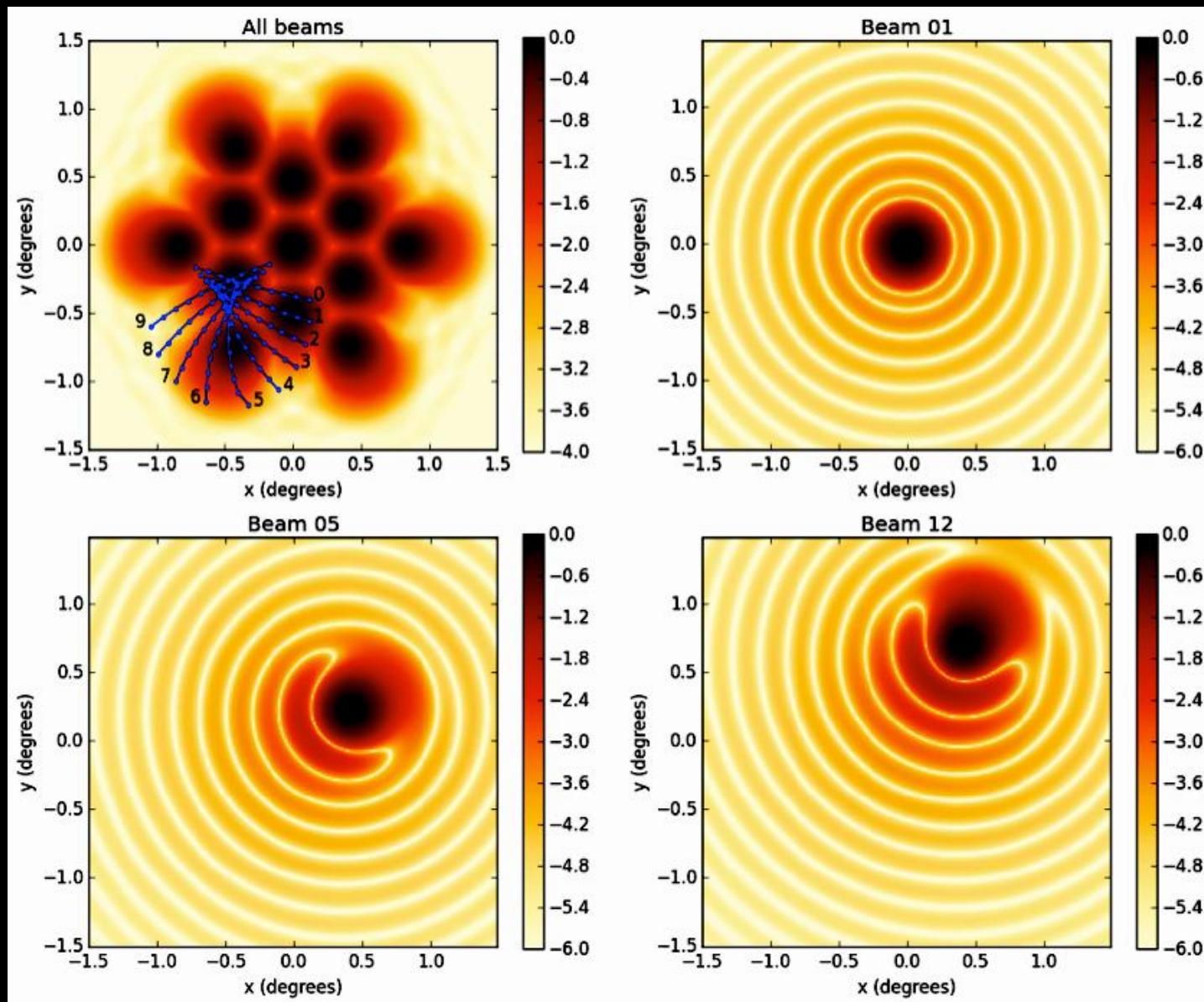


# Deep synoptic array prototype for FRB localization

Vikram Ravi  
Caltech – Millikan fellow

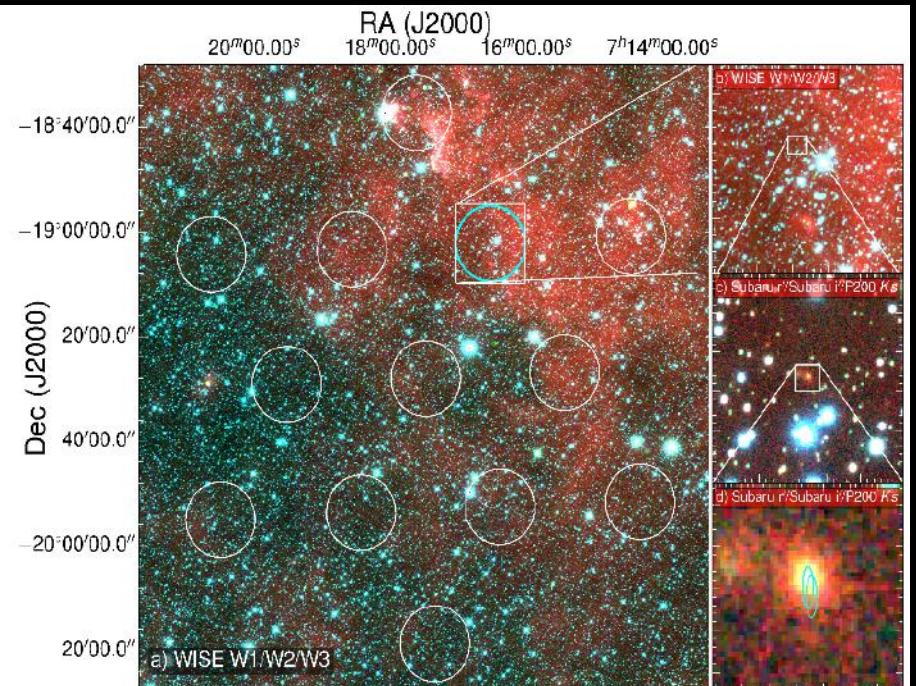
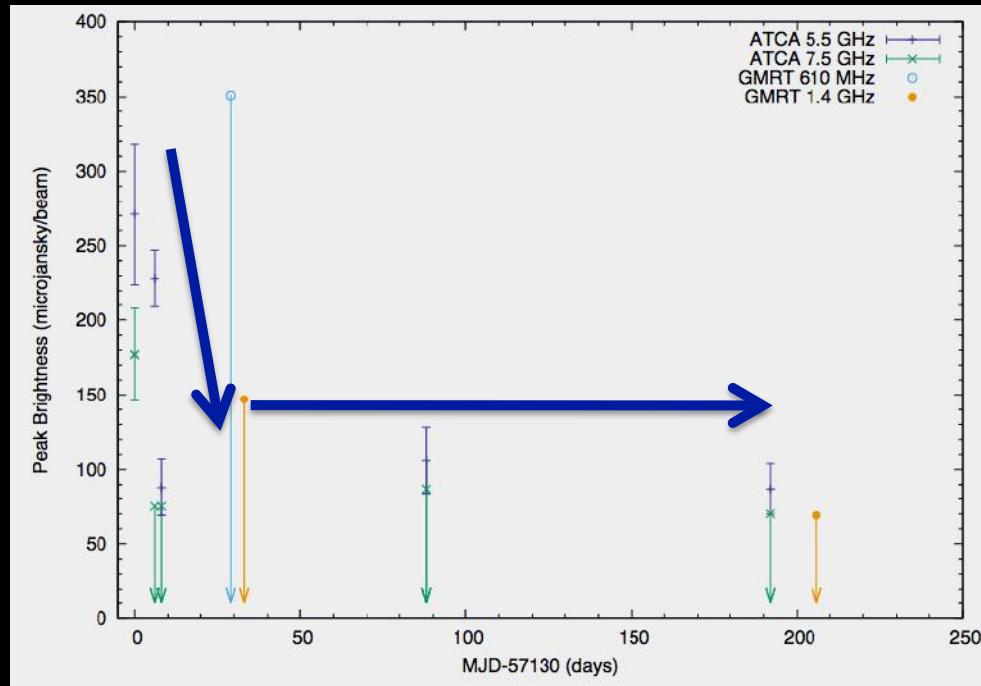
<http://www.astro.caltech.edu/~vikram/>

# Uncertainty in FRB flux densities and direct localizations



# Indirect localisation: afterglows

*Keane et al. FRB afterglow claim*

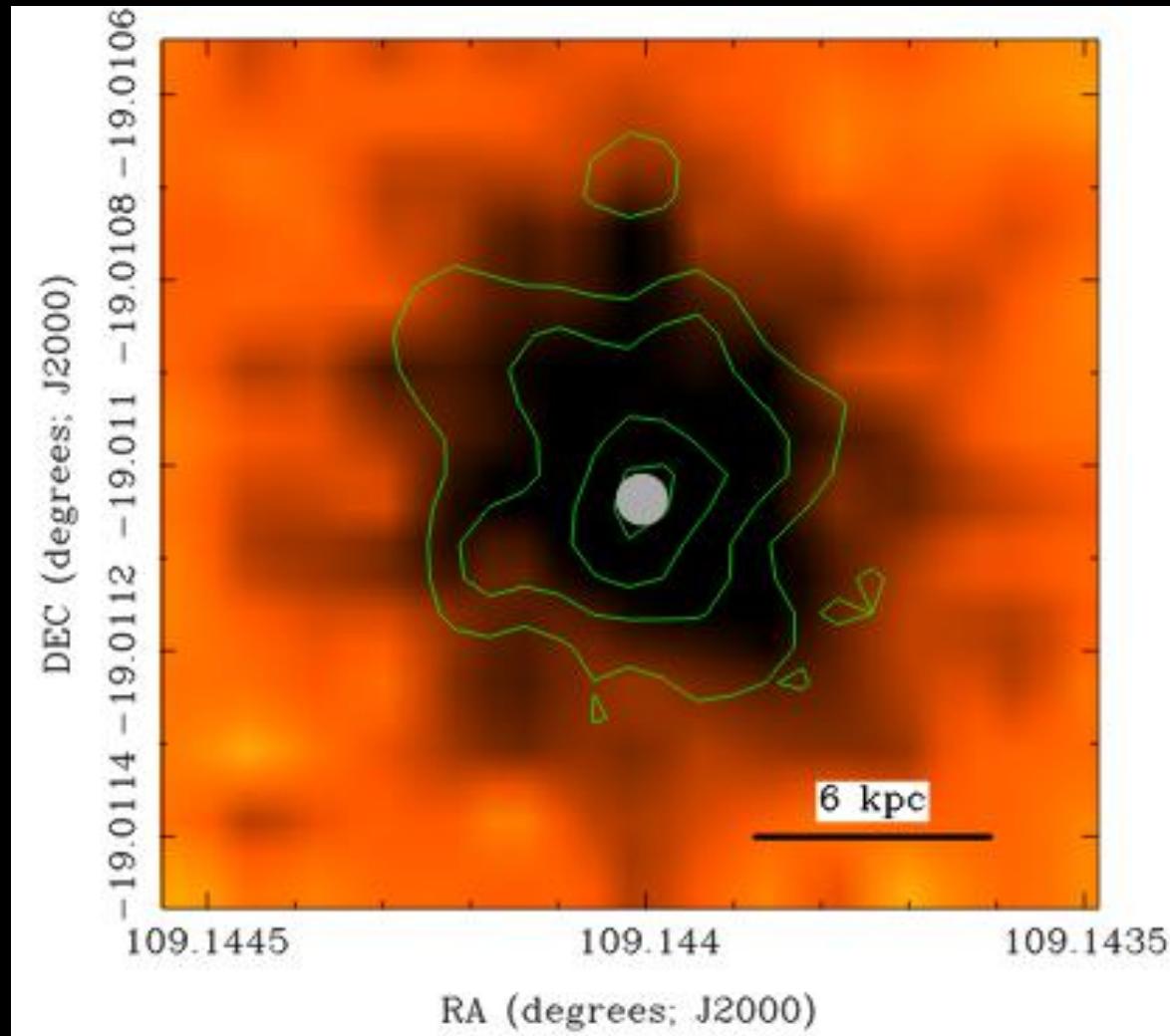


Follow-up radio observations of Parkes beam-area of FRB 150418: discovery of fading radio source

