SIRA and scattering in the IPM

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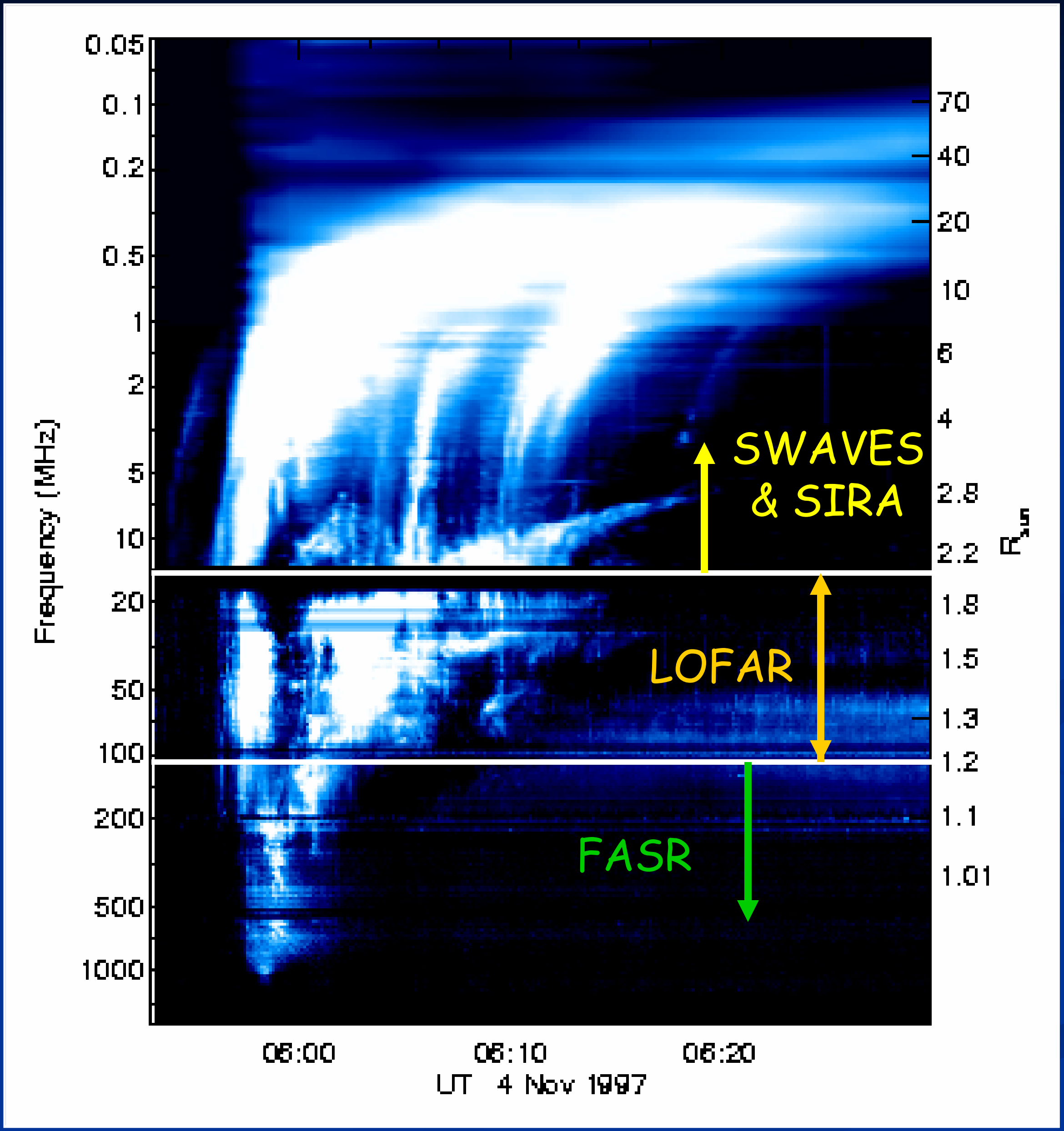
Plan of the Talk

- Relevant emission mechanisms?
- Propagation phenomena (scattering)
- Zeroeth order implications for SIRA
- Conclusions

space

ionosphere

ground



Dulk et al. 2001

Emission mechanisms

- Thermal free-free radiation?

  50 km array: S ~ 1.3 T_6 Jy/beam
- Nonthermal gyrosynchrotron radiation?

  self-absorption

  free-free absorption   all act to absorb/supress

  Razin suppression   GS emission
- Plasma radiation

  electrostatic plasma oscillations

  emission at ν_{pe}, $2\nu_{pe}$ ($\nu_{pe}=9n_e^{1/2}$ kHz)

  will be the dominant player

Scattering in the IPM

The solar corona and IPM are complex media characterized by:

