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XRT Detection of Hot Plasma in Active Regions and Nanoflare Heating

Fabio Reale

Dipartimento di Scienze Fisiche & Astronomiche, Università di Palermo, &
INAF/Osservatorio Astronomico di Palermo, Italy *reale@astropa.unipa.it*

Jim Klimchuk

NASA Goddard Space Flight Center, Greenbelt, USA

Susanna Parenti

Royal Observatory of Belgium, Brussels, Belgium

Paola Testa

Harvard-Smithsonian Center for Astrophysics, Cambridge, USA

and the XRT team

Summary

- Introduction: the importance of detection of hot plasma in the non-flaring corona
- The XRT observation: active region
- The analysis and preliminary results

The nanoflaring corona

- 20 years since G. Parker's (1988) conjecture on nanoflares

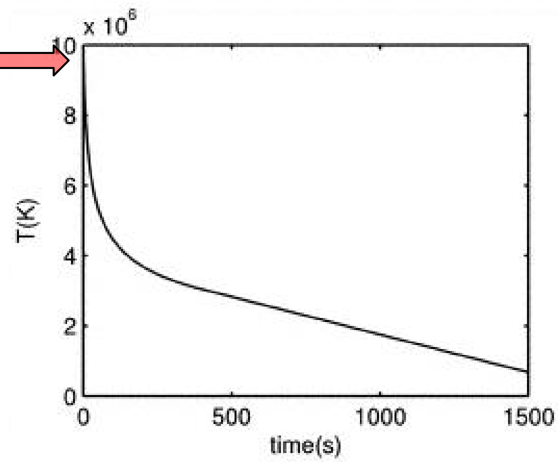
- Their role is still debated and conclusive evidence elusive, because difficult to detect

Hot plasma in the non-flaring corona

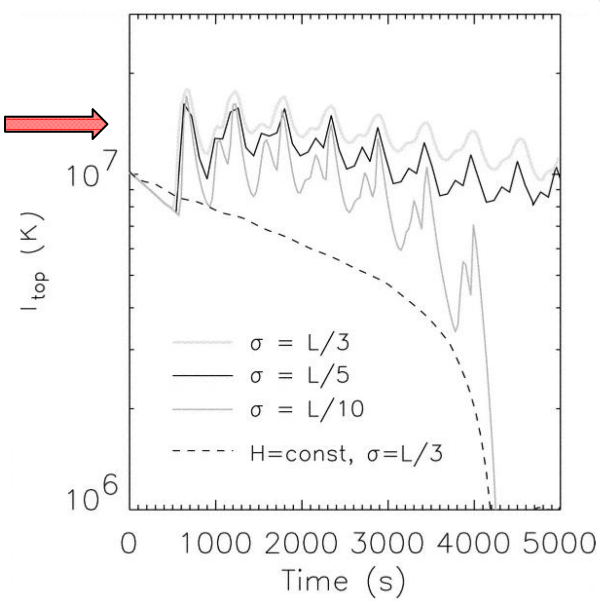
- Hot plasma predicted by models of multi-stranded nanoflare-heated loops: widespread and low EM

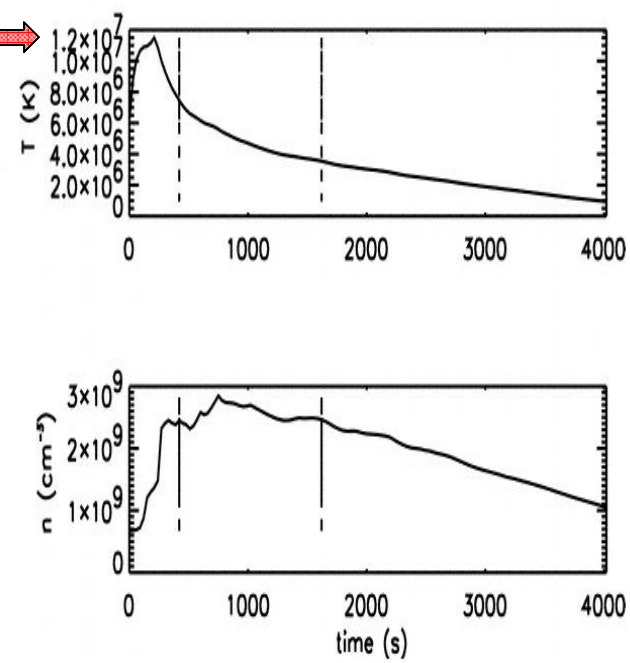
Patsourakos & Klimchuk (2006)

Cargill & Klimchuk (2004)



Testa et al. (2005)





Detection of hot plasma in the non-flaring corona

- **The importance**: indicator of nanoflaring corona (e.g. Klimchuk 2006)

> the temperature range from about 0.5 to 10 MK. The high end of the temperature range is especially important for diagnosing impulsive heating, since relatively little can be learned about the energy release (duration, spatial distribution along the field, etc.) once the plasma enters the slow radiative cooling phase (Winebarger and Warren, 2004, 2005; Patsourakos and Klimchuk, 2005a,b). Since the evolution

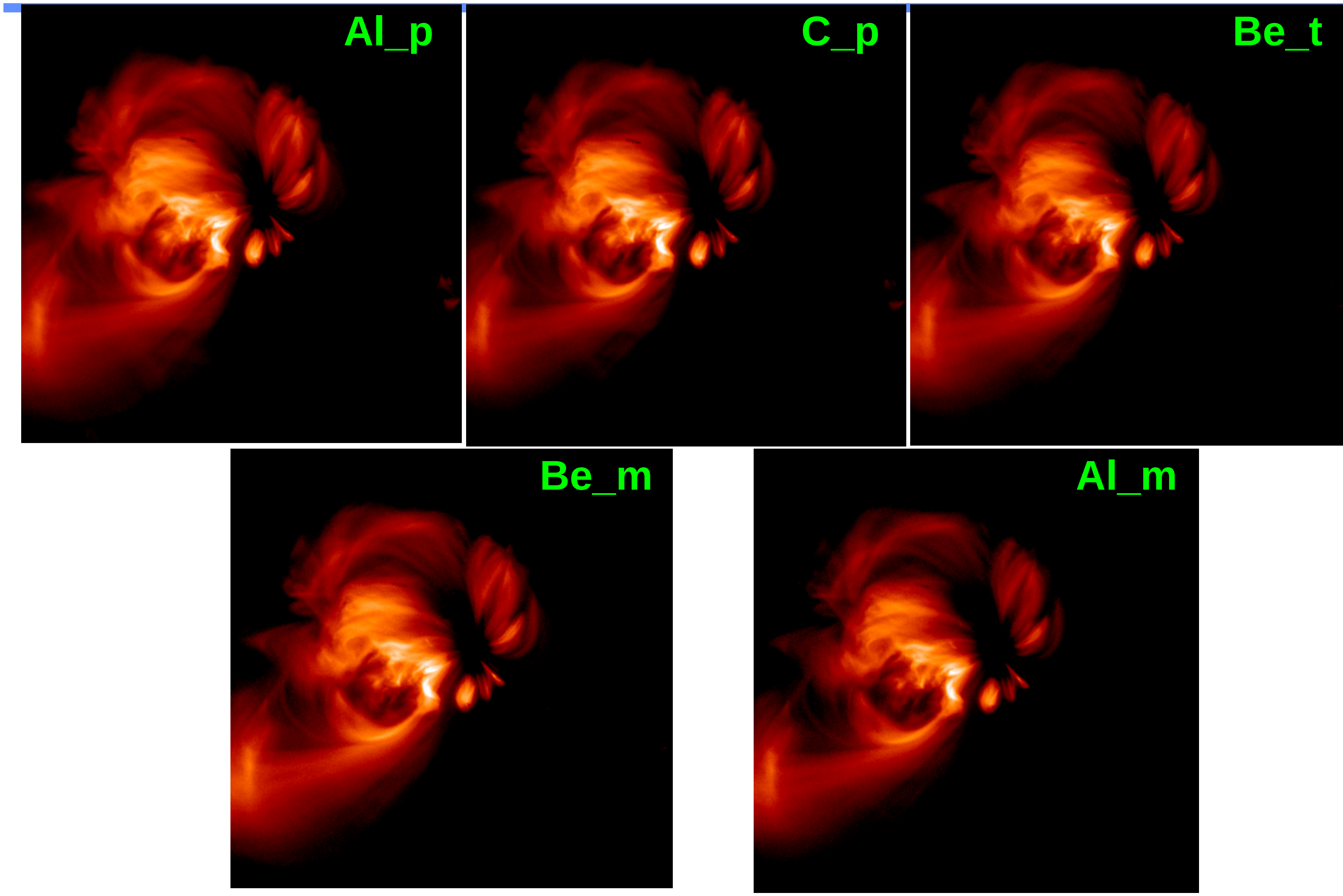
- **The problem**: Difficult because expected at low EM and overwhelmed by lower T plasma, and of possible NEI effects (Reale & Orlando 2008)

- **The possible key:** XRT medium thickness filters
  - **thick** enough to cut off cool plasma,
  - **thin** enough to detect low EM hot plasma

The observation

- Data and analysis:
  - Date: 12 Nov 2006 (early observation)
  - FOV: AR10923 (512"x512")
  - Filters: 5 (Al_poly, C_poly, Be_thin, Be_med, Al_med)
  - Time coverage: 1 hour (12 images for each filter)
  - Data preparation: XRT_prep & cross-correlation alignment