Keane et al. (2016)

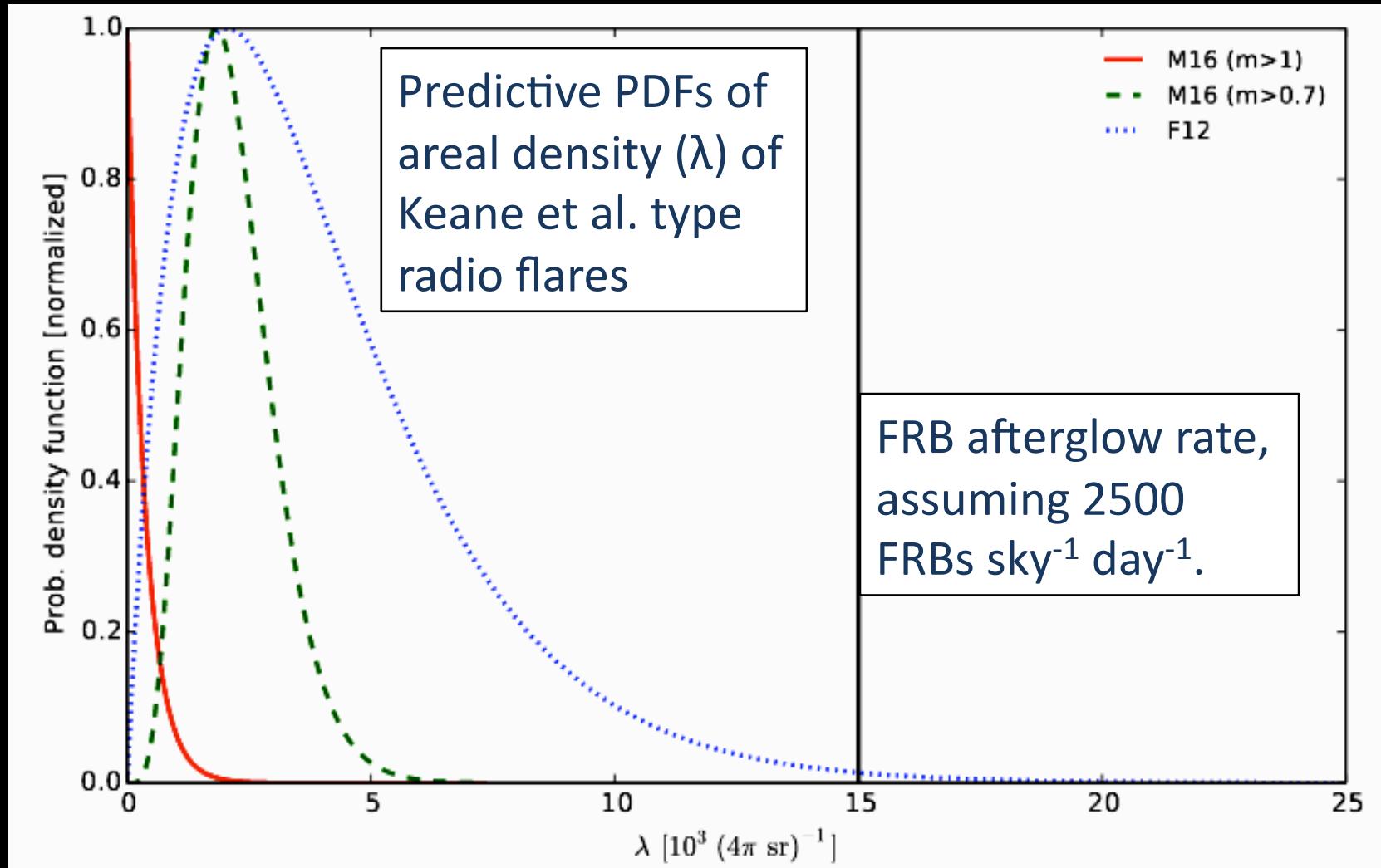
Association of radio source with a  $z \sim 0.5$  early-type galaxy

# Identification of radio source as persistently variable and nuclear



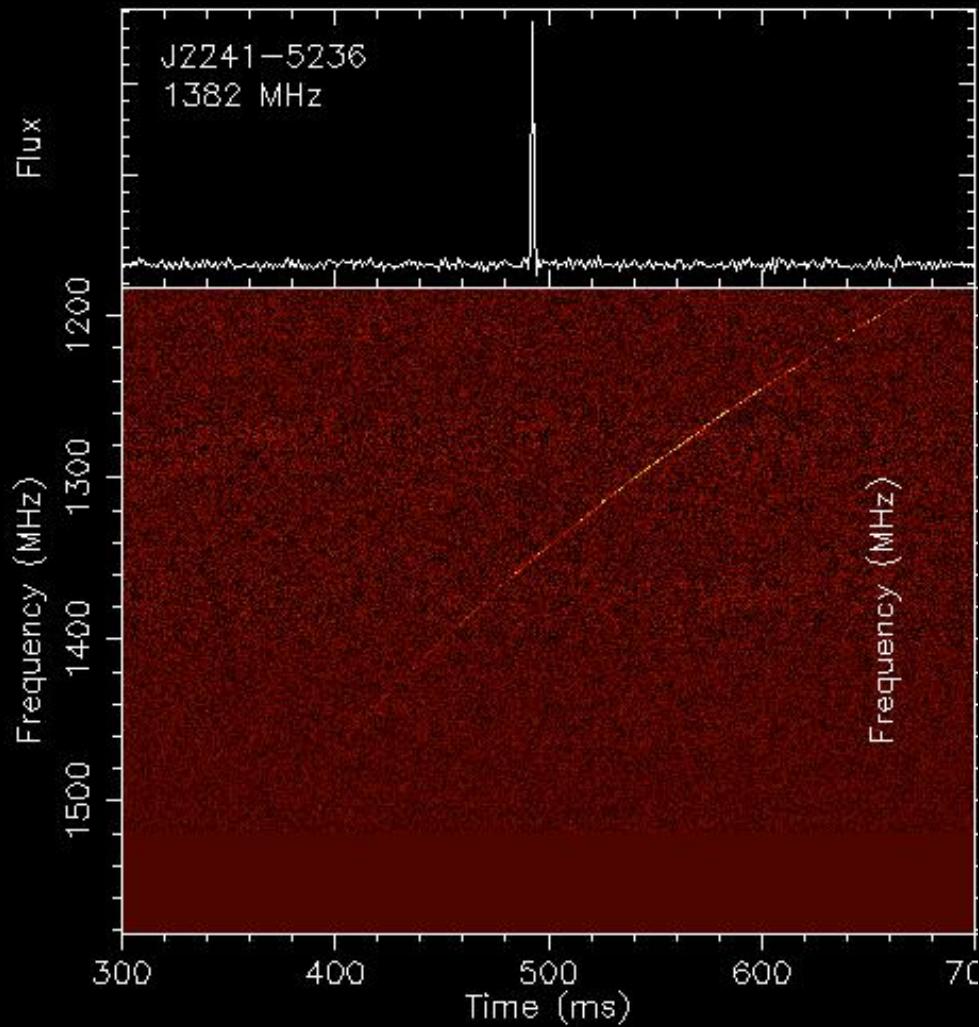
Vedantham, Ravi et al. (2016); also Williams & Berger (2016)

# Afterglow association statistics



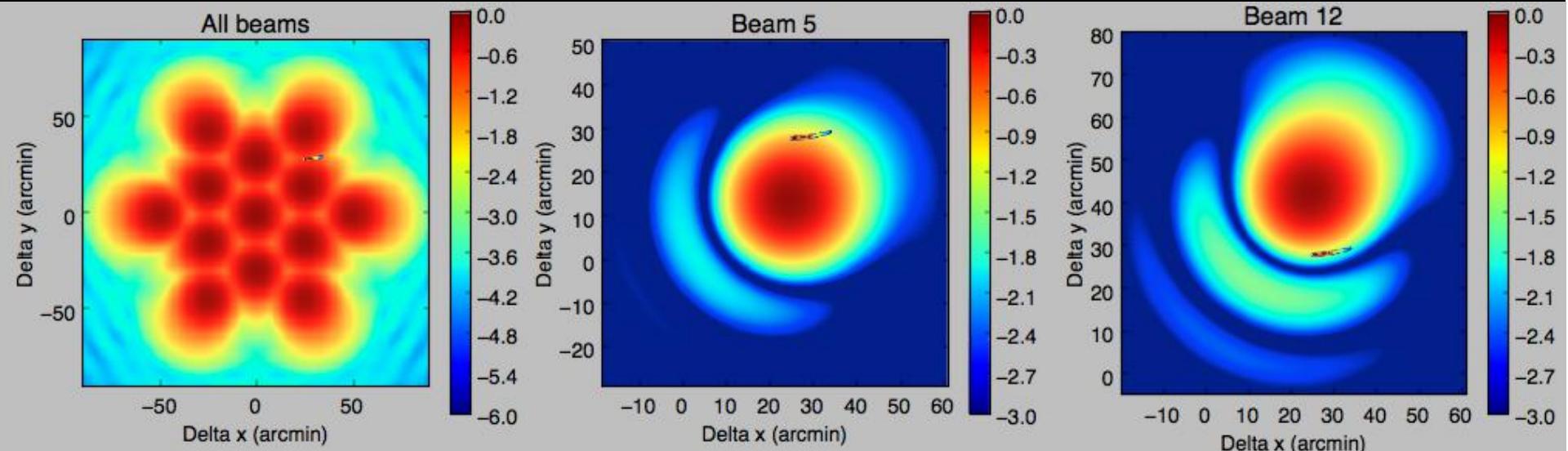
Vedantham, Ravi et al. (2016)

# FRB 150807 – a remarkably bright Parkes burst



- Detected in adjacent beam during timing observations of millisecond pulsar J2241-5236.
- Galactic  $l = 338.2$ ,  $b = -55$ . Expected Milky Way + halo DM of  $\sim 70 \text{ pc cm}^{-3}$ .
- Detected with SNR approx. 100 (full band), DM =  $266.5 \text{ pc cm}^{-3}$ .

