Observations of Interplanetary Scintillation with the Murchison Widefield Array

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MWA SHI collaboration

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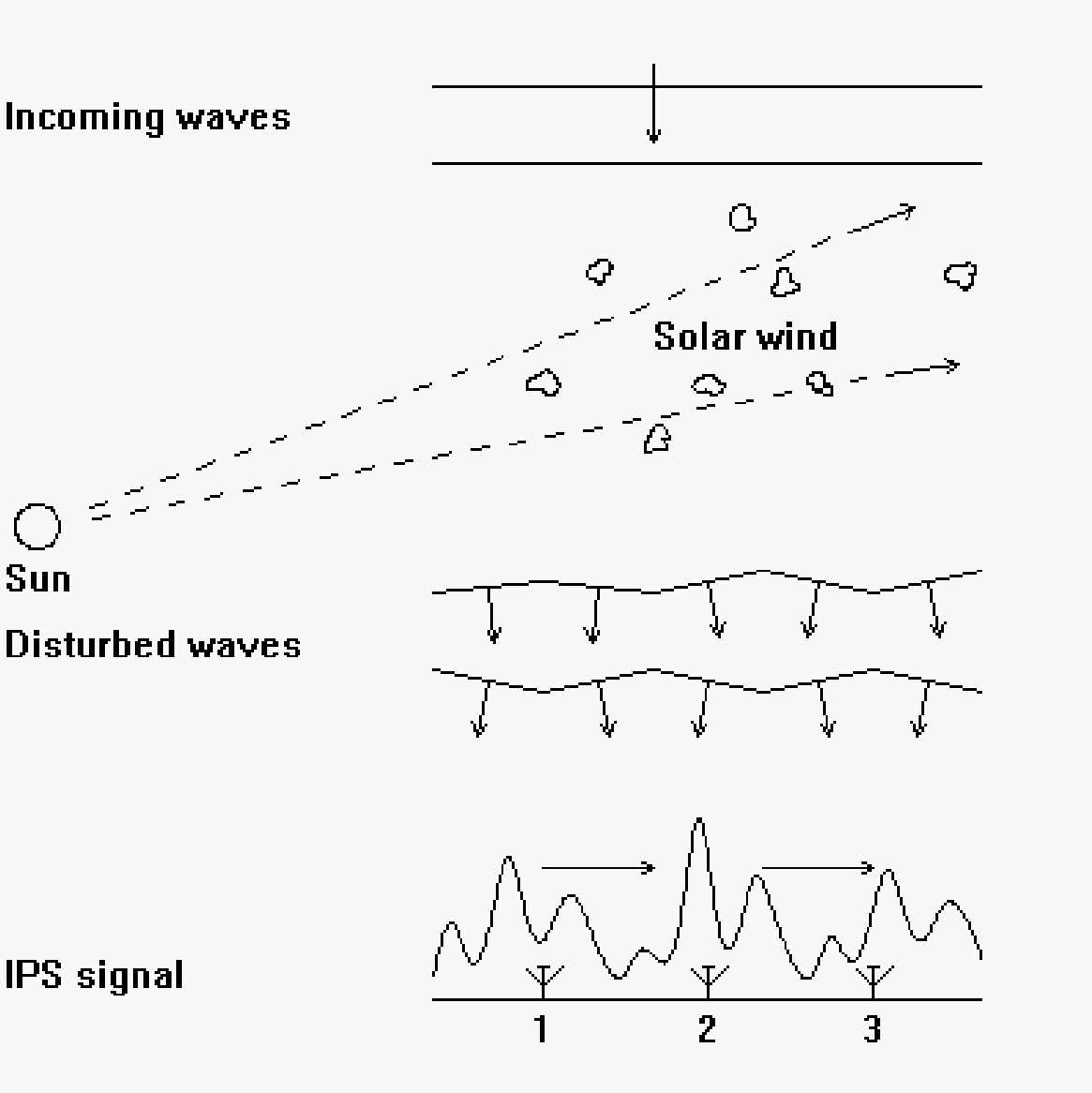
Discovery

- Margaret Clarke discovered short-term variability of some sources.
  - All but one sources showing this behaviour were known to be $< 2''$
  - All but one which didn't were known to be $> 3''$

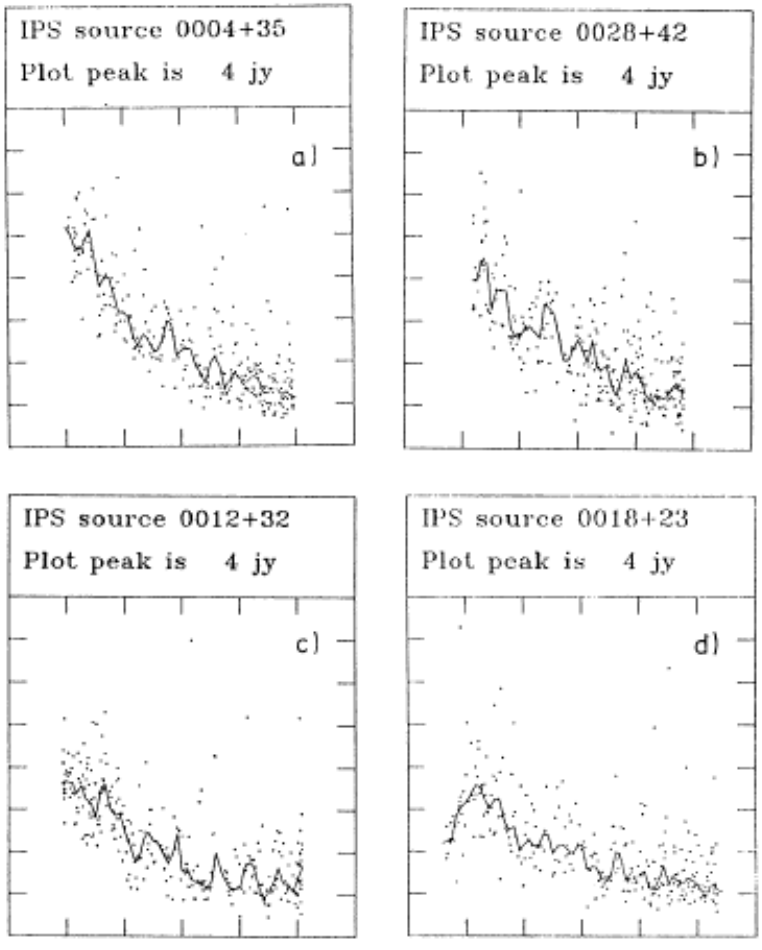
"If some mechanism similar to that which causes scintillations is operating, the lateral scale of the irregularities must be on the scale of 1km and if no fluctuations are observed when the source diameter is greater than about $5''$ it can be estimated that the irregularities must be more than 30 000 km away . . . it is not inconceivable that the phenomenon is associated with solar corona effects" Margaret Clarke (PhD Thesis 1964)]