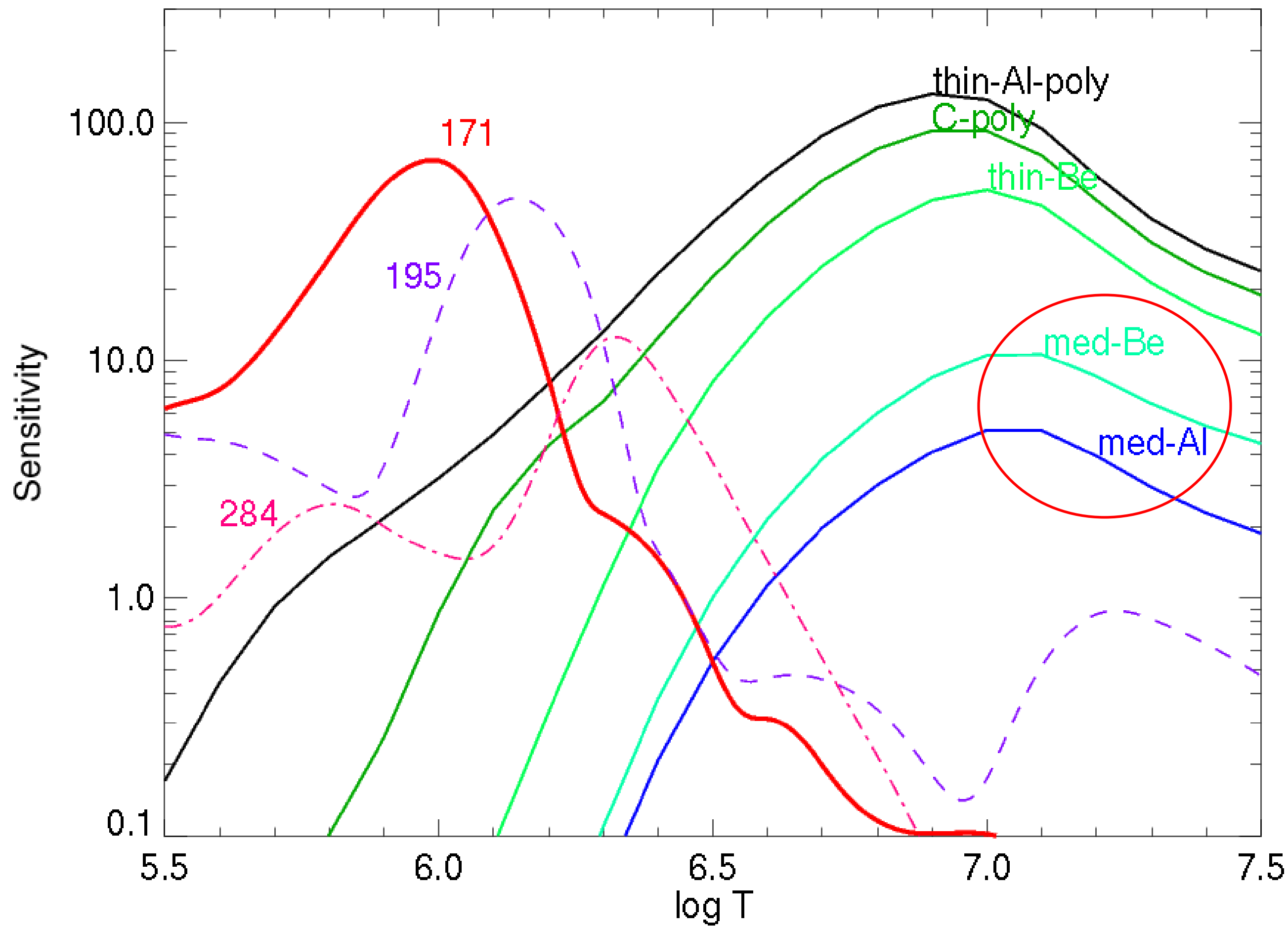
The field of view



- 1h average
- Log color scales:
  - 100-5000
  - 100-3000
  - 20-1000
  - 3-150
  - 2-80 DN/s

The diagnostics: filter T response

- Nominal calibration (ssw)
- TRACE included



The diagnostics: filter ratios

- For isothermal plasma ALOS, filter ratios provide T diagnostic (e.g. Vaiana et al. 1973)

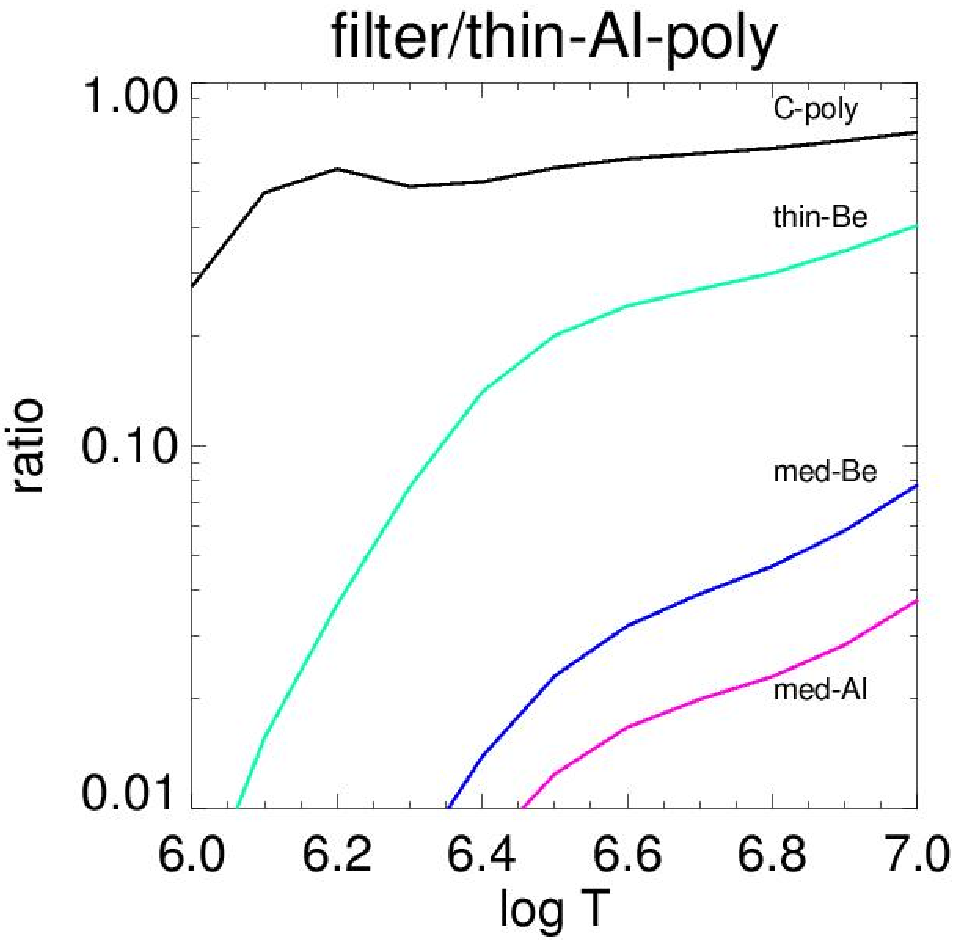
  - Flux detected in j-th filter:

$$I_j = EM \times G_j(T)$$

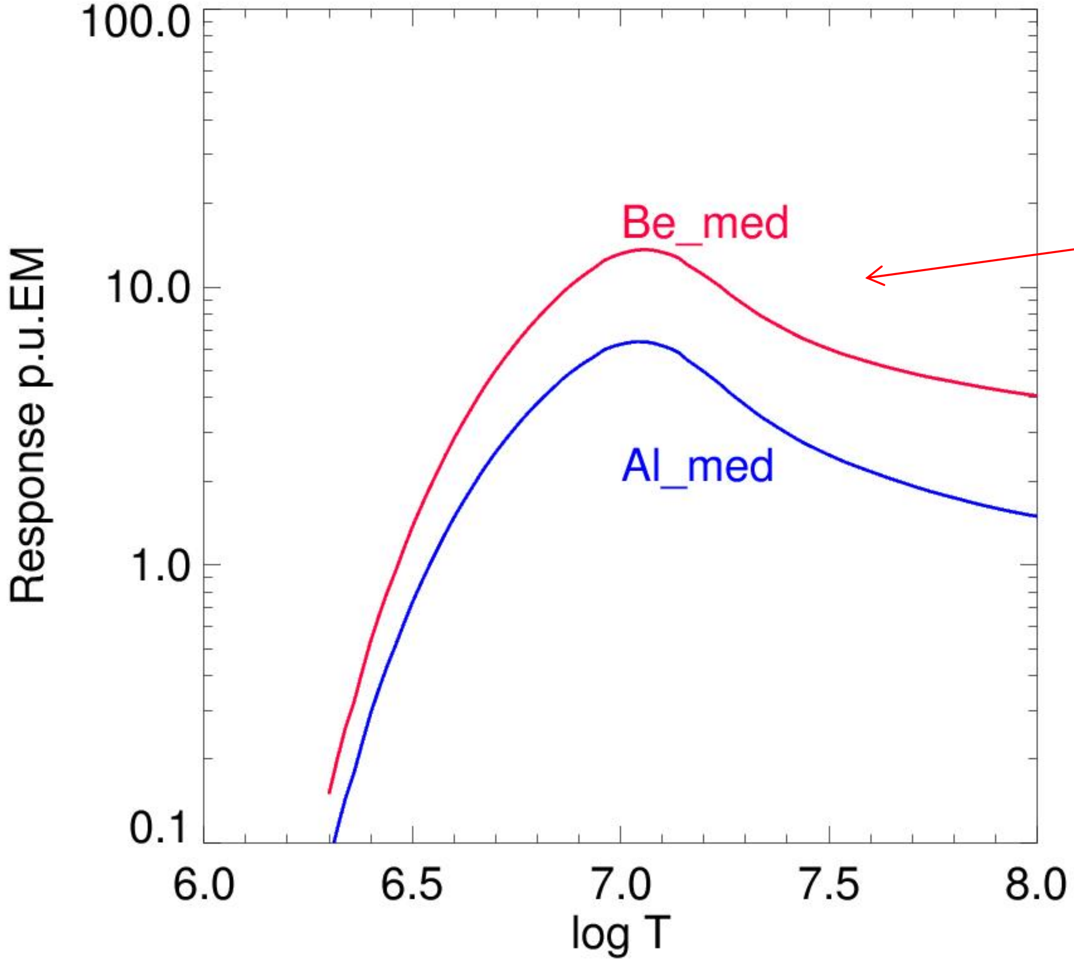
$$EM = \int_V n^2 dV$$

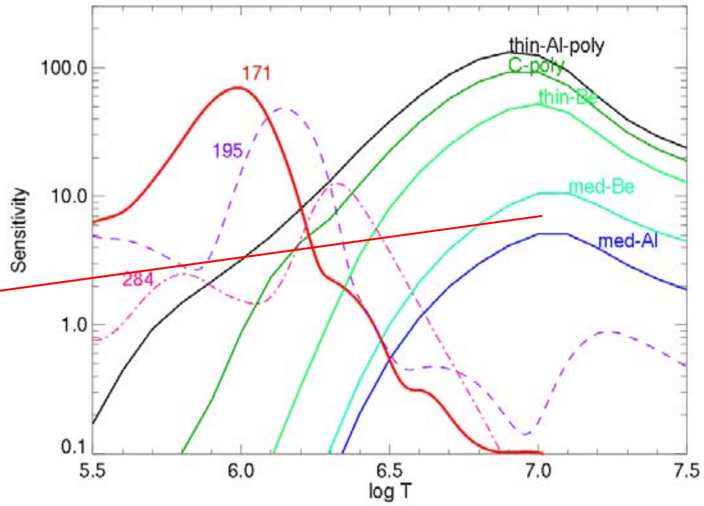
  - Filter ratio provides T (EM cancels out):

