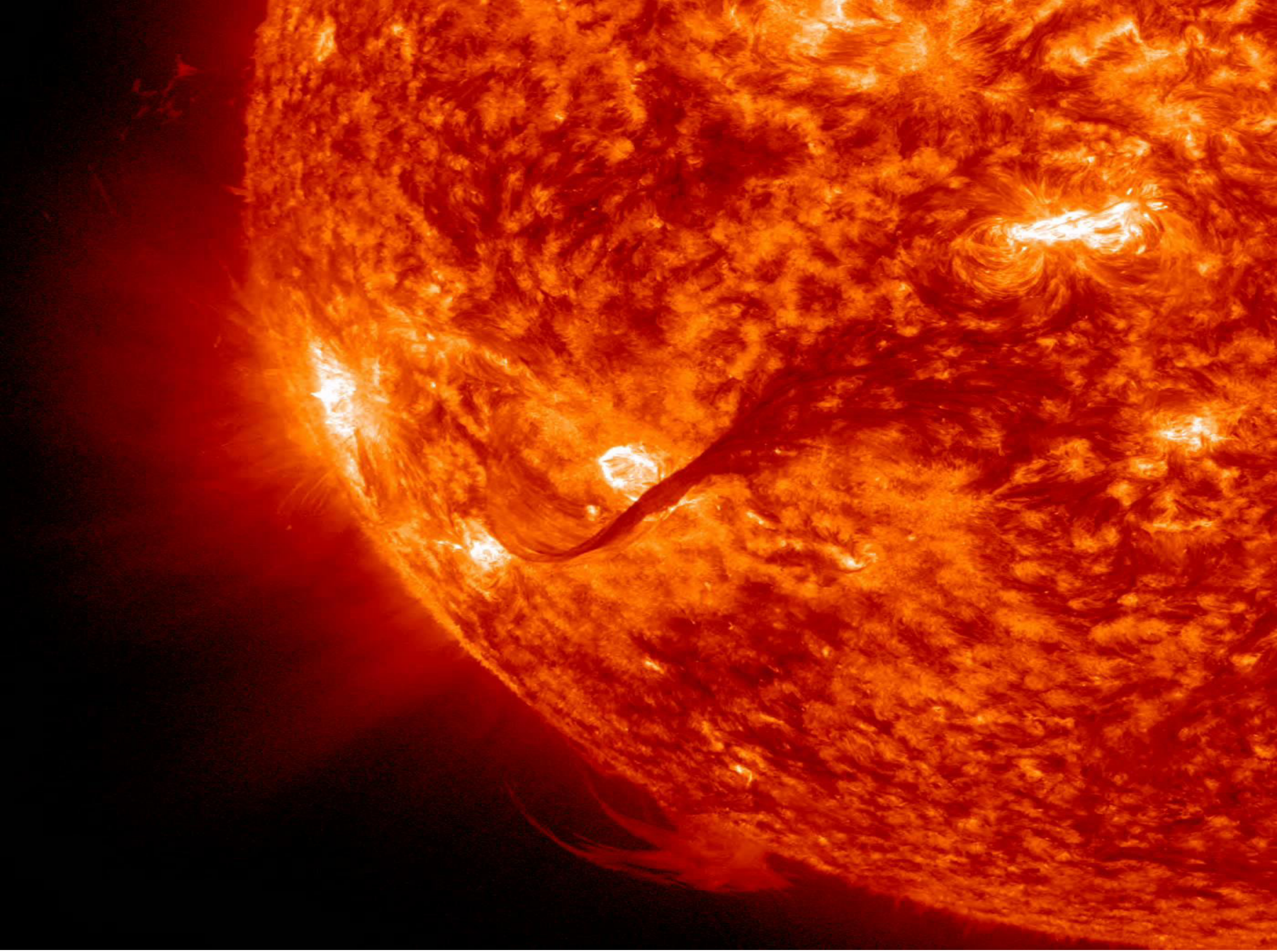
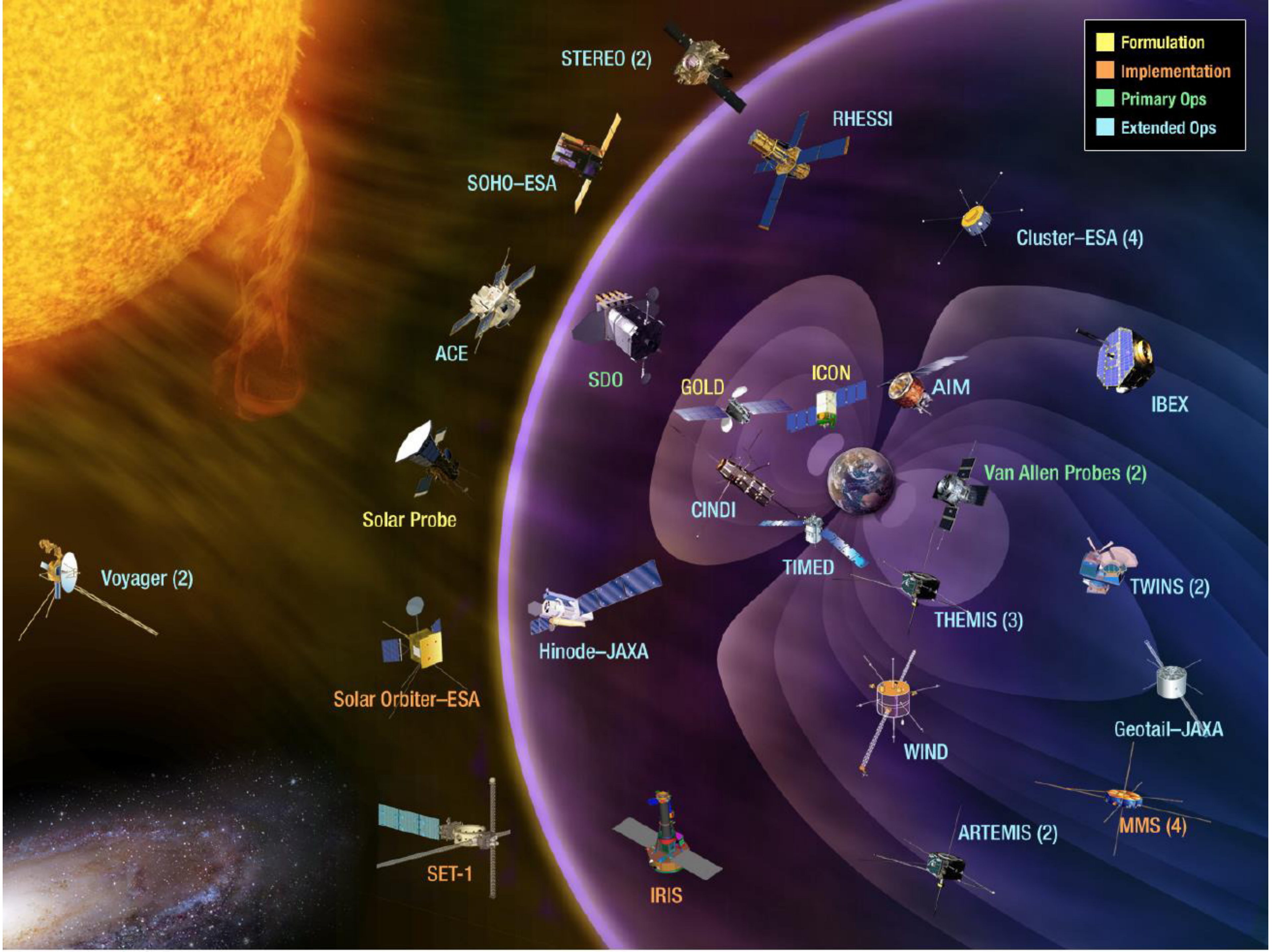
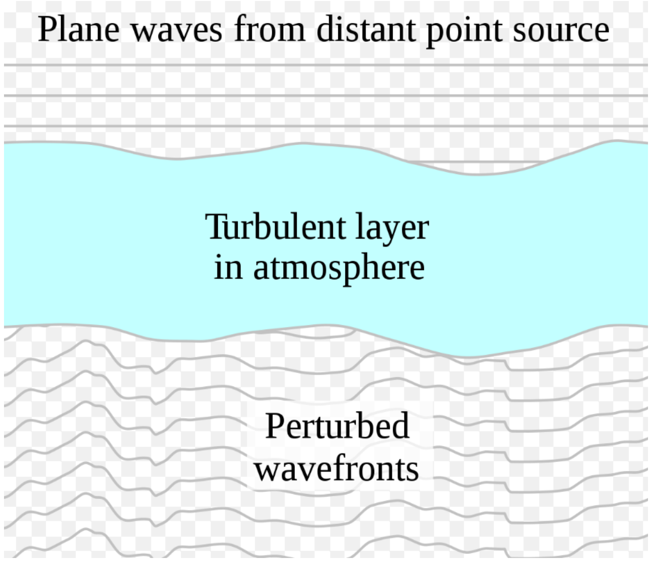



