# Solar Imaging
# Progress Report

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Solar Key Science Project

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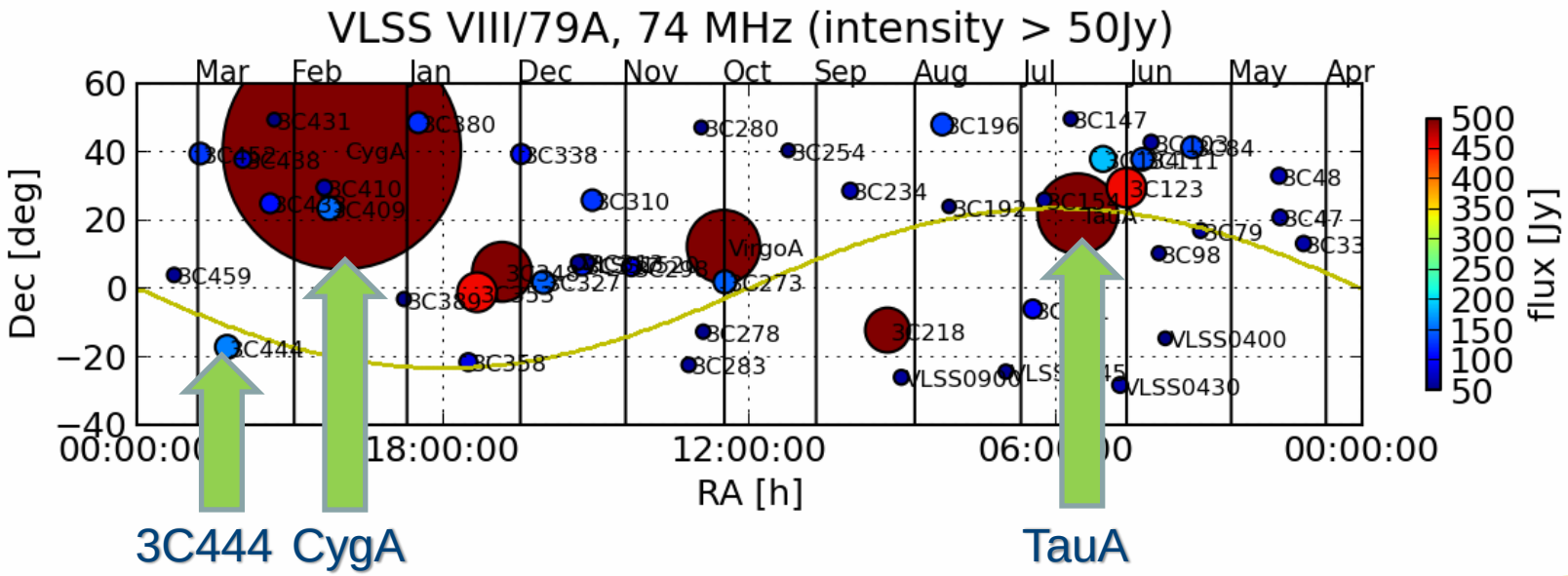
ASTRON (via Vidyo)

# Overview

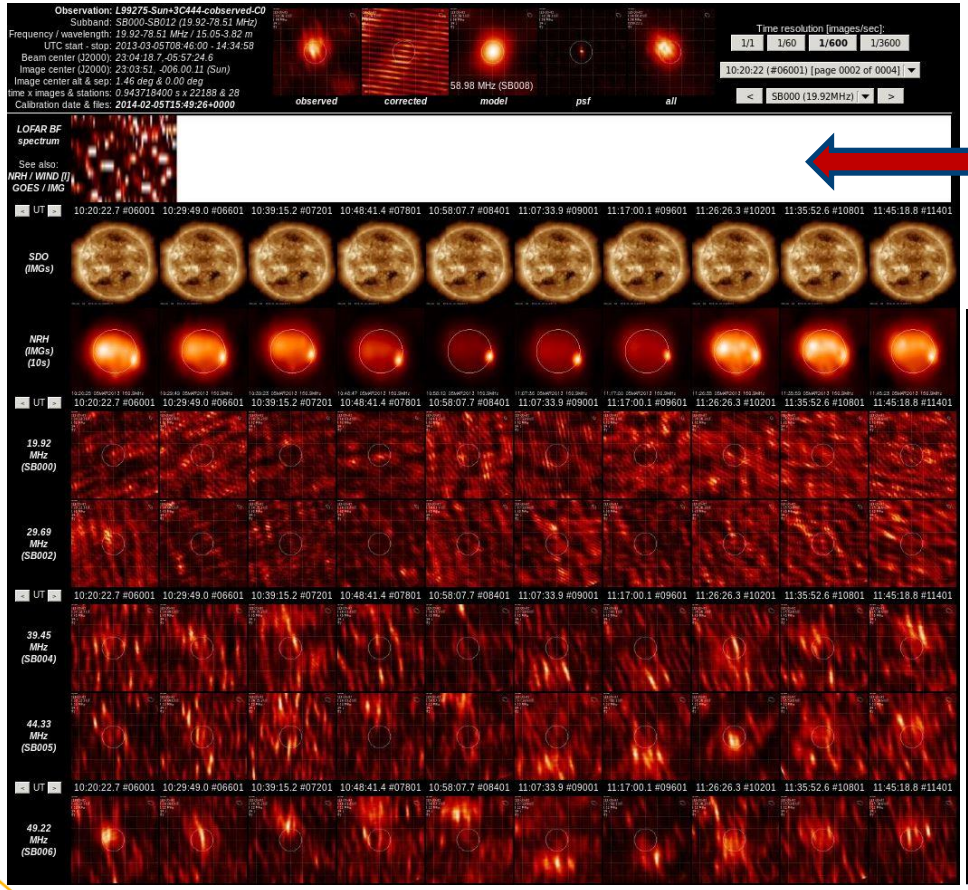
I. Results from cycle 0
II. Results from commissioning

# Solar imaging

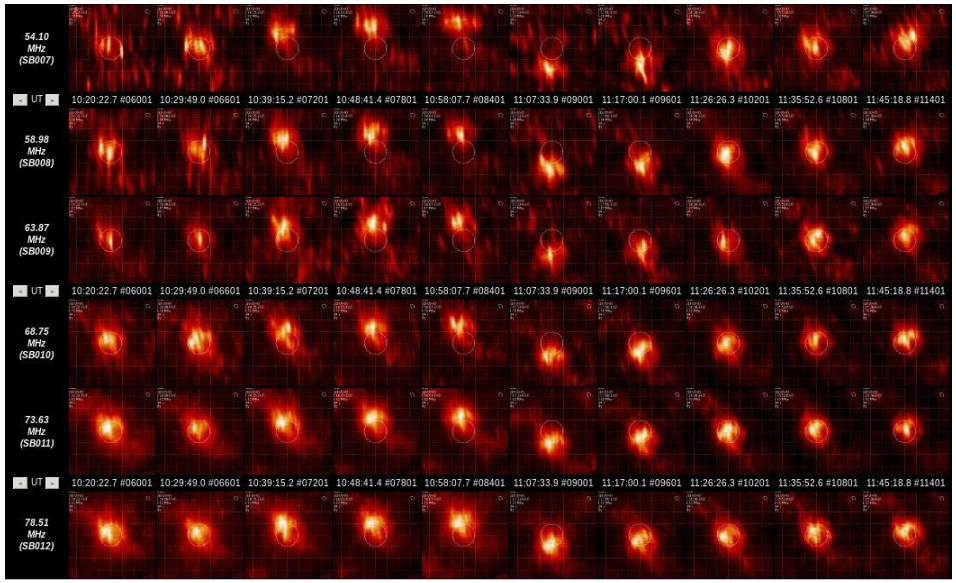
- uses intense and close by calibrators to deal with
  - the Sun's variability
  - the ionosphere
- calibrators in cycle 0:  Cyg A, Tau A, 3C444