- Large scale density gradients

  background corona and solar wind

  Refraction/reflection

- Large scale structures

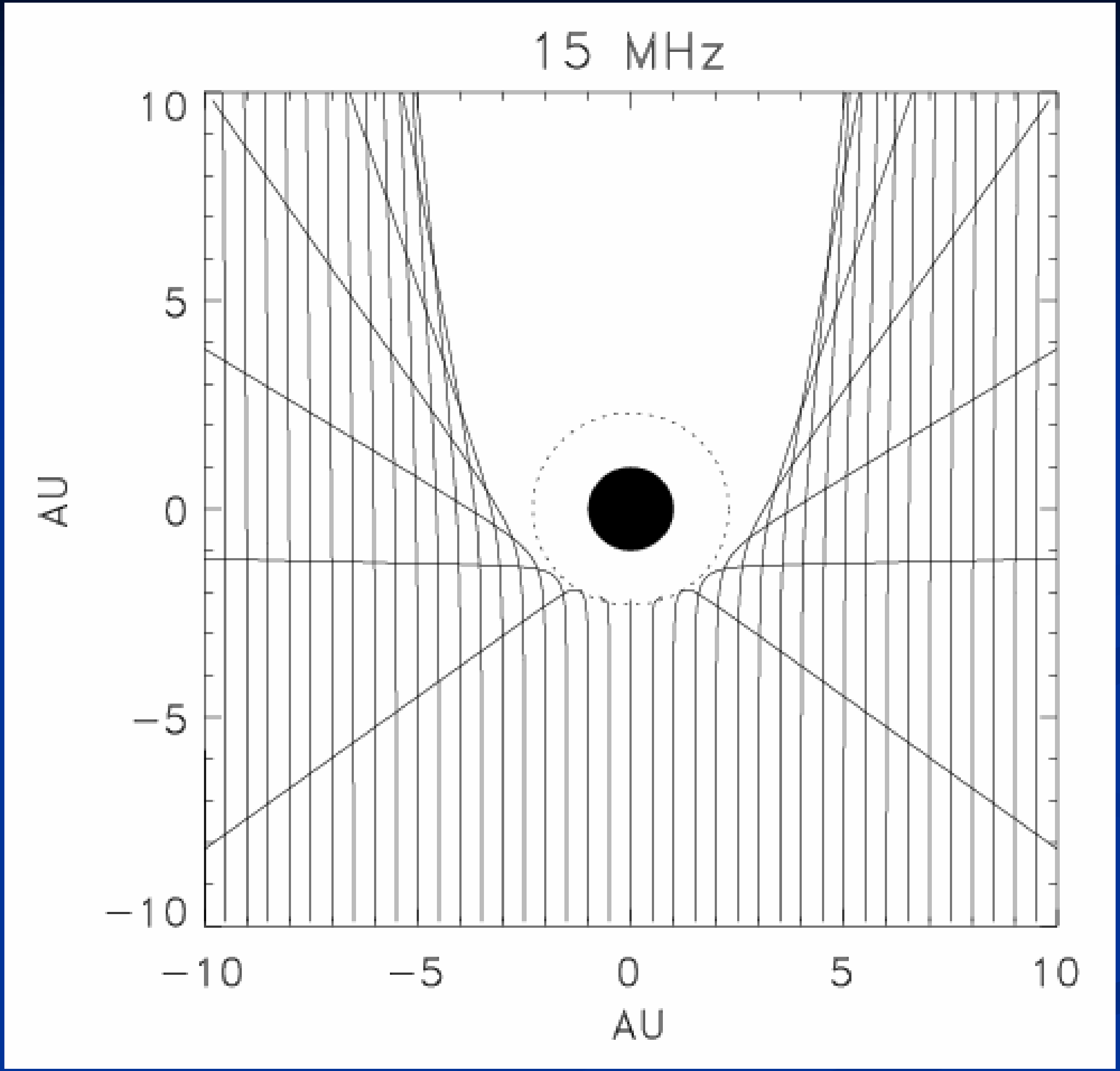
  streamers, coronal holes

  fast/slow solar wind streams

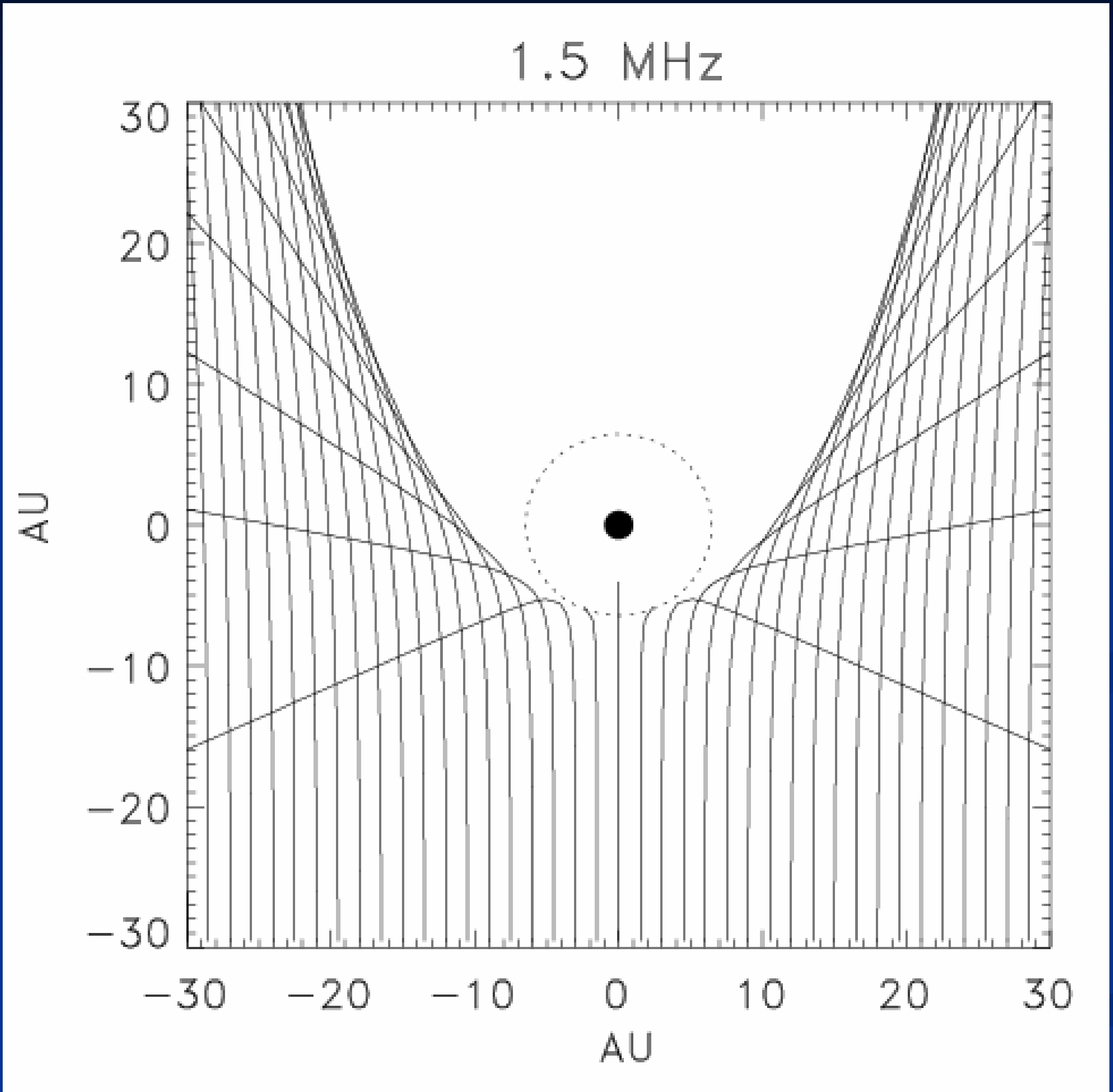
- Small scale density inhomogeneities

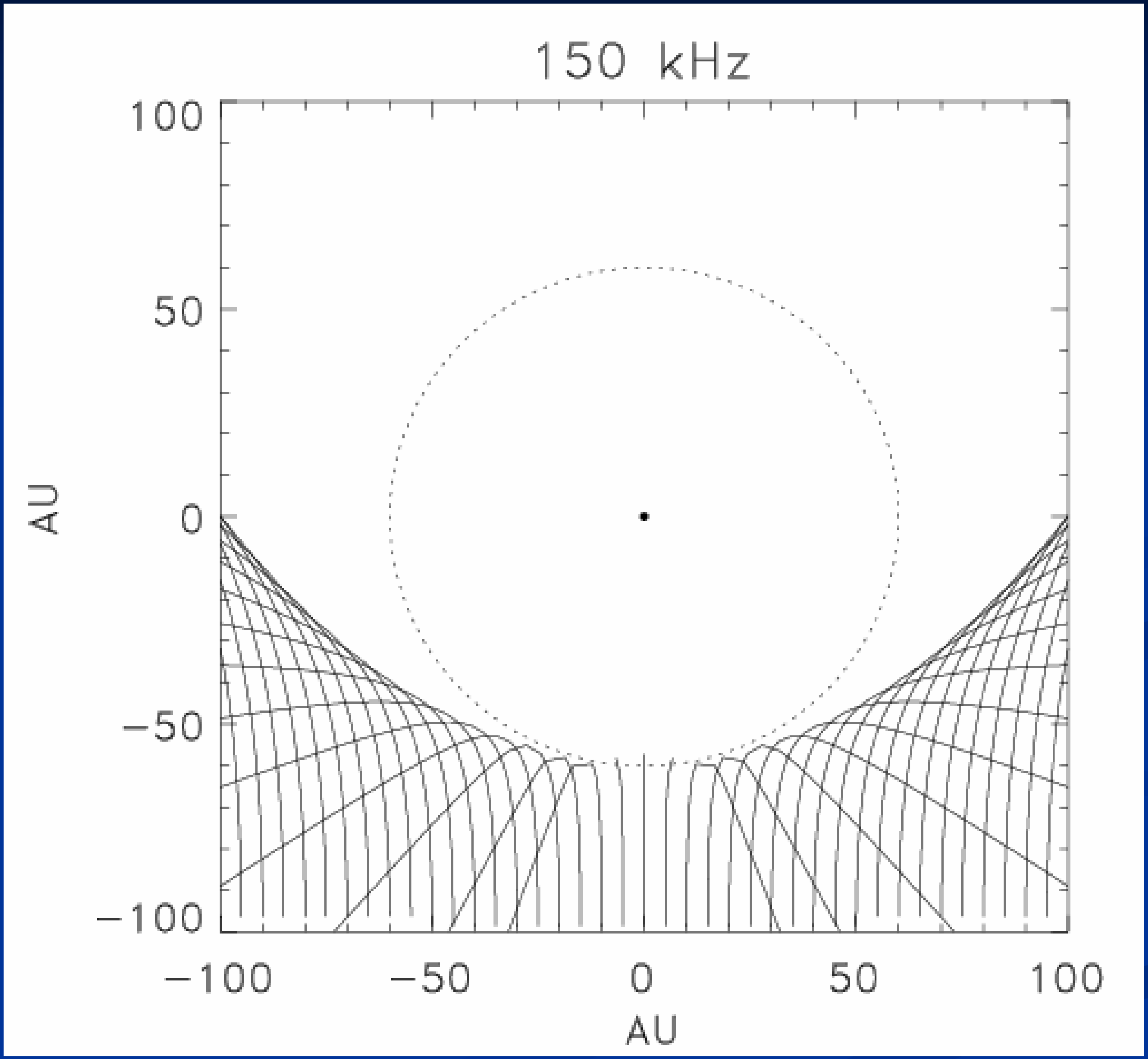
  magnetic field

  turbulence and waves



15 MHz
10
5
0
−5
−10
AU
−10
−5
0
5
10
AU


1.5 MHz
30
20
10
0
−10
−20
−30
AU
−30
−20
−10
0
10
20
