Future instrumentation for high-energy solar physics

a partial and partial survey

David Smith

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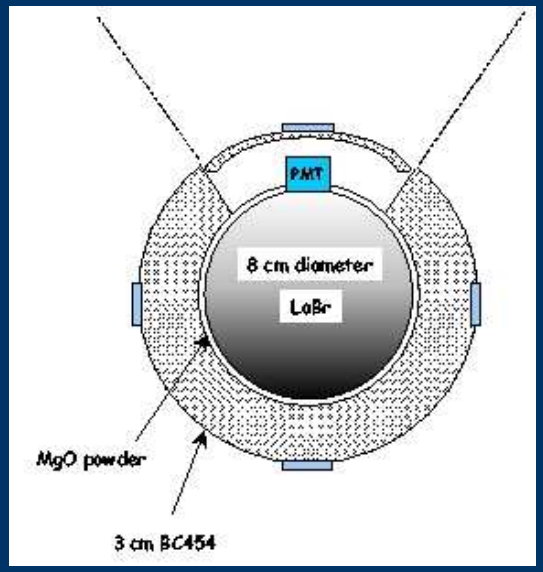

Crystal ball

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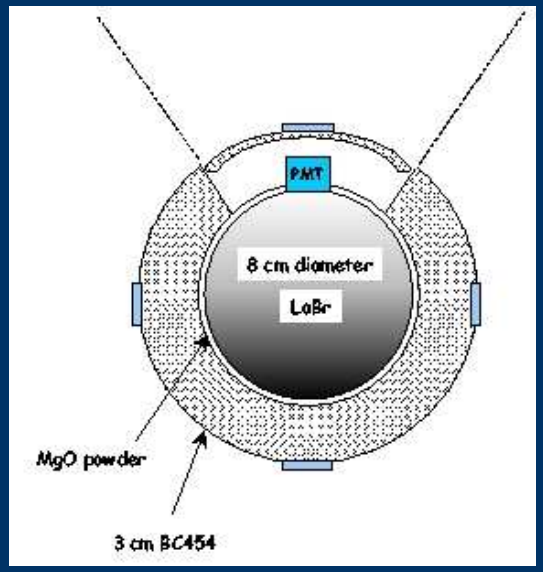

Crystal ball

OK, it's really the neutron and gamma-ray detector proposed for Solar Orbiter

Future instrumentation for high-energy solar physics

a partial and partial survey

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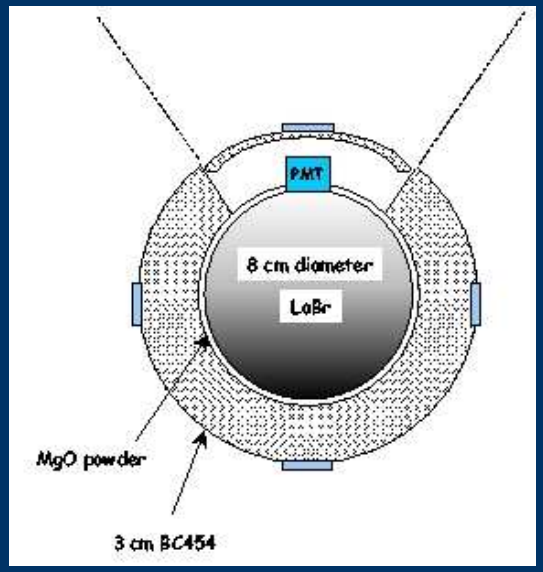


Crystal ball

OK, it's really the neutron and gamma-ray detector proposed for Solar Orbiter

But it **IS** a crystal ball, anyway

Part 1: upcoming missions

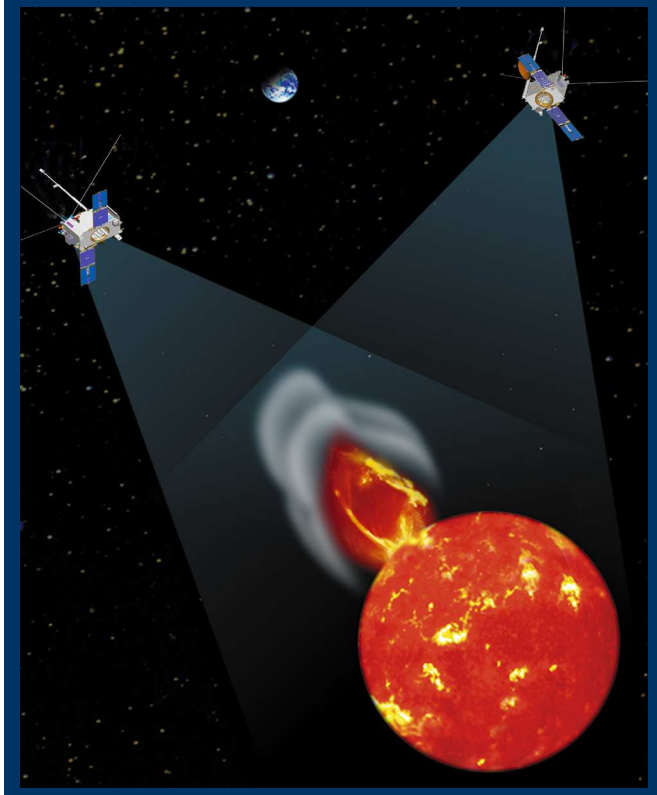
- Near term
- Further out

Part 2: evolving technologies

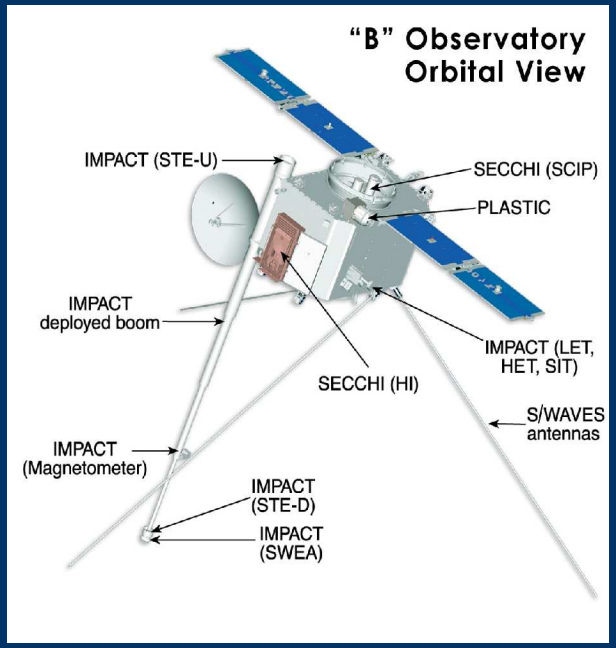
STEREO: launch in 1 month!