Formulation
Implementation
Primary Ops
Extended Ops
STEREO (2)
RHESSI
SOHO–ESA
Cluster–ESA (4)
ACE
SDO
GOLD
ICON
AIM
IBEX
Van Allen Probes (2)
Solar Probe
CINDI
TIMED
Voyager (2)
TWINS (2)
THEMIS (3)
Hinode–JAXA
Solar Orbiter–ESA
WIND
Geotail–JAXA
ARTEMIS (2)
MMS (4)
SET-1
IRIS

first question

why so many space instruments
since we may have telescopes on earth?

atmospheric blurring



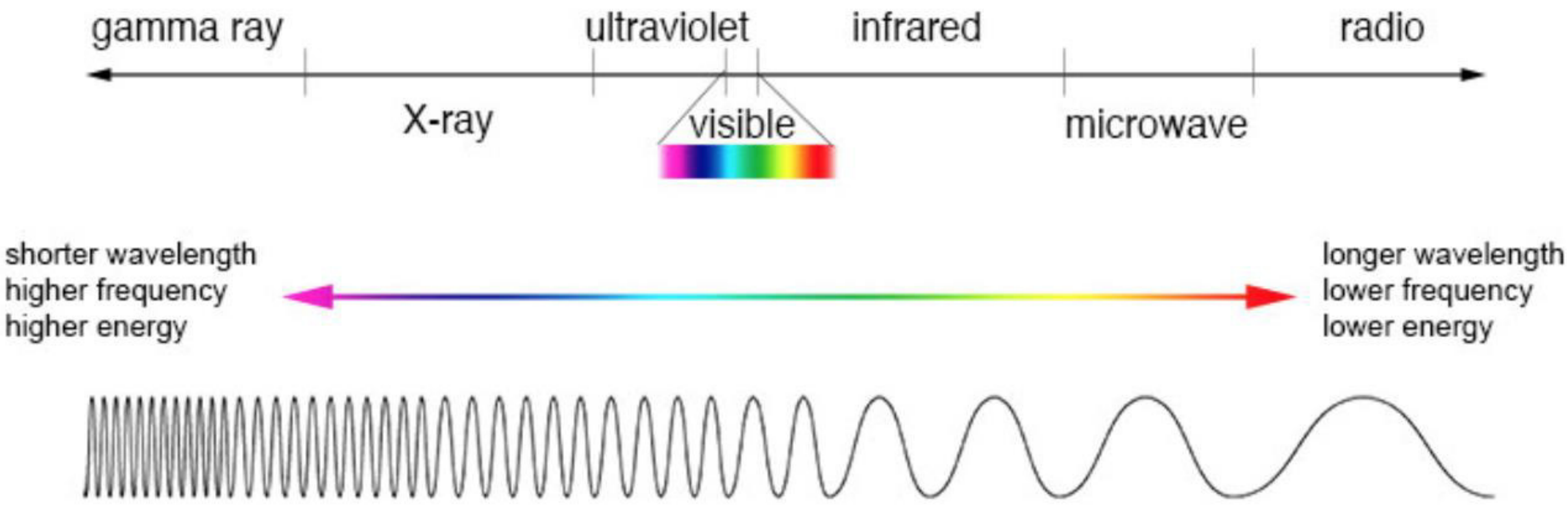
if you want to get rid
of atmospheric blurring
you need (a sophisticated,
not always completely reliable,
computationally consuming)
math

or: go into space!!

second question

why do we need so many satellites to look at the sun?

the electromagnetic spectrum



- low wavelength = high frequency = high energy
- the sun emits at all possible wavelengths
  (both at rest and in full activity)

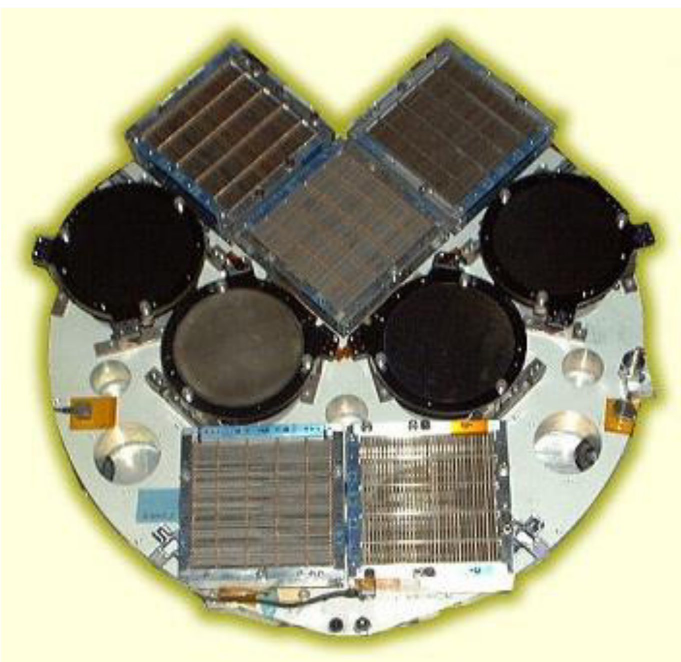
wavelengths and hardware

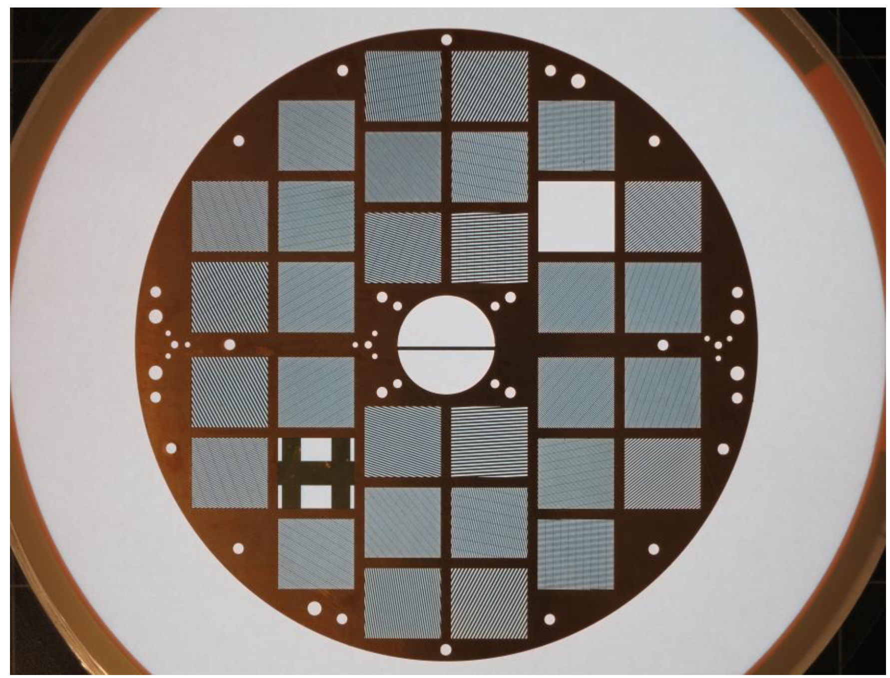
- the relation between wavelength and energy impacts on the design of hardware detectors: there is no hardware for all seasons

- the design of hardware detectors impacts on the nature of captured data: there is no data for all seasons

