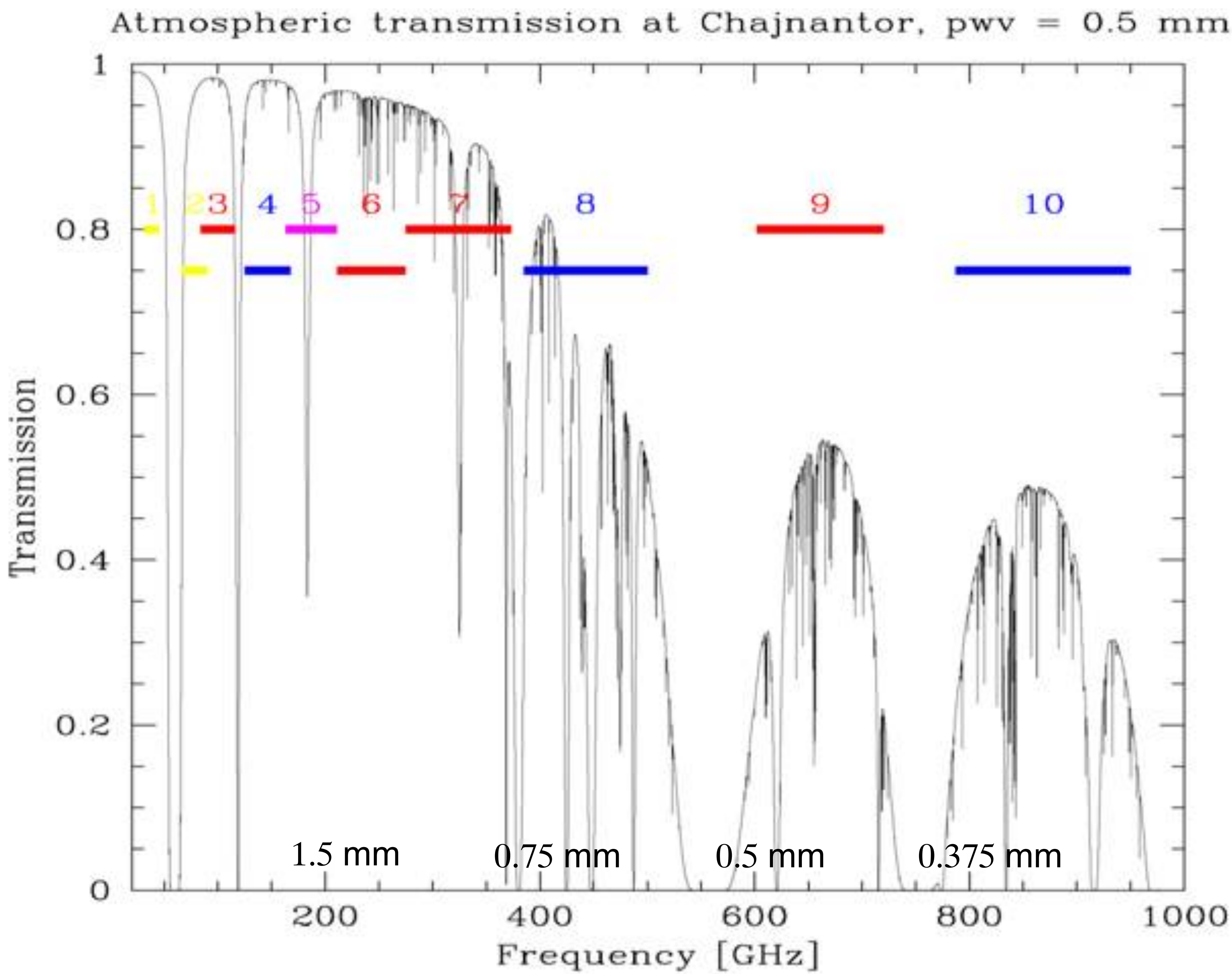
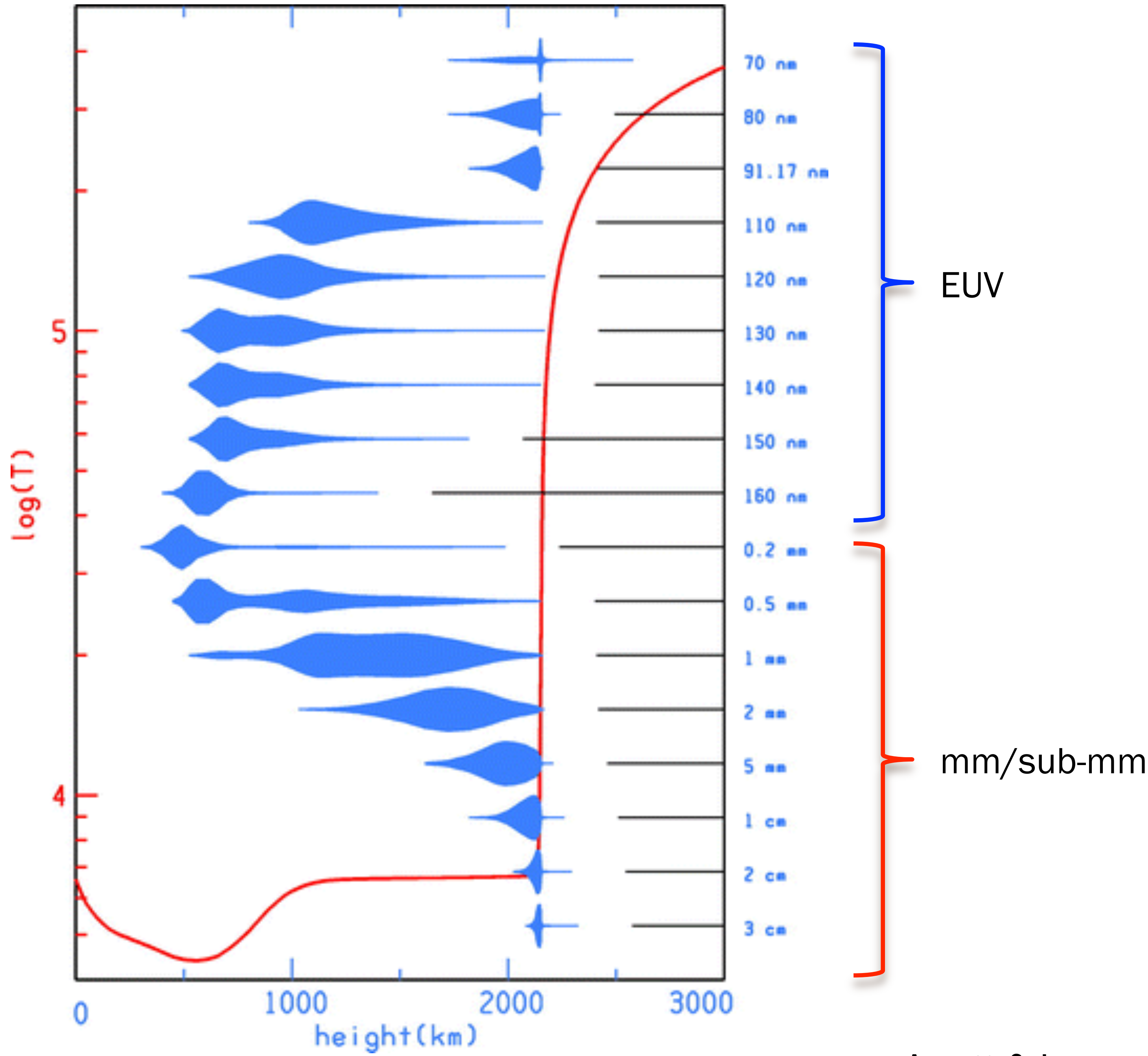
Future of Radio Coronal Magnetography