http://stereo.gsfc.nasa.gov/instruments/instruments.shtml

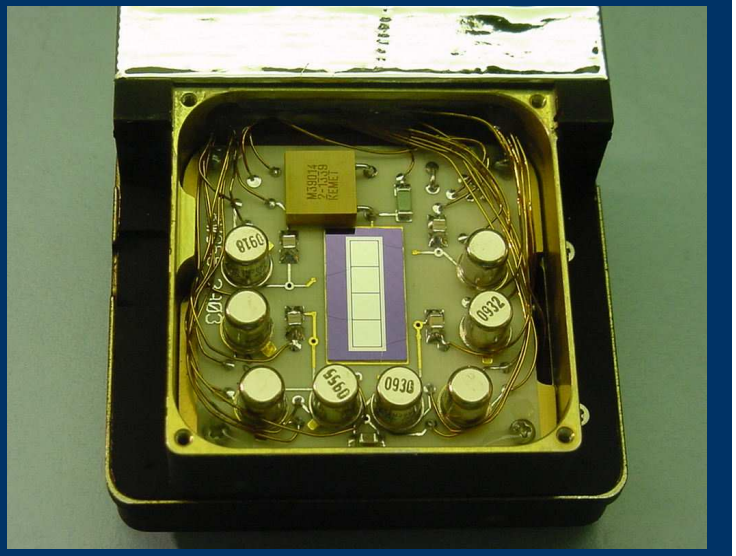
LET/HET: dE/dx vs E technique for high-energy particles
suprathermal electron telescope 2-20 keV, Si
radio waves instrumentation
also: EUV, white light, plasma composition



Graphics: NASA



Suprathermal electron telescope
Graphic: U. C. Berkeley



Solar-B (Japan/US/UK) Launch this year!
(Solar-A was Yohkoh)

http://www.isas.ac.jp/e/enterp/missions/solar-b/

Optical telescope:
- Filter vector magnetograph
- Spectropolarimeter
- Subarcsec resolution, active region FOV

Soft x-ray telescope:
- 2" resolution, full sun FOV

EUV imaging spectrometer:
- Few arcmin FOV
- 2" resolution
- Dispersive slit spectroscopy
- Wavelength ranges: 170-210A, 250-290A

Graphics: JAXA

CORONAS-Photon; Launch 2007, third in a series of Russian solar spacecraft, part of ILWS. LEO.

Strategy is many smaller, somewhat redundant instruments

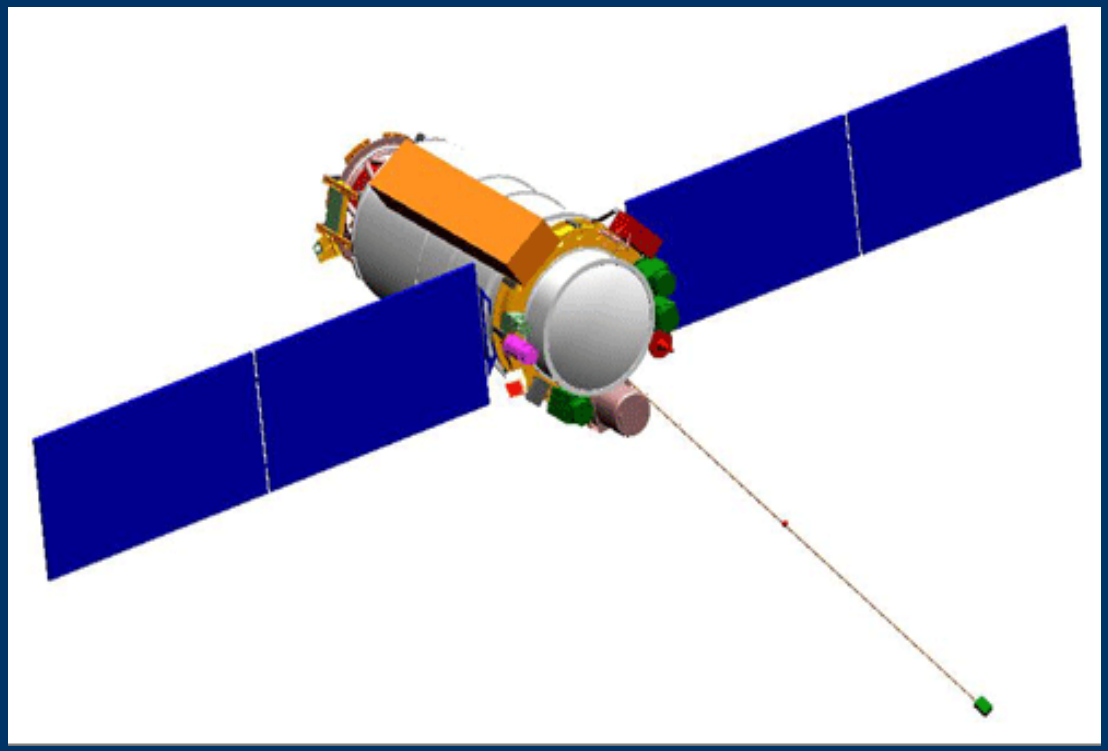
Led by Moscow Engineering Physics Institute (State University)

http://www.astro.mephi.ru/english/e_photon/e_instr.htm

5 high-energy photon instruments (including Penguin polarimeter)

2 high-energy particle instruments

UV, magnetometer, etc.

