Possible stereoscopic Hard X-ray observations with STIX and SORENTO instruments

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Motivation

Since YOHKOH/HXT there is no significant improvement of angular resolution of observations in HXRs.

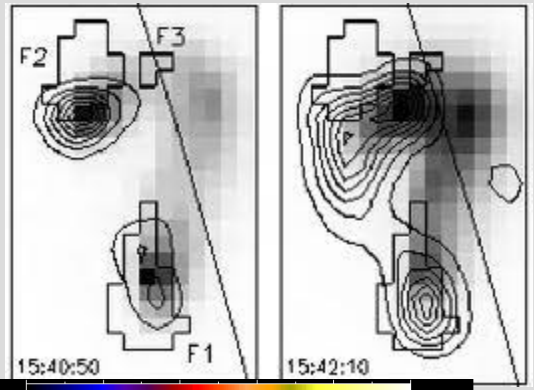
HXT ~5arcsec
RHESSI ~7-9 arcsec, with some special methods
(we can rarely achieve better values)
NuSTAR ~7 arcsec

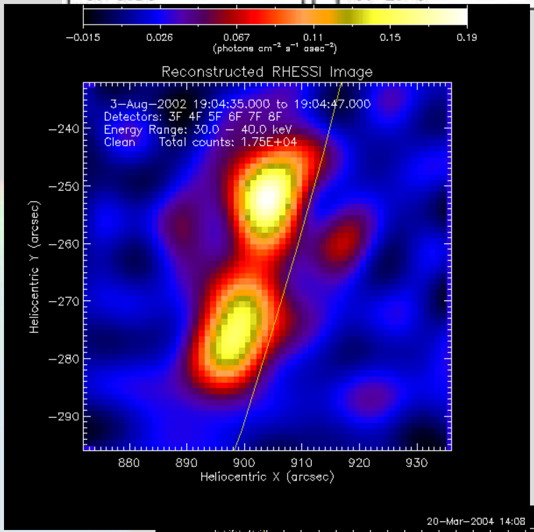
20 years of the same angular resolution, but in the future:

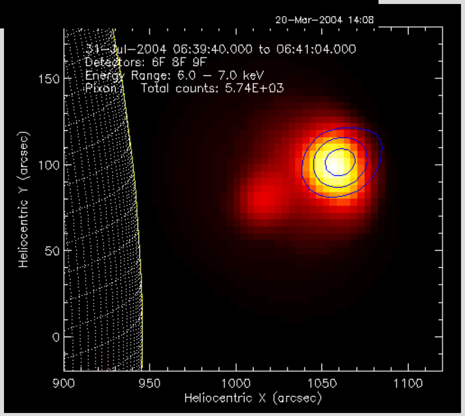
STIX not better than 7 arcsec
SORENTO close to above

We need special/new methods to improve angular resolution 10 times

Motivation: to start a discussion about future of HXR observations that will give a possibility for discoveries





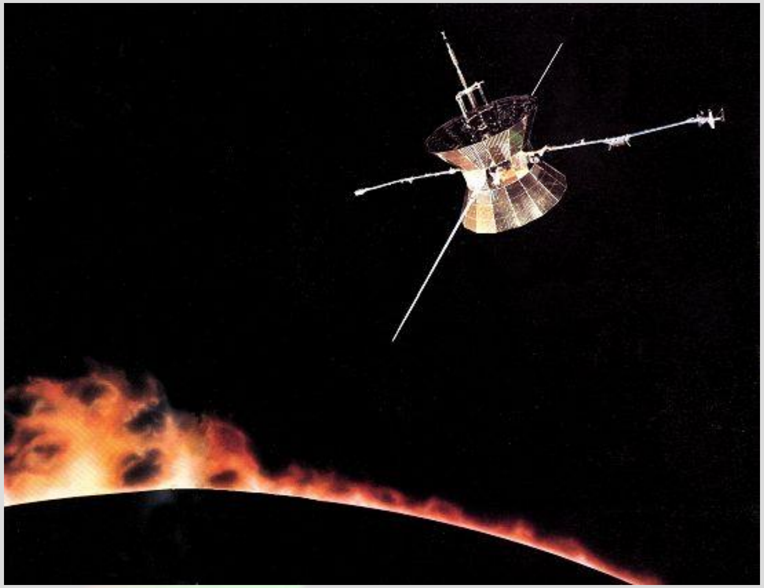


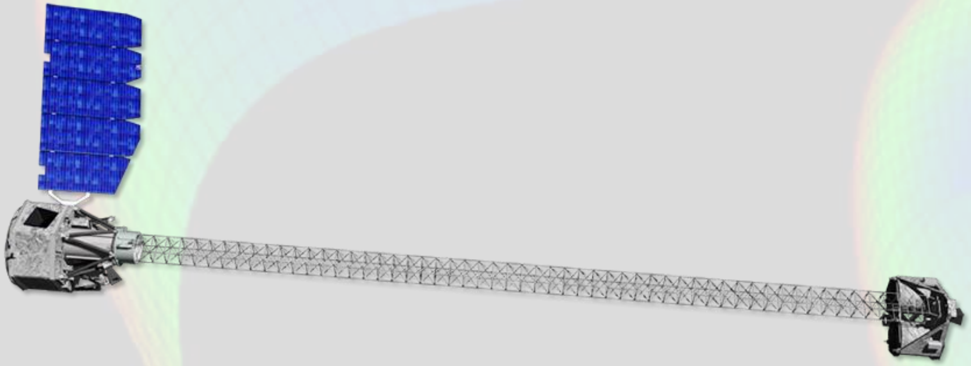
How to get more information about HXRs?

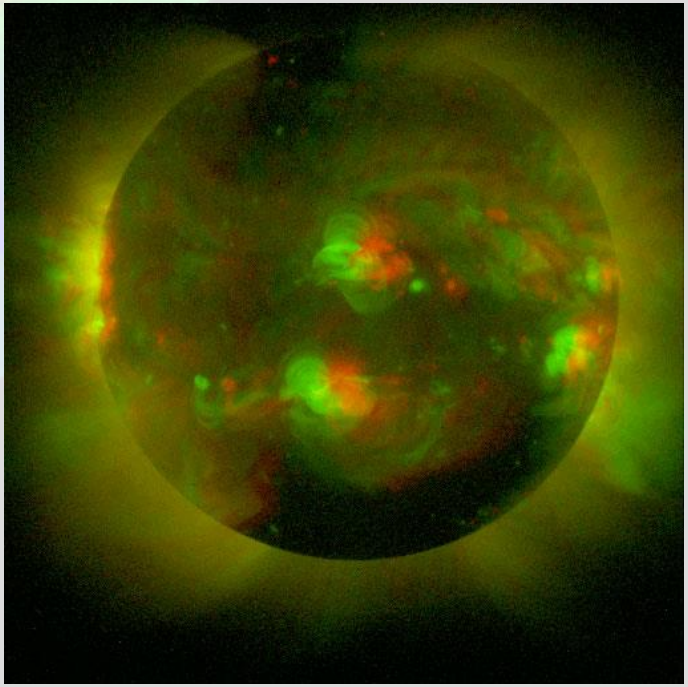
1. improve existing observational methods

