Numerical simulations of particle acceleration & low frequency radio emission in stellar environments

Sofia Moschou

Harvard-Smithsonian Center for Astrophysics

sofia.moschou@cfa.harvard.edu

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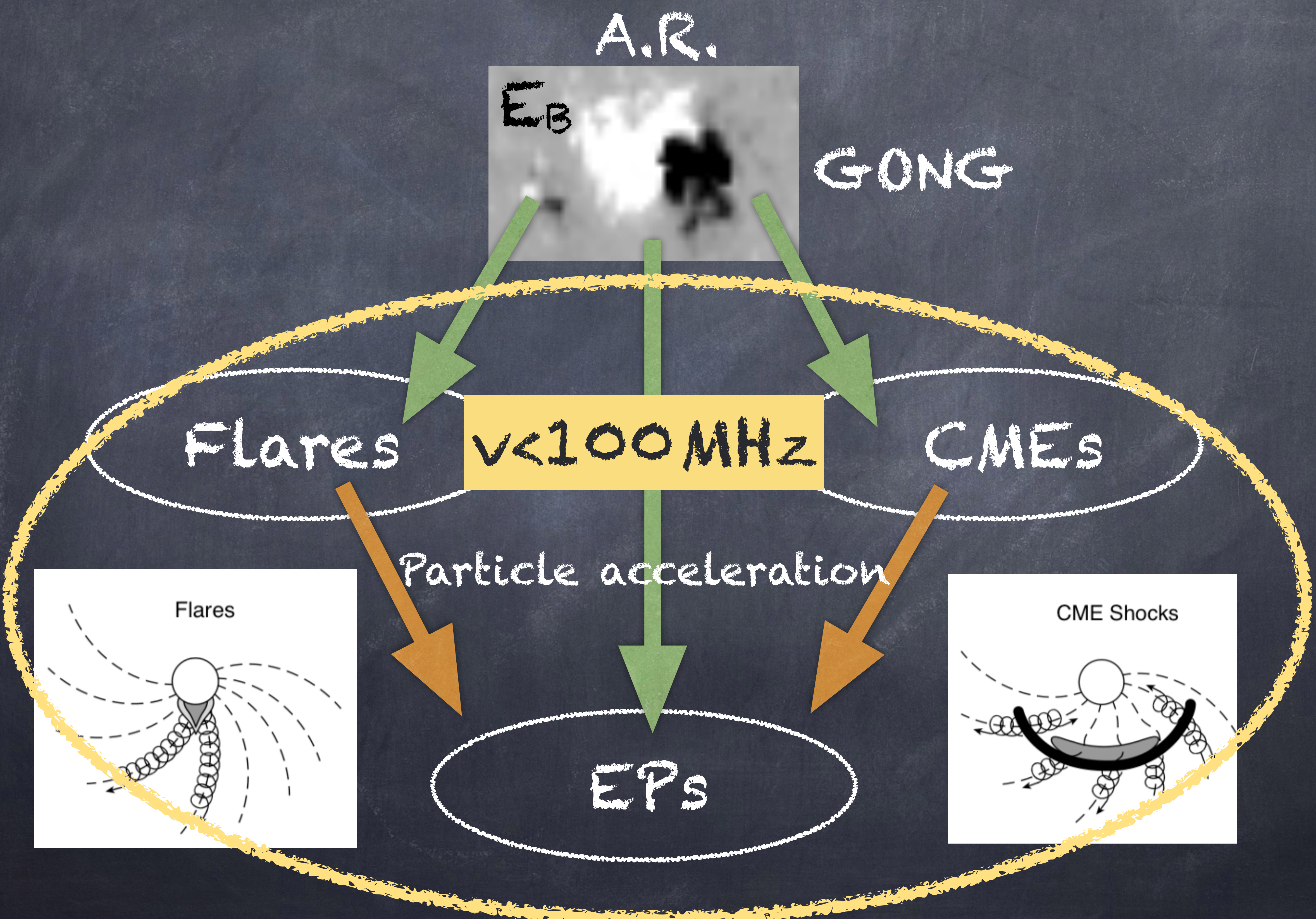
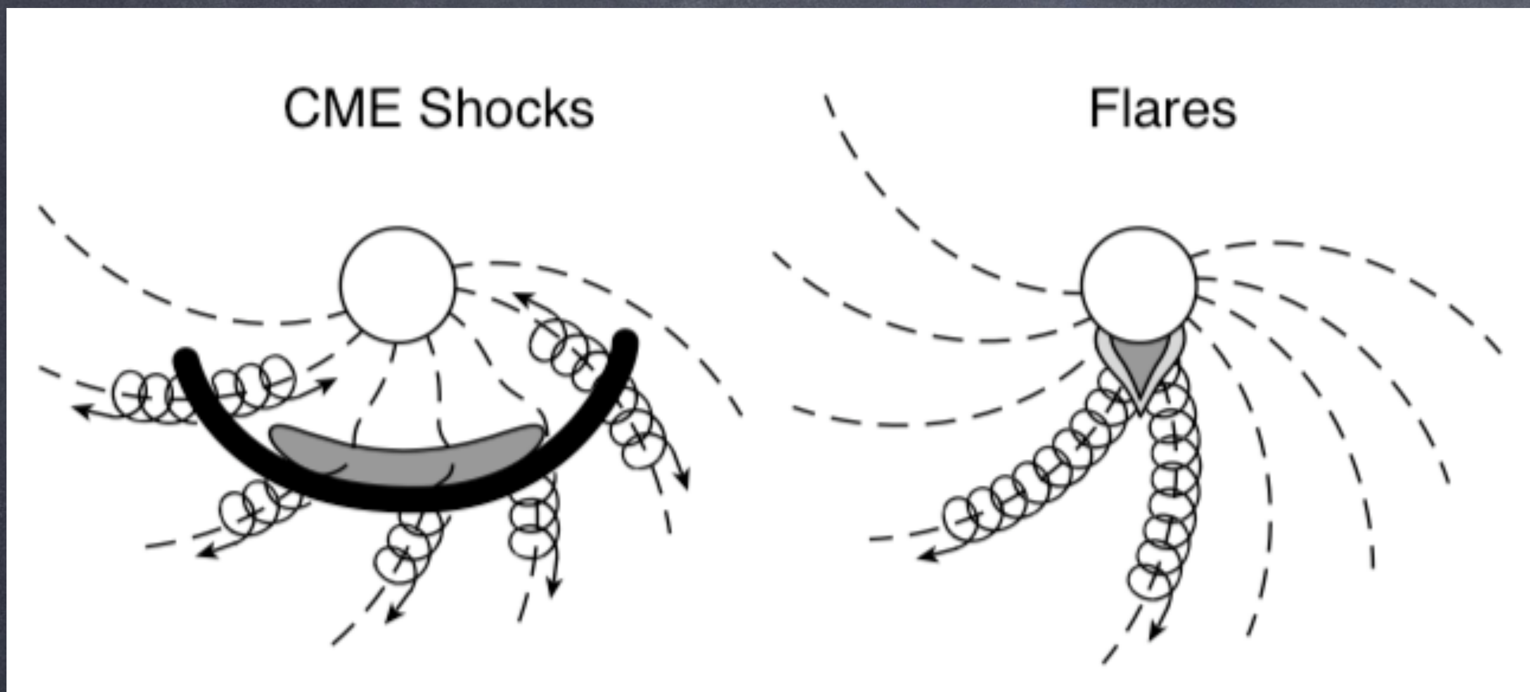
Why Radio?

- √ Characterizing exoplanetary environments
- √ Promising for stellar CME observations
- √ Favorable atmospheric window
- √ Plethora of astronomical radio sources
- √ Produced by a wide range of mechanisms
- √ New low frequency regime from space

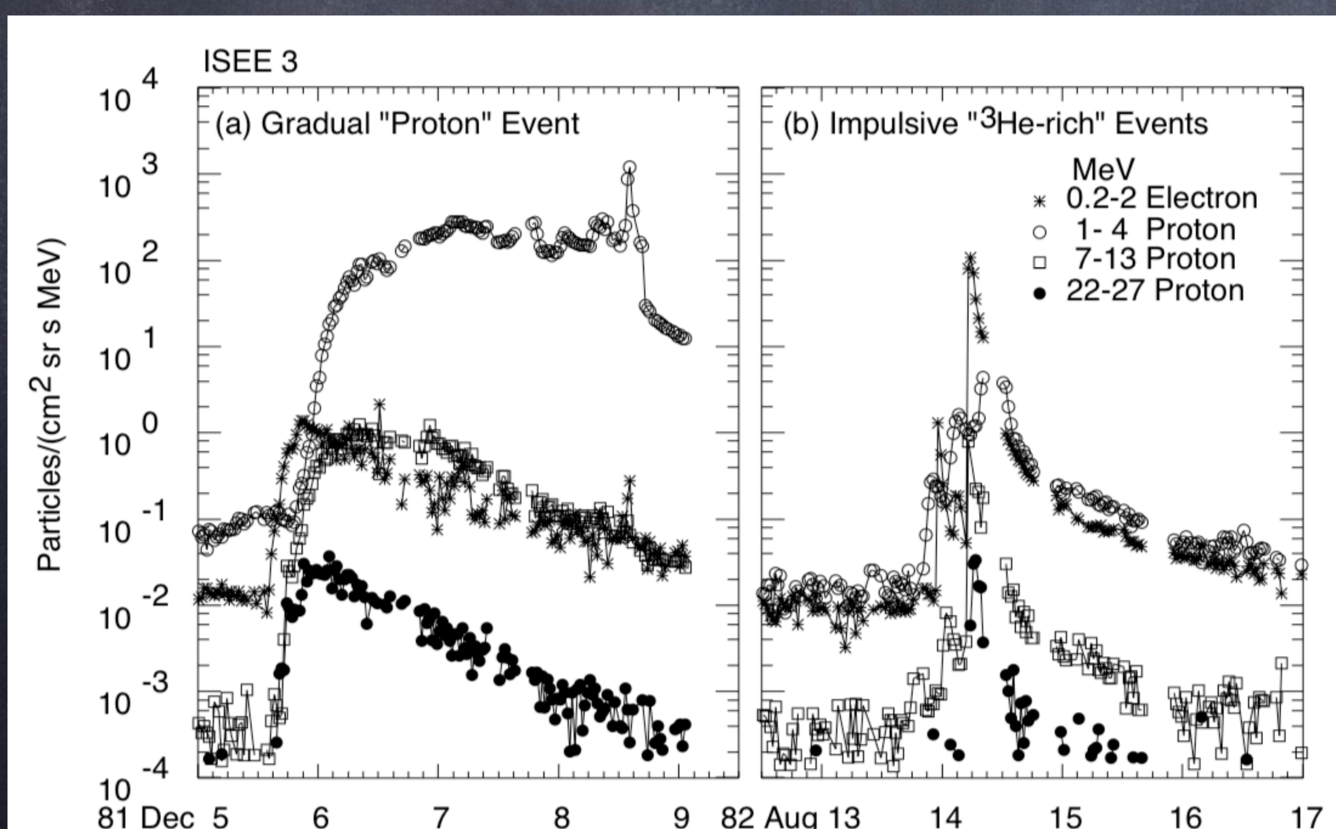
Follow the energy for particle acceleration