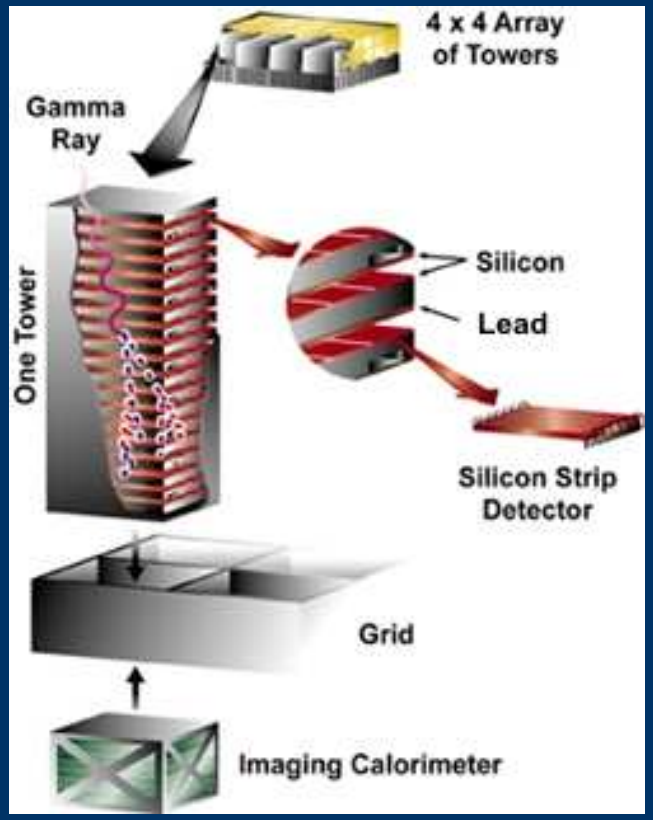


Graphic: MEPhI

GLAST: Launch 2007, NASA/DOE astrophysics mission

LAT (Si tracker) > 30 MeV (Pion range)
Burst Monitor -- NaI/BGO -- line range
(comparable to instruments on CORONAS)

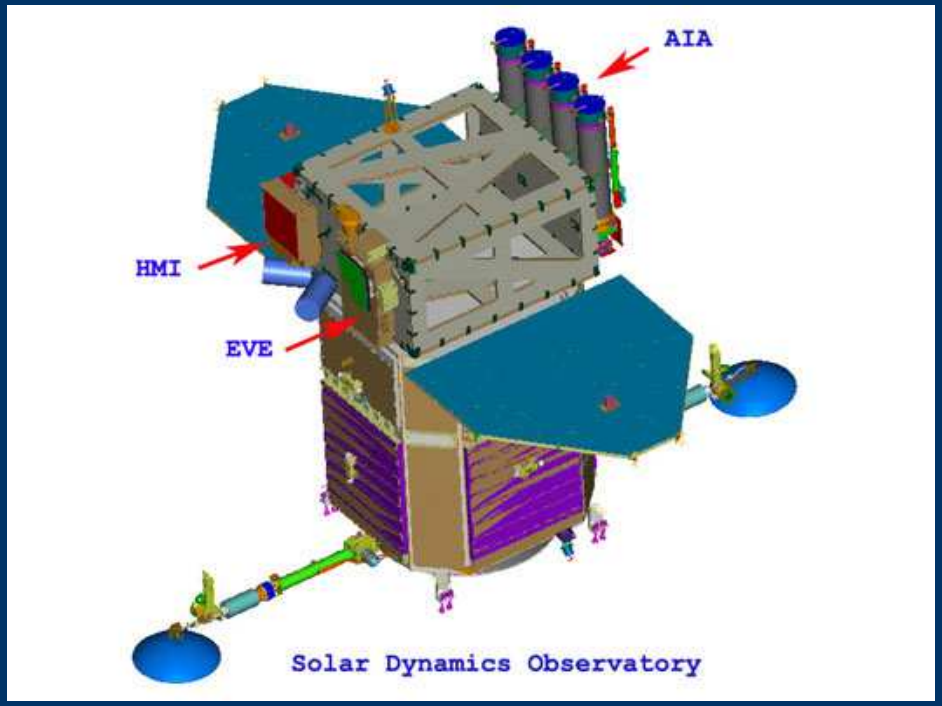
http://glast.gsfc.nasa.gov/



Graphics: NASA

Solar Dynamics Observatory (Launch Aug. 2008)
No direct high-energy measurements, but superb
- Magnetograms
- Optical images
- EUV irradiance measure

http://sdo.gsfc.nasa.gov/

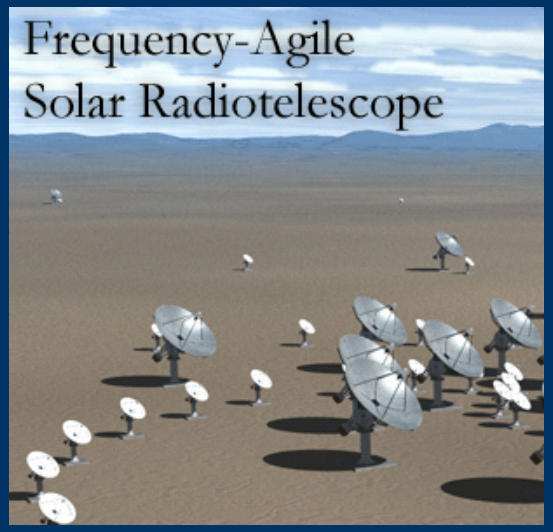


Graphic: NASA

Missions -- further out

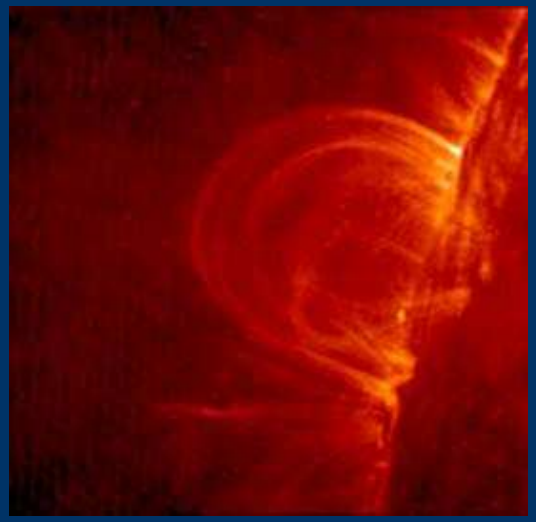
FASR: Expected completion in 2010

Combines broad spectral coverage, high time resolution, high spatial resolution -- an enormous data rate!