IPS Geometry

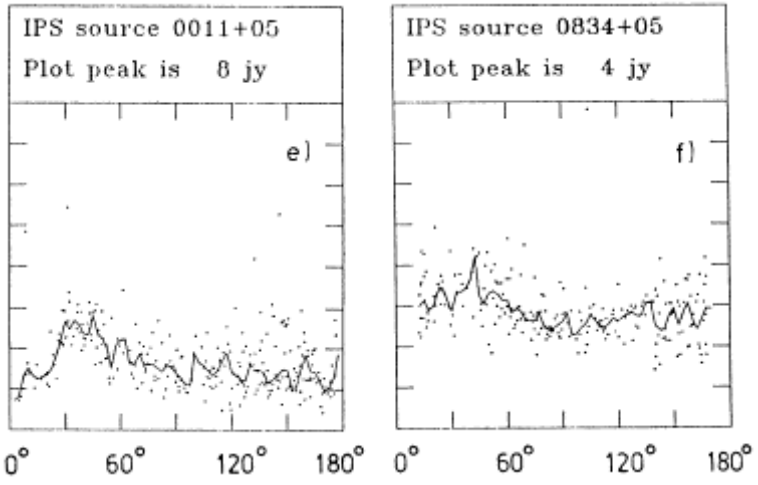


ips.ucsd.edu

“g-factor”



Purves et al. 1987



As the source moves closer to the Sun, smaller and smaller spatial scales are probed – source diameter scales of 0.1–1″ can be determined.

Current IPS facilities

Regular monitoring carried out by:-

- **Ooty (327 MHz)**
- **STELab (327 MHz, multiple stations)**
- **MEXART (87 MHz)**

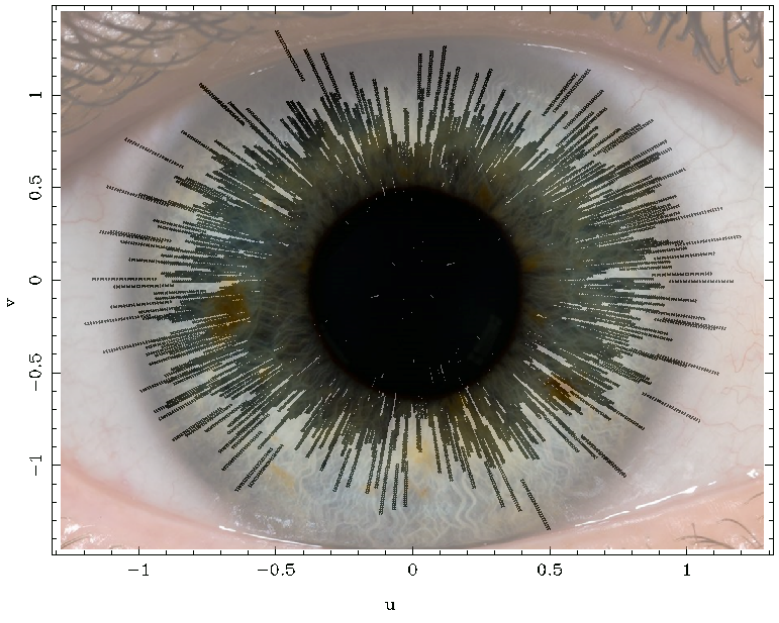
- **Traditional phased arrays rather than imaging arrays**
- **Allows modelling of solar wind with addition of in-situ measurements[1]**

[1] ips.ucsd.edu

MWA

Advantages:-

- Huge field of view
  - High survey speed
  - Understanding of systematics
- Outstanding instantaneous imaging capability
  - Separation of sources
  - Localisation of sources to $<1'$



MWA

Disadvantage:-

- **Can't just hook a chart recorder up to analogue electronics**
- **Time resolution <0.5s requires non-standard mode**

(Voltage capture followed by offline beamforming / correlation – rapidly developing but still experimental)

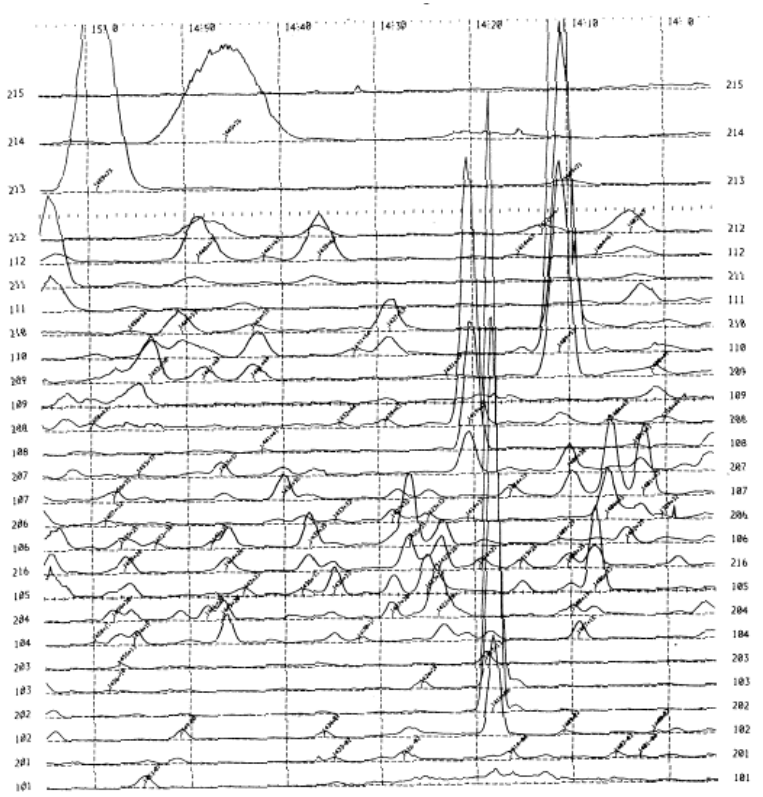


Figure 4. A segment of scintillometer records averaged over the elongation range 20°–90°. Local sidereal time (figures along the top) increases to the left. The beams are arranged in order of increasing declination towards the top, and are numbered as described in the text. Vertical deflection from the horizonal dashed lines is proportional to mean square scintillating flux density.