2. get closer to the Sun

3. perform stereoscopic observations

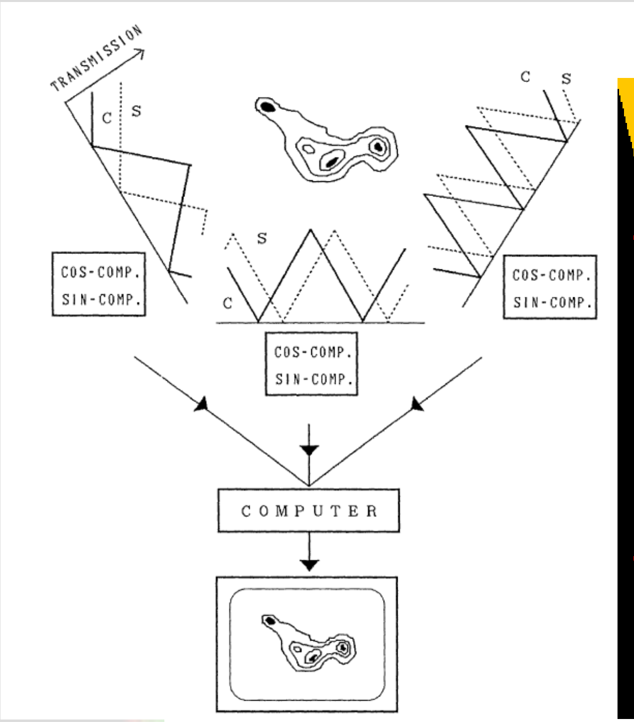


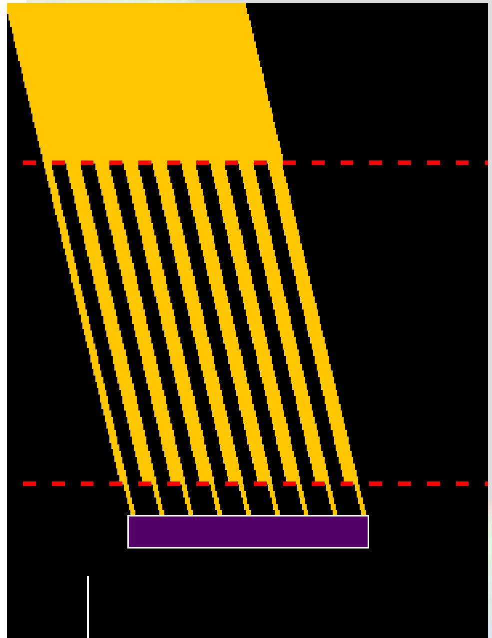


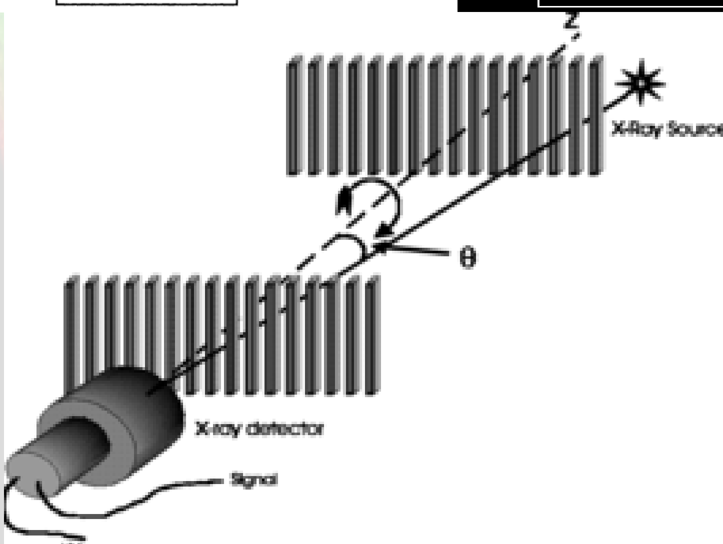


1. improvement of existing observational methods

Fourier imagers







- get Fourier components of the emission distribution
- many stationary pairs of grids (HXT)
- few grids on rotating satellite (RHESSI)

Disadvantages:

- images are reconstructed
- problem with fine angular resolution (need for fine grids and/or large distance between them)

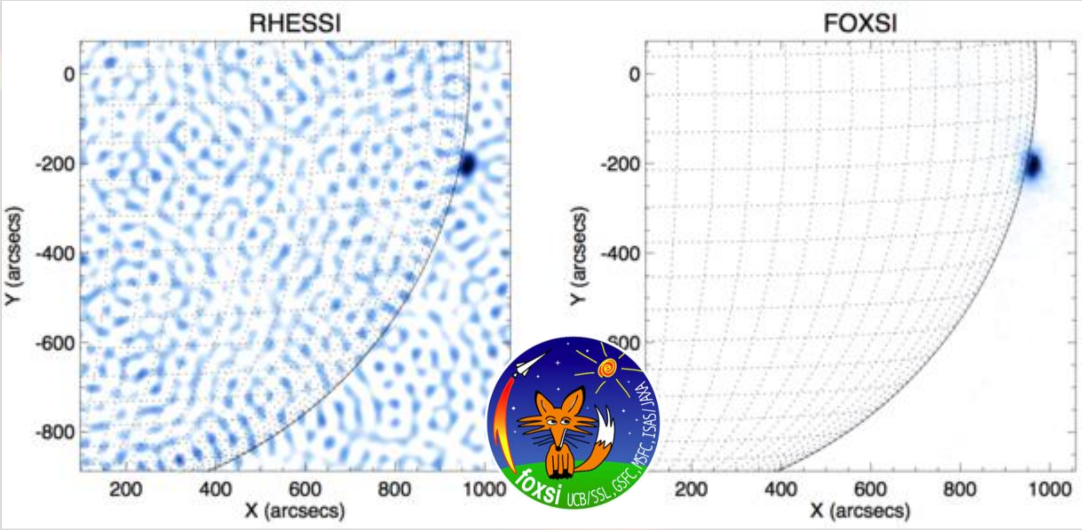
Grazing incidence

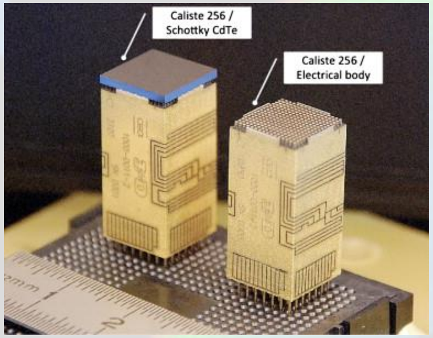
Today we are able to construct a grazing-incidence optics that will work up to 80 keV