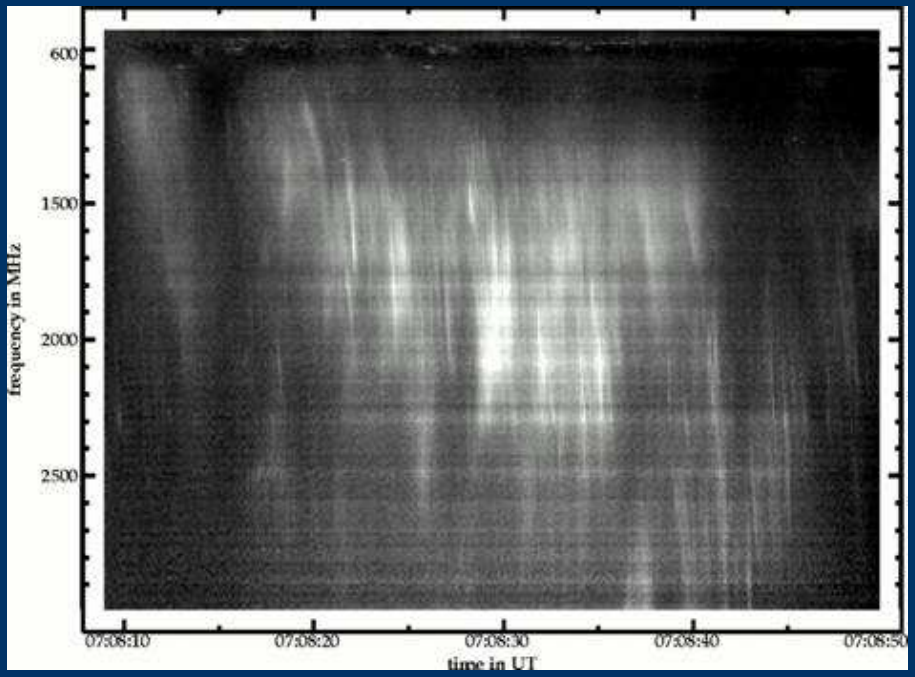


AUI, NRAO/NSF, NJIT, et al.

Simulation of expected image quality



Graphics: NJIT/NSF

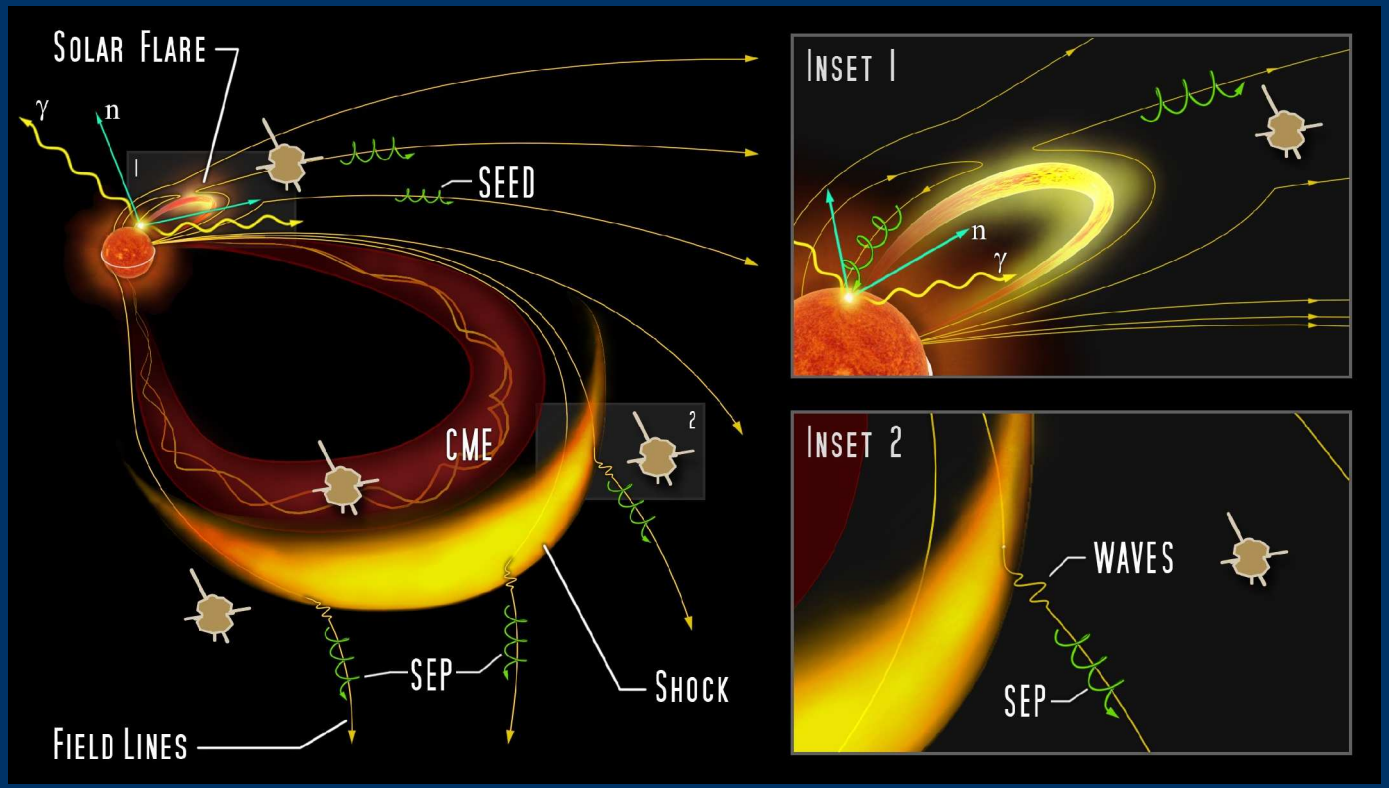


http://www.ovsa.njit.edu/fasr/

Imagine an image of this quality for each spectral and temporal bin of a spectrogram:

Inner heliosphere sentinels (LWS):

- Full high-energy particle suite
- Gamma-ray spectrometer (LaCl3, LaBr3, or NaI)
- Neutron spectrometer/imager
- Hard x-ray imager (may spin either way, CZT & Si detectors)
  - Close-in stereoscopy, far side as well
- Plasma, magnetometer, waves instruments



