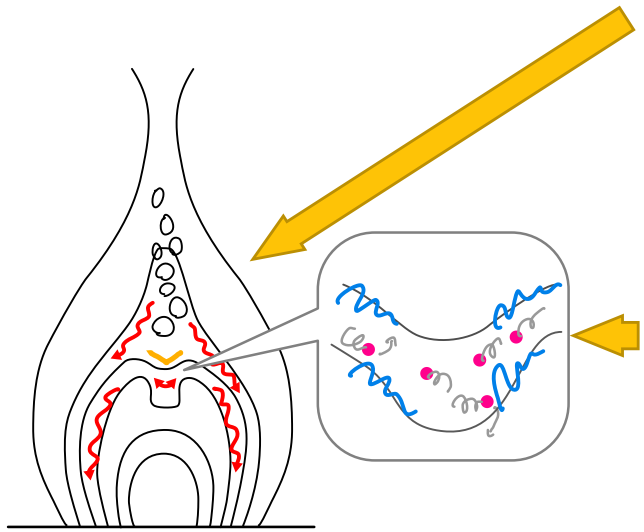


R_e = 1.54



Effective plasma size $\lambda \equiv \dfrac{L}{d_i}$

Strategy of numerical approach



- **MHD calculation (~ 10^7 - 10^{10} cm) + test particle**
  - Determine global energy release process
  - Provide the magnetic field and velocity field structures (boundary conditions of particle calculations)
    - e.g., **Shocks, Magnetic mirror**
- **Particle calculation (~ 10^0 - 10^2 cm)**
  - e.g., **Scattering processes via the wave-particle interaction**, etc.

  →For example, pick up local regions and study acceleration & trapping processes using kinetic models (e.g., PIC)

- **Comparison between numerical simulation and observation**
  - via emission model
    - **Energy spectrum ⇔ Photon spectrum**
    - **Electron anisotropy ⇔ Polarization,** etc.

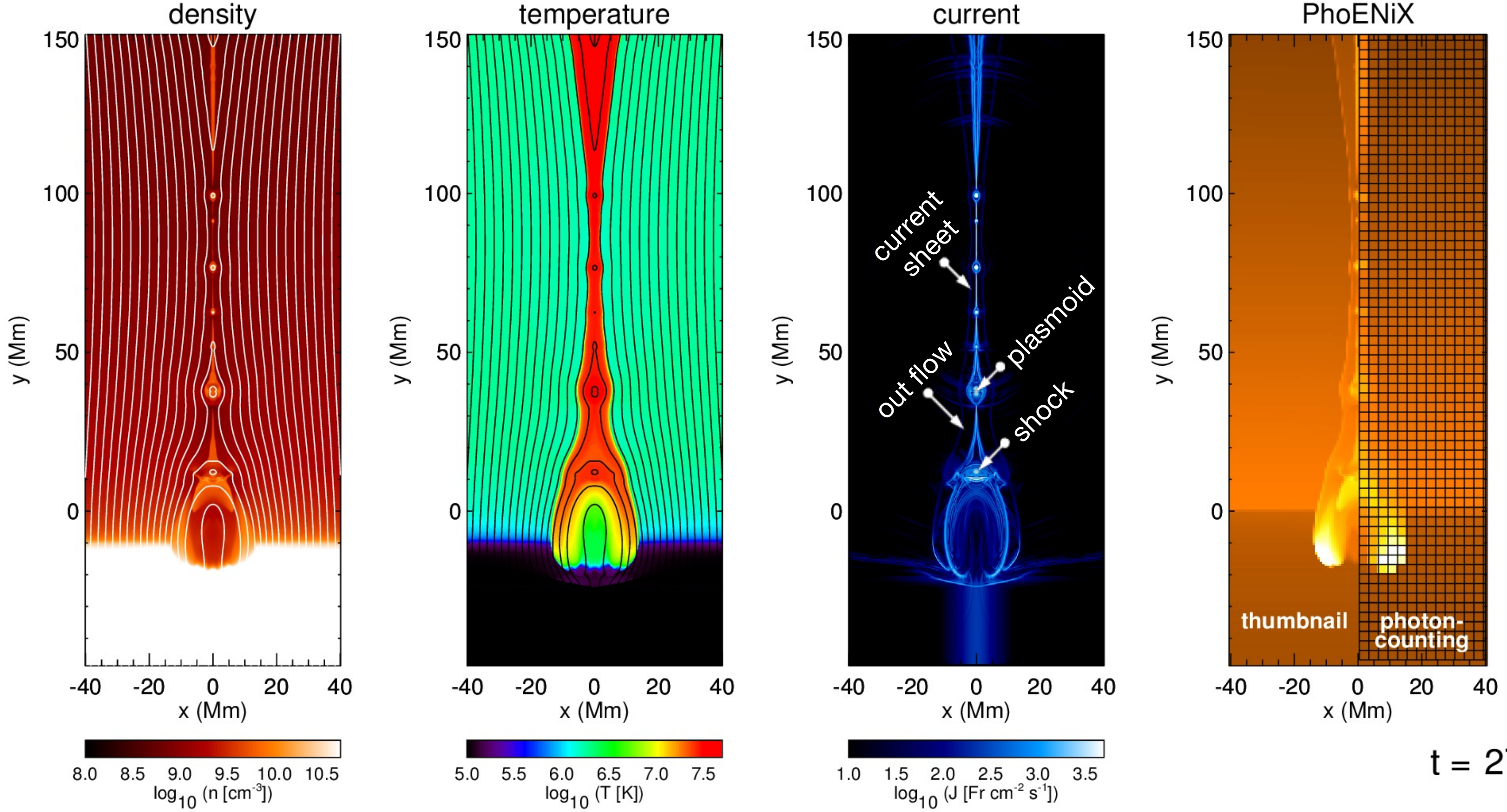
Numerical Approach in macro scale

MHD for understanding of ambient plasma

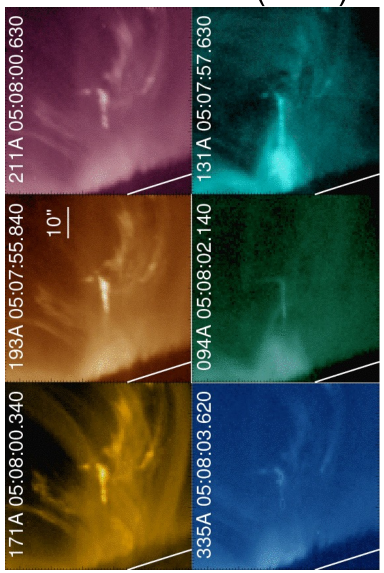
MHD simulation of a solar flare (magnetic reconnection)