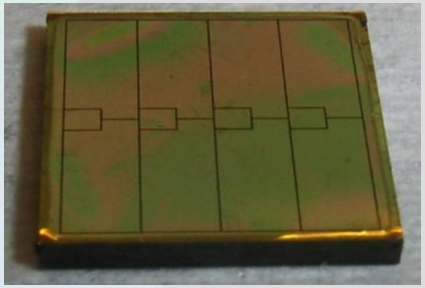
New, pixelized detectors (like Caliste) are able to detect fotons above 150 keV

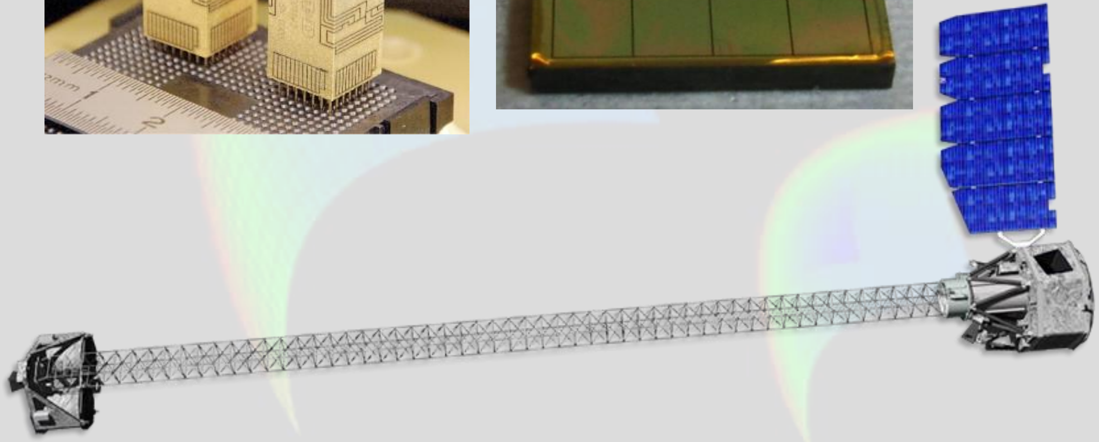
However, present and planned missions will not break the 2-4 arcsec border. Therefore…

With existing angular resolution we can get closer to the Sun and improve spatial resolution



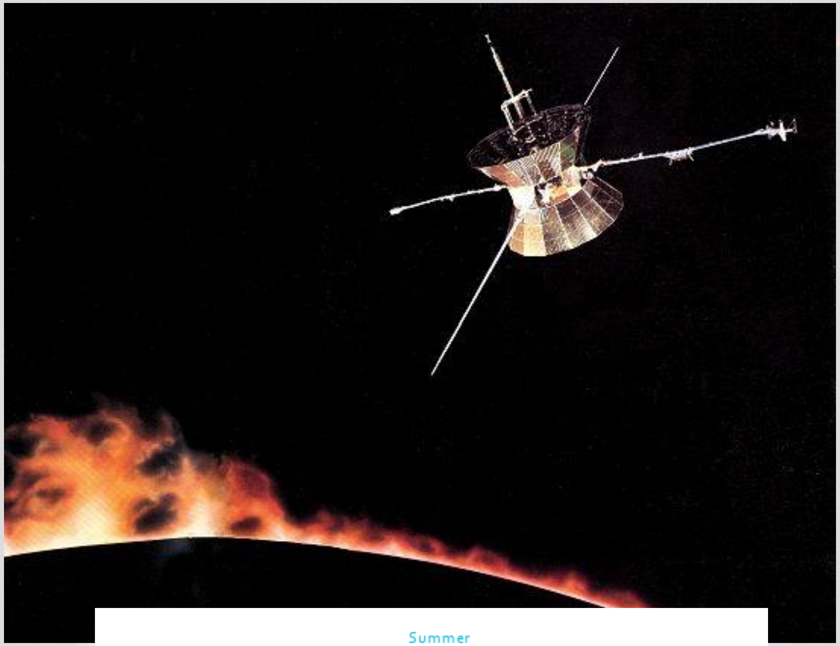


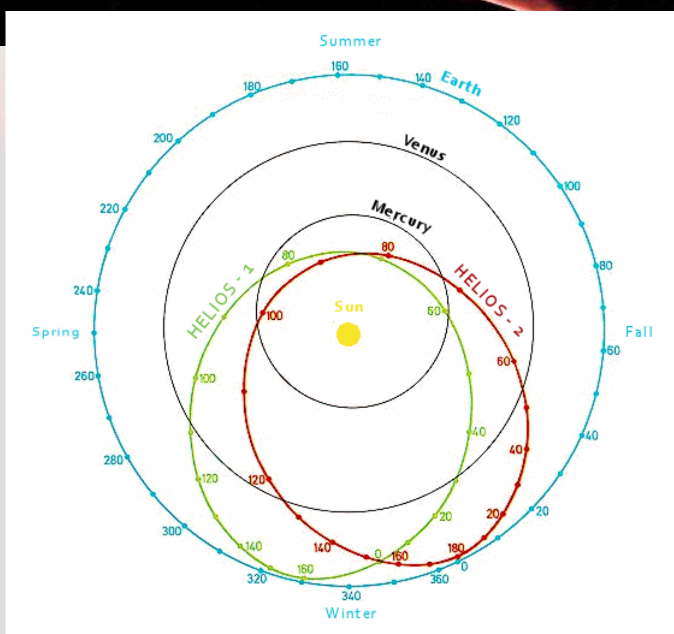




2. getting closer to the Sun

Closer to the Sun – past





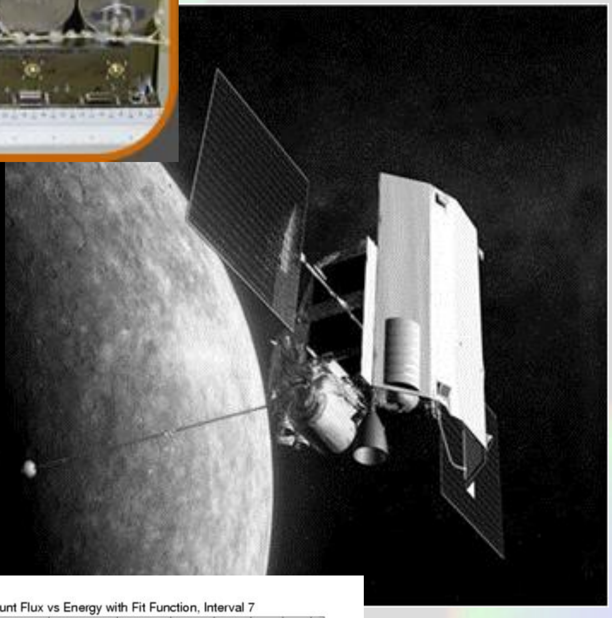
Helios 1,2
(December 1974 – November 1981)

