Results from the Balloon-borne Hard X-ray Spectrometer

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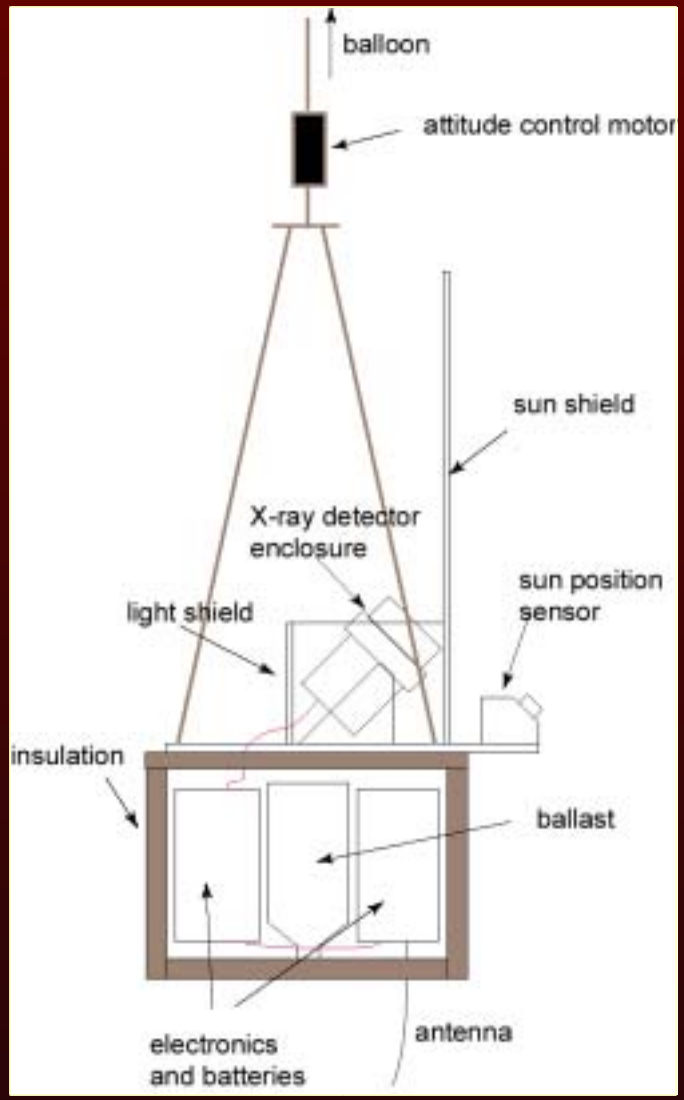
Introduction

- High resolution hard X-ray spectra in the 20-100 keV region provides quantitative information on particle acceleration and >20MK plasma.
- Lin et al. observed M6 flare with high-resolution Ge detector in 1980; no successful follow-up until RHESSI.
- Recent advances in CdTe detectors make high-resolution hard X-ray spectroscopy simpler.
- Goal is to make independent observation of high-resolution (< 3 keV FWHM) solar flare spectra.
- Two flights conducted:
  - August 2001 flight partially successful, no flares.
  - May 2002 flight successful, M1.1 flare observed.

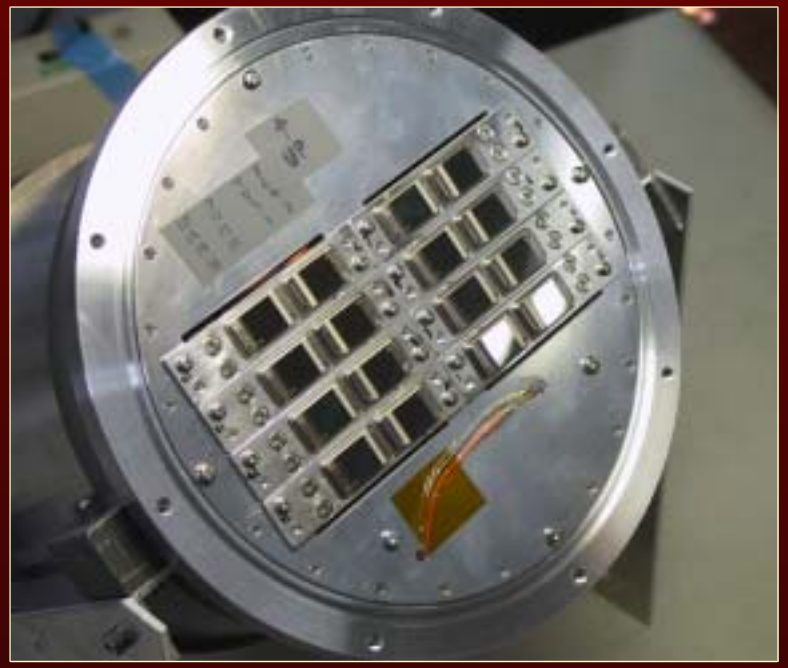
Instrument Overview

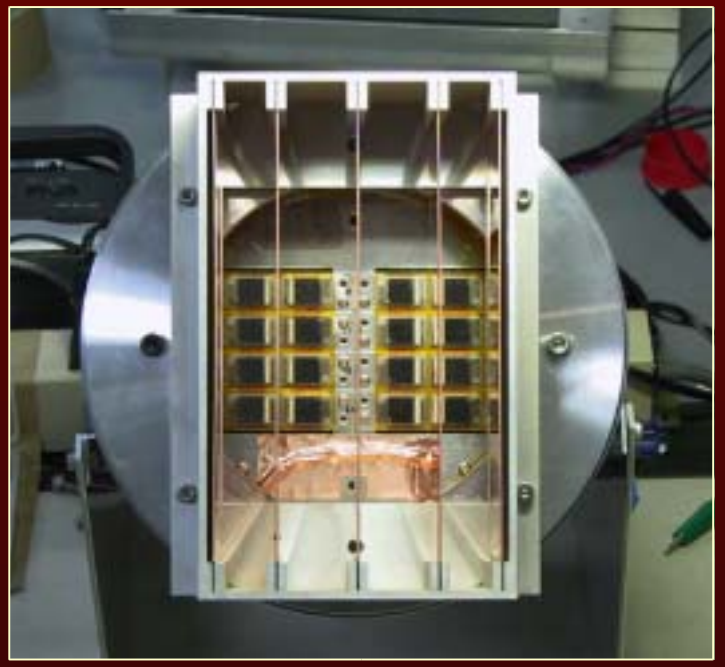
Detector type:	CdTe, 1cm^2 x 16 Passively cooled
Resolution:	< 3 keV @ 60 keV (goal) (2.6 keV actual)
Energy range:	20-130 keV
Spatial resolution:	(none)
Pointing:	azimuth only, ± 5° accuracy
Field of view:	Collimated to 10x60 degrees
Total gondola weight:	80 kg
Flight altitude:	41 km
Flight duration:	1 day (morning→evening)