$$R_{ij} = \frac{I_i}{I_j} = \frac{G_i(T)}{G_j(T)}$$



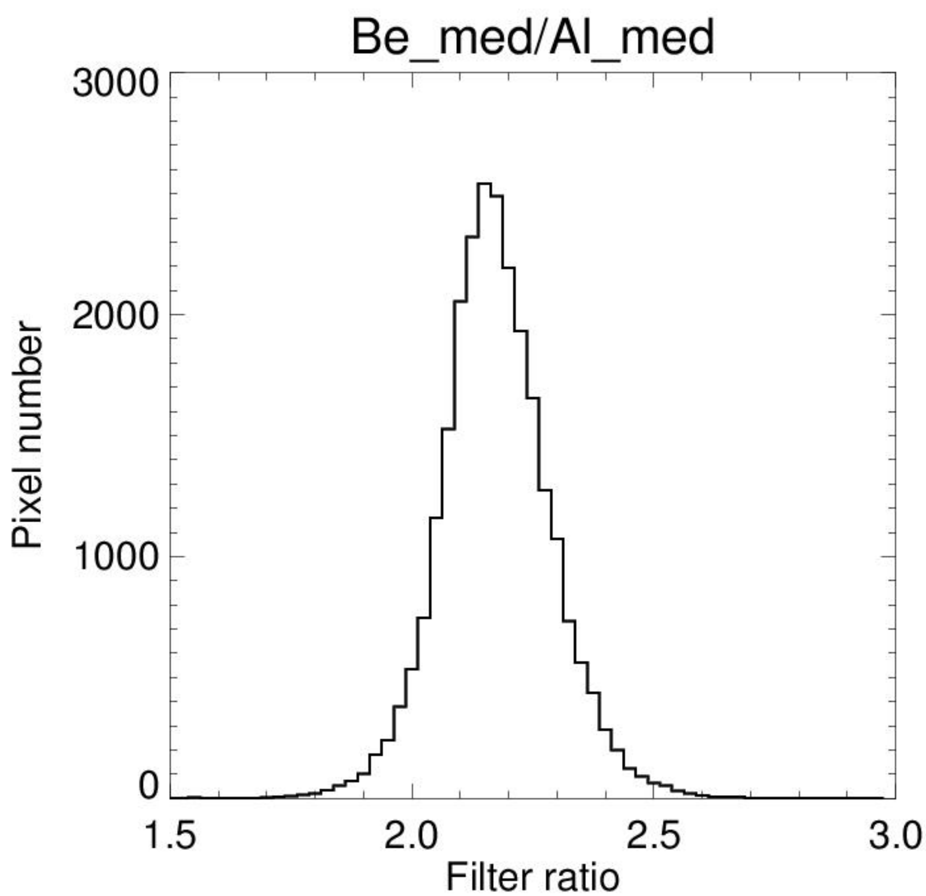
Medium thickness filters

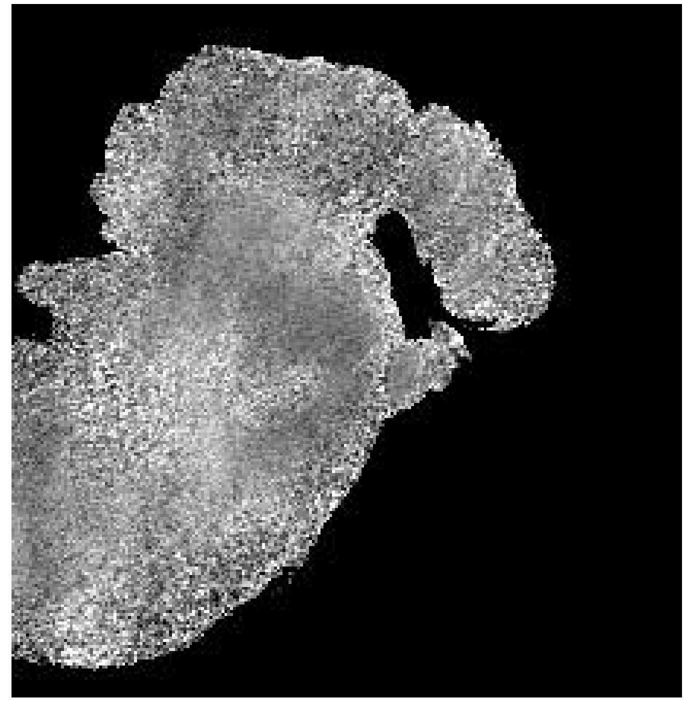




Be_med/Al_med filter ratio: map & pixel histogram

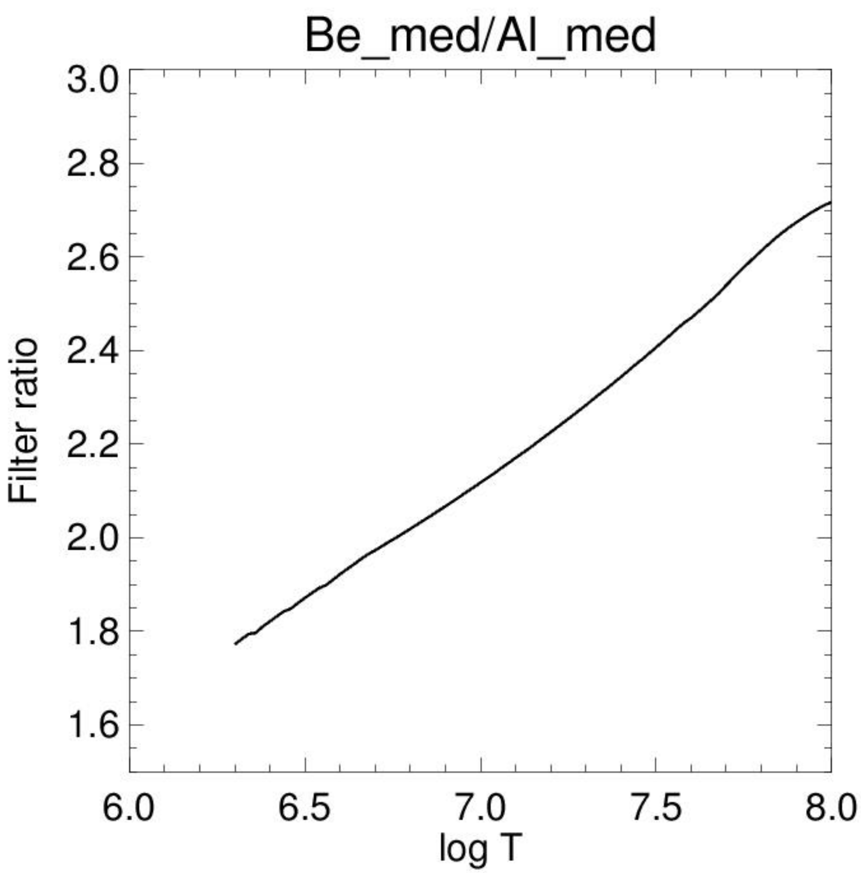
- Threshold (Al_med): 1 DN/s

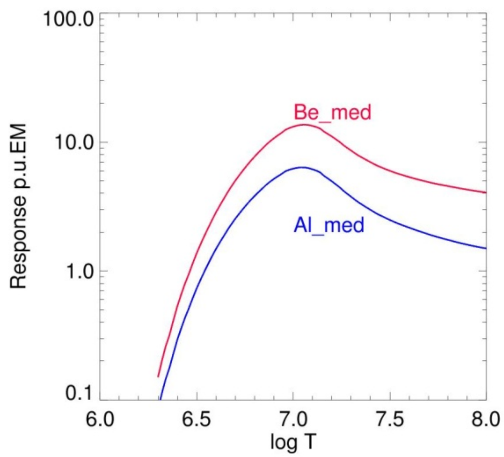




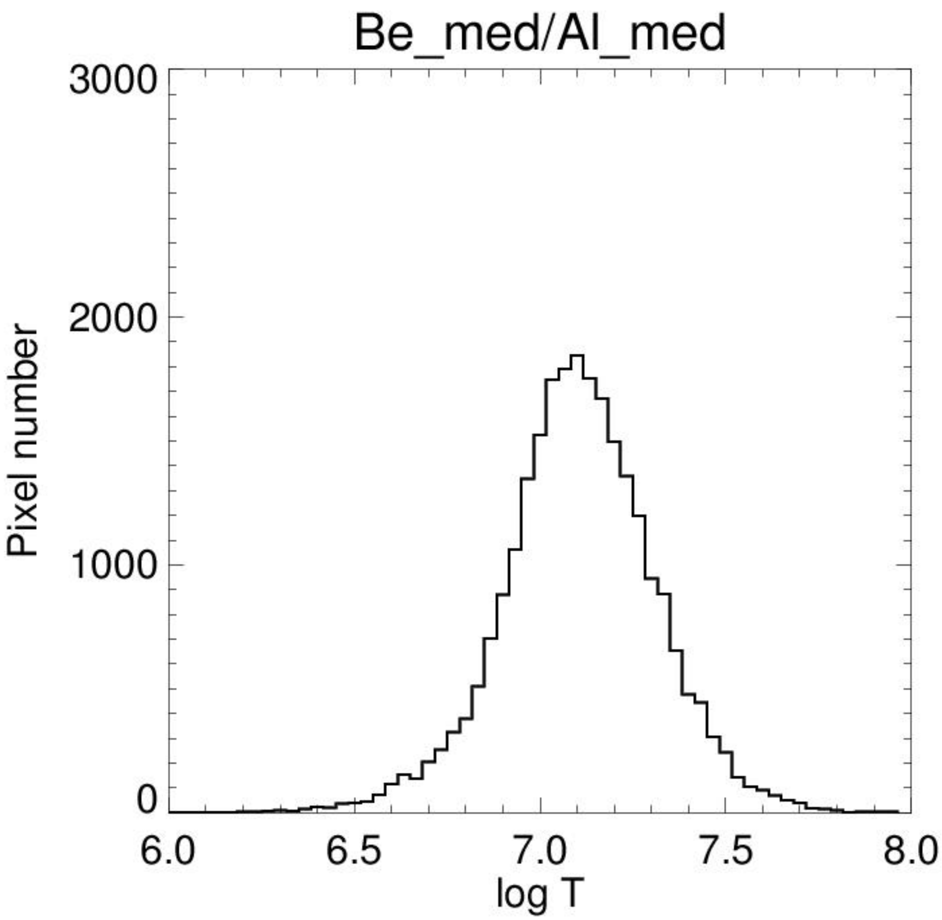
Medium filter ratio: ratio vs T

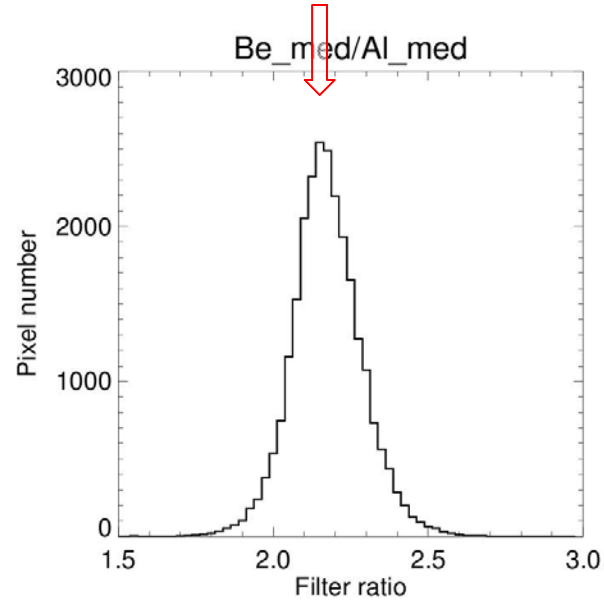
- SSW calibration, up-to-date APED
- Assumption: blind for logT < 6.3