Purves et al. 1987

Pilot Observations

- 70-85 MHz; 150-165MHz (Sun in the null for the latter)
- 288 s (=576 samples)
- Image full data with wsclean
- Sourcefind with Aegean down to 5-σ
- Image each timestep with wsclean
- Measure brightness in pixel corresponding to peak pixel in "continuum" image.

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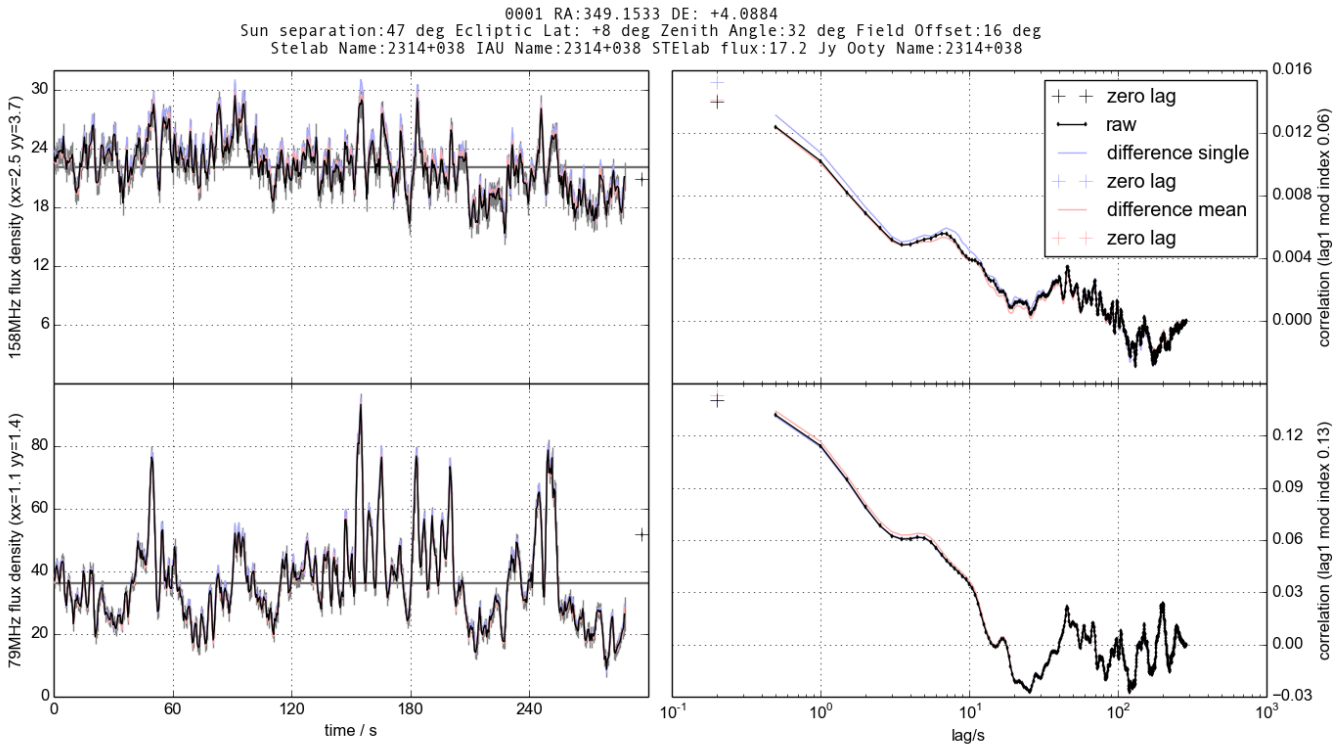
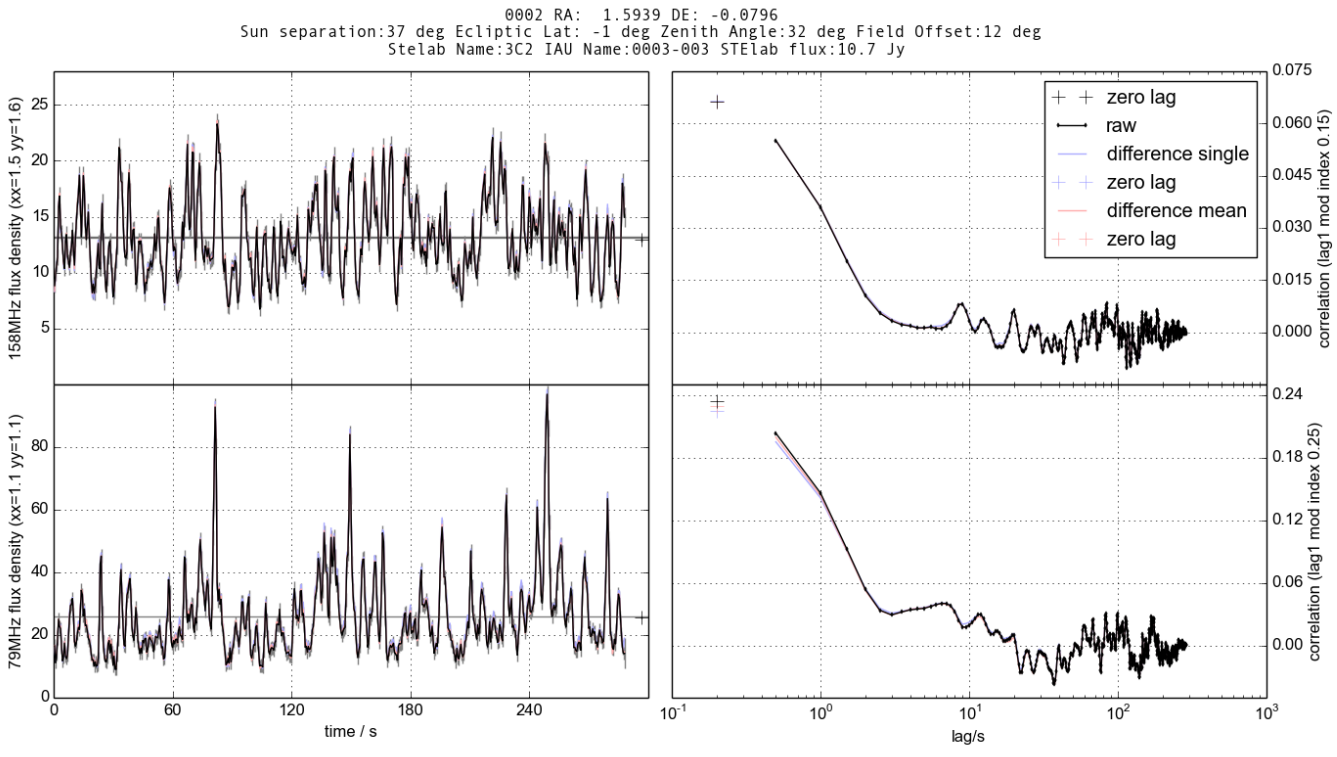
Source 1