30
AU


150 kHz
100
50
0
−50
−100
AU
−100
−50
0
50
100
AU

Scattering in the IPM

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  Refraction/reflection

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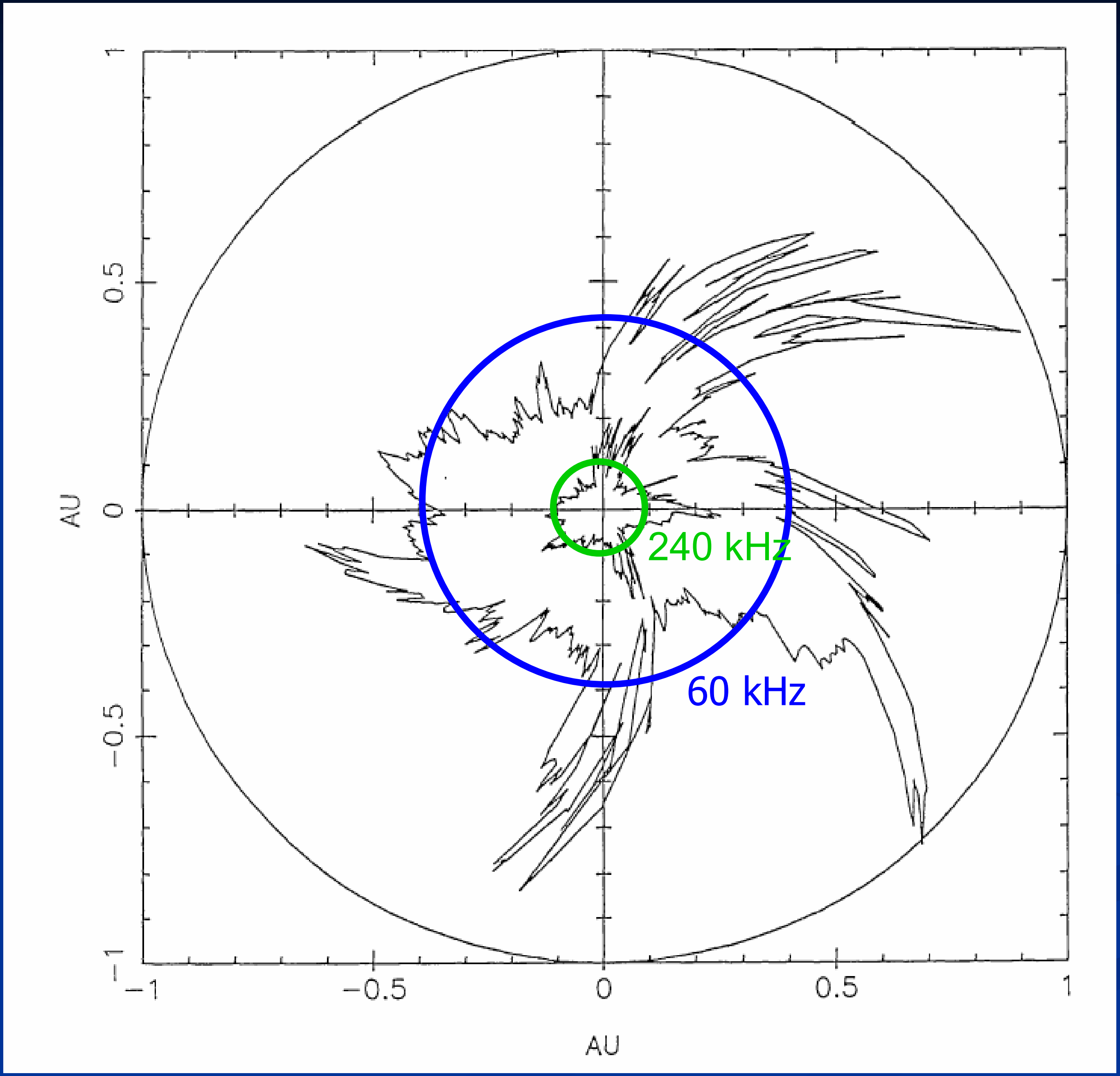
  magnetic field

  turbulence and waves



The reality

Large scale structures serve to reflect and refract source emissions.

This can result in apparent position offsets and/or distortions of the radio brightness distribution.