# Cycle 0 - LBA (2013-03-05): The Sun - uncalibrated

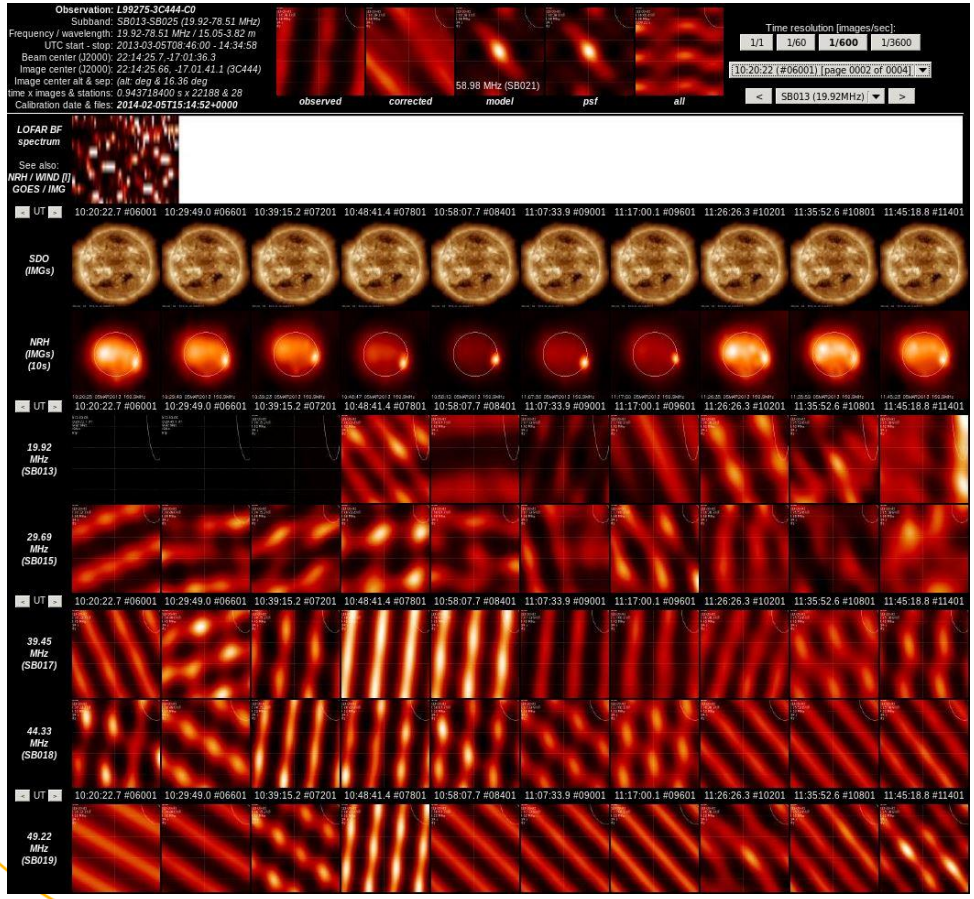



Problem: Beam formed spectrum often stops recording!