Instrument Overview



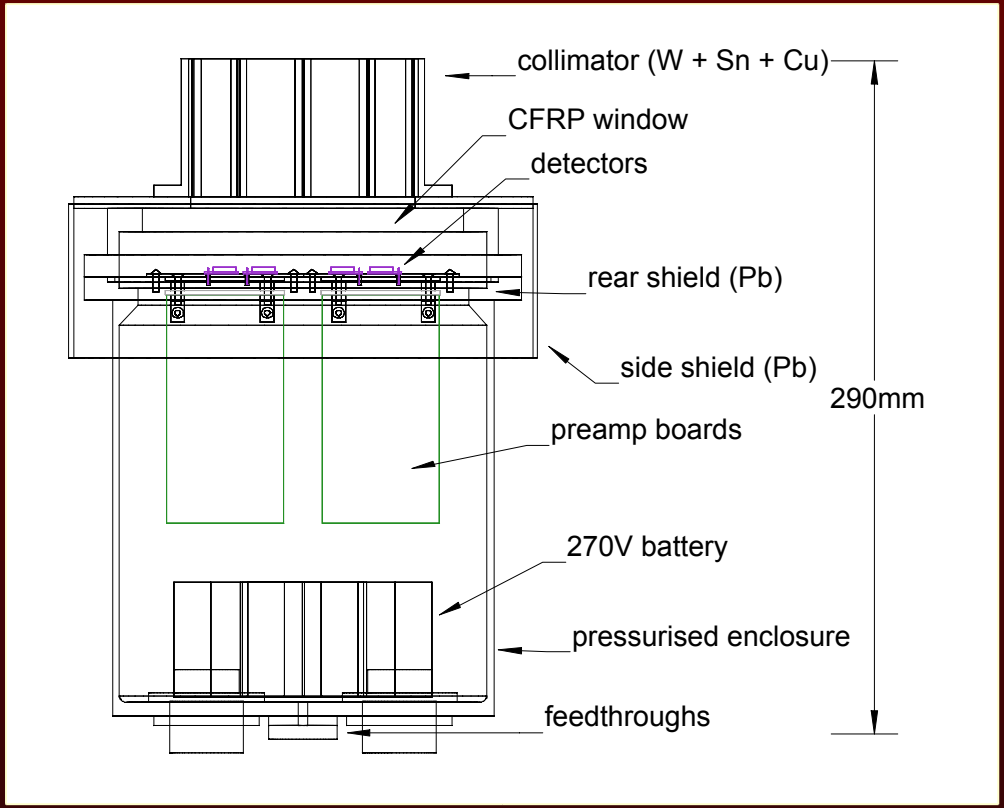
Detectors





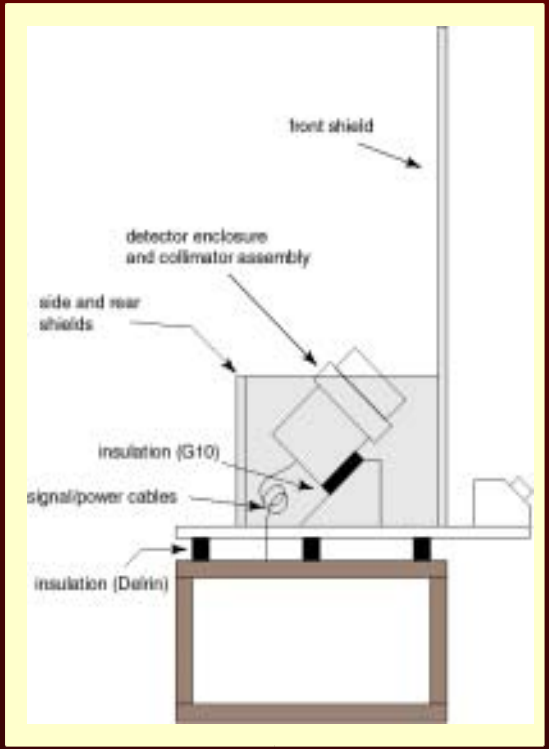
- 10x10x0.5mm CdTe detectors, fabricated by AcroRad (formerly Japan Energy)
- In/Pt Schottky electrodes
- Bias voltage = 200V
- Operating temperature: < 0 ℃ (for 3 keV resolution)
- Passive shielding only (2mm lead)

Detector Enclosure



- Detector enclosure pressurised at 1 atm
- Enclosure contains detectors, preamp boards, battery (200 V bias), Pb shield
- 14cm diameter CFRP/Rohacell™ window provided by Mitsubishi Heavy Industries, weight = 0.1 g/cm^2

Thermal Design



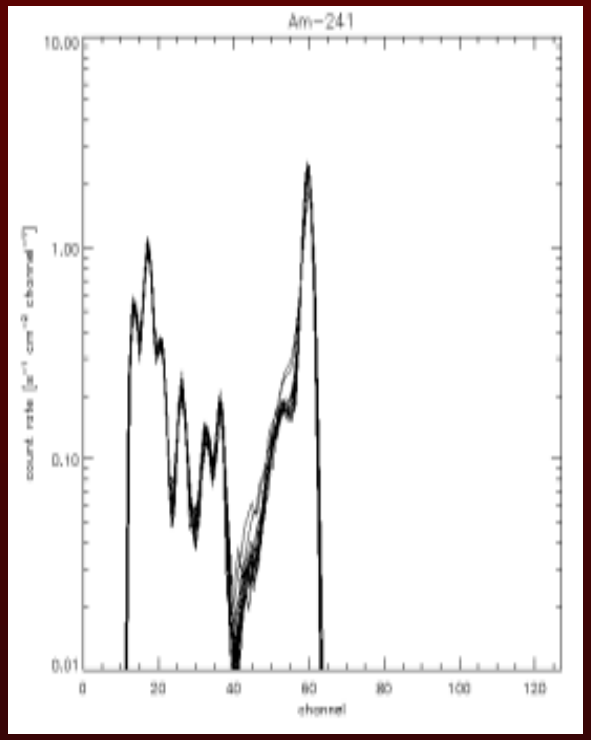
- Detector temperature of 0℃ achieved with passive cooling only.
- High emissivity Ag/Teflon tape on detector enclosure surface.
- Shielded from sunlight and ground IR while maximising view of sky.
- Detector system insulated from gondola.

Electronics

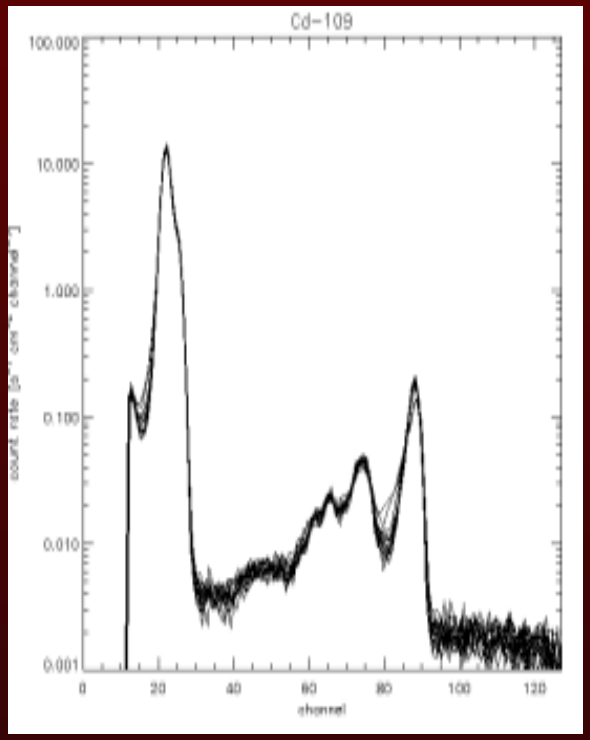
- 16 separate spectra, 128 channels each (1 keV / channel).
- Pulses integrated into spectra by onboard electronics
  → constant load on microprocessor and telemetry.
- All spectra read every 0.54 seconds.

