CRAAM

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THE EUV EMISSION AS A COUNTERPART OF THE SUBMILLIMETER RADIATION DURING A SOLAR FLARE

This work was financed by the Universidade Presbiteriana Mackenzie and FAPESP

Context

- Submillimeter emission : $\nu > 100$ GHz
- During Flares, sub-mm radiation is related to
  - $\gamma > 2$ synchrotron eléctron
  - Thermal Bremsstrahlung
- Previous Works focused on comparing sub-mm with
  - Hard X-Rays (synchro)
  - Soft X-Rays (Bremsstrahlung)
- There are no sub-mm images yet!
  - But, we can determine the source centroid
- Ultra-Violet observations are either
  - Narrow band images
  - Spectral line irradiances

Goals

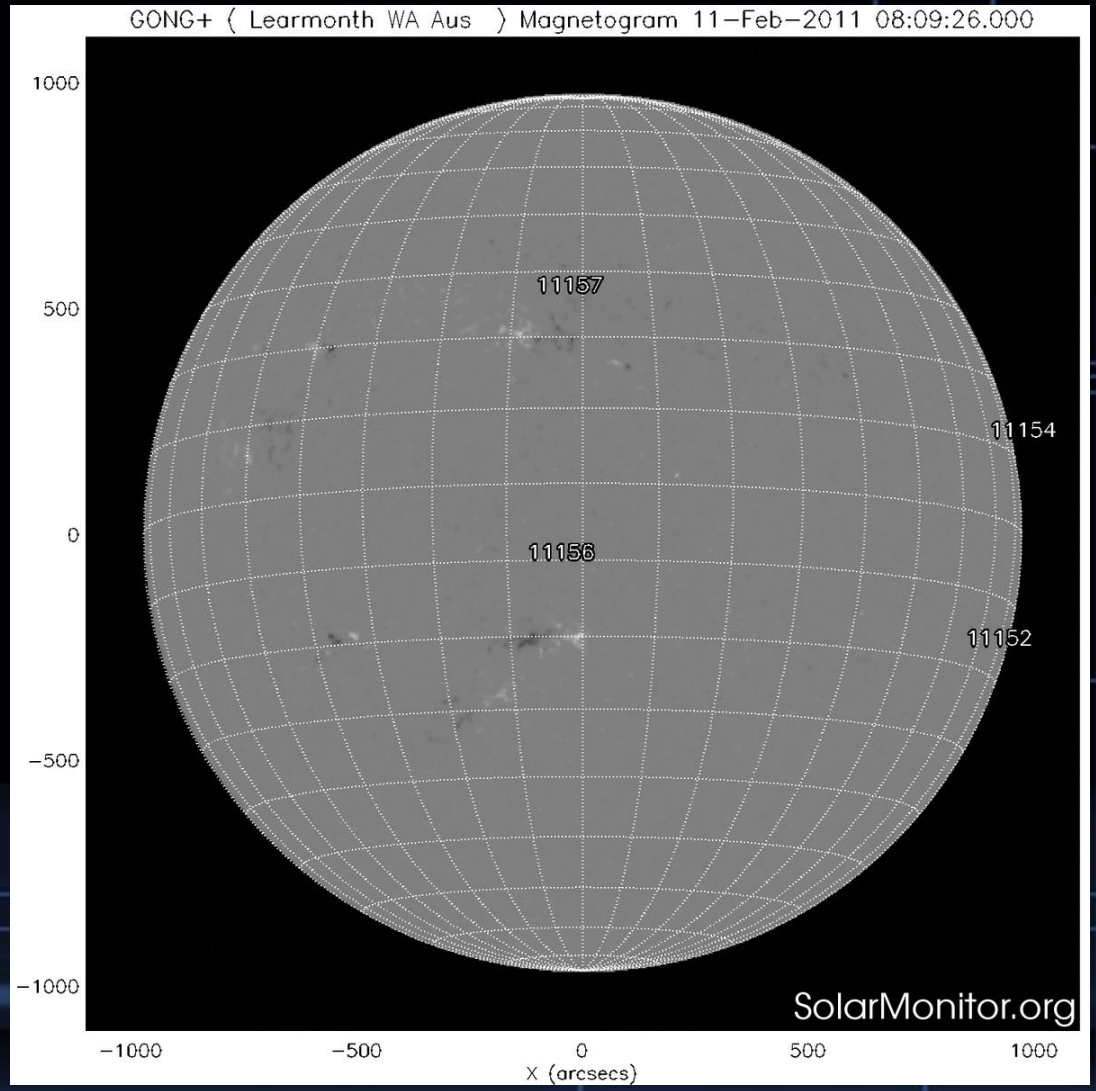
- Extend the sub-mm analysis using UV data.
  - Compare sub-mm centroid sources with UV sources.
  - Compare sub-mm and spectral lines time profile.

Solar Submillimeter Telescope (SST)

- Operating since 2001
- Total Power non-polarized room temperature receivers at 212 and 405 GHz
- Single dish with a Multifocal array at 212 GHz
- *Multibeam* technique allows position determination @ 212 GHz

NOAA 11158 in perspective

- First Named on February 12
- Disappeared on February 21
- First classified as $\beta\gamma$
- Maximum size : 600 10^{-6}
- > 30 spots
- ~ 70 Events in 10 days
  - 5 B
  - 56 C
  - 5 M
  - 1 X

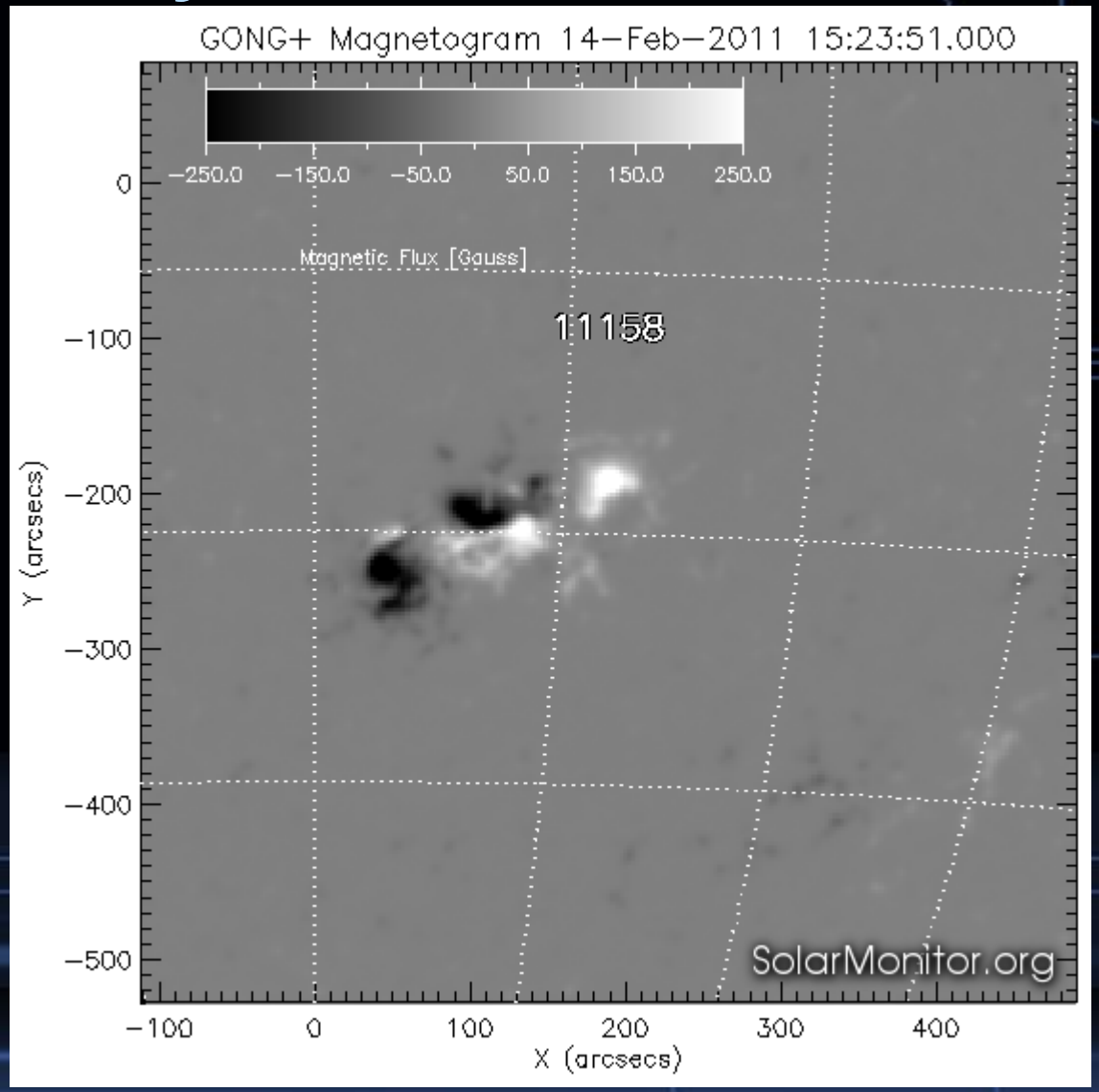


NOAA 11158 on February 14

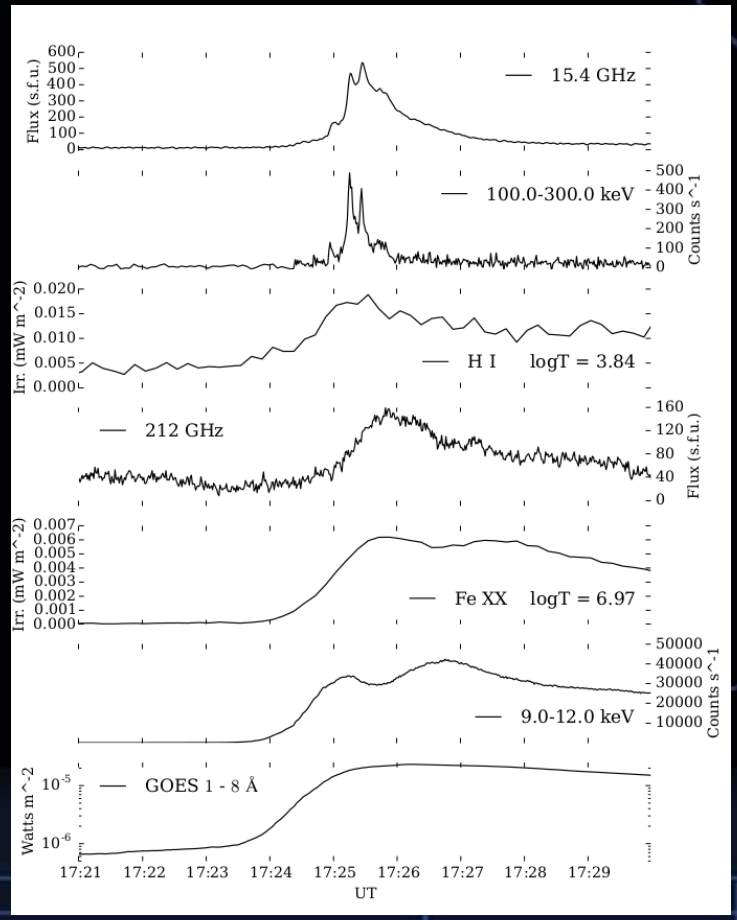
Position: S20W04 @ 0 UT
Many C class events before