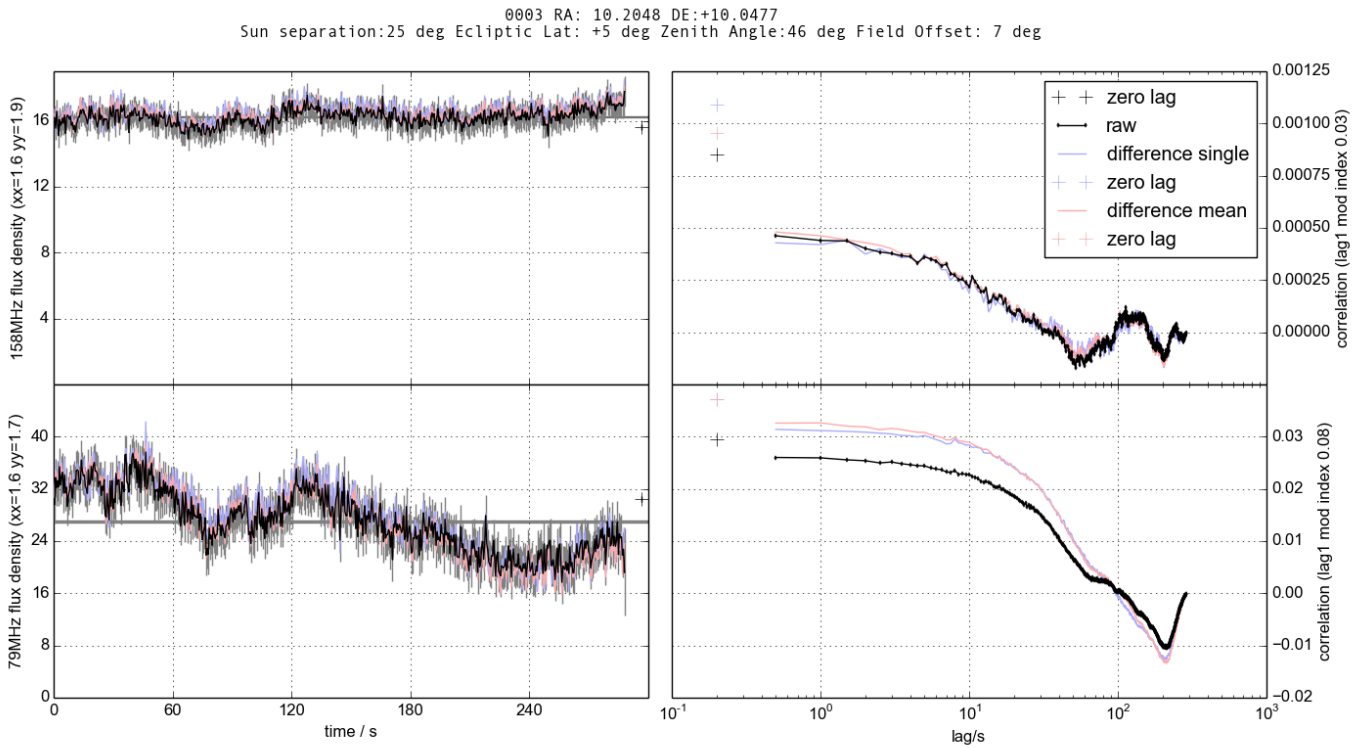
Variation on the shortest timescales: IPS

Source 2



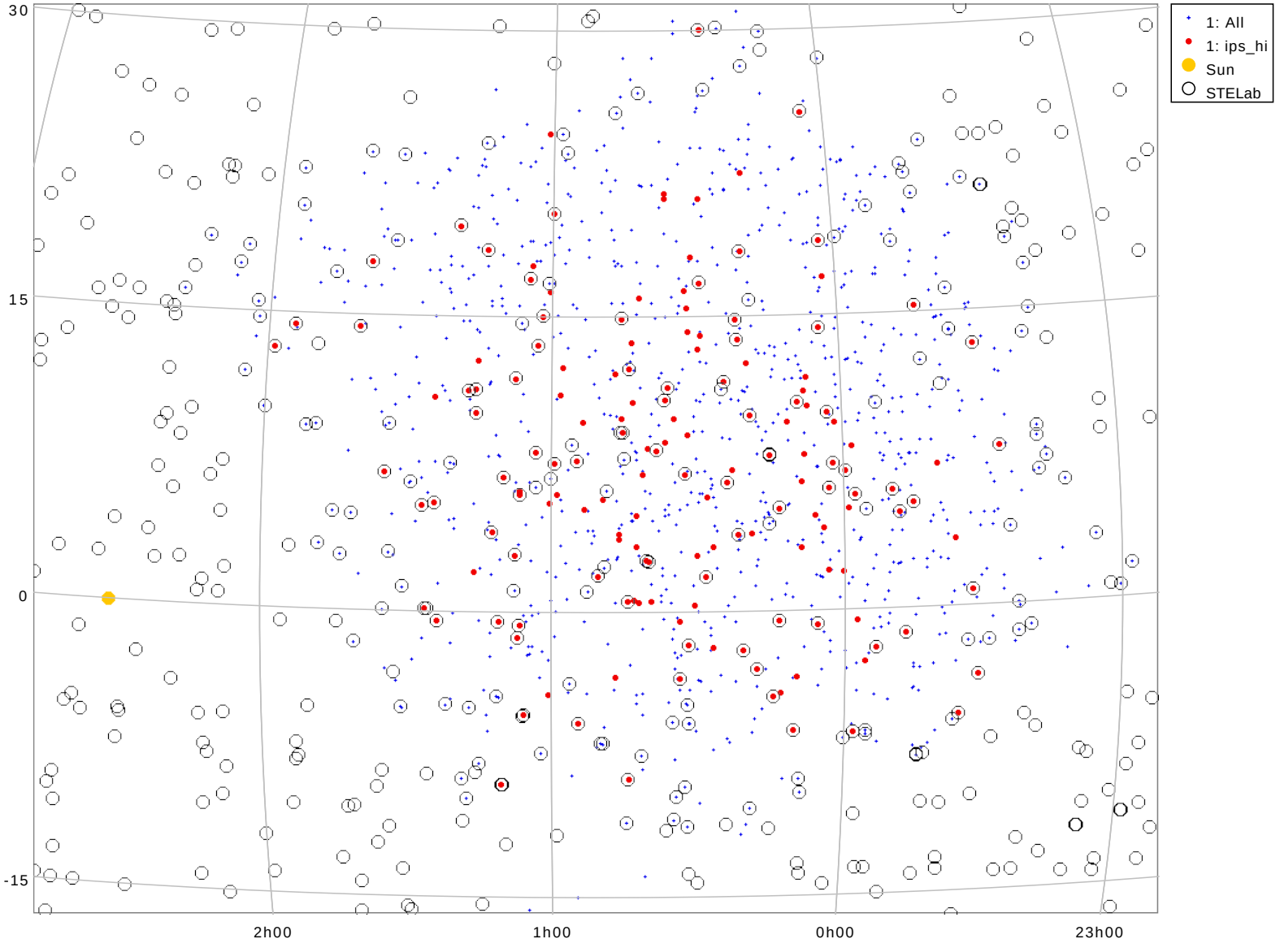
Exponential excursions at lower frequency: strong scintillation