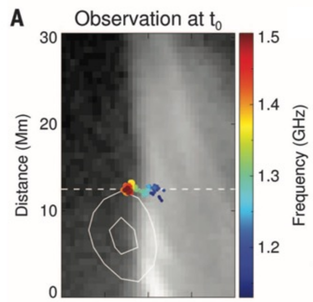
calculated by Kaneko

Possible acceleration sites



Takasao et al. (2012)





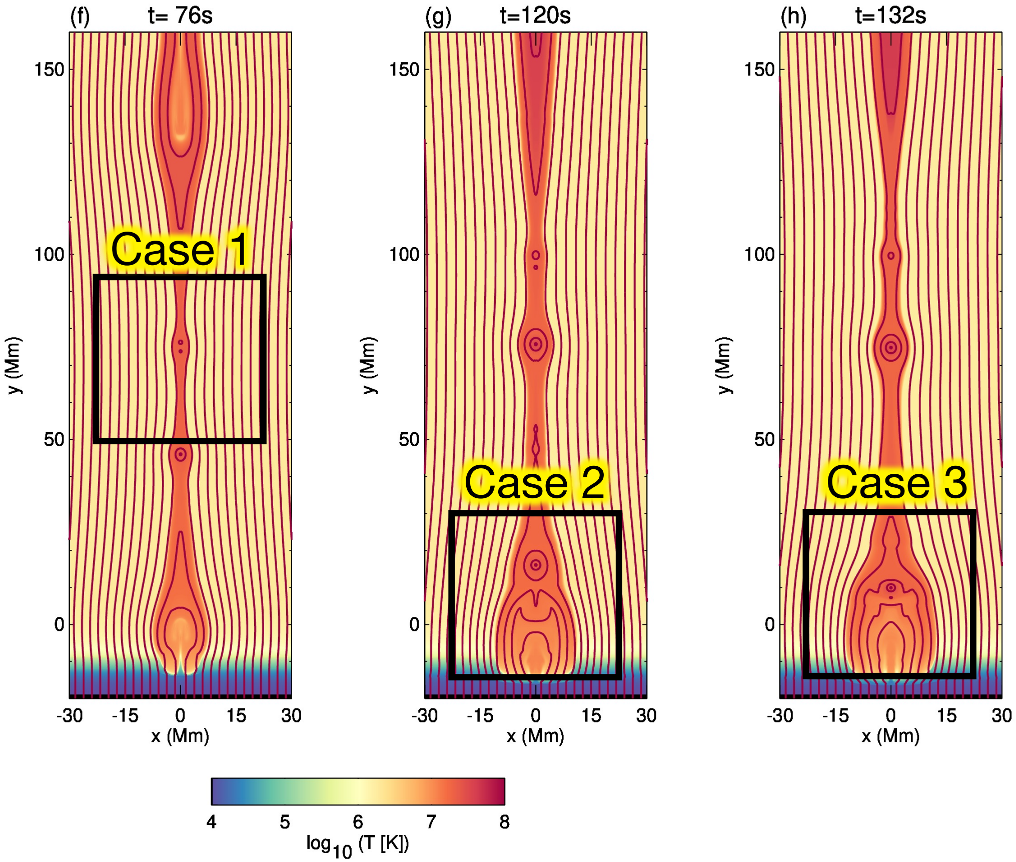
Chen et al. (2015)