Detector Performance

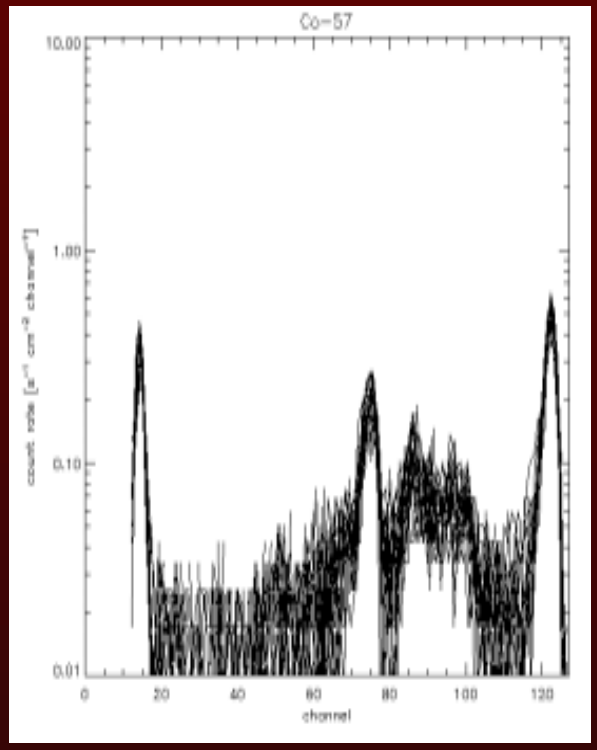
Am-241



Cd-109

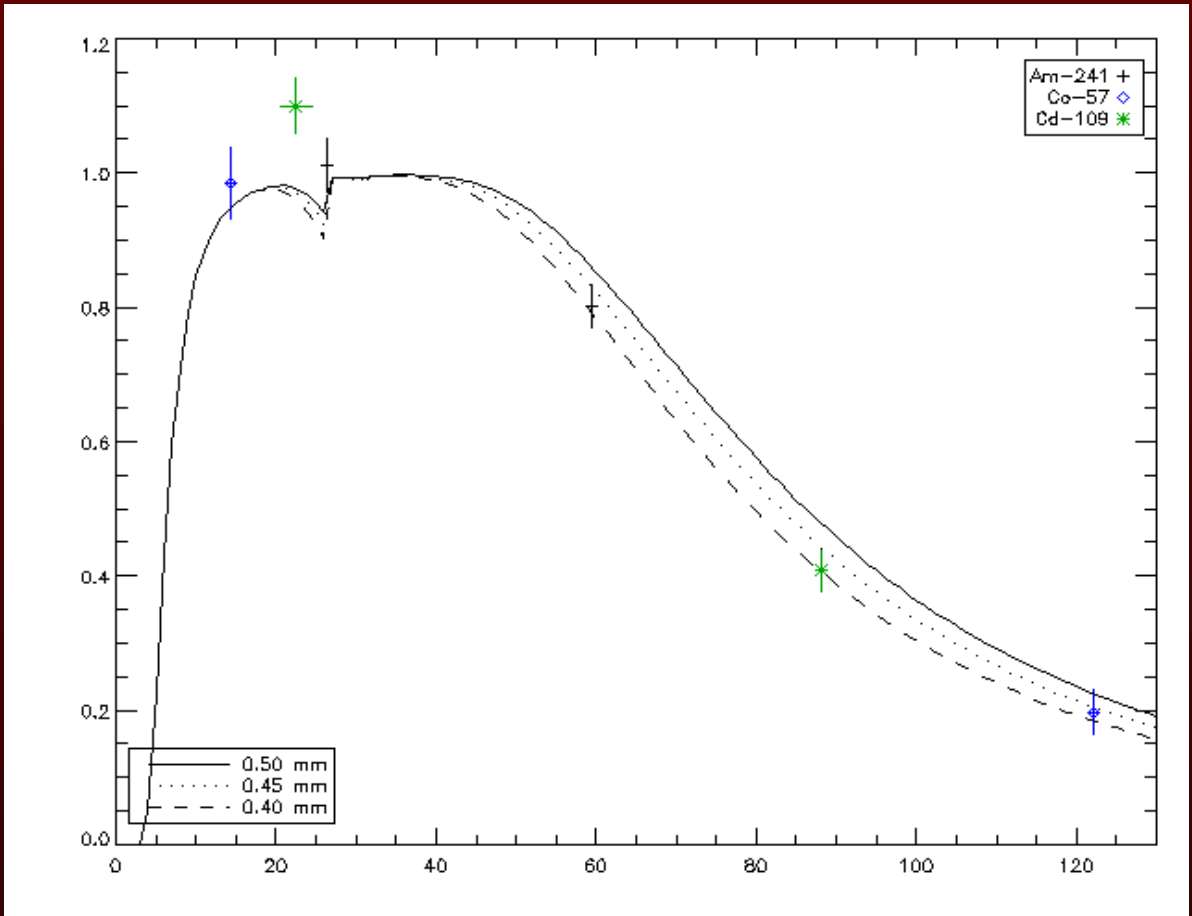


Co-57



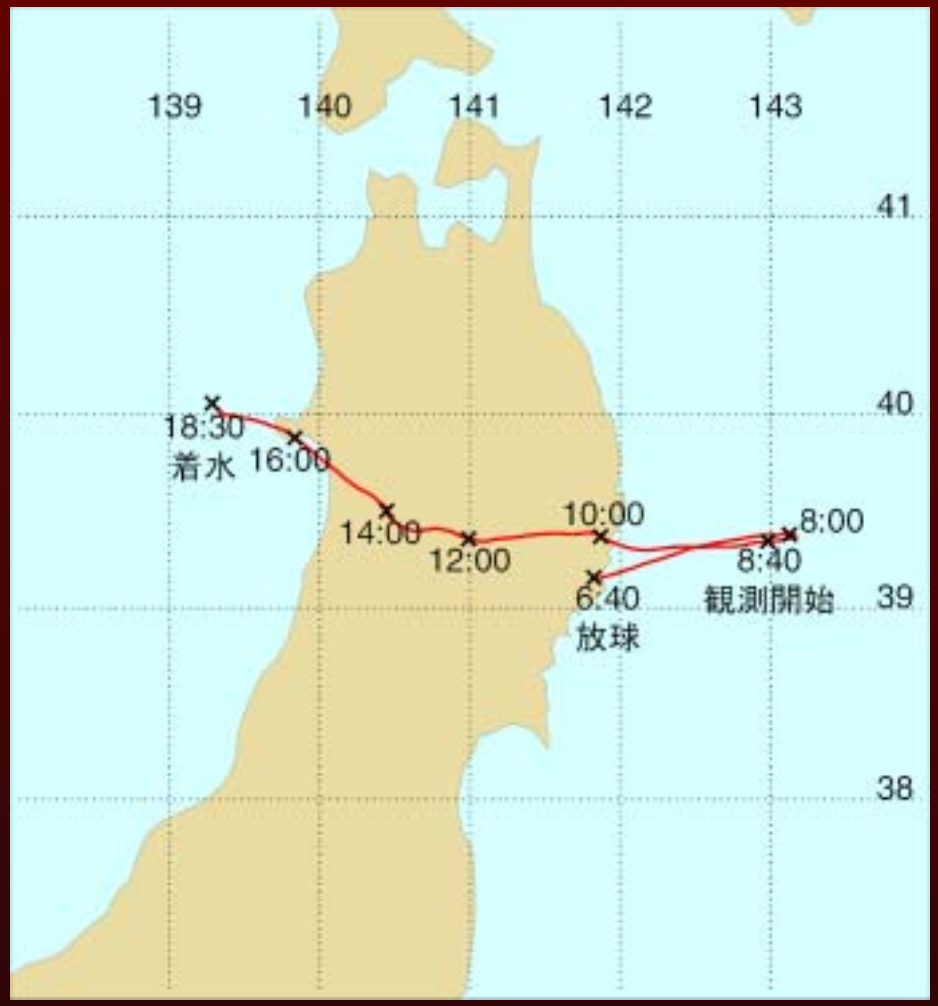
- Calibration tests done using Am-241, Cd-109 and Co-57 sources.
- Resolution: FWHM = 2.6 keV @ 60 keV.
- Line at 85 keV is secondary emission from Pb shield.

