

Hot onsets at radio wavelengths

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Synopsis: Flare precursors begin at high temperatures (~10 MK), the “Hot Onsets” (2021MNRAS.501.1273H) as seen by GOES.

(1) What do radio wavelengths show?

(2) Can we use this information for prediction?

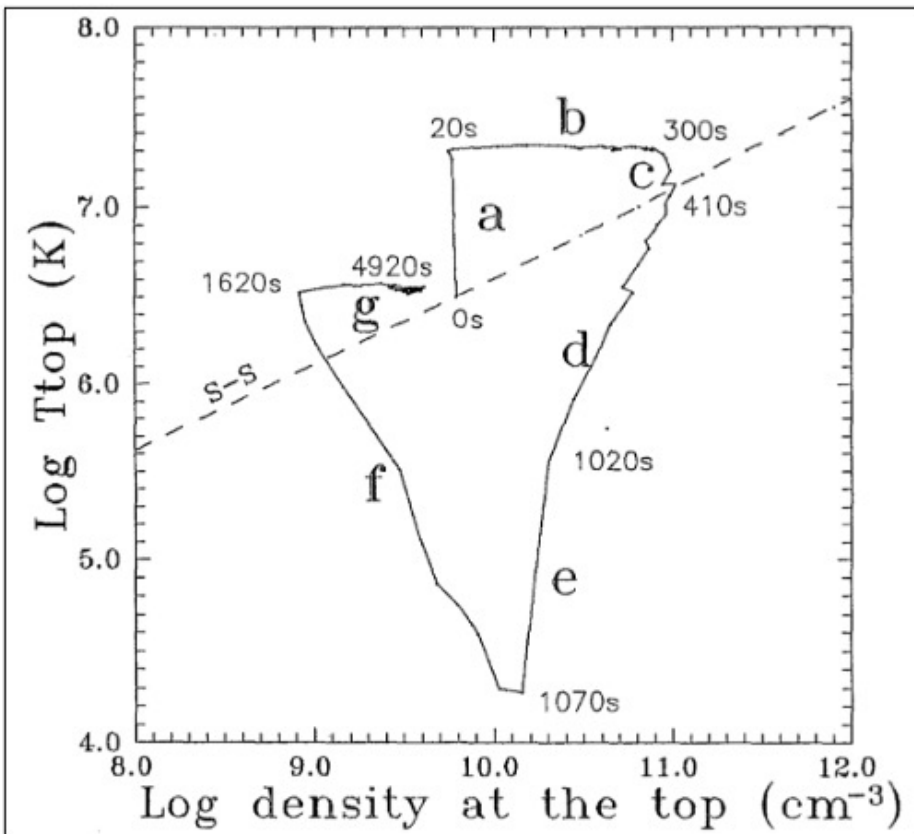
Flare precursor phenomena

- Expansion of magnetic field
- Filament activation
- Pre-event flare events
- Dm spike bursts
- Preflare EUV dimmings
- “Turbulent” line broadening
- Thermal gyroresonance (Van Hoven & Hurford 1984)
- ...
- ***HOPE (Hot Onset Precursor Event) (Hudson et al. 2021)***

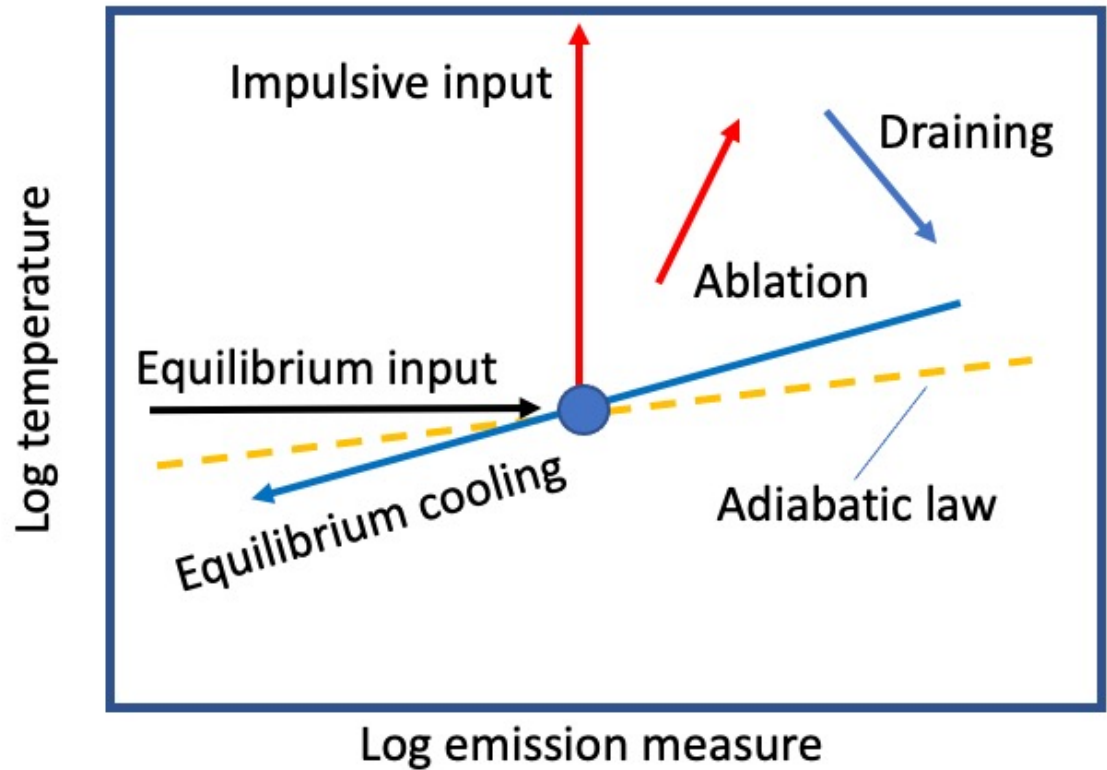
HOPE and the “horizontal branch”

- “Hot onsets” for solar flares recently recognized:
 - GOES (T, EM) data show the initial flare to be hot already
 - The hot onset phase precedes the impulsive phase and is not described by standard theories
- The observational characteristic in Sun-as-a-star data is a “horizontal branch” in the (T, EM) diagram *preceding* the Neupertian clockwise loop

No-HOPE behavior (the Neupert effect)



Barbara Sylwester original (1996)