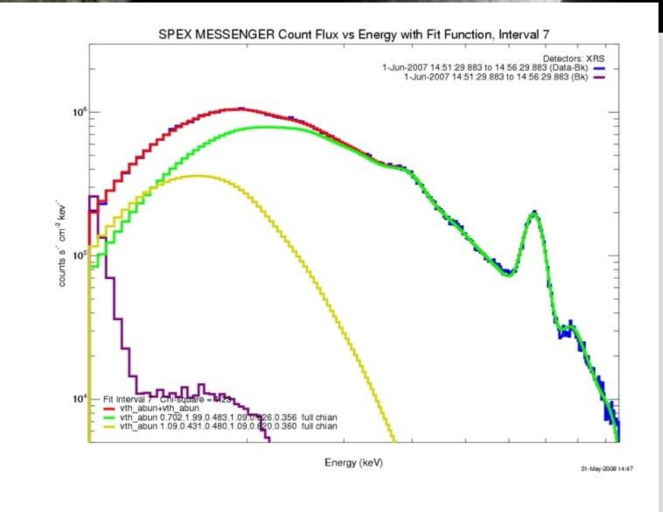
Equipped with a number of detectors:

- *Plasma Experiment Investigation*
- *Flux-gate Magnetometer*
- *Search Coil Magnetometer*
- *Plasma Wave Investigation*
- *Cosmic Radiation Investigation*
- *Low-Energy Electron and Ion Spectrometer*
- *Zodiacal Light Photometer*
- *Micrometeoroid Analyser*

17 April 1976 (Helios 1) – perihelion distance 0.29 AU

Closer to the Sun – present

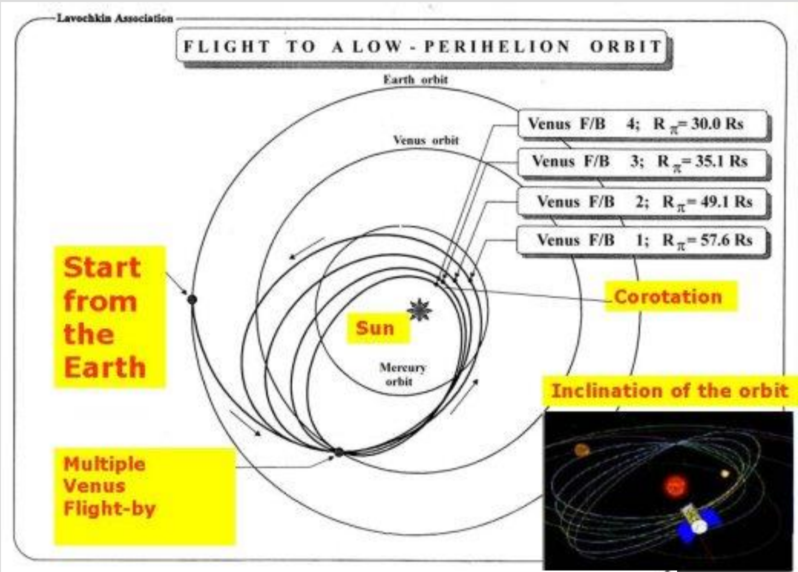




X-Ray Spectrometer (XRS) aboard MESSENGER

- mounted on the sushade
- single Si PIN detector
- effective area 0.03 mm2
- energy range 1-10 keV
- energy resolution 0.7 keV
- common observations with SphinX and RHESSI

*CHIANTI-predicted line-plus-continuum thermal spectra (**green**, **yellow**)*
***summed spectrum** (best fit to the data)*
*pre-flare **backgound** spectrum*



InterHelioProbe

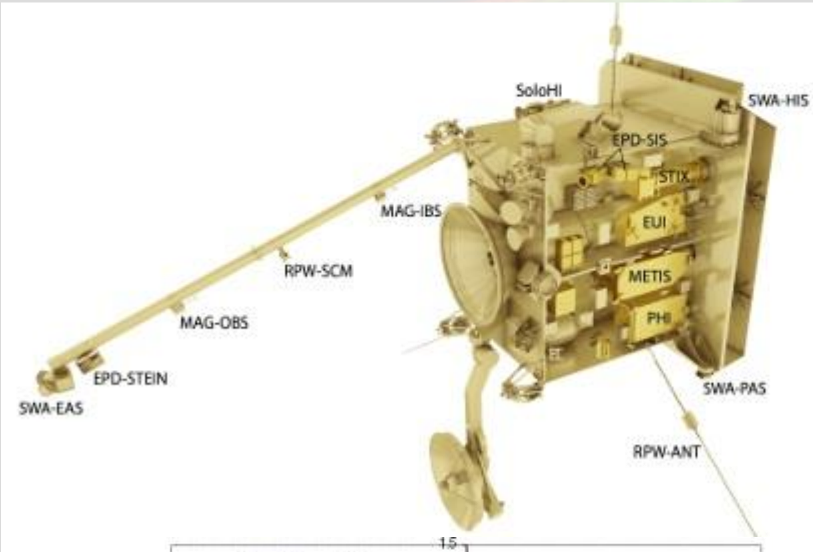
SOLAR INSTRUMENTATION

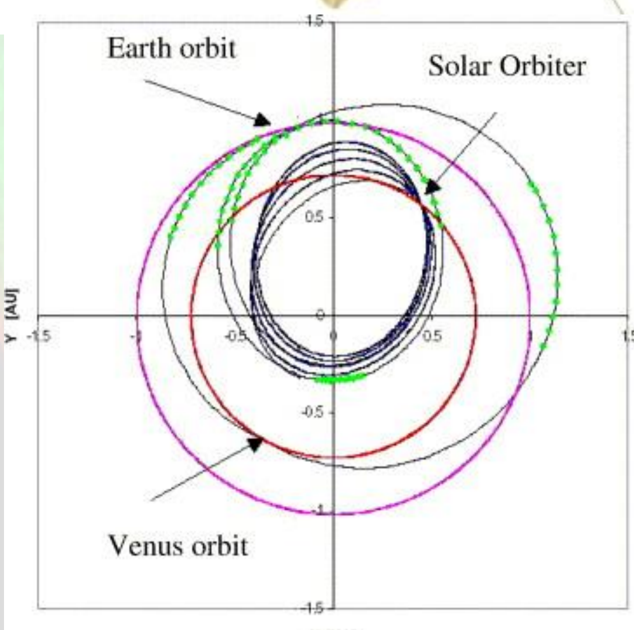
- **X-ray telescope (SORENTO)**
- X-ray spectrometer
- Magnetograph
- Coronagraph
- White-light Photometer