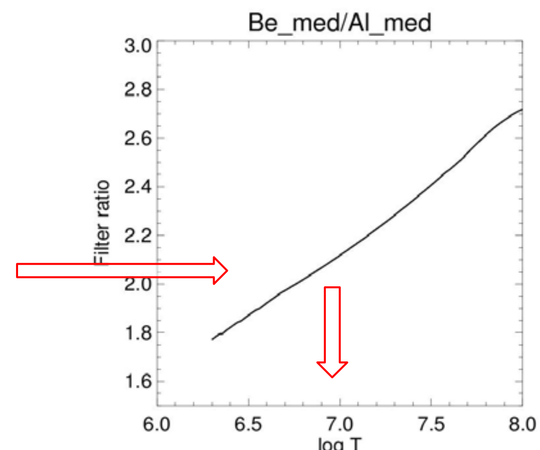




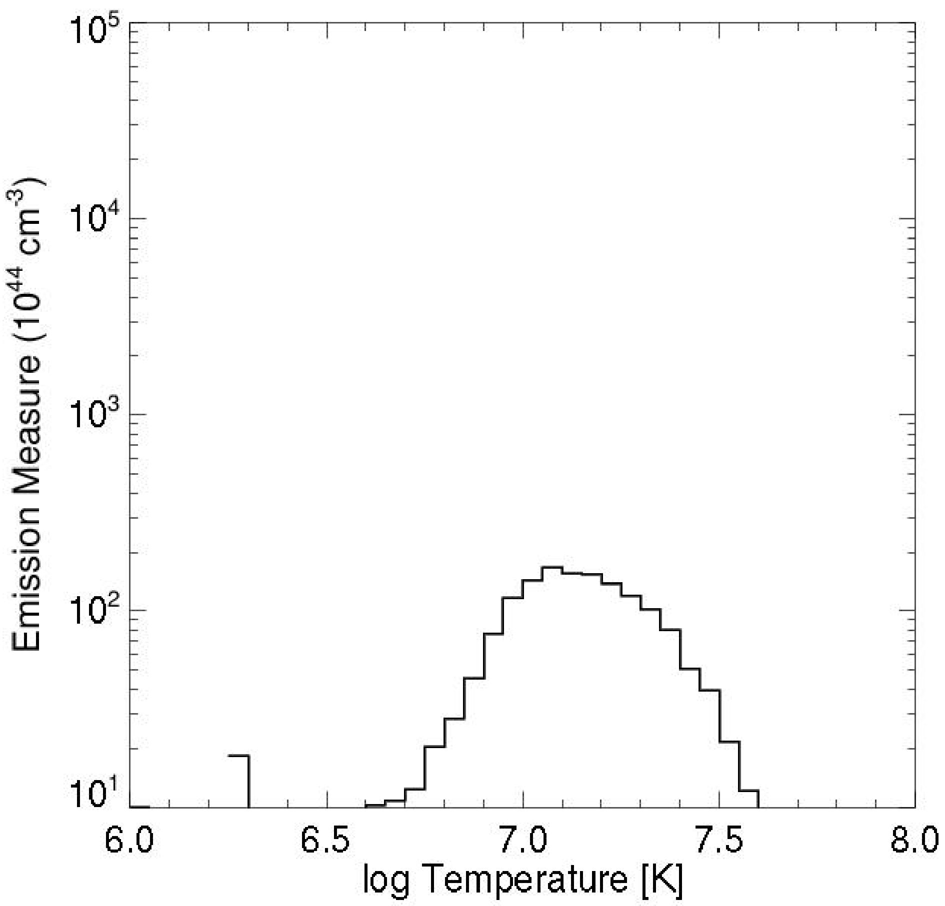
T pixel distribution

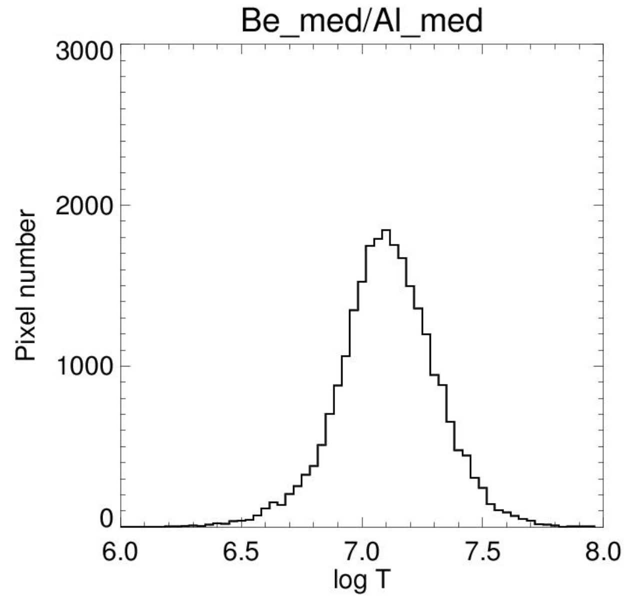




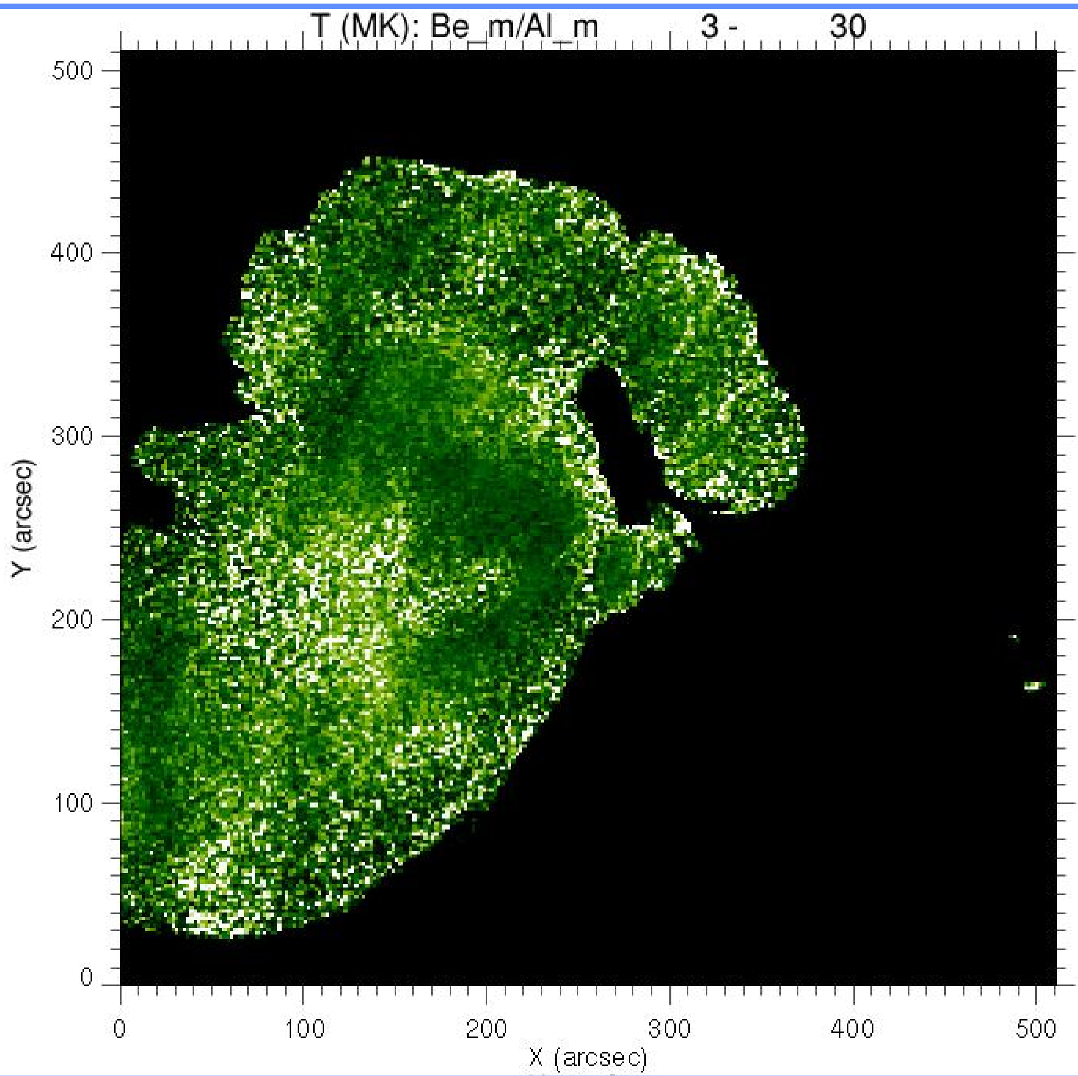


EM(T) distribution





Hot Temperature map