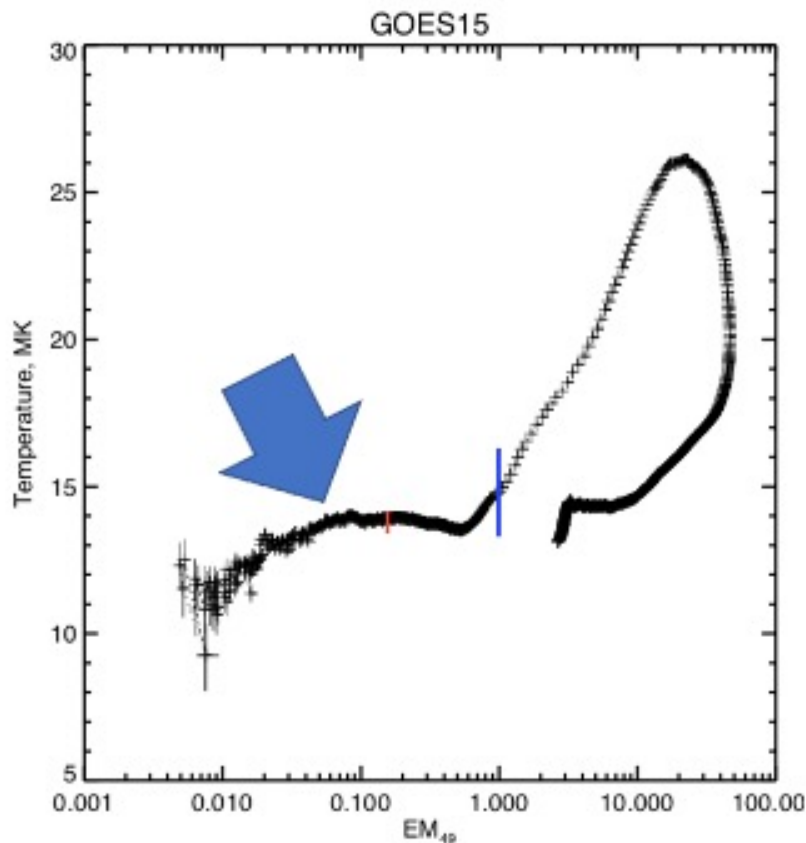
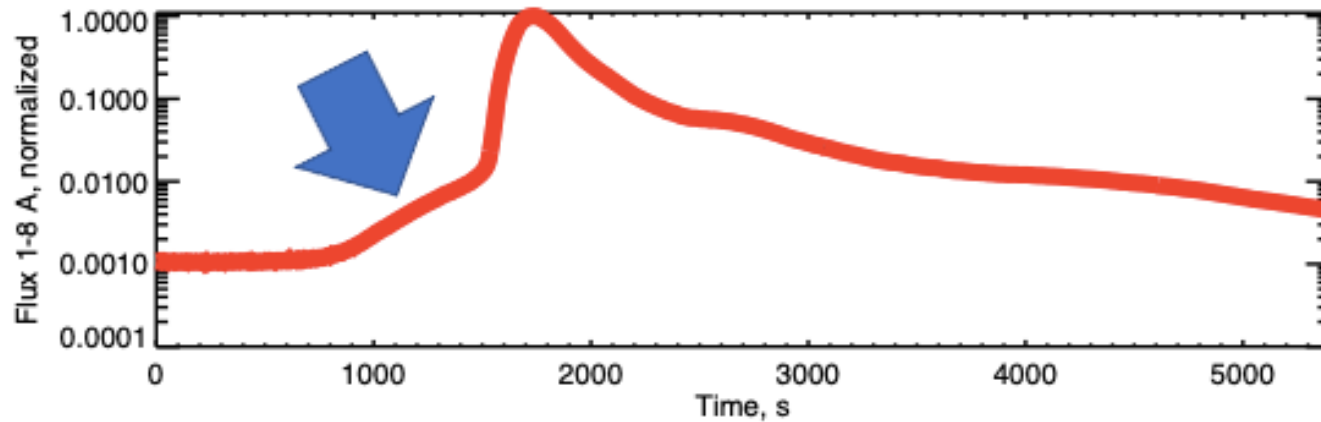


Explanations...

About HOPEs

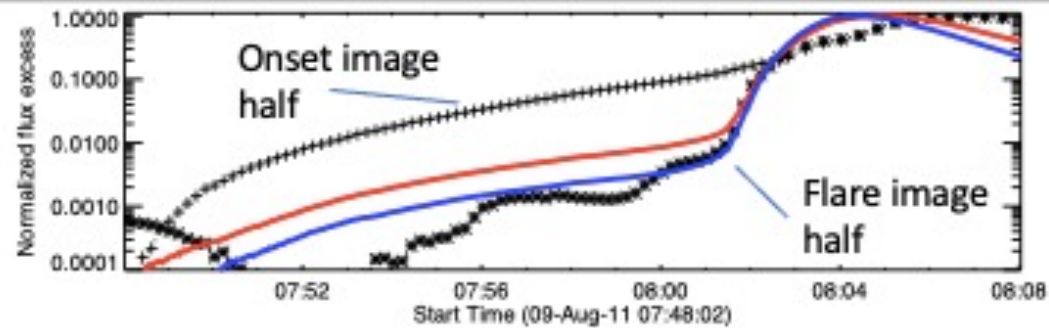
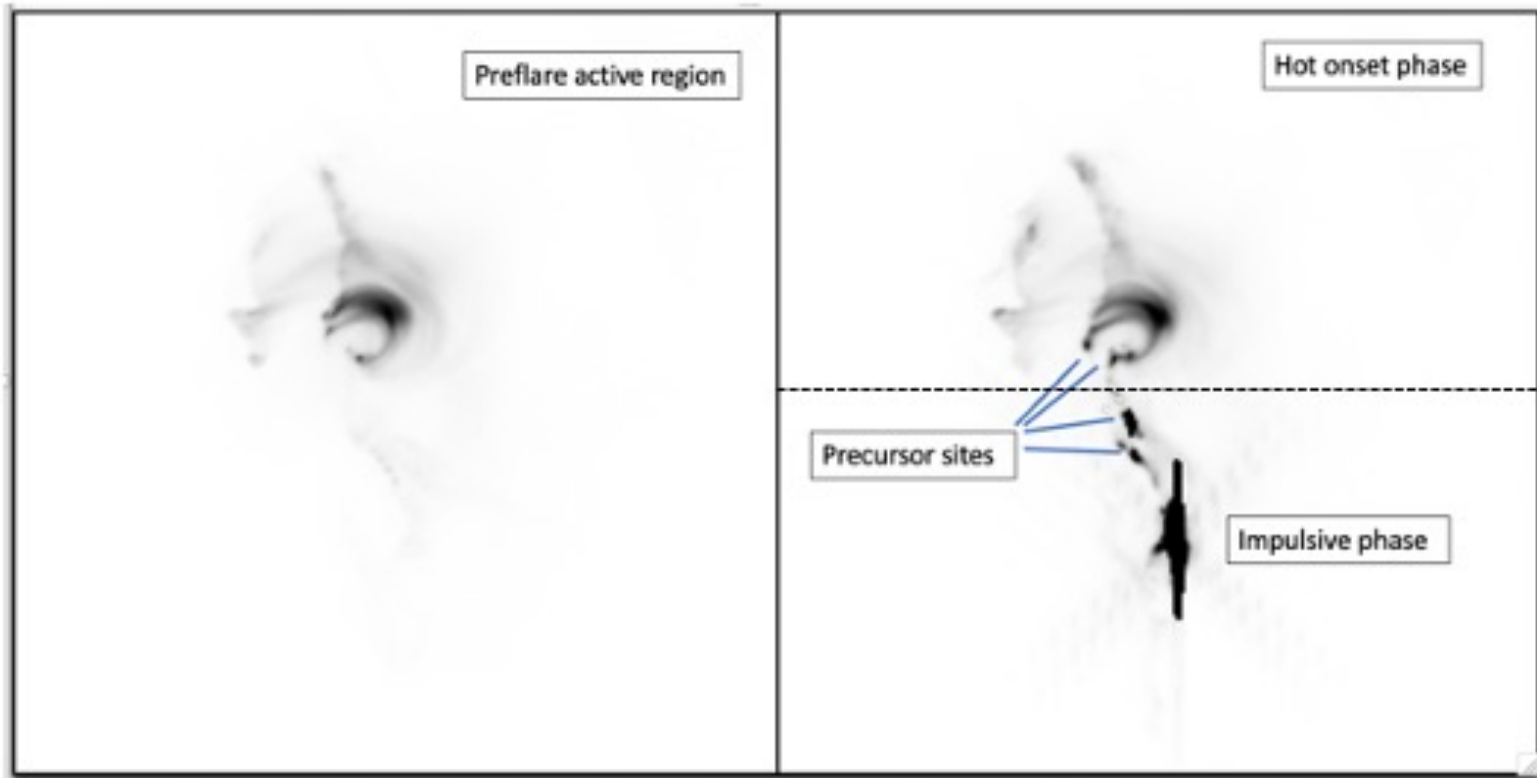
- Virtually every flare shows this behavior
- The initial temperatures (the “horizontal branch”) tend to be at 10-15 MK
- The HOPE precedes the hard X-ray “impulsive phase” (Kane) and represents different plasma physics
- It is not “*pre-heating*”; we can’t measure dT/dt
- It is not the Neupert effect