At 17:25 produced an M2.2

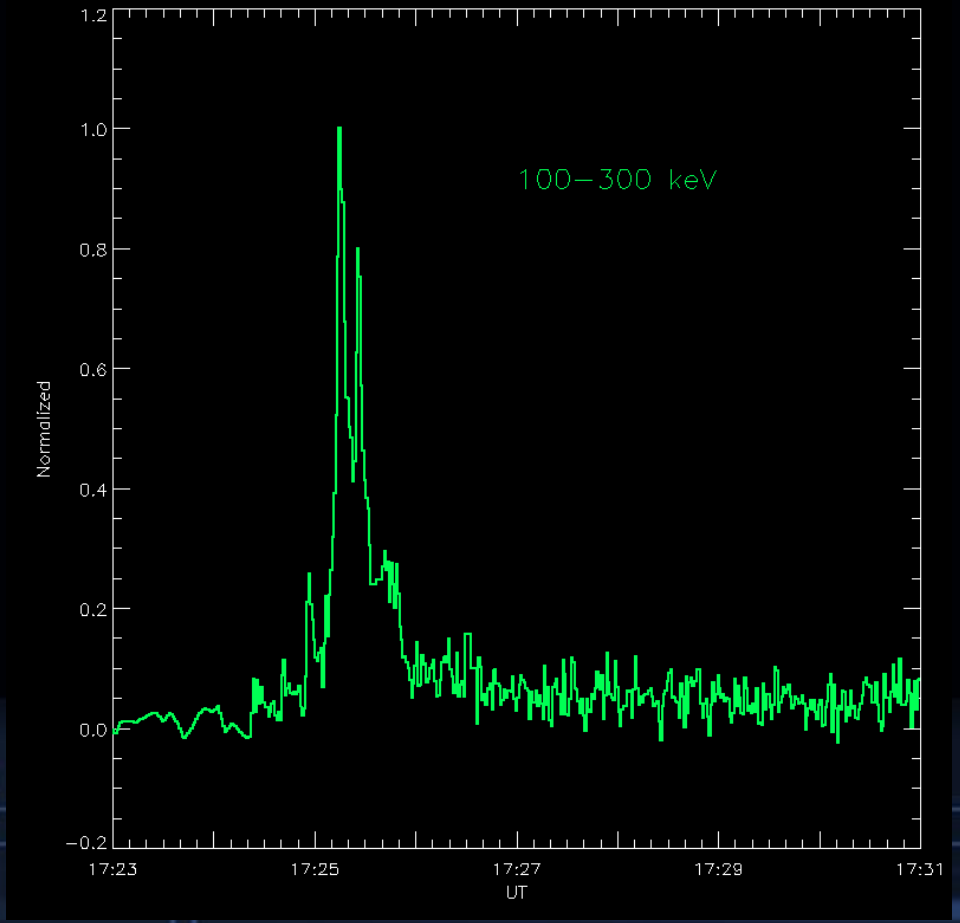
One of the weakest events observed at 212 GHz (SST)