Source 3



Slower variations, much bigger at lower frequency: Ionospheric Scintillation

Are these the sources we expect to scintillate?

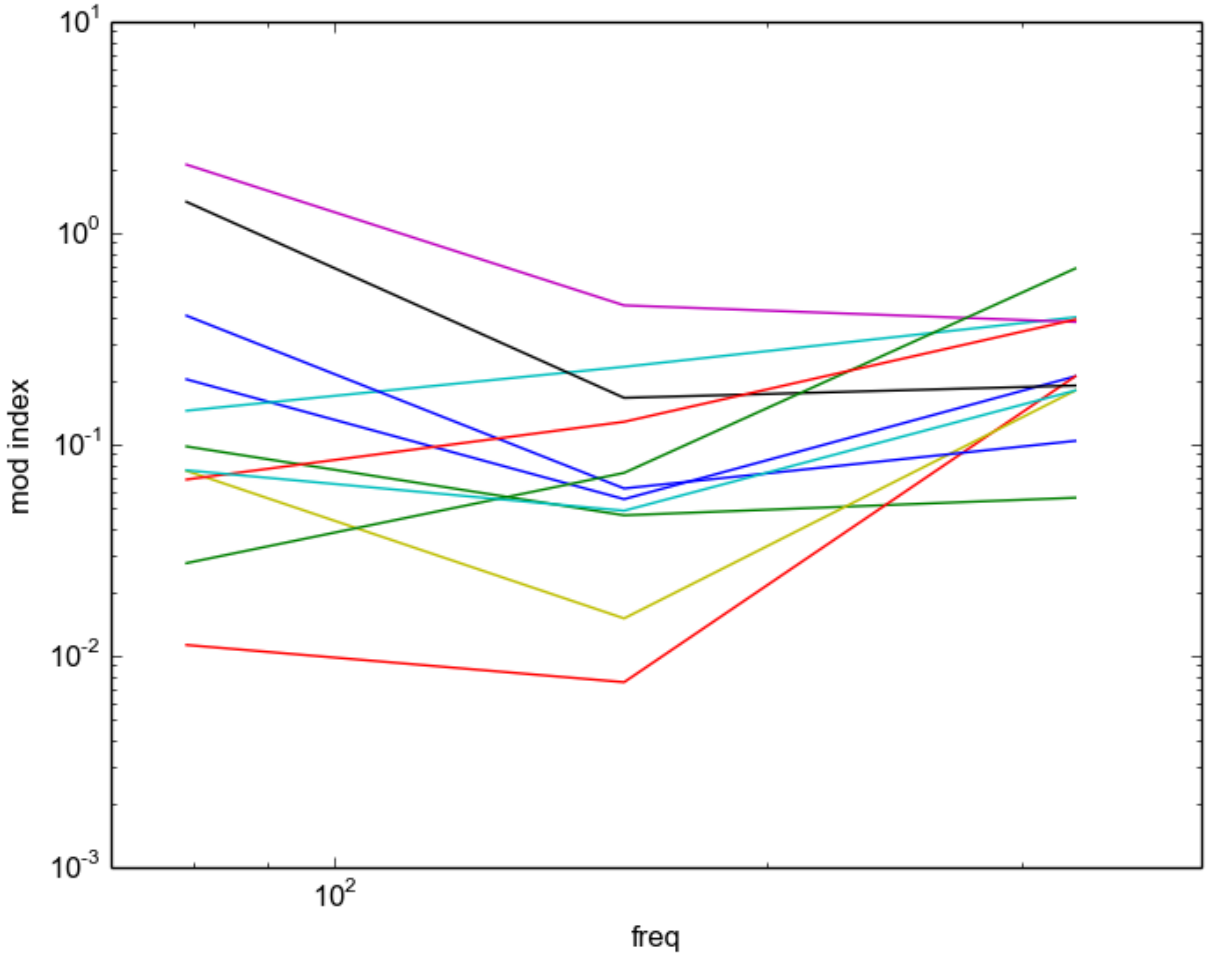


Are these the sources we expect to scintillate?