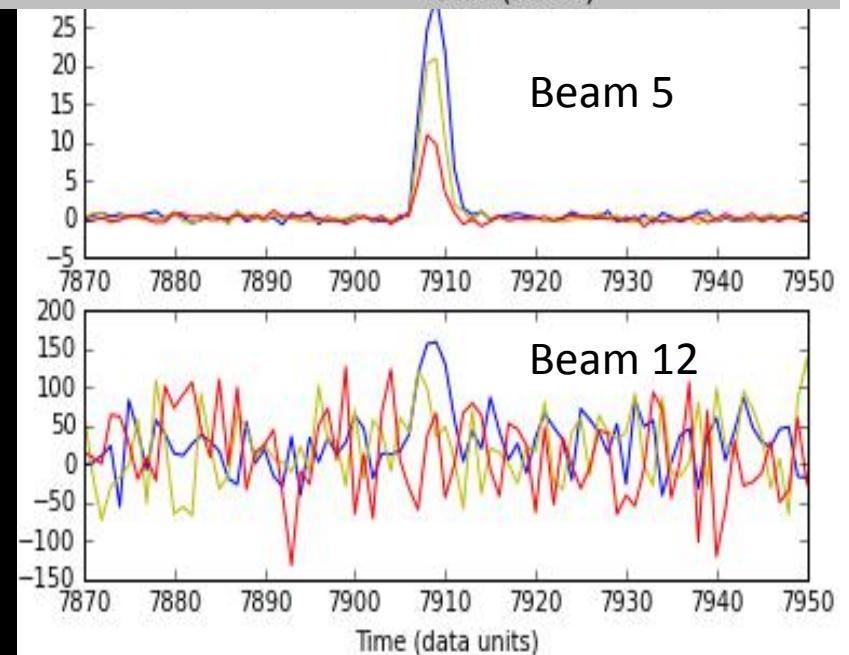
# The localization and flux-density



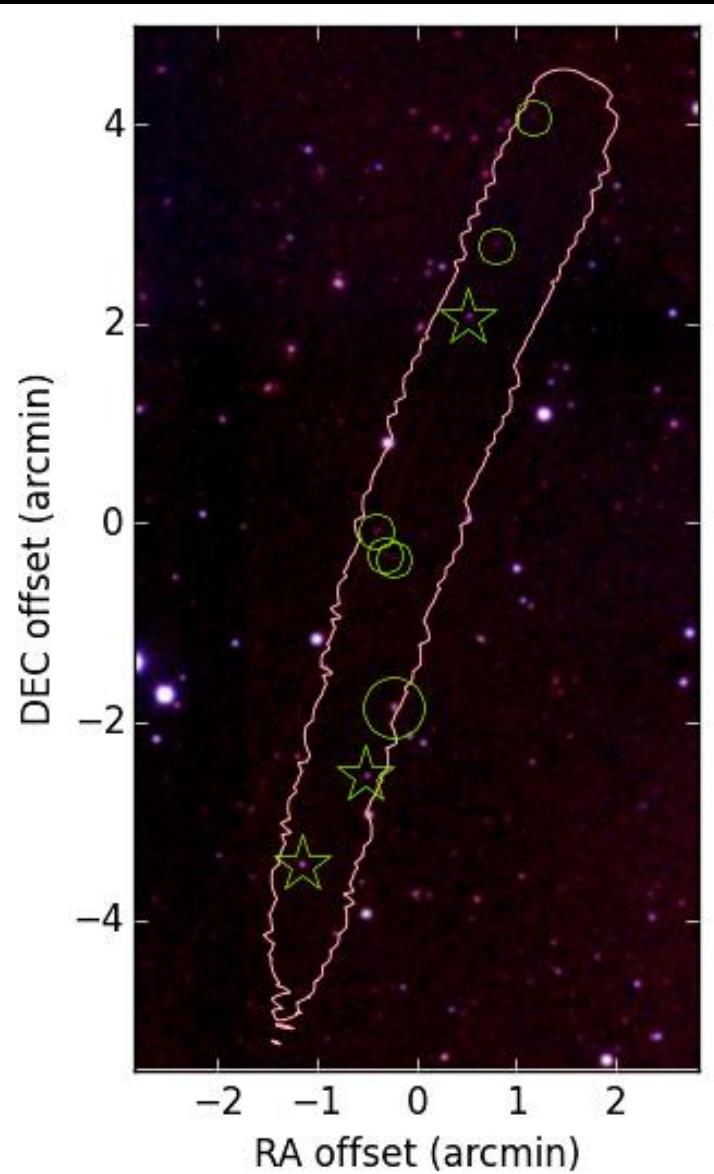
*Physical optics modeling of Parkes multibeam response*

Two-beam detection + spectral information, and null detection in other beams  $\rightarrow 9 \text{ arcmin}^2$  localization

Ravi et al., submitted



# Localization implies > 500 Mpc distance



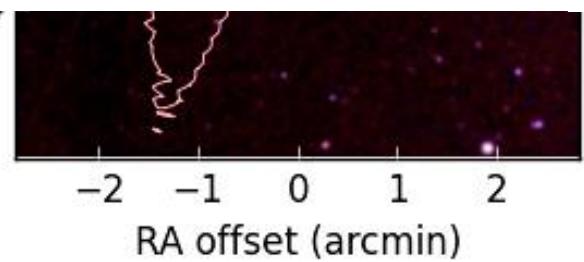
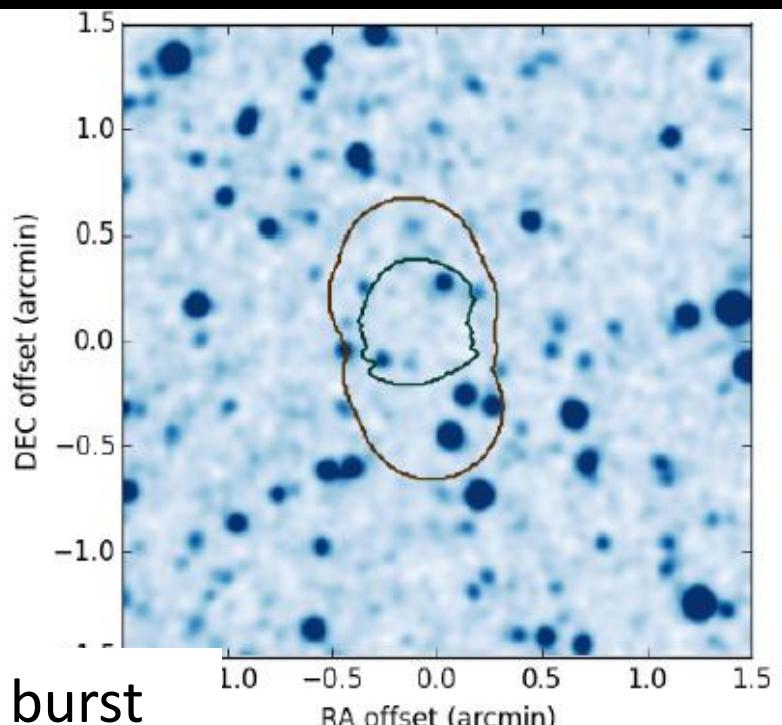
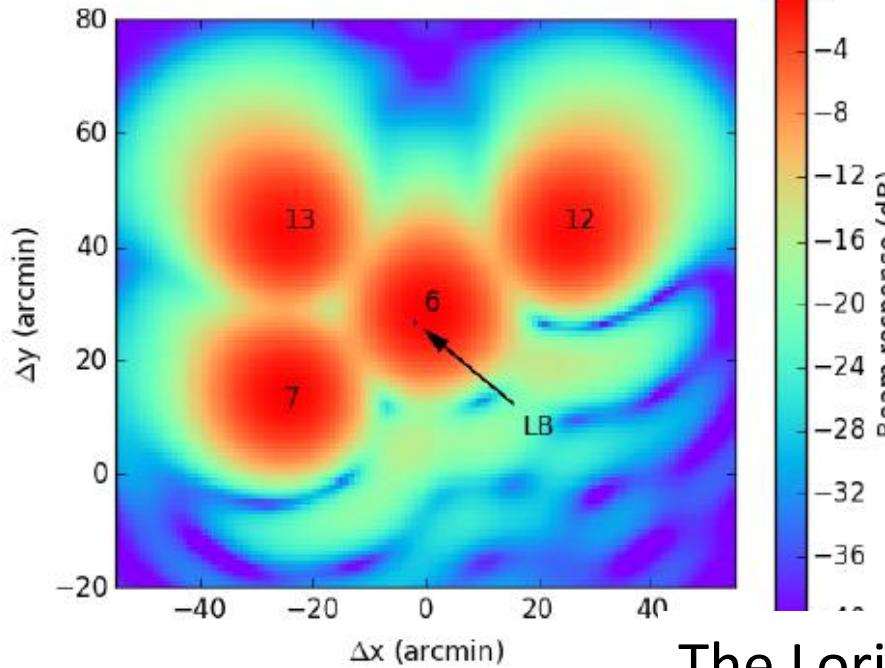
Consistent with DM if all extragalactic contribution were from IGM + host halo

- 3 main-sequence Galactic stars (expected from pop synthesis model)
- 6 galaxies – brightest has photo-z.
- Other 5 galaxies likely as distant (95% confidence).