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Hot EM map (log T > 6.8)

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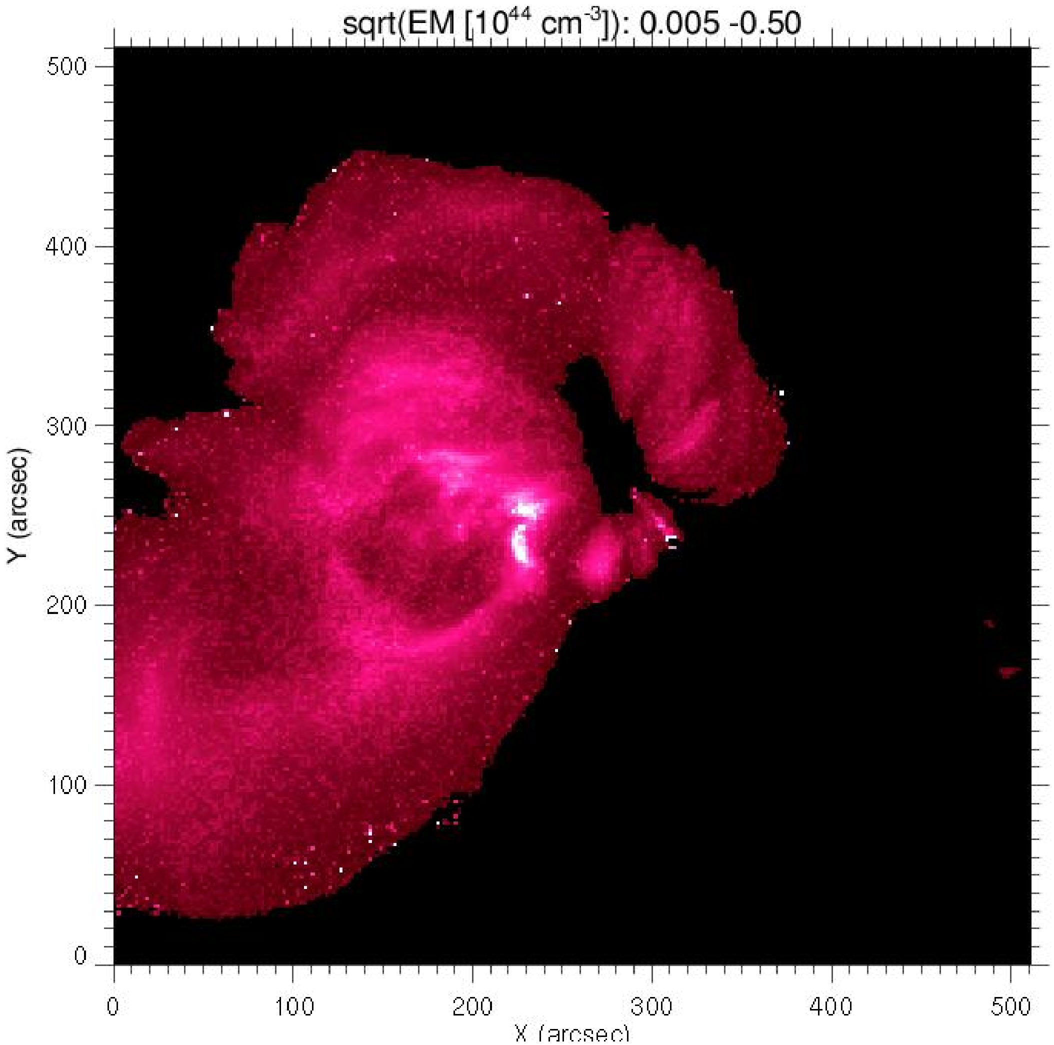
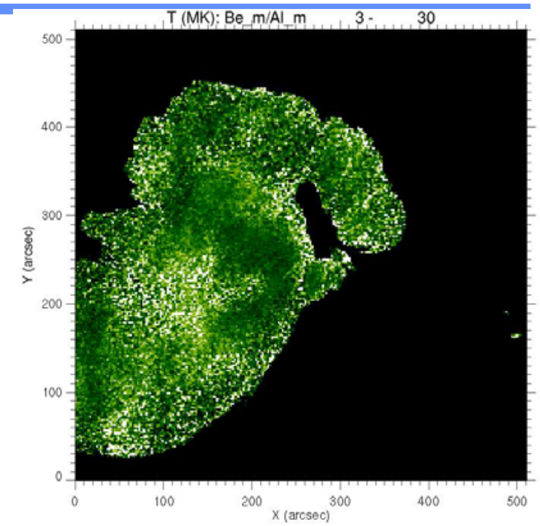
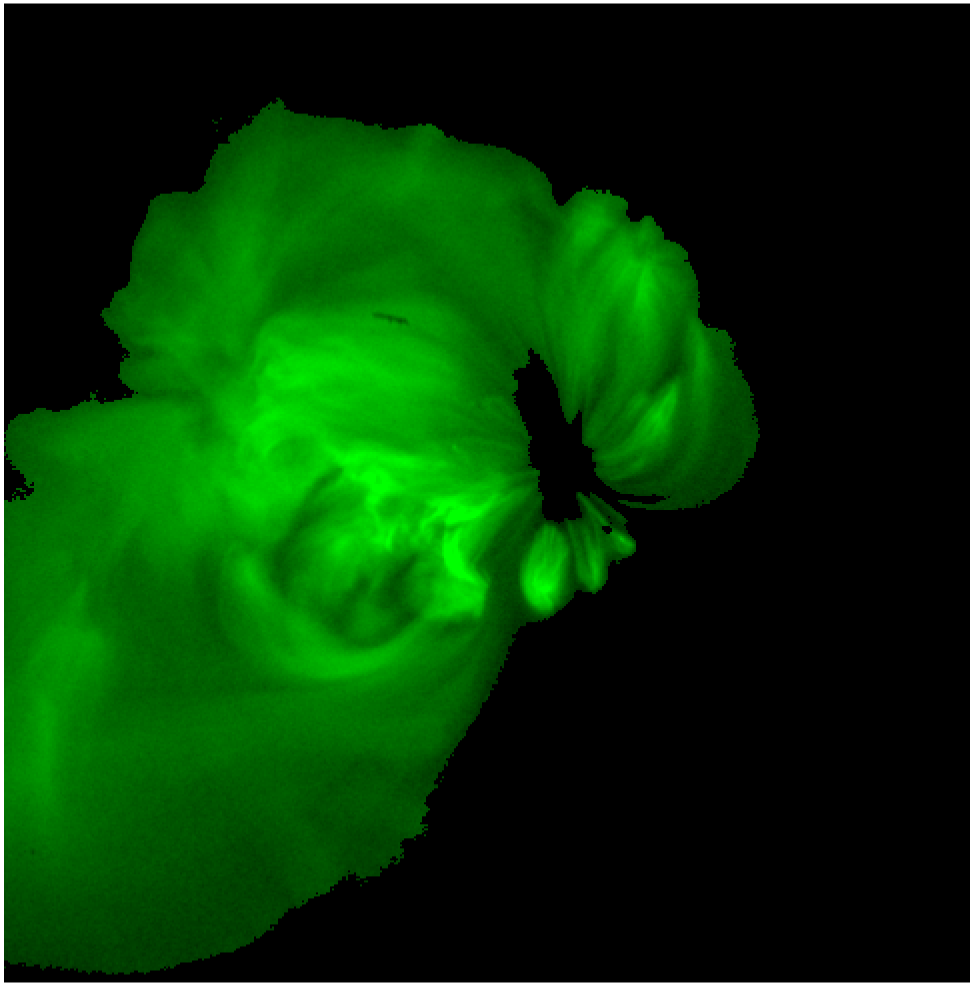