Diagnostic	Application	Inst. Req.	References
Thermal gyroresonance	Active regions ($\|\mathbf{B}\| \rightarrow \mathbf{B}$**?**)	Imaging spectroscopy & polarimetry (cm-λ)	White & Kundu 1997
Nonthermal gyrosynchrotron	Flares & CMEs ($\|\mathbf{B}\| \rightarrow \mathbf{B}$)	Imaging spectroscopy & polarimetry (cm-λ, flares; m-λ CMEs)	Bastian et al. 1998 Fleishman et al 2009
Thermal free-free	Quiet sun ($B_{\|}$)	Imaging spectroscopy & polarimetry (m-λ to cm$-\lambda$)	Gelfriekh 2004
Loop oscillations	Flares (discrete loops)	Imaging spectroscopy & polarimetry (m-λ to cm-λ)	Benz et al. 1984 Aschwanden et al.
Mode coupling	Active region corona (topological)	Imaging spectroscopy & polarimetry (cm-λ)	Ryabov 2004
Radio bursts	Corona (statistical, cases)	Imaging spectroscopy & polarimetry (dm-λ, m$-\lambda$)	Dulk & McLean 1978
Propagation techniques	Corona & heliosphere ($B_{\|}$ and fluctuations)	Imaging spectroscopy (submm-λ, flares; m-λ heliosphere)	Bastian 2001

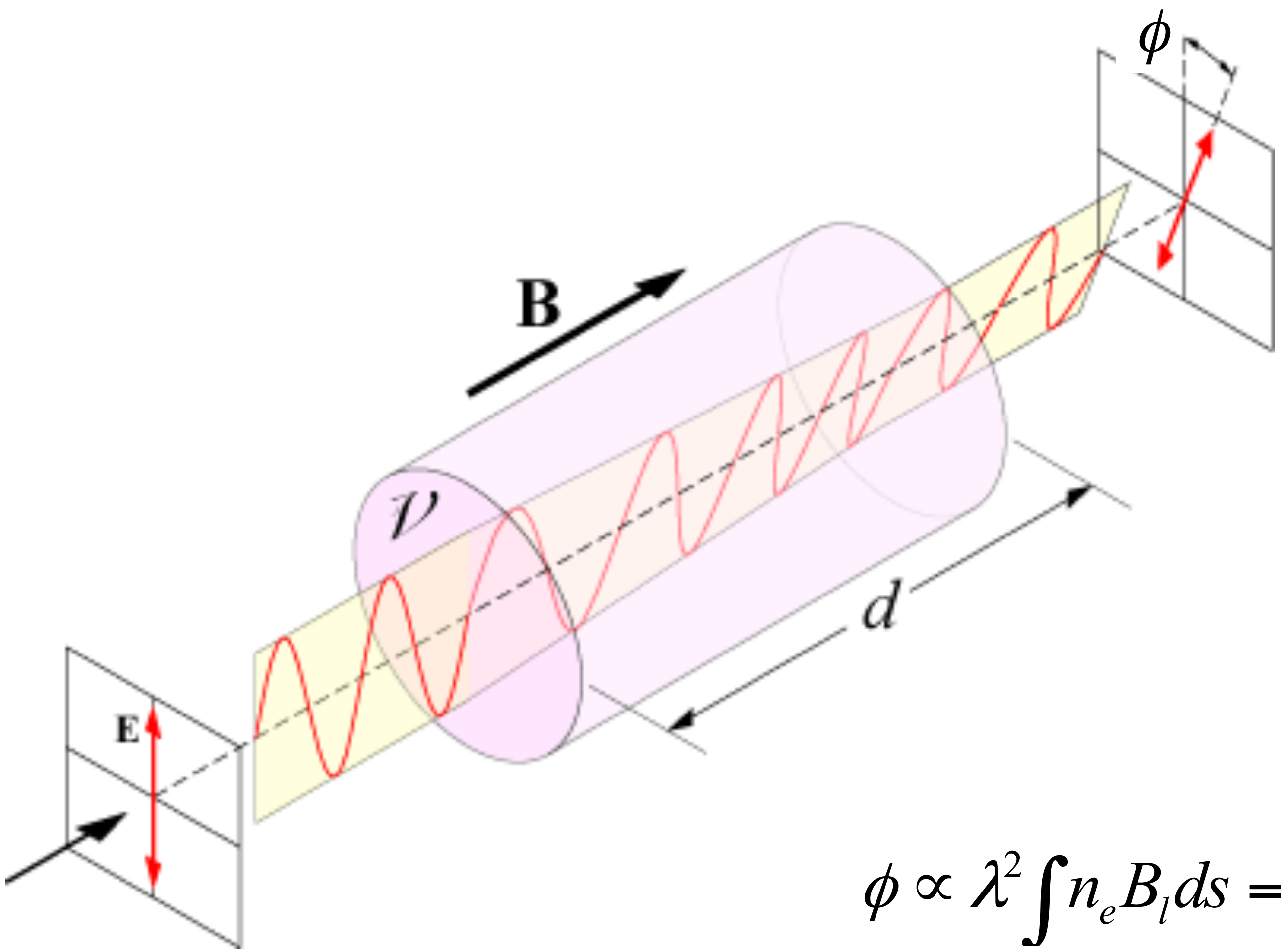
ALMA



Atmospheric transmission at Chajnantor, pwv = 0.5 mm
Transmission
Frequency [GHz]
1
0.8
0.6
0.4
0.2
0
200
400
600
800
1000
1
2
3
4
5
6
7
8
9
10
1.5 mm
0.75 mm
0.5 mm
0.375 mm