Solar EPs



Reames, 1999, SSR



SEP Classes	Gradual (CMEs)	Impulsive (flares)
Duration	Days	Hours
X-rays	Gradual	Impulsive
Radio-bursts	Type II	Type III, IV

Radio emission mechanisms

Bremsstrahlung radiation ($\propto n_e^2\, T_e^{-1/2}$)

Gyromagnetic radiation

(gyroresonance, gyrosynchrotron, synchrotron)

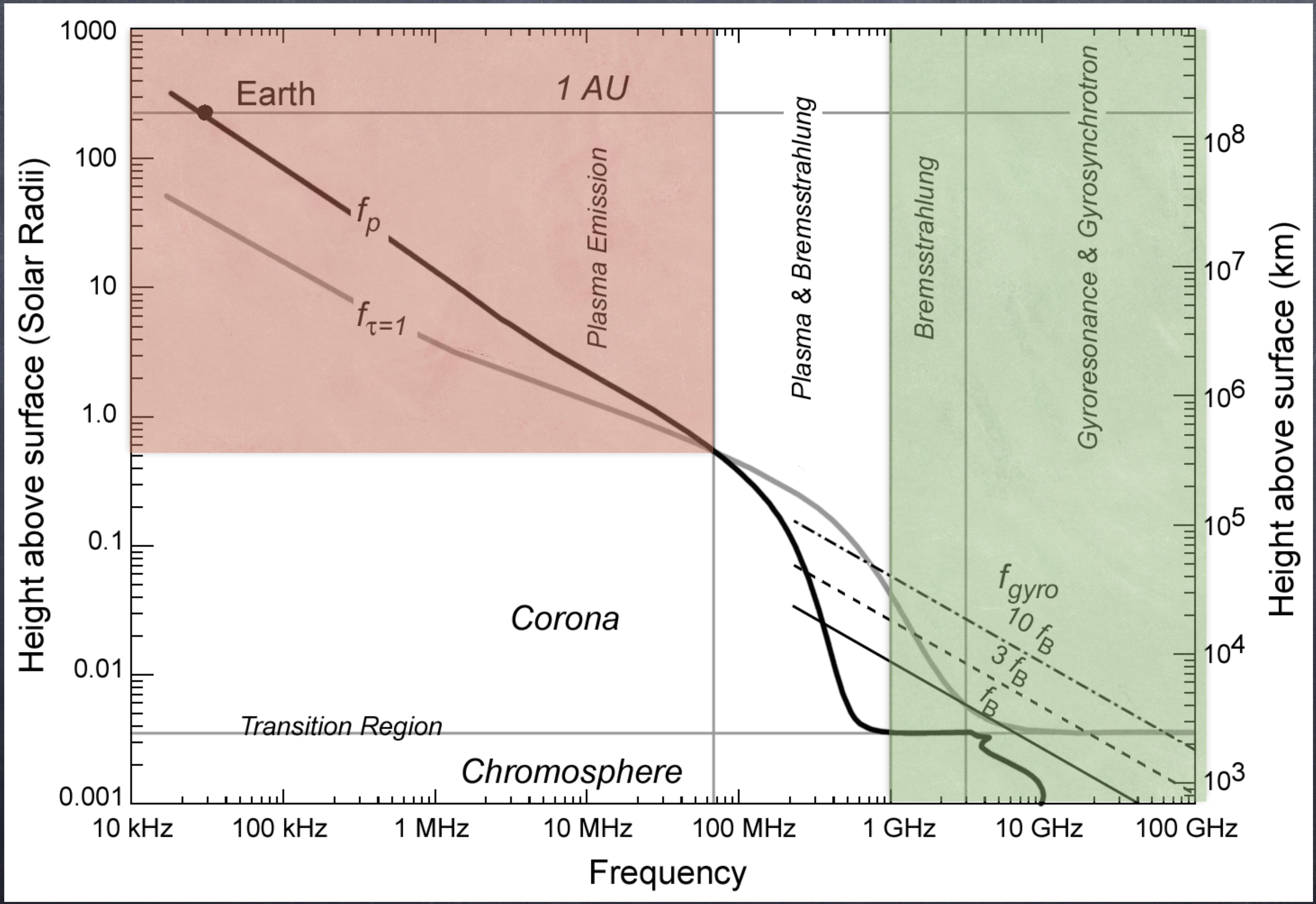
Plasma radiation (ν_p, $2\nu_p \propto n_e^{1/2}$)

N.E. VDFs ➜ Langmuir waves ➜ E/M

a) e- beams (Type III)

b) MHD shocks (Type II)

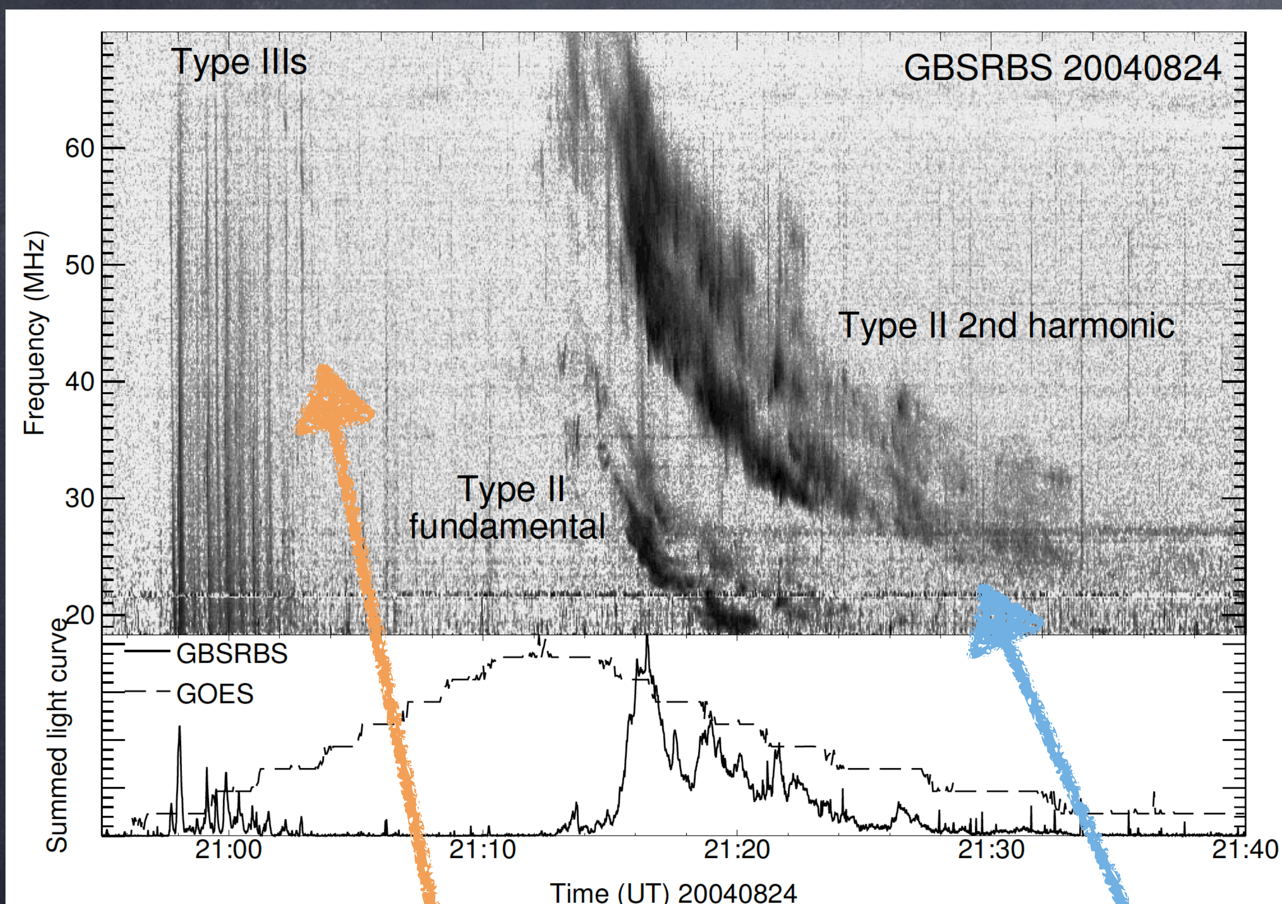
Radio solar atmosphere

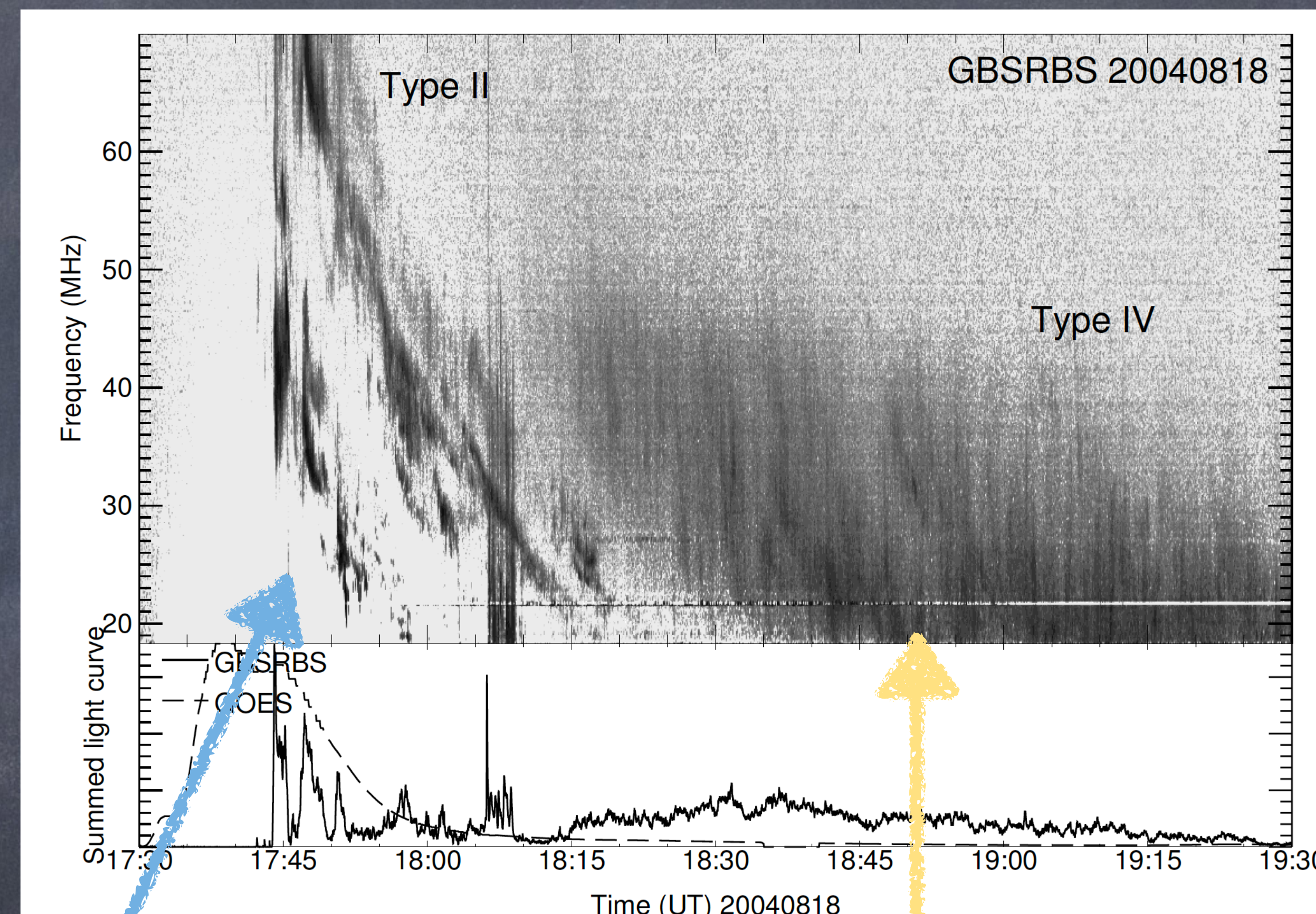


source: web.njit.edu, Prof. D. Gary

Radio bursts

Green Bank Solar Radio Burst Spectrometer (GBSRBS)