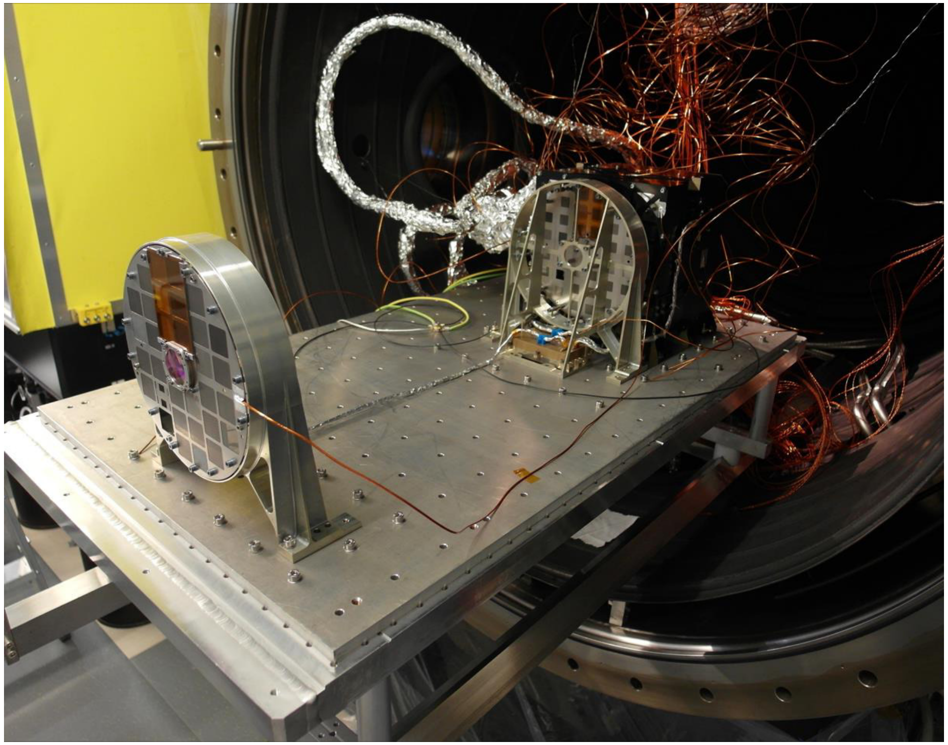
example 1 – hard X-rays


Canon
EOS

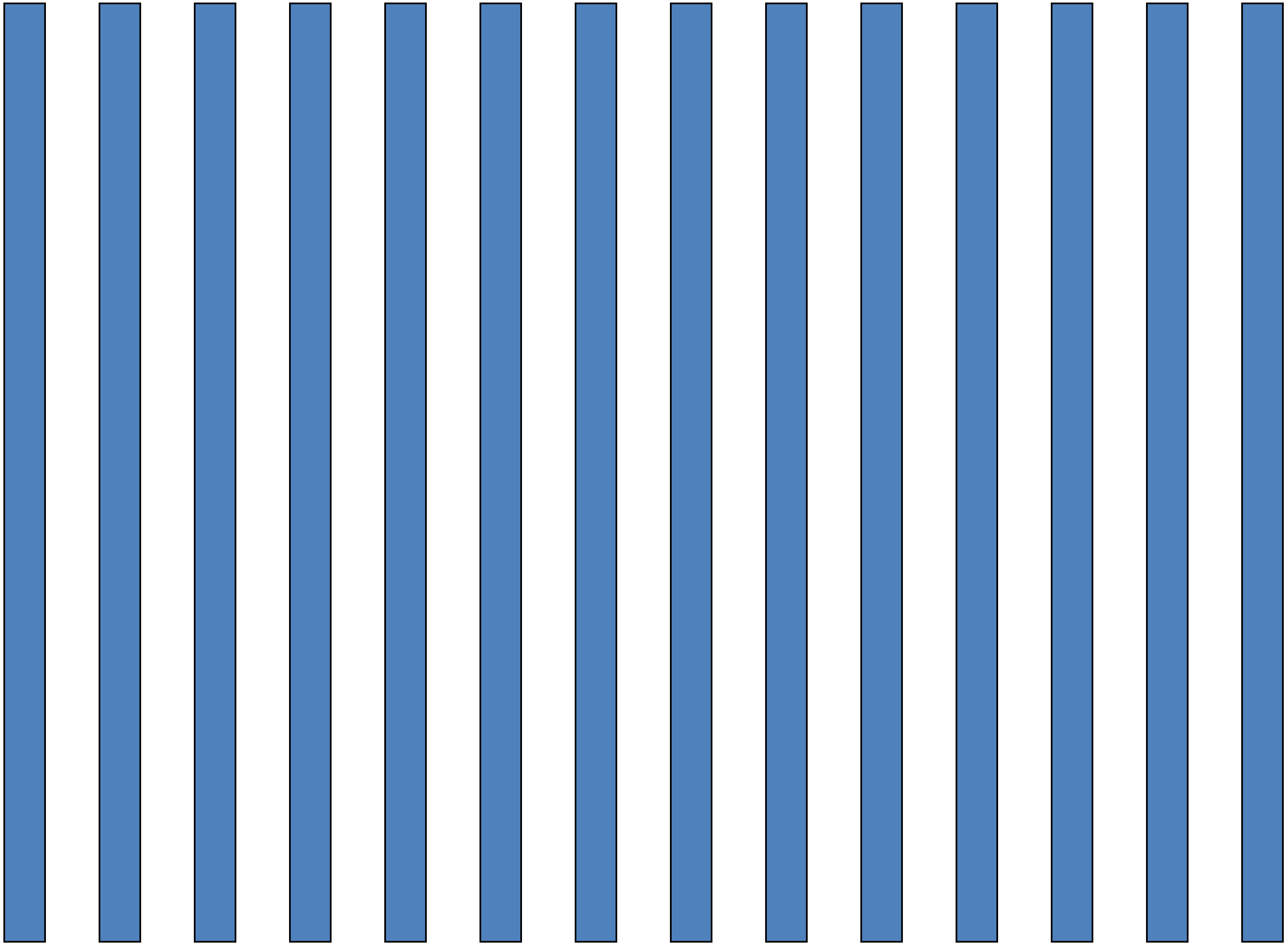


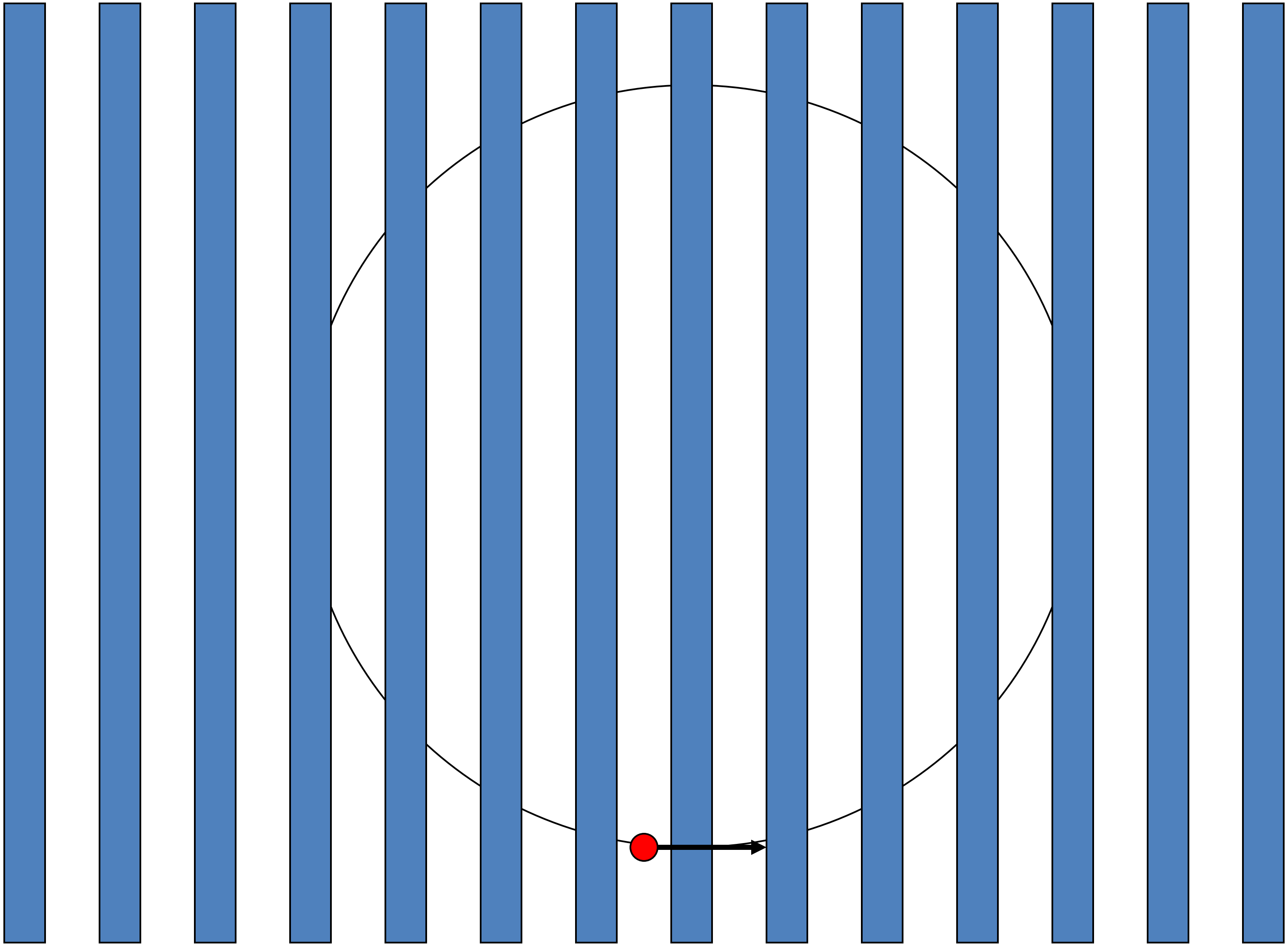


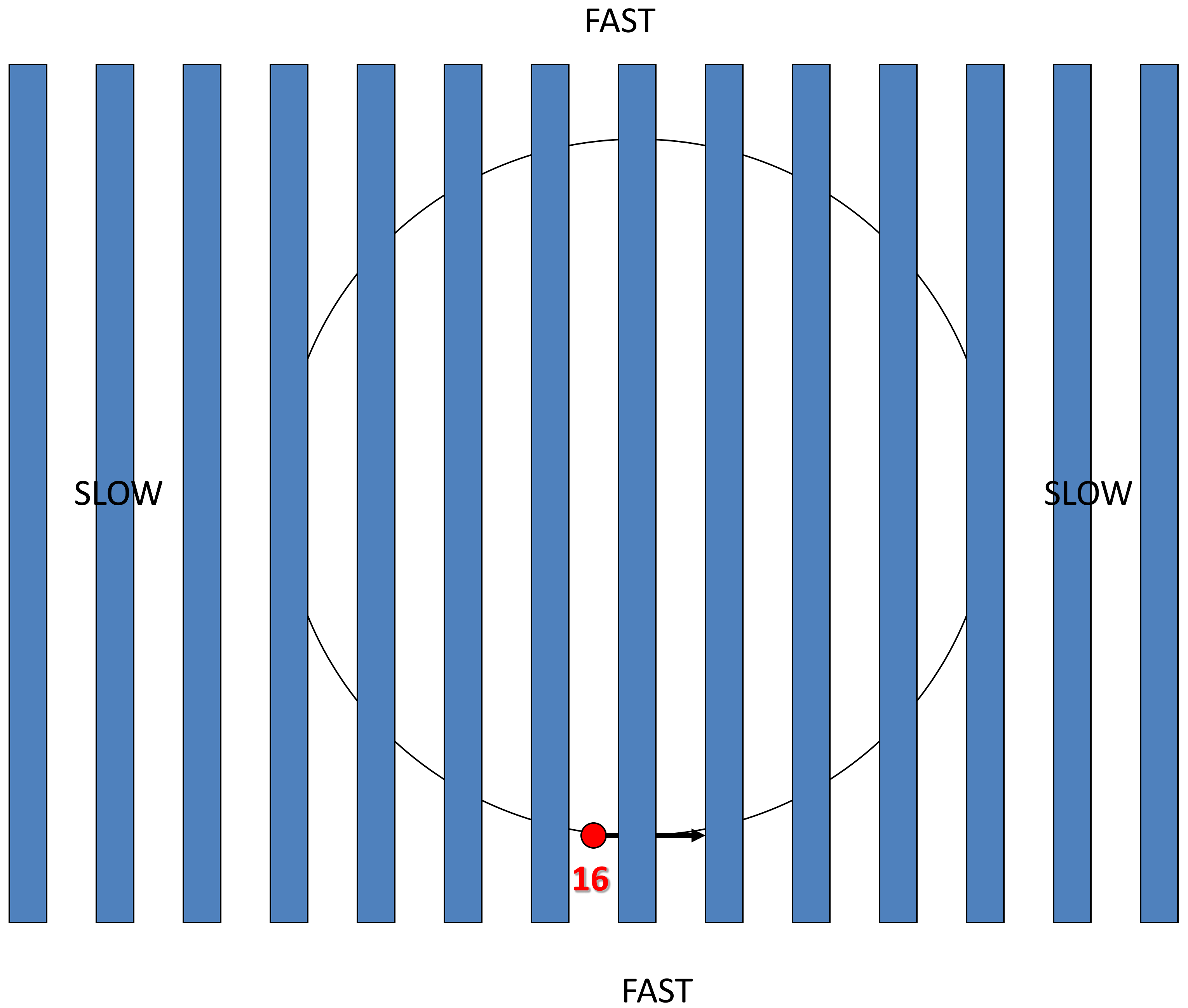
RHESSI and STIX in SO

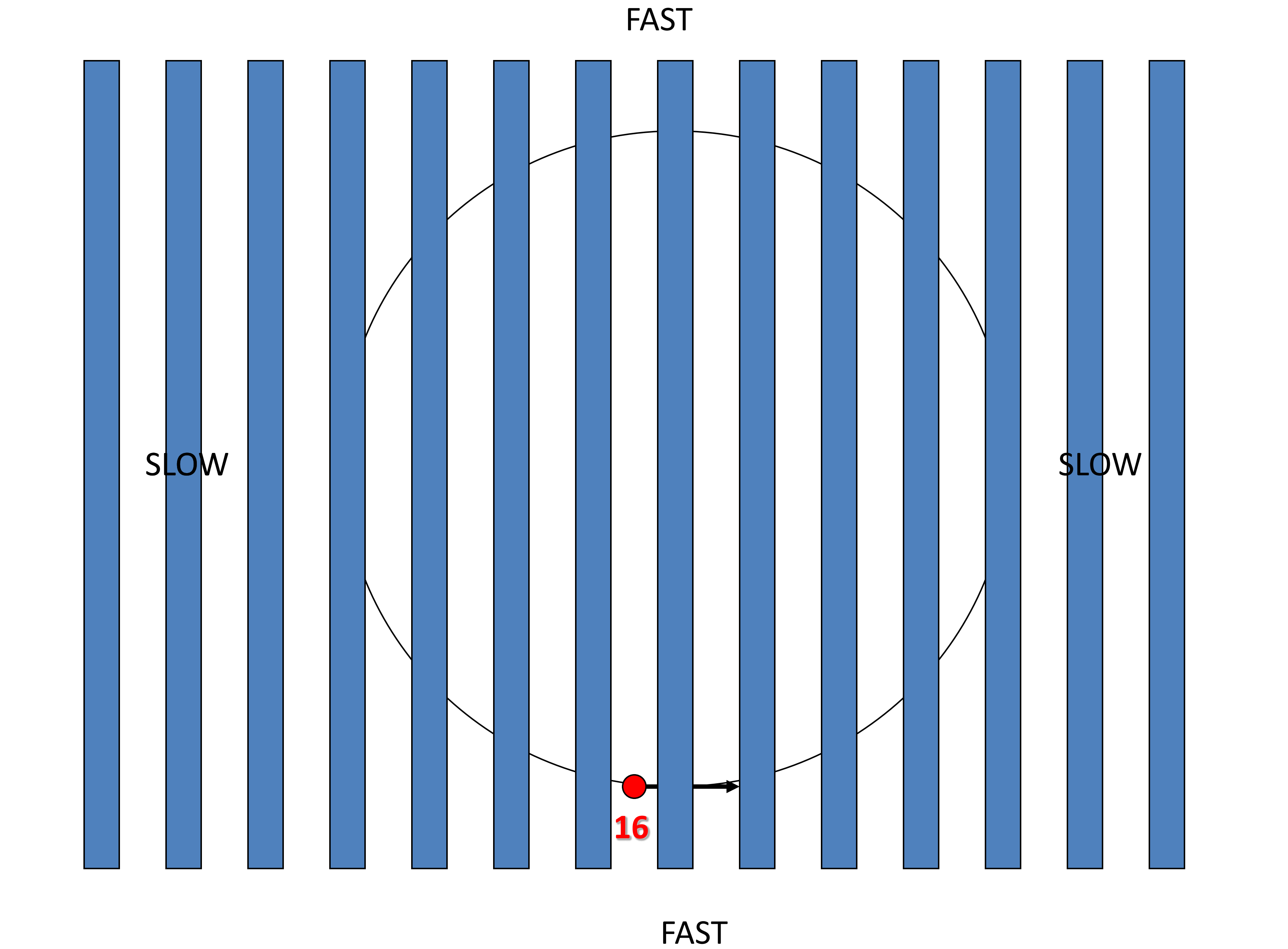