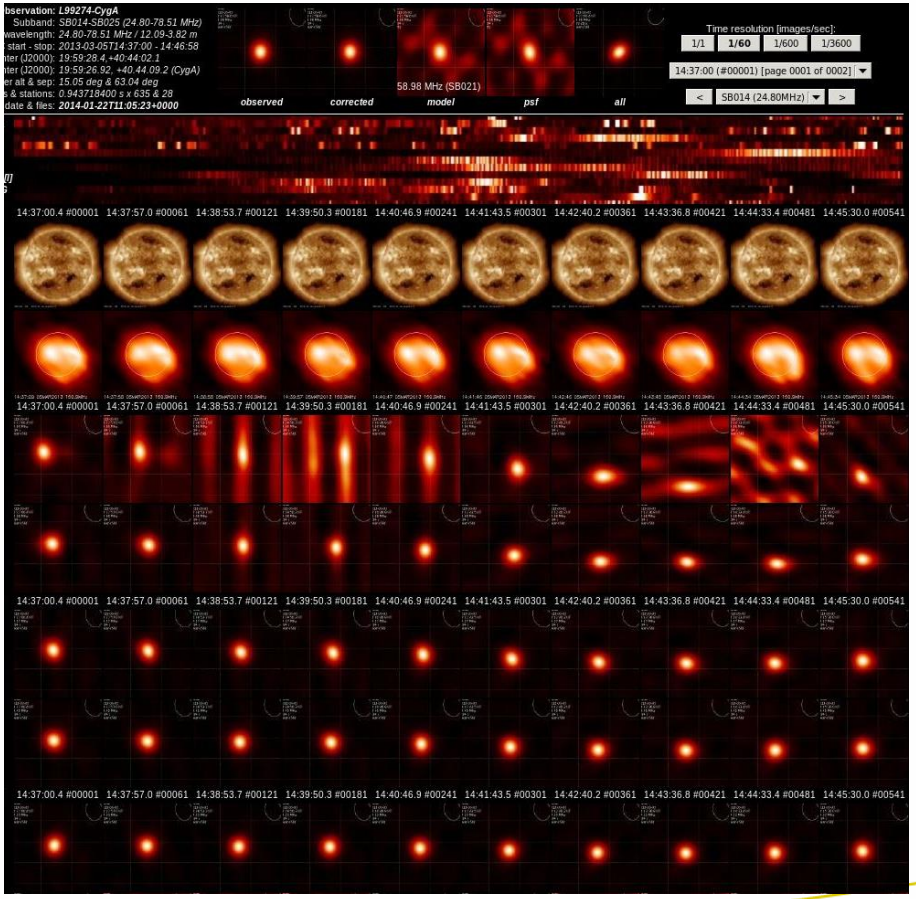


# Cycle 0 - LBA (2013-03-05): The calibrators

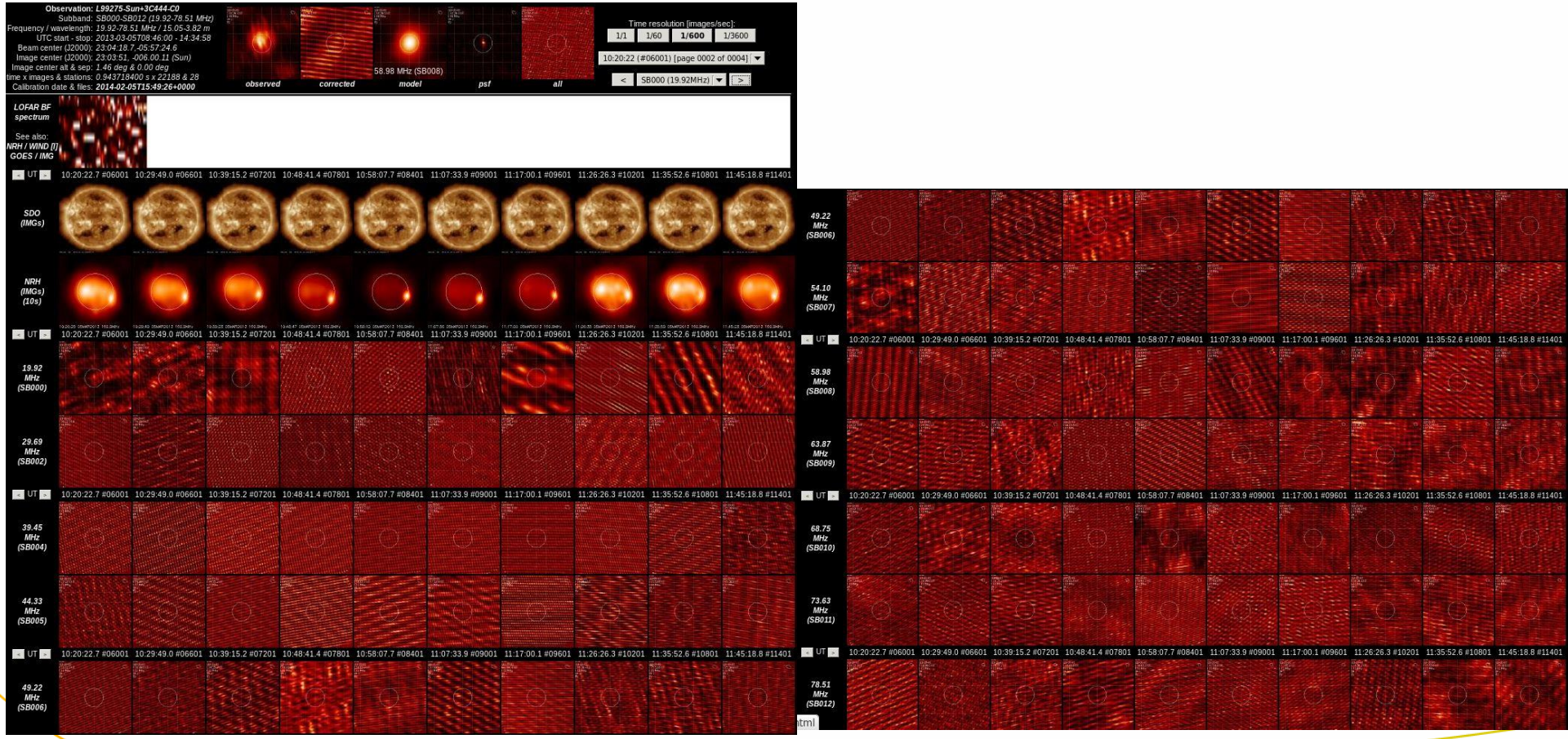
## 3C444



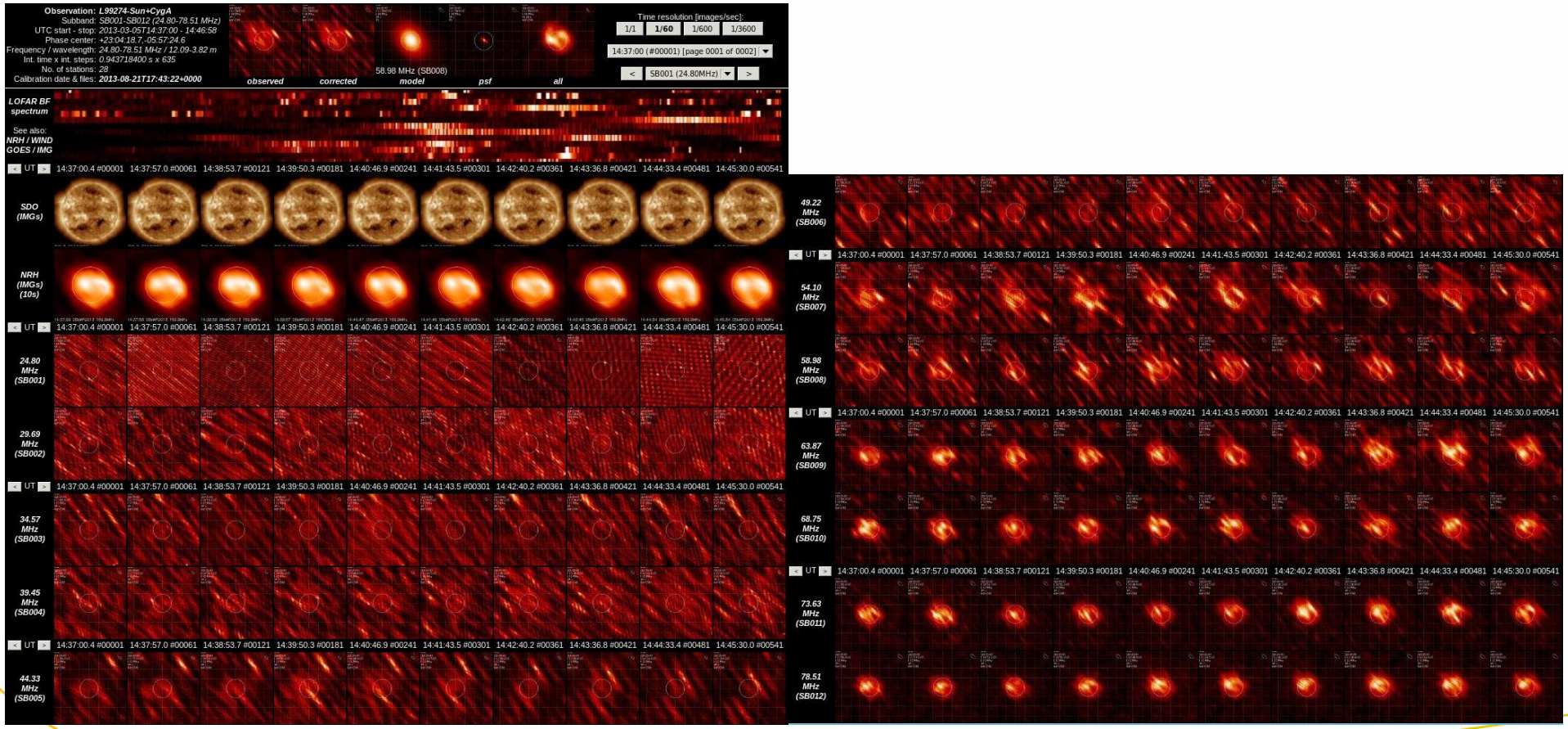

## Cygnus A



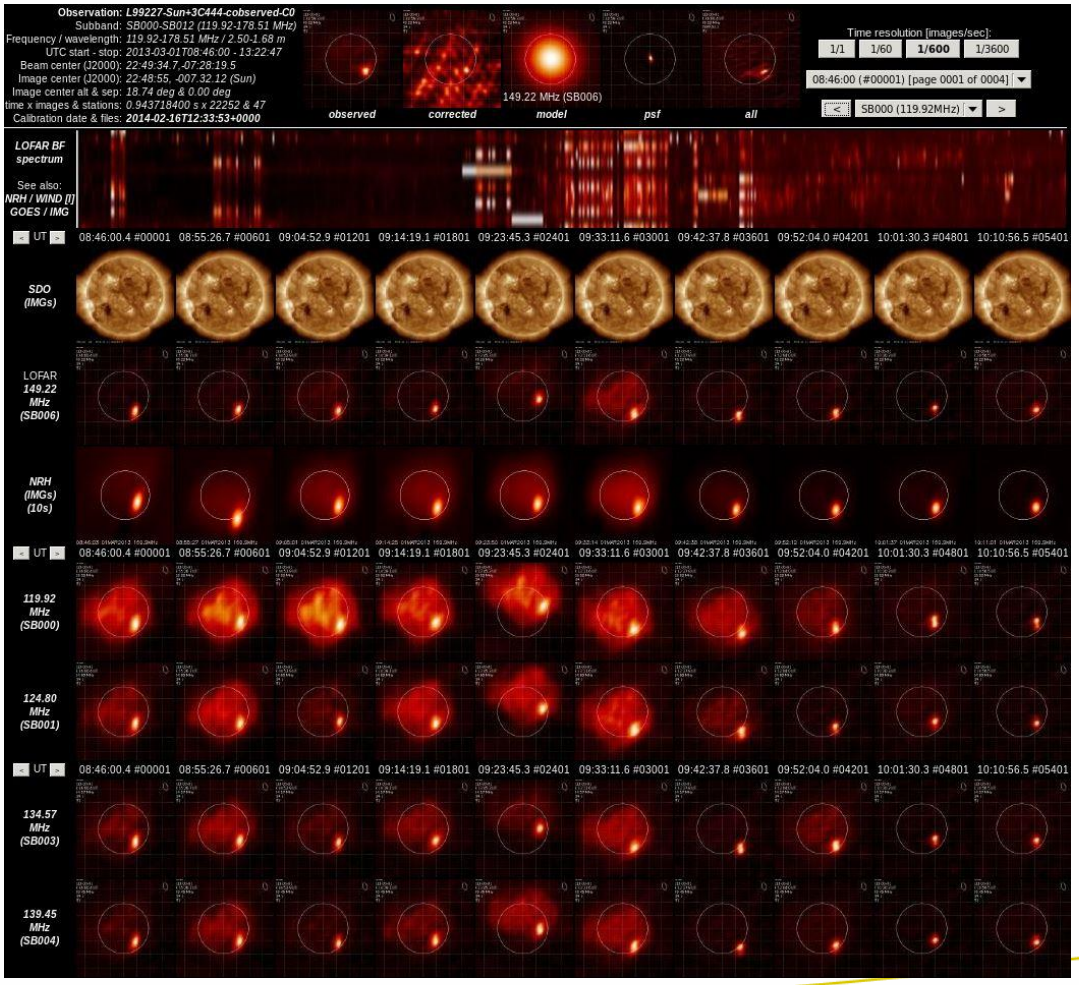
# Cycle 0 - LBA (2013-03-05): The Sun calibrated with 3C444