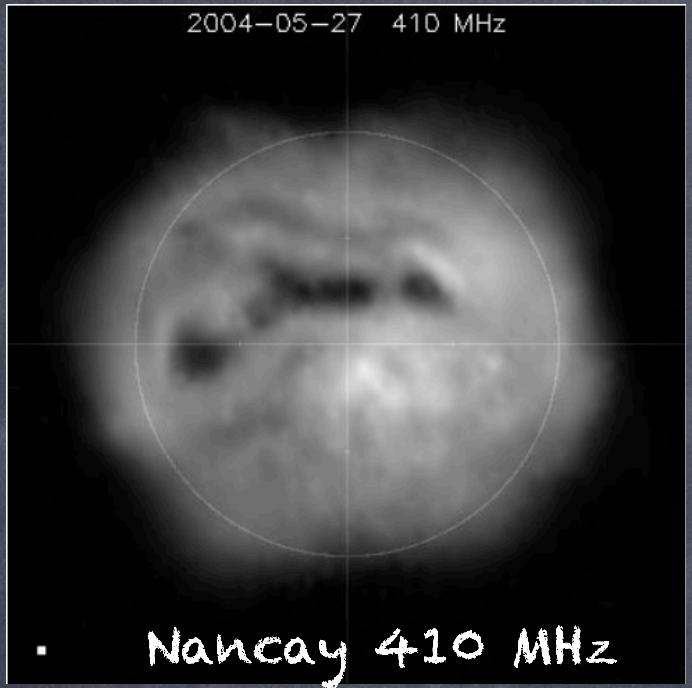


Impulsive phase
flare rise
Type III

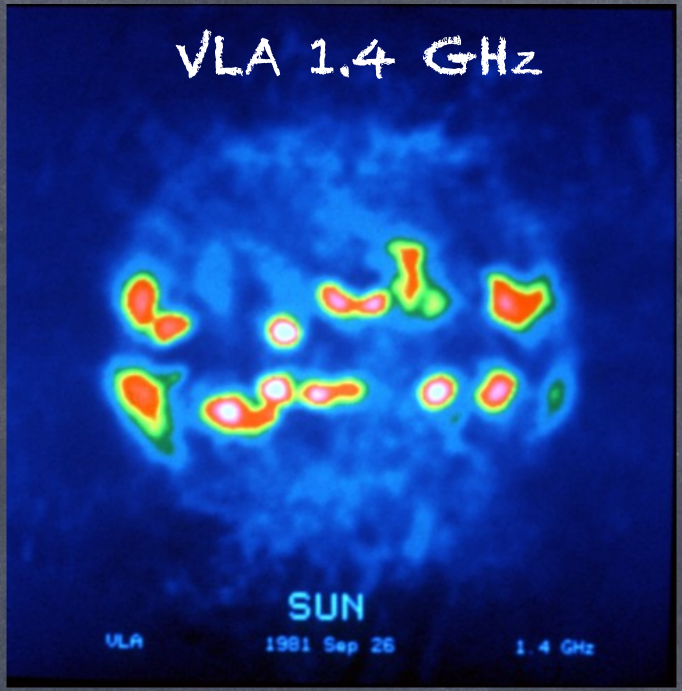
CME
Type II

flare decay
Type IV

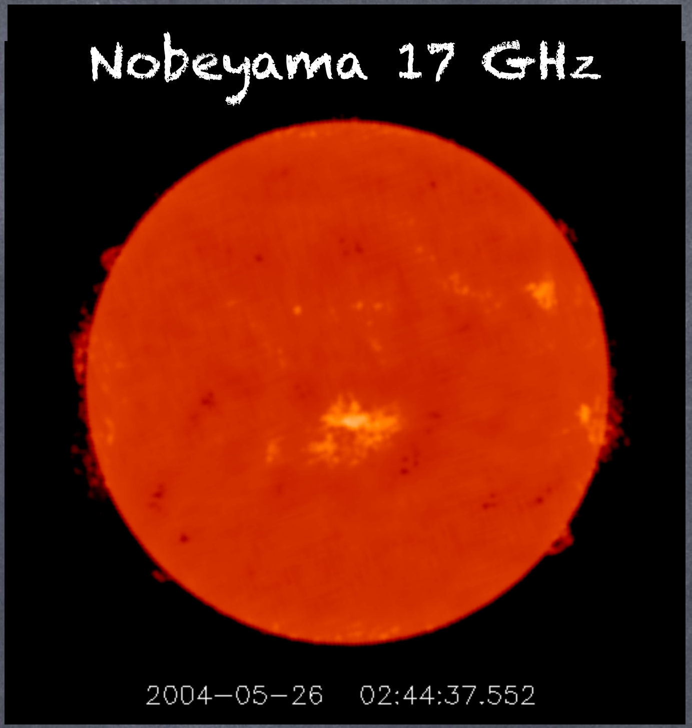
Refraction of Radio waves

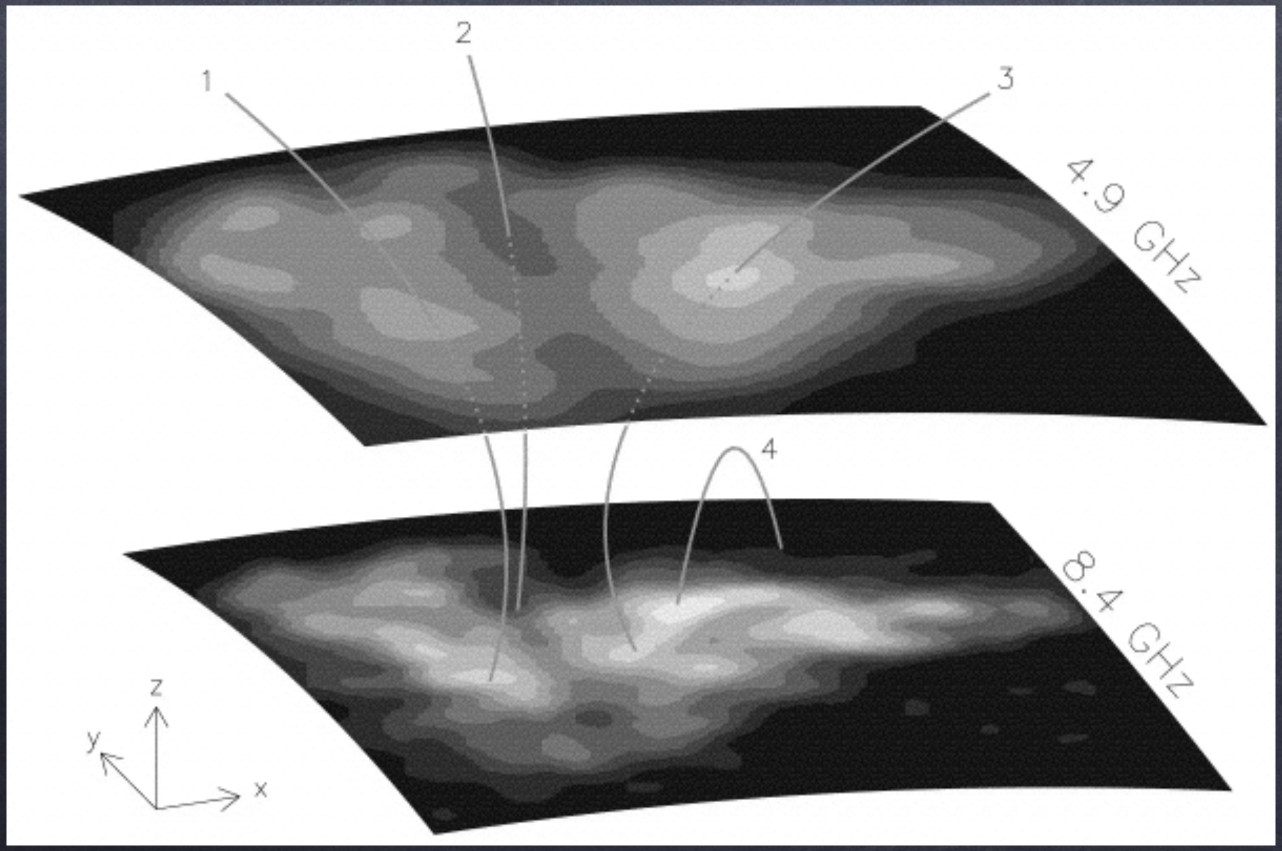


Mercier + Chambe, 2015



Dulk + Gary, 1983