Quantum Efficiency



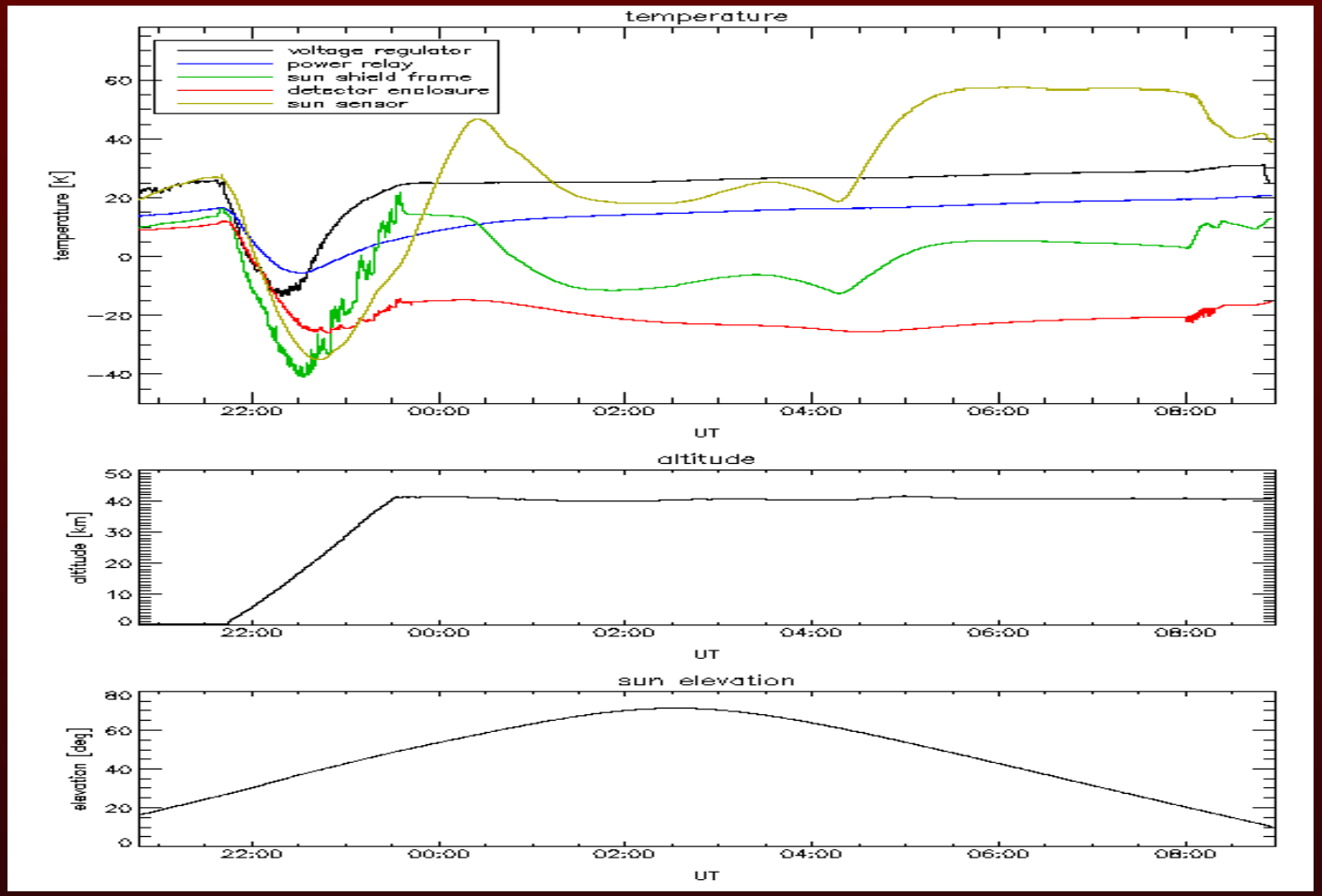
- QE measured using calibrated sources
- Fit to 0.45mm thick CdTe + 0.08 g/cm^2 carbon

Flights



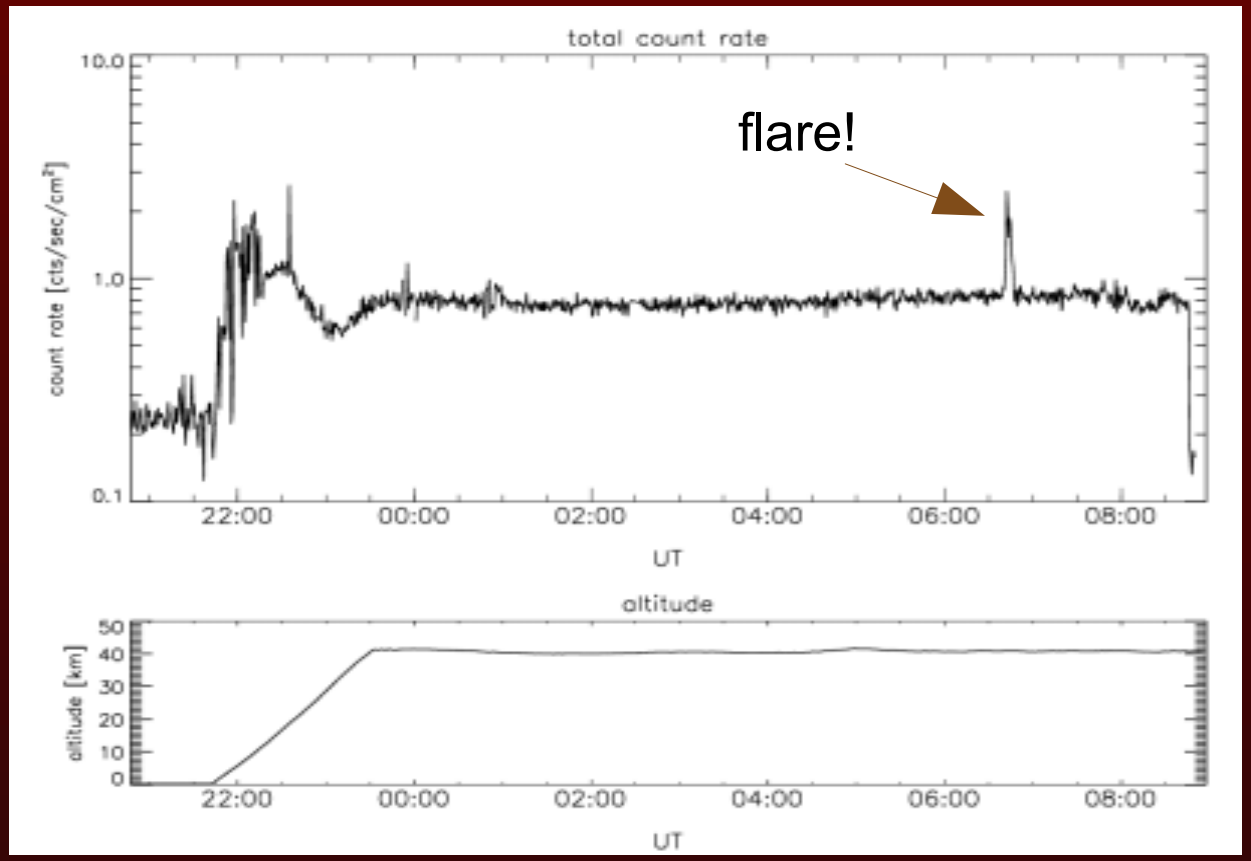
- 2001/8/29 First flight:
  - 45 min. observation.
  - No flare seen.
- 2002/5/24 Second flight:
  - 8 hours of observation.
  - Successful flare observation.