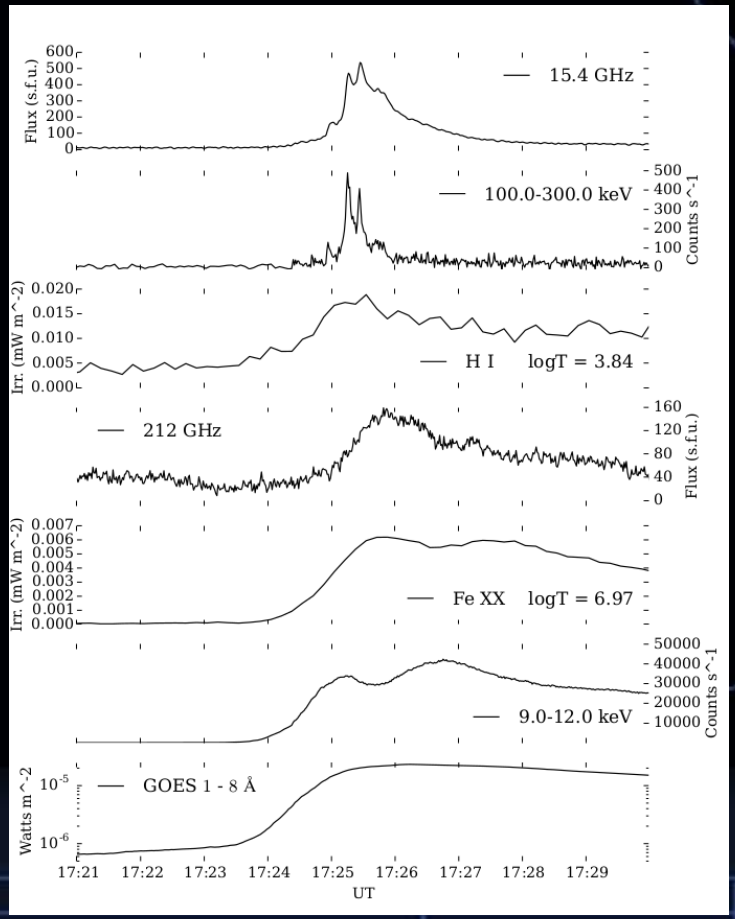


Light Curves at selected wavelengths

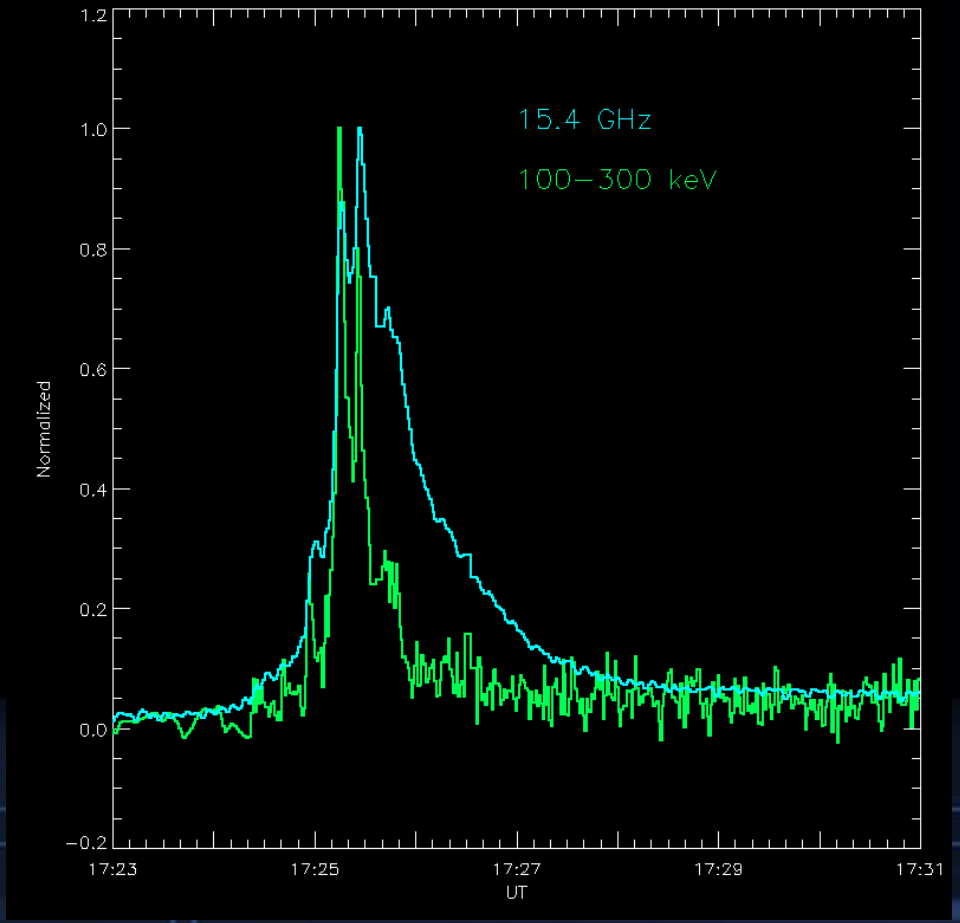


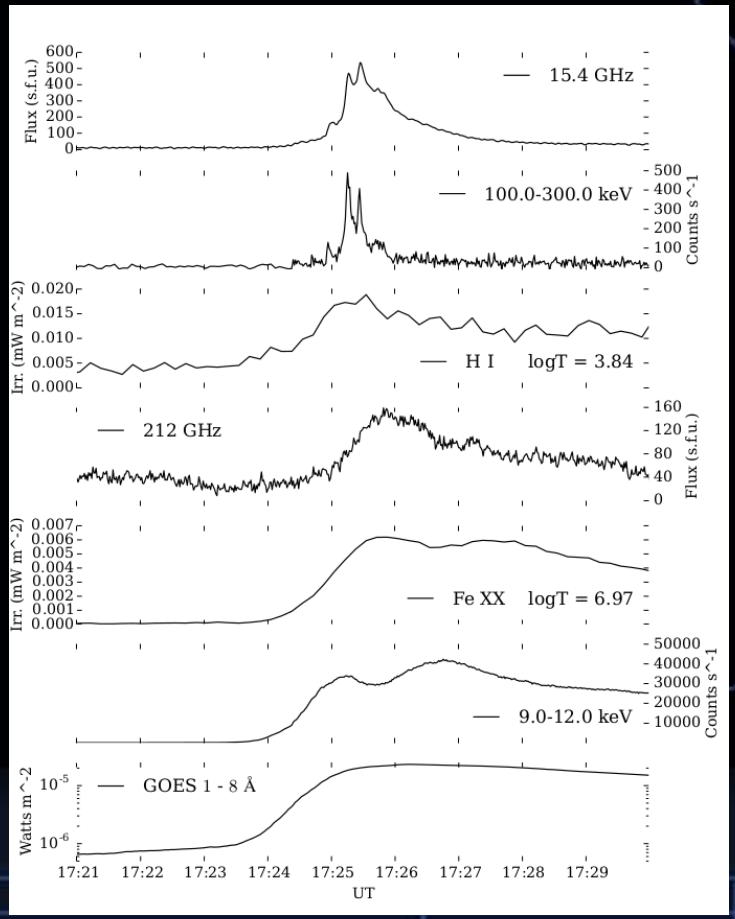
HXR vs microwaves





HXR vs microwaves





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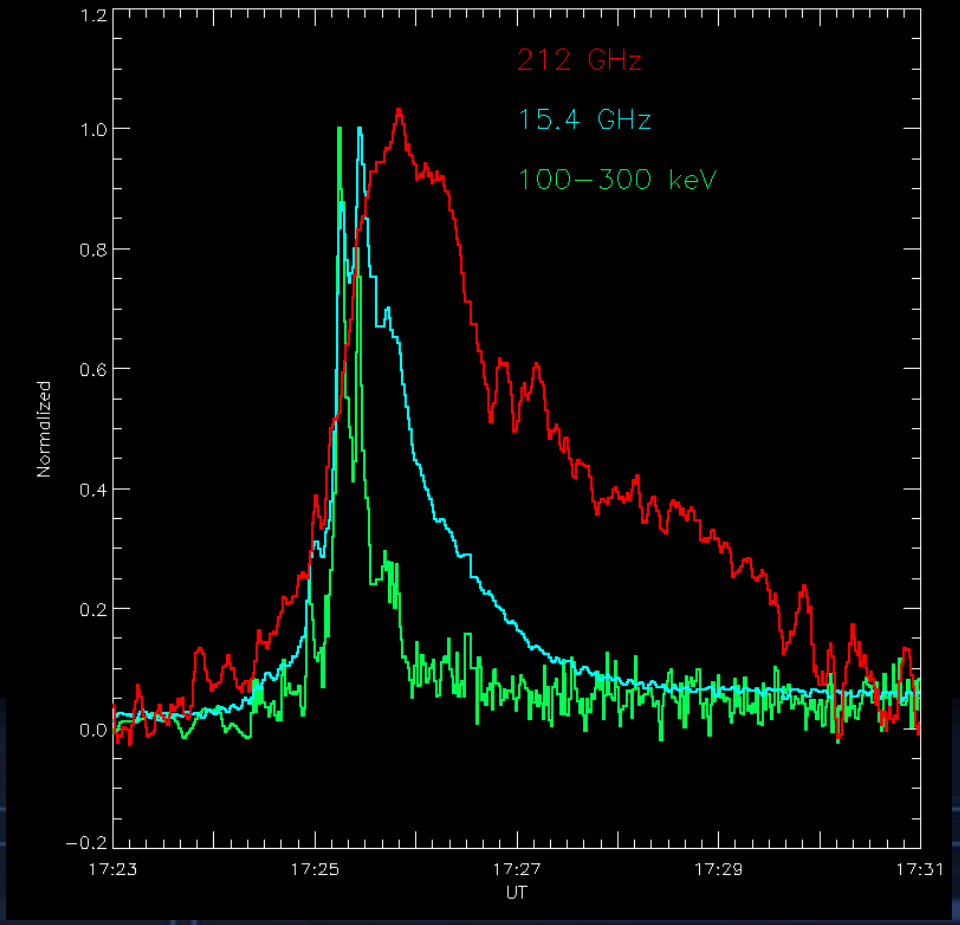
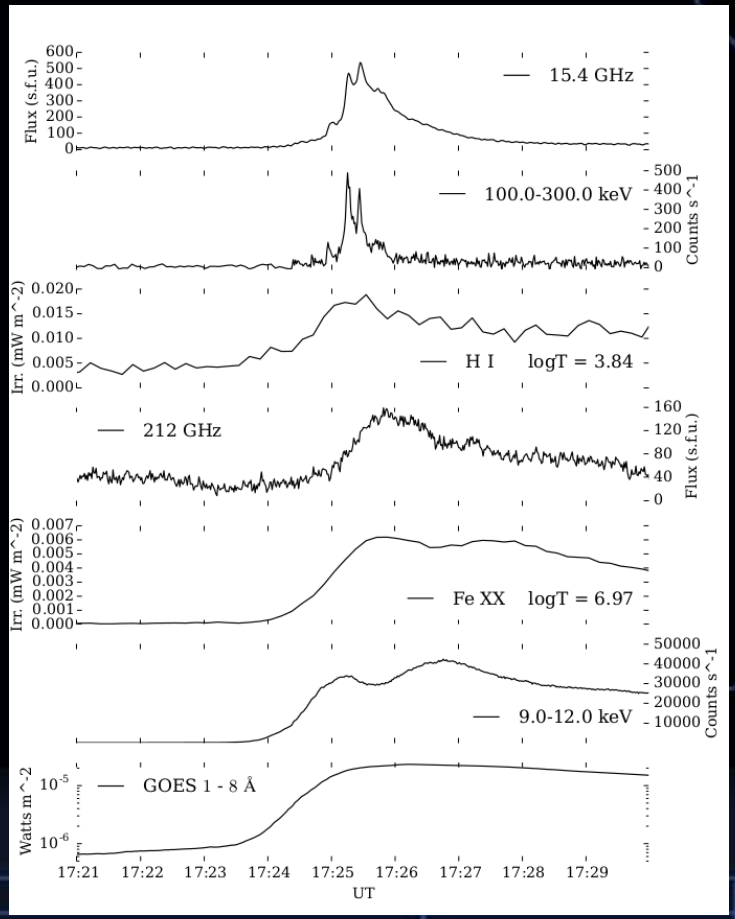
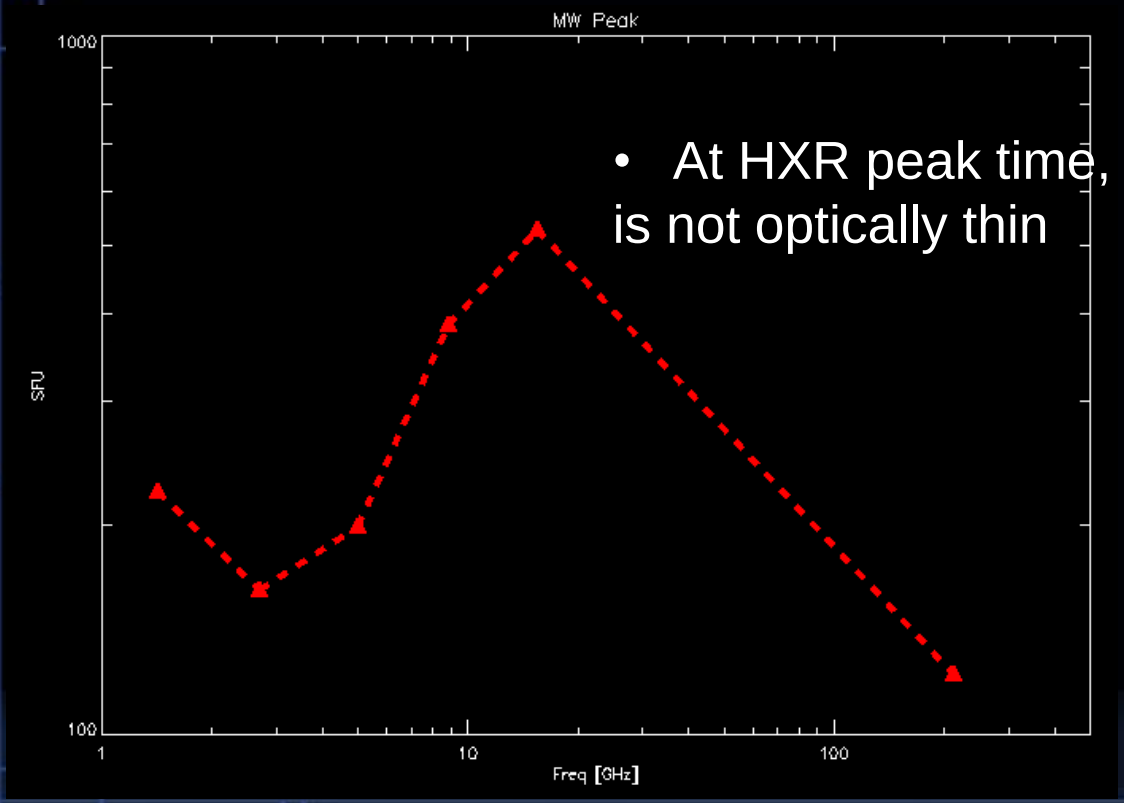