HELIOSPHERIC INSTRUMENTATION

- Solar wind ion analyzer
- Solar wind electron analyzer
- Dust and plasma analyzer
- Magneto-wave complex
- Magnetometer
- Energetic particle detector
- Solar neutrons detector
- Gamma-spectrometer
- Radio spectrograph

Solar Orbiter – medium-class mission of ESA's Cosmic Vision 2015-2025 Programme





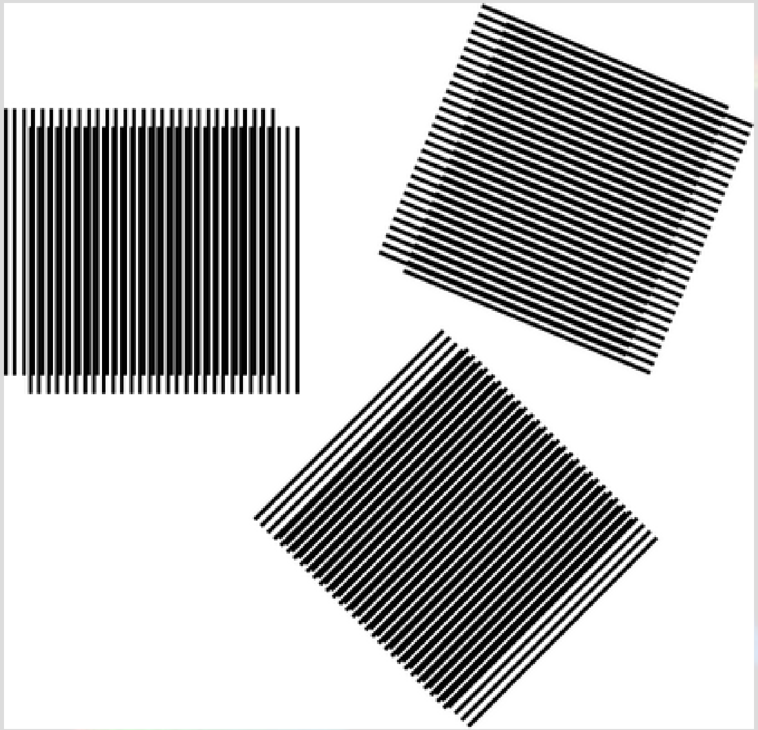
SOLAR INSTRUMENTATION

- Extreme Ultraviolet Imager
- Coronagraph
- Polarimetric and Helioseismic Imager
- Heliospheric Imager
- Spectral Imaging of the Coronal Environment
- **X-ray Spectrometer/Telescope (STIX)**

HELIOSPHERIC INSTRUMENTATION

- Energetic Particle Detector
- Magnetometer
- Radio and Plasma Waves
- Solar Wind Plasma Analyser

STIX, SORENTO



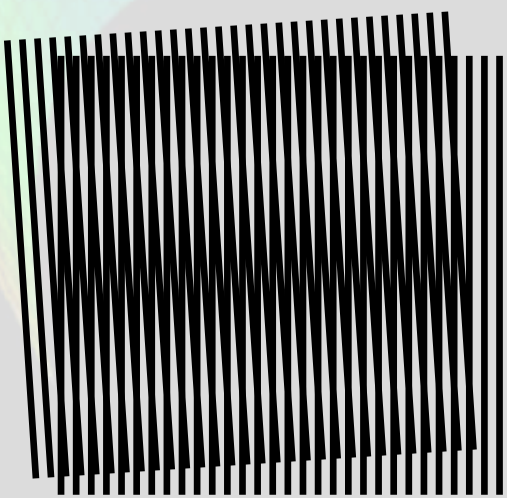
Fourier imagers (similar to HXT, not RHESSI)

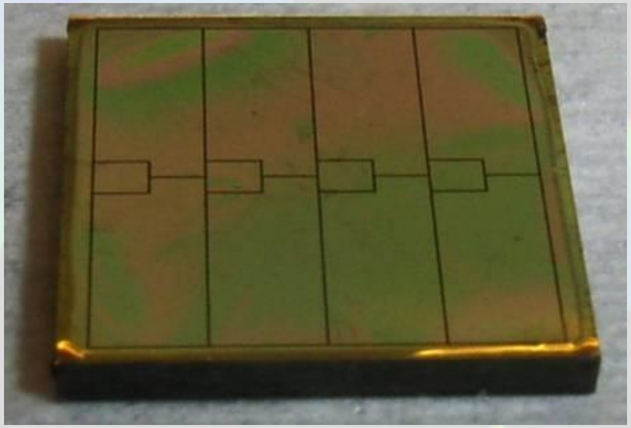
32 or 64 grids

Finer angular resolution not better
than 7 arcsec

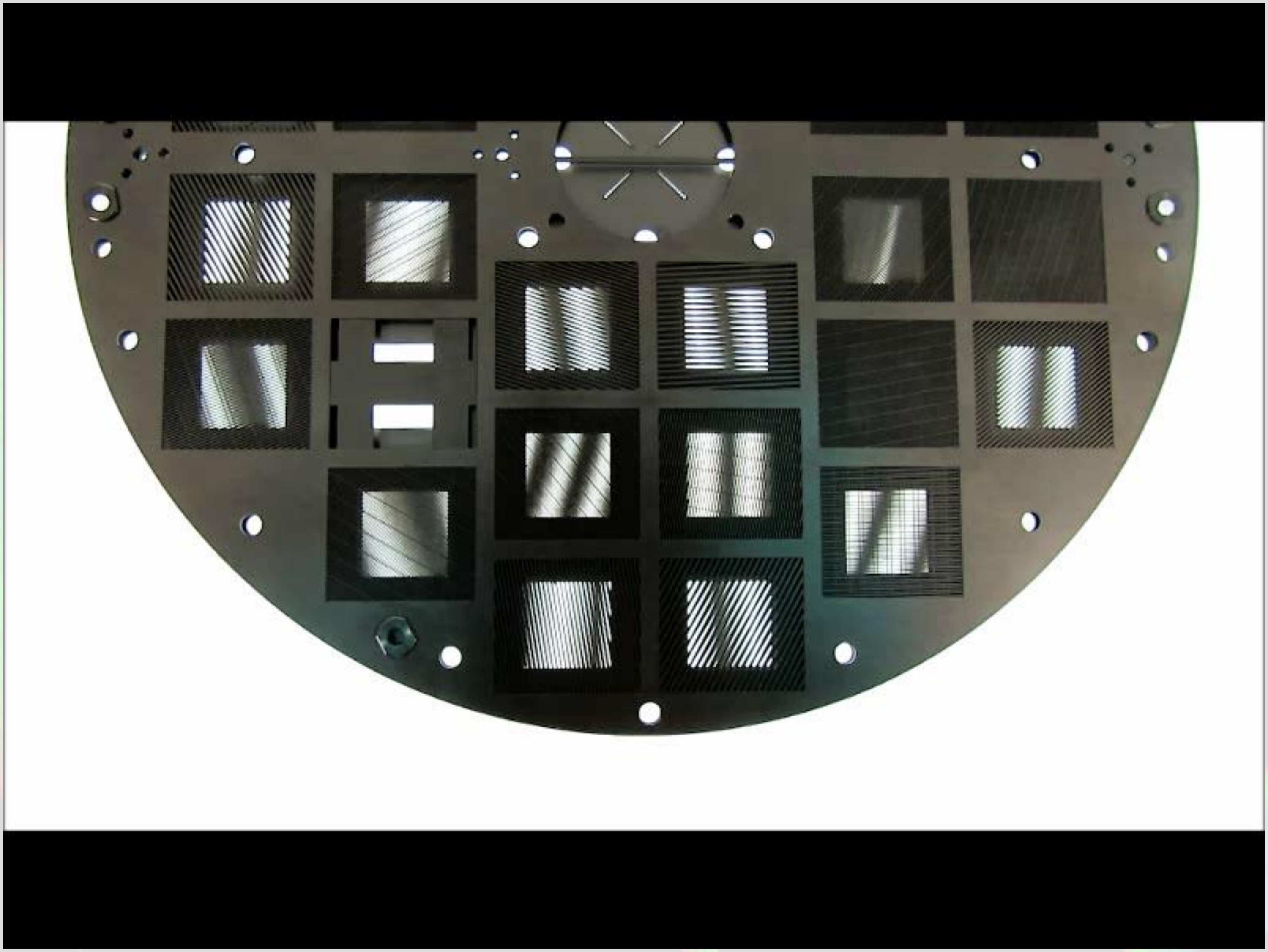
Caliste detectors (12 pixels)