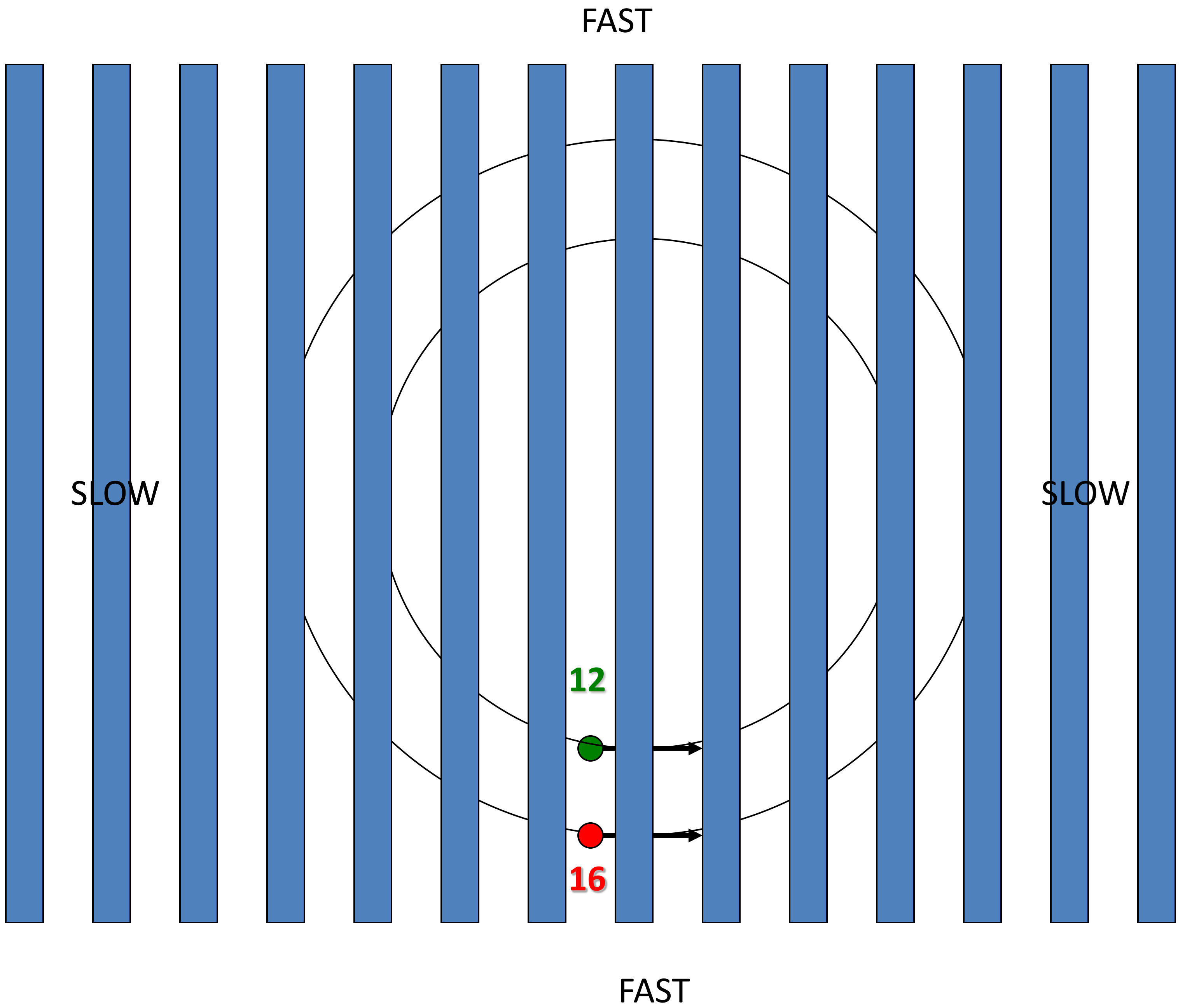
Grid Pattern



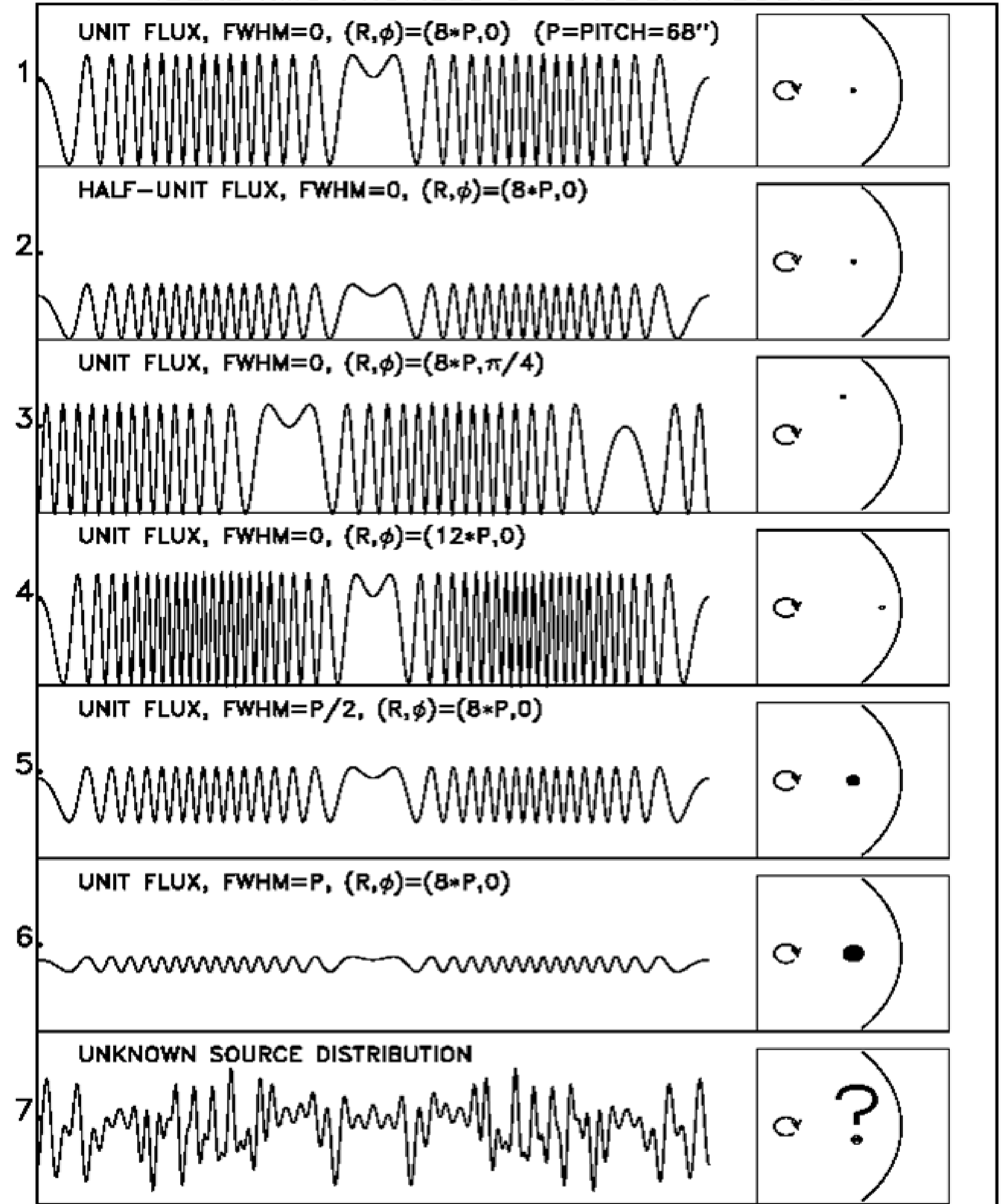



FAST
SLOW
SLOW
16
FAST

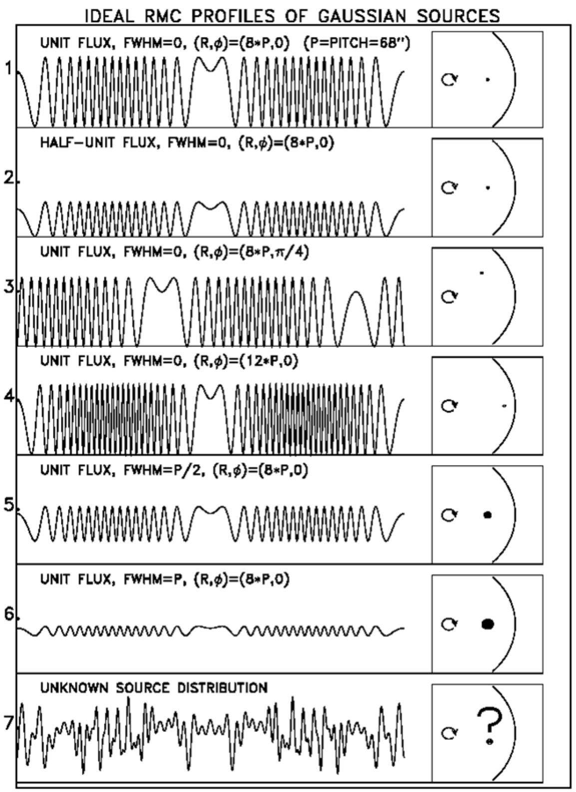

FAST
SLOW
SLOW
16
FAST

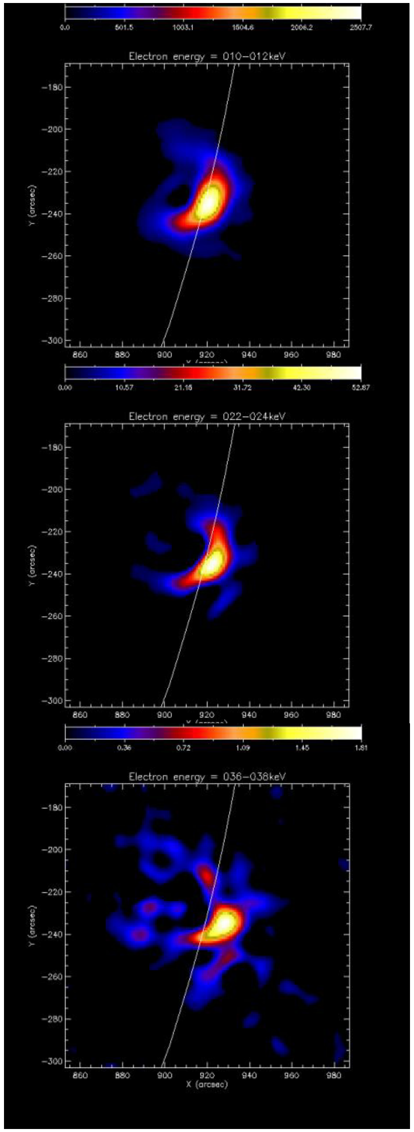

FAST
SLOW
SLOW
12
16
FAST