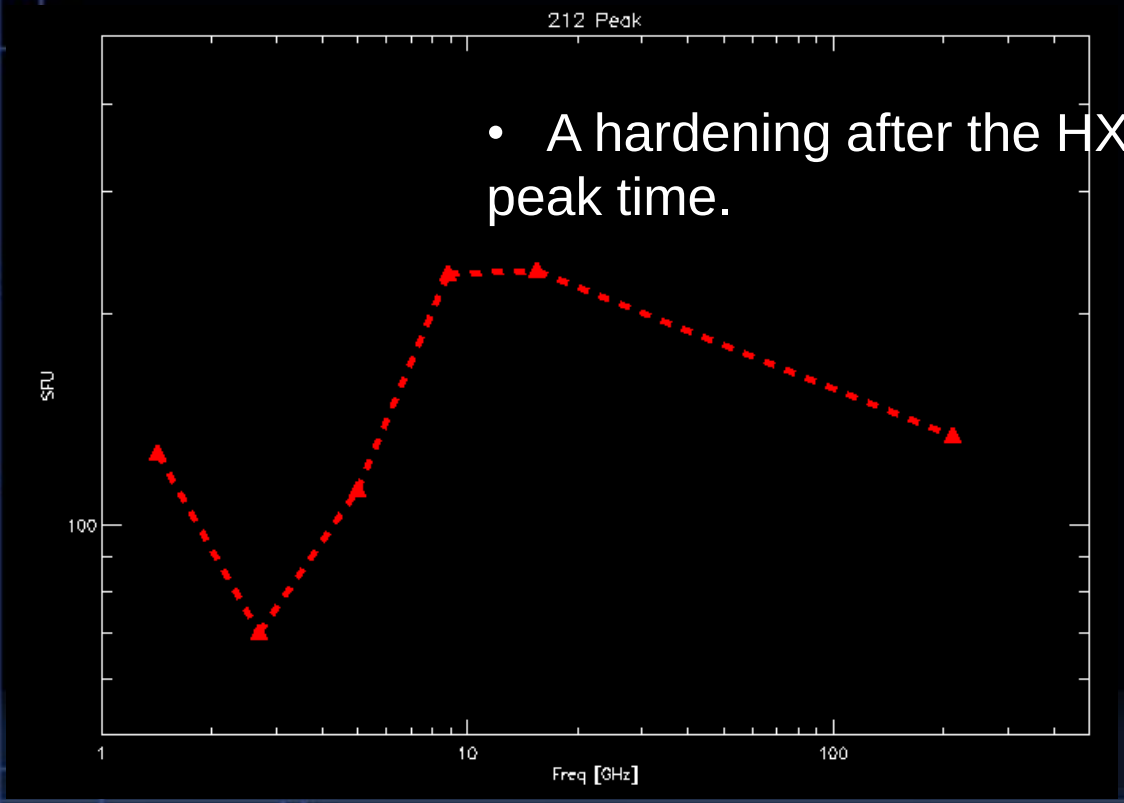


Microwaves spectra



- At HXR peak time, 15.4 GHz is not optically thin

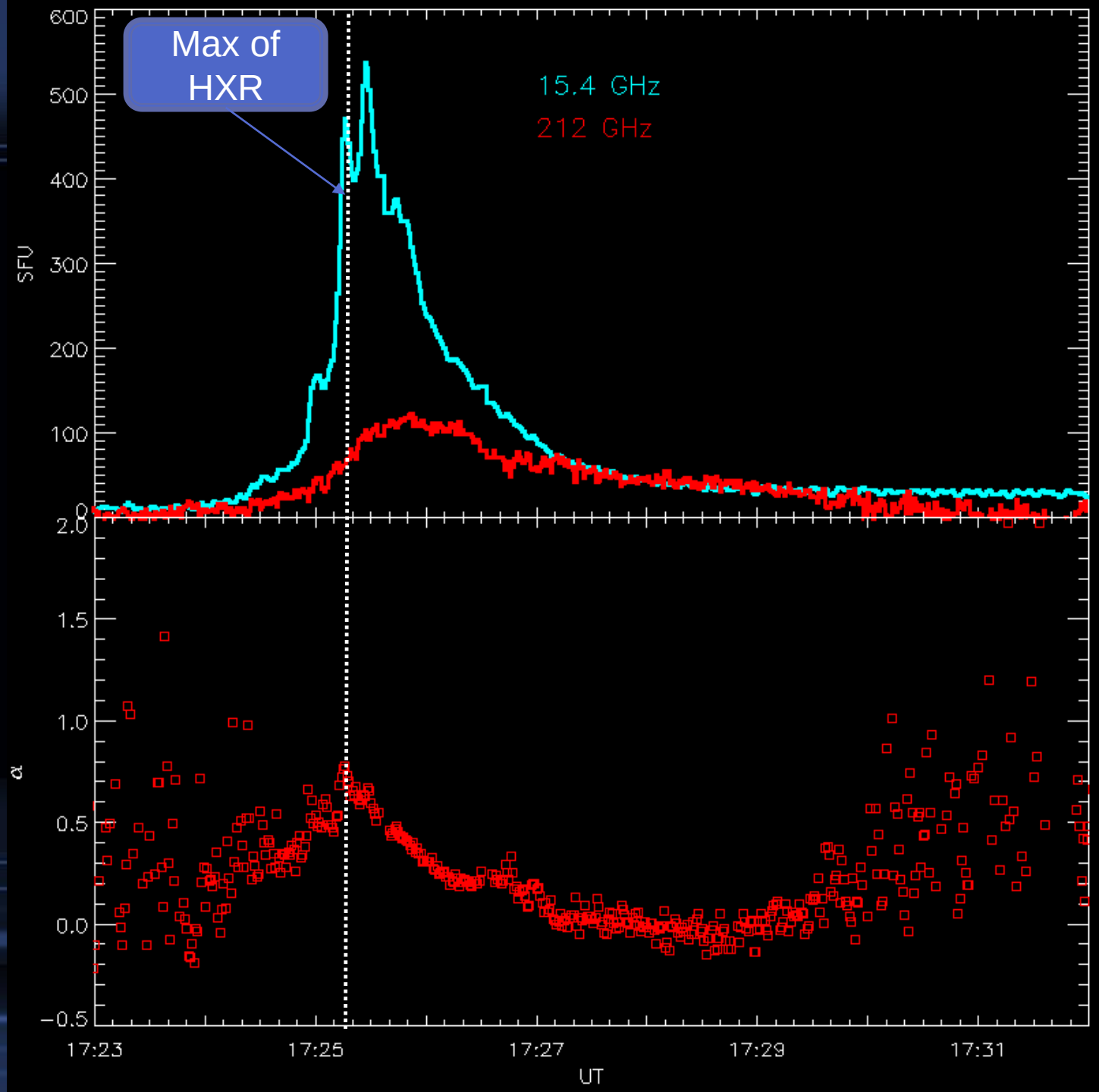
Microwaves spectra



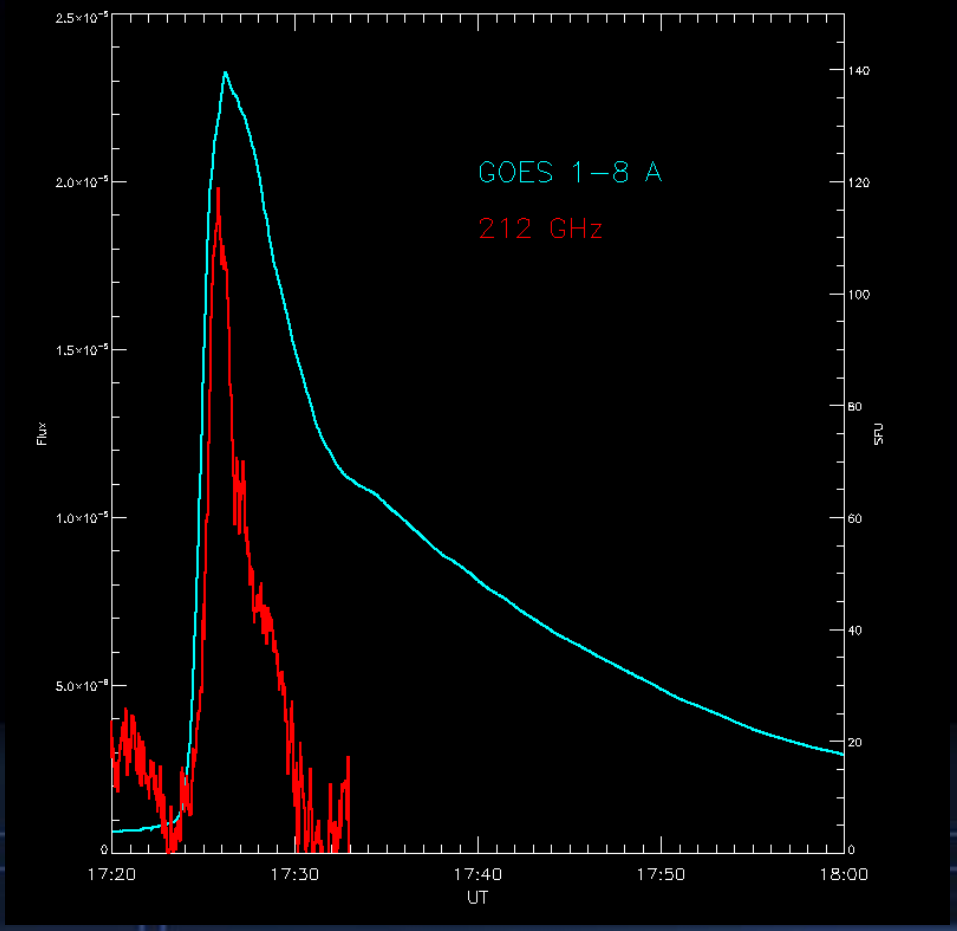
- A hardening after the HXR peak time.

Spectral Index

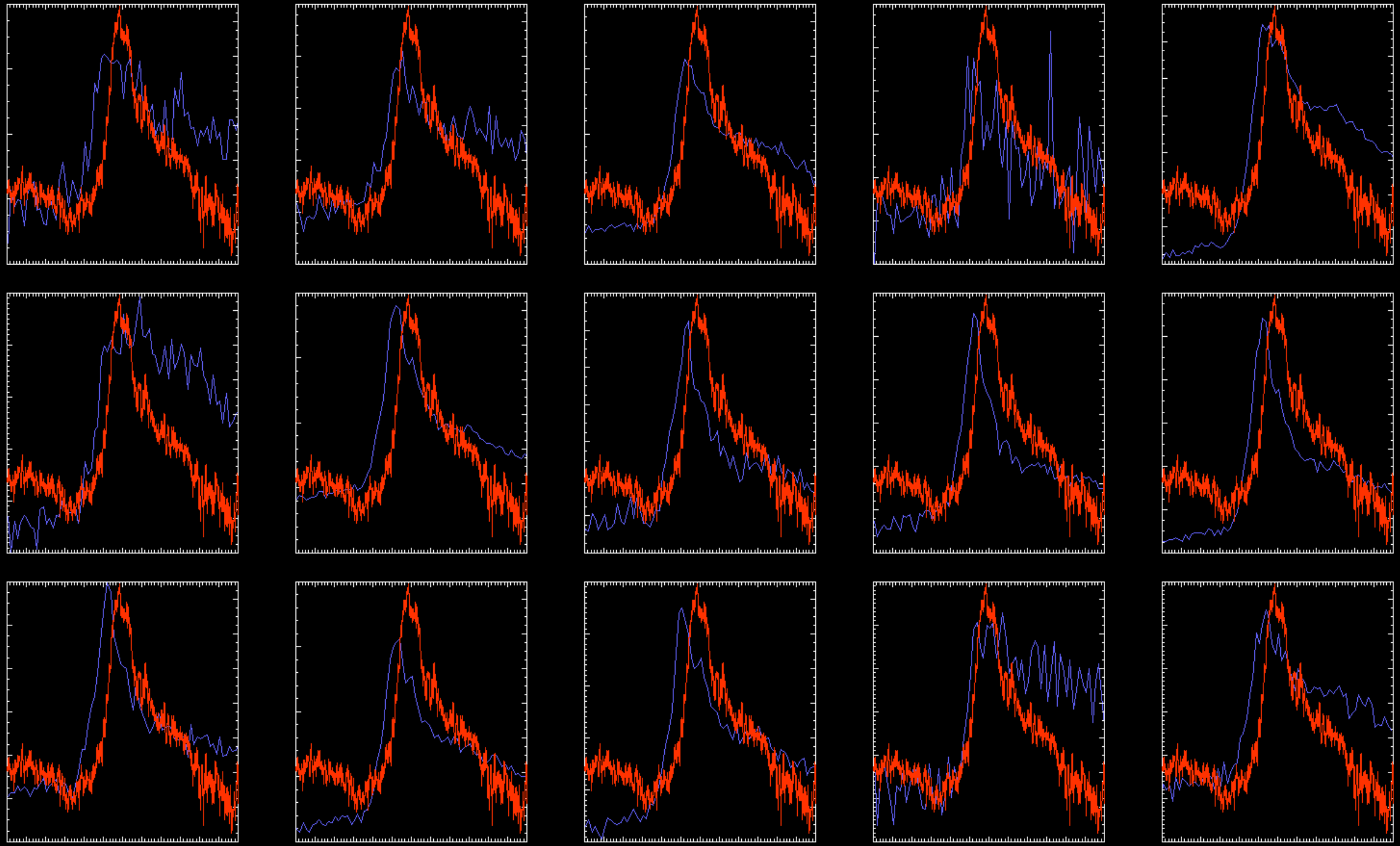
$$\alpha = -\frac{\log\left(\frac{f_{212}}{f_{15.4}}\right)}{\log\left(\frac{212}{15.4}\right)}$$