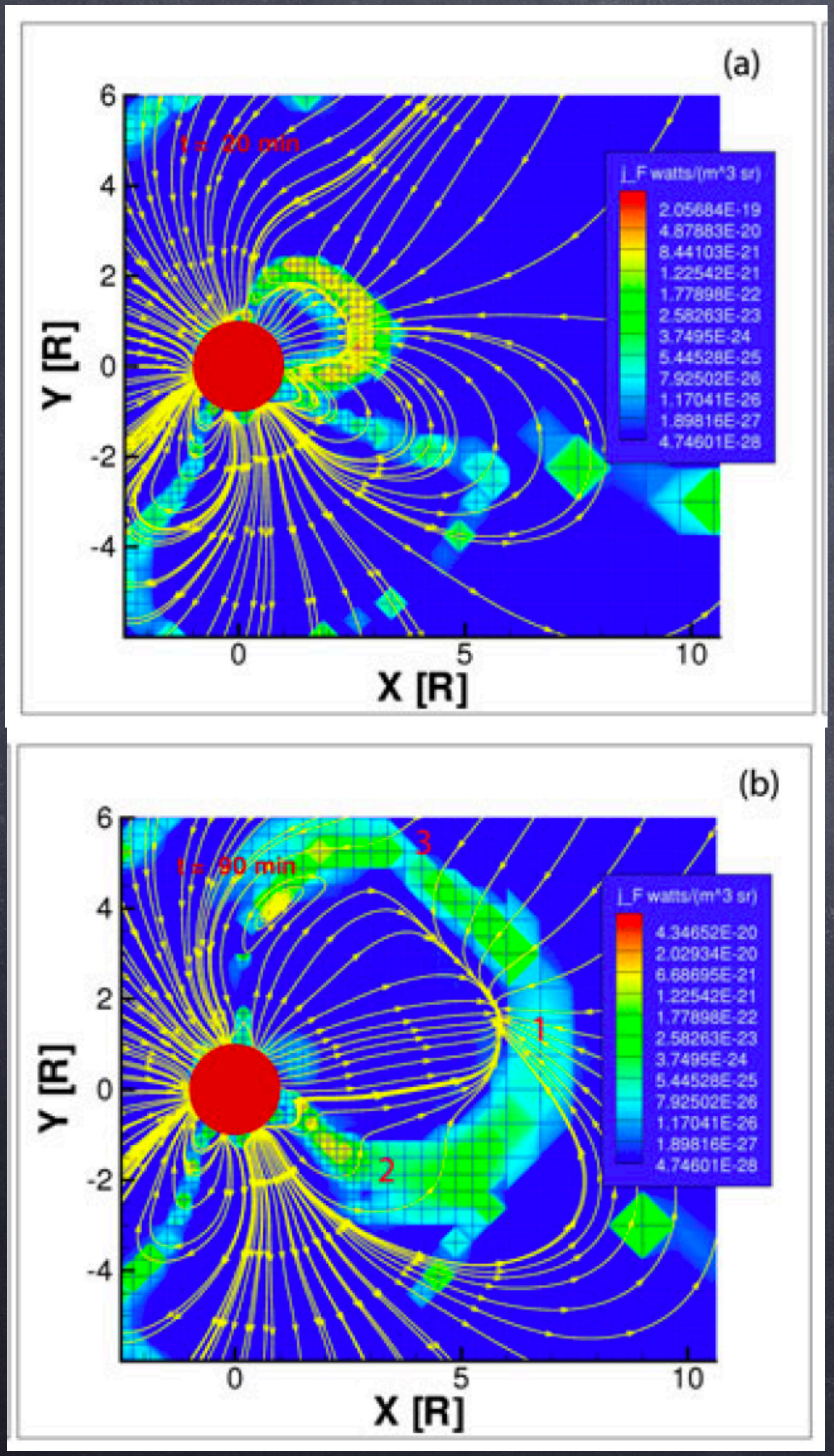




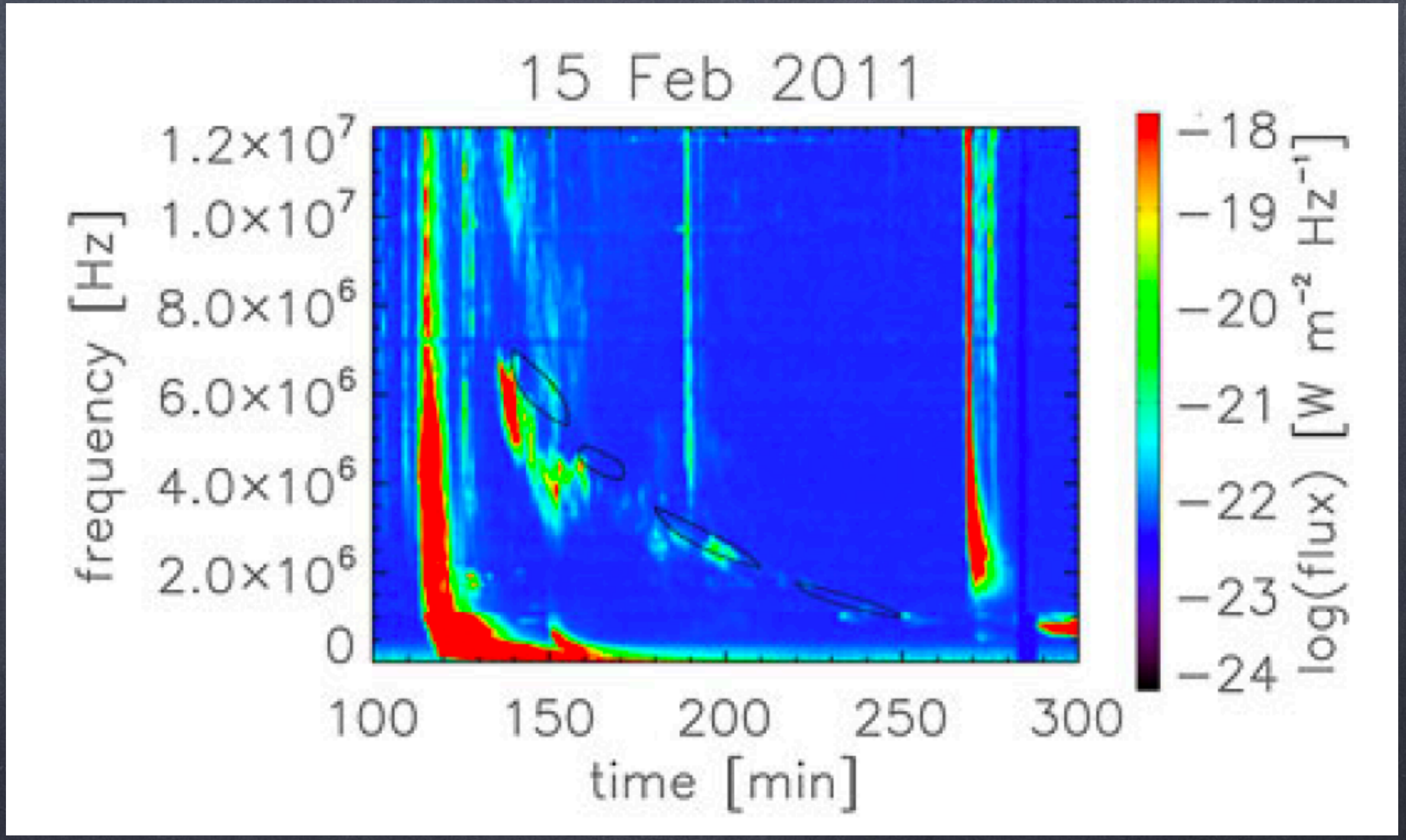
Lee et al. 1999, ApJ

Models & Simulations

Simulations of type II radio bursts

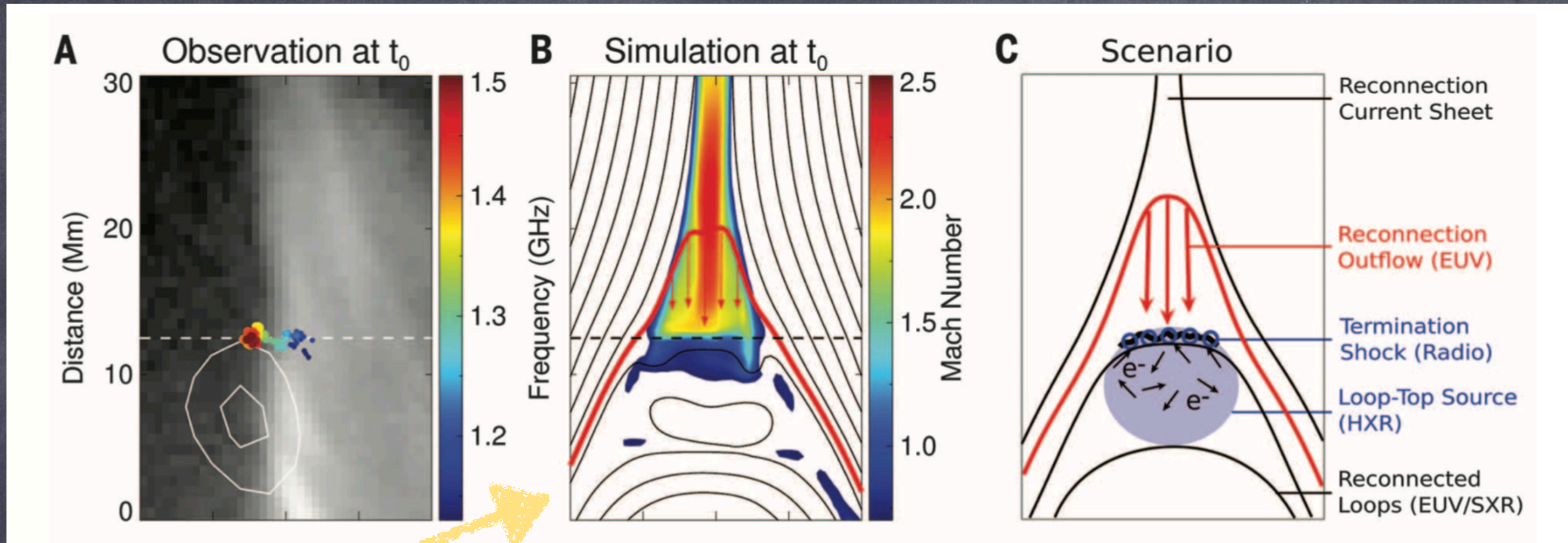


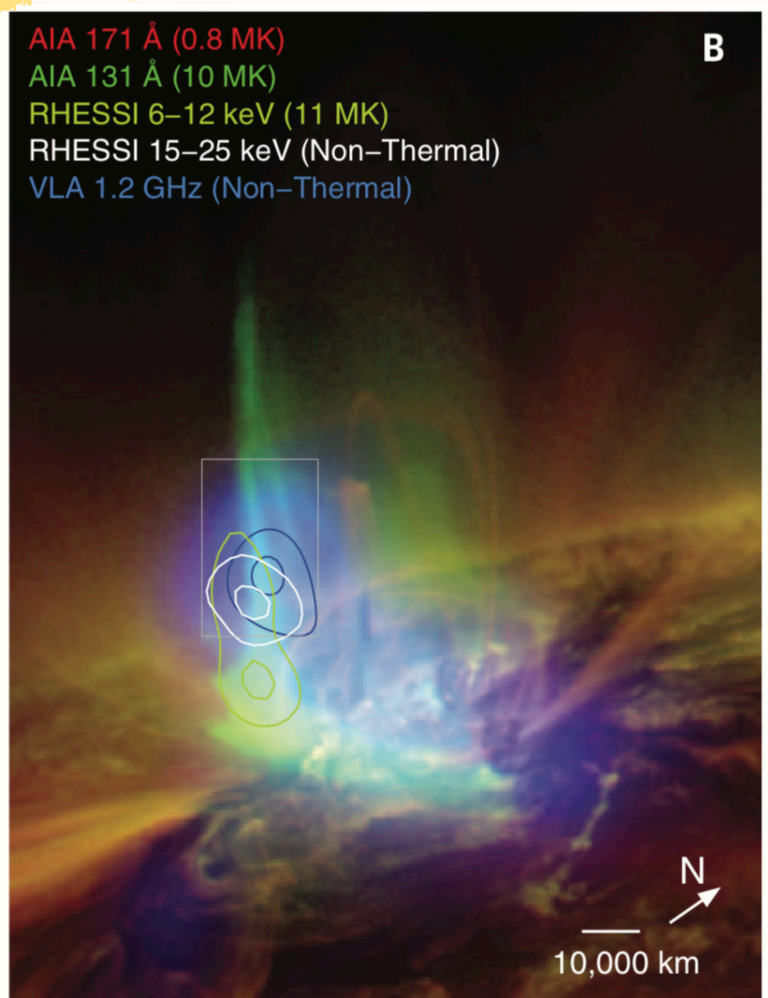
BATS-R-US + WSA + analytic Kappa VDFs



Schmidt et al., 2012, 2014

Flare particle acceleration