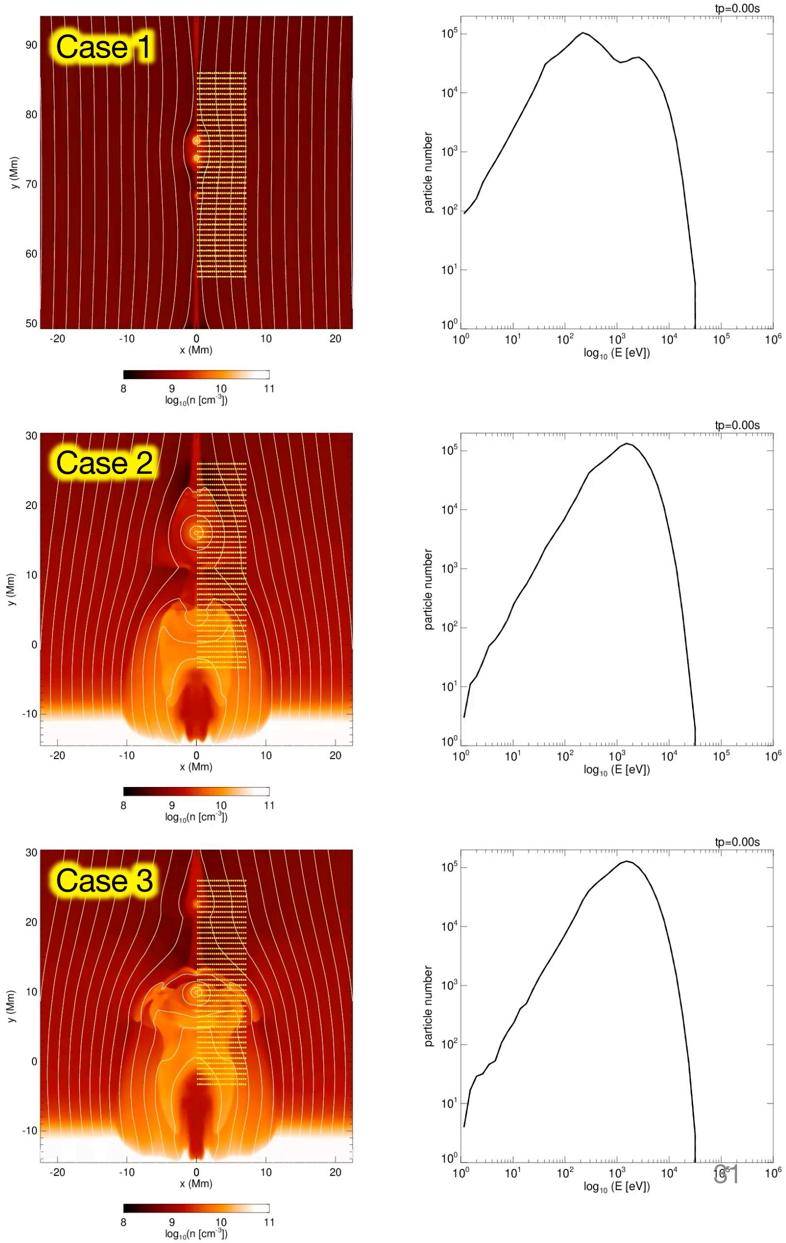
t = 270.0 sec

Numerical Approach in macro scale

MHD + GCA for understanding of particle acceleration

calculated by Kaneko

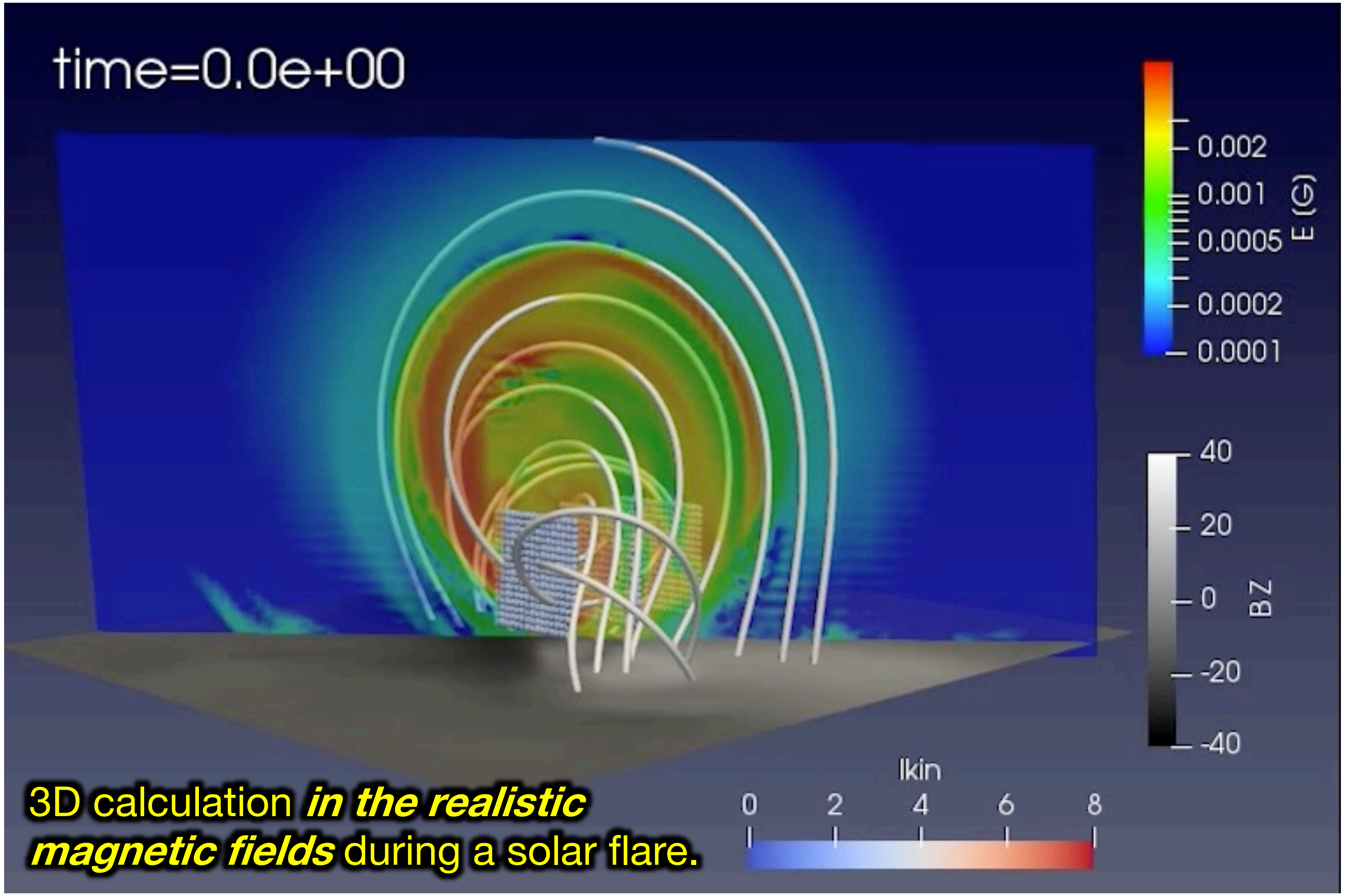




Numerical Approach in macro scale

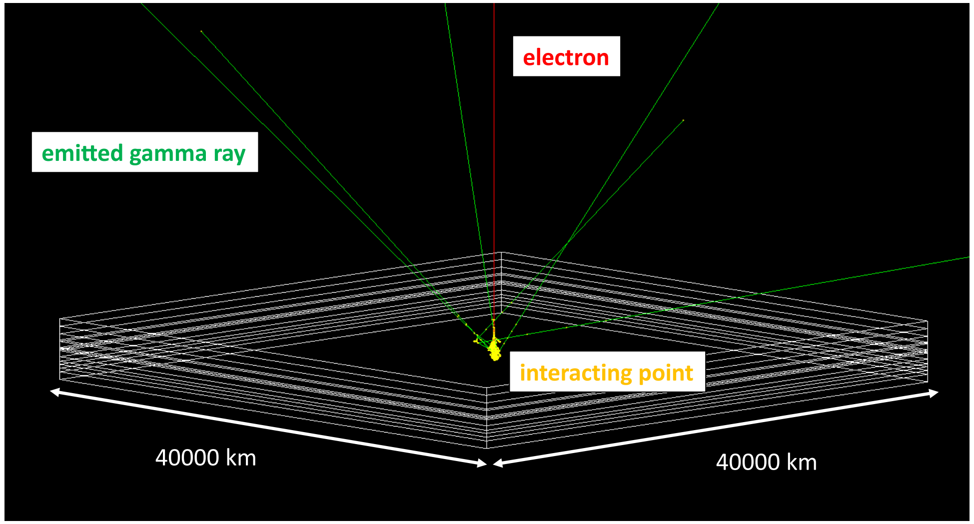
MHD + GCA for understanding of particle acceleration