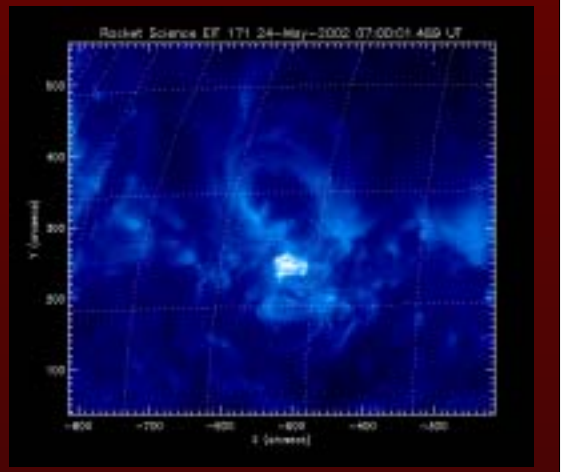
Altitude & Temperature Profiles



- Temperature of exposed frame varies between -10°C and +10°C
- Detector temperature maintained below –15°C throughout level flight

Total light curve

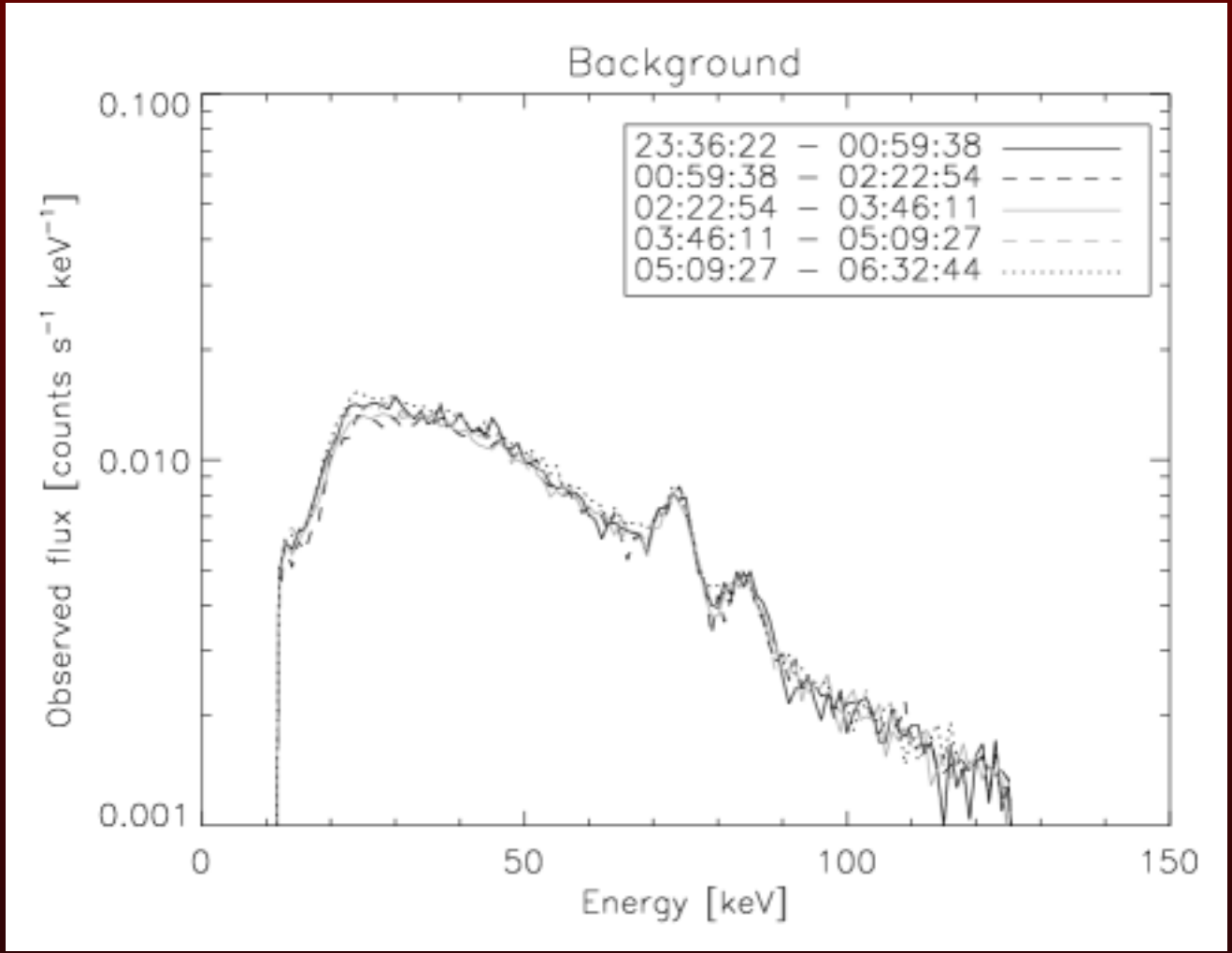




EIT image of flare loops