A “Slow HOPE”



- SOL2011-08-09 (X6.9) has a HOPE lasting for minutes
- The GOES T vs. GOES EM “loopdiagram” plot has an apparently smooth horizontal branch.

What does AIA say?

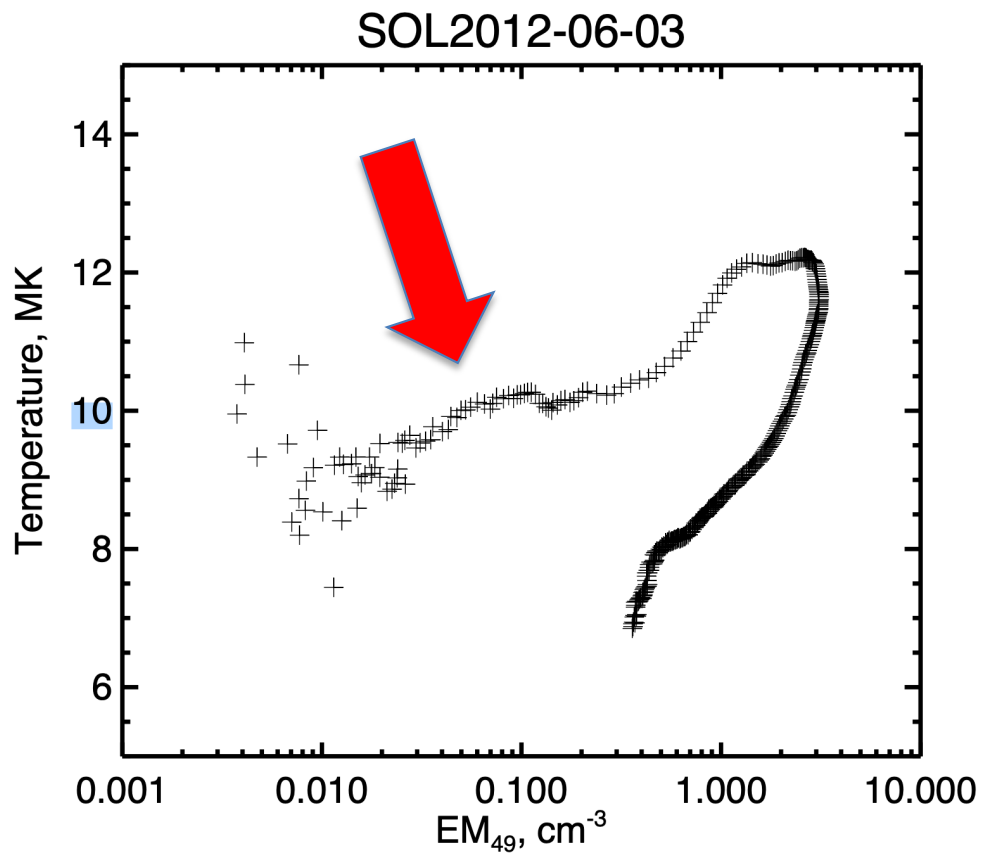


Comments

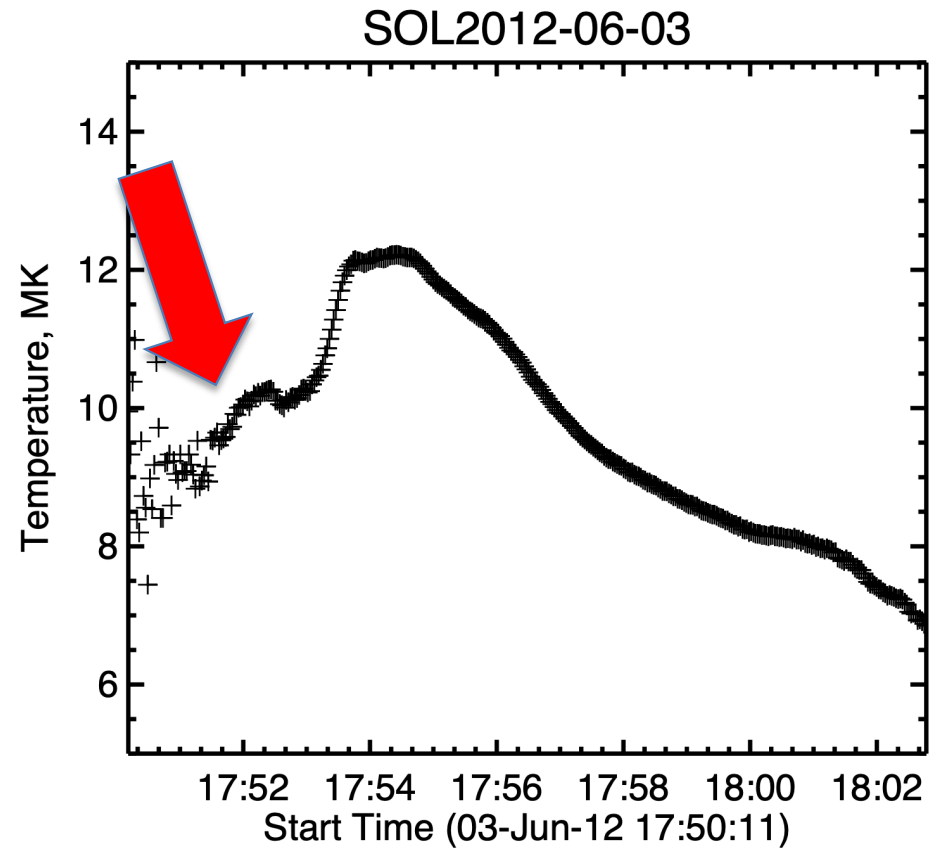
- There may be microflaring during the HOPE, (Fárník et al. 1998) but the horizontal branch is usually smooth
- The precursors in general don't match the location of the flare (Hudson 2012)
- New literature expected
 - A. Battaglia et al (in prep)
 - D. Silva et al. (submitted)
 - O'Donnell & Hannah (UoG student project)

If not ubiquitous, the hot onsets always had been present. Many precursor studies had anticipated this result in numbers of cases.