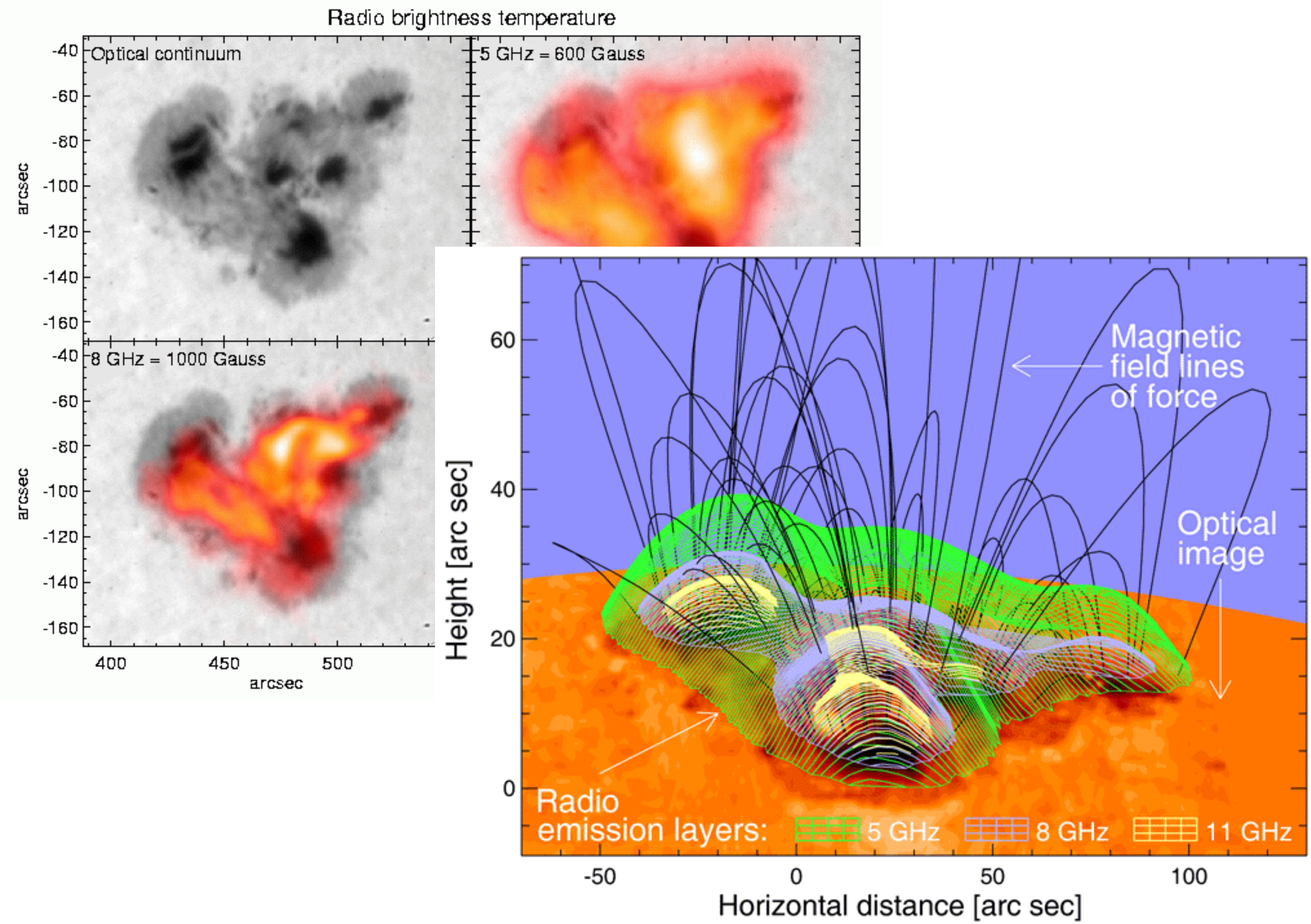


Avrett & Loeser 2008



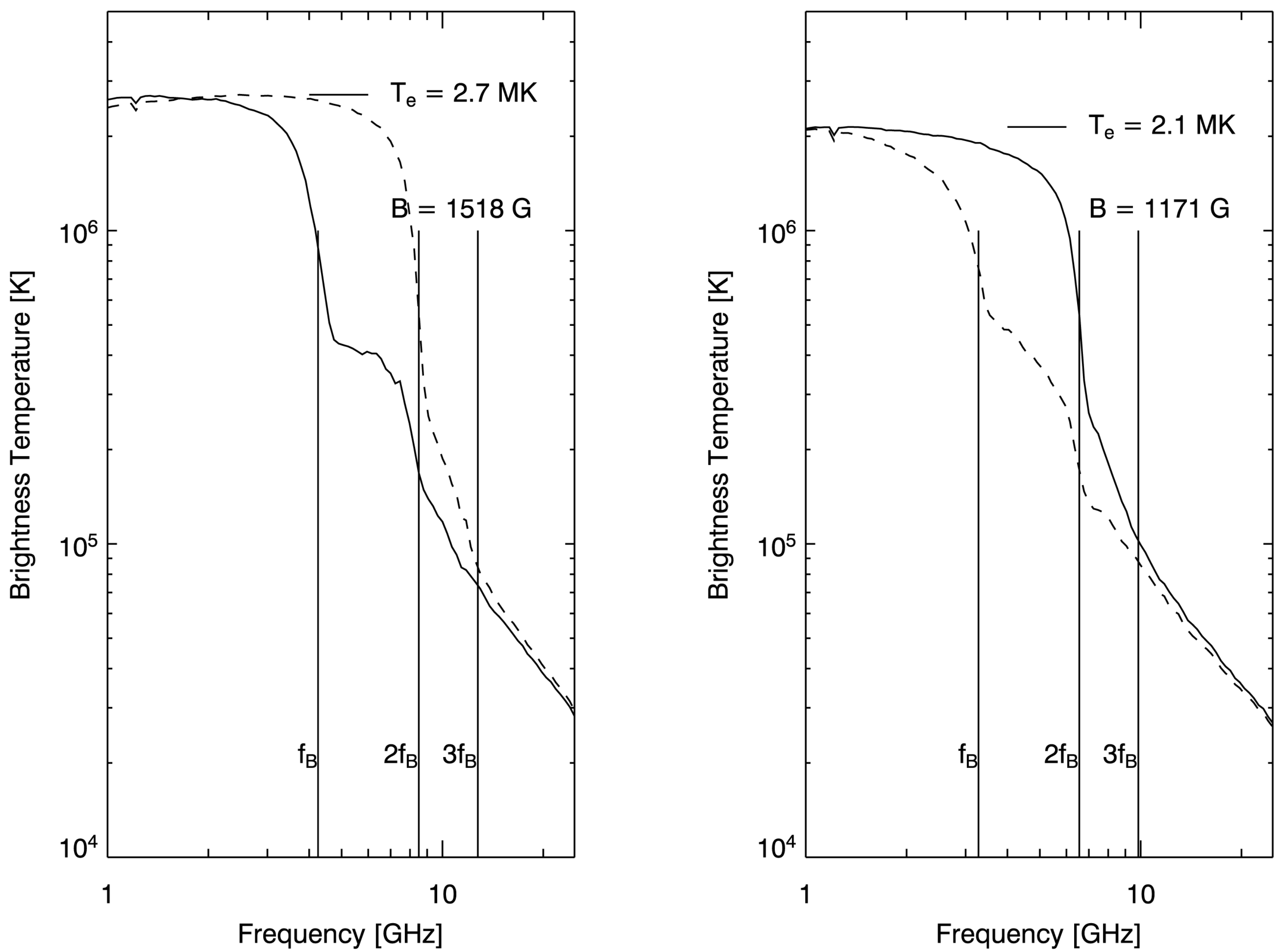
$$\phi \propto \lambda^2 \int n_e B_l ds = \lambda^2 RM$$