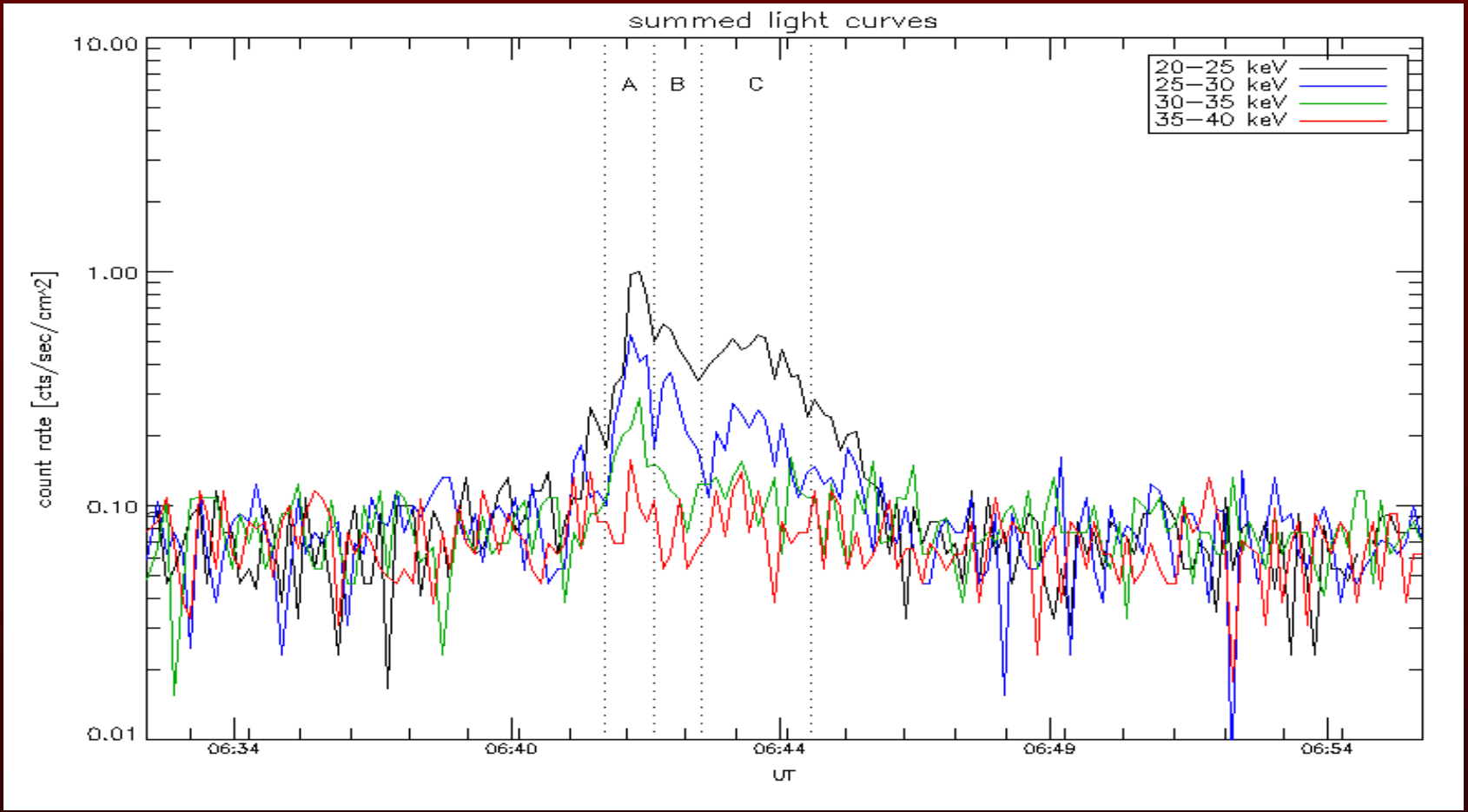
- Noise during ascent caused by transponder and sirens.
- Background stable during level flight.
- Class M1.1 flare seen at 6:41 UT.

Background



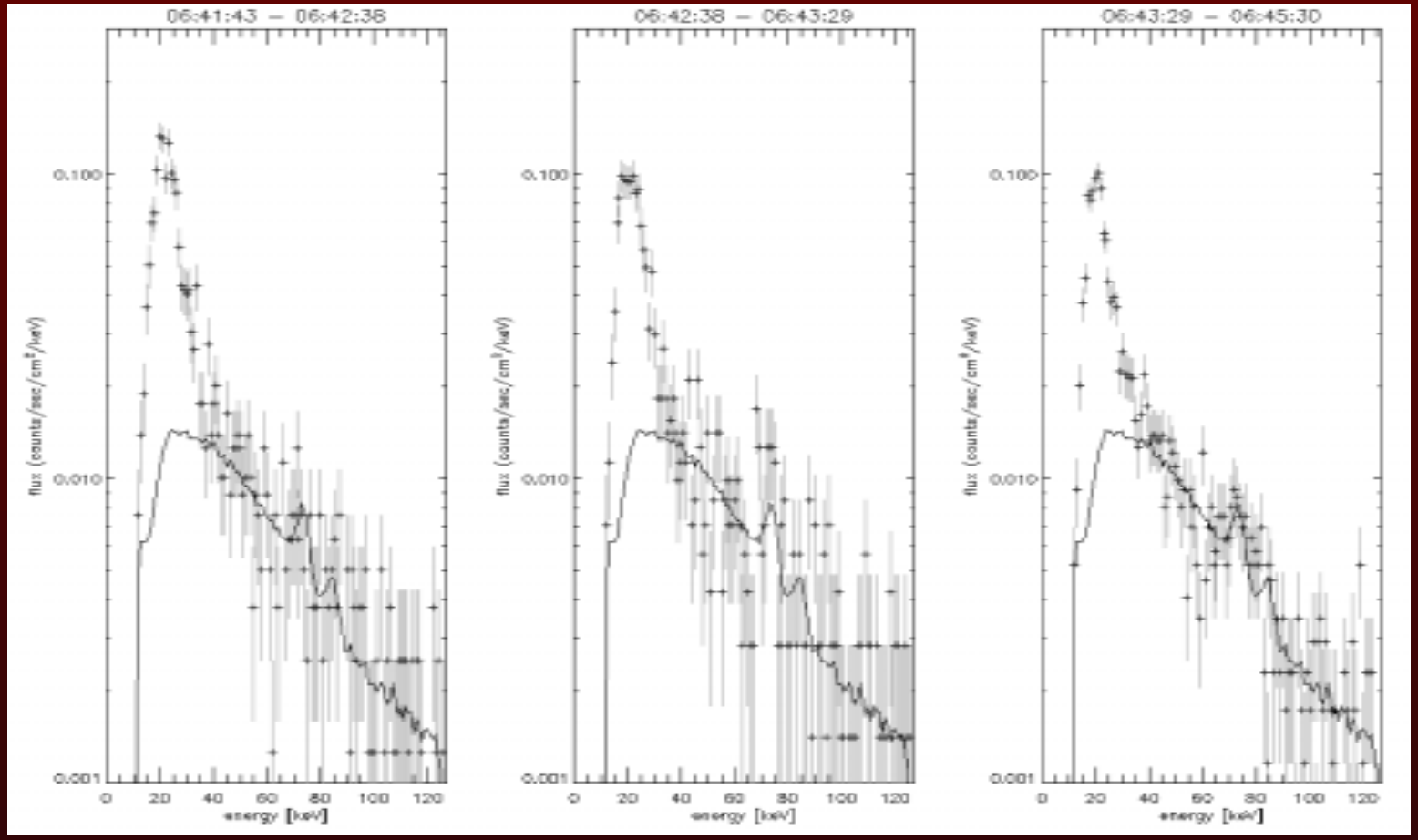
- Pb line from shields seen at 75 and 85 keV.
- Gain and resolution of Pb line stable.