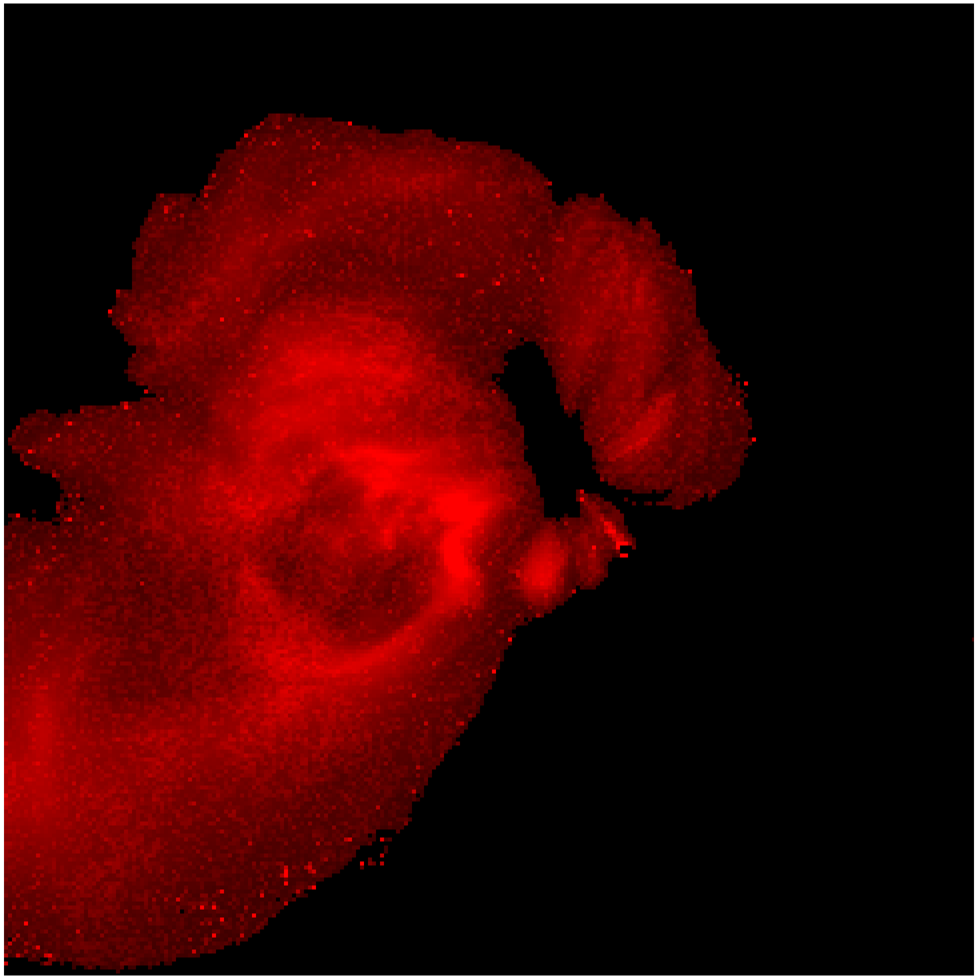


Combined Improved Filter Ratio (CIFR, Reale et al. 2007)



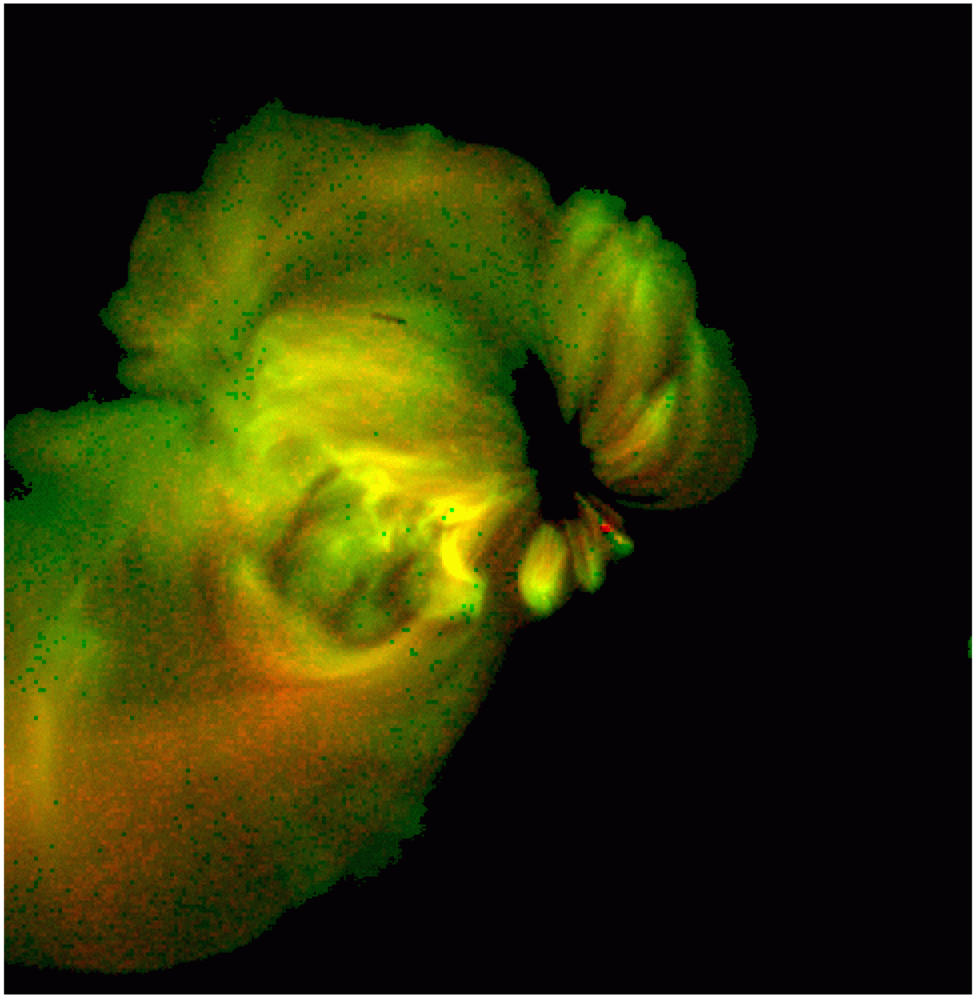
- Soft filter ratio: log T < 6.6
- EM map

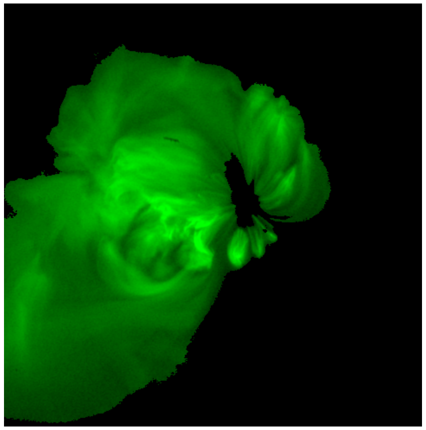
Hot EM map

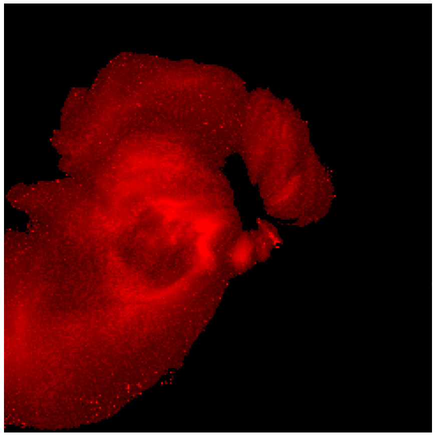


- Emission measure map from Be_med/Al_med (log T > 6.8)