calculated by Kaneko

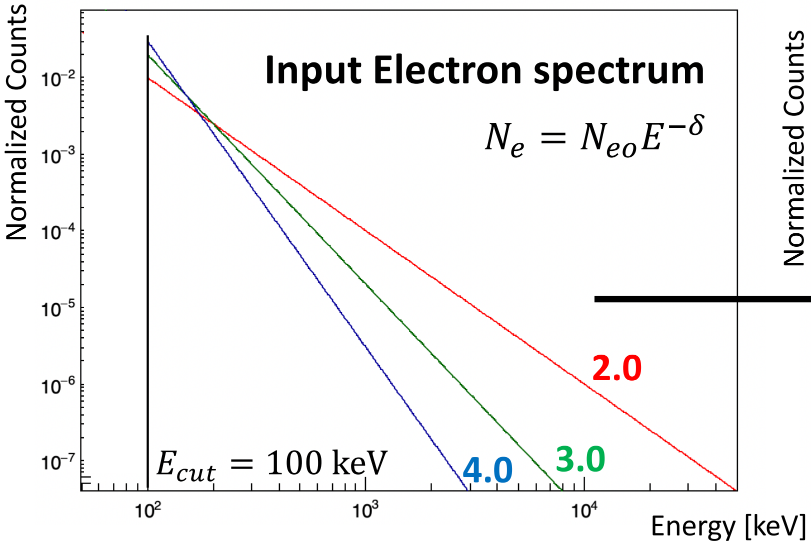


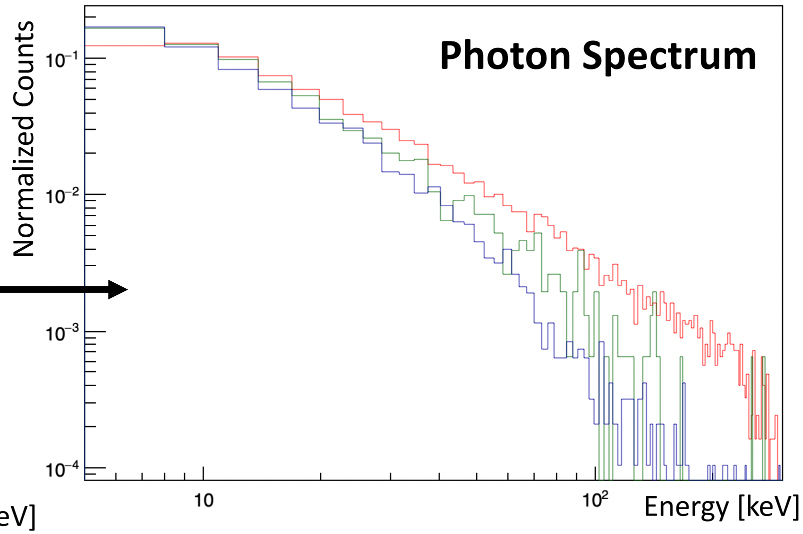
Numerical Approach
Emission model for comparison between observation and numerical simulation