Within the central area

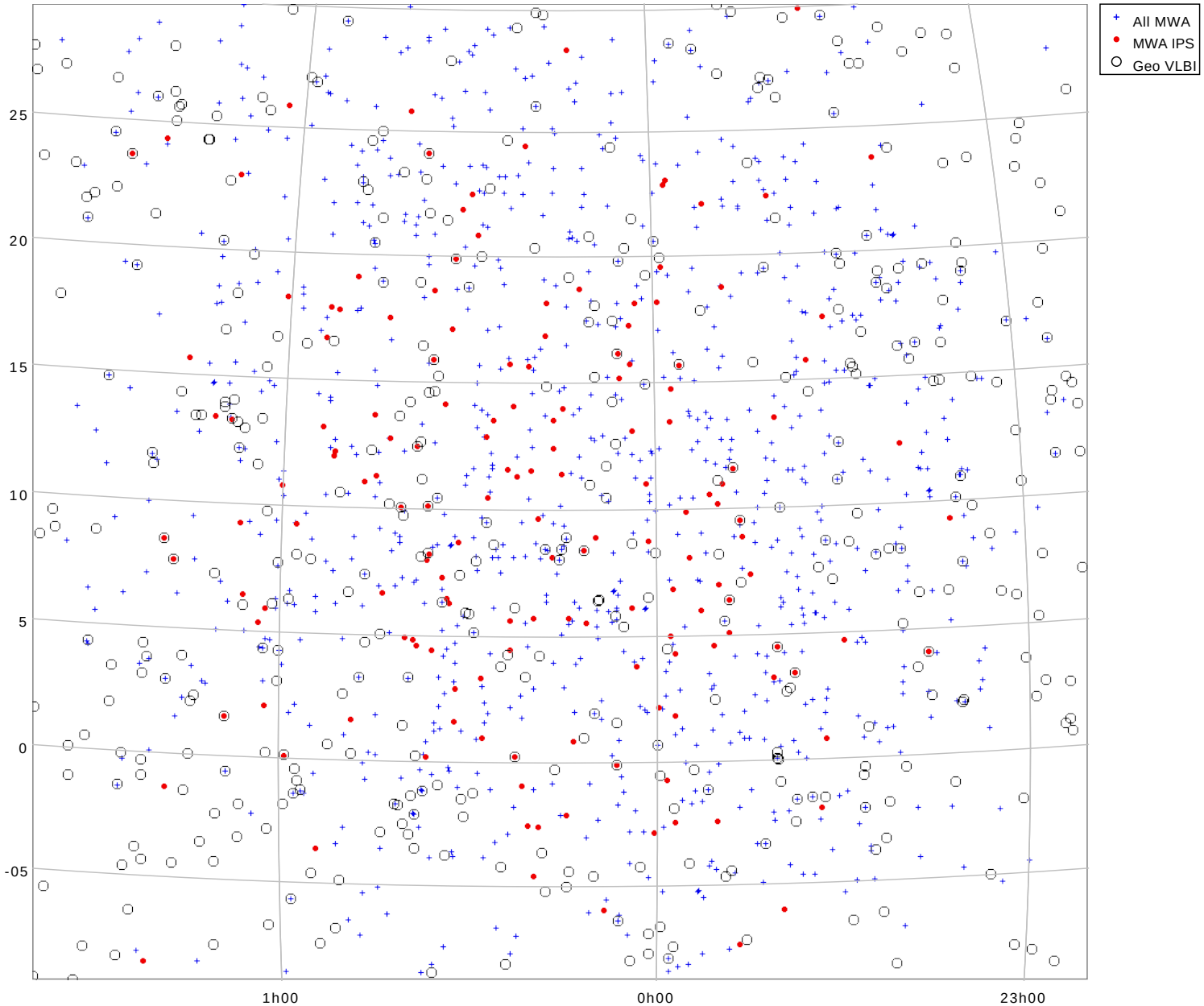
- 453 MWA sources
  - 96 Scintillate
- All 56 STELab sources detected by the MWA
  - 41 Scintillate
- 40 new(?) compact sources

Is the scintillating power consistent with contemporaneous observations?



With thanks to M Tokumaru (STELab) and PK Manoharan (Ooty)

How does this compare with VLBI?

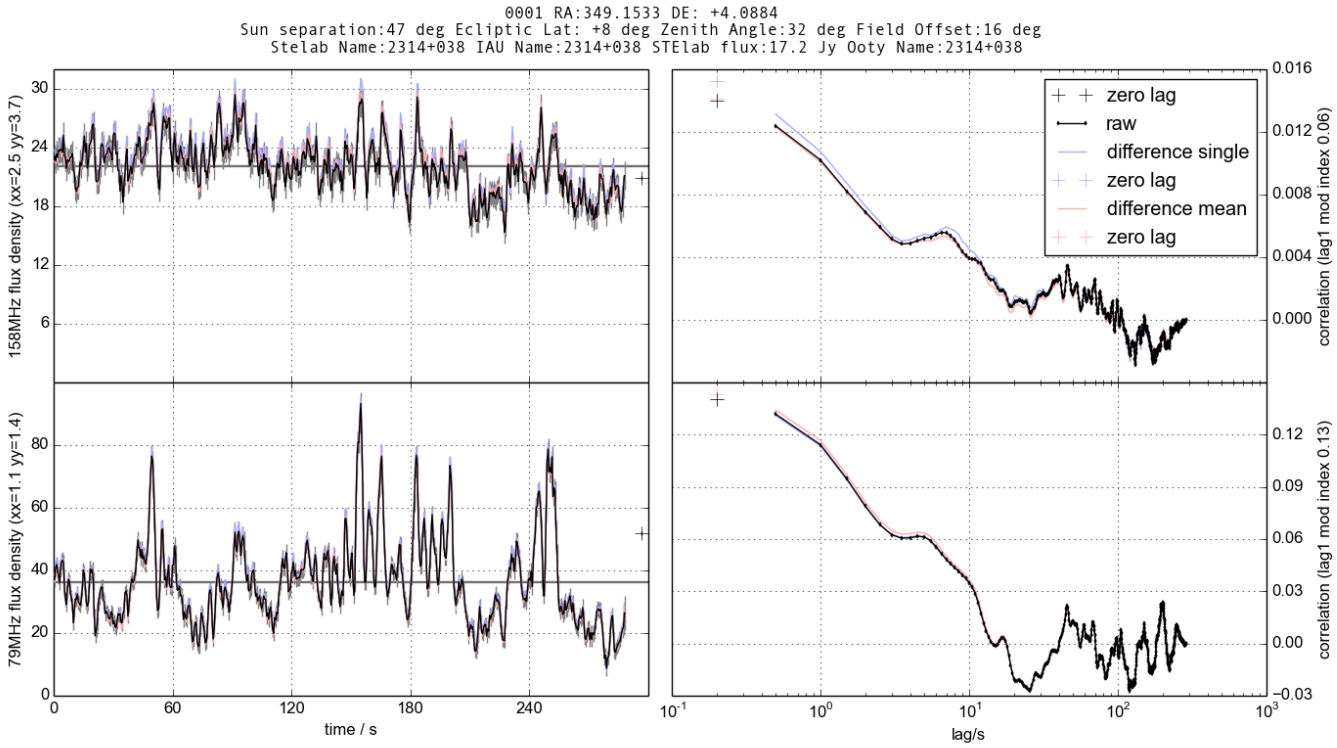


How does this compare with VLBI?