# Cycle 0 - LBA (2013-03-05): The Sun calibrated with Cygnus A

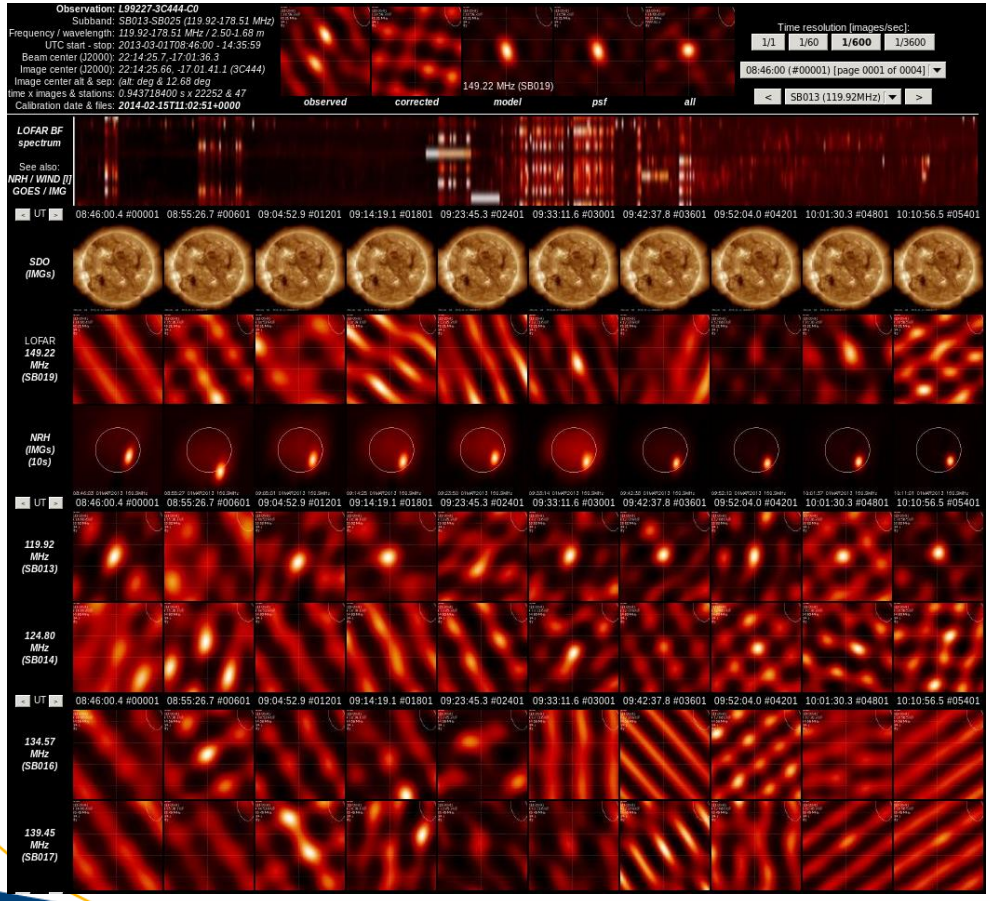


# Cycle 0 - HBA (2013-03-01): The Sun uncalibrated

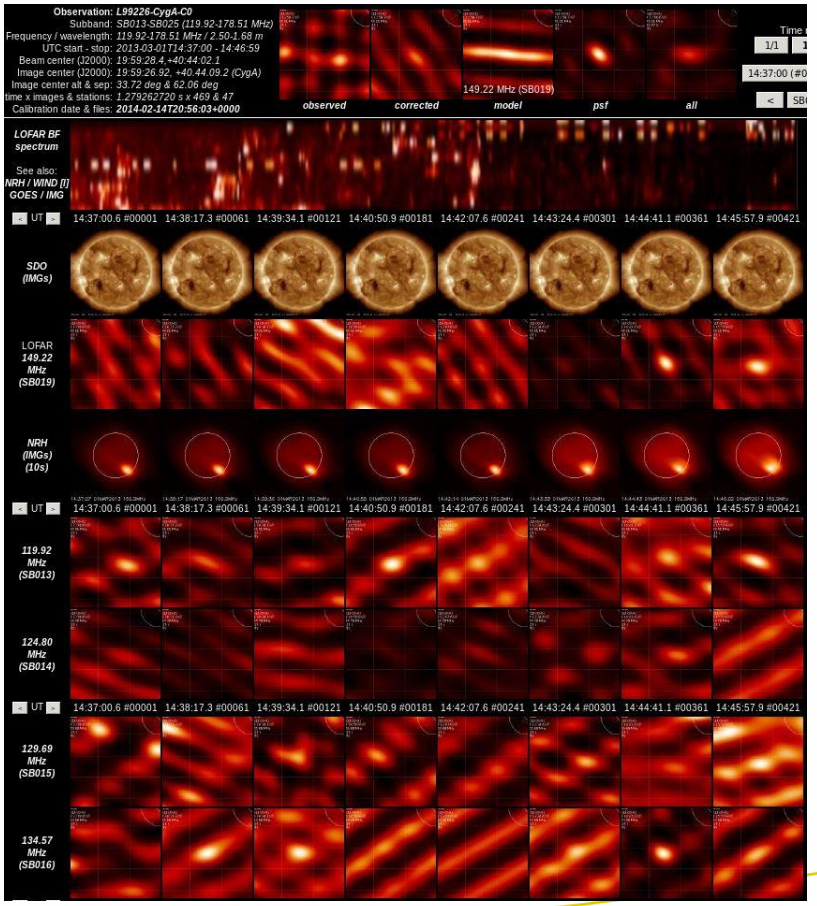


# Cycle 0 - HBA (2013-03-01): The calibrators

## 3C444

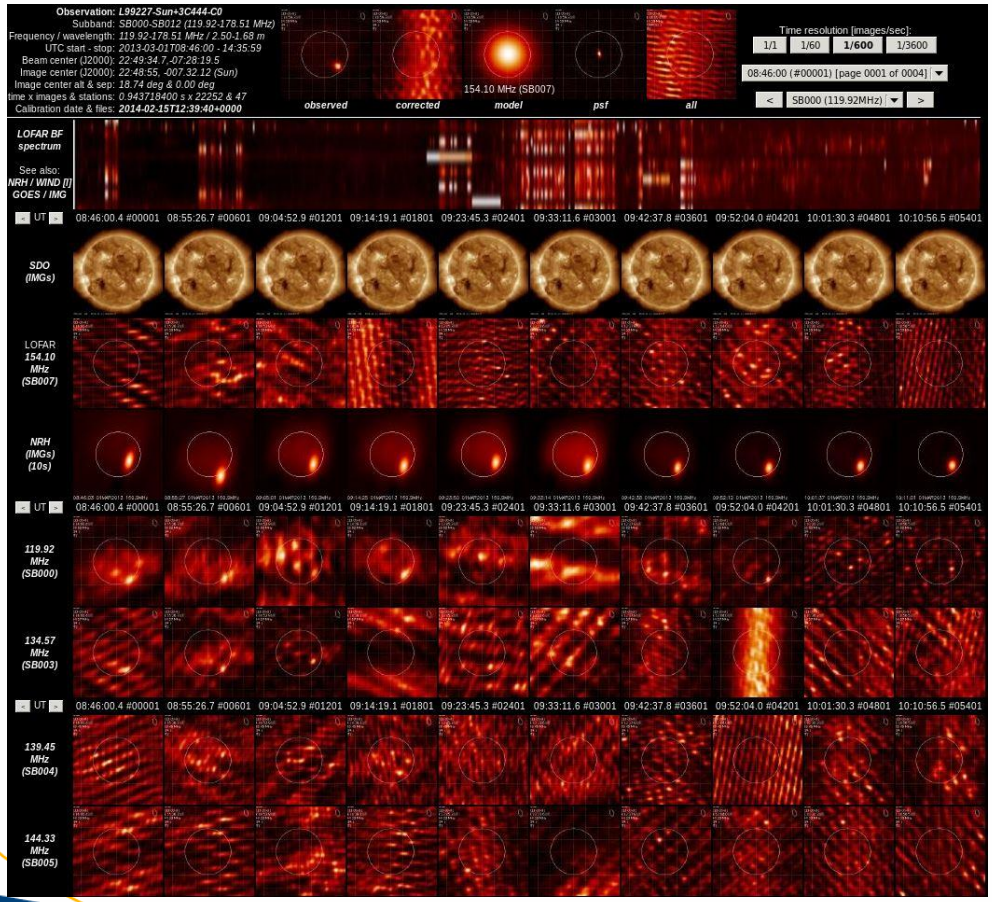



## Cygnus A

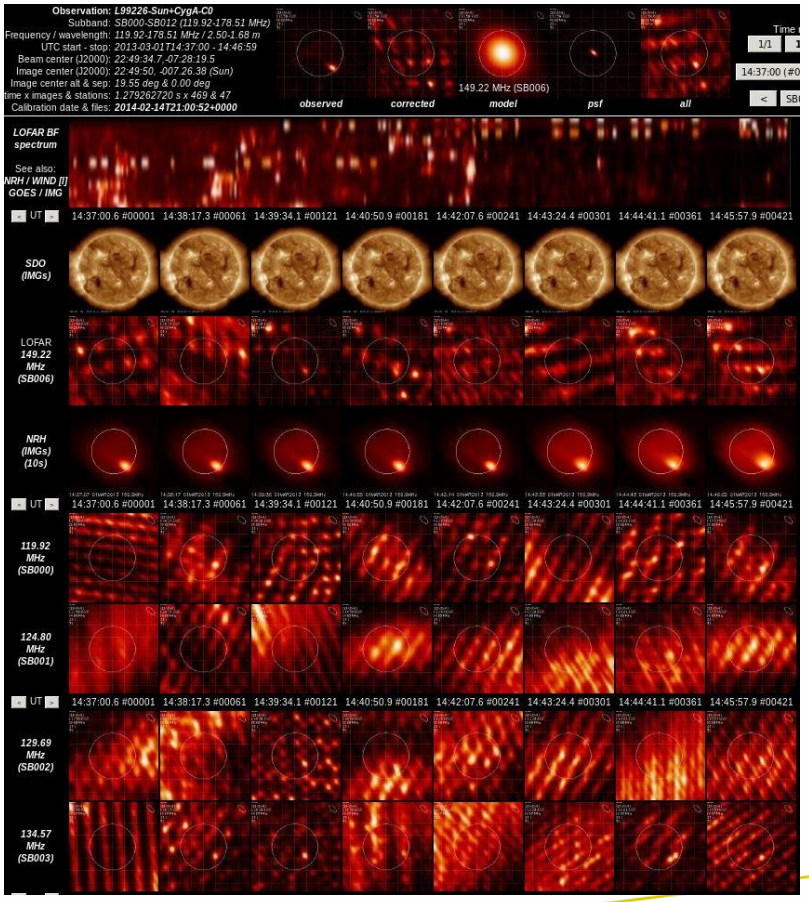


# Cycle 0 - HBA (2013-03-01): The Sun calibrated

## 3C444




## Cygnus A



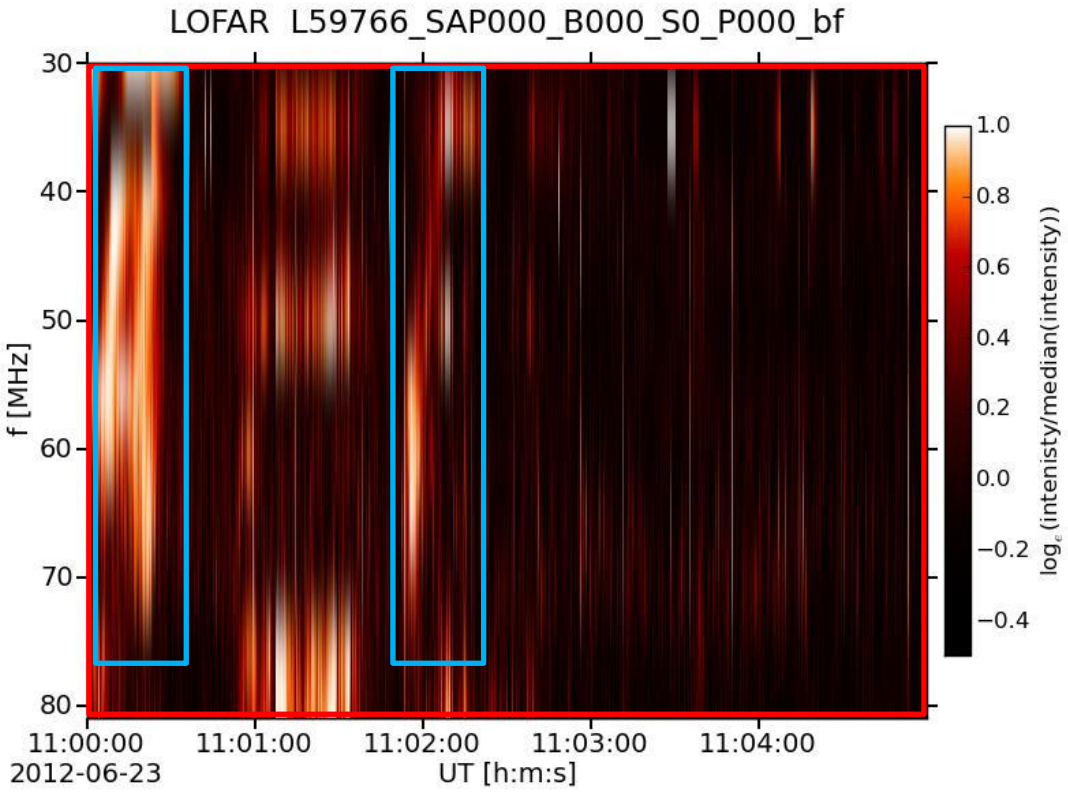