IDEAL RMC PROFILES OF GAUSSIAN SOURCES



from modulations to images



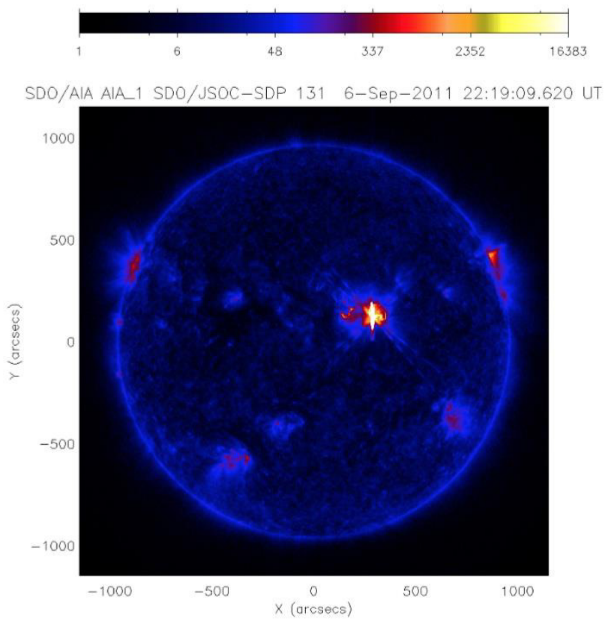


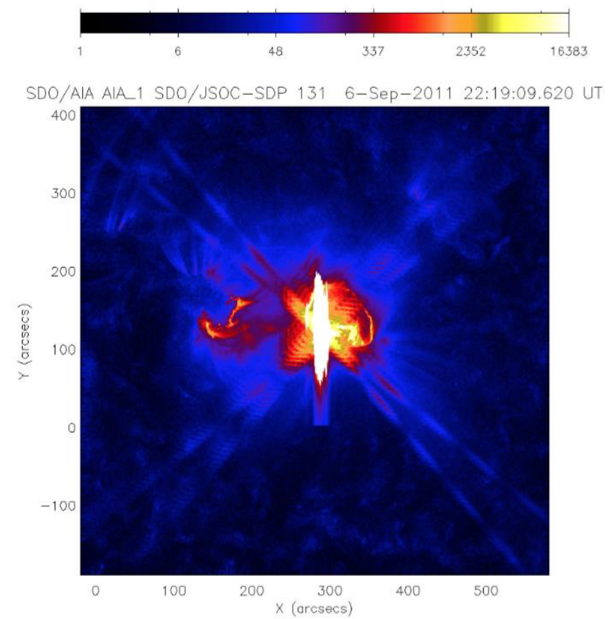
example 2 – extreme ultraviolet (EUV)

SDO/AIA

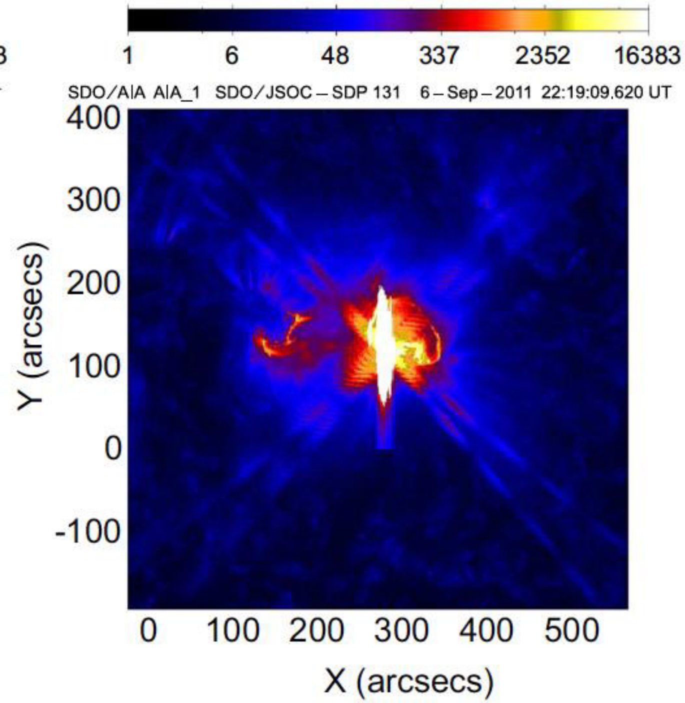
saturation

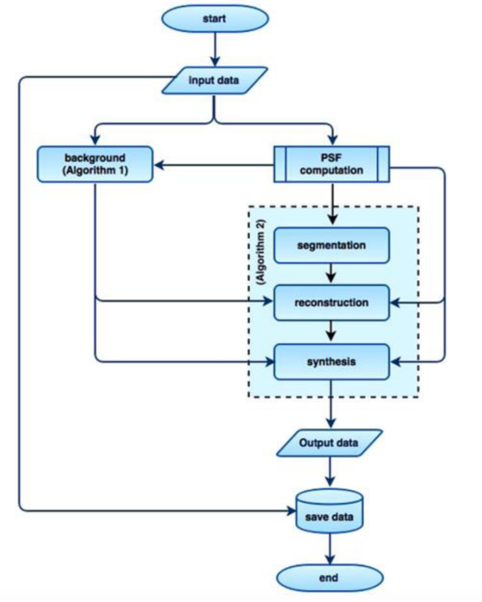