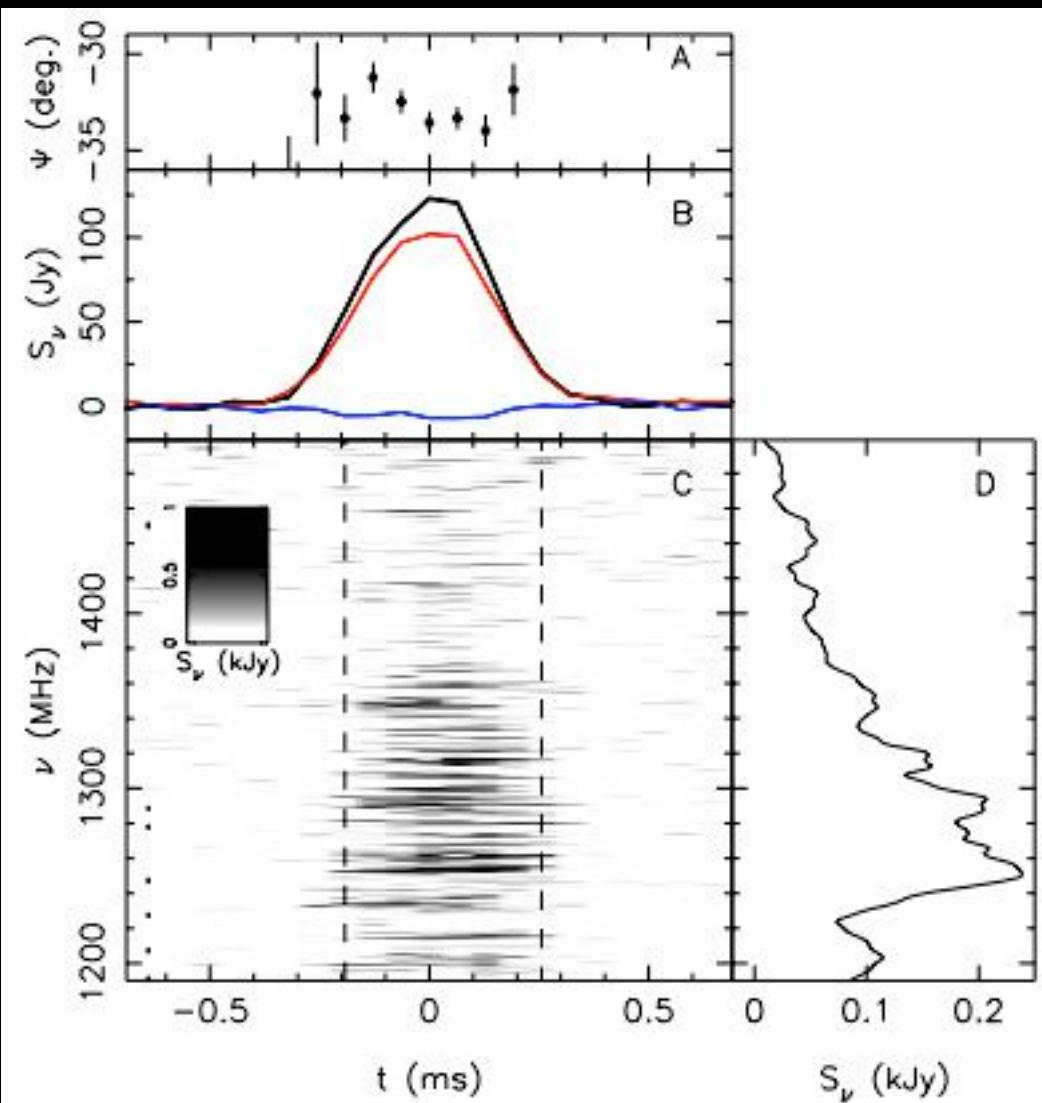
# Localization implies > 500 Mpc distance



Consistent with DM if all extragalactic contribution were from IGM + host halo



The Lorimer burst  
distance (95% confidence).



The pulse profile:

- Total intensity
- Linearly polarised intensity
- Circular polarisation

The dedispersed dynamic spectrum.

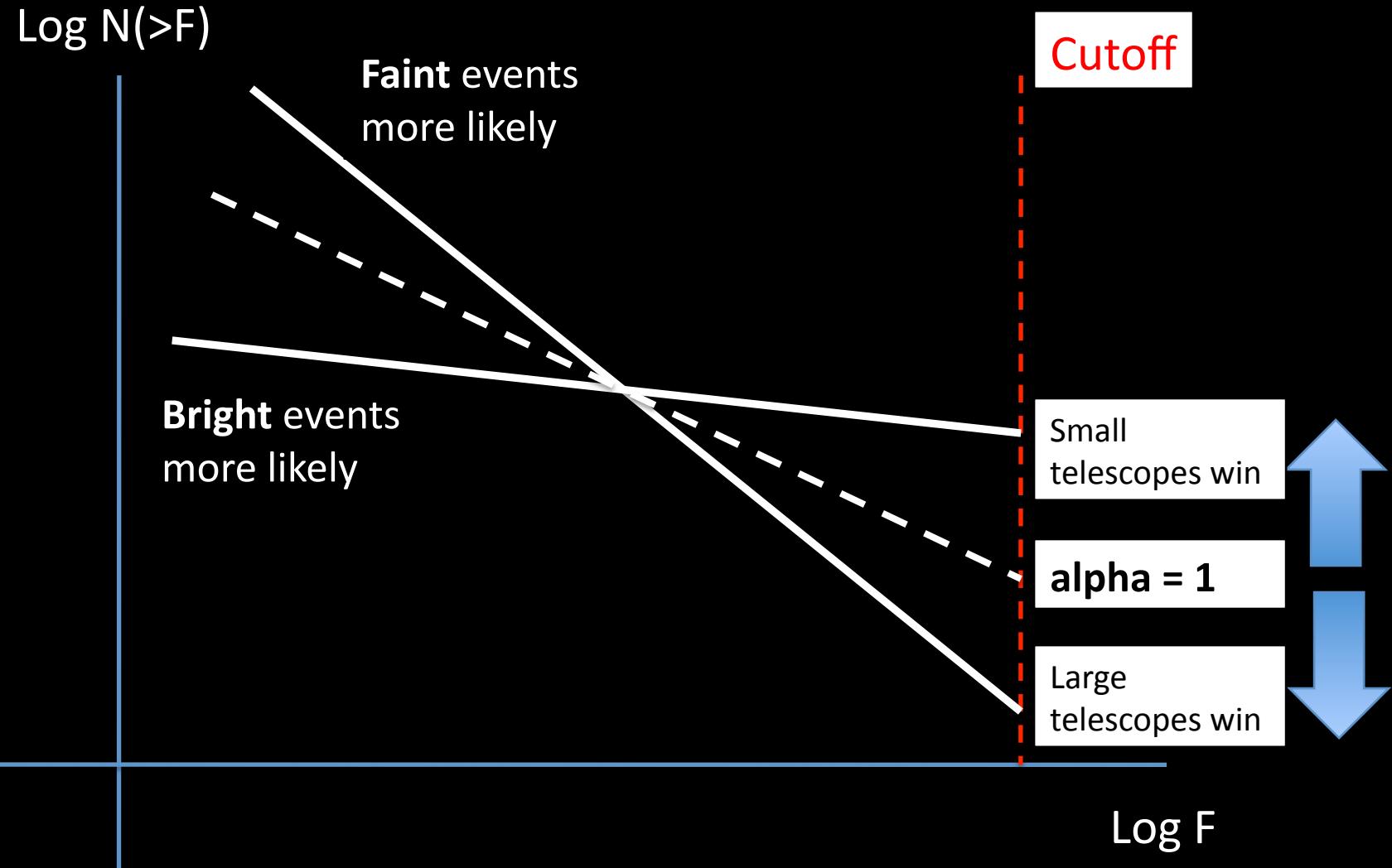
- Flux densities up to a kiloJansky are measured.
- The striations are best interpreted as strong diffractive scintillation.



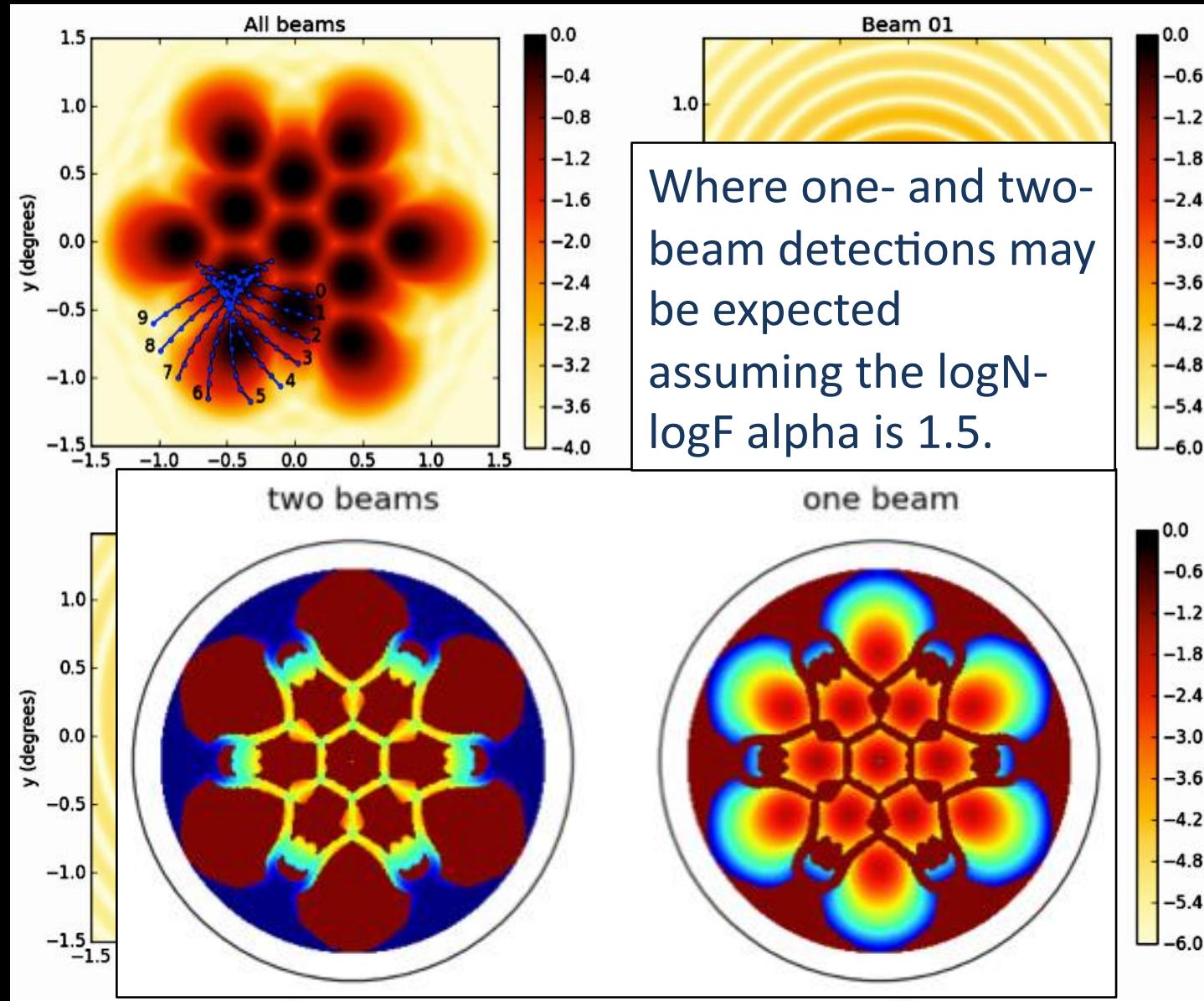
- **17 published FRB detections: 15 from Parkes, 1 from Arecibo and GBT.**
- **Rate estimates between 2000 and 10000 per sky per day, depending on assessment of survey selection functions.**