Graphic: NASA

Solar Orbiter

http://sci.esa.int/science-e/www/area/index.cfm?fareaid=45

Launch ~2015; approach as close as 45 solar radii (0.2 AU)

Payload definition document includes

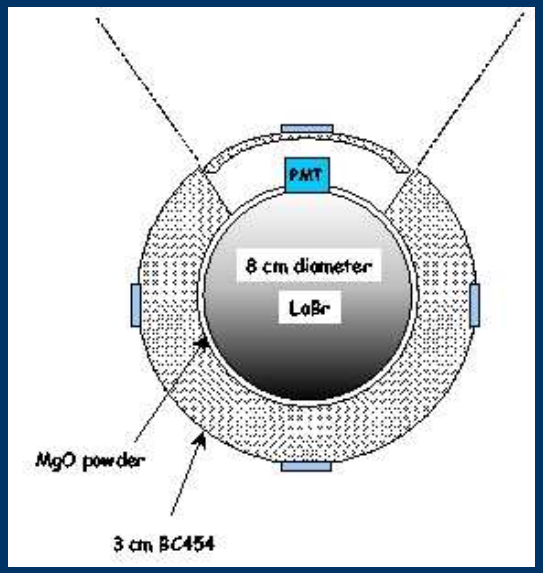
"Neutron Gamma-ray Detector" (NGD):

5kg, 0.6-20 MeV (n), 0.05-10 MeV(g)

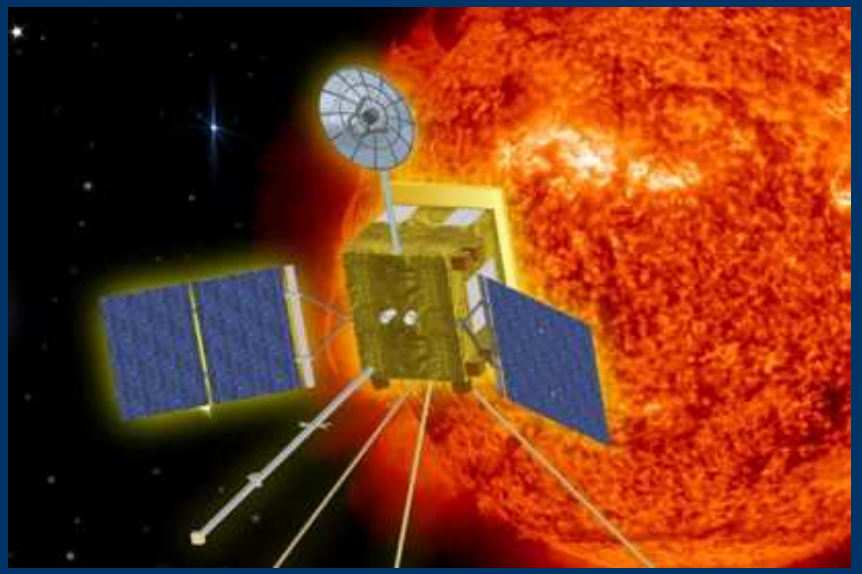
LaBr3 inside, boron-doped plastic anticoincidence & n-detector

"Energetic Particle Detector" (EPD), 2 keV - 100 MeV, 8.1 kg

"Spectrometer telescope imaging x-ray" (STIX), bigrid, CZT, nonrotating (Yohkoh style), 3-150 keV, 4 kg



Graphics: ESA



Far-off astrophysics missions with good flare science:

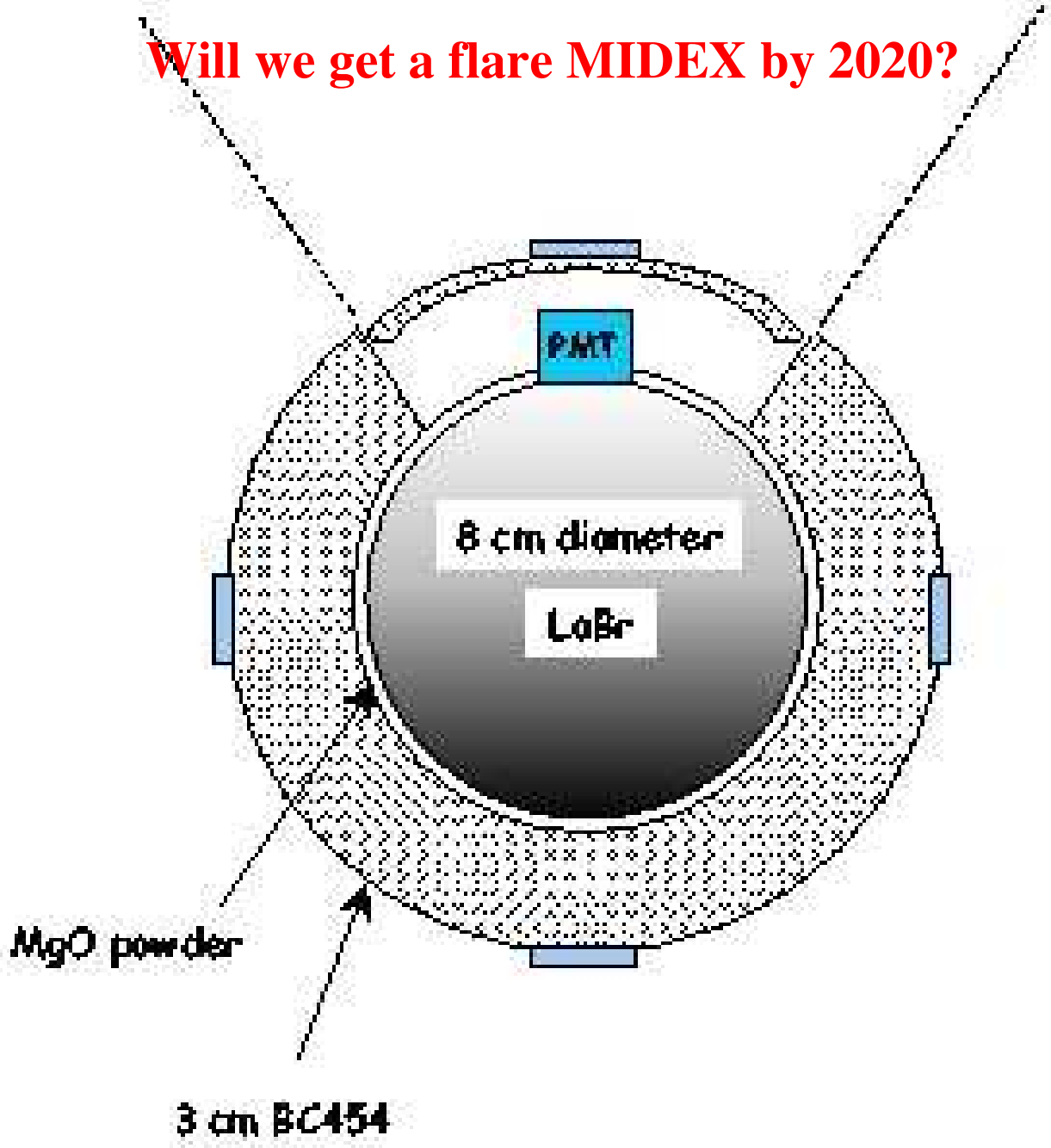
Black Hole Finder Probe (CASTER or EXIST):