HOPEs at radio wavelengths

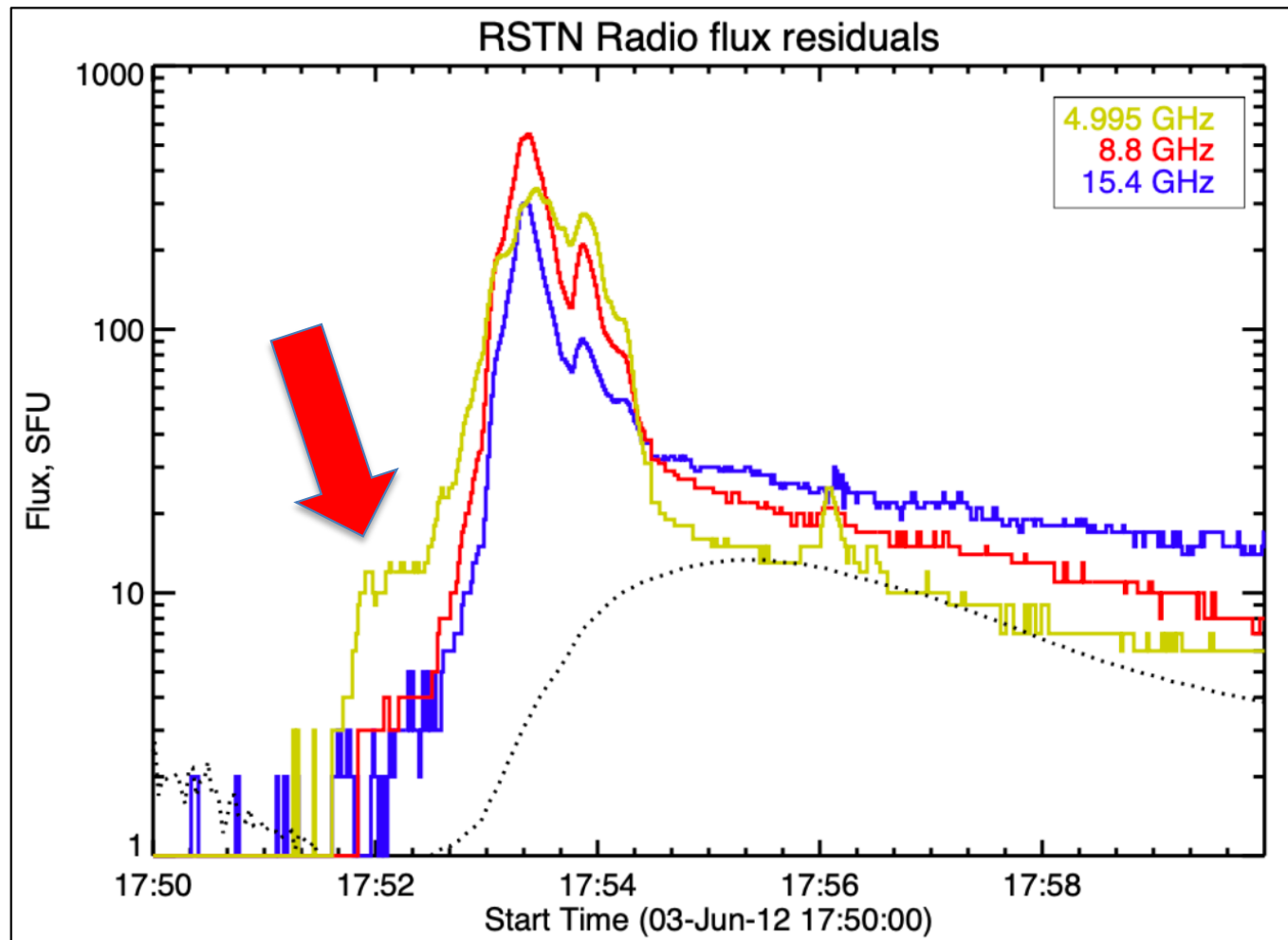


Correlation plot, GOES T vs EM
- Horizontal branch
- Neupert loop



Timeseries plot, GOES T vs time

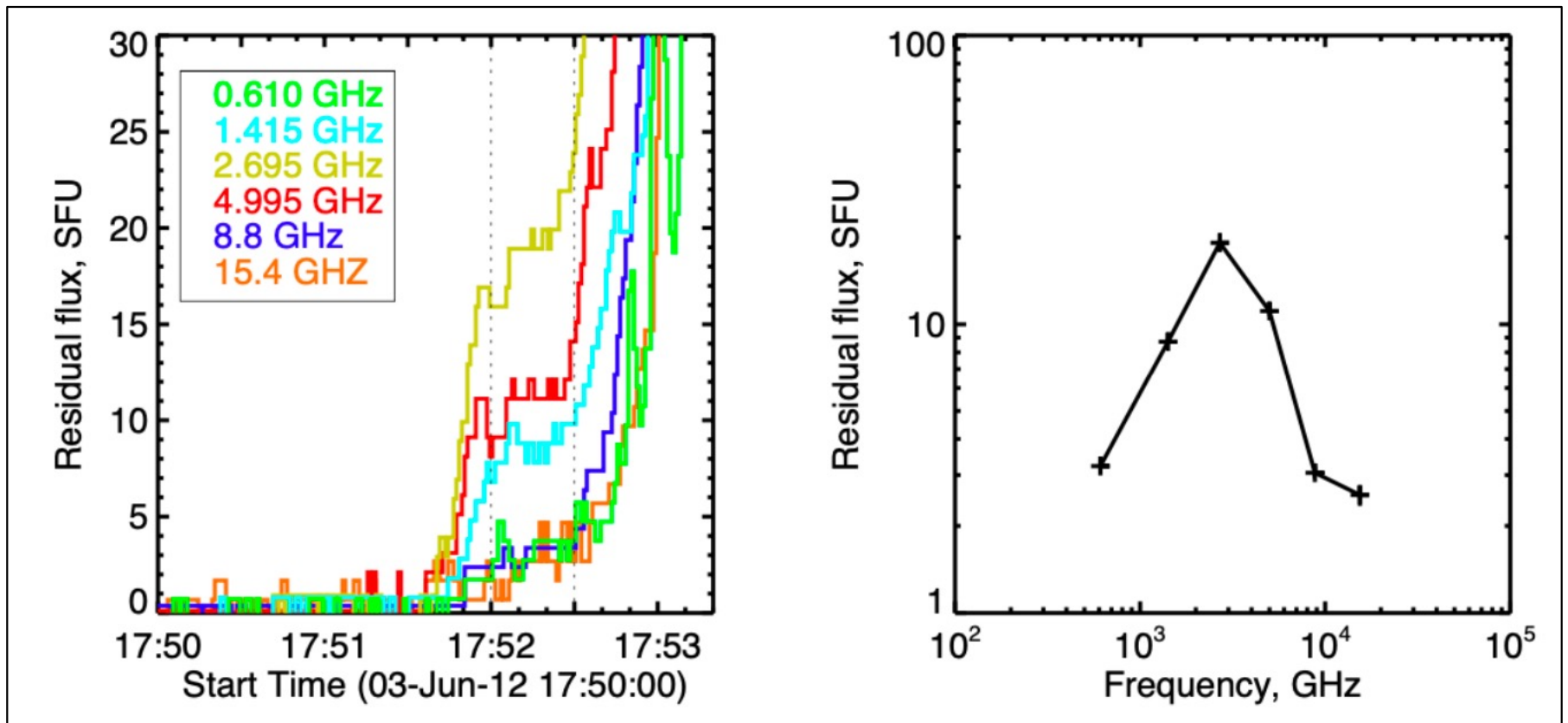
HOPEs at radio wavelengths



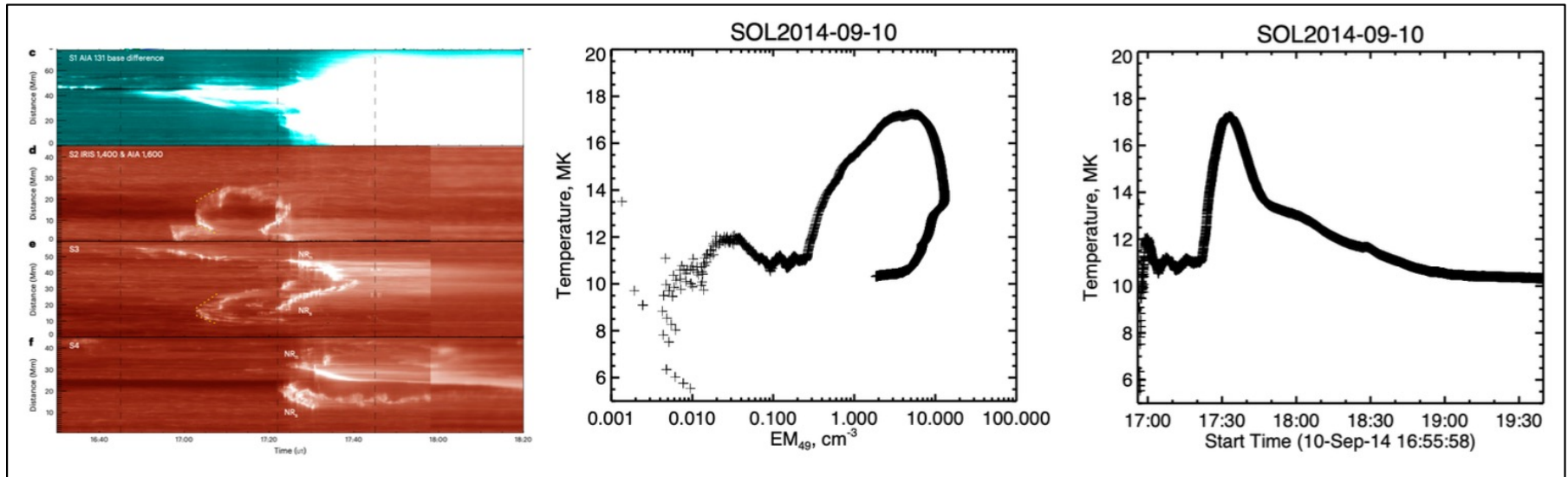
HOPE clearly detectable in RSTN data

- Far above free-free level