Lecacheux et al 1989

Scattering in the IPM

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  streamers, coronal holes

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- Small scale density inhomogeneities

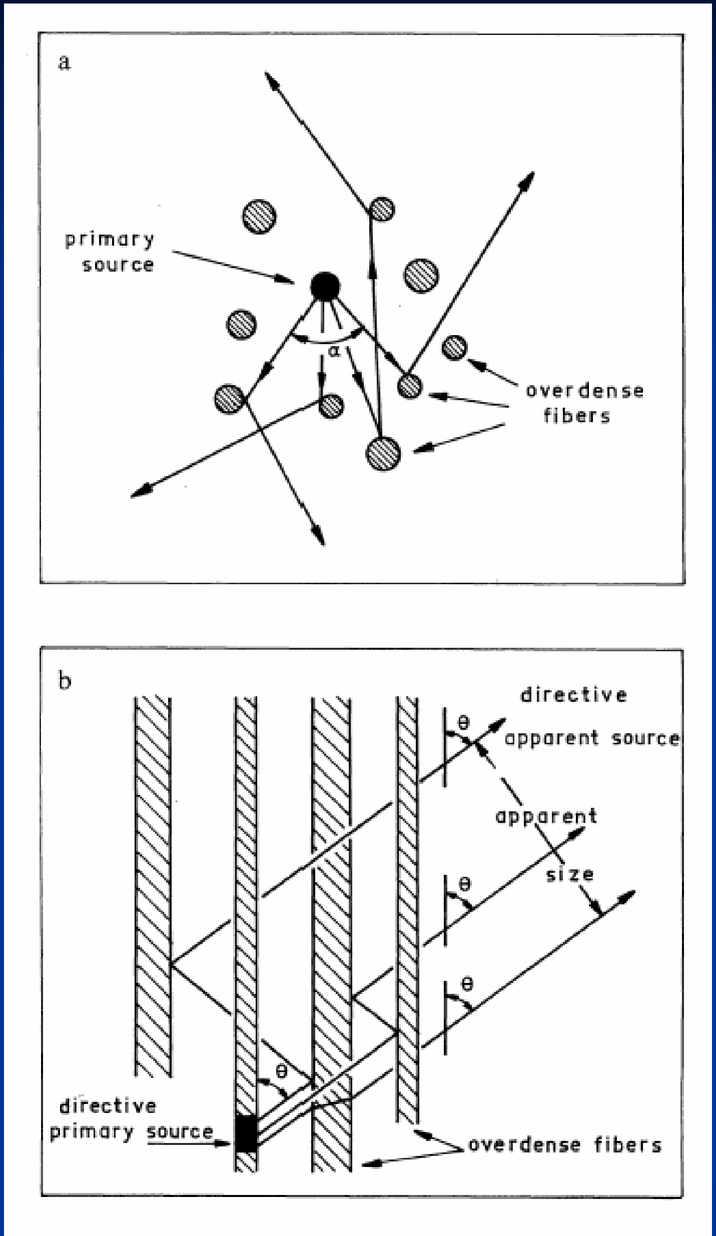
  magnetic field

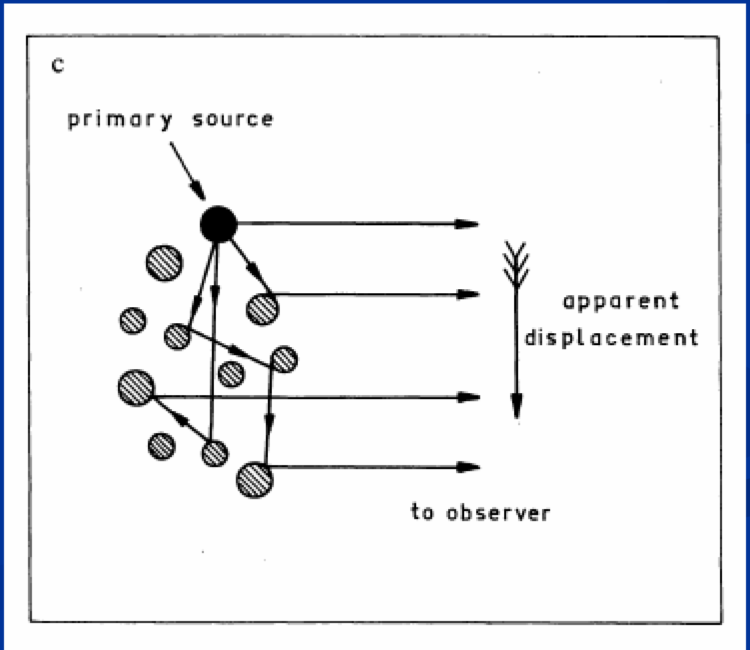
  reflection (ducting)

  turbulence and waves

“Ducting”

(Bougeret & Steinberg 1977)





The presence of small scale inhomogeneities can result in a variety of scattering phenomena at radio wavelengths. These include:

- Scattering

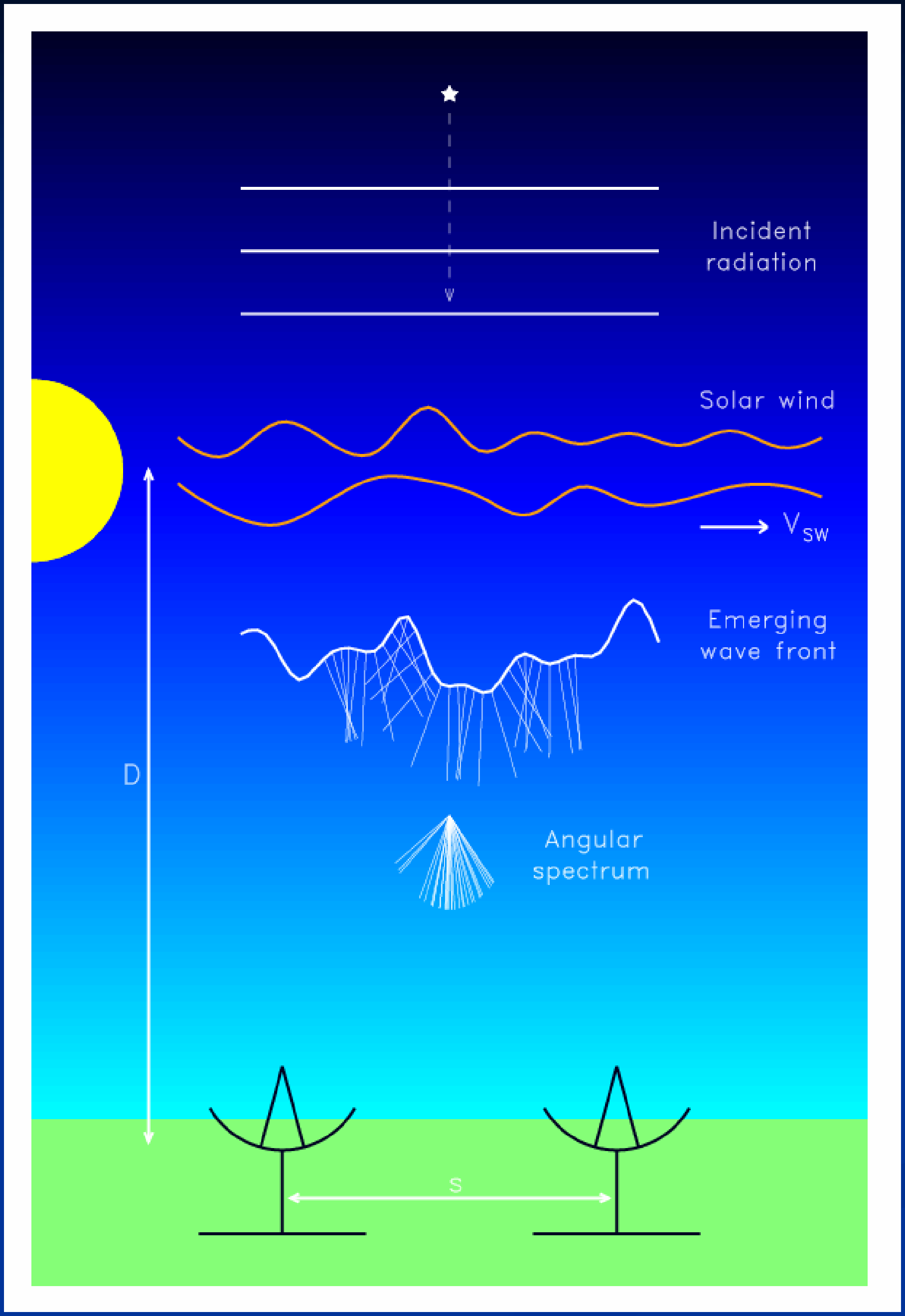
  angular broadening

  spectral broadening

  temporal broadening

  scintillations

For the purposes of this talk I will just say a few words angular broadening but will ignore most other phenomena.



Angular Broadening

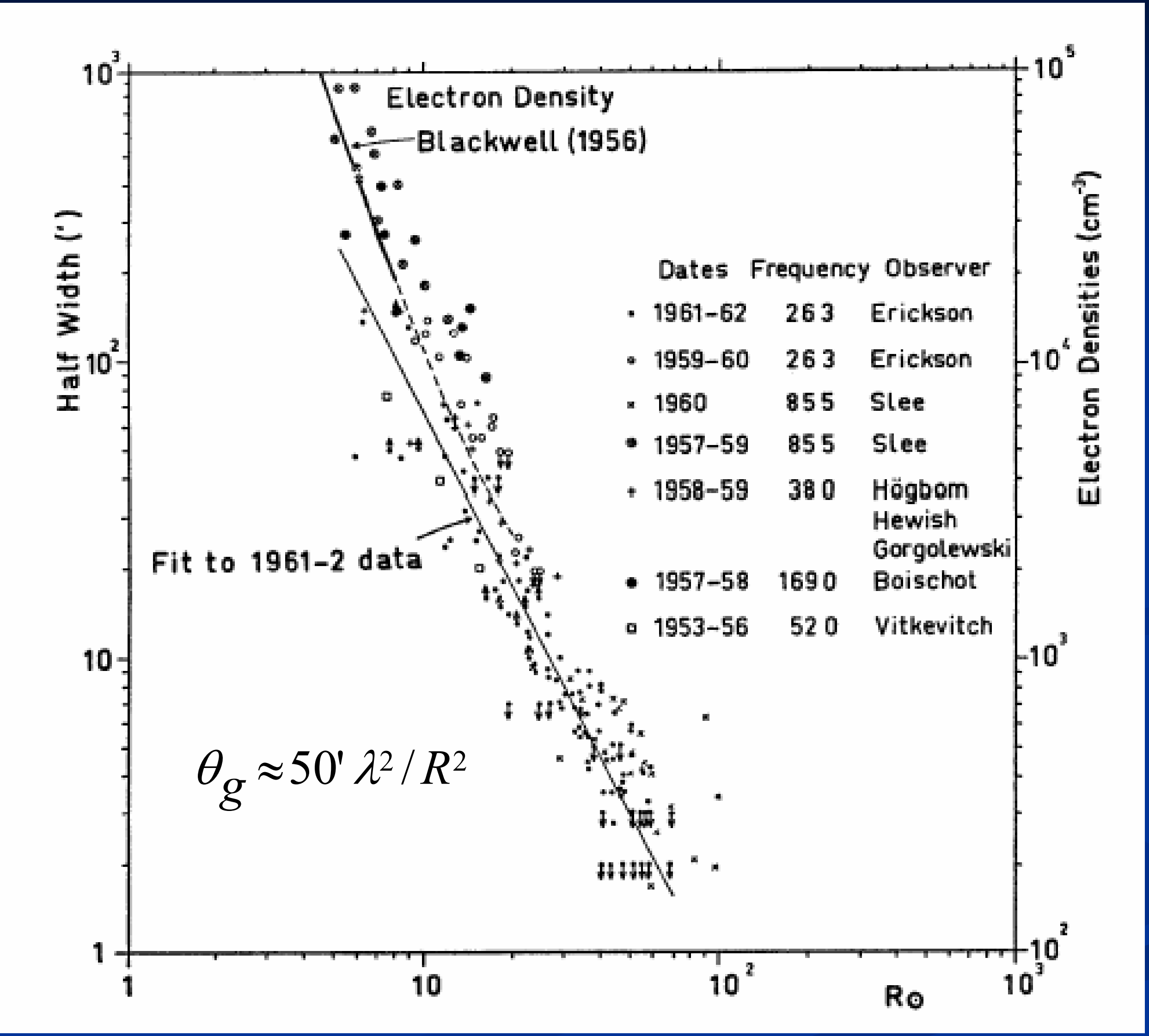
- o Consider a plane wave incident on the solar wind
- o Density inhomogeneities cause inhomogeneities in the refractive index
- o These, in turn, impress phase irregularities on the incident wave
- o Taking the direction of the wave at any location to be the direction of the local phase front, we see that the solar wind has scattered the wave into an angular spectrum
- o The width of the angular spectrum depends on the details of the spatial spectrum of electron density inhomogeneities and the wavelength

Some simple estimates

- PWE formalism (small angle forward scattering)
- Simple power law assumed for spatial spectrum of electron density inhomogeneities
- Inhomogeneities assumed to be isotropic
- Instrument baselines assumed to be less than the (projected) inner scale
- Spectrum normalized to minimum corona