Hot and cool EM maps overlapping

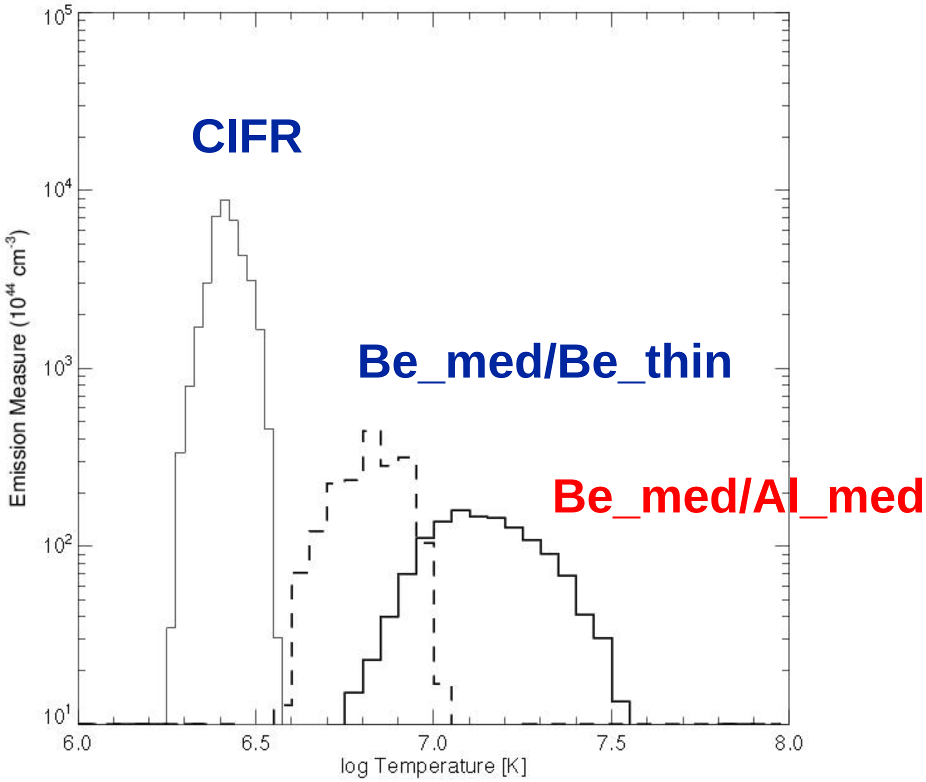






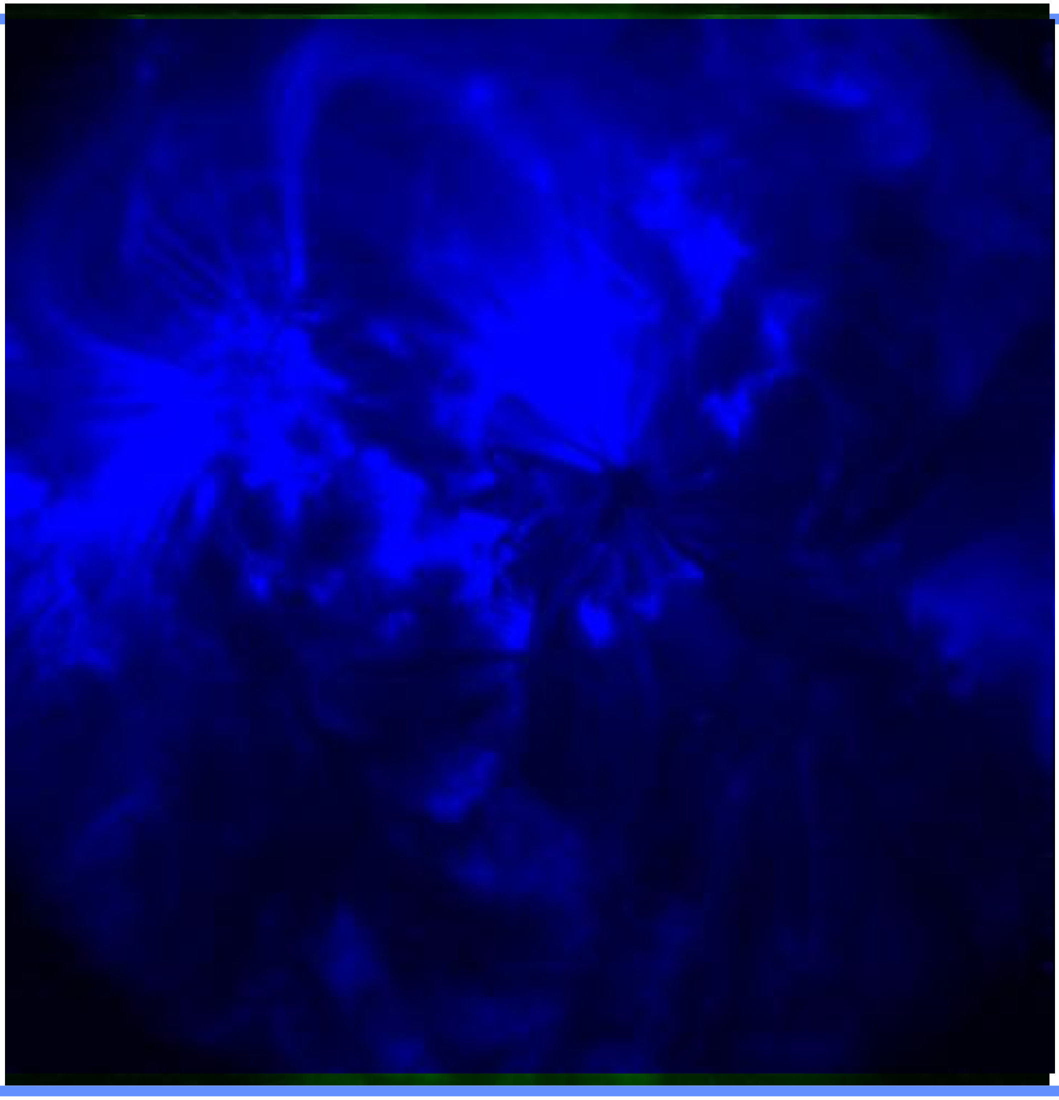
EM(T): cool, medium and hot contributions

- Filter ratios are sensitive in different ways to EM distribution ALOS
- Hot plasma with lower EM

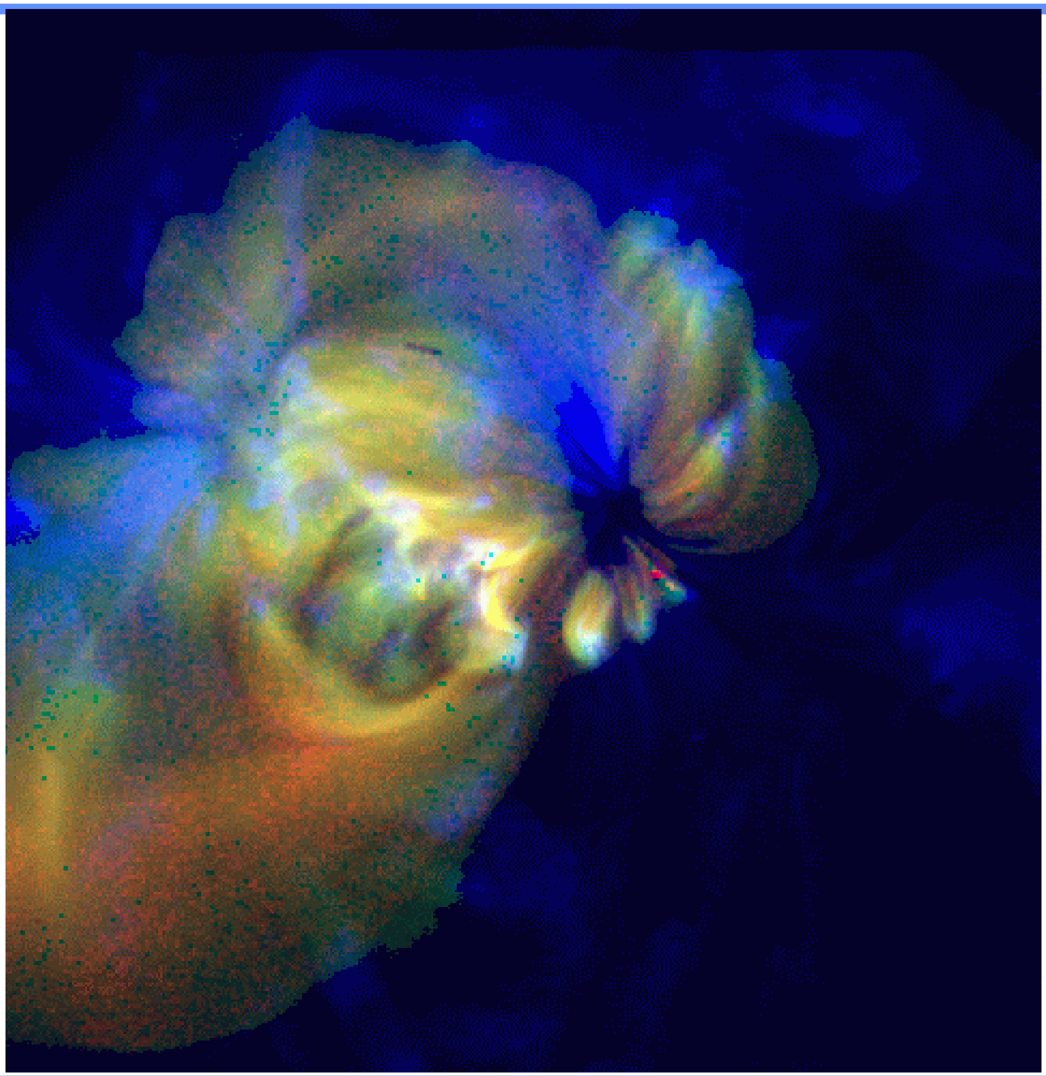


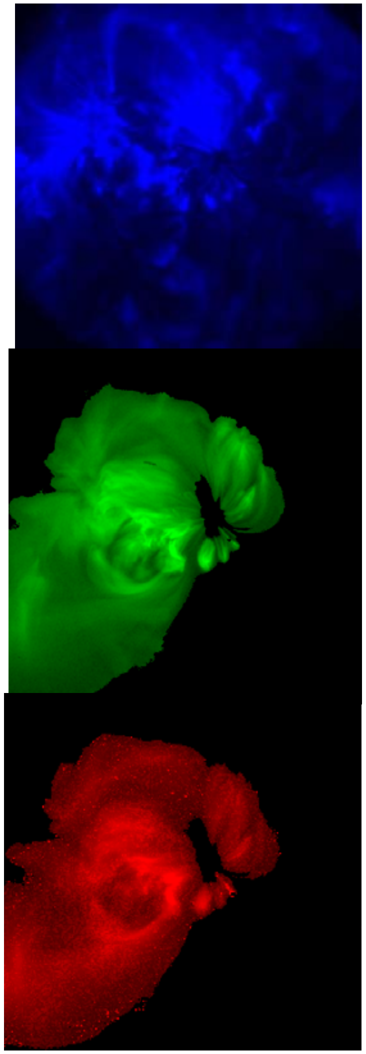
Hot + cool + TRACE

- TRACE 171 A



Hot + cool + TRACE





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Fabio Reale

Perspectives

- Evidence of widespread hot plasma detected by XRT medium filters and diagnosed by their ratio: potentially very important