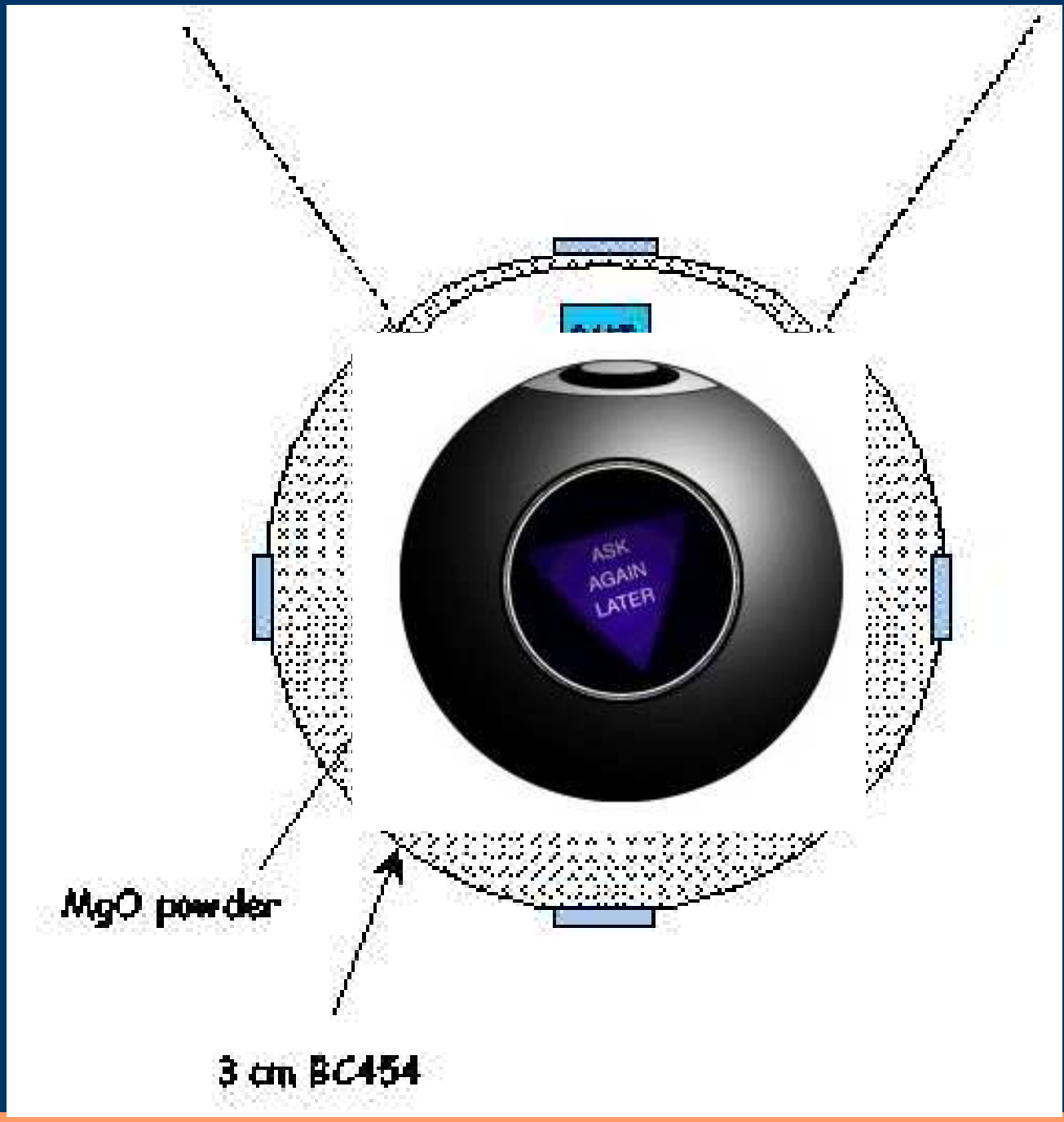
Huge all-sky monitor; detectors sensitive from 5 or 10 keV up to 200 or 600 keV, coded masks, very large area. Good nanoflare sensitivity. Unlikely before 2020.

Advanced Compton Telescope (ACT):

High sensitivity, possibly high resolution, 300 keV to 30 MeV range; Unlikely before 2020.

Will we get a flare MIDEX by 2020?