Flare Light Curve



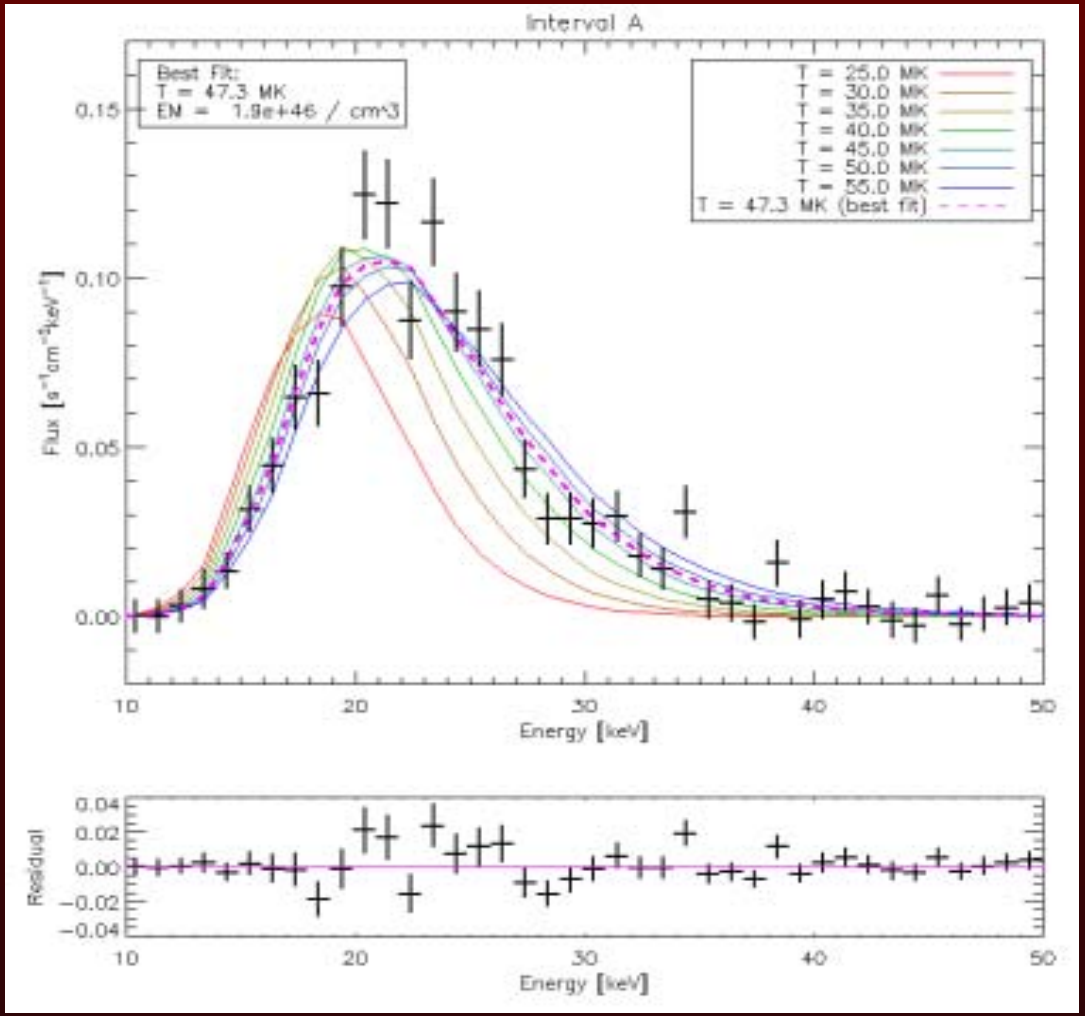
- 4 minutes of X-ray emission observed.
- Emission is primarily in low energy (< 35 keV), high energy X-ray flux is very small for this size flare.

Raw Spectra



- Solid line: background (200 minute period before flare).
- Data points: flare flux.