calculated by Nagasawa

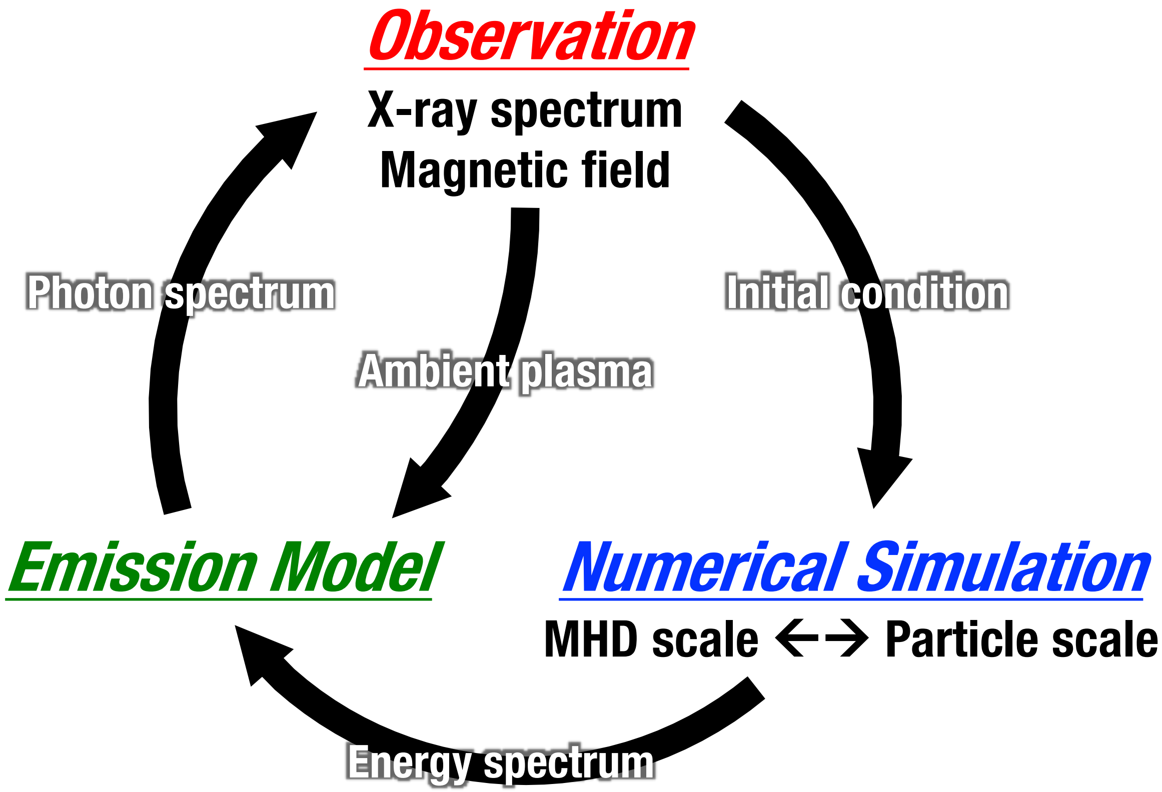


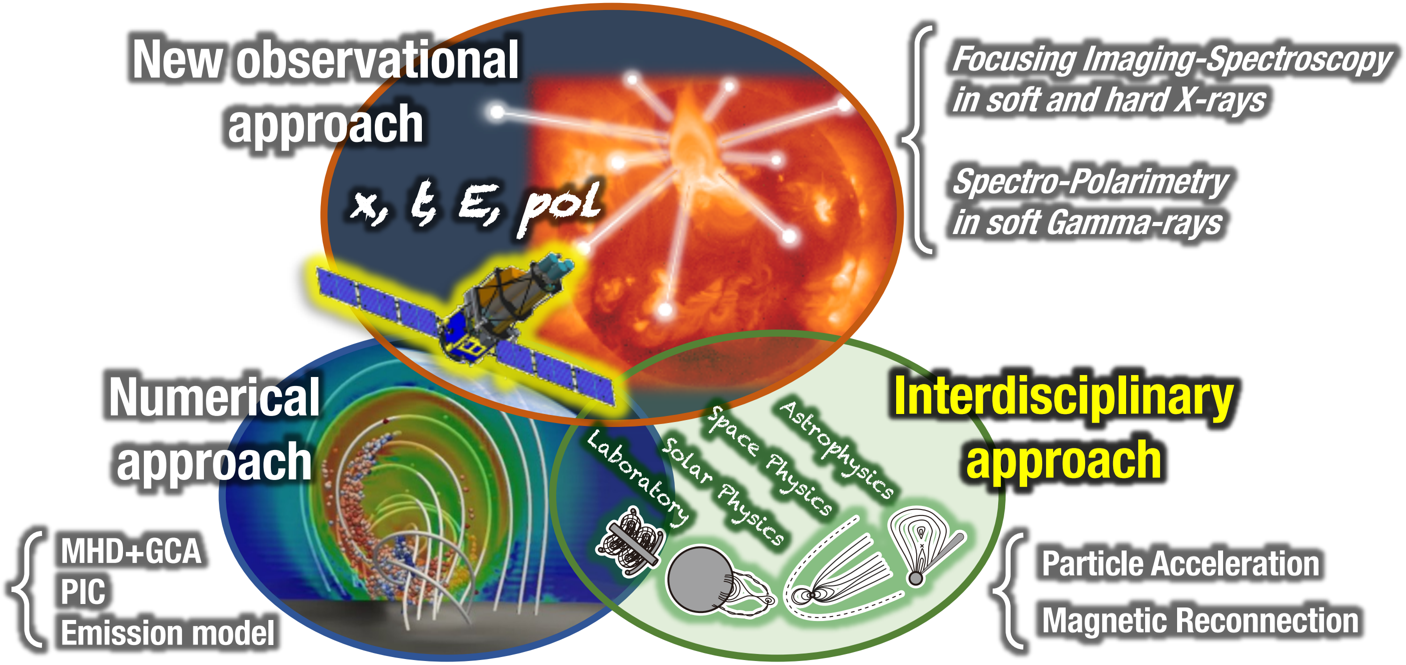
Solar corona model
in ComptonSoft





Iteration between observation and numerical simulation





Science Objectives of *PhoENiX* mission

1. Identify particle acceleration sites in solar flares [where]
2. Investigate temporal evolution of particle acceleration [when]
3. Characterize properties of accelerated particles [how]

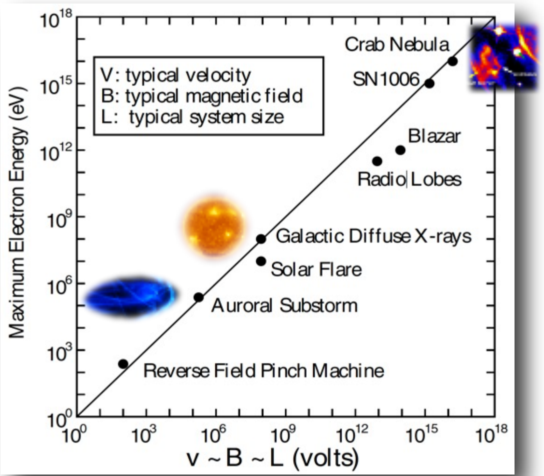
PHYSICS OF ENERGETIC AND NON-THERMAL PLASMAS IN THE X-REGION

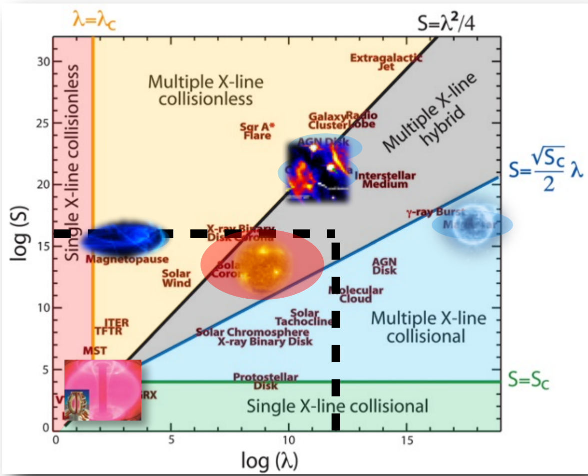
PHOENIX

planned to be realized in Solar Cycle 26 (2030')

Interdisciplinary approach
with strength and heritage of each research field

- **Space Physics**
  - Observation in interplanetary space (trace of plasmas from the sun)
  - PIC simulation





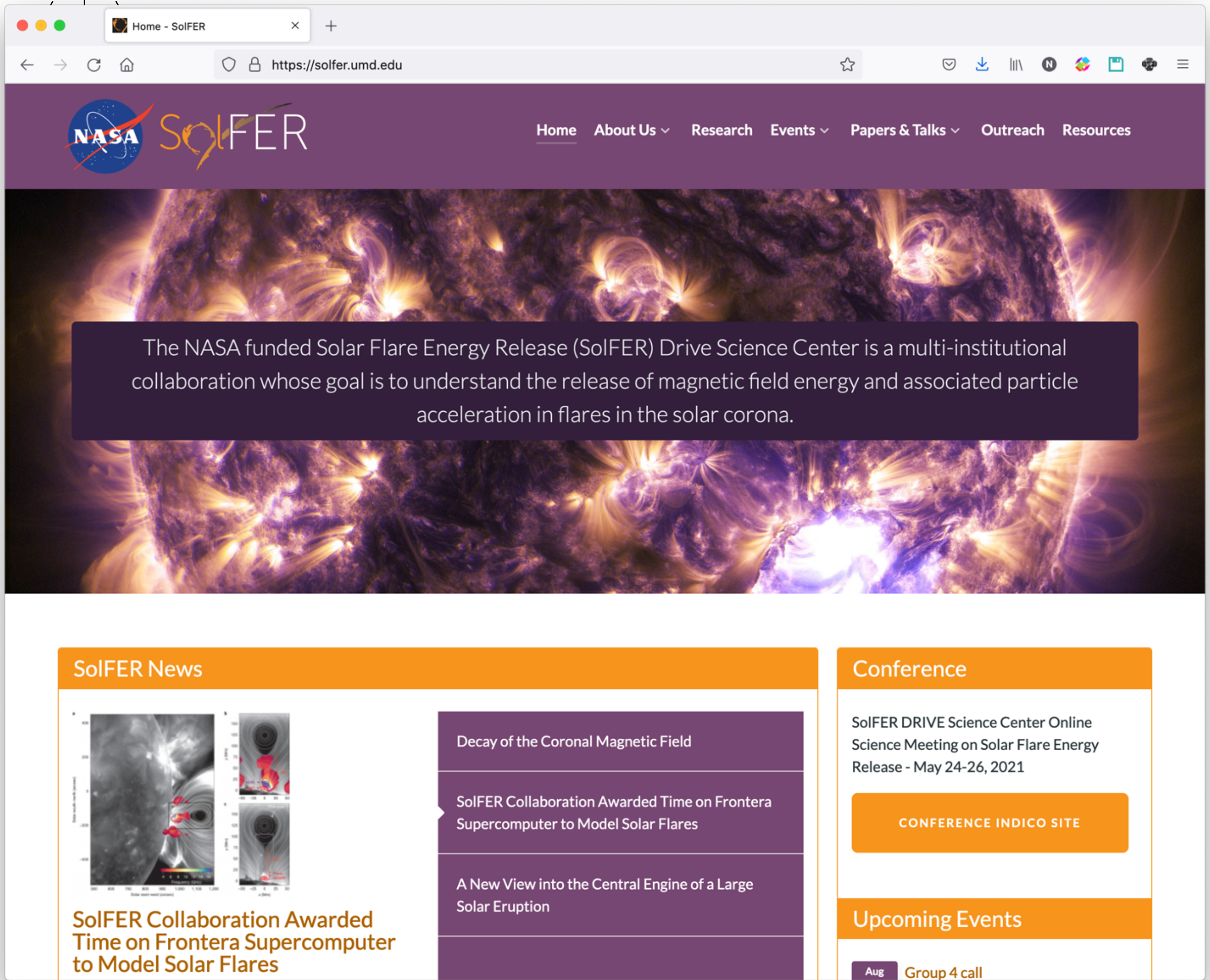
- **Laboratory plasma physics**
  - Laboratory experiment of MR