# Learned from Cycle 0

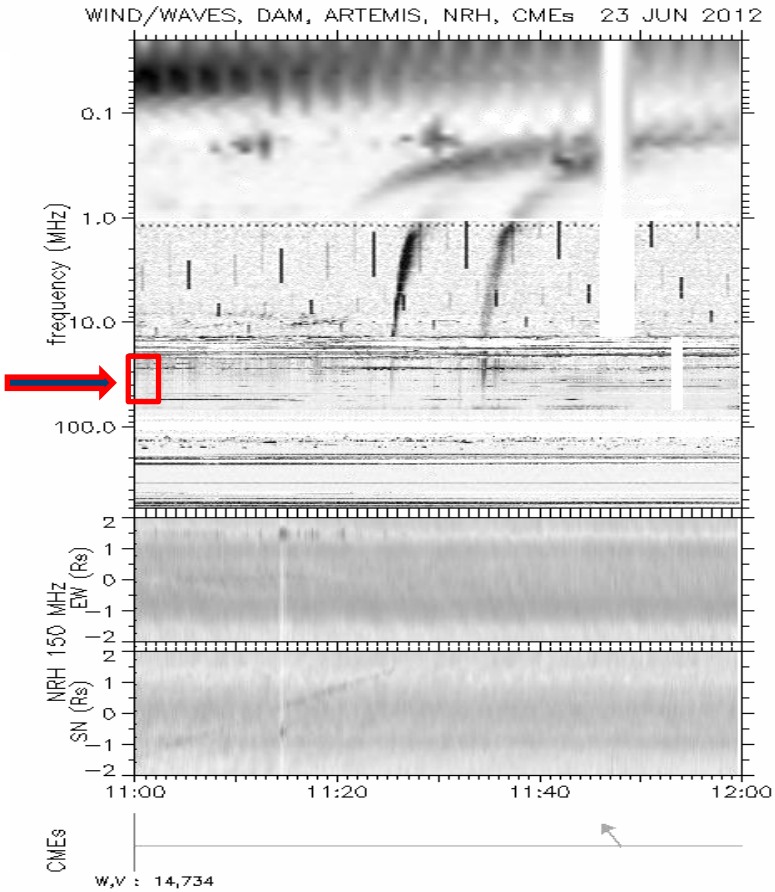
- Still problems with the calibration
  - especially in HBA
  - and with 3C444 (80”x40”, $distance_{\odot}$=16deg)

| Flux 3C444 | Flux Sun |
|---|---|
| 164 Jy @ 74 MHz | > 8560 @ 80 MHz |
| 80 Jy @ 160 MHz | > 35000 Jy @ 160 MHz |

- Demixing also doesn’t work well
- Imaging particularly difficult <50 MHz (ionosphere?)
- Beam formed spectra unstable

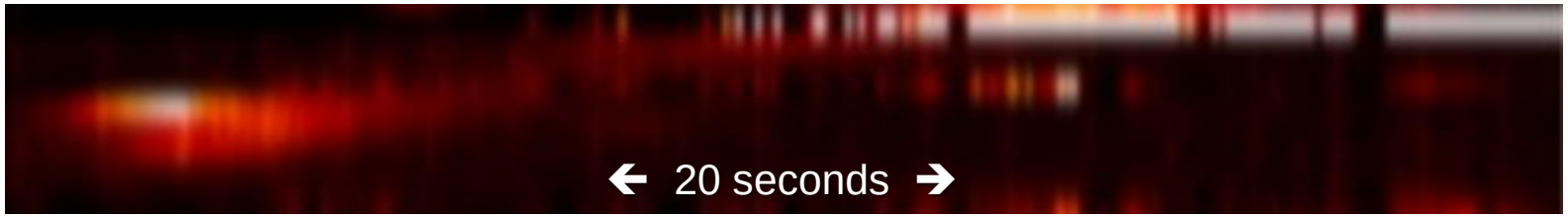
# Solar type III bursts in commissioning data