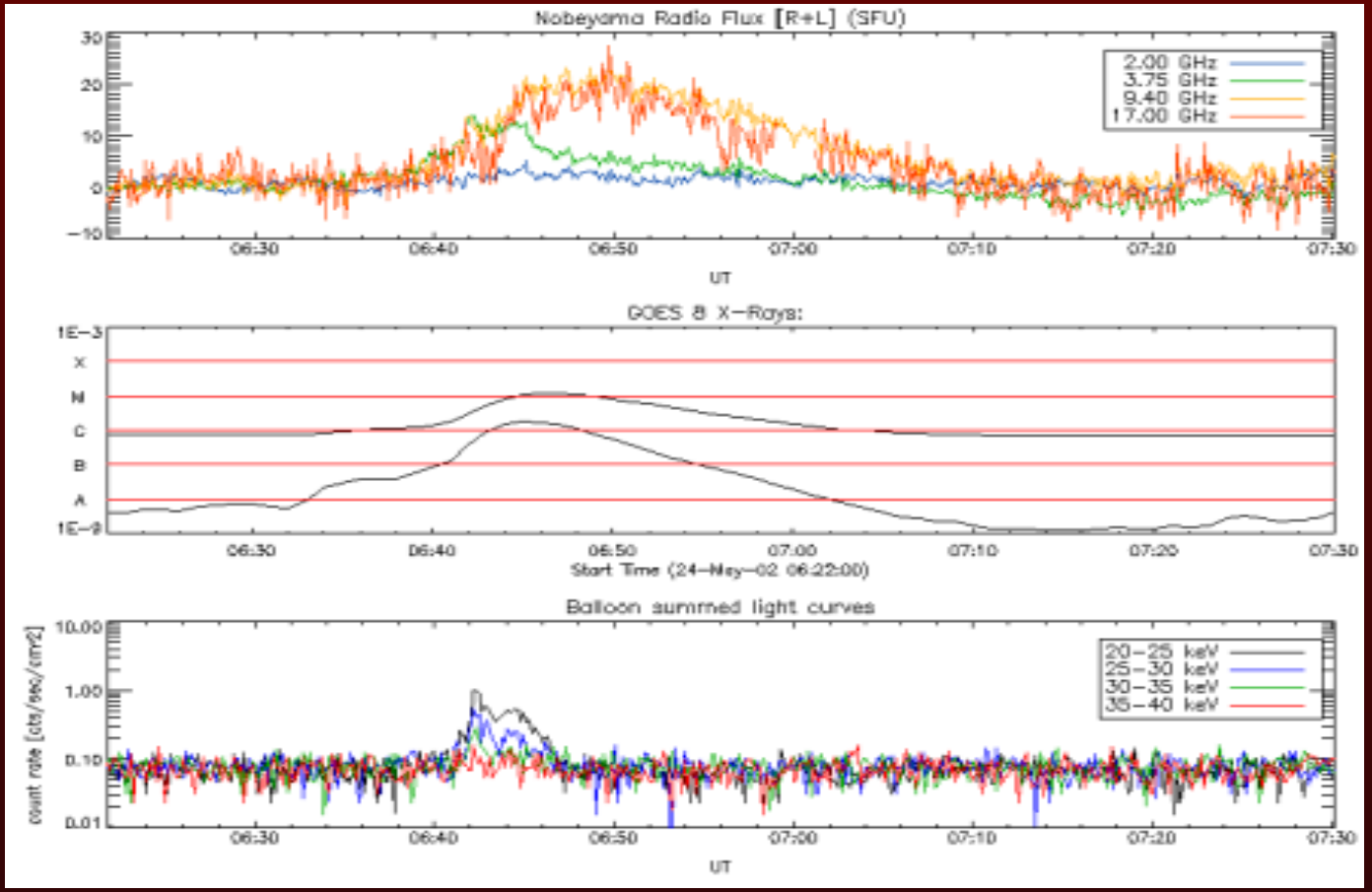
Spectrum Analysis



（error bar ＝ 1σ）

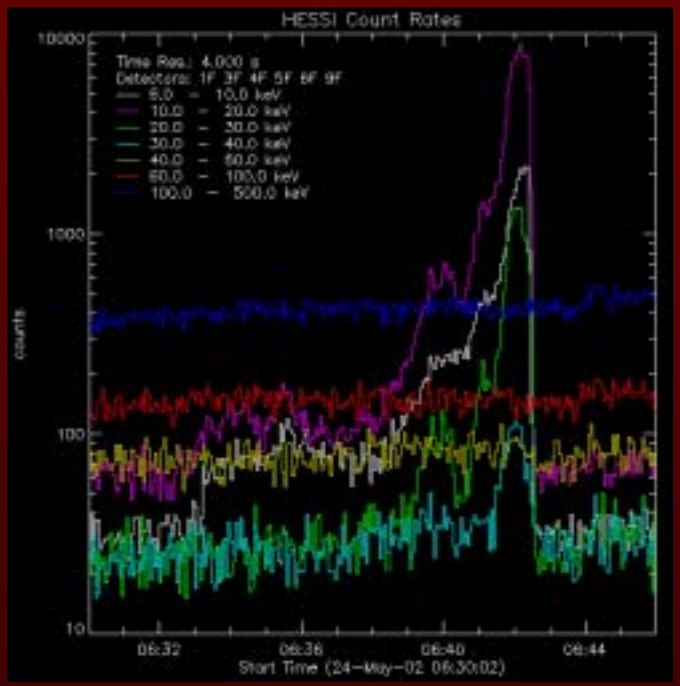
- Result of spectral fit to purely thermal spectra
- Solid lines show fit at fixed temperatures; dashed line is best fit
- Best fit values:
  - **T＝47MK**
  - **EM＝** 1.9e46 cm^{-3}
- Thermal spectra agrees with data; no non-thermal emission detected

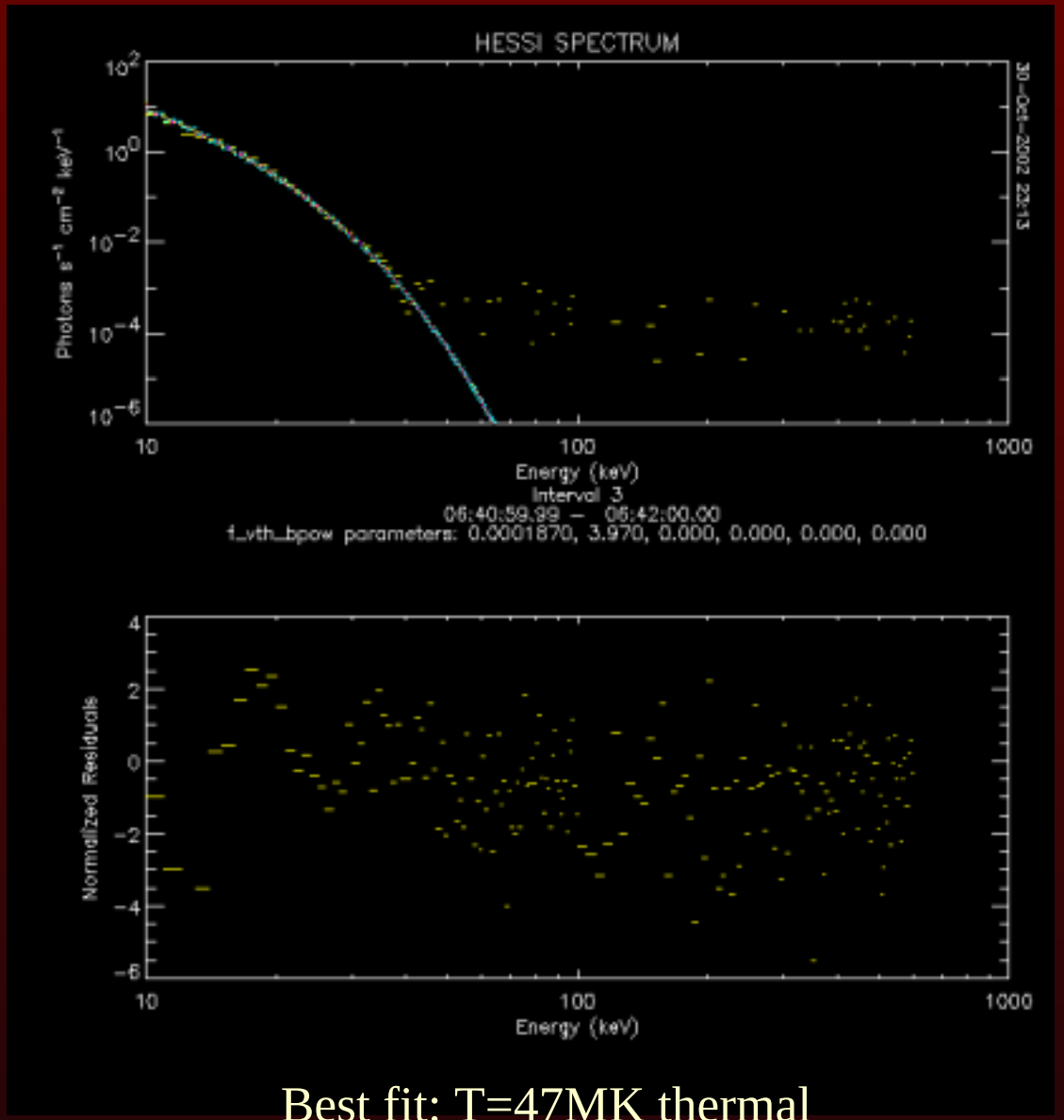
Light Curves



- Top: Nobeyama solar microwave polarimeter data (flux at 2, 4, 9 and 17 GHz). Note good correlation between balloon data and 4GHz flux.
- Middle: GOES soft X-ray flux
- Bottom: Balloon data

RHESSI Spectrum





Best fit: T=47MK thermal

Analysis Results (preliminary)

- Spectrum consistent with single-temperature thermal emission with T=47 MK.
- Microwave (4GHz) shows corresponding emission at 4GHz.
- Possible interpretations:
  - •Hard X-ray emission dominated by 47MK thermal emission, nonthermal component only visible in microwave.
  - •Superhot component absent; “47MK thermal emission” is actually multiple nonthermal components.

Summary

- 2.6 keV resolution (at 60keV) achieved using 1cm^2 CdTe detectors.
- -20 °C detector temperature achieved by passive cooling.
- Successful observation of a class M1.1 solar flare.
- First successful scientific observation using CdTe detectors.