Moiré pattern (more sensitive to emission distribution) instead of simple shift in phase (HXT)





STIX, SORENTO



Even with such sophisticated methods we still do not improve below 7 arcsec. Therefore…

3. stereoscopic observations

Stereoscopic observations – past

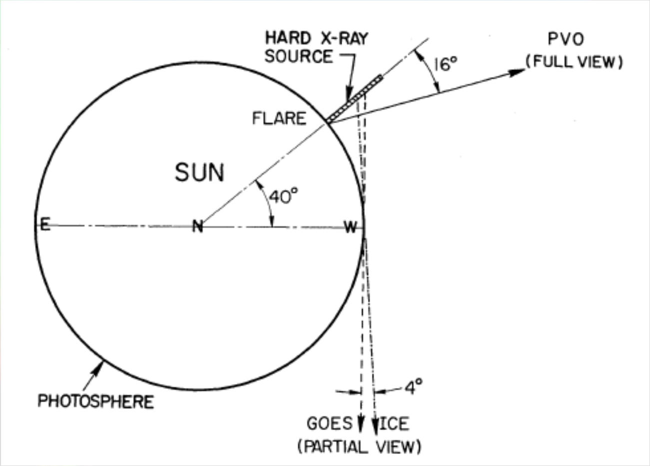
Spatial structure of greater than 100 keV X-ray sources in solar flares
Kane, S.R. et al. 1982, ApJL 254, 53

ISEE 3 + Pioneer Venus Orbiter:
Height of HXR sources, model testing

Directivity of 100 keV-1 MeV photon sources in solar flares
Kane, S.R. et al. 1988, ApJ 326, 1017

ISEE 3 + Pioneer Venus Orbiter:
no detected directivity of photon sources

Stereoscopic observations of a solar flare hard X-ray source in the high corona
Kane, S.R. et al. 1992, ApJ 390, 687



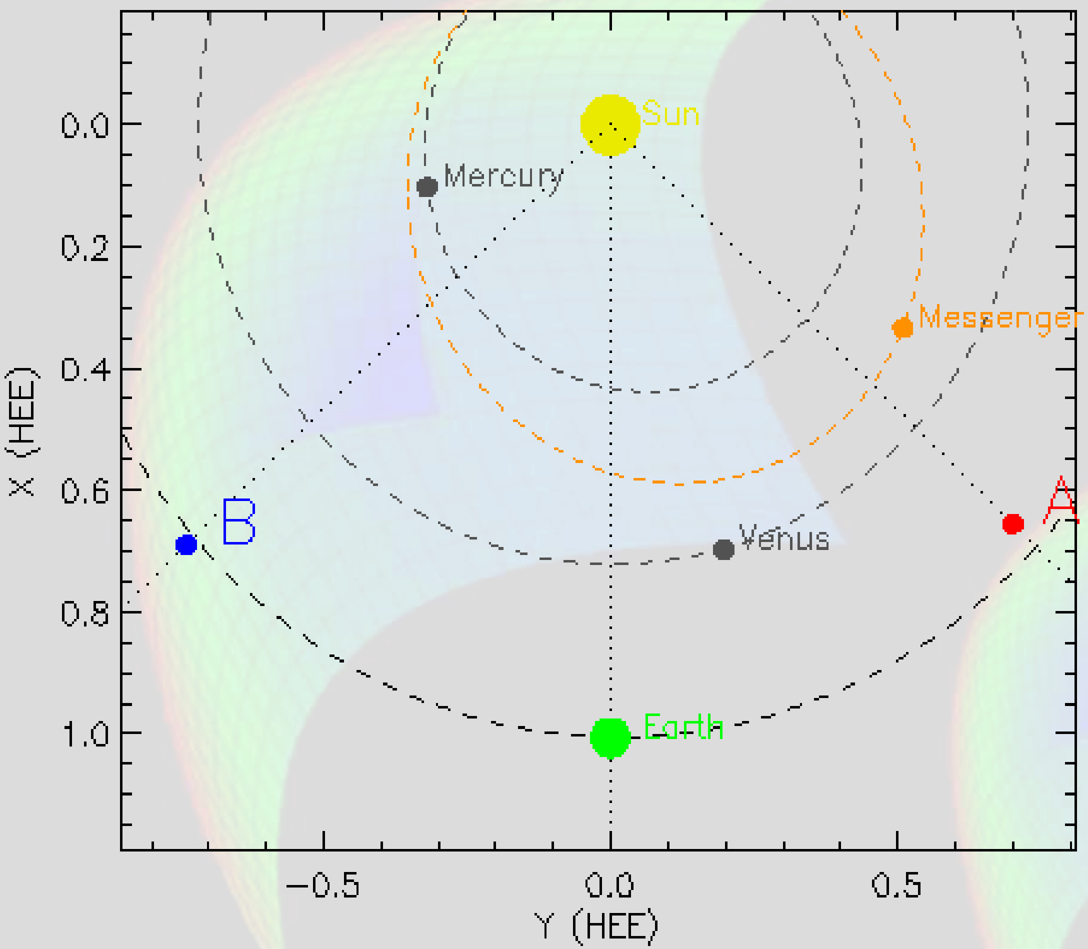
ISEE 3 + Pioneer Venus Orbiter+GOES:

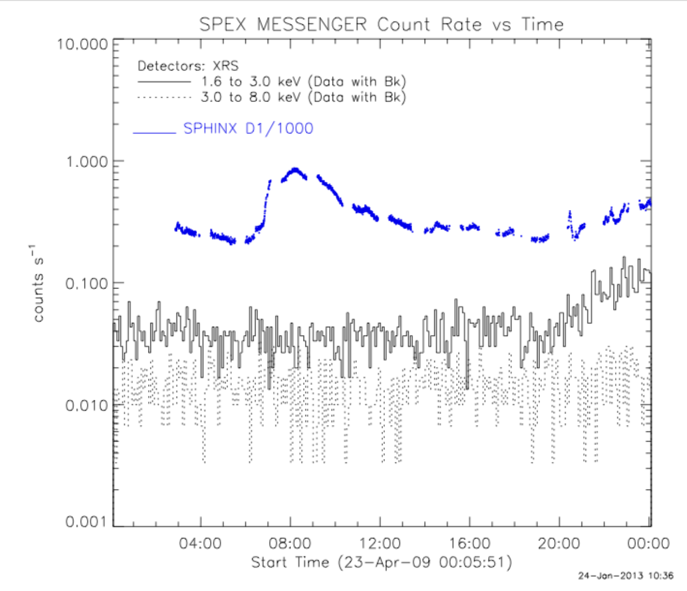
- HXR at heights >2x10^5 km above photosphere
- coronal source brightness is 10^{-3} of the total brightness (at 100 keV) during impulsive phase
- low energy cutoff < 5 keV

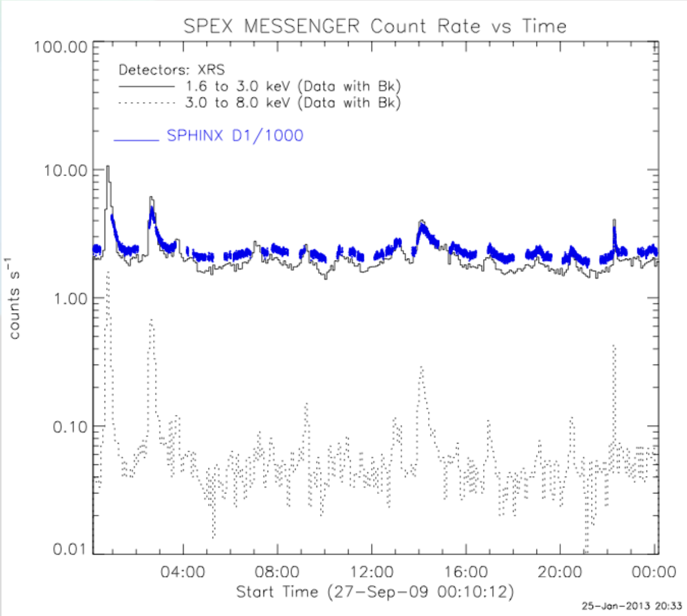
Stereoscopic observations of solar hard X-ray flares made by ULYSSES and YOHKOH
Kane, S.R. et al. 1982, ApJL 254, 53

ULYSSES+YOHKOH:
no directivity of HXR photons

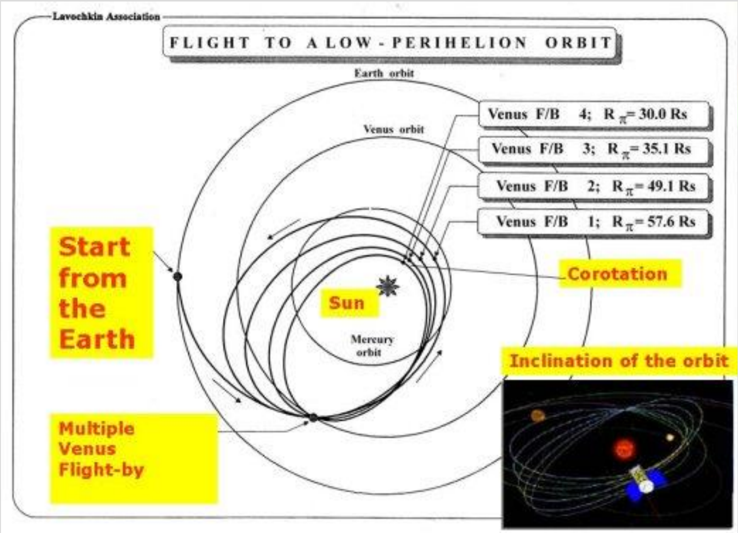
Stereoscopic observations – present

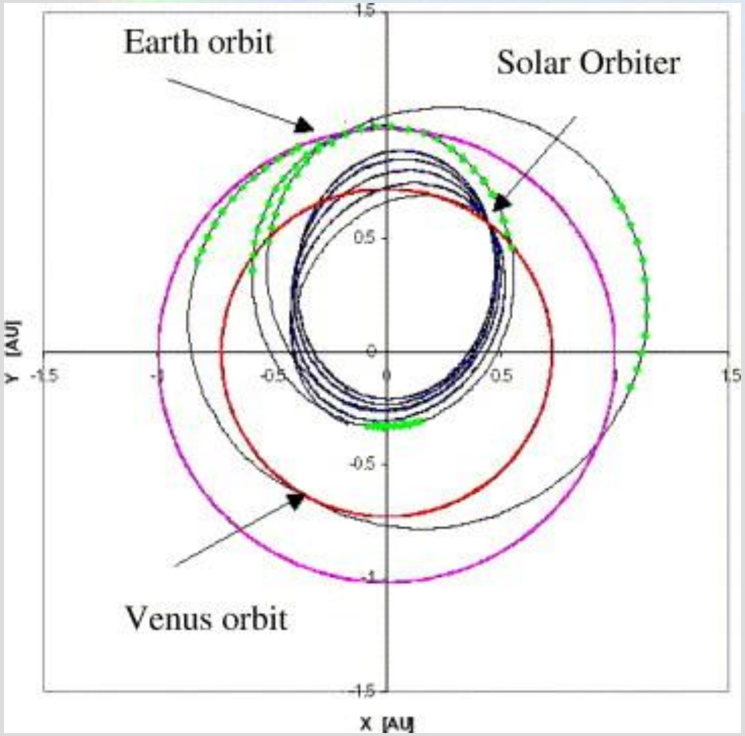






Stereoscopic observations – future





STIX, SORENTO – twin instruments which will operate at similar time period

Identical detectors

Similar imaging method

Therefore we will:

- have an occasion to develop new reconstruction methods that will take into account Fourier components obtained from two points in space
- record hundreds of flares observed from two points in space – detailed information about height distribution of emission in coronal sources
- see reconnection region operating

Stereoscopic observations – how to do better?