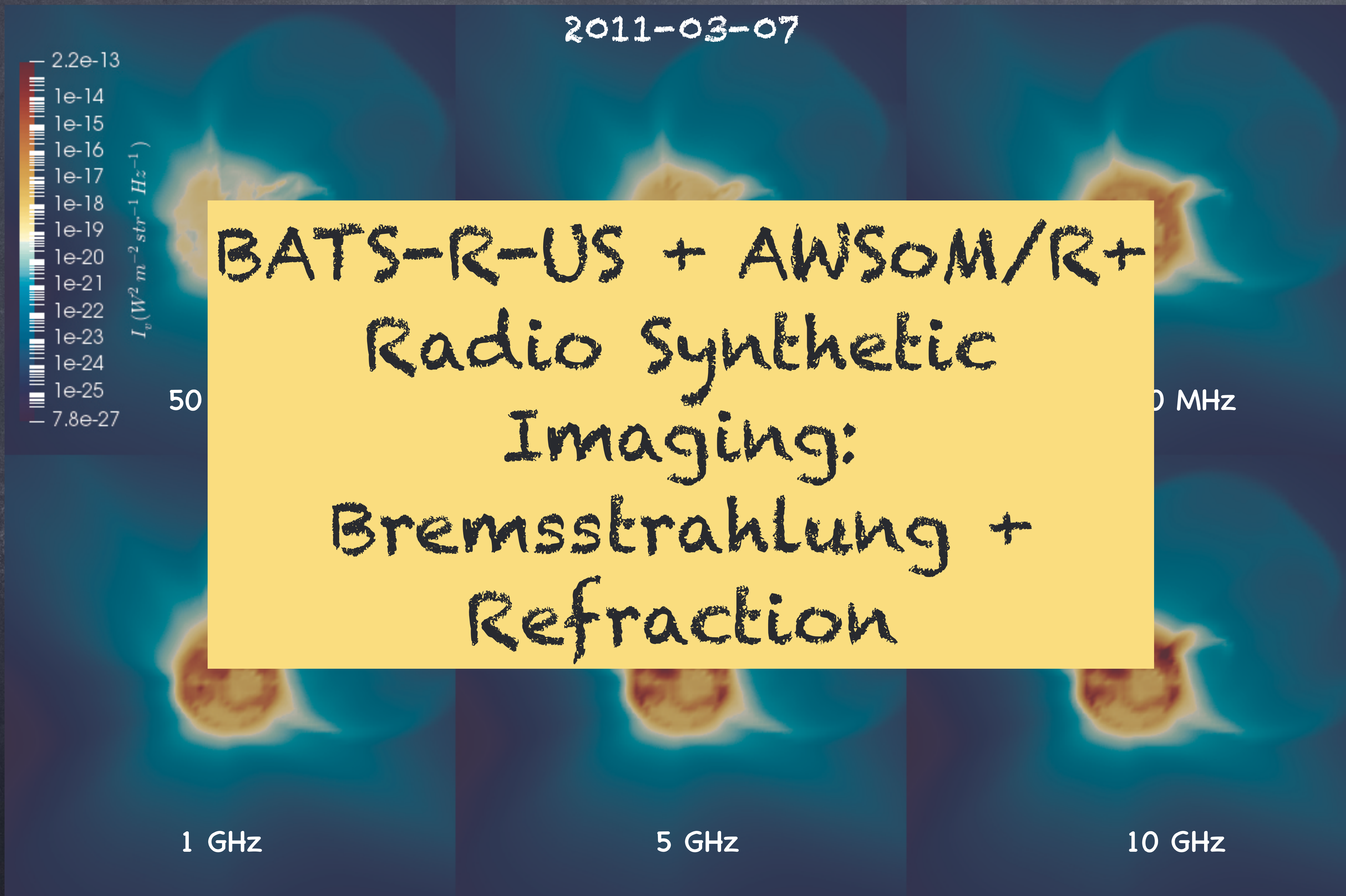




MHD reconnection simulation of Termination Shock

Chen et al., Science, 2015

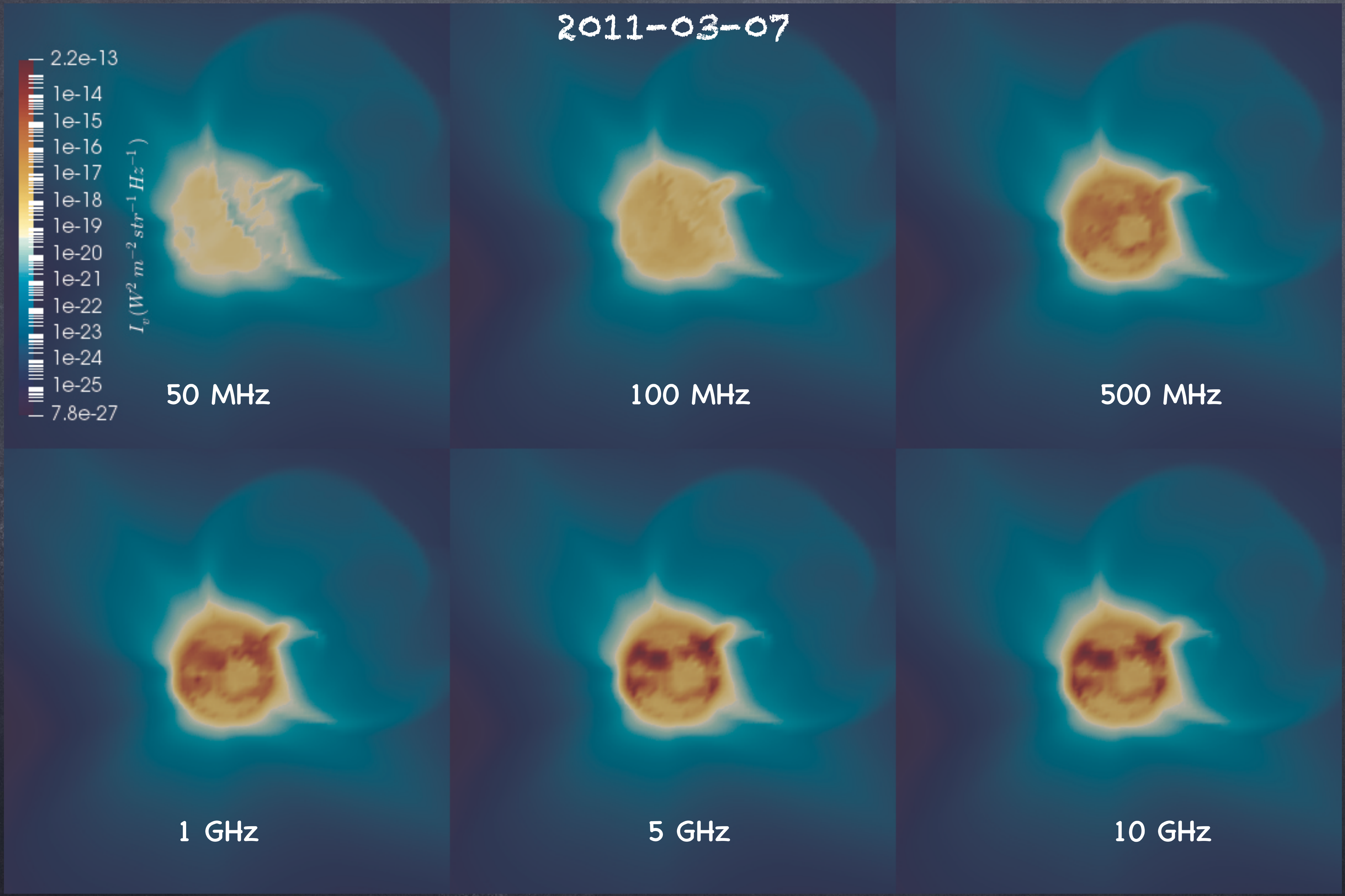
Towards a realistic radio corona



BATS-R-US + AWSoM/R+
Radio Synthetic Imaging:
Bremsstrahlung +
Refraction

Moschou et al. 2018a (submitted)