VLA



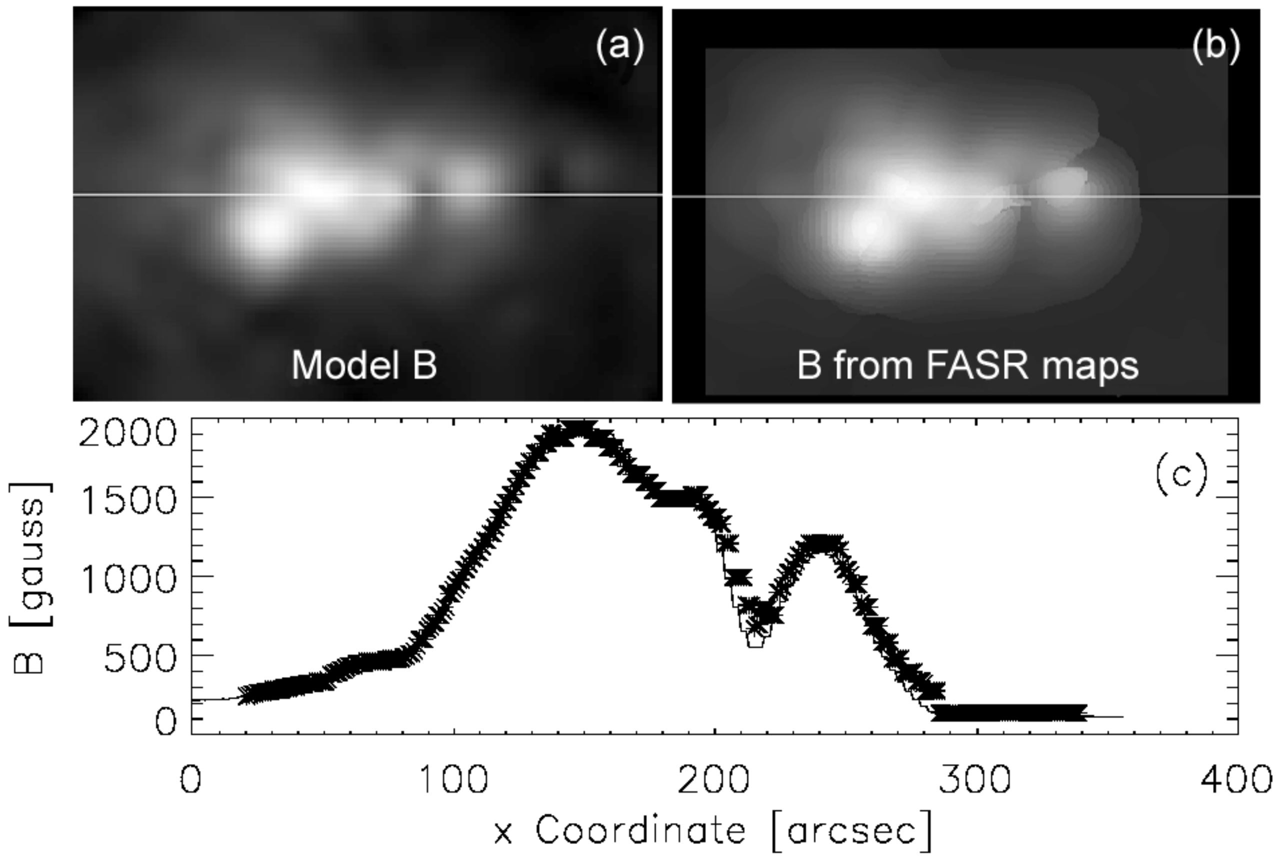
Radio brightness temperature
Optical continuum
5 GHz = 600 Gauss
8 GHz = 1000 Gauss
arcsec
arcsec
arcsec
-40
-60
-80
-100
-120
-140
-160
400
450
500
Magnetic field lines of force
Optical image
Radio emission layers:
5 GHz
8 GHz
11 GHz
Height [arc sec]
Horizontal distance [arc sec]
60
40
20
0
-50
0
50
100

Lee et al



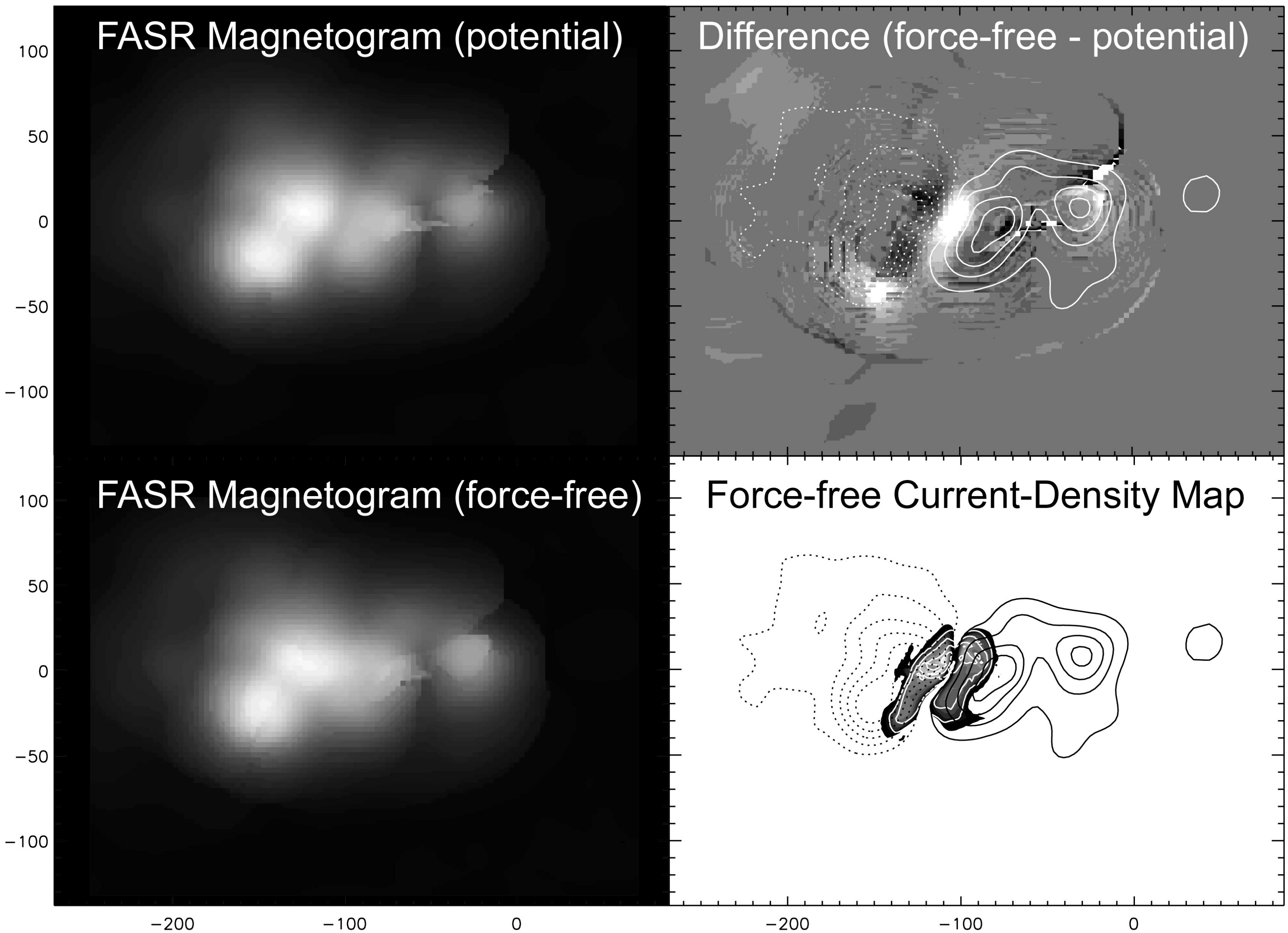
T_e = 2.7 MK
B = 1518 G
f_B
$2f_B$
$3f_B$
Brightness Temperature [K]
Frequency [GHz]
T_e = 2.1 MK
B = 1171 G
f_B
$2f_B$
$3f_B$
Brightness Temperature [K]
Frequency [GHz]