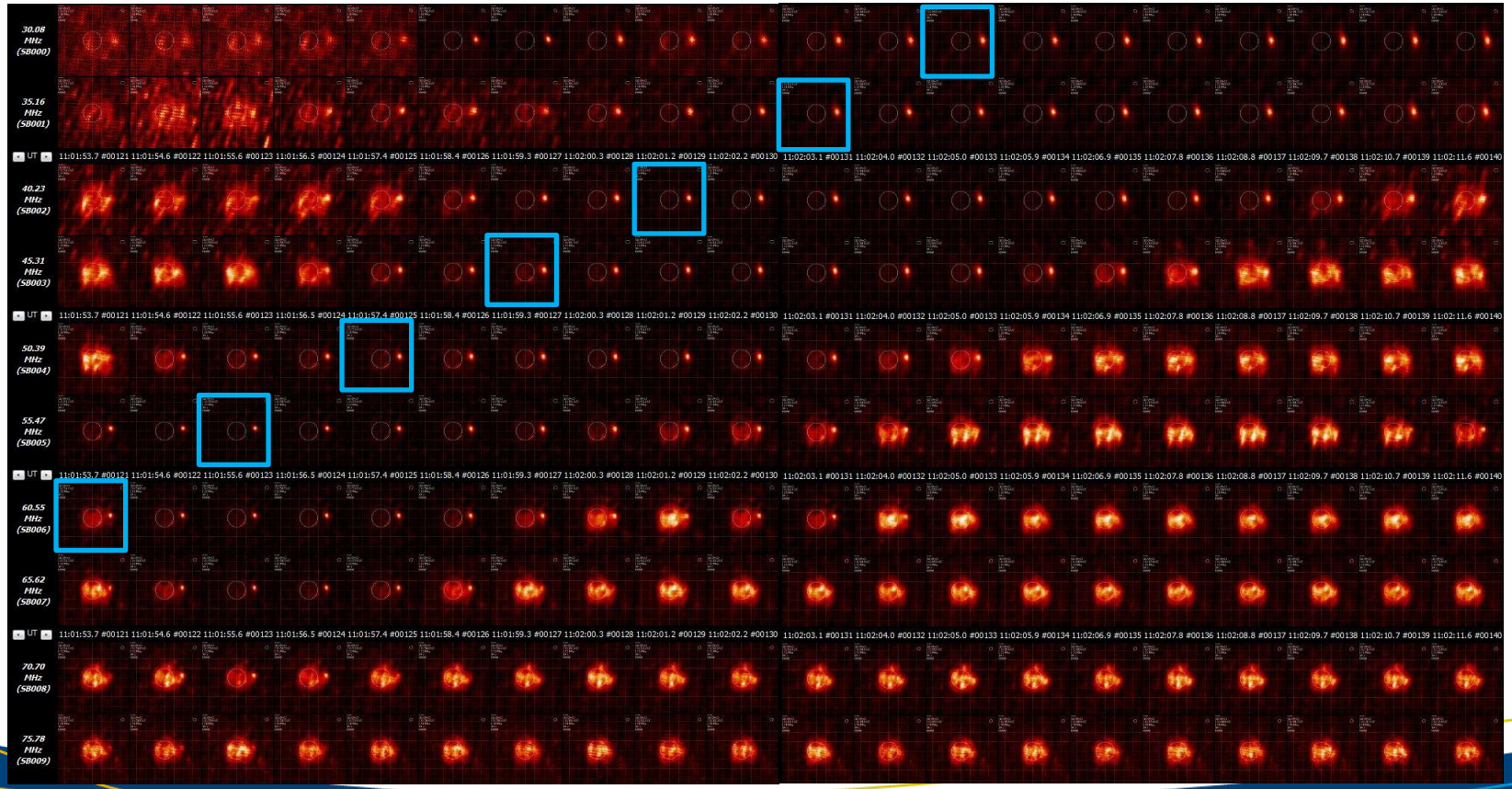




➔The bursts are only visible in the LOFAR spectrum not in spectra from other observatories