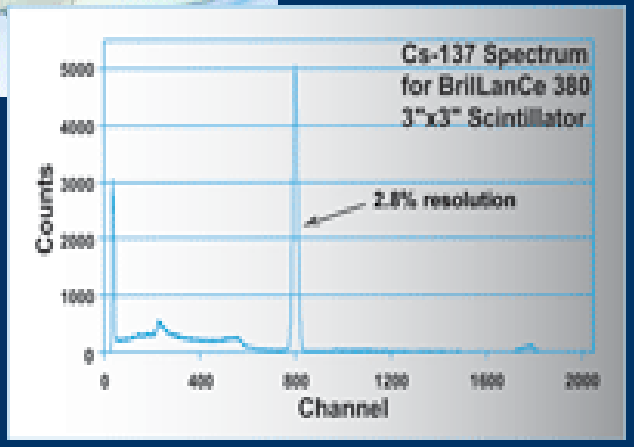

ASK
AGAIN
LATER
MgO powder
3 cm BC454

Part 2: Emerging technologies

Some recent detector advances:

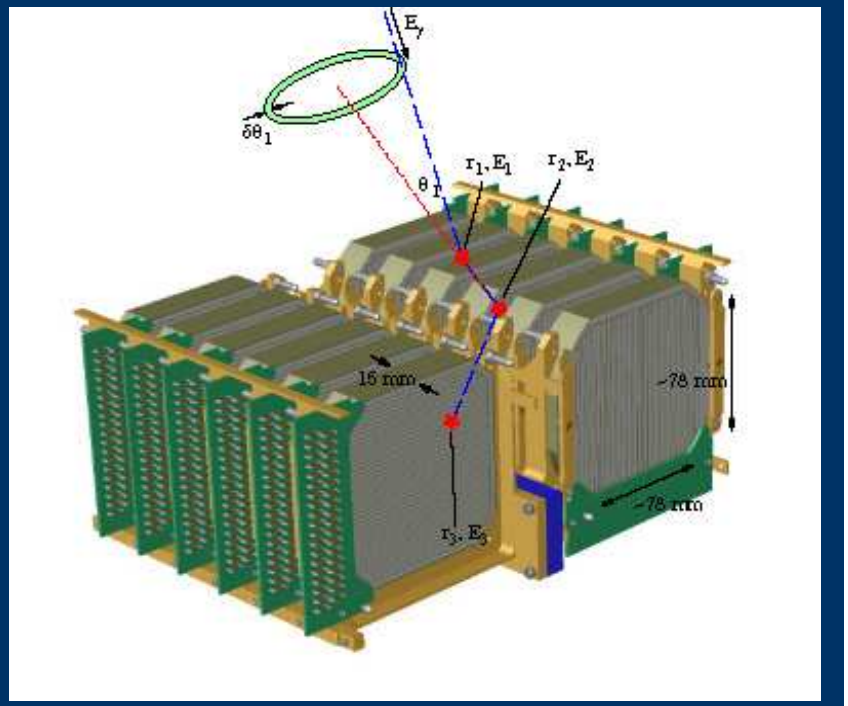
Lanthanum scintillators (LaCl3, LaBr3):
Resolution 2-3 times better than NaI,
more stopping power, 10x faster response.
3"x3" available as of June 1! (so says
the manufacturer, Saint-Gobain)

Graphics:
St-Gobain Inc.



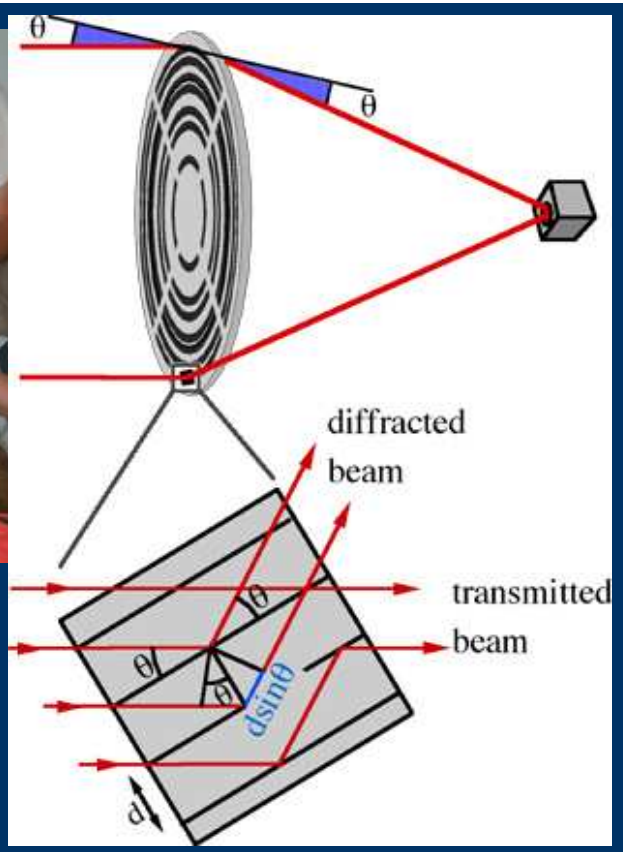
Germanium strip detectors:
Full Ge resolution
Full 3-d position of every interaction to 1mm
Enables Compton tracking for:

- Crude imaging
- Background rejection
- Rejection of incomplete collection
- Polarimetry



Graphic: S. Boggs, UCB

Some recent advances in imaging:



Laue-lens focusing for MeV gamma-rays in a narrow energy band. Being designed for astrophysics at nuclear line bands, but some of these (511, 847) are good for solar, too. Optimize for 2.2 MeV?
CLAIRE balloon, P. von Ballmoos, CESR Toulouse

Graphics:
P. von Ballmoos

Multilayer-coated grazing incidence optics; high/low Z thin layers (e.g. W/Si). Interference-based, too, but longer wavelengths. Extend capabilities of mirrors from ~10 keV to ~70 keV. Good possible use for nanoflare studies.
SIMBOL-X, ESA; [NuSTAR, NASA]