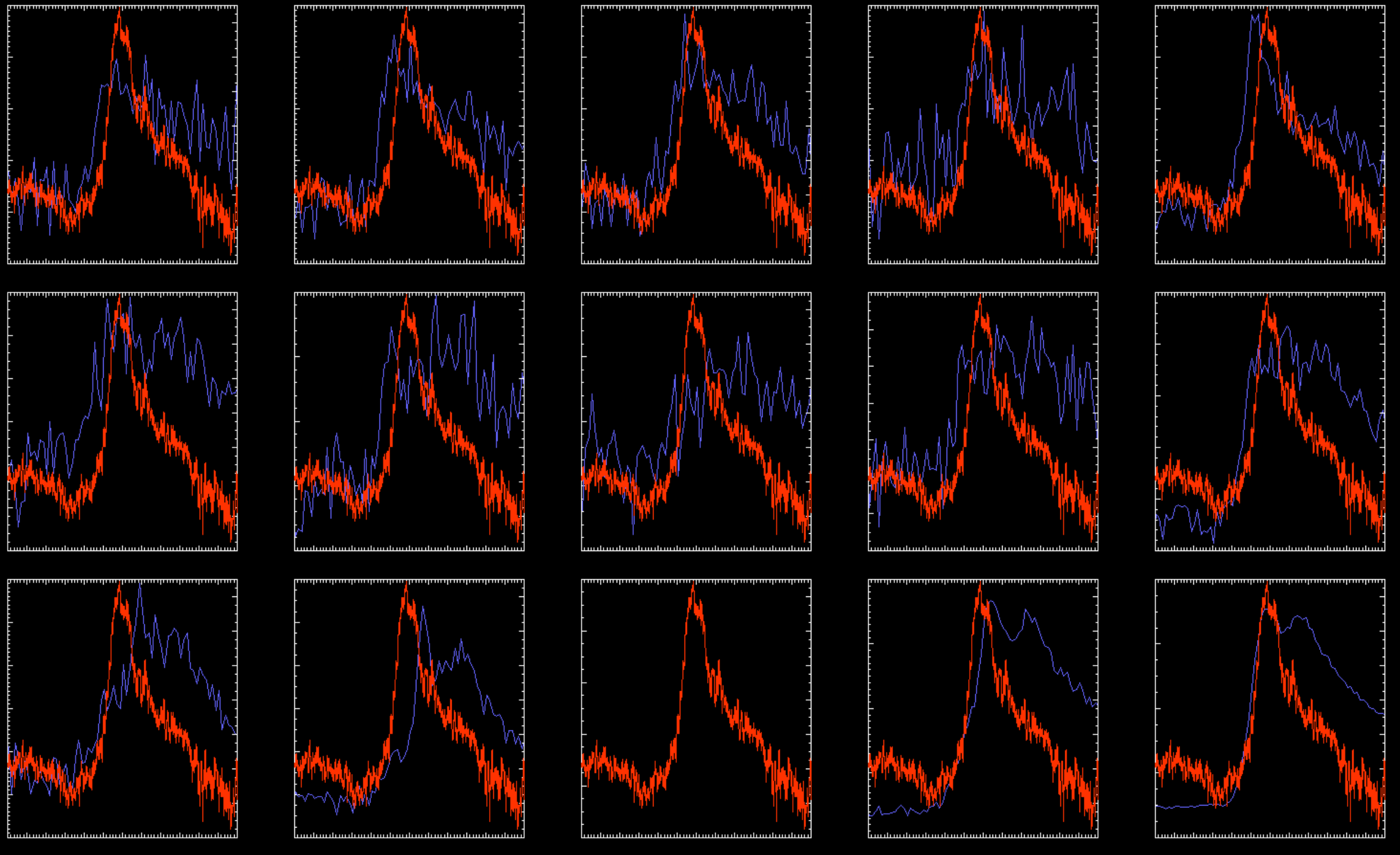


Soft X-Ray vs Sub-mm



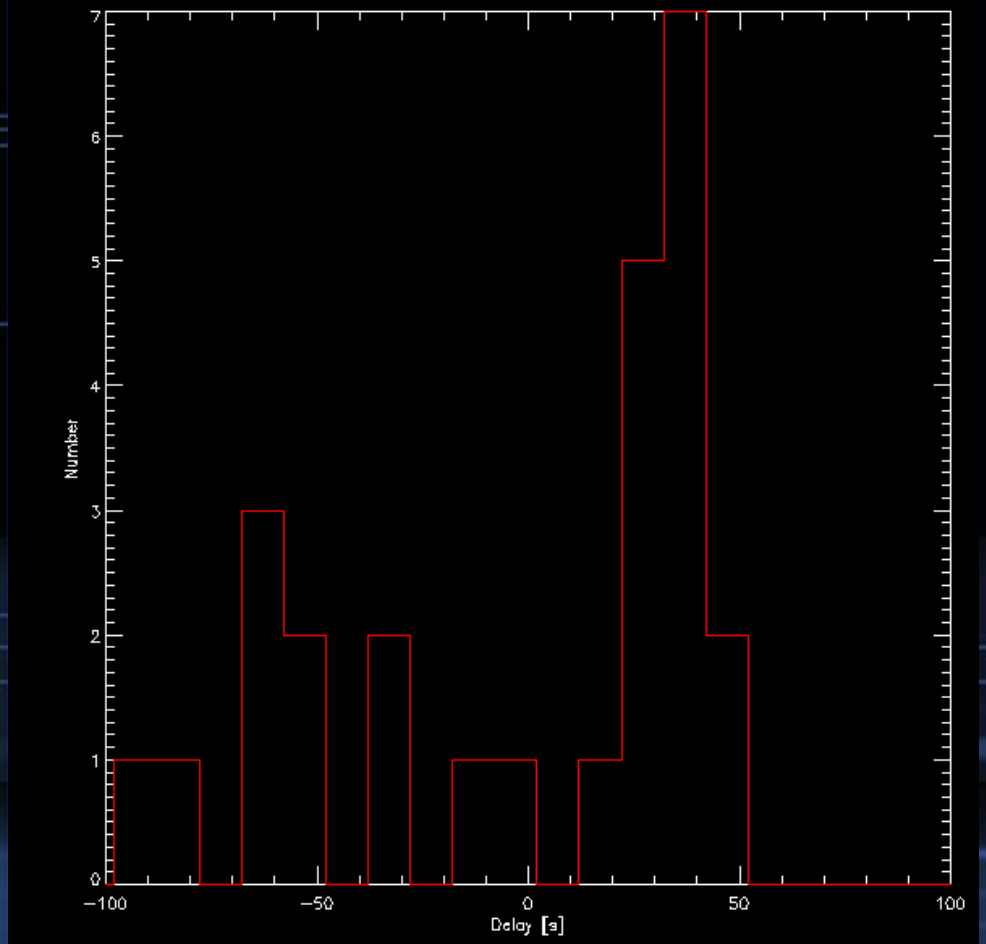
UV lines vs Sub-mm

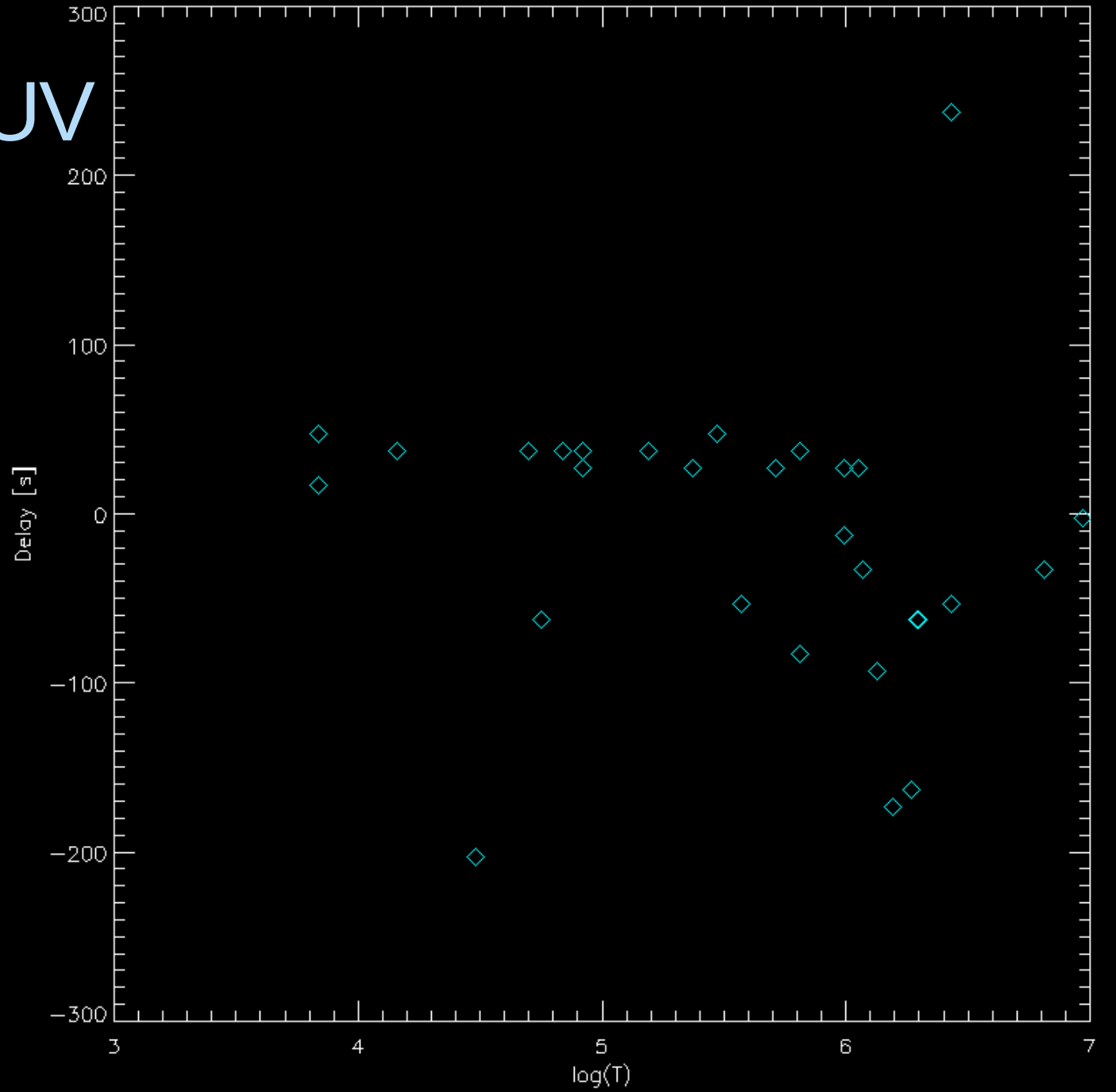




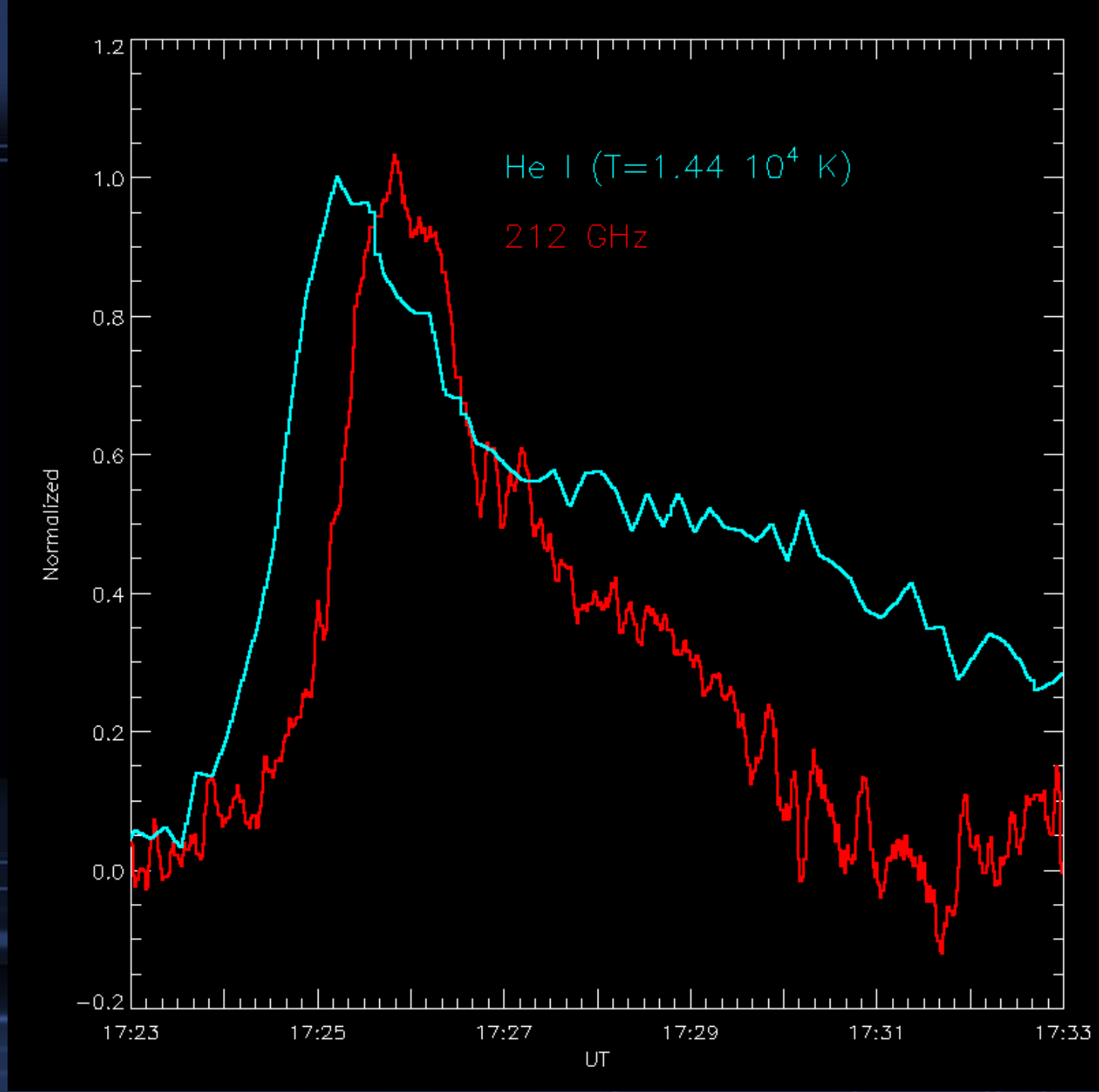
Delay: sub-mm vs UV