2D MAGNETOGRAM



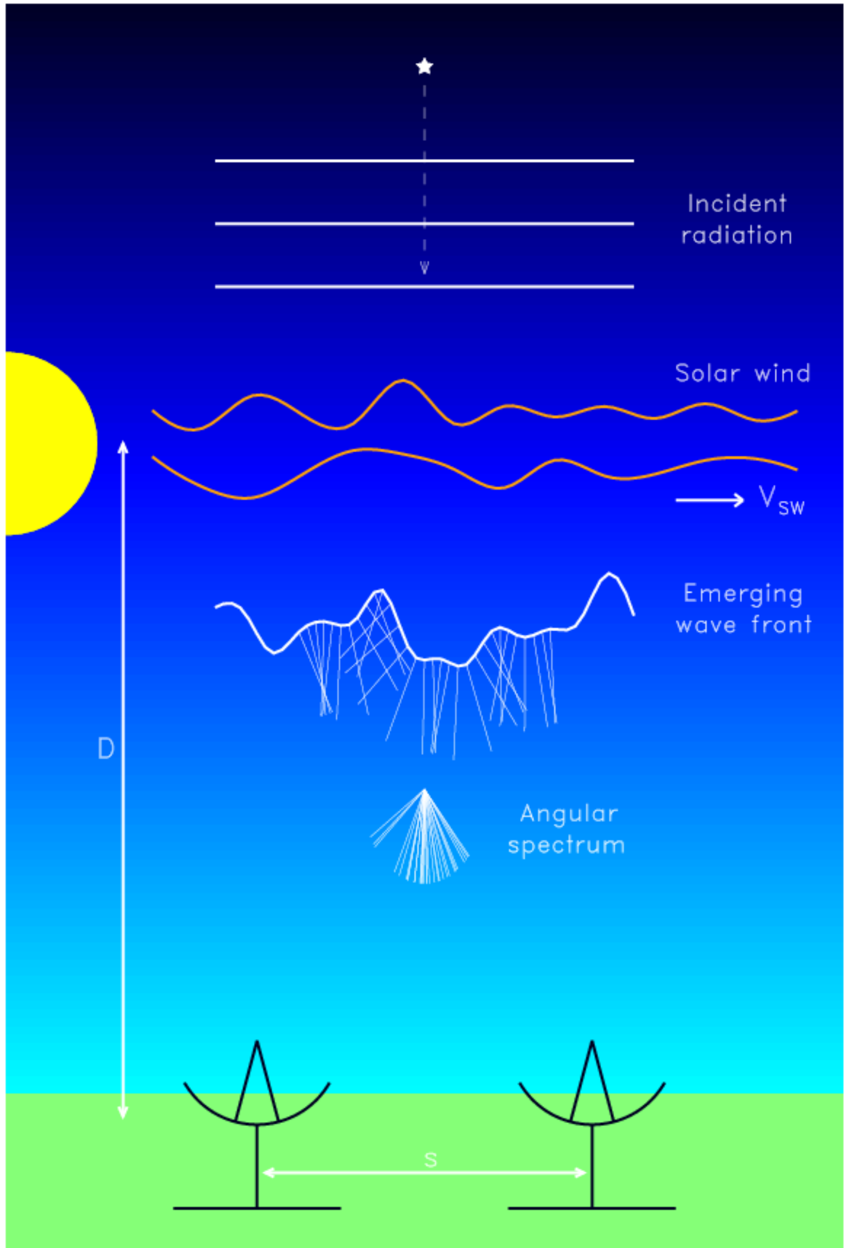
- *B* map deduced from 1—24 GHz spectra (*b*) match the model (*a*) very well, everywhere in the region. (*c*) is a comparison along a line through the center of the region.
- The fit only works down to 119 G (corresponding to $f = 3 f_B = 1$ GHz)

from Gary et al. 2004



FASR Magnetogram (potential)
Difference (force-free - potential)
FASR Magnetogram (force-free)
Force-free Current-Density Map
100
50
0
−50
−100
−200
−100
0

Angular broadening



Example:

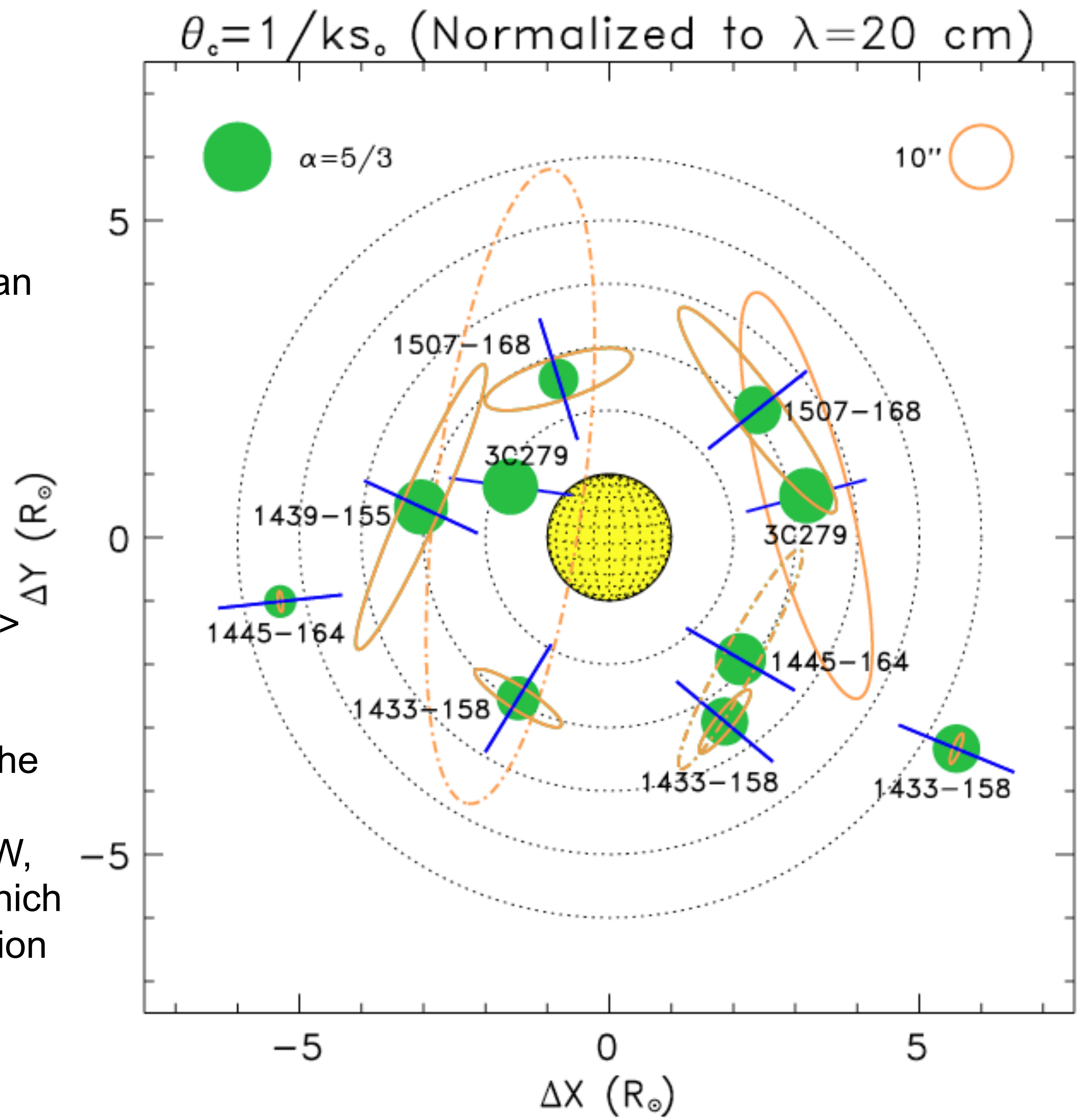
351 antenna pairs can be used to measure:

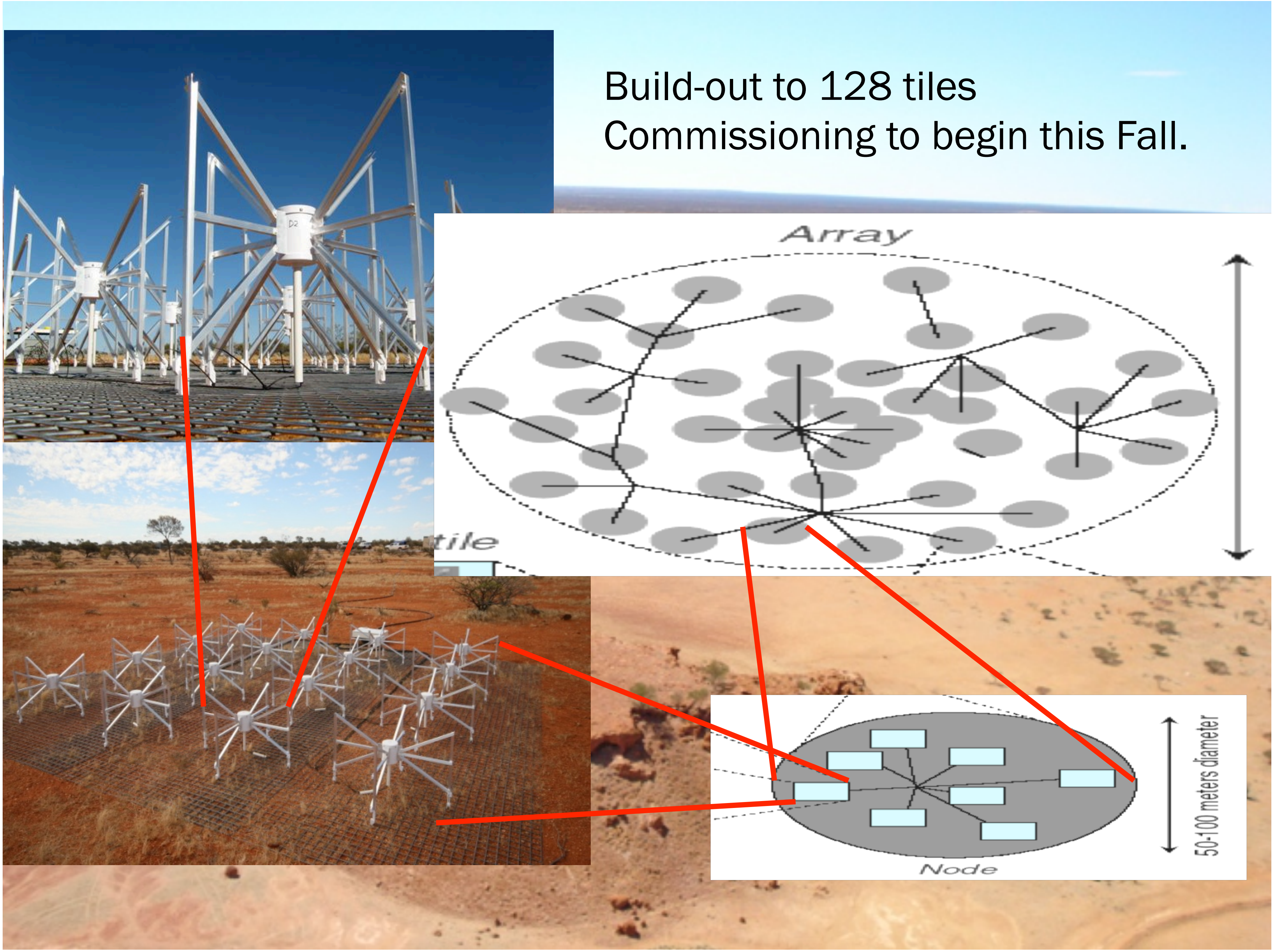
$$\Gamma(s)=\frac{\langle E(r)E^*(r+s)\rangle}{\langle|E^2|\rangle}$$

$$= \exp[-D(s)]$$

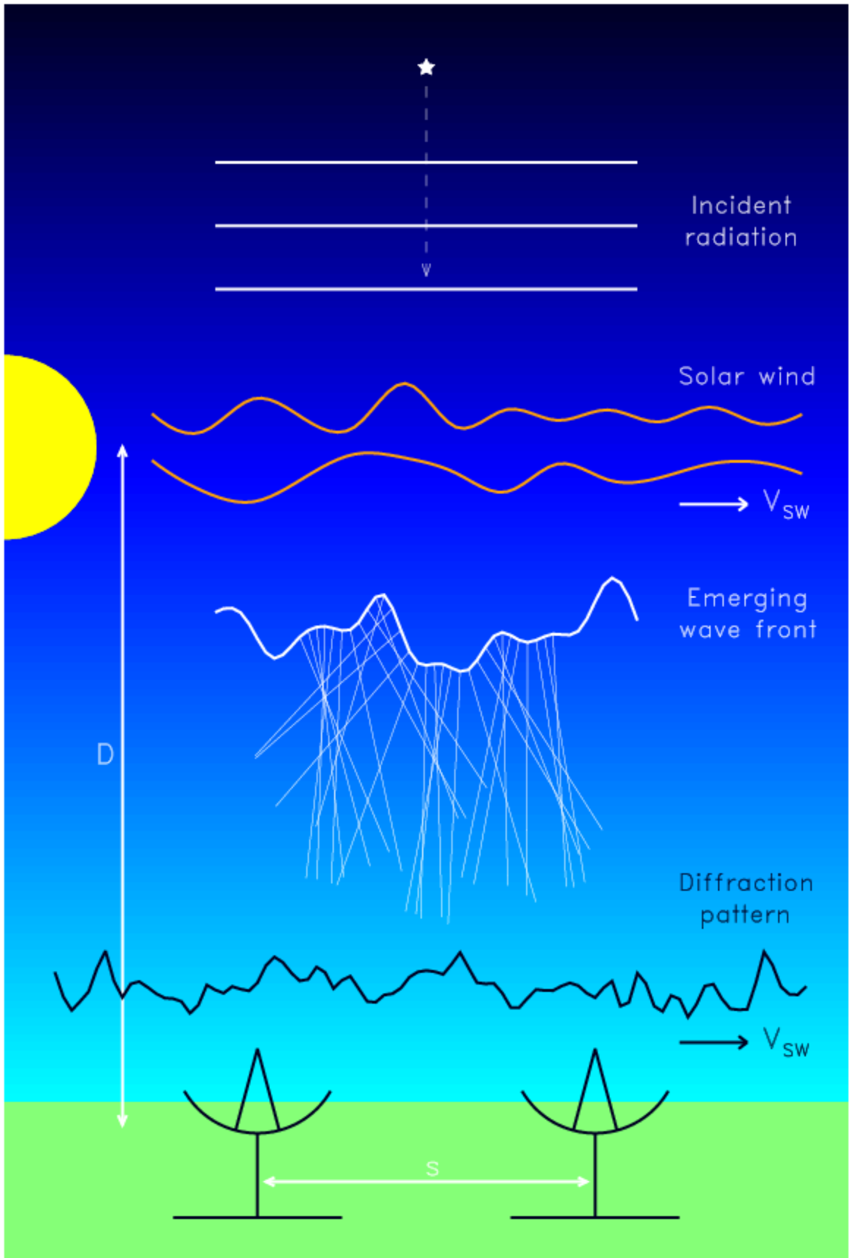
$$D(s)=\langle[\Phi(r)-\Phi(r+s)]^2\rangle$$

D(s) is related to the spatial spectrum of the electron density fluctuations in the SW, the parameters of which may be fit as a function of radius and P.A.