- High-frequency cutoff

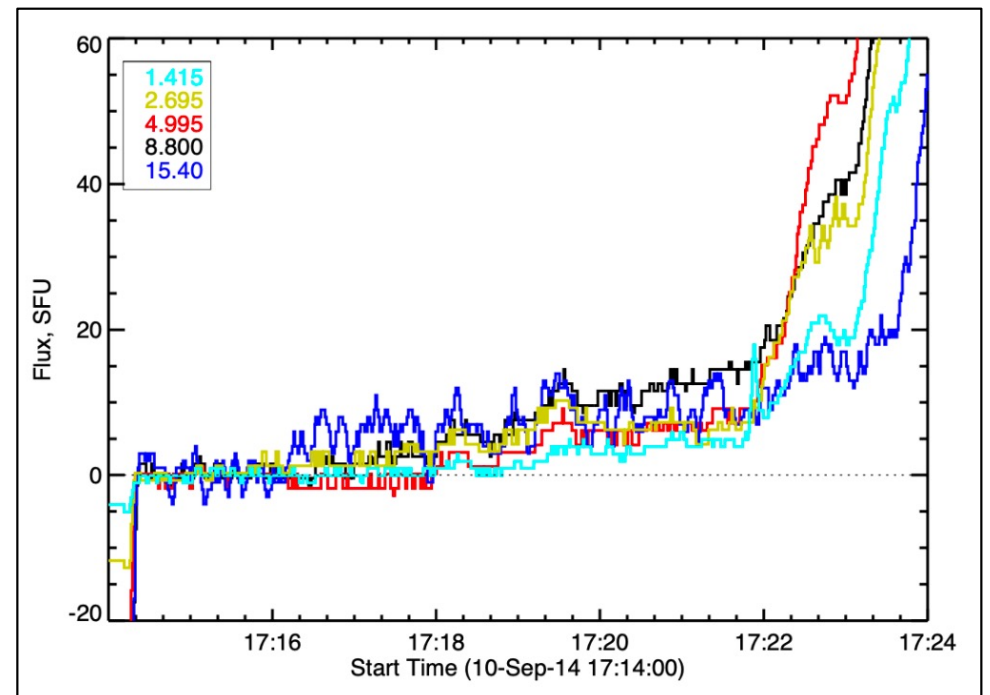
RSTN spectrum



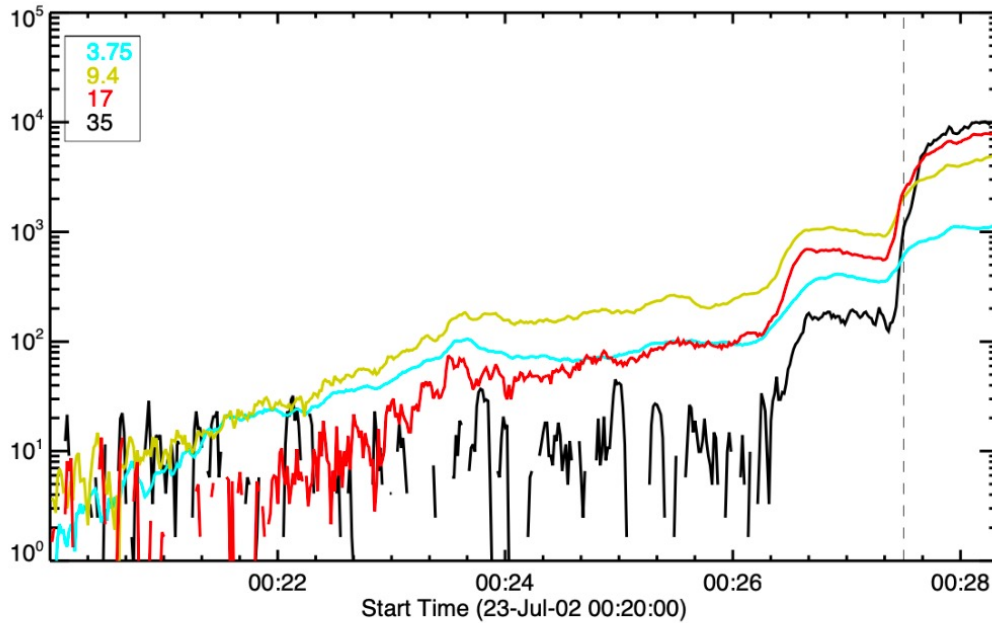
Another example



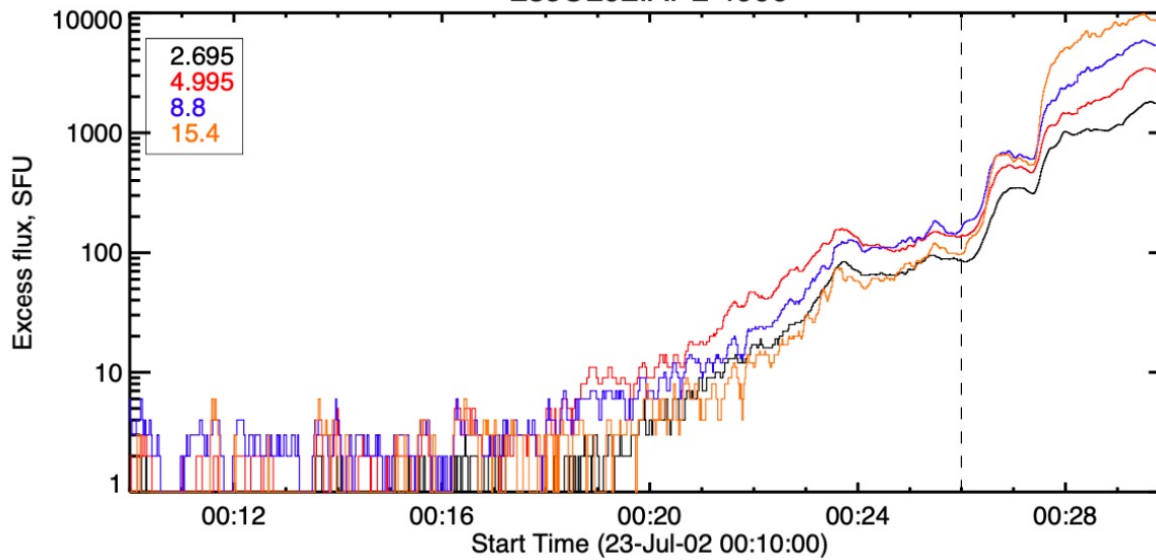
- SOL2014-09-10 IRIS observations (Gou et al., 2023)
 - note precursor dimming
- RSTN possibly to 15.4 GHz
- But this X1.8 flare is still marginal via RSTN