Within the central area

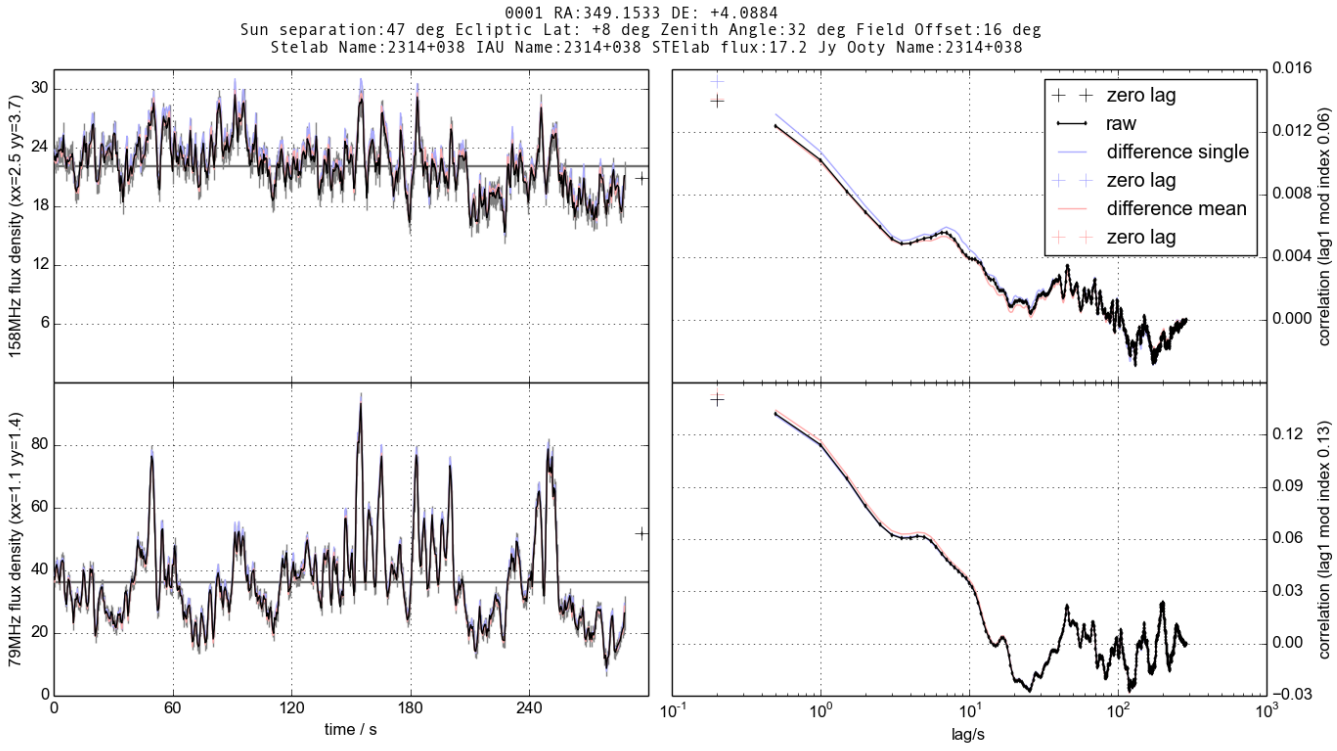
- 453 MWA sources
  - 96 Scintillate
- 100 RFC sources within the field
  - 30 RFC sources detected by MWA
    - 13 Scintillate
- Almost as many compact sources detected in 5-minute of this field as are known from VLBI!

Mapping Source Structure



Bump in the ACF around 5s lag

Mapping Source Structure



- $\sim$ **500 km/s solar wind speed**
- $\sim$ **1 AU distance**
- **1s$\approx$1$''$**

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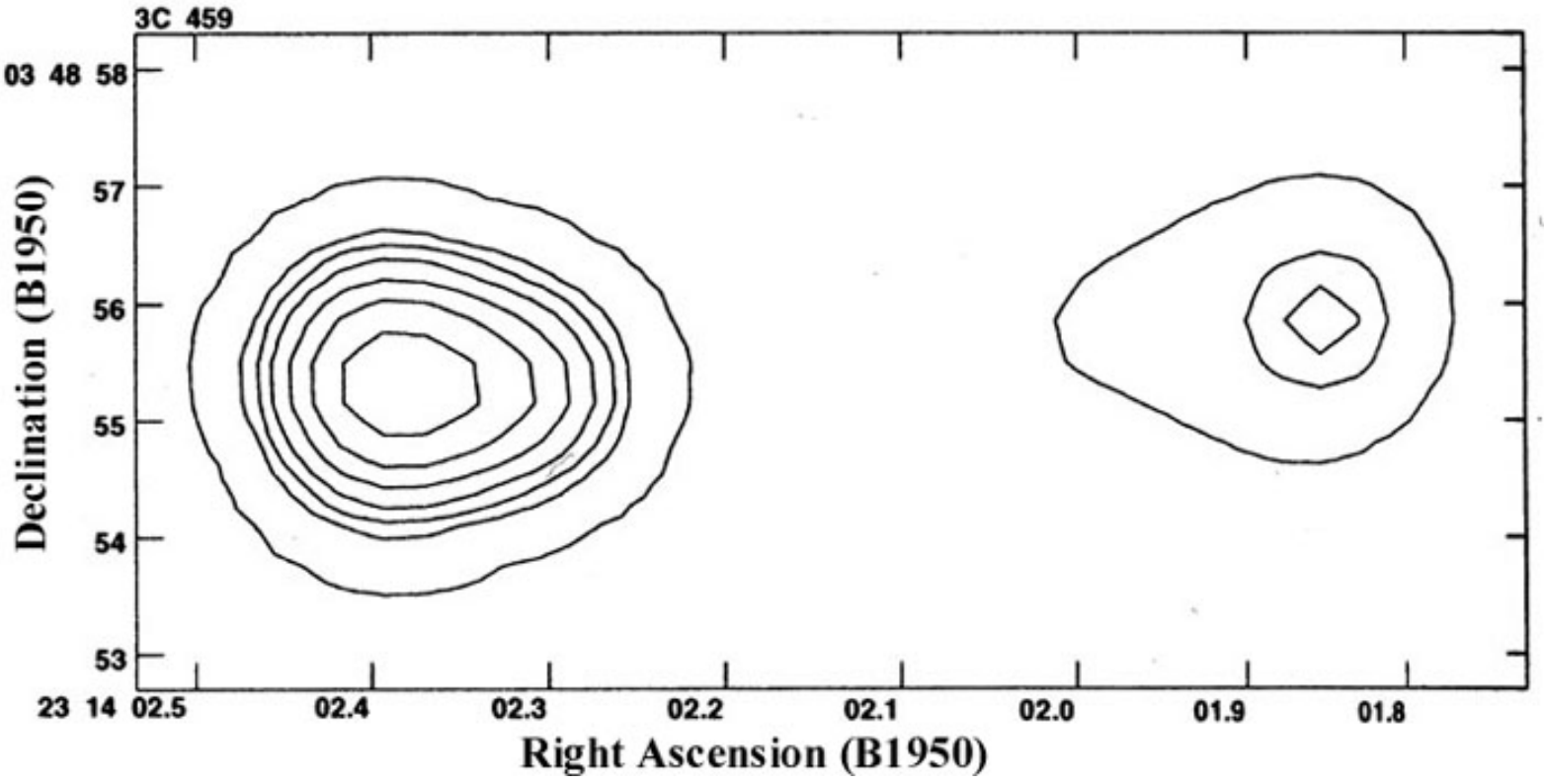