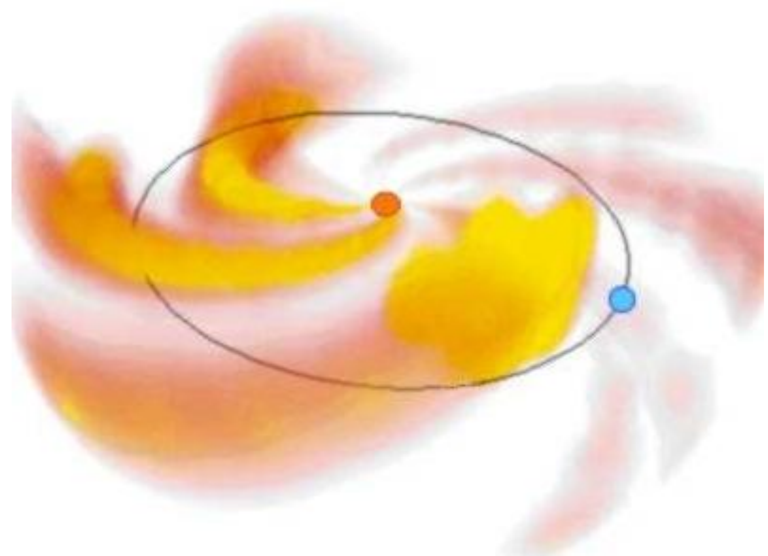




Build-out to 128 tiles
Commissioning to begin this Fall.
Array
tile
Node
50-100 meters diameter



Tomographic reconstruction of recurrent structures in the inner heliosphere using observations of inter-planetary scintillation (IPS).



LOFAR could provide much more comprehensive maps at higher angular resolution.

Jackson et al. 2001

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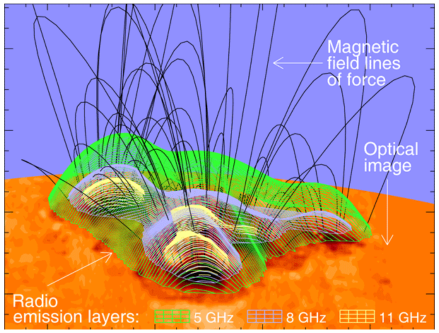
FREQUENCY AGILE SOLAR RADIOTELESCOPE

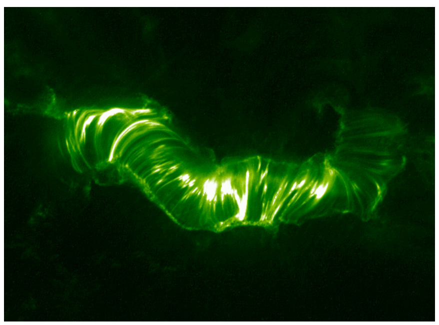
- FASR's fundamental innovation is the ability to perform ***dynamic, broadband, imaging spectroscopy*** over an extremely large frequency bandwidth – from 50 MHz to 21 GHz (or l=1.4 cm to 6 m).
- FASR therefore measures the polarized brightness temperature spectrum along every line of site as a function of time.
- By imaging the entire solar atmosphere at once, it will provide insights into these phenomena and processes as ***coupled phenomena.***

FASR SCIENCE OBJECTIVES



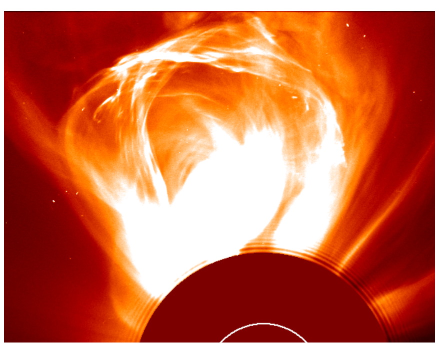
✓ **Nature & Evolution of Coronal Magnetic Fields**

- Coronal magnetography
- Temporal & spatial evolution of fields
- Coronal seismology



High energy solar physics

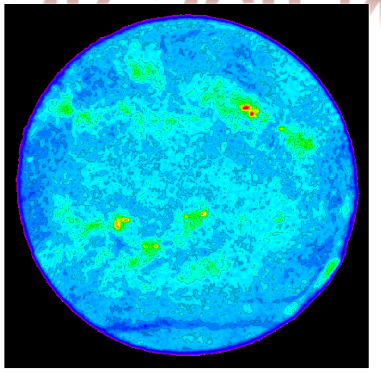
- Magnetic energy release
- Plasma heating and dynamics
- Electron acceleration and transport



Drivers of Space Weather

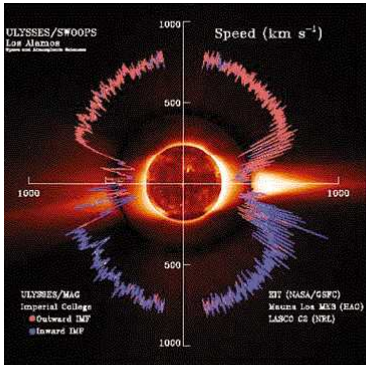
- Birth & acceleration of CMEs
- Prominence eruptions
- Origin of energetic particles

FASR SCIENCE OBJECTIVES



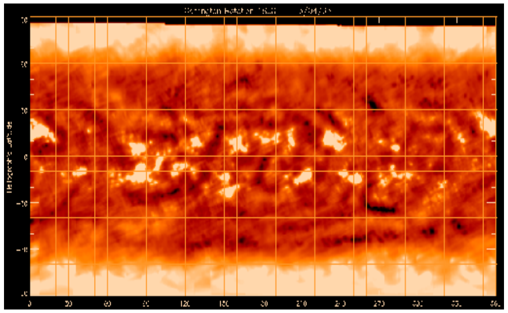
The "thermal" solar atmosphere

- Coronal & chromospheric heating
- Thermal structure & dynamics
- Formation & structure of filaments
- Spicules, jets