# The FRB logN-logF from Parkes multiple-beam detections



# The FRB logN-logF from Parkes multiple-beam detections

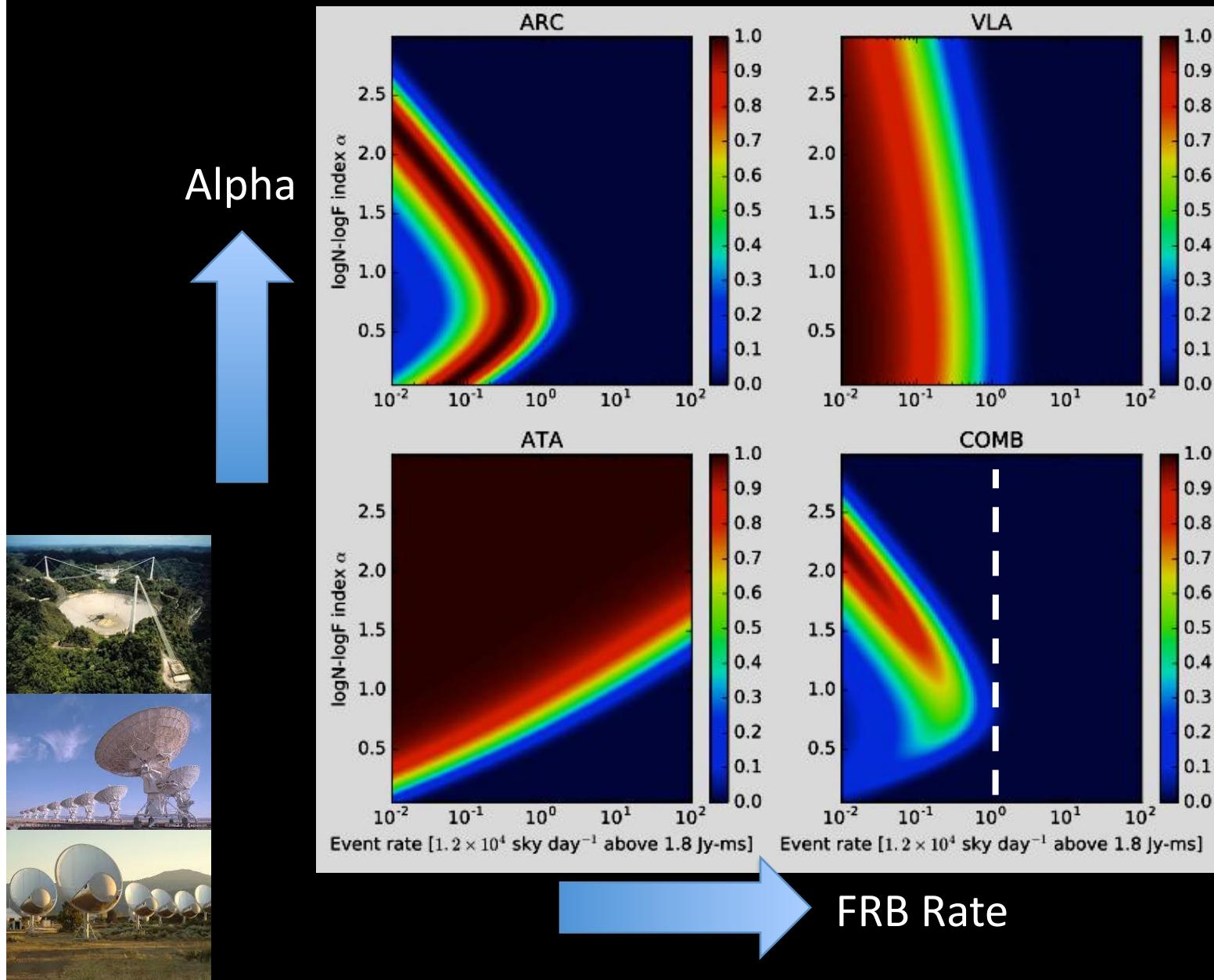


# The FRB logN-logF from Parkes multiple-beam detections

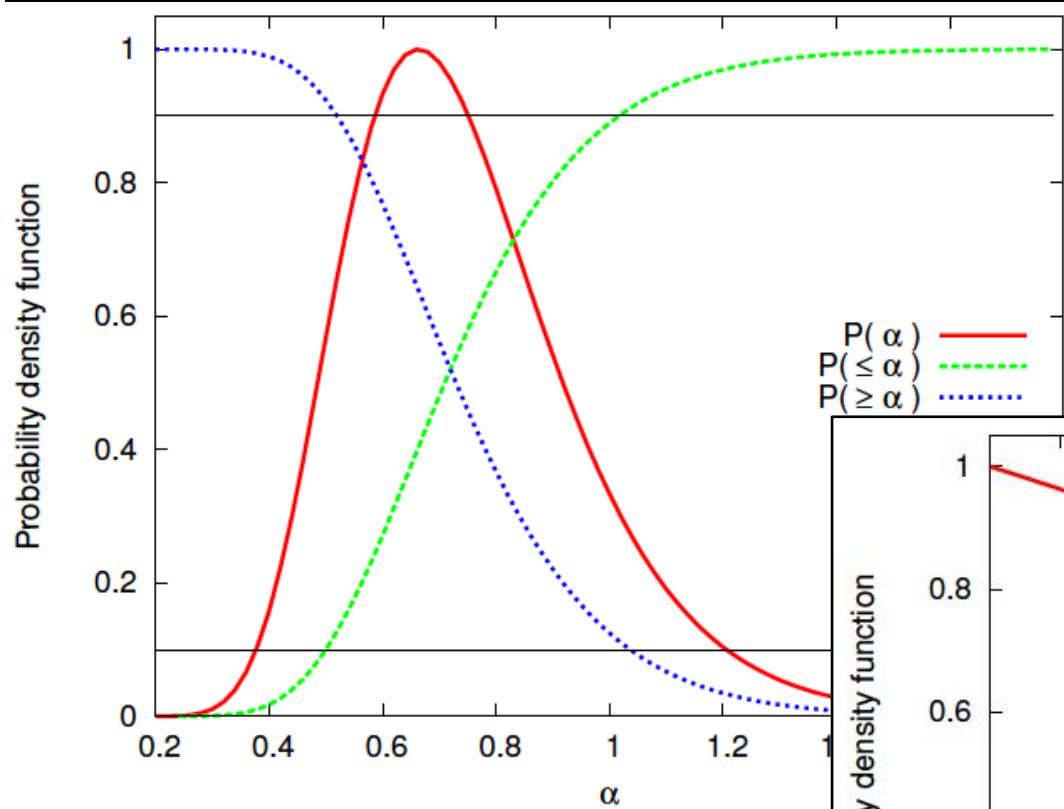
Probabilities of single and multiple beam detections for different Parkes beams, and different logN-logF slopes

Feed, $\alpha$	1-beam	2-beam	3-beam
Central, $\alpha = 0.5$	0.7839	0.0452	0.0476
Central, $\alpha = 1.0$	0.9608	0.0146	0.0116
Central, $\alpha = 1.5$	0.9935	0.0033	0.0019
Inner, $\alpha = 0.5$	0.7506	0.1074	0.0530
Inner, $\alpha = 1.0$	0.9542	0.0311	0.0099
Inner, $\alpha = 1.5$	0.9918	0.0065	0.0014
Outer, $\alpha = 0.5$	0.8409	0.0155	0.0155
Outer, $\alpha = 1.0$	0.9775	0.0194	0.0014
Outer, $\alpha = 1.5$	0.9954	0.0044	0.0001

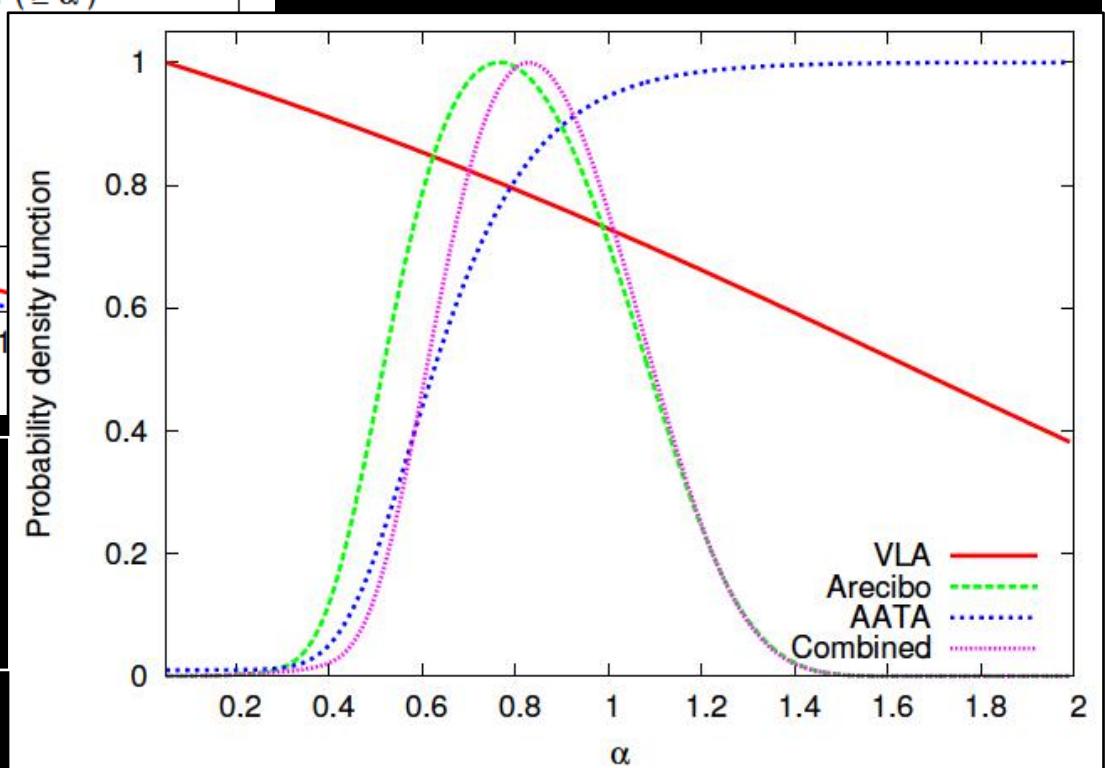
# The FRB logN-logF from other telescope surveys



LogN-LogF:  $0.63 < \alpha < 0.95$  (90% confidence)



Constraint on  $\alpha$  given 2/16 Parkes events in multiple beams.