- **Astrophysics**
  - X-ray & gamma-ray observations
  - X-Ray Spectral Fitting Package (Xspec)
  - X-ray emission model
  - Key technologies

Common Physics
- ***Particle Acceleration***
- ***Magnetic Reconnection***

- **Solar Physics**
  - Solar observations
  - MHD simulation
  - Key technologies

SolFER (Solar Flare Energy Release) – NASA funded Drive Science Center



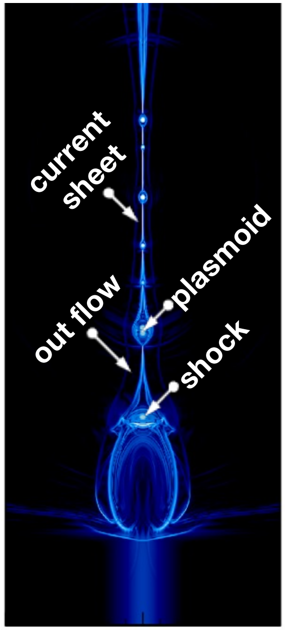
1. Fast Release Mechanisms
2. Onset of Energy Release
3. Energization of Electrons
4. Energization of Ions
5. Particle Transport
6. Plasma Heating

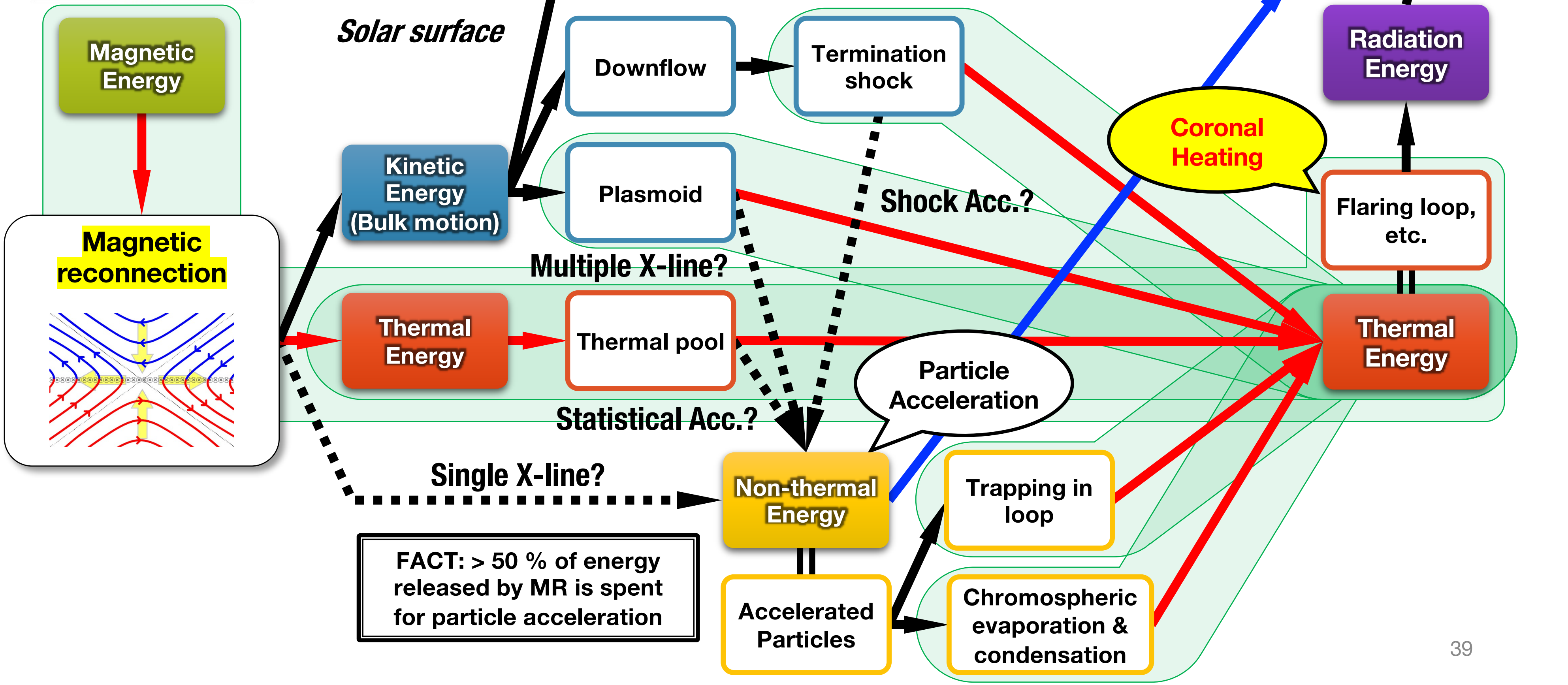
PhoENiX can contribute to and collaborate with these topics.

Extra Science

Beyond the PhoENiX Scientific Objectives

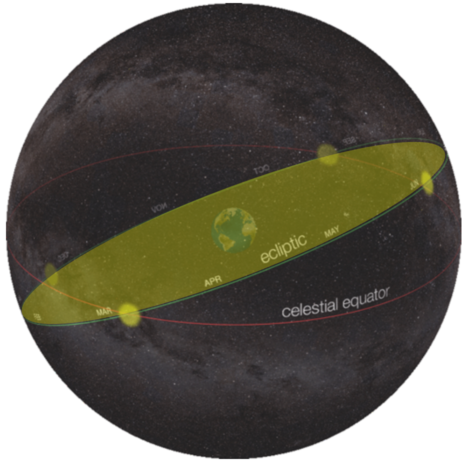
Contribution to
Coronal Heating (thermalization) &
Space Weather (Impulsive SEP, CME onset, pre-flare heating)