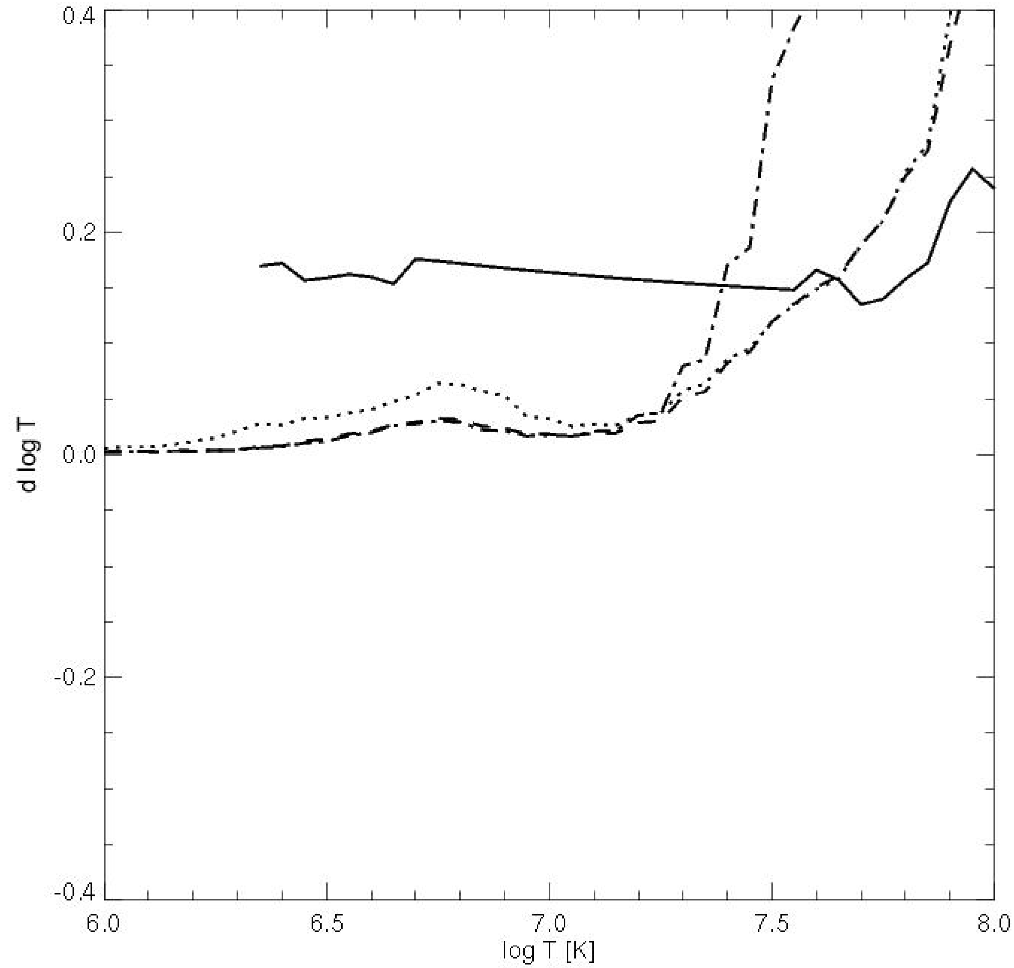
- Problems:
  - Small ratio range requires highly accurate calibration
  - Not obvious interpretation of multi-ratio diagnostics

- We need confirmation through a very accurate and tested final XRT calibration

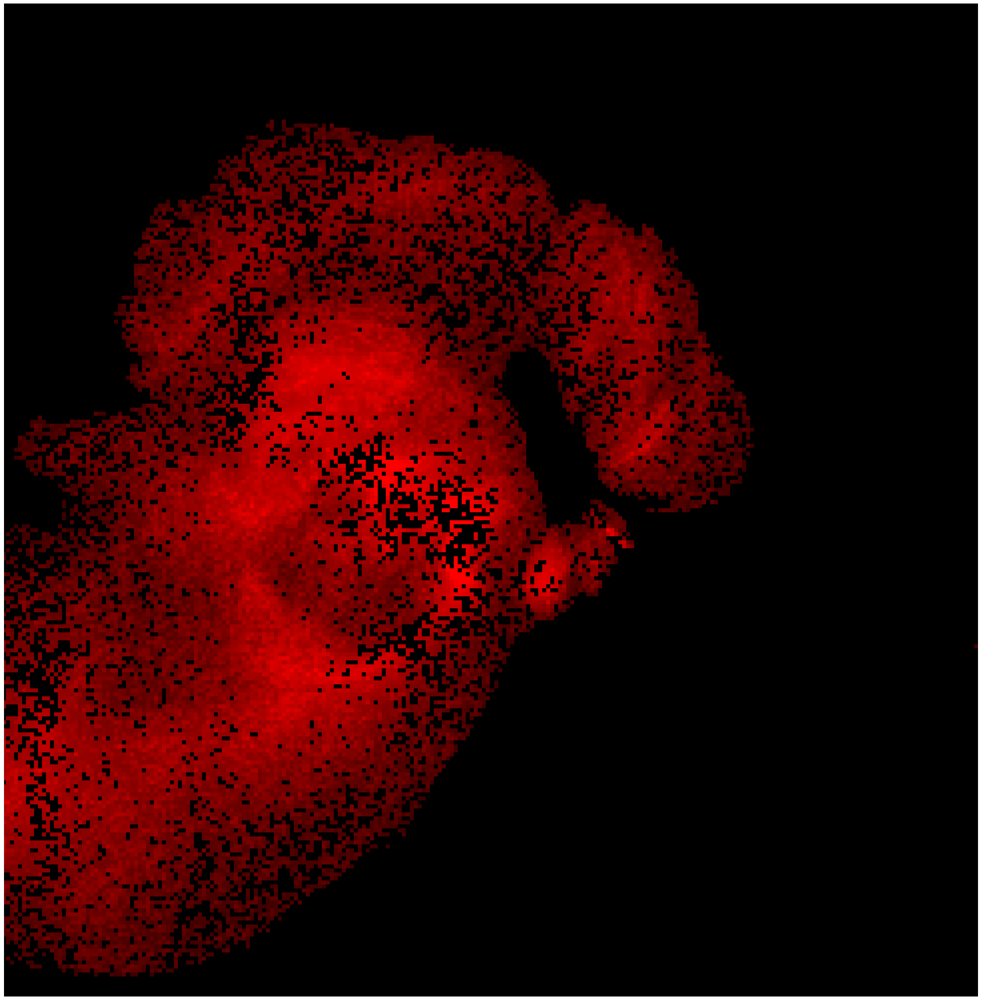
- If confirmed: positive for multi-stranded nanoflaring loops?

Importance of filter calibration

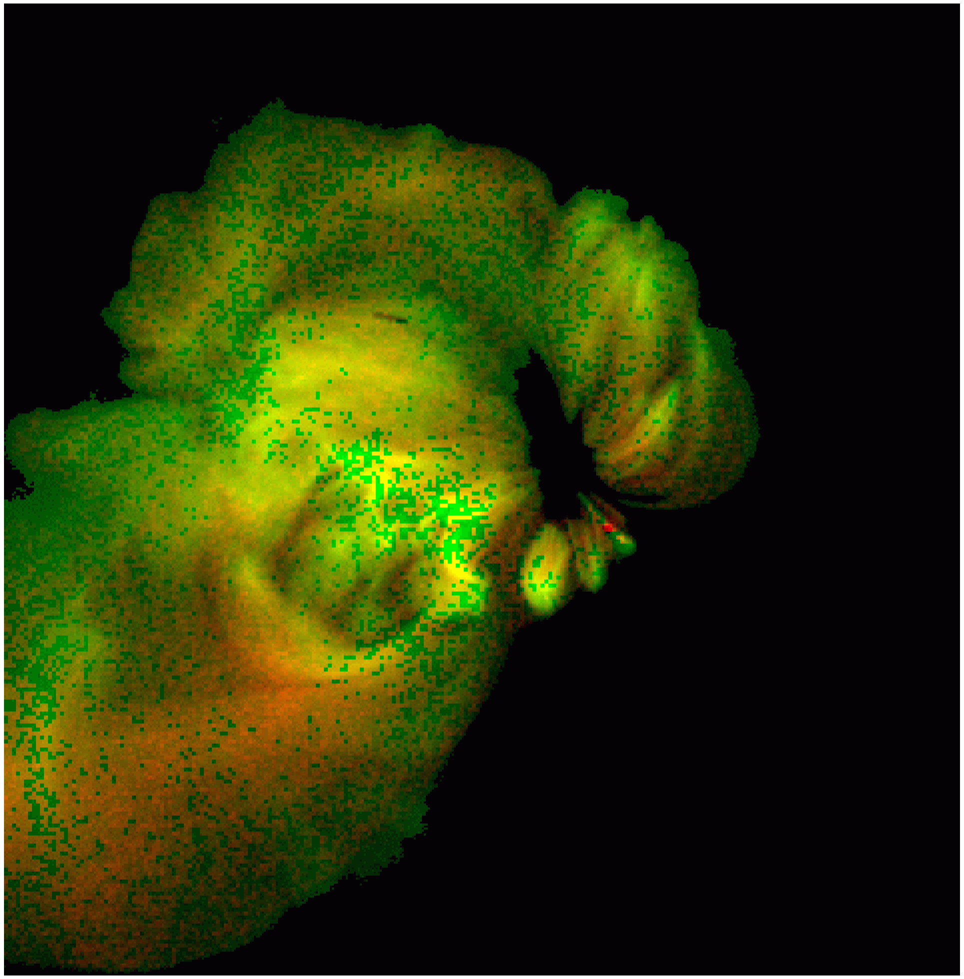
- Be_med/Al_med 4% mis-calibration leads to about 35% mis-calibration in T

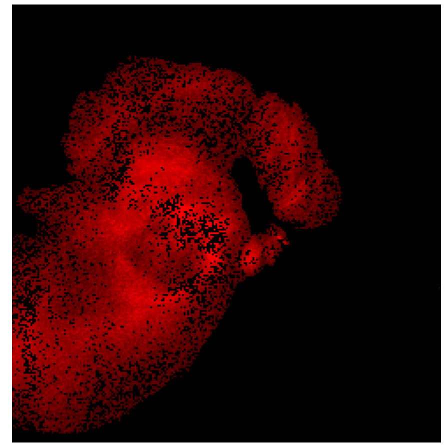


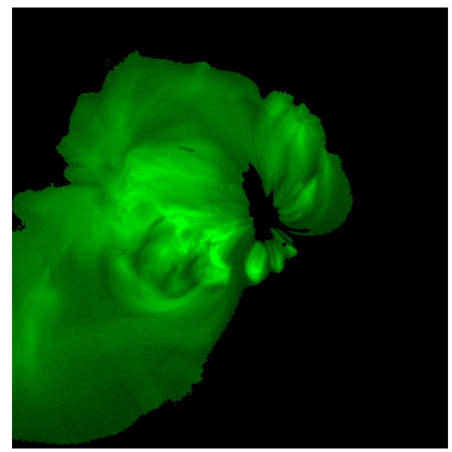
Very hot plasma map (log T > 7)



Very hot and cool maps overlapping







The field of view & evolution: C_poly

- No flare
- No major re-arrangements
- Rapid variations
- Structures constant for most of the time