Constraint on  $\alpha$  given (non-)detections in other surveys, assuming rate

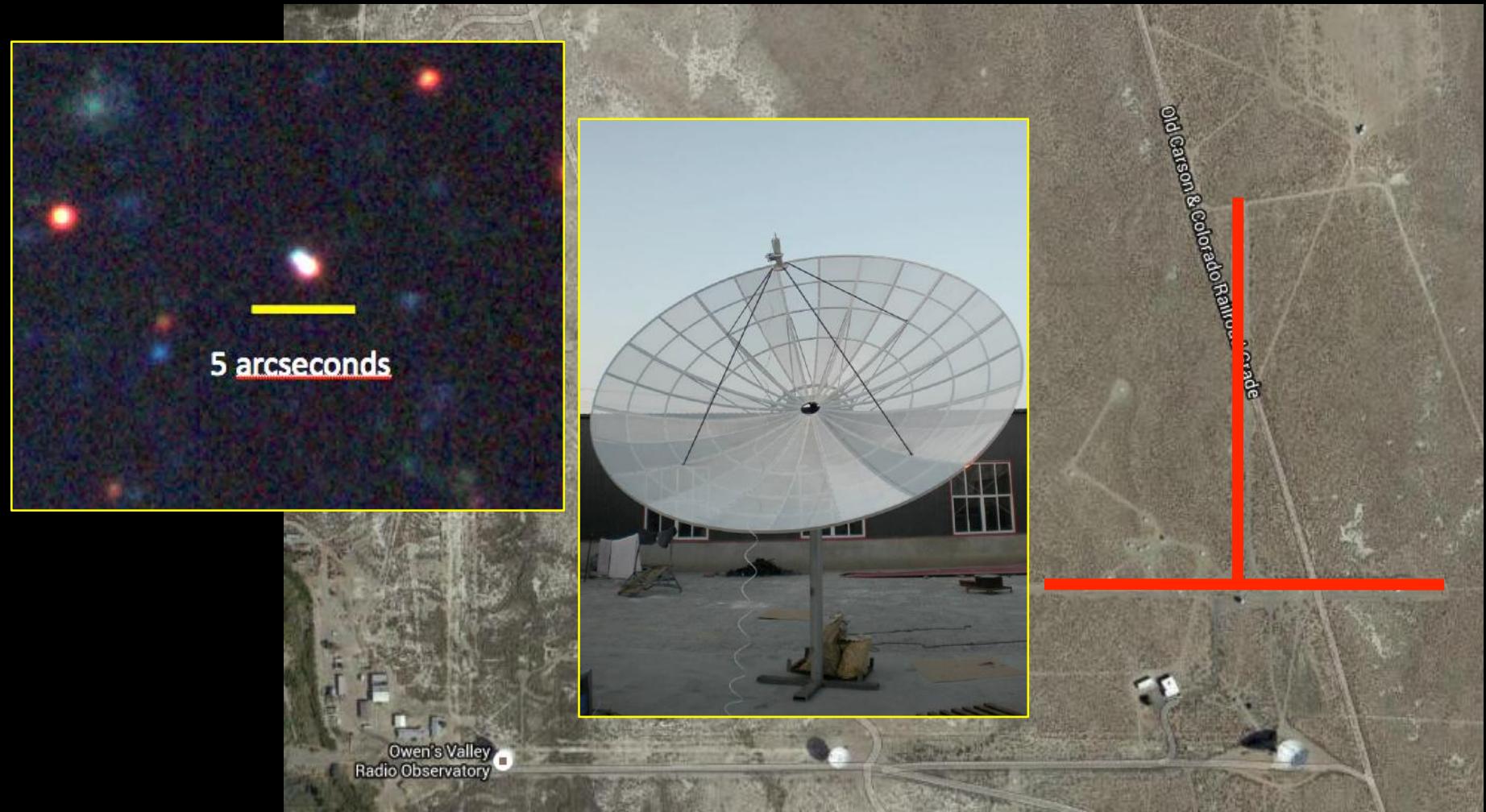
# Implications

- *May exclude a nearby extragalactic origin for FRBs.*
- $dN(R)/dR \sim R^{0.1}$  to  $R^{0.74}$  – distant sources are preferentially seen!
- Excludes any Galactic latitude dependence as being caused by scintillation latitude dependence (Macquart & Johnston 2015).
- $\alpha < 1$  implies, all else being equal, smaller dishes see more events than larger dishes!
- Interpretations:
  - Perhaps a *cosmological population*, evolving with star-formation rate?
  - Multiple populations, even among Parkes events?

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  - Multiple populations, even among Parkes events?

# An array to localize FRBs at Caltech's Owens Valley radio observatory



**Table 1**  
 Summary of assumed DSA-10 single-dish  
 parameters.

Parameter	Value
Dish diameter, $d$	5 m
Aperture efficiency*, $A_e$	0.6
Total system temperature, $T_{\text{sys}}$	60 K
Effective bandwidth**, $\Delta\nu$	220 MHz
Centre frequency, $\nu_c$	1.4 GHz
Channel resolution	122 kHz
Sampling time	50 $\mu$ s

**Note.** — \*Some under-illumination of the dish is assumed. \*\*The effective bandwidth assumes some loss due to RFI and edge-of-band filter effects.

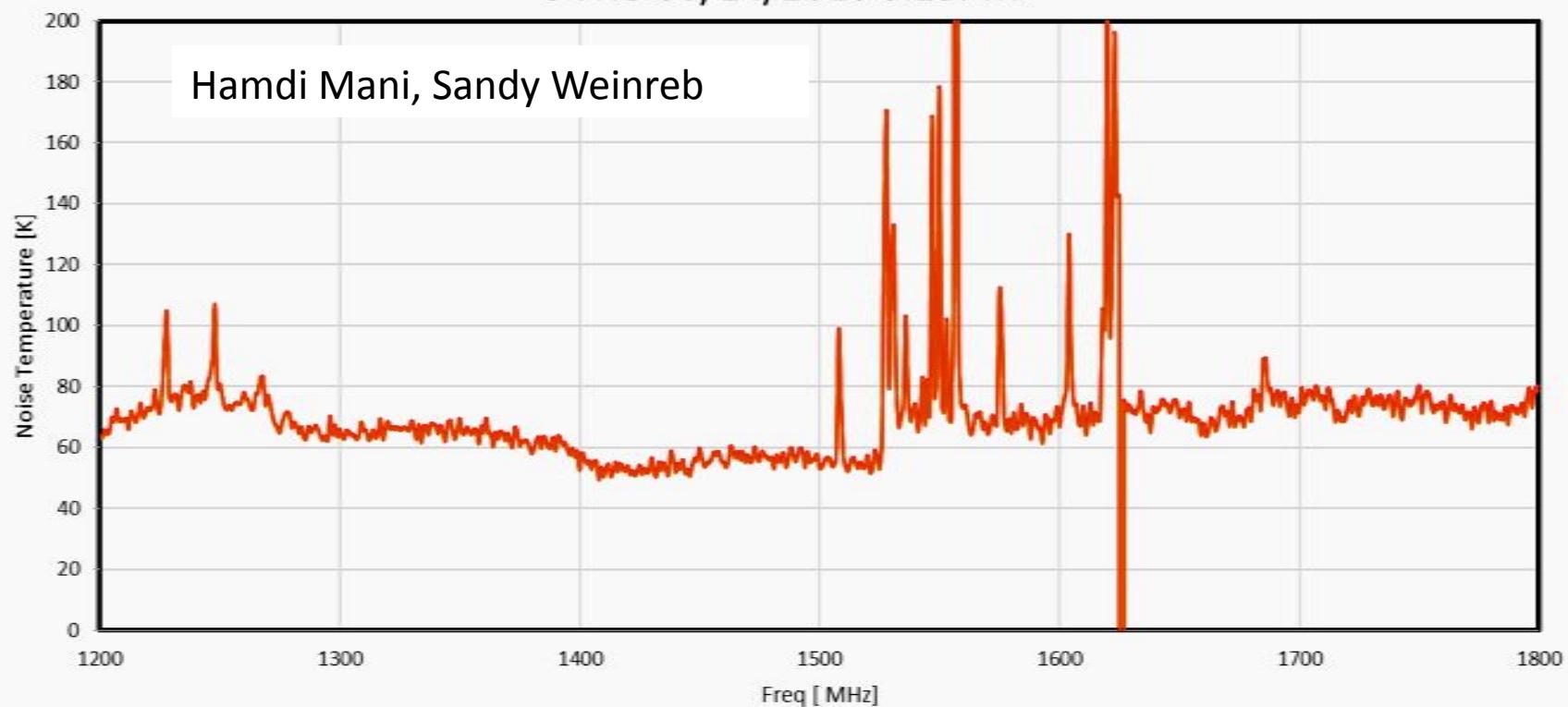
**Table 1**

**Noise Temperature of the DSA 3.8m Antenna (36 Deg Elevation)**

LNA: SBA 1.3-1.7GHz #02 @ 12 V 100mA

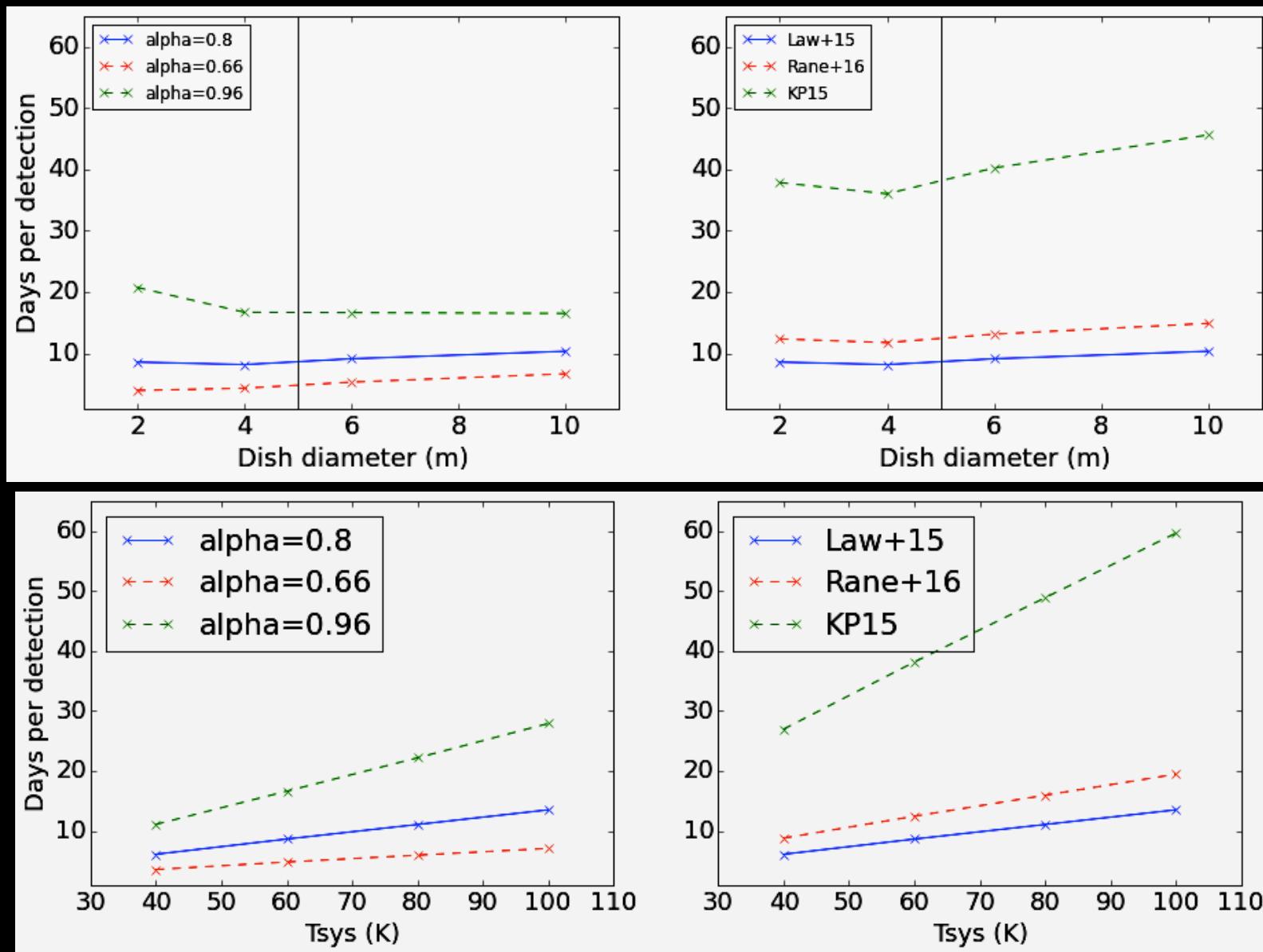
— T[K] uncorr

OVRO 06/14/2016 6:15PM



Inter effects.