- EUV data are collected by pretty standard CCDs (it's like having a gigantic and giganticly effective digital camera)
- intense phenomena saturate the CCD





de-saturation





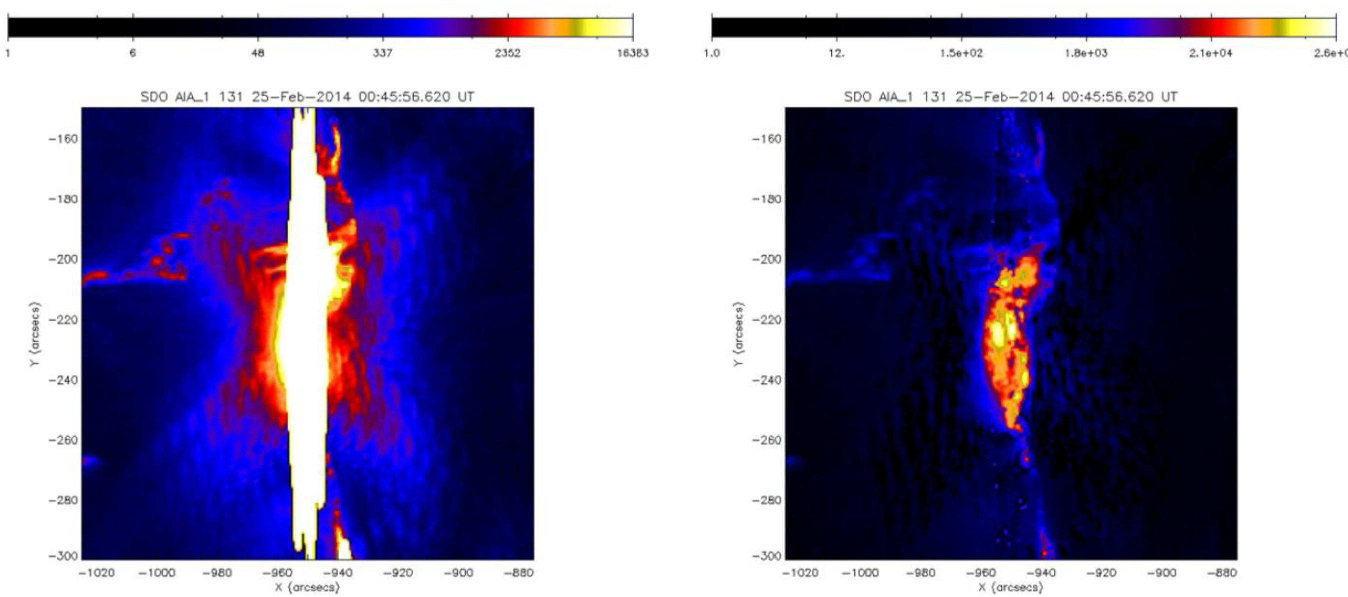
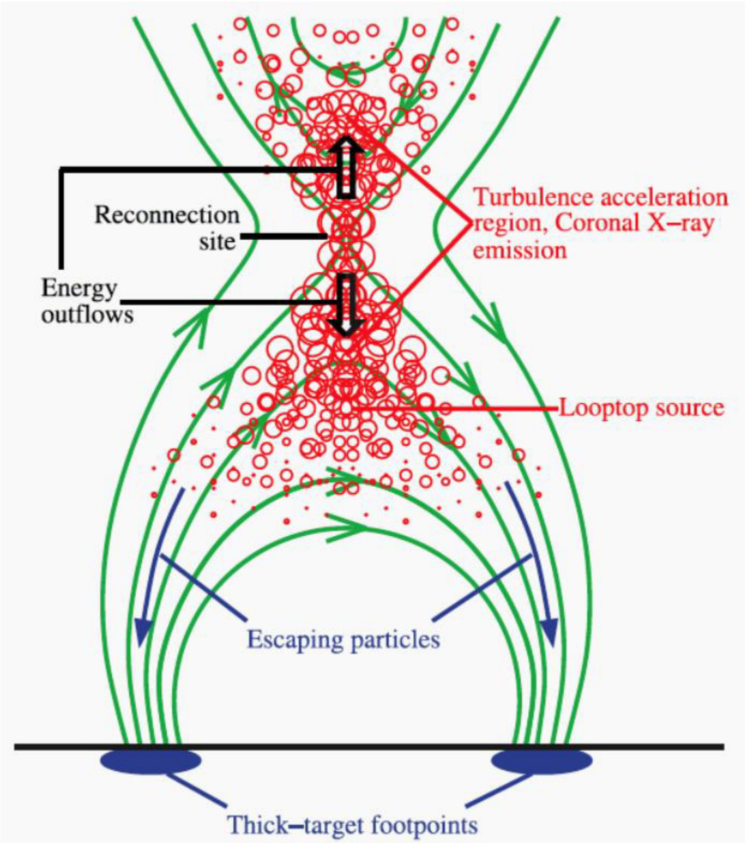