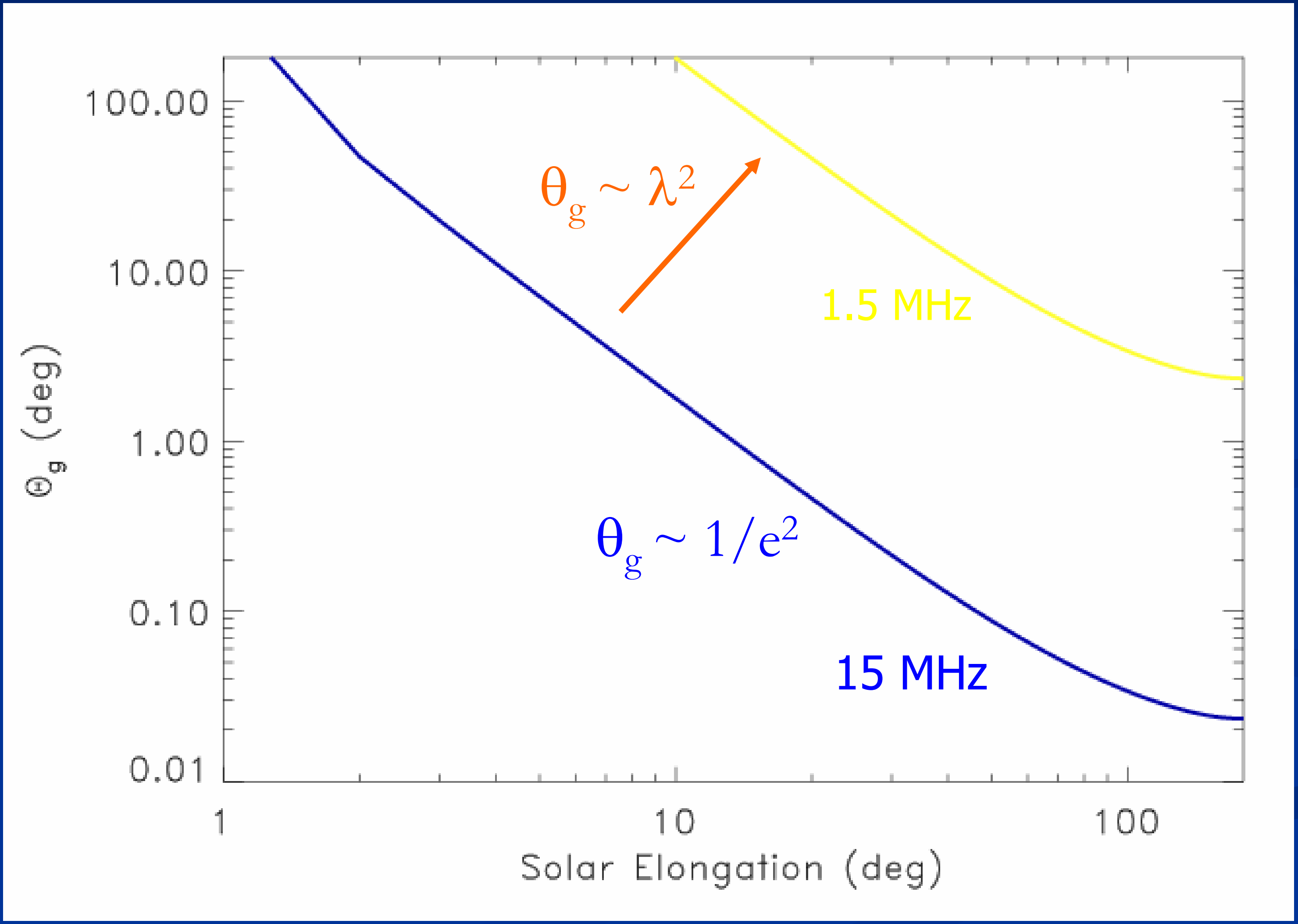
This does not tell the whole story! Note that Dulk et al. (1985) and Lecacheux et al. (1989) report type IIIs detected on the opposite side of the Sun from the receiver!!