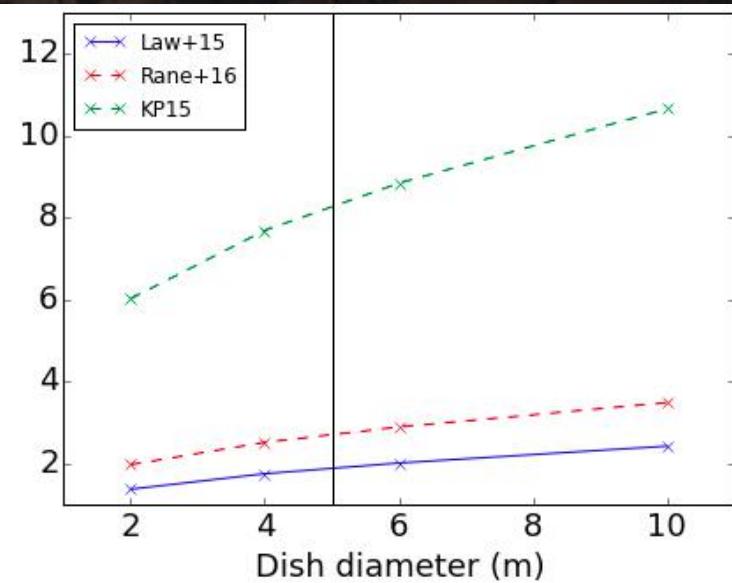
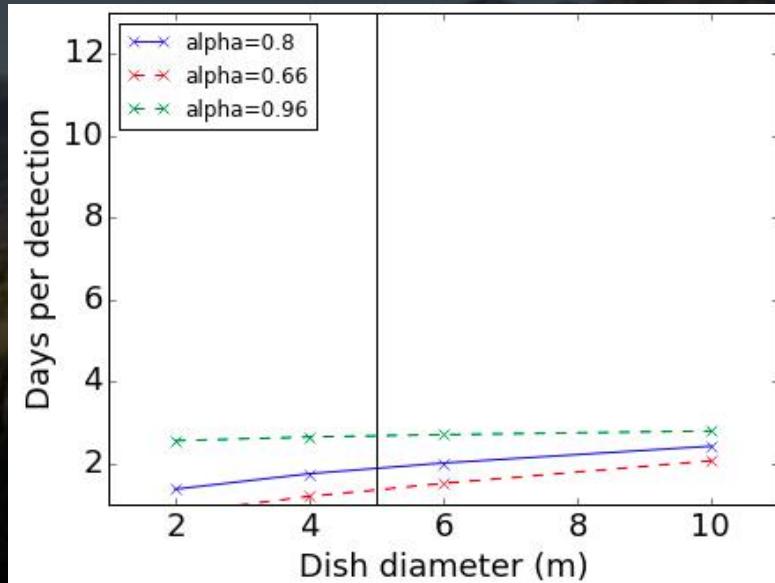
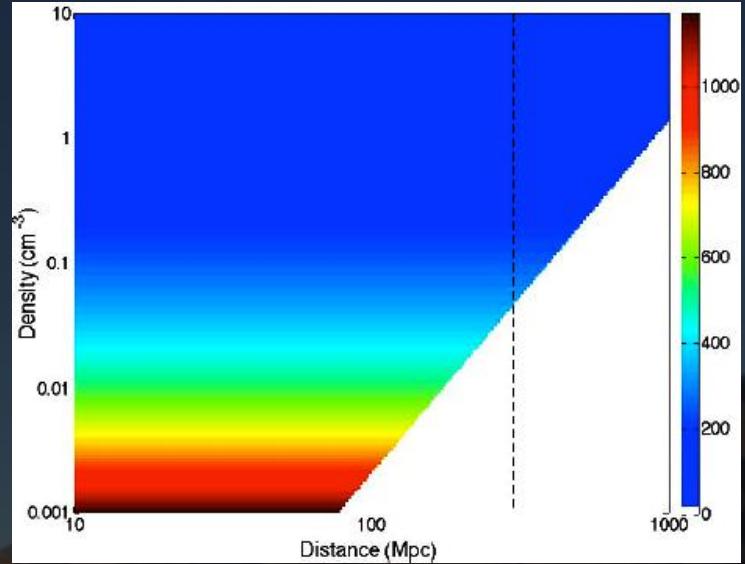
10 antennas, 60 K Tsys, dual pol, 22,000 Jy SEFD/ant