The Solar Wind

- Solar wind sources
- Coronal holes and fast solar wind

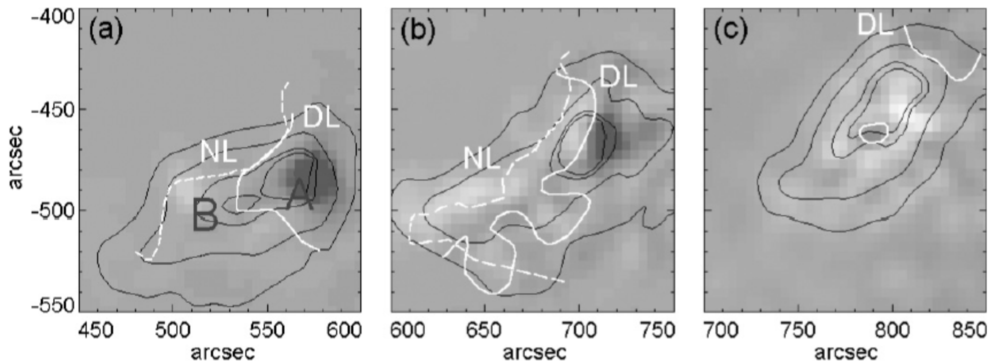


Synoptic Studies

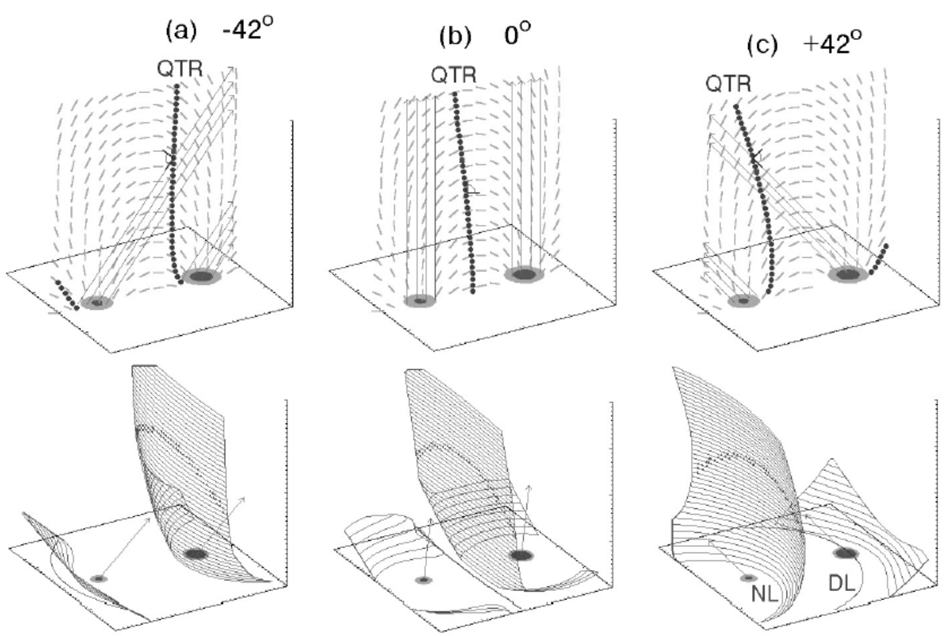
- Radiative inputs to the upper atmosphere
- Global magnetic field & dynamo
- Flare statistics

[redacted]

MAGNETIC TOPOLOGY FROM QT LAYER

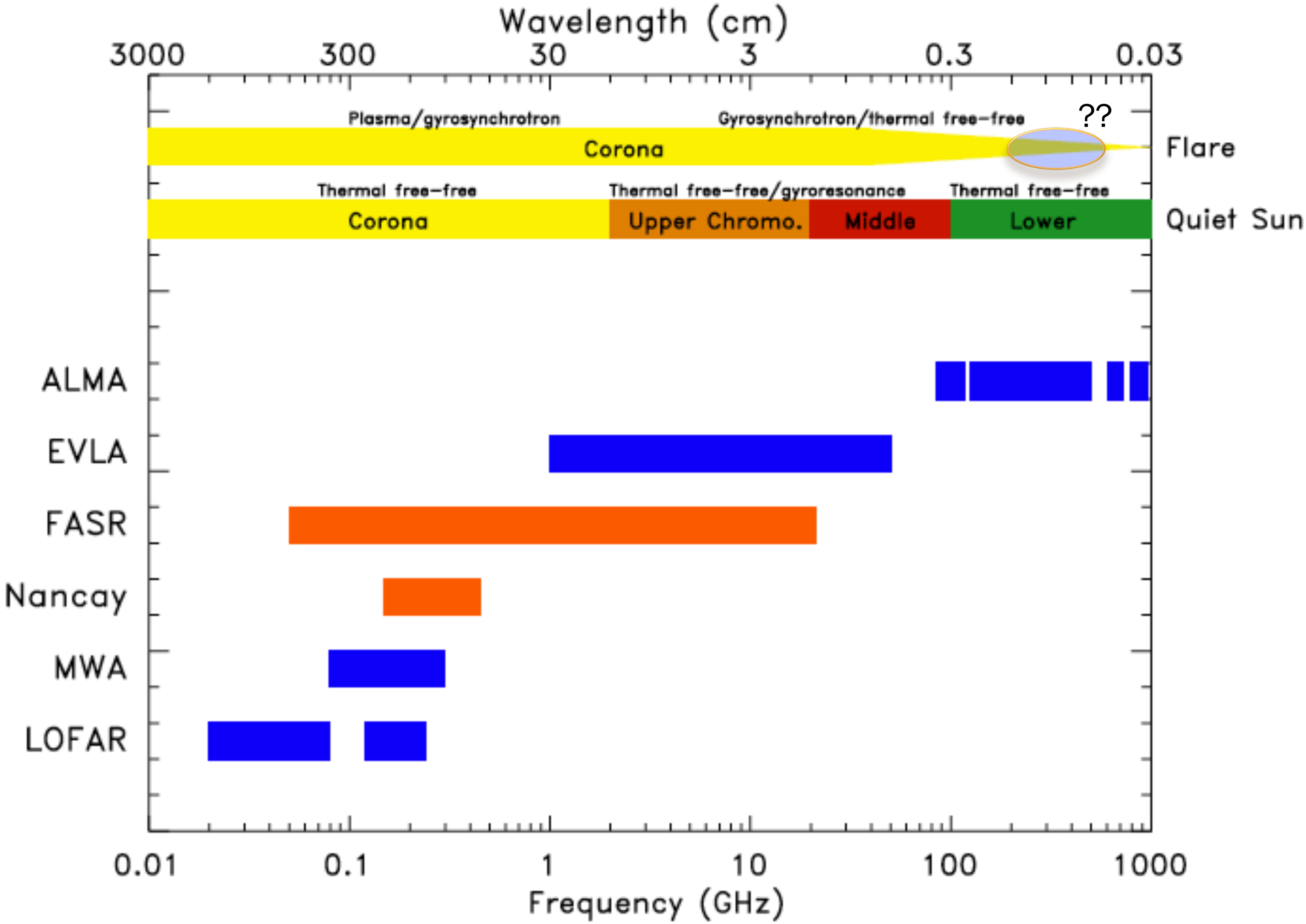


- Upper panels show radio "depolarization line" at a single frequency due to mode-conversion at a quasi-transverse layer, vs. photospheric neutral line.



- Using FASR's many frequencies, a QT surface can be mapped in projection. The surface changes greatly with viewing angle.

from Ryabov, 2004—Chapter 7


Wavelength (cm)
3000
300
30
3
0.3
0.03
Plasma/gyrosynchrotron
Gyrosynchrotron/thermal free-free
??
Corona
Flare
Thermal free-free
Thermal free-free/gyroresonance
Thermal free-free
Corona
Upper Chromo.
Middle
Lower
Quiet Sun
ALMA
EVLA
FASR
Nancay
MWA
LOFAR
0.01
0.1
1
10
100
1000
Frequency (GHz)