Angular broadening measurements of background sources by the IPM

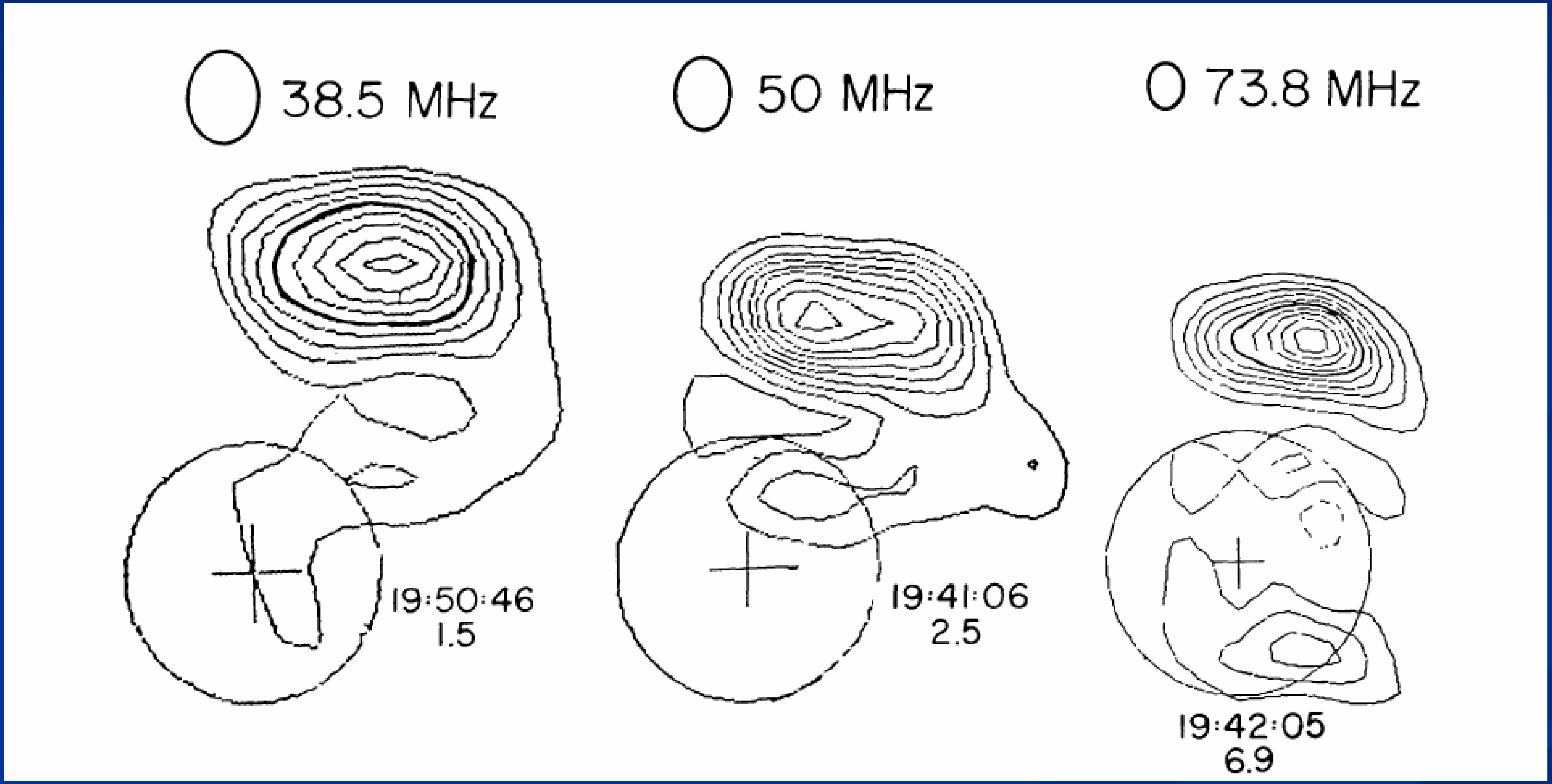


Erickson 1964

Angular broadening of background sources

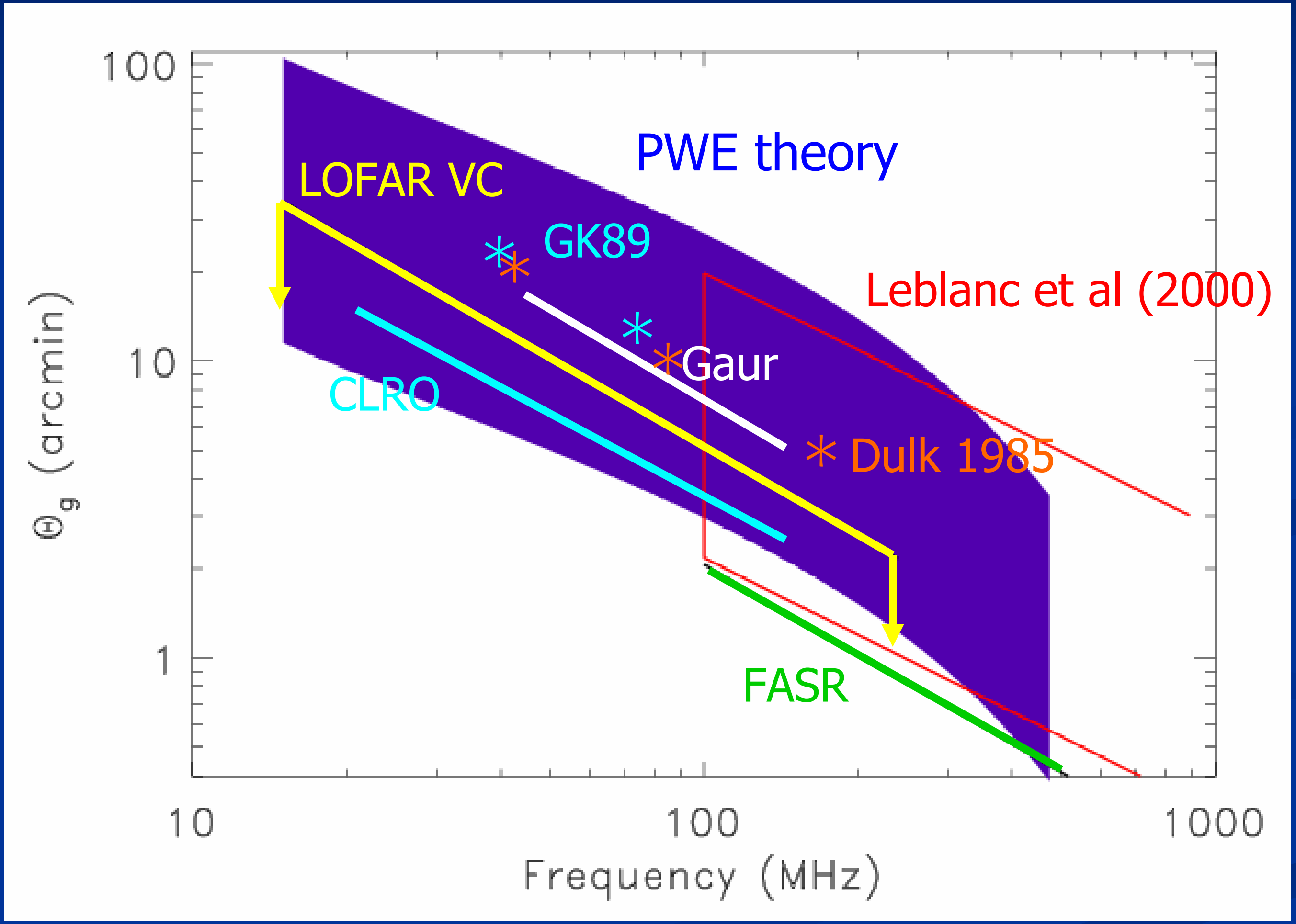


Clark Lake Radio Observatory



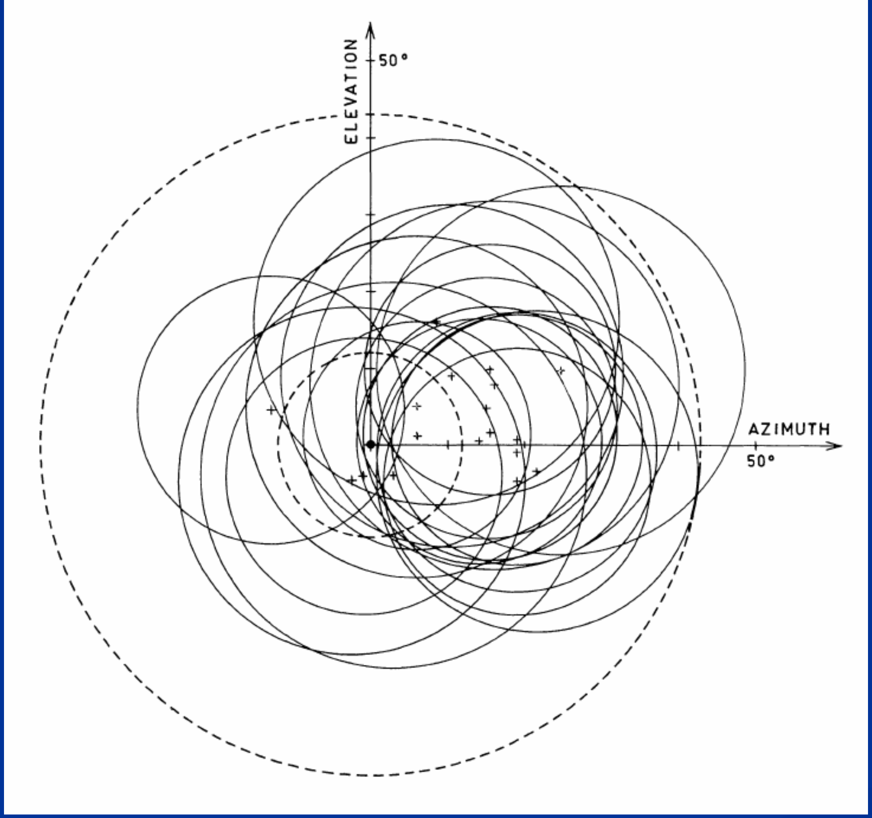
Gopalswamy & Kundu 1989

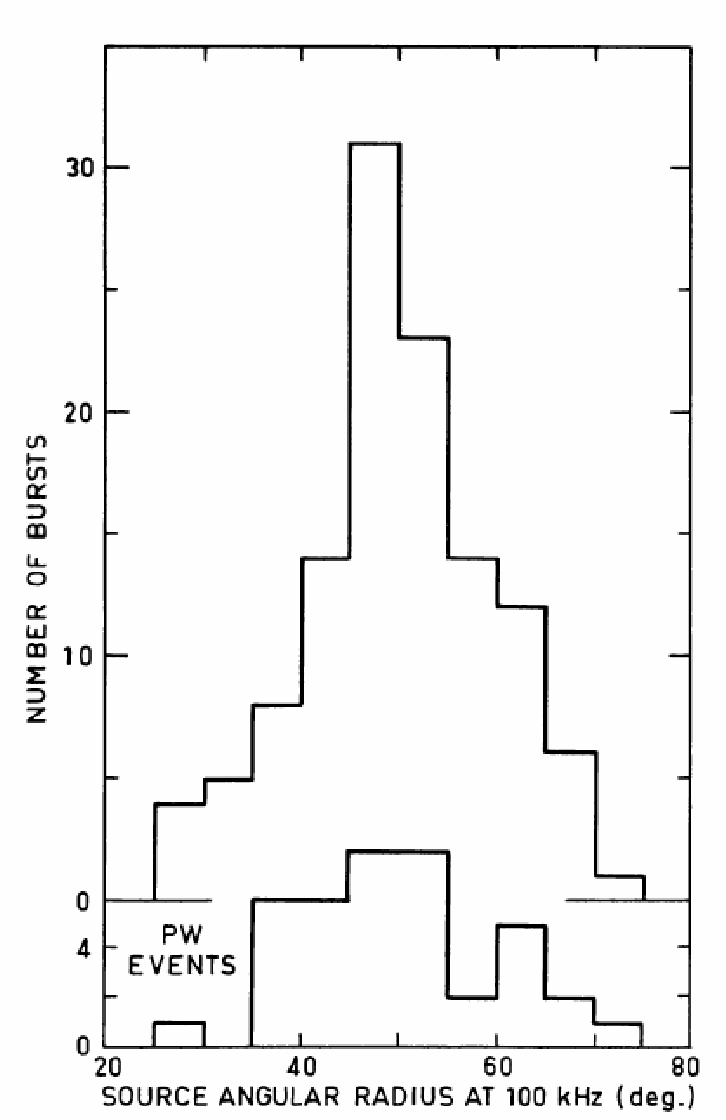
Angular broadening of solar radio sources by coronal turbulence

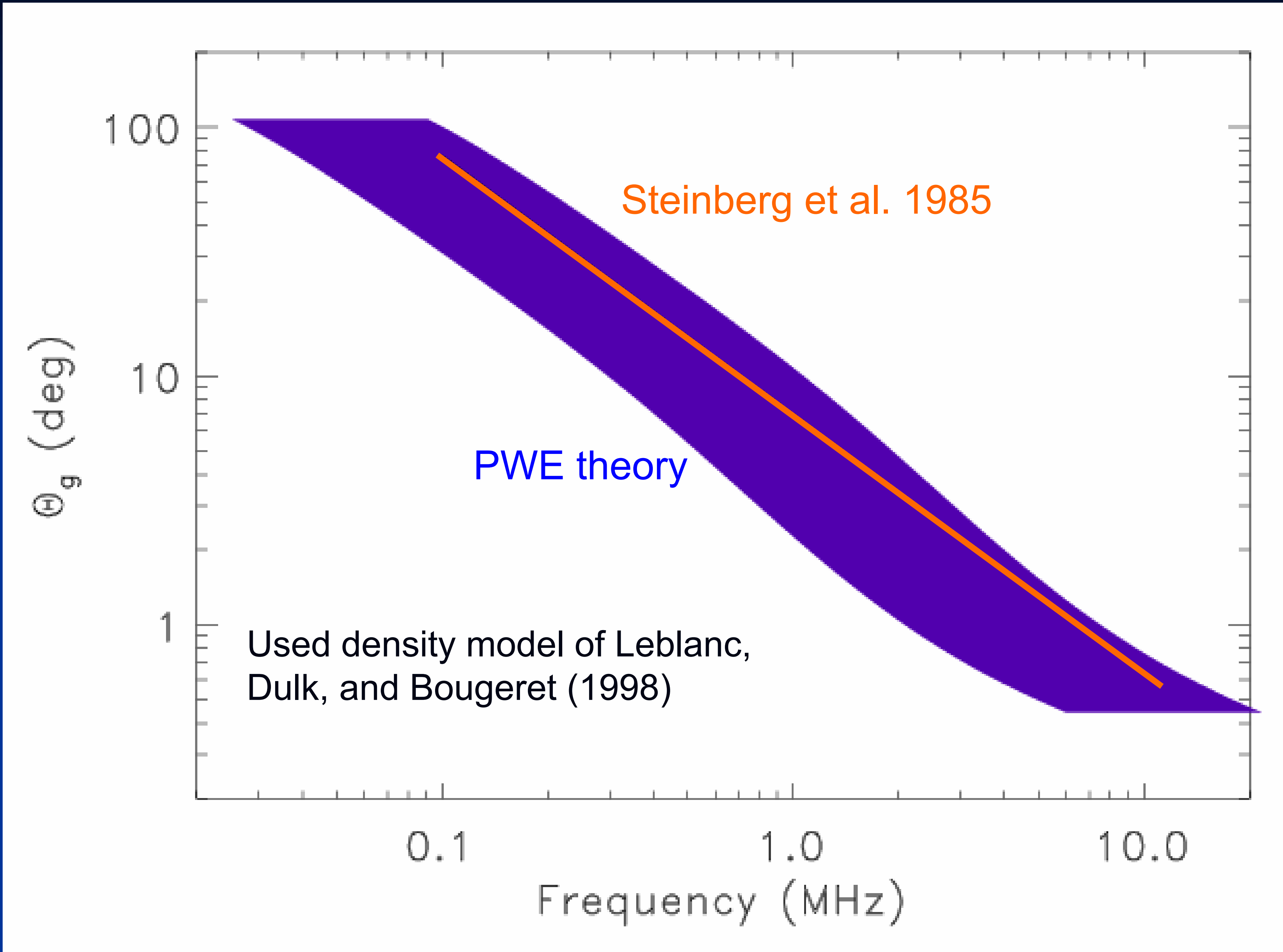


Conclusion: LOFAR baselines longer than ~3 km not needed.

Steinberg et al. 1985







100
10
1
Θ_g (deg)
Steinberg et al. 1985
PWE theory
Used density model of Leblanc, Dulk, and Bougeret (1998)
0.1
1.0
10.0
Frequency (MHz)

Some Implicaitons

- SIRA is nominally 50 km in size, 12-16 antennas configured for uniform sampling
- The minimum antenna spacing would therefore be ~10 km
- This configuration would resolve out all solar/heliospheric phenomena
- The configuration should be scaled down by one order of magnitude (~5 km)
- It is extremely important to define SIRA science* and to simulate SIRA science – including all propagation effects - in order to optimize the frequency range, the antenna configuration, etc.

* Including requirements for astrophysics!