Fig. 3. *DESAT* at work. Left panel: the same saturated image as in Fig. 1. Right panel: the result of de-saturation.

third question

why do we need to look at the sun
at so many different wavelengths?

the standard model of flares

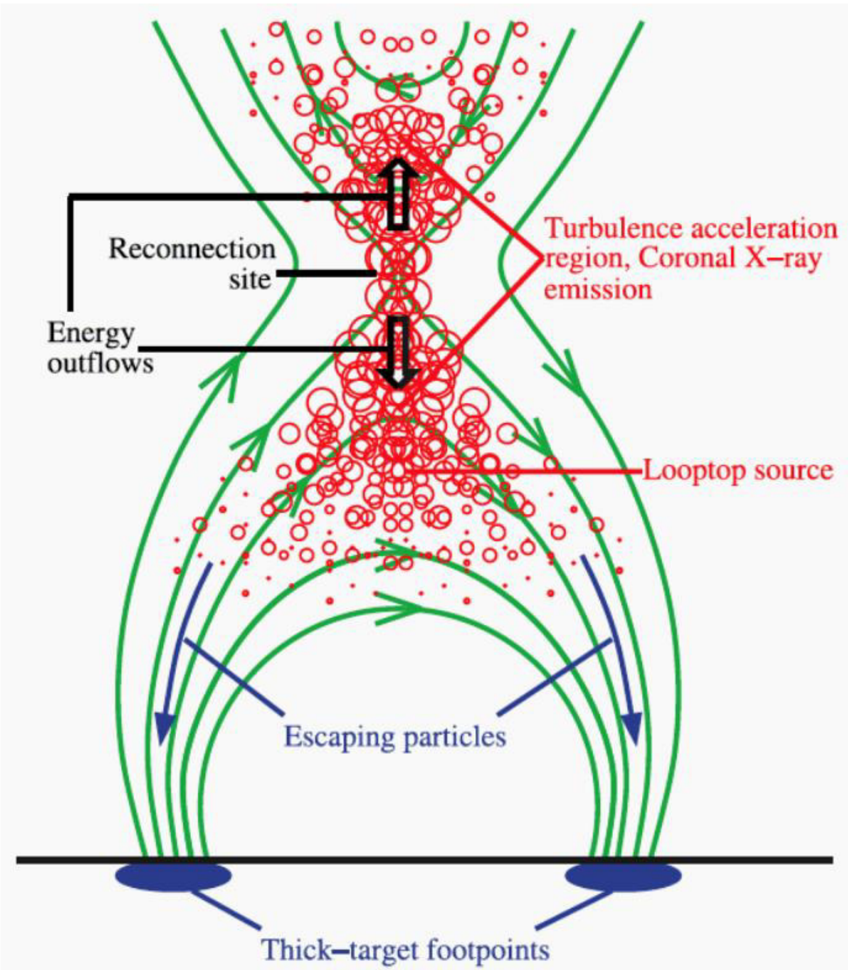


- (maybe) magnetic reconnection high in the corona
- if the density is high: coronal emission: X-rays
- loop-top source: hard X-rays
- gyro-sinchrotron radiation along magnetic field lines: radio
- thick-target foot-points: hard X-rays
- plasma heating: EUV

fourth question

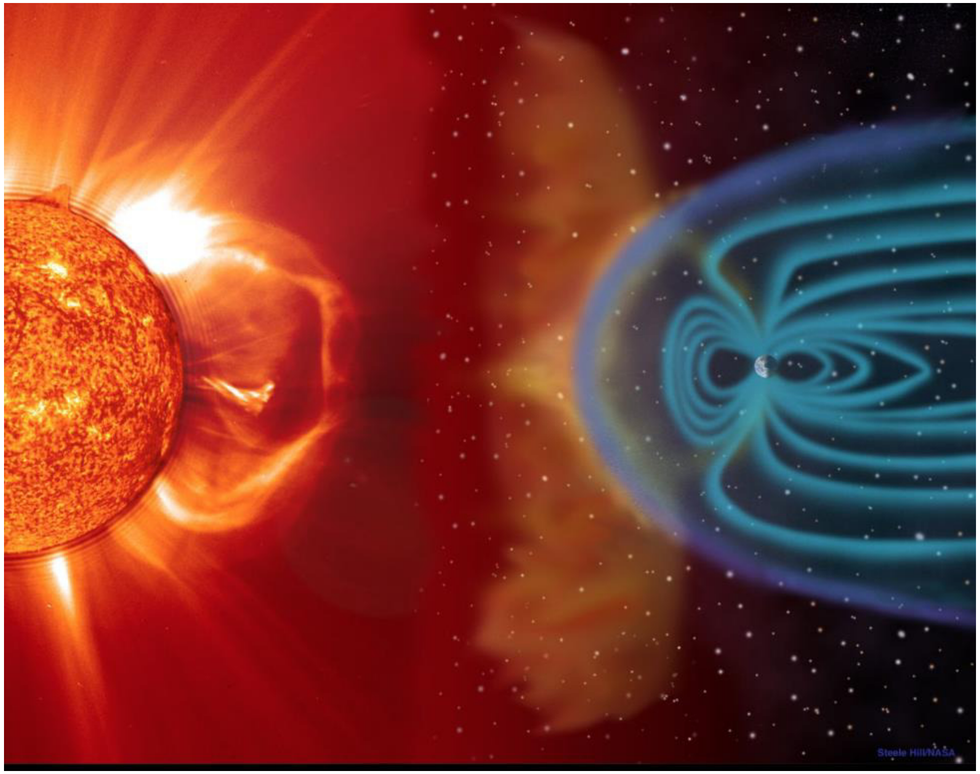
why are flares so interesting?

science-based answer 1



- magnetic reconnection has never been observed
- no way so far to understand the acceleration mechanism in the loop
- the thick-target model is still under construction
- the released energy predicted by the models is systematically smaller than the energy measured by the instruments

science-based answer 2



the mechanism why
flares trigger
coronal mass ejections
and solar wind
is still not explained

society-oriented answer

2003, october 23: a huge amount of coronal mass was ejected toward the earth at a speed of around 8 million km per hour:

- in sweden, strong induced currents provoked power grid black-outs
- in USA, all flight travelling along polar routes were cancelled
- on orbit, the ISS astronauts took shelter behind protective shields
- everywhere at high latitudes, GPS malfunctions occured

a new terminology...

is on the way...:

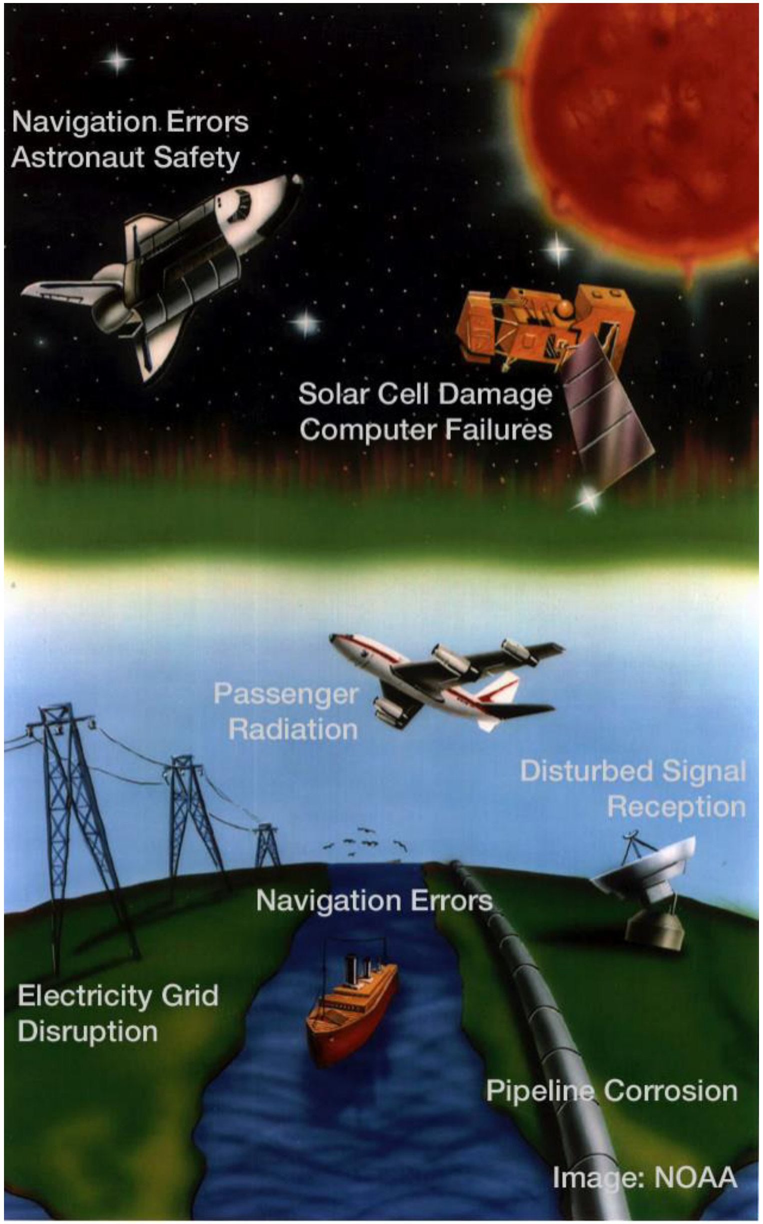
active regions
solar sunspots
solar flares
solar energetic particles (SEPs)
coronal mass ejections (CMEs)
solar wind

space weather
flare forecasting
solar storms
geomagnetic storms
NOAA SWPC
SDO/HMO

a new science/practice:

space weather

...with notable societal impacts



in the 21st century, we have become more vulnerable due to the technologies our societies depend on

should a very strong solar storm hit the Earth, it may not only cause damage to **space-based technology** but also to **communication systems, transportation networks, pipelines,** and **power grids** on earth.