Towards a realistic radio corona



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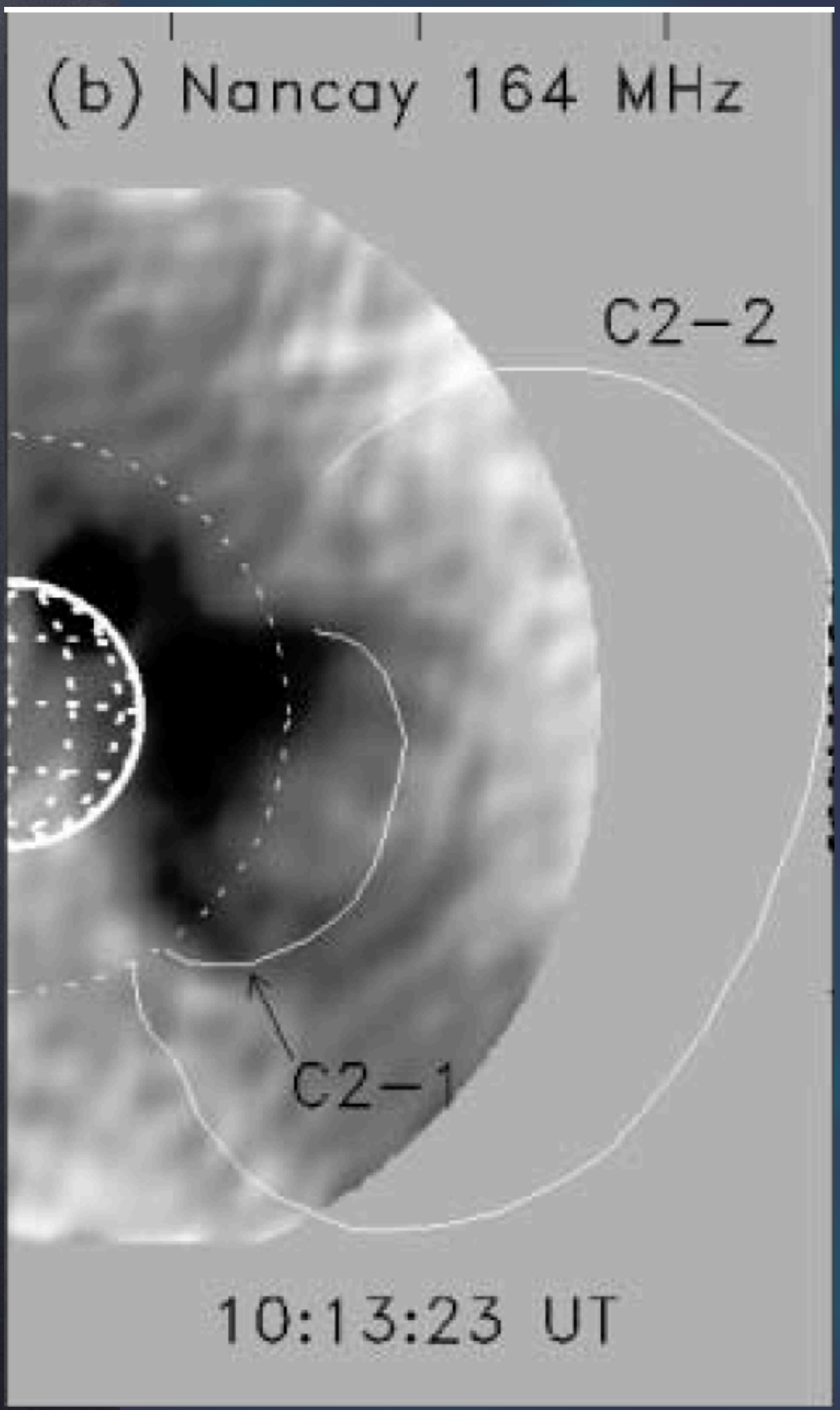
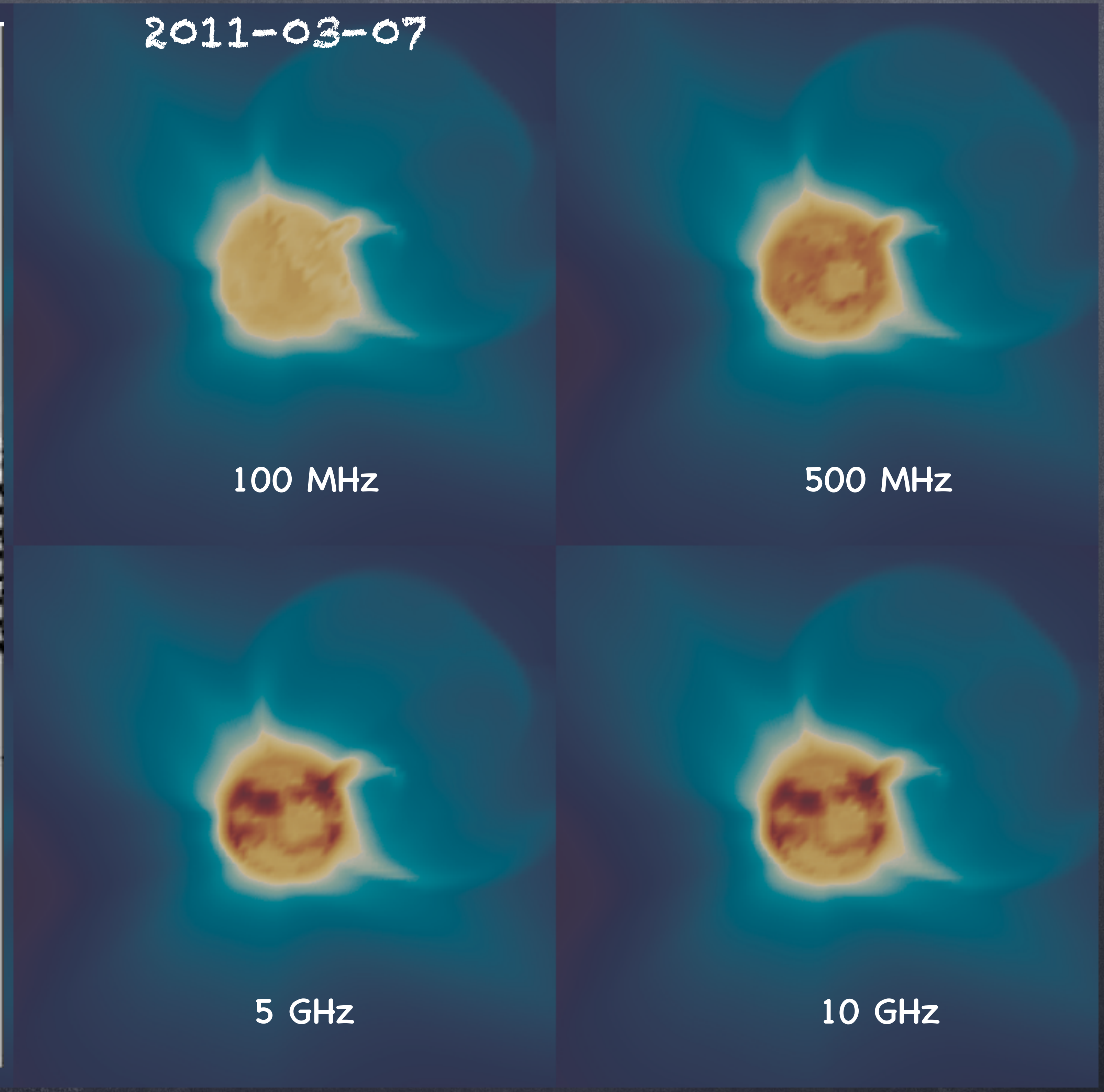
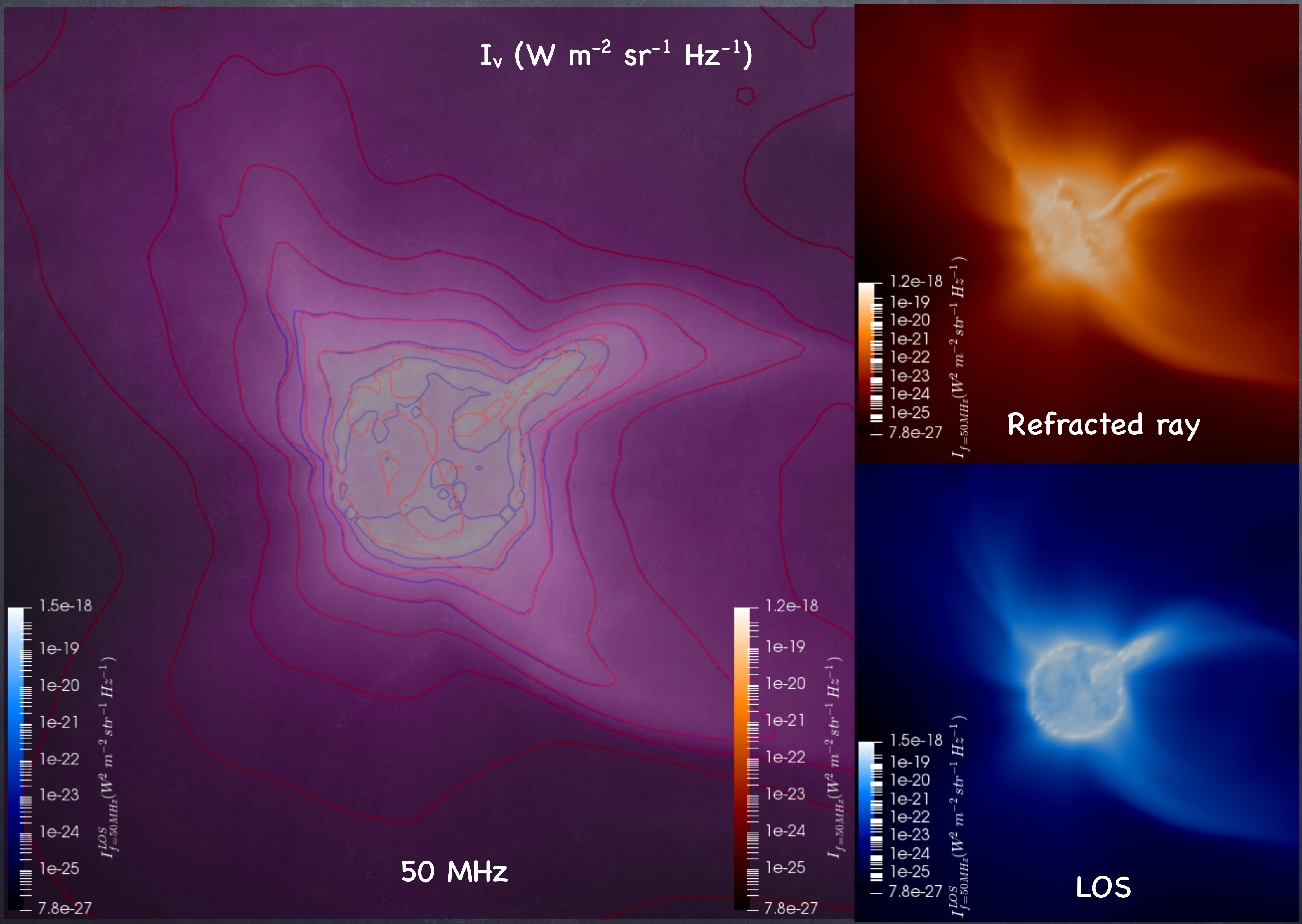


Bastian et al. 2001



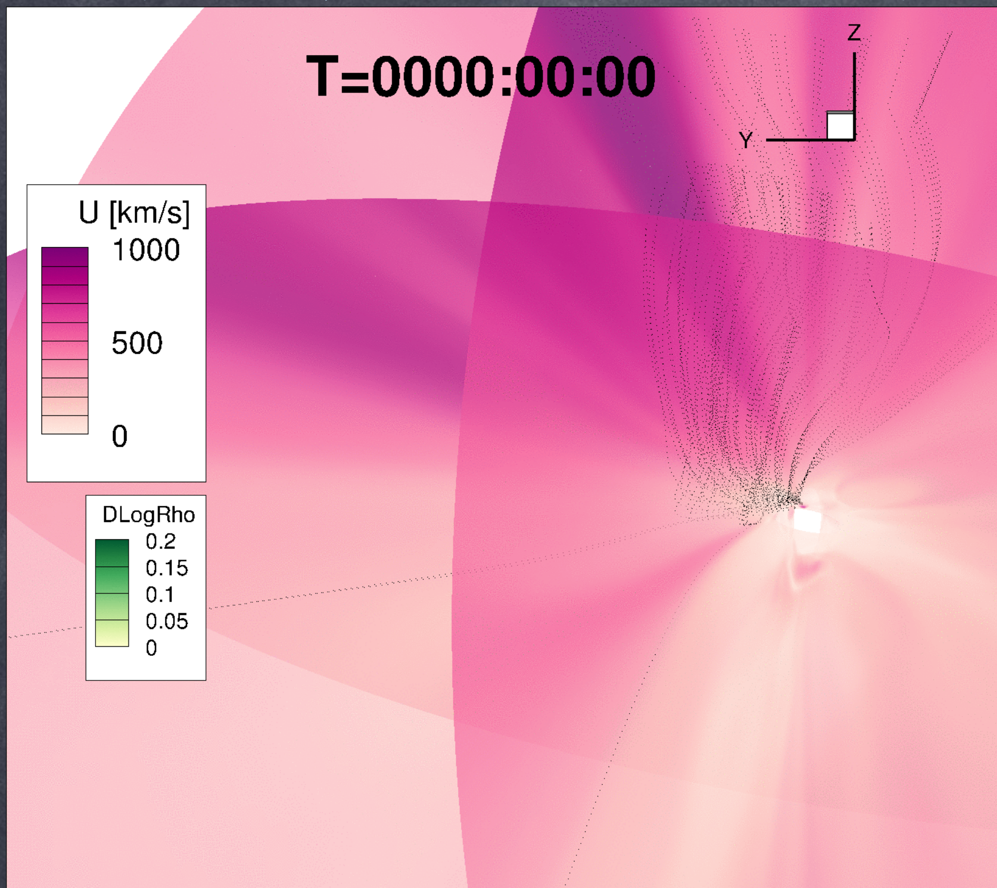
Moschou et al. 2018a (submitted)