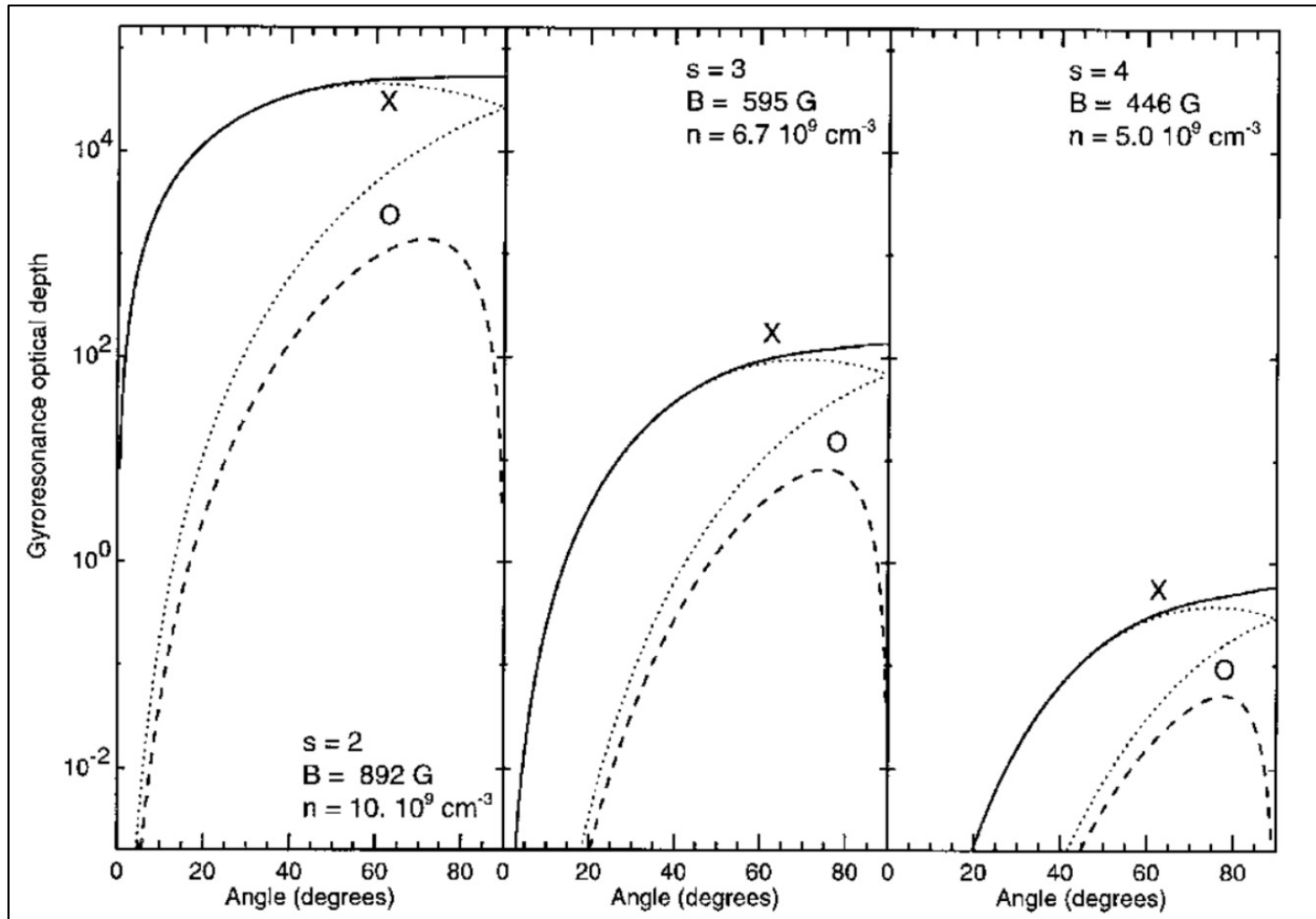
SOL2002-07-23 with NoRP



23JUL02.APL 4000

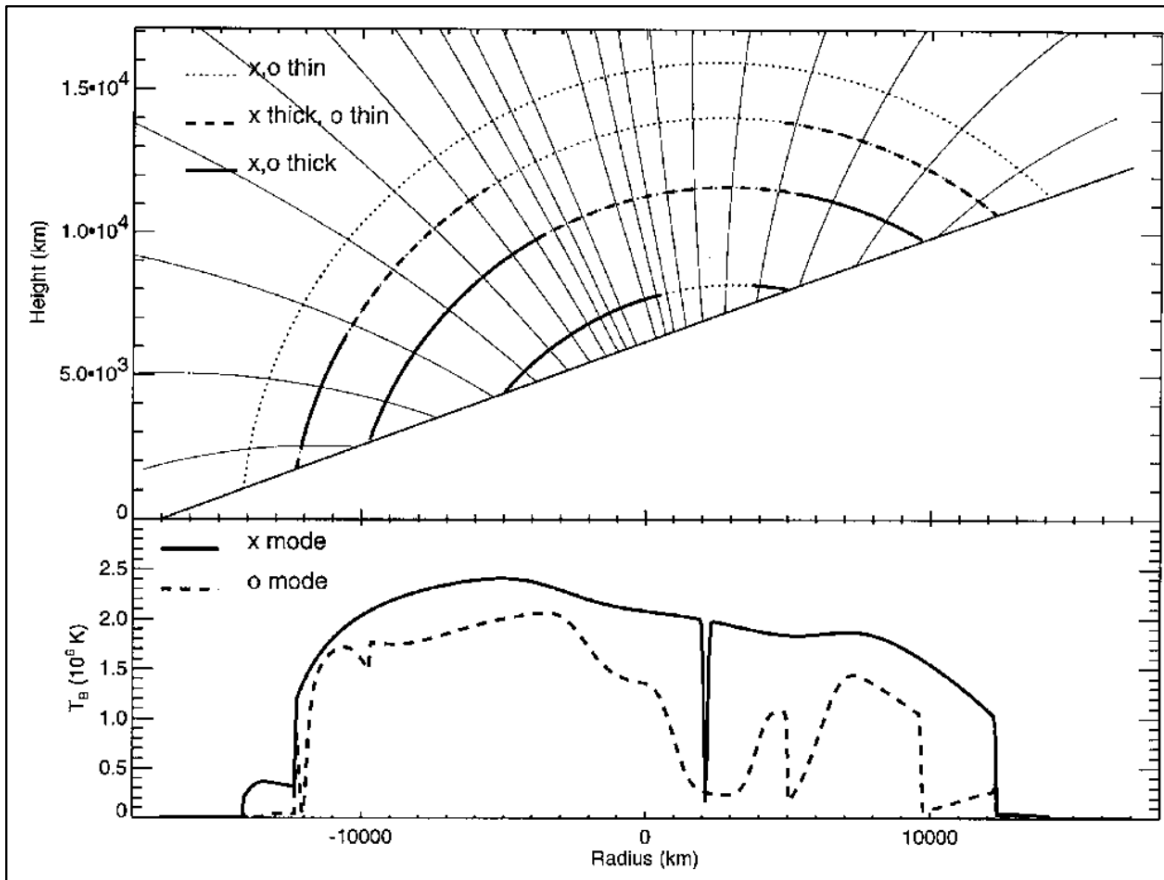


Gyroresonance



White & Kundu 1997

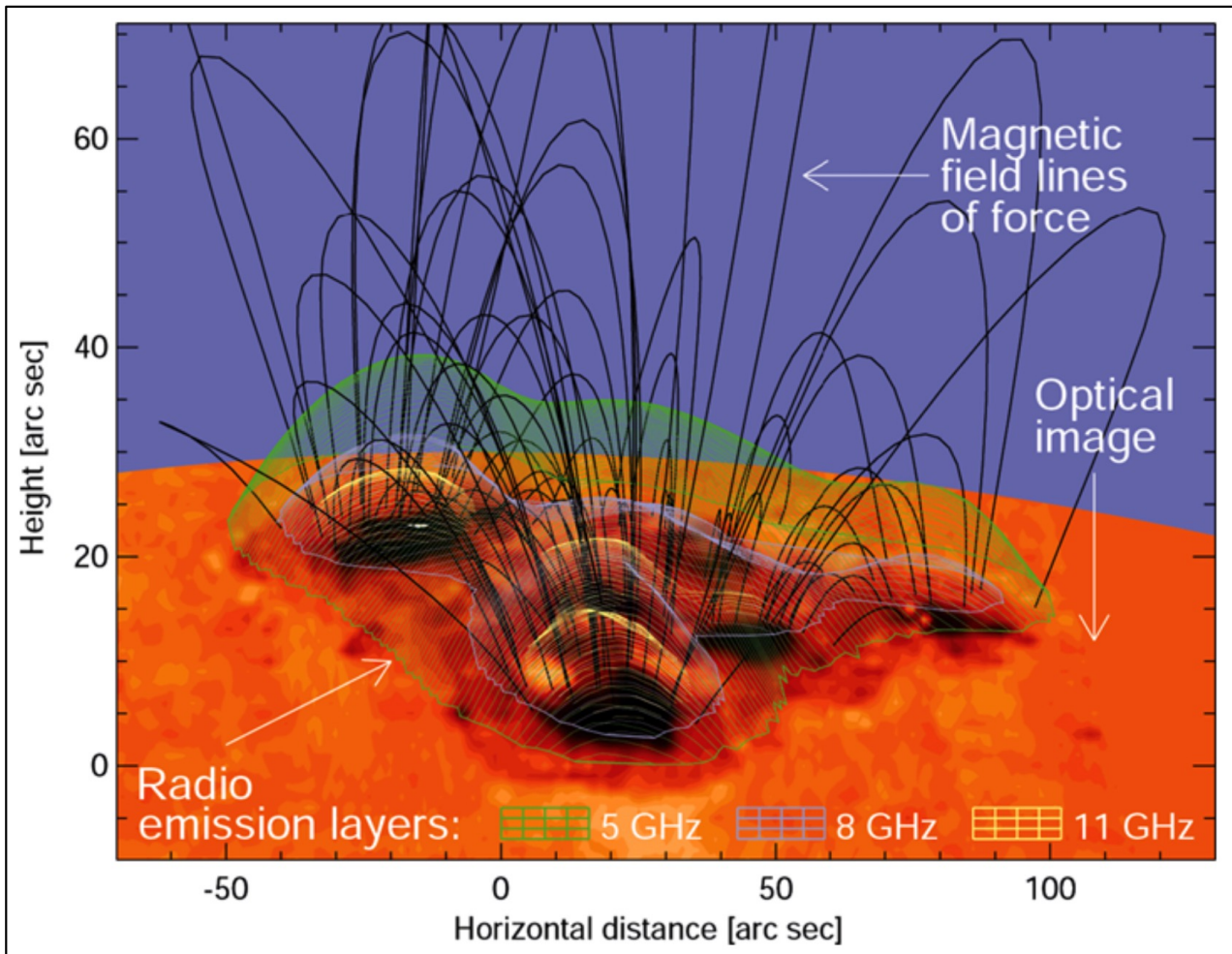
Gyroresonance



- Simplest possible model, but great complexity
- We would like to study this in HOPEs, where we know [T, EM] vs space and time
- Serious messiness in the opacity calculation, but great opportunities await