$$Delay = peak\ time_{212} - peak\ time_{UV}$$

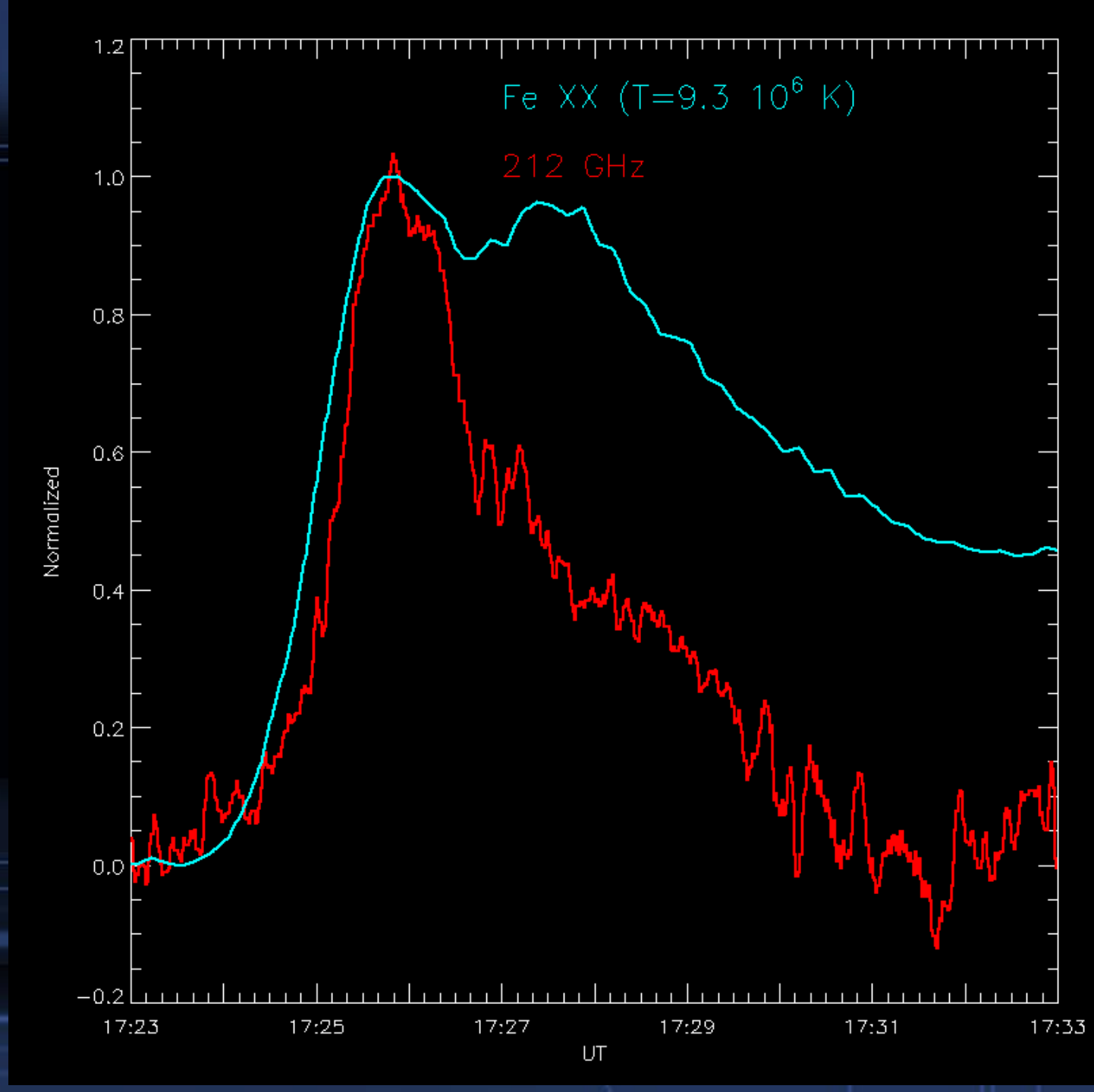




UV vs Sub-mm


He I (T=1.44 10^4 K)
212 GHz
Normalized
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
17:23
17:25
17:27
17:29
17:31
17:33
UT