# Images of the burst at 11:02

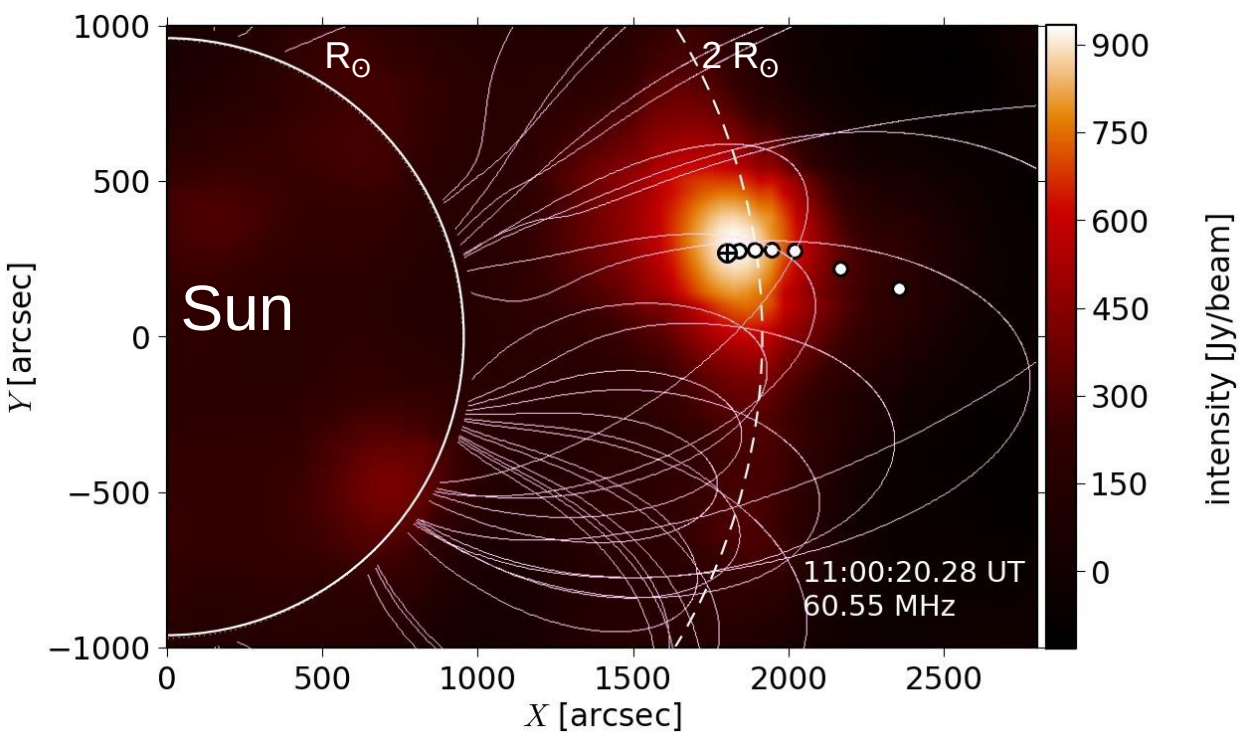



30 MHz



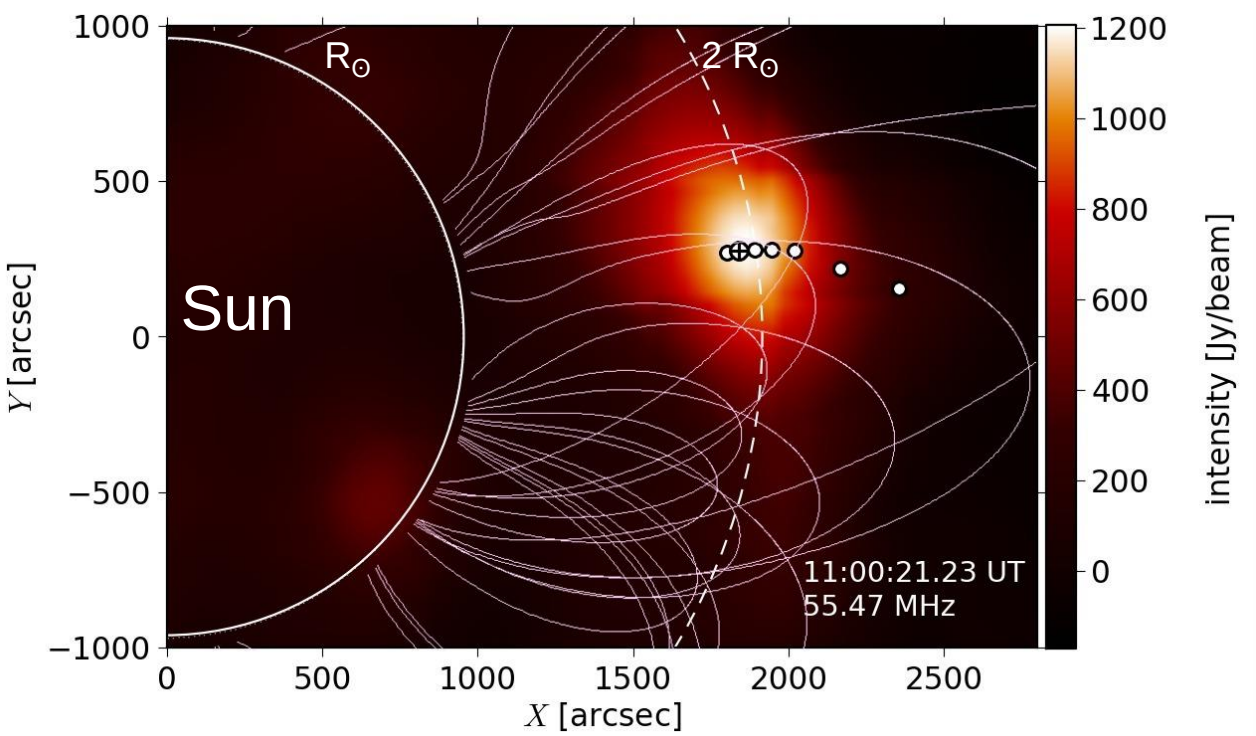

75 MHz

# Direction of max intensity between 60 - 30 MHz

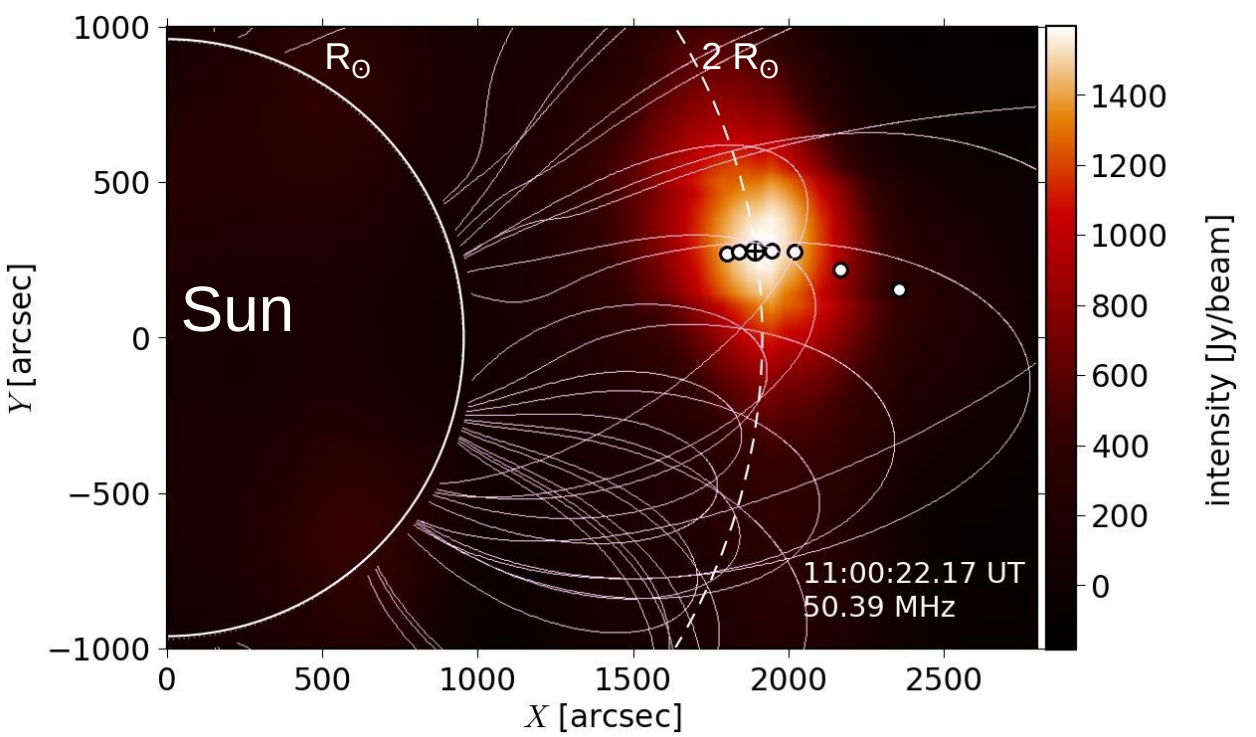



Magnetic field lines from ***Potential-Field Source-Surface*** method (Schrijver & De Rosa 2003)

# Direction of max intensity between 60 - 30 MHz



# Direction of max intensity between 60 - 30 MHz



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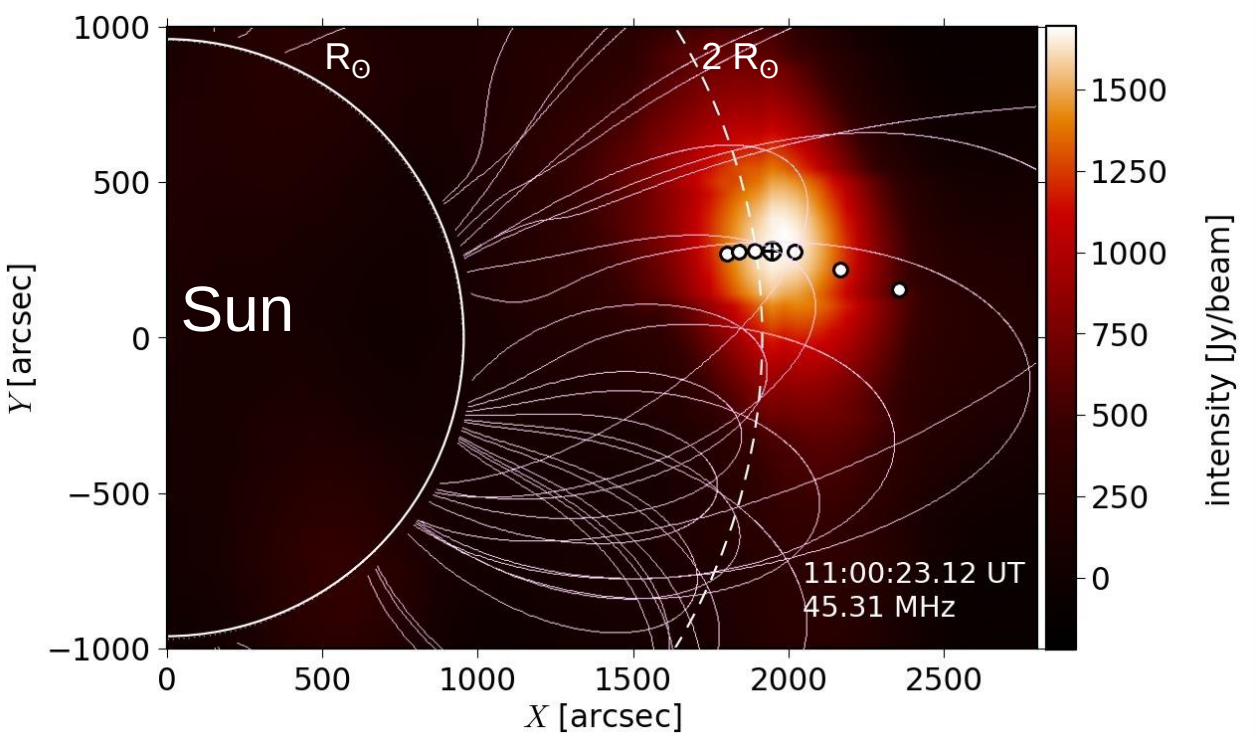

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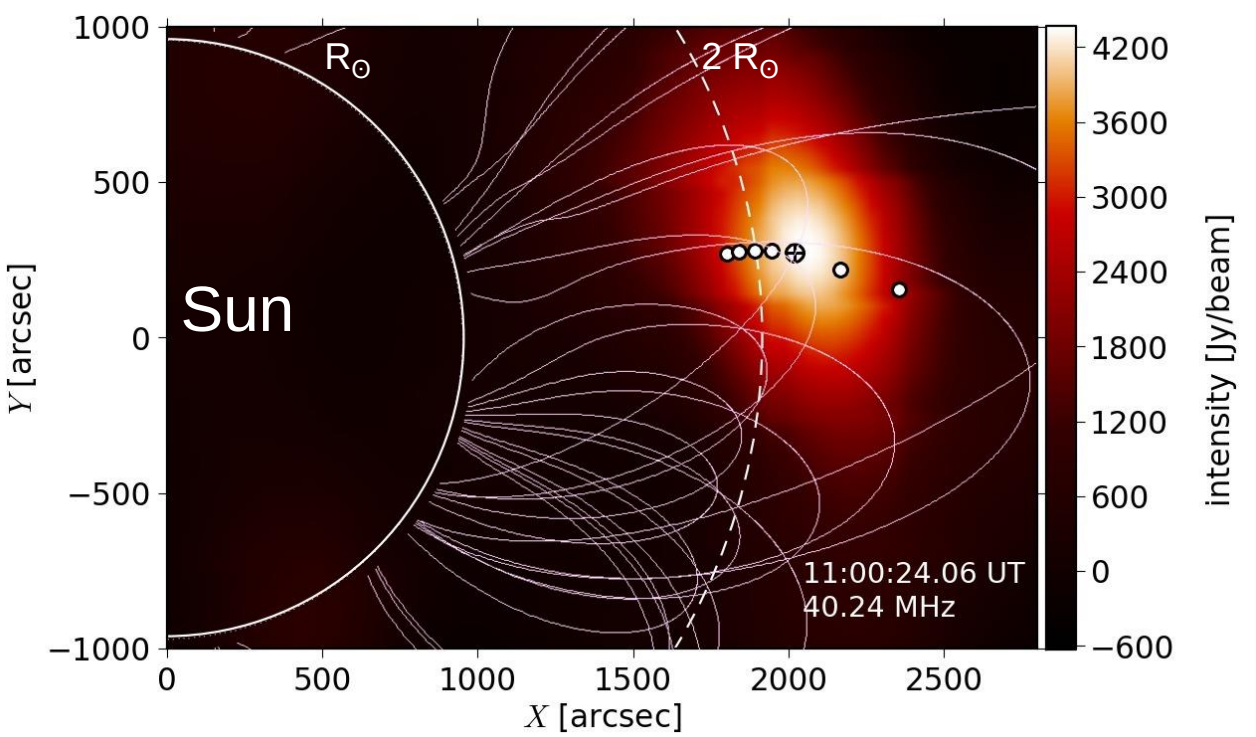