Graphic:
Caltech/LLNL

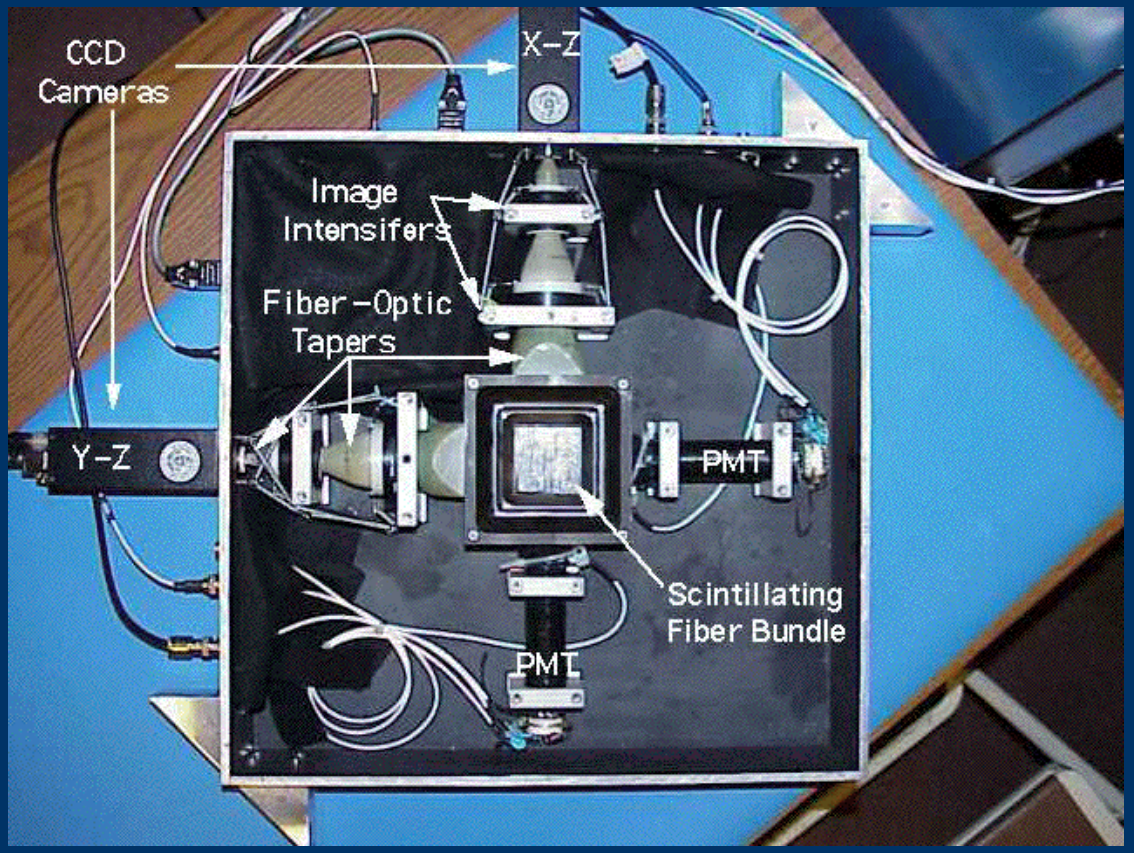
Advanced neutron detection (here at UNH): SONTRAC

Energy range: 20-250 MeV neutrons (and gammas, protons, electrons....)

Scintillating plastic fibers, layered in crossed directions

Images recoil protons, gets direction as well as energy, 3D!

Greatest potential is near the Sun, where neutrons at lower energies are still undecayed.



Graphic: J. Ryan, UNH

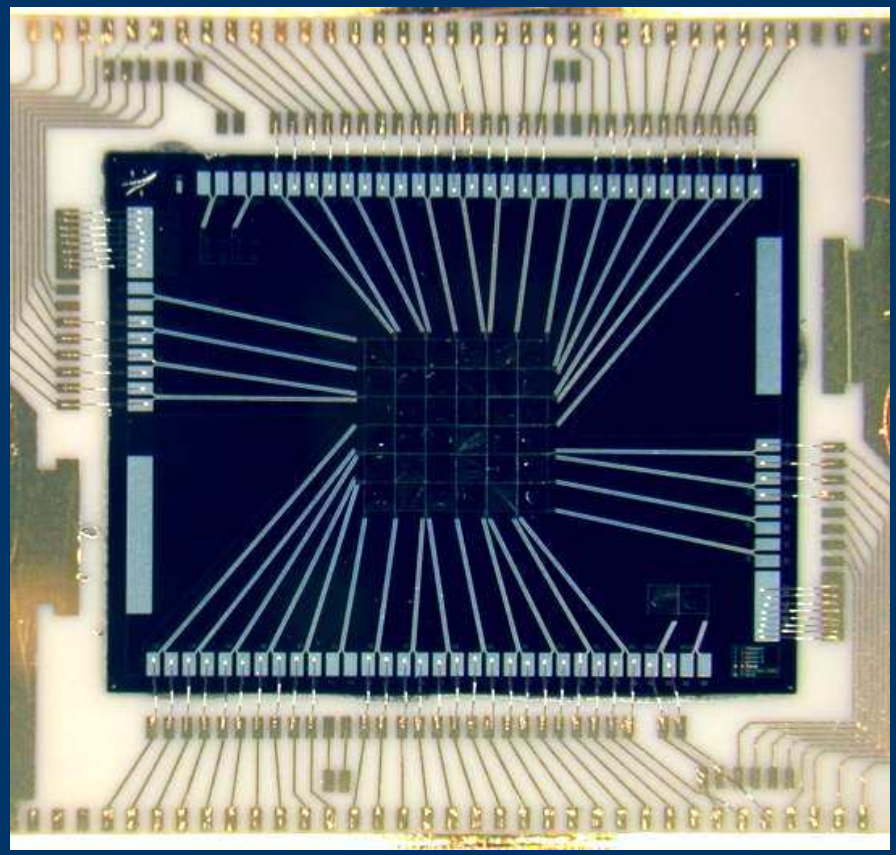
Microcalorimeters for nondispersive, high resolution thermal x-ray spectroscopy

Combines high energy resolution like a bent-crystal or other dispersive spectrometer with wider energy range and true 2D imaging of a Si or CZT pixel detector.

Requires 60 mK operation.

Resolution around 10 eV from 0.2 to 10 keV

Unit on Suzaku (AstroE2), an astrophysics mission, had a failure in its cooling system soon after launch



XRS microcalorimeter for Suzaku (Graphic: NASA Goddard)

Wanted: a way to detect ions at the Sun below the 2 MeV threshold for the beginning of nuclear lines

Protons in flight can charge-exchange with thermal neutrals when they reach 40 keV; results in atomic lines with strong redshifts.

Gives an integral measure of total proton flux above 40 keV.

Lyman-alpha red wing can be dominated by this effect.

Requires neutral H -- look at start of flare.

UV telescope must strongly suppress line center.

Similar technique used to image proton aurora on Earth (IMAGE satellite, instrument led by S. Mende).

[YOUR IDEA HERE]