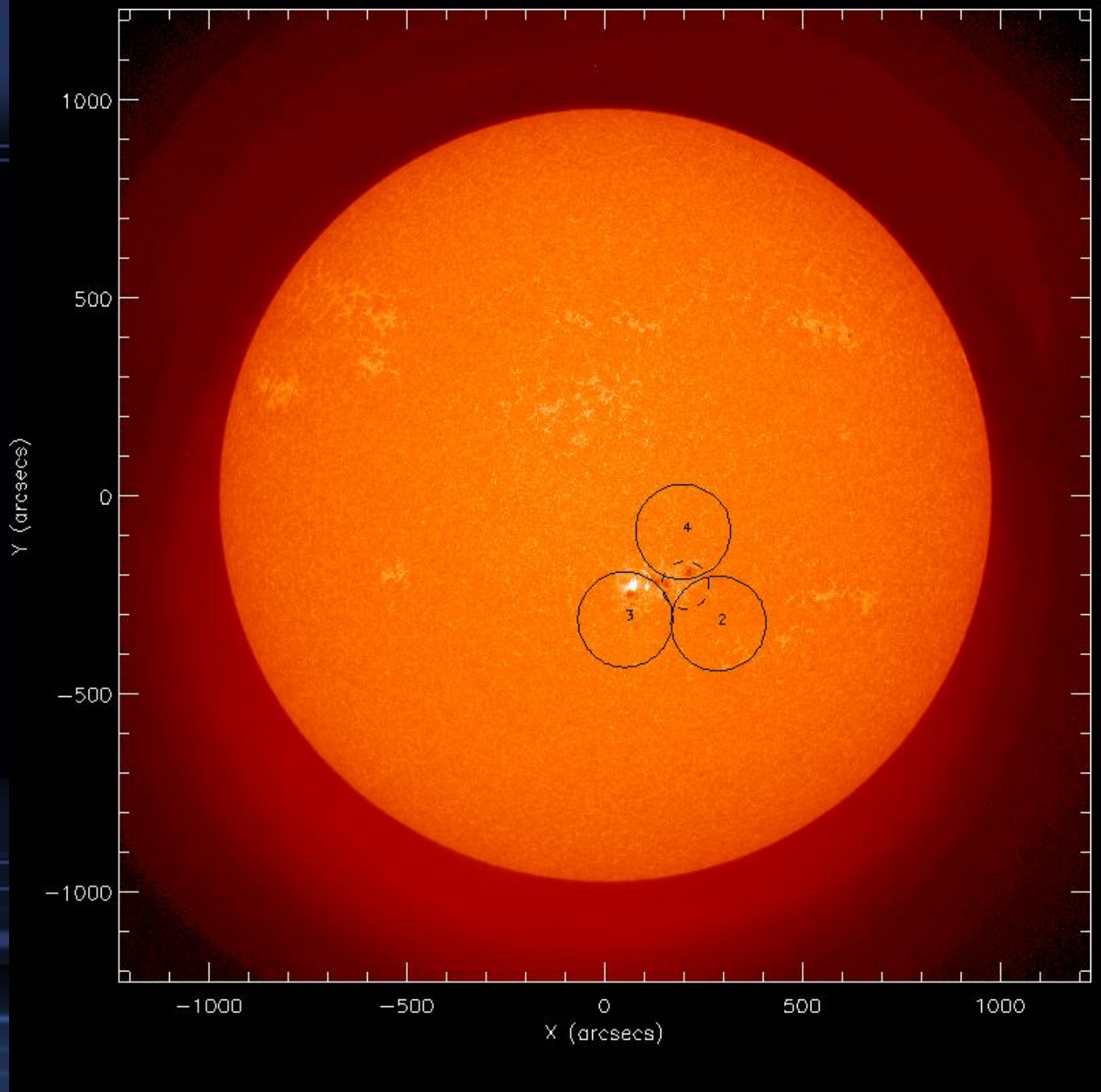
UV vs Sub-mm


Fe XX (T=9.3 10^6 K)
212 GHz
Normalized
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
17:23
17:25
17:27
17:29
17:31
17:33
UT

Sub-mm Positions

Continuum at 1700 Å @ 17:25 UT

Circles represent the nominal SST beams



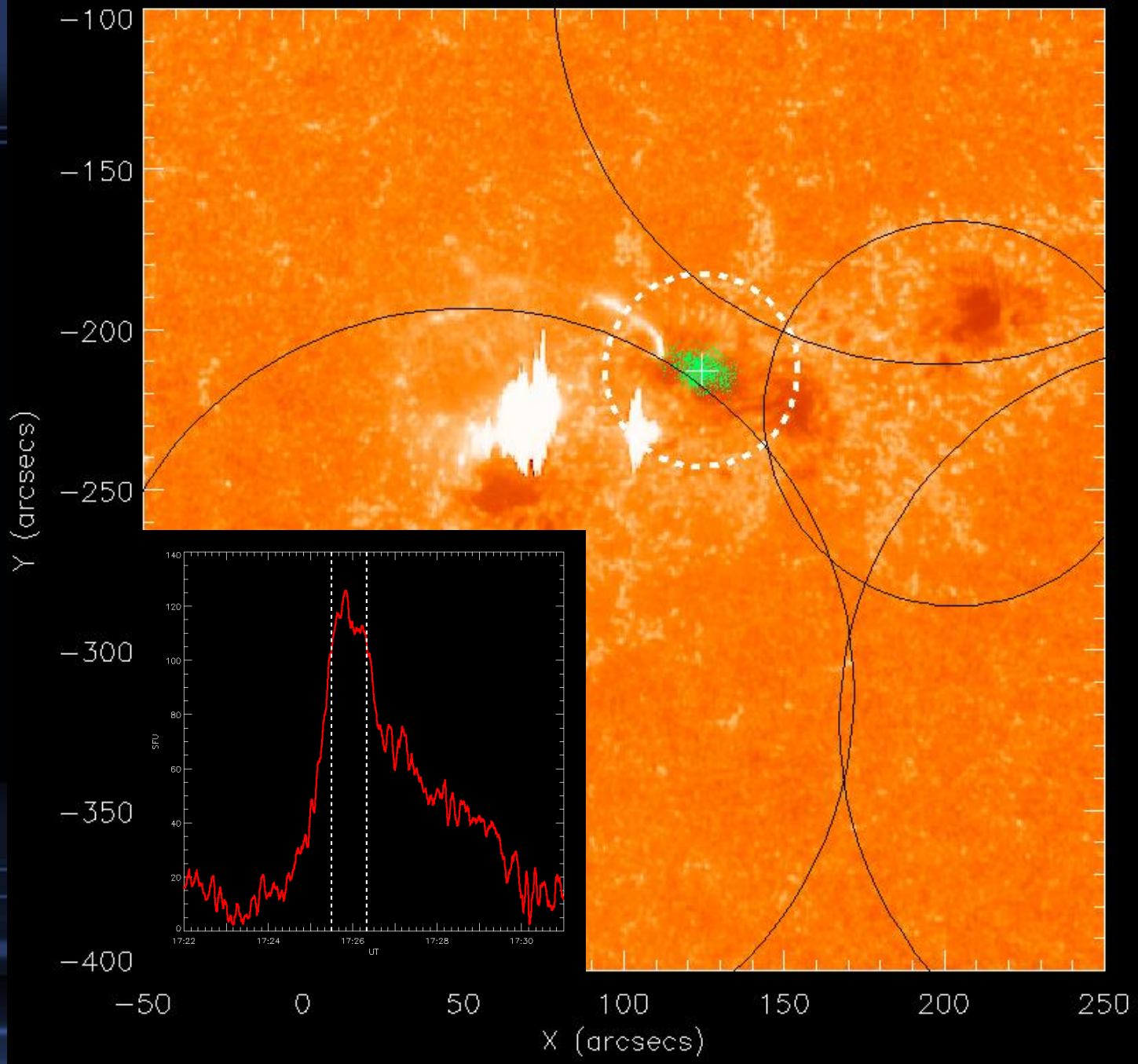
Sub-mm Positions

Green dots are the multibeam solutions along the time

Dashed circle represents the absolute uncertainty in position

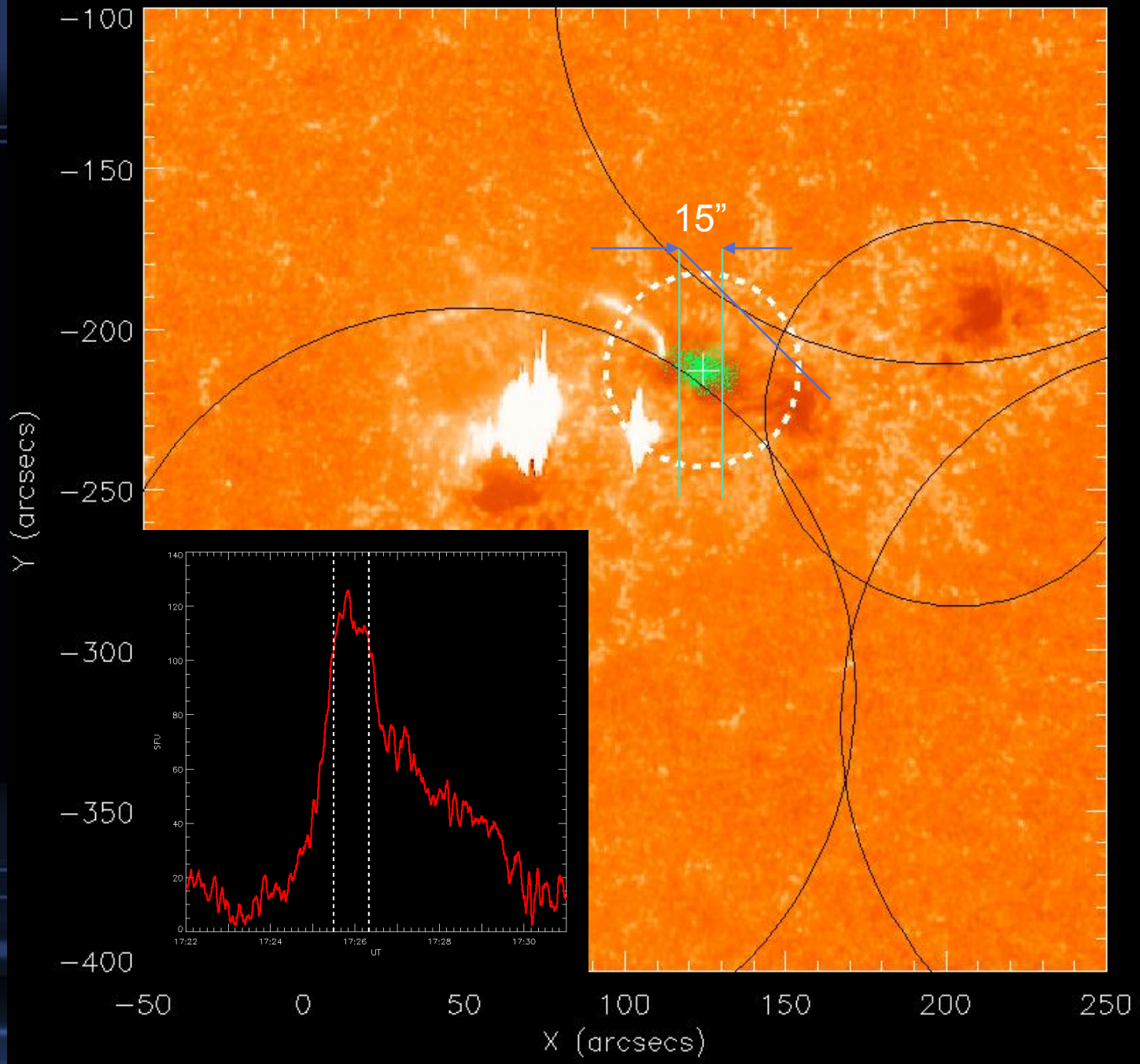
The inlet shows the 212 time profile.