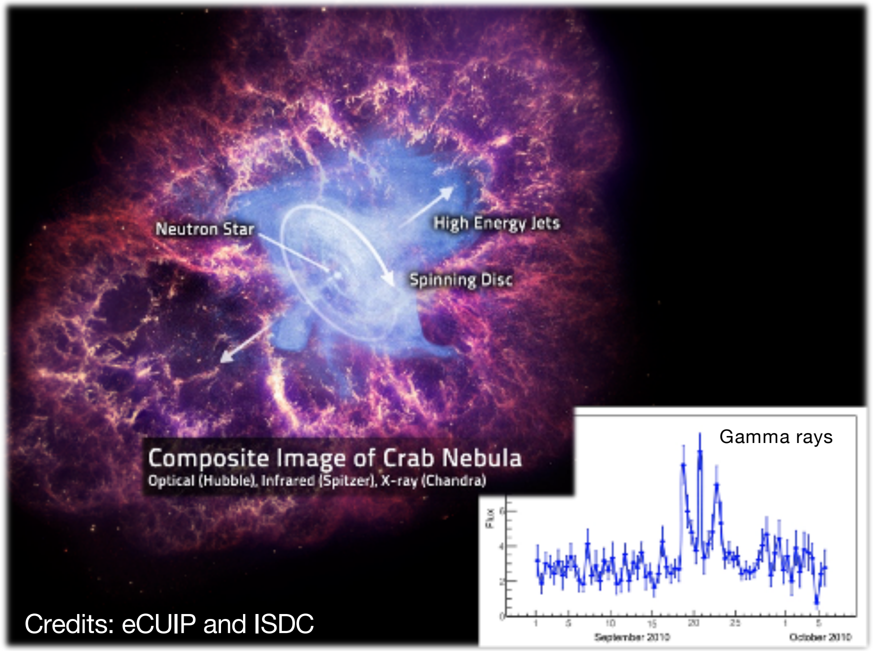




Observation of astronomical objects

PhoENiX can observe
the astronomical objects near the ecliptic plane (within 5 degree).





Balbo+ 2011

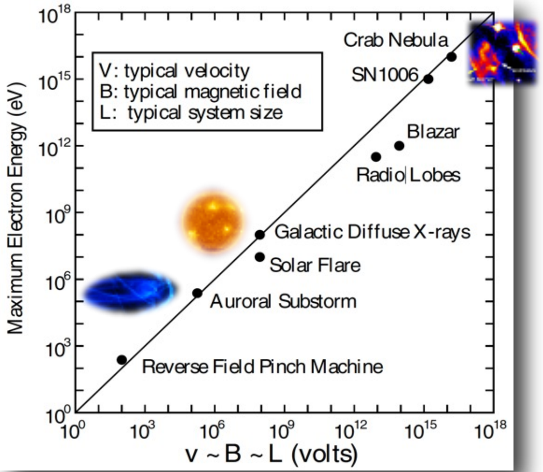
Carb Nebula

Scorpius X-1

Interdisciplinary approach

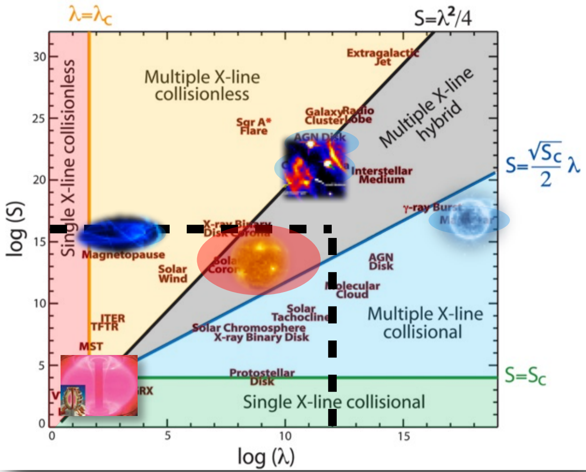
for the understanding of plasma physics beyond individual research field

Maximum Energy



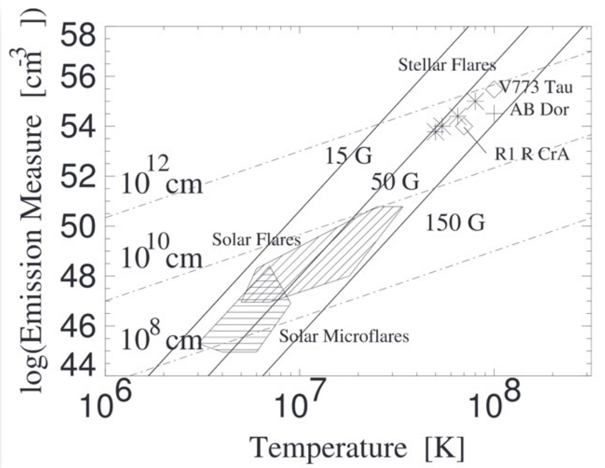
Makishima (1999)

Magnetic Reconnection



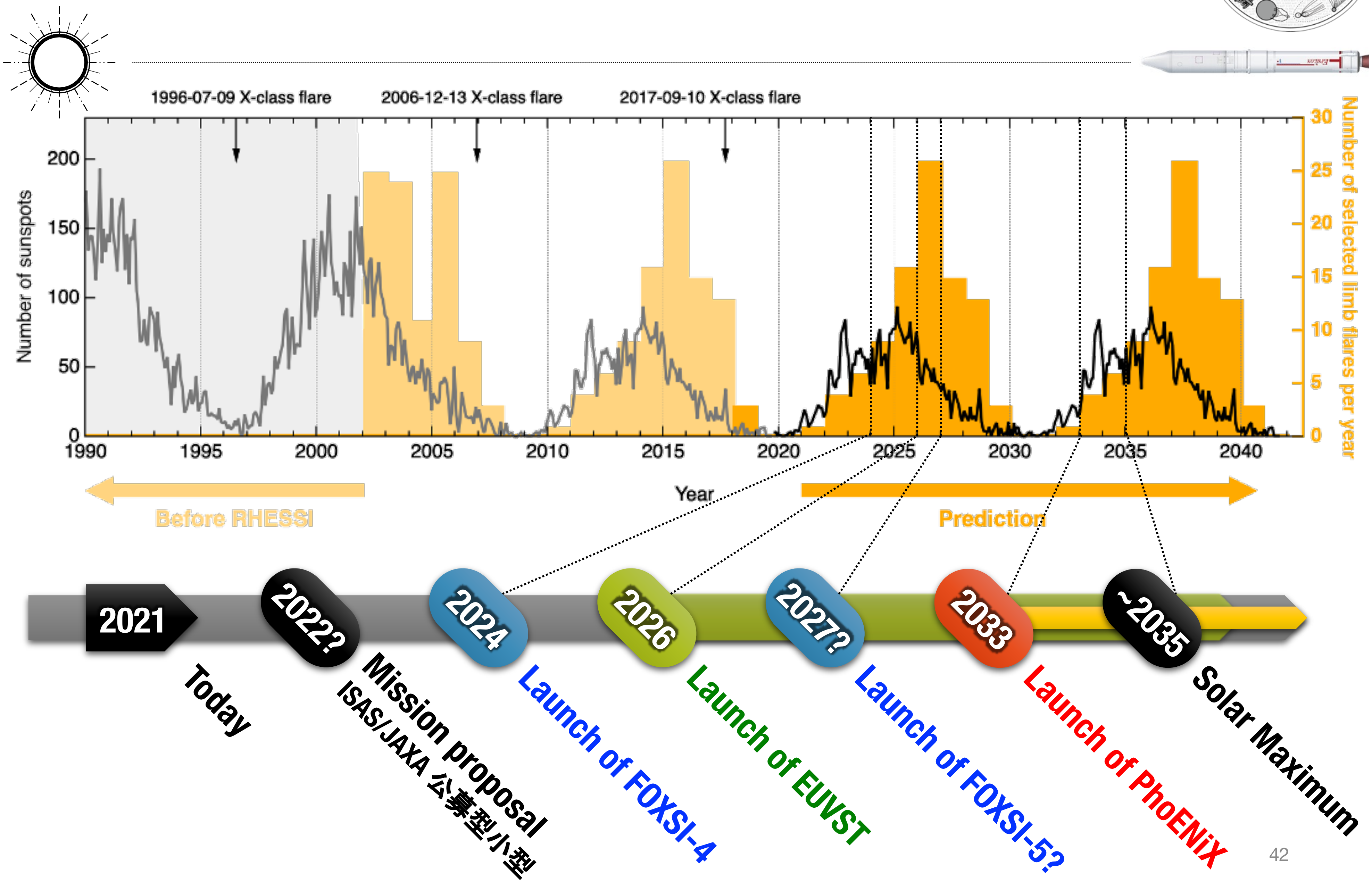
Ji & Daughton (2011)