FLARECAST: a service for solar flare forecasting

to identify the properties of the solar atmosphere that play the role of predictors for solar flares

to construct a prediction service analogous to the one provided by national weather forecasting agencies

to make these predictions reliable, accessible, at low cost, real-time

space weather service

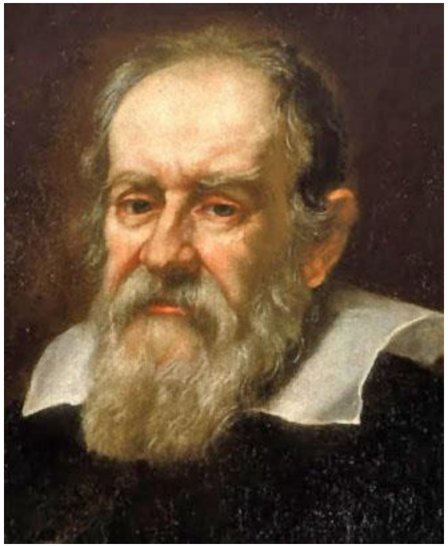
ingredient 1: properties

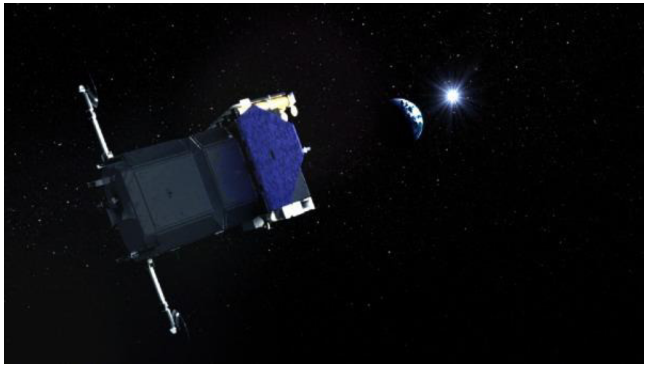
ingredient 2: machine learning

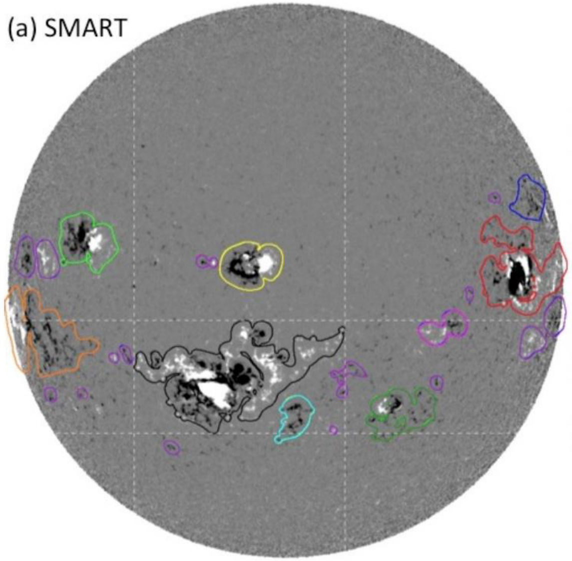
ingredient 3: technological platform

ingredient 1: properties

- data providing information on solar active regions (mainly: magnetic field, topography of the sunspots)
- pattern recognition methods able to extract properties from data
- property database







ingredient 2: artificial intelligence (AI)

AI: two possible approaches:

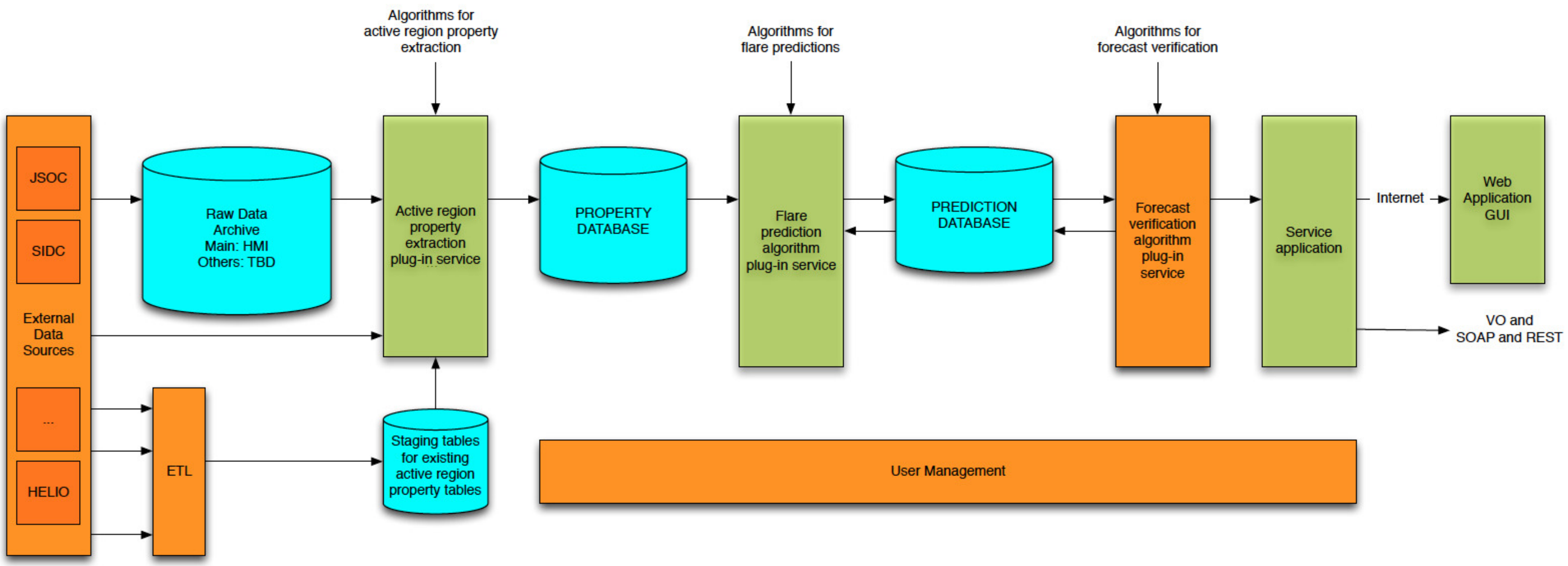
- supervised learning: a set of historical data are at disposal where features are tagged by means of labels representing the observation outcome, and the prediction task consists in determining the label associated to the incoming features' set

- unsupervised learning: no training set is used, while data are clustered in different groups according to similarity criteria involving data features.

$$\hat{\beta} = \arg\min_{\beta}(||y - X\beta||_2^2 + \lambda||\beta||_1)$$

the importance of feature selection

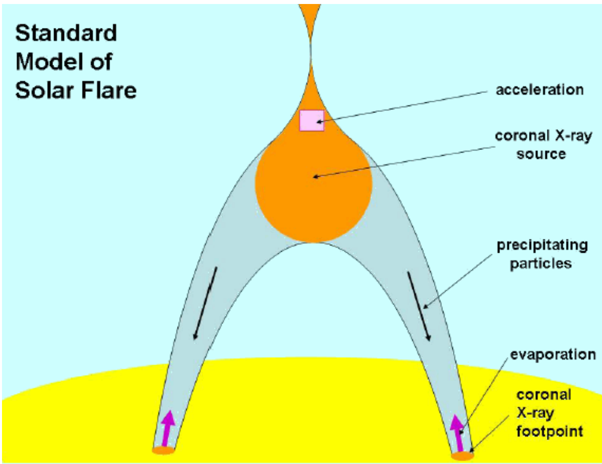
ingredient 3: technological platform



passwords: automation; big data; cloud; open access

two dreams

1. understanding the physics of solar flares:



2. forecasting flares in the same way
as thunderstorms are forecasted