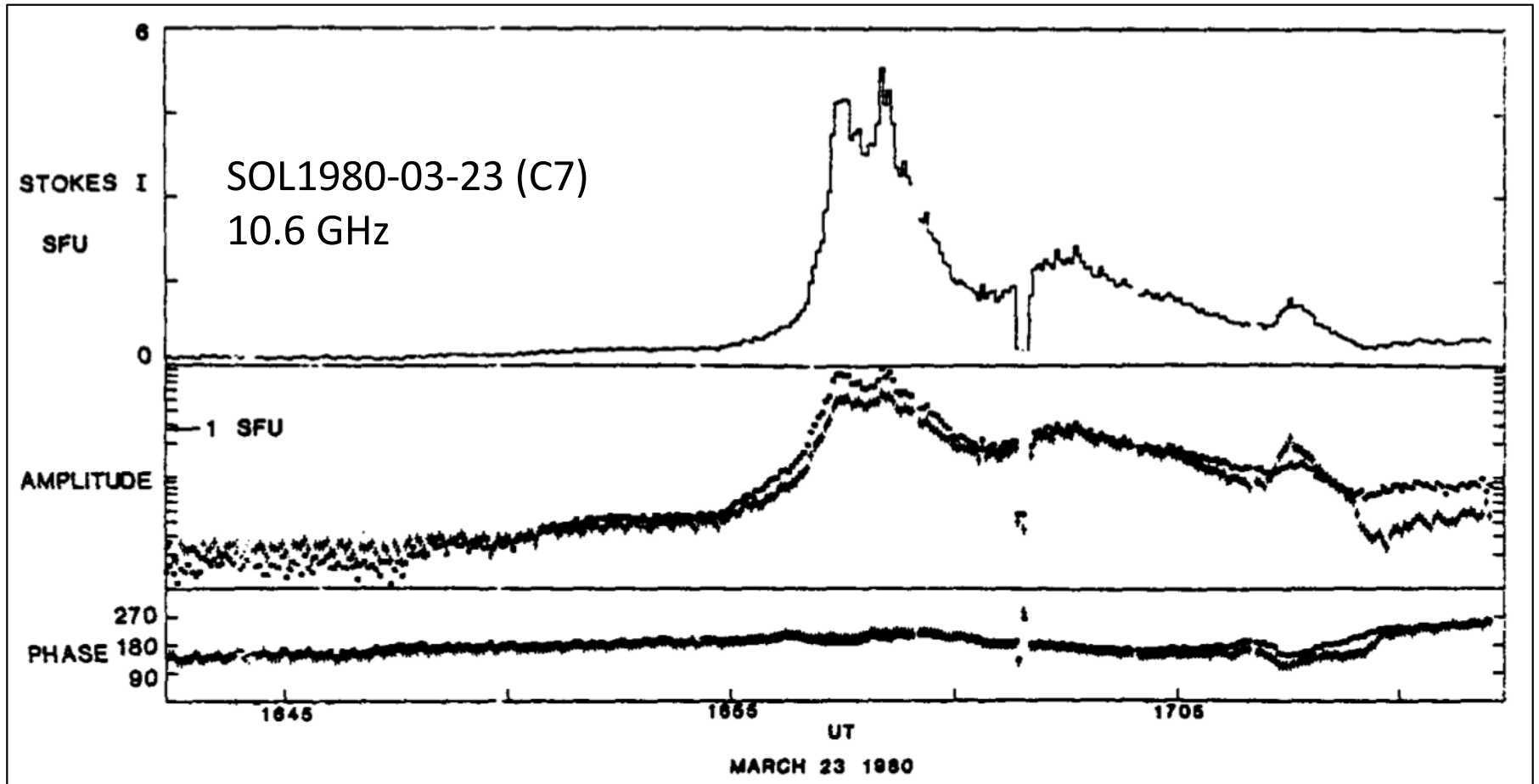
White & Kundu 1997

Gyroresonance



Apologies to the artist, but this iconic figure shows a model with smooth features. The field may be smooth, but X-ray images show the AR/flare density to be highly structured – hence so is the gyroresonance opacity.

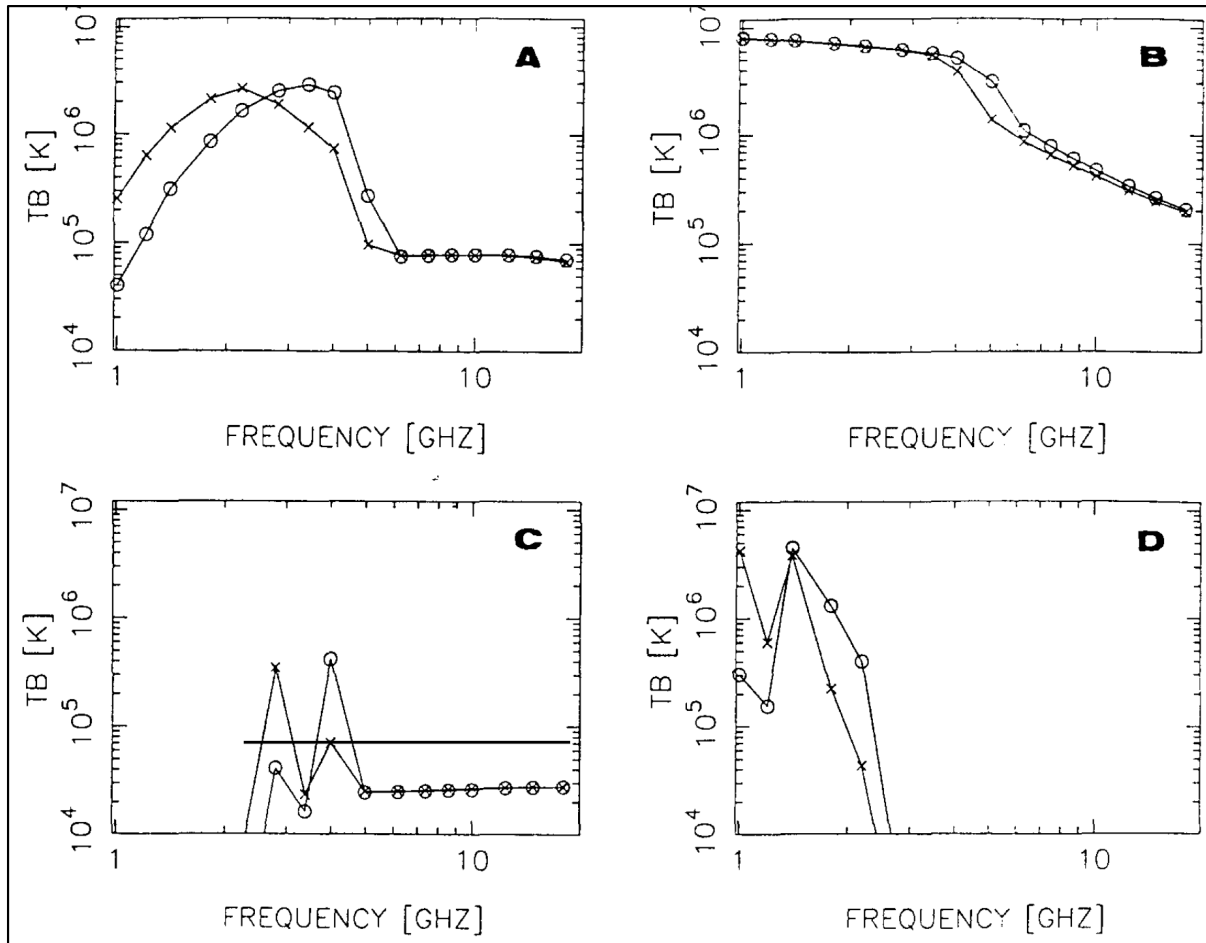
Some rHOPE history



Van Hoven & Hurford (1984)

- Interferometer sensitivity (better than 1 SFU!)
- Circular polarization diagnostics

Thermal gyroresonance models



Van Hoven - Hurford 1986

Urgency in flare “prediction”

- The radio HOPE sources promise to be very interesting diagnostically
- But in the short term we are hoping that we can find a handle on flare anticipation
 - HOPE alone doesn't predict flare class
- Such a handle would be an outstanding aid to the flare rocketeers

Survey of NoRP data

- NoRP has polarization, a powerful aid
- There is a new and refined event list (White)
- Imaging at 17 GHz may be possible!
- A quick survey of 2015 data (23 MX events) could generate an empirical result
- The initial look is a bit disappointing, but it depends on how much I can do Tuesday morning...

Two new uses for GX Simulator

- The radio HOPE (subject of this talk)
 - does not get confused by restructuring
- The “negative DEM” of a CME-related dimming event (“Fe Cascade” graphic)
 - does not get confused by restructuring