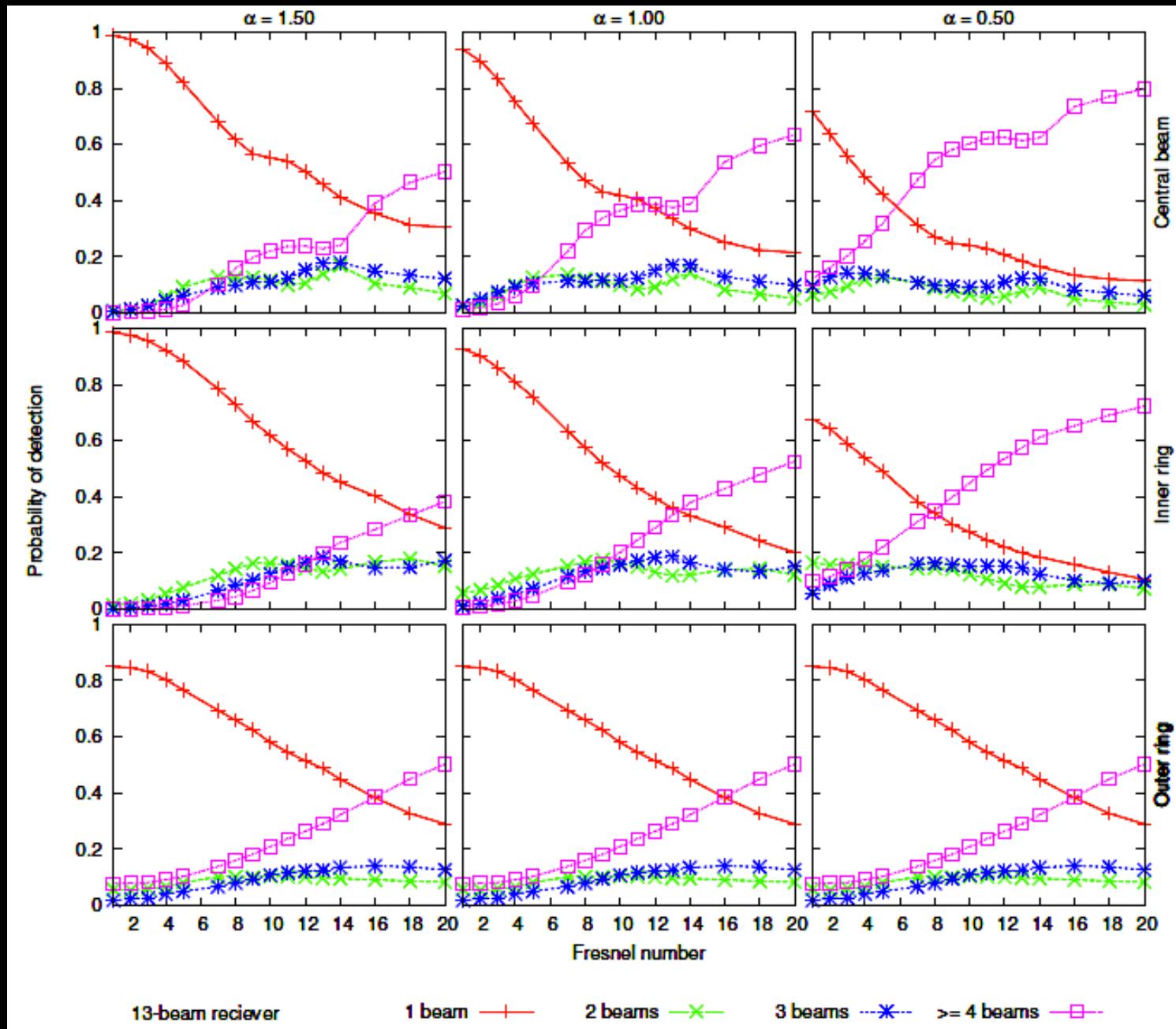


# The deep synoptic array concept

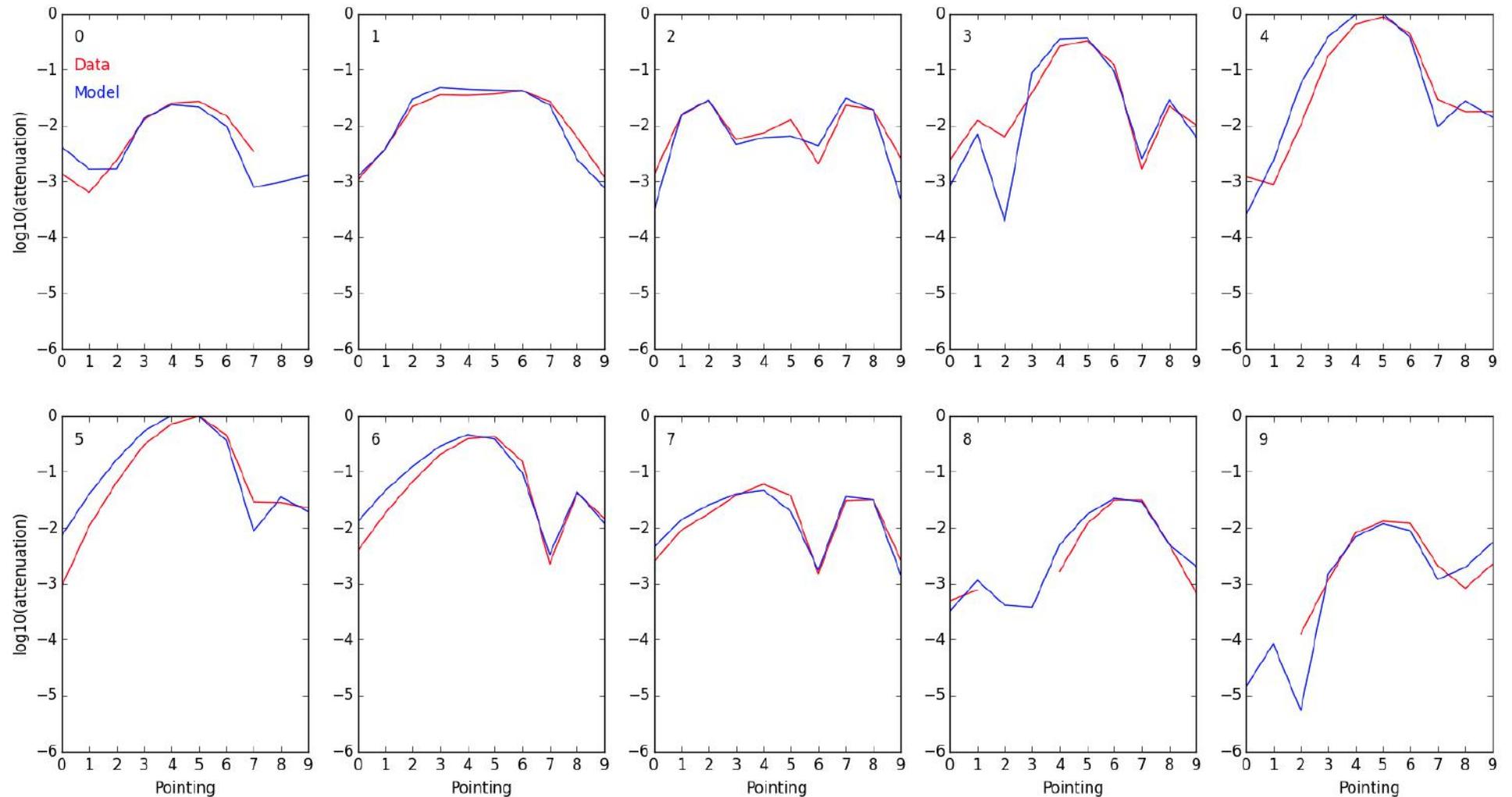
Image from Gregg Hallinan

A large-N ( $\sim 400$ ), small-D ( $<\sim 5\text{m}$ ) array, based on commercial dishes, uncooled 1-2 GHz receivers, inexpensive RFOF links, and a beast of a correlator.

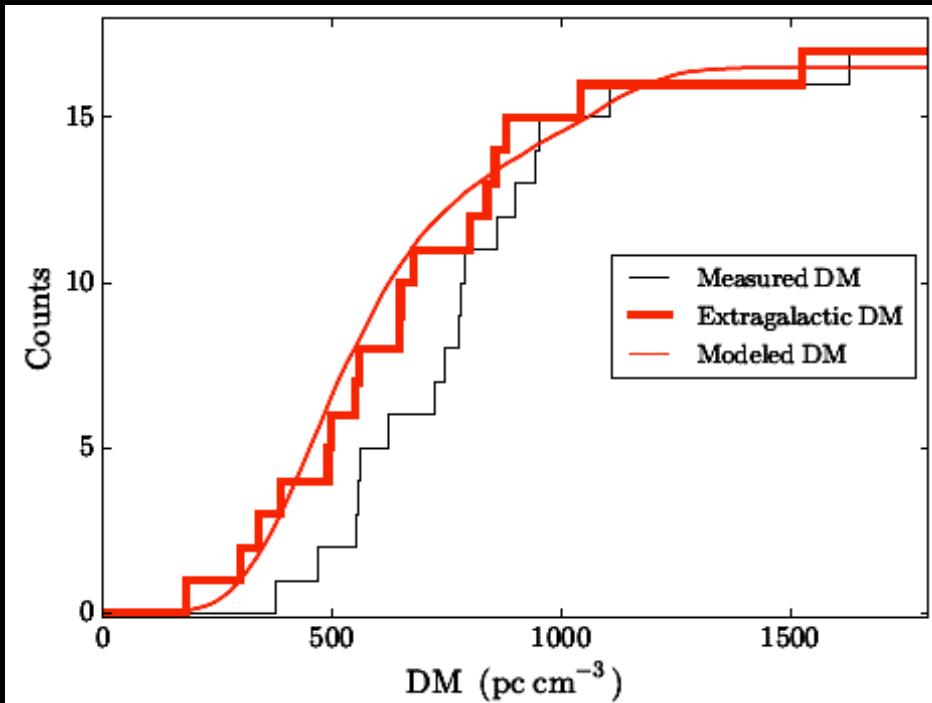
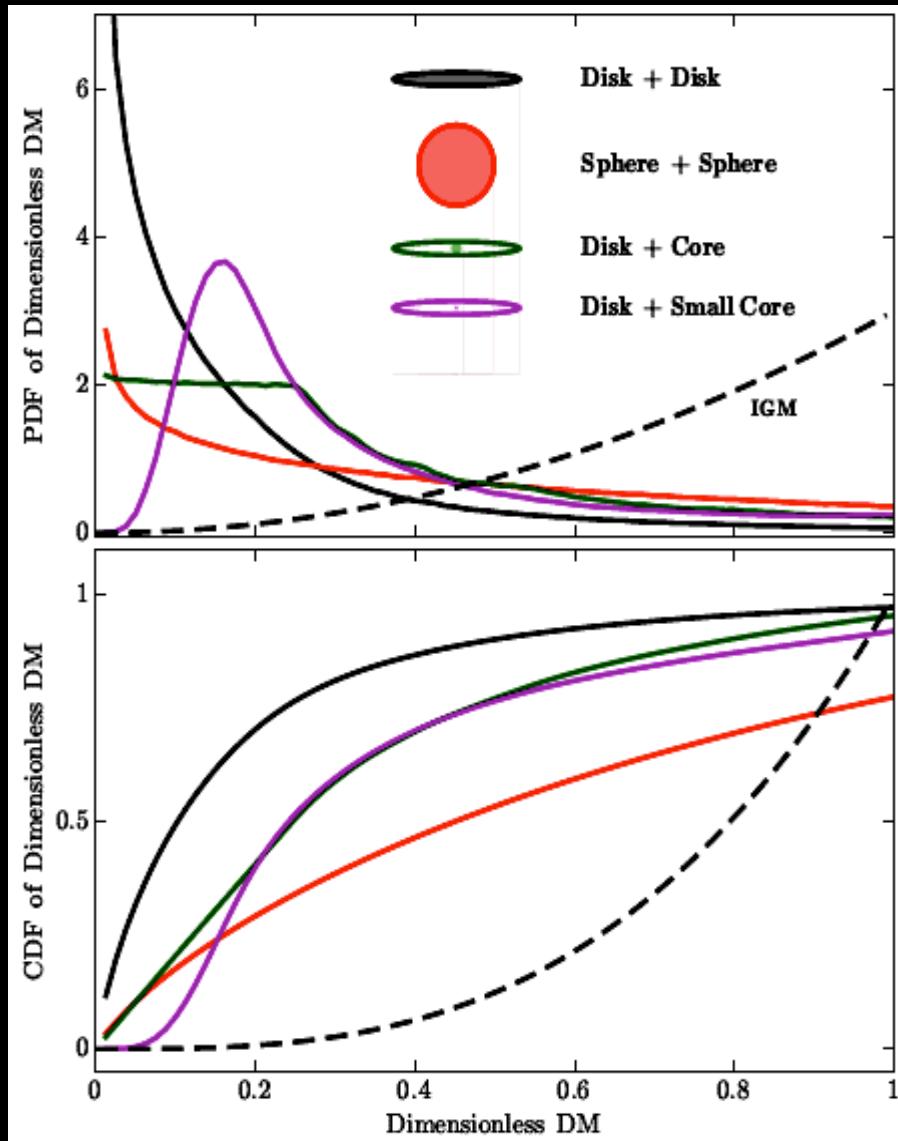




# Beam model tests

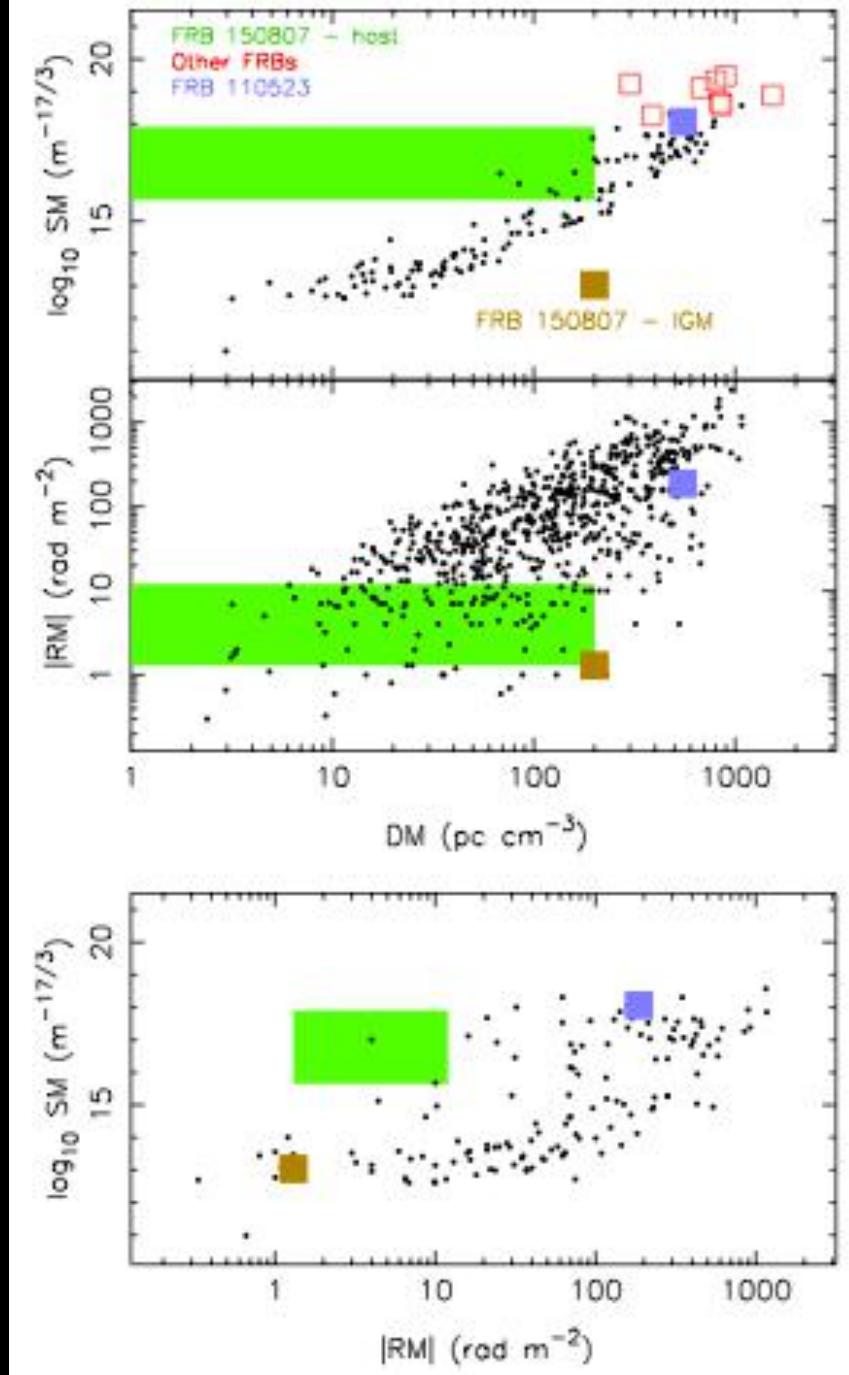


# Cumulative FRB DM/z distribution