LOS .vs. Refracted

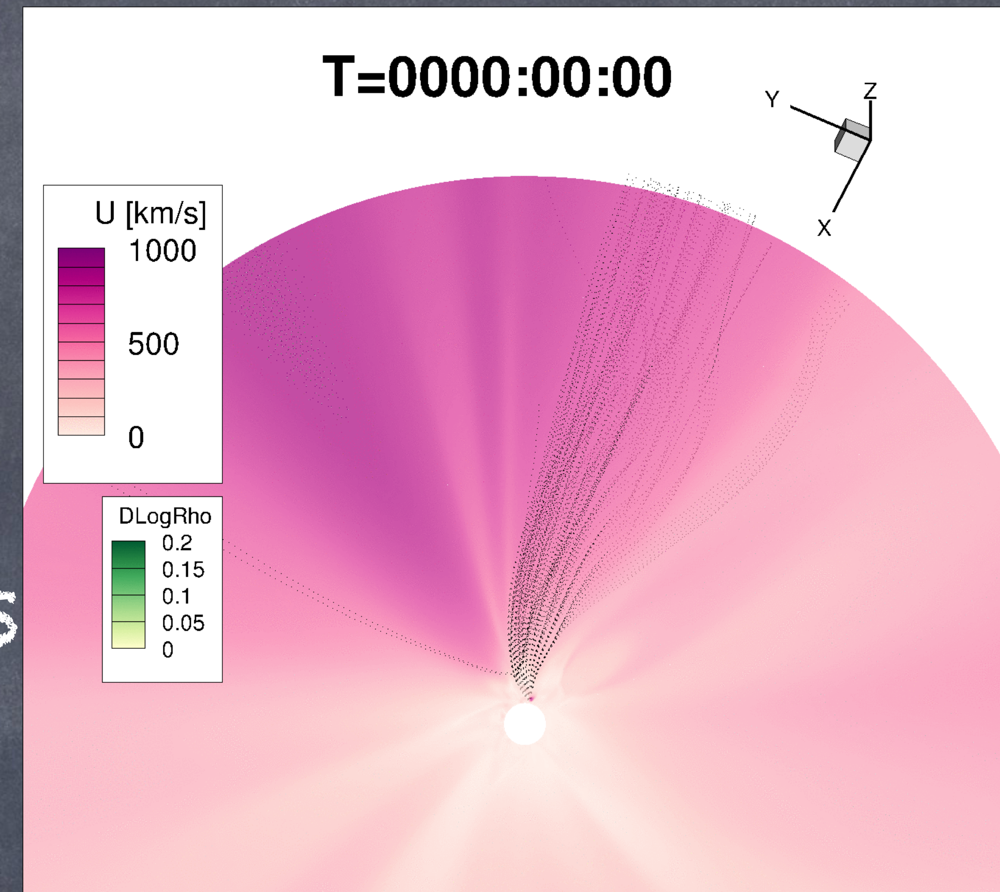


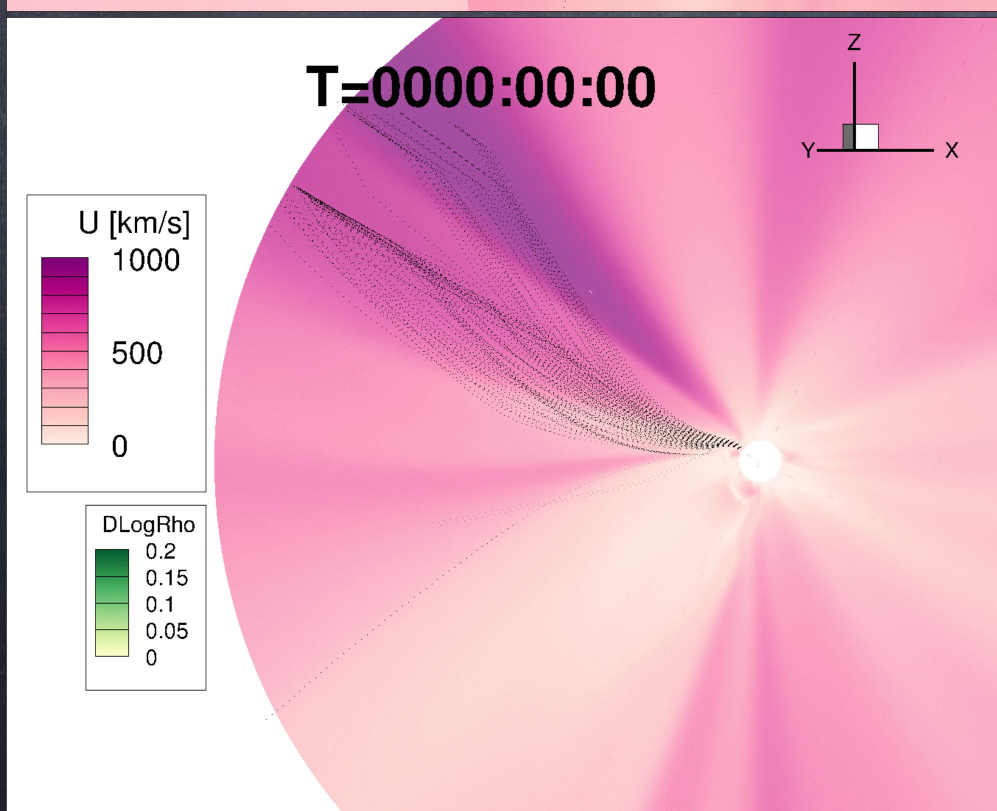
Moschou et al. 2018a (submitted)

Next: include kinetic physics

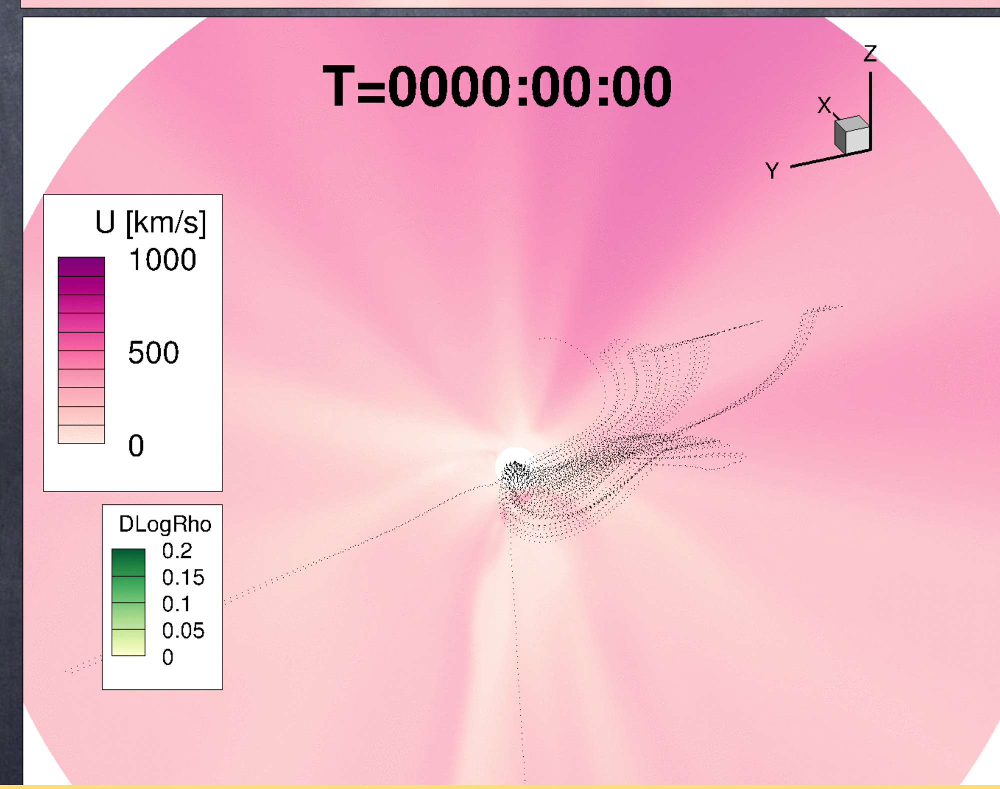


BATS-R-US
&
MFLAMPA





Videos: D.Borovikov

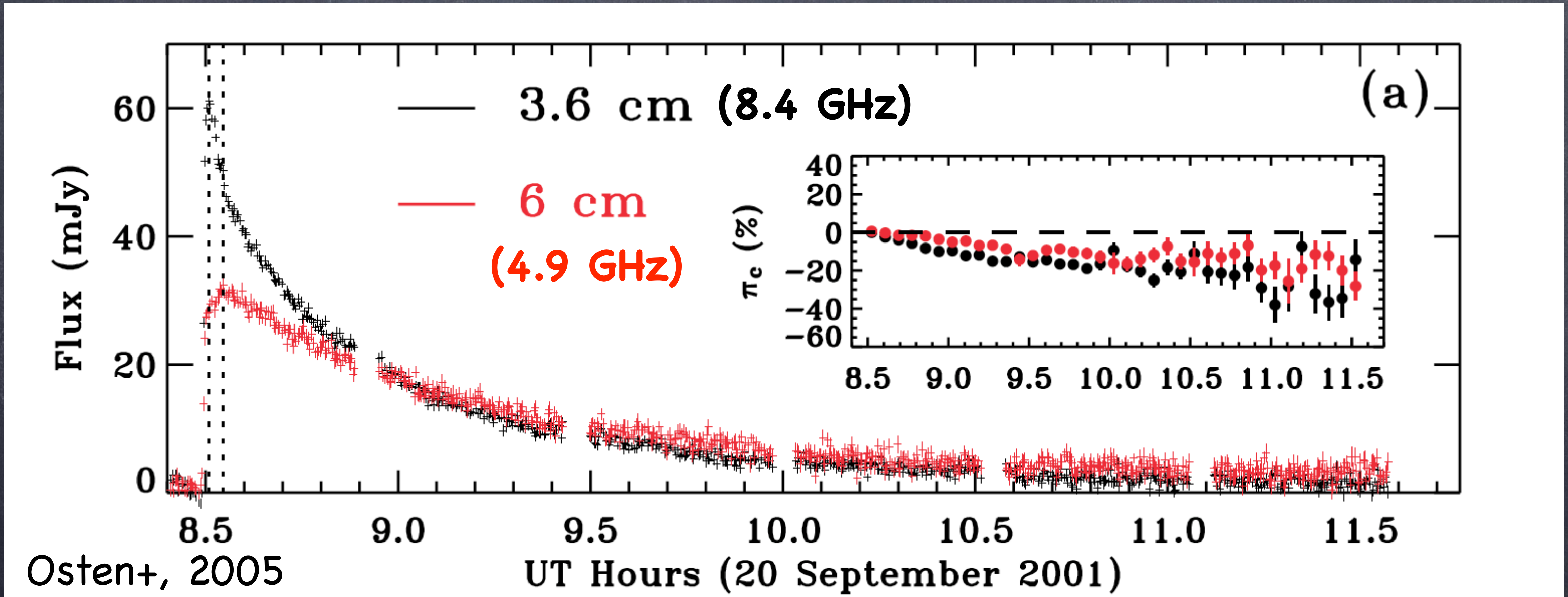


Moschou et al. 2018b, in prep

Radio Stellar flares

Radio stellar flares

- Incoherent stellar flares in both Sun-like (FGK)-stars (e.g. Gudel+,'98) & M-dwarfs (e.g. Bastian,'90)