Multibeam solutions were computed for the maximum (between vertical dashed lines)



Sub-mm Positions

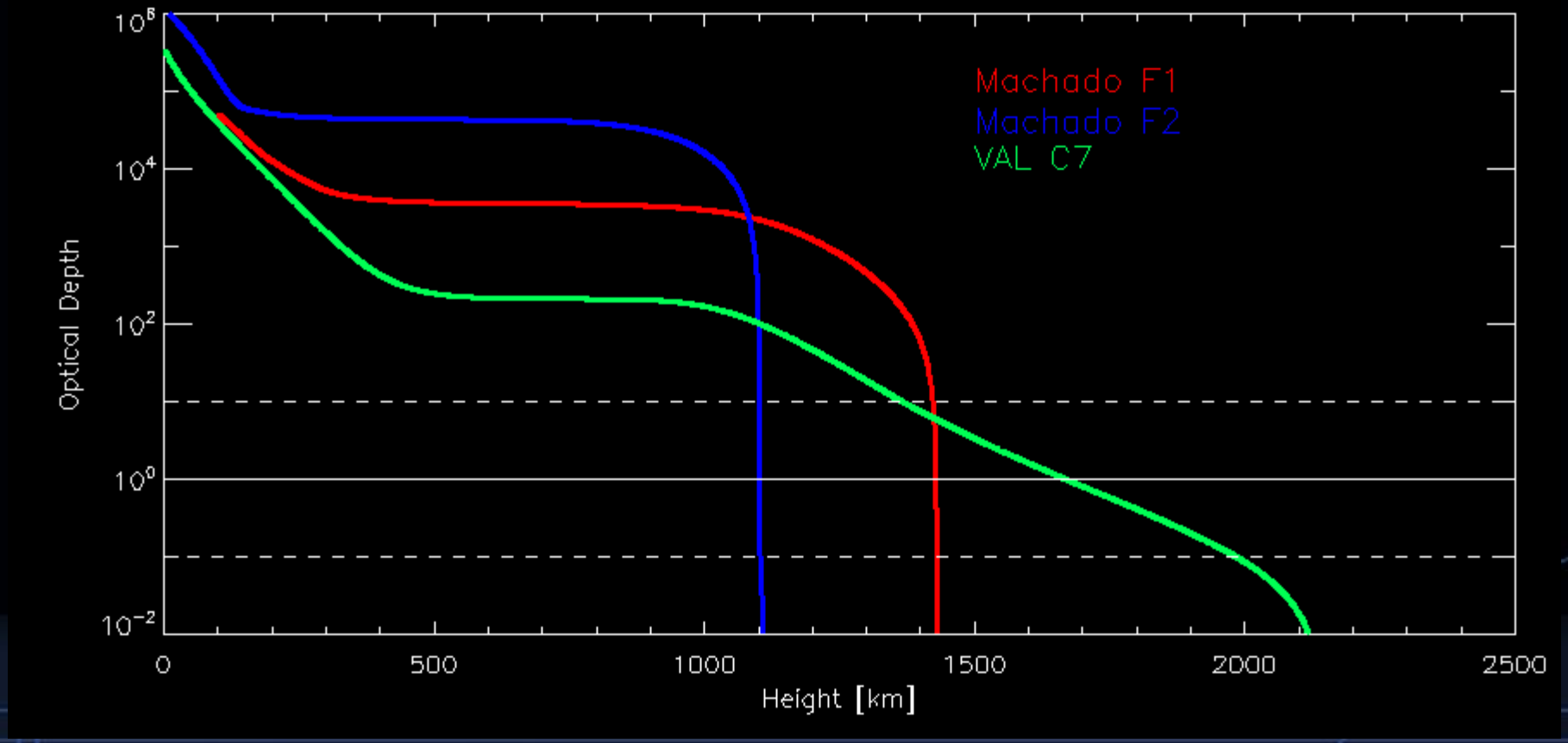
Standard deviation of the multibeam solution $\sigma \approx 4.5$”



Thermal characteristics of sub-mm

- Flare atmosphere profiles determined by Machado et al (1980)
- Jaguar code computes the NLTE atmospheres (de la Luz et al 2011)
- Pakal code computes the radiative transfer equations (de la Luz et al 2011)
- Results are compared with VAL C7 (quiet sun)

Thermal Emission @ 212 GHz

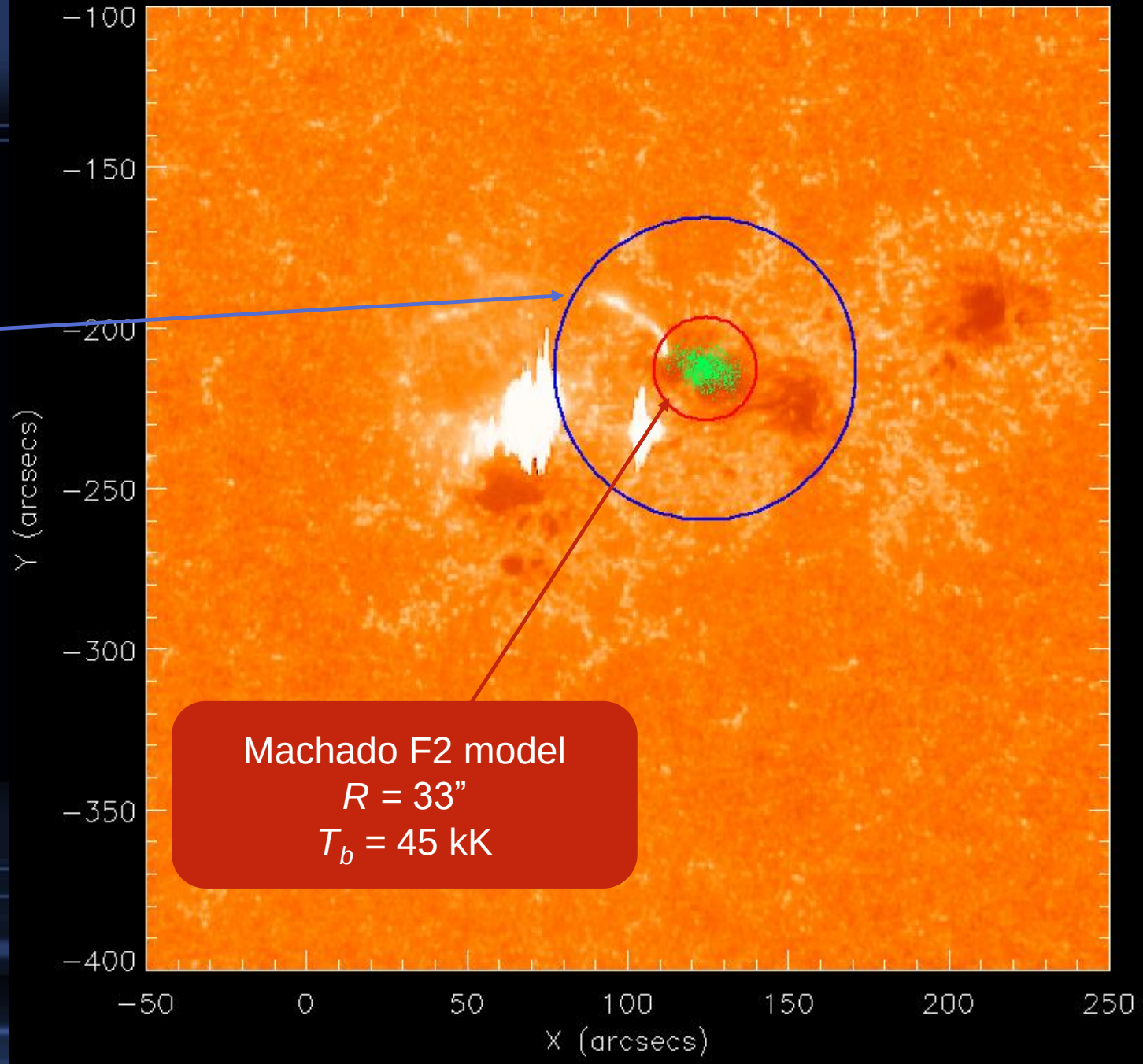


Thermal Emission

Model	Height [km]	T_b [kK]	ΔT_b [K]	$\Delta F_x \Omega^{-1}$ [erg cm^{-2}s^{-1}str^{-1}]	Source Size ["]
F1	1430	12.4	5.6	8 10^{-11}	100
F2	1100	51.5	44.9	6 10^{-10}	33
C7	1350 – 2000	6.65	-		

Thermal Emission

Machado F1 model
R = 100”
Tb = 5.6 kK



Machado F2 model
R = 33”
T_b = 45 kK

Concluding Remarks

- Sub-mm flux time profile does not have similar features as HXR and micro-waves
- Sub-mm flux peak time has delays with HXR and micro-waves of the order of 30 s
- During peak time, multibeam solution has a small dispersion (~15” or $\sigma \approx 4.5$”)
- The sub-mm centroid solution is near a small UV bright spot
- Sub-mm flux peak time has delays with UV independent of the temperature line formation
- Excellent correlation with Fe XX ($T \approx 10^7$ K) first peak
- Assumming a thermal source for 212 GHz, and flare atmosphere profiles, we determine a size between 30” and 100”.
  - The former seems to be more compatible with the observations.
  - The sub-mm emission forms between 1100 to 1450 km above Photosphere

Future Work

- For this Event
  - Use HXR to determine the accelerated electron characteristics
  - RADYN to compute the atmosphere 1D profile,
  - Recompute the flux density at 212 GHz

- Is this the only event where Fe XX and 212 GHz match so well?
  - Why?