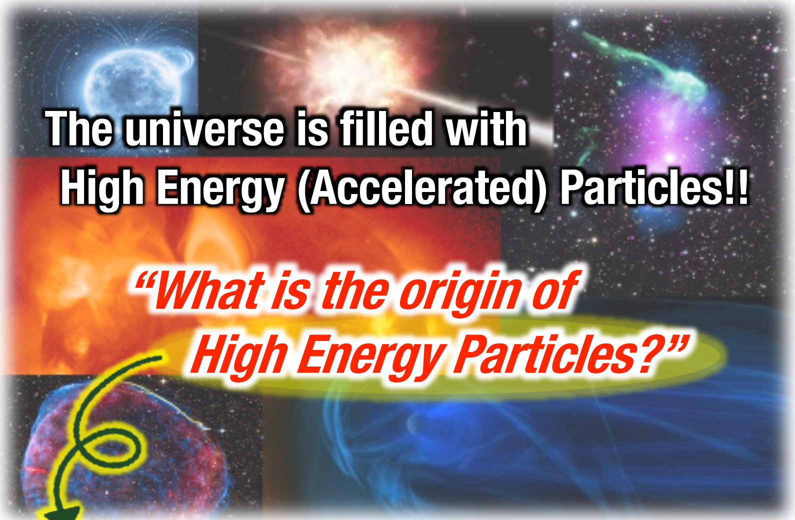
Flare



Shibata & Yokoyama (1999)

Schedule of PhoENiX





- ✓ Energization of space plasmas
- ✓ Formation and evolution of life
- ✓ Influence on planetary environments

Science Objectives of *PhoENiX* mission

1. Identify particle acceleration sites in solar flares [where]
2. Investigate temporal evolution of particle acceleration [when]
3. Characterize properties of accelerated particles [how]

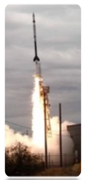
PHYSICS OF ENERGETIC AND NON-THERMAL PLASMAS IN THE X-REGION
PhoENiX

planned to be realized
in Solar Cycle 26 (2030')

The sun is unique in that:

- ✓ A natural laboratory of high energy plasmas
- ✓ Mother of life
- ✓ Impact on earth and social environments

Sounding Rocket *FOXSI* series

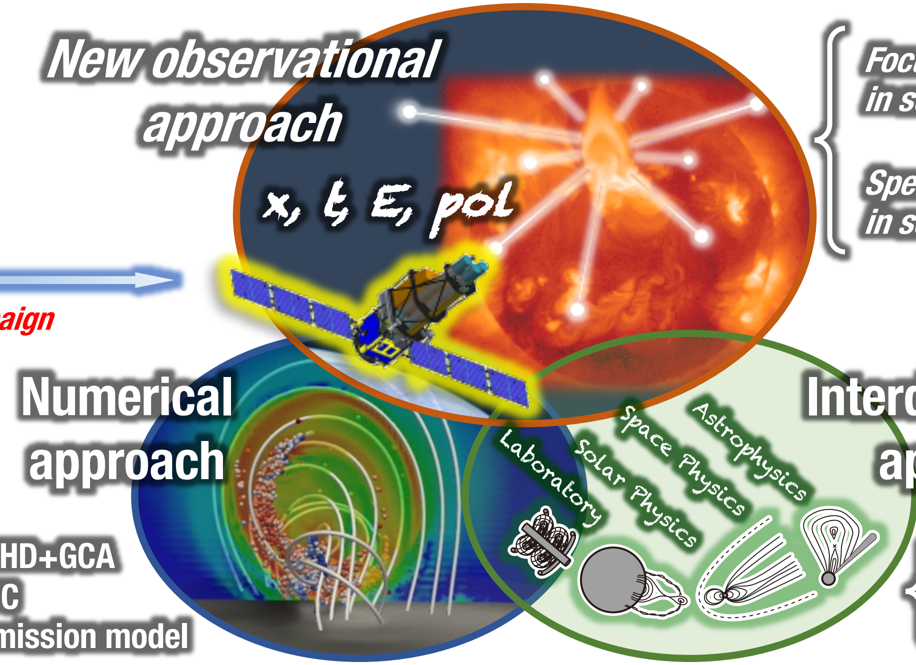


2012 2014 2018 FOXSI

2024
Flare campaign

NASA DRIVE Science Center

SolFER
Solar Flare Energy Release
https://solfer.umd.edu/



Focusing Imaging-Spectroscopy in soft and hard X-rays
Spectro-Polarimetry in soft Gamma-rays

- MHD+GCA
- PIC
- Emission model

- Particle Acceleration
- Magnetic Reconnection

https://indico.ipmu.jp/event/395/

Particle acceleration in solar flares and the plasma universe -- Deciphering its features under magnetic reconnection

15-19 November 2021

Asia/Tokyo timezone

- Overview
- Call for Abstracts
- Registration
- Participant List
- Kavli IPMU Code of Conduct

Contact

seminar@ipmu.jp

Dates and time:

Monday, 15 November - Fri, 19 November, 2021
22:00–3:00 JST* each day
(* 21:00–2:00 CST / 14:00–19:00 CET / 8:00–13:00 EST / 5:00–10:00 PST)

Venue:

The workshop will be held as a virtual, online-only event. A link will be sent out later to registered participants.

Registration and Abstract Submission:

Abstract submission deadline is October 19, 2021, 23:59 UT.

Registration is available through November 10, 2021.