InterHelioProbe – there is idea to launch second one after the succesfull launch of the first

Thus, we will have three identical instruments!

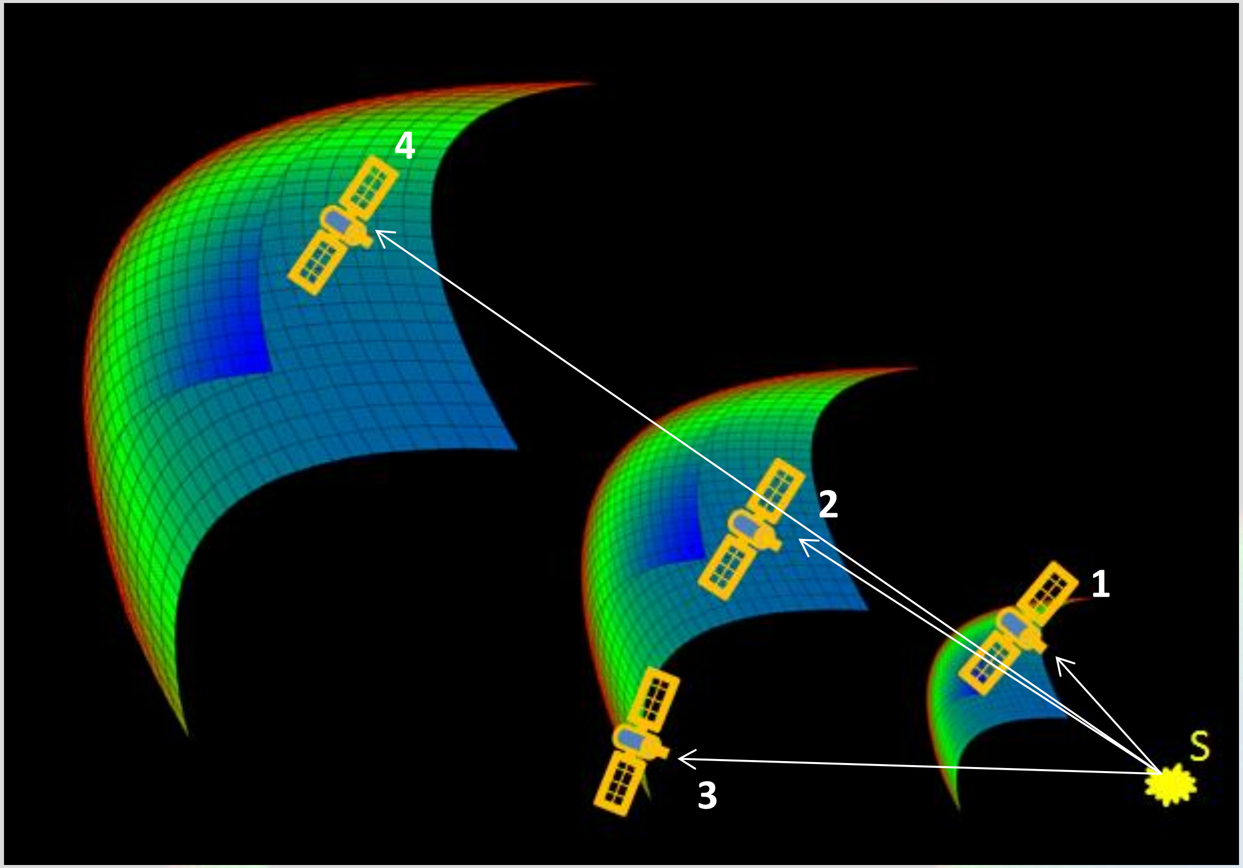
But let’s go further. We can add another one on the Earth orbit.

The fourth satellite will give a possibility for multilateration

Time delays are used for estimation of the position of a plane.

At least four stations are needed for exact position

Multilateration & HXRs



Unknowns:

source position (x,y,z)
time of signal generation

With four (or more) instruments we can resolve equations

It seems that if we will be able to record HXR signal with 1 ms time resolution then we are able to estimat ethe position with the accuracy of few hundreds of kilometers

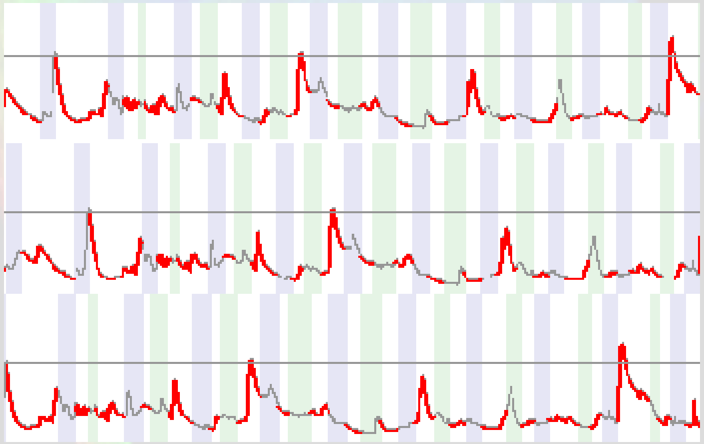
$$c(t_n - t) = R_n = \sqrt{(x_n - x)^2 + (y_n - y)^2 + (z_n - z)^2}$$

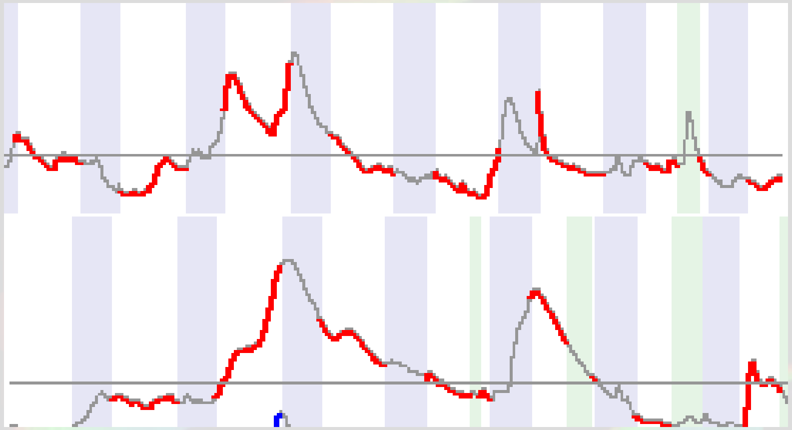
It means that we are 10 times better and we obtain 3D location of HXR source

Multilateration & HXRs

Possibility for:

- investigation of directivity
- footpoint separation
- location/assymetry of the acceleration region
- energy-height relation for footpoints
- improvement of Fourier methods due to fixed location in reconstruction procedure (two satellites will also give valuable information)





It is the best time to start think of new reconstruction algorithms and/or a small instrument that will work as additional source of delay information.