Rhee et al. 1996

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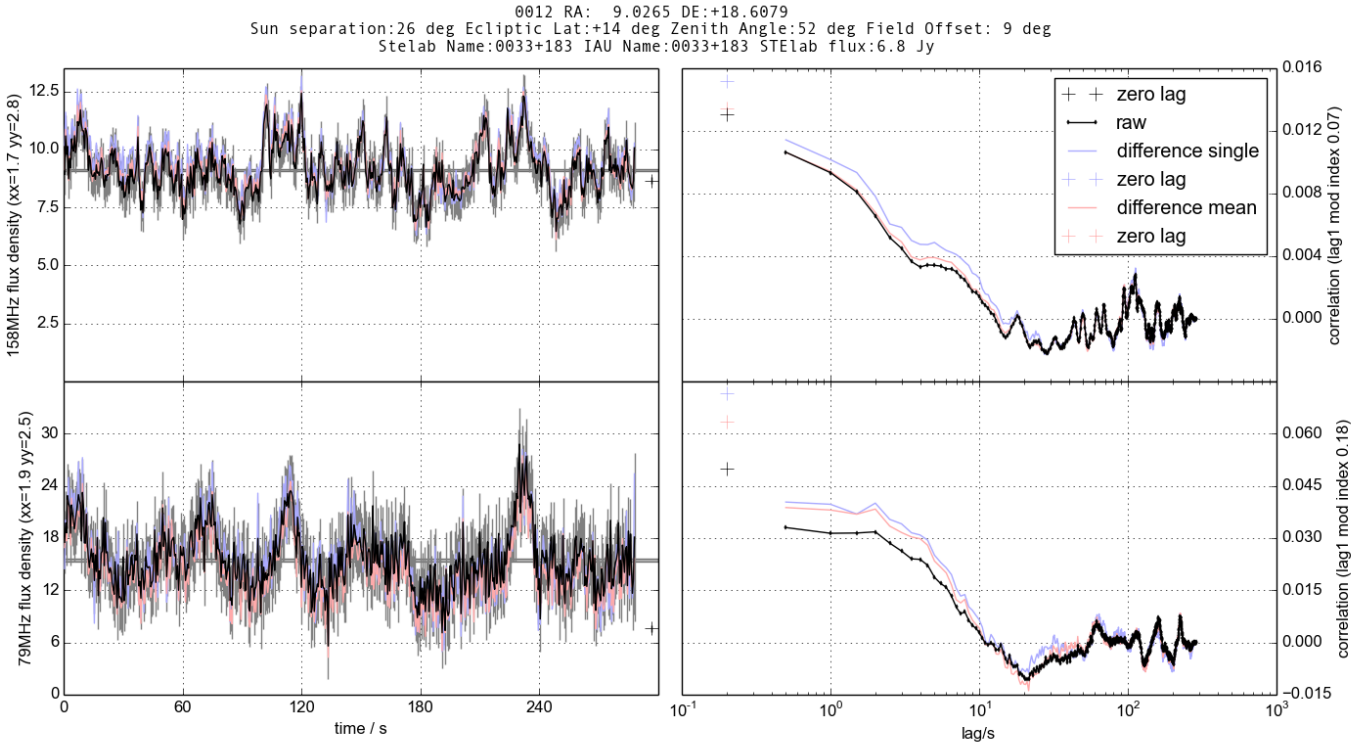

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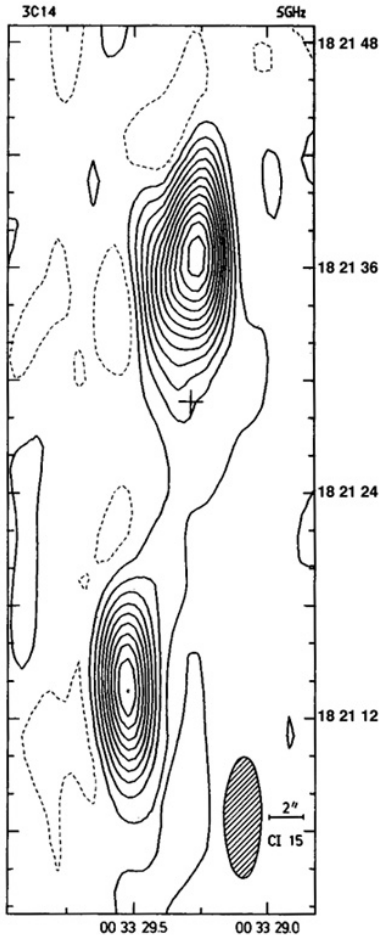

Jenkins et al. 1977

Conclusions

- Unique way use wide-field instrument to do high-resolution studies
  - up to the limit of terrestrial VLBI at lowest frequency
- Mapping of compact components on arcsecond scales
- Discover new candidates for e.g. HI absorption studies
- Pushing very deeply into new parameter space
- A full survey with the MWA is being planned