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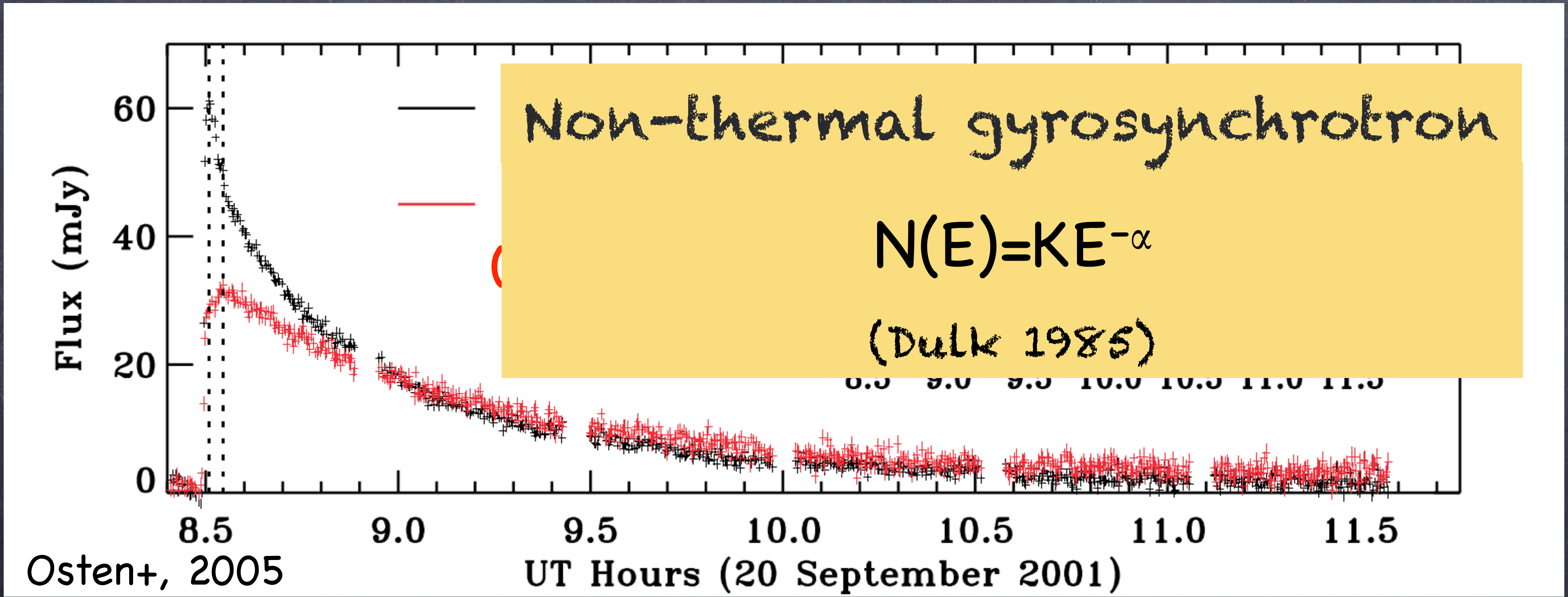

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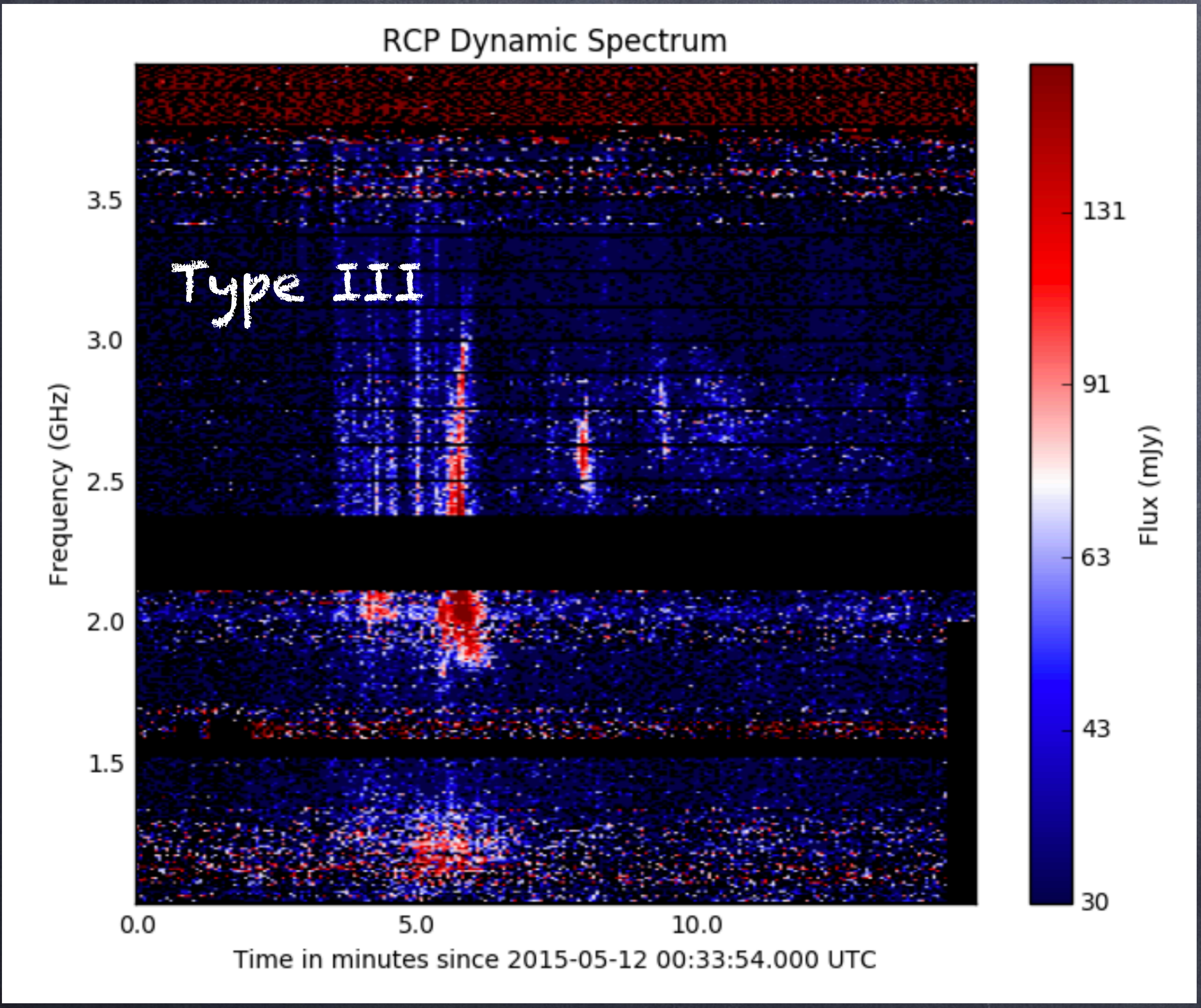
Stellar radio bursts

YZ CMi



Campaigns for Type II

VLA, New Mexico

Credit: NRAO

Jackie Villadsen, 2017, PhD thesis

Stellar radio bursts

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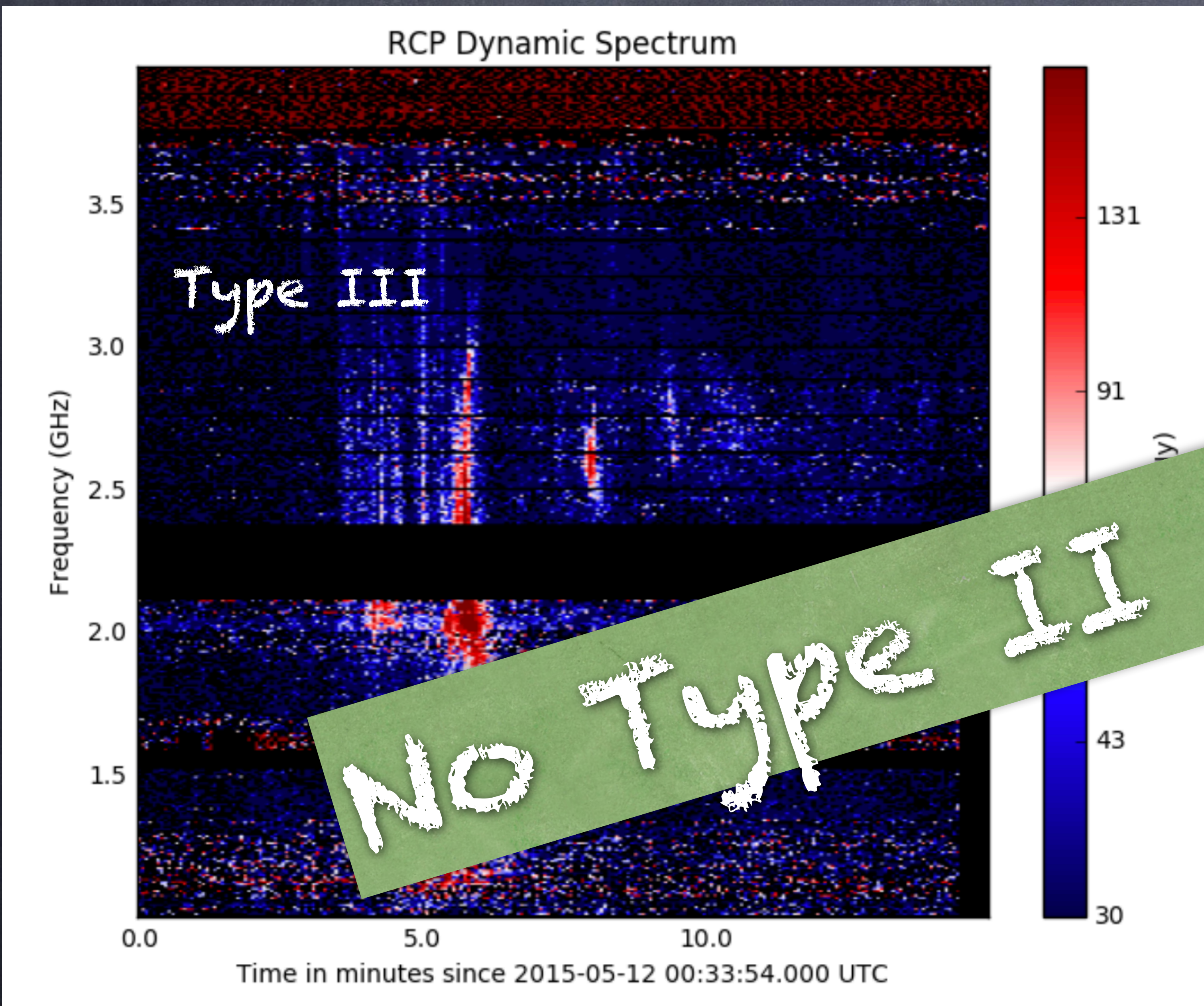

Campaigns for Type II

VLA, New Mexico

Credit: NRAO

No Type II detection

Jackie Villadsen, 2017, PhD thesis

Conclusions

- Ground-based radio observations have been a valuable tool for years
- Multiple radio emitting processes
- Particle acceleration through CMEs and flares in low frequencies
- Refraction needs to be examined systematically

What do we need?

- Low frequency radio observations from space
- Modeling: include kinetic physics consistently
- Synthetic imaging tool + capabilities to examine different emission mechanisms in different setups

Thank you!

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