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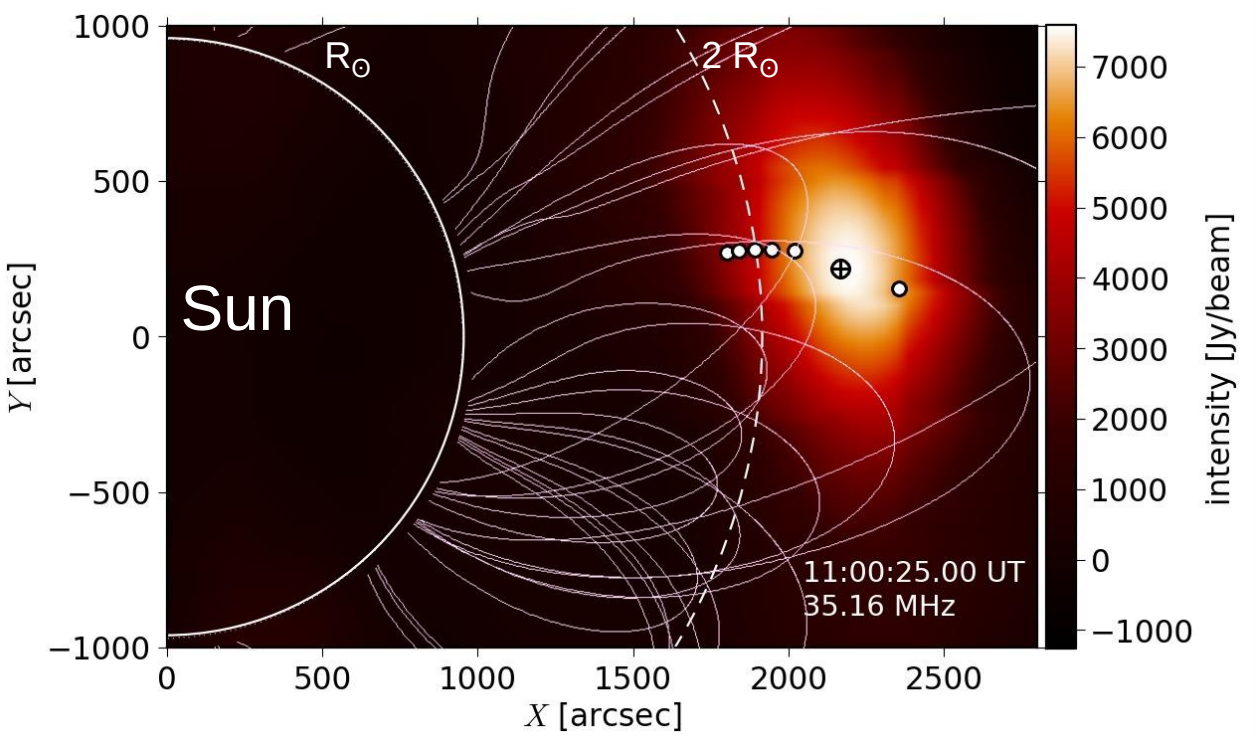

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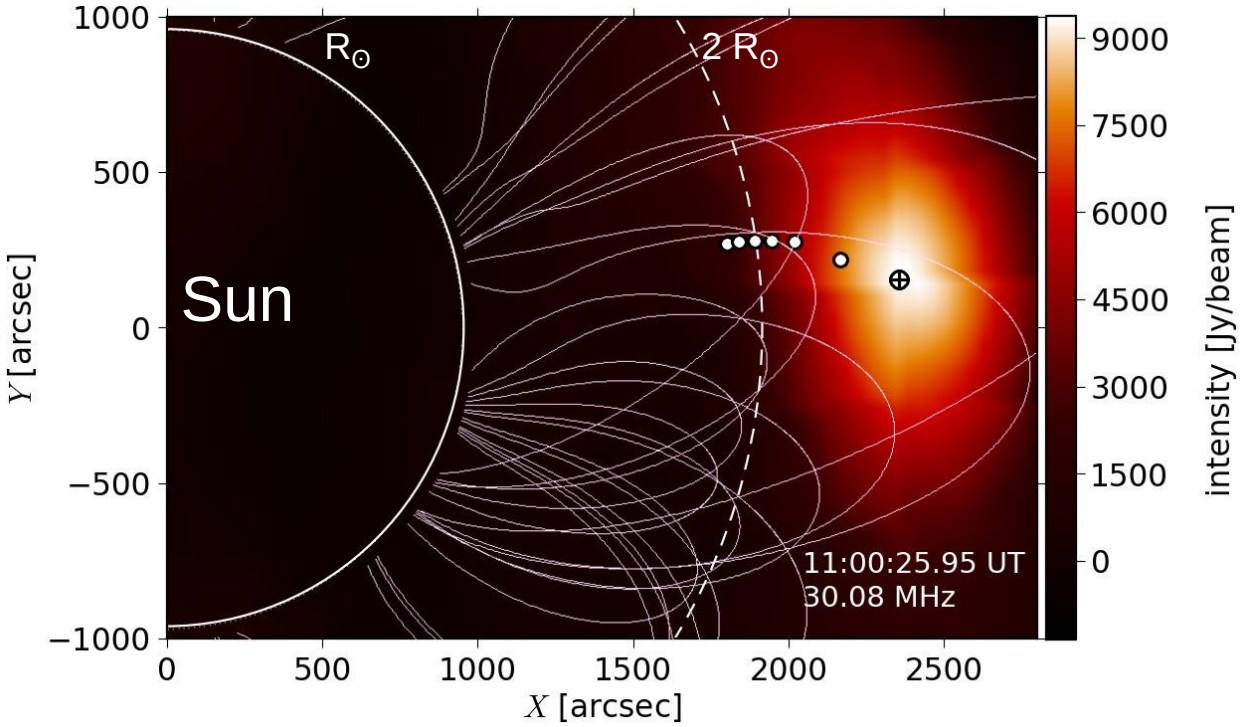


| f [MHz] | X ["] | Y ["] | $r/R_\odot$ |
|---|---|---|---|
| 60.5 | 1777 | 298 | 1.87 |
| 55.5 | 1881 | 311 | 1.95 |
| 50.4 | 1896 | 294 | 1.99 |
| 45.3 | 1973 | 323 | 2.07 |
| 40.2 | 2024 | 306 | 2.12 |
| 35.2 | 2222 | 313 | 2.33 |
| 30.1 | 2385 | 216 | 2.48 |

Propagation distance:

$\Delta r = 0.6\ R_\odot$

Propagation velocity:

$\Rightarrow\ V_r = 0.6\ R_\odot / 5.5\ s =$
$= 76\,000$ km/s $= 0.25c$

=> We can image the propagation of a type III burst in the corona with unprecedented accuracy

=> The propagation appears along the magnetic field lines as predicted

# Conclusion

- We still have problems with the calibration
- Any help or ideas would be welcome
  (in particular with 3C444 and demixing)

- LOFAR is a sensitive instrument for the detection of solar radio bursts
- LOFAR supports the explanation of type III bursts by $e^-$ beams that propagate along coronal field lines
- We have also derived a coronal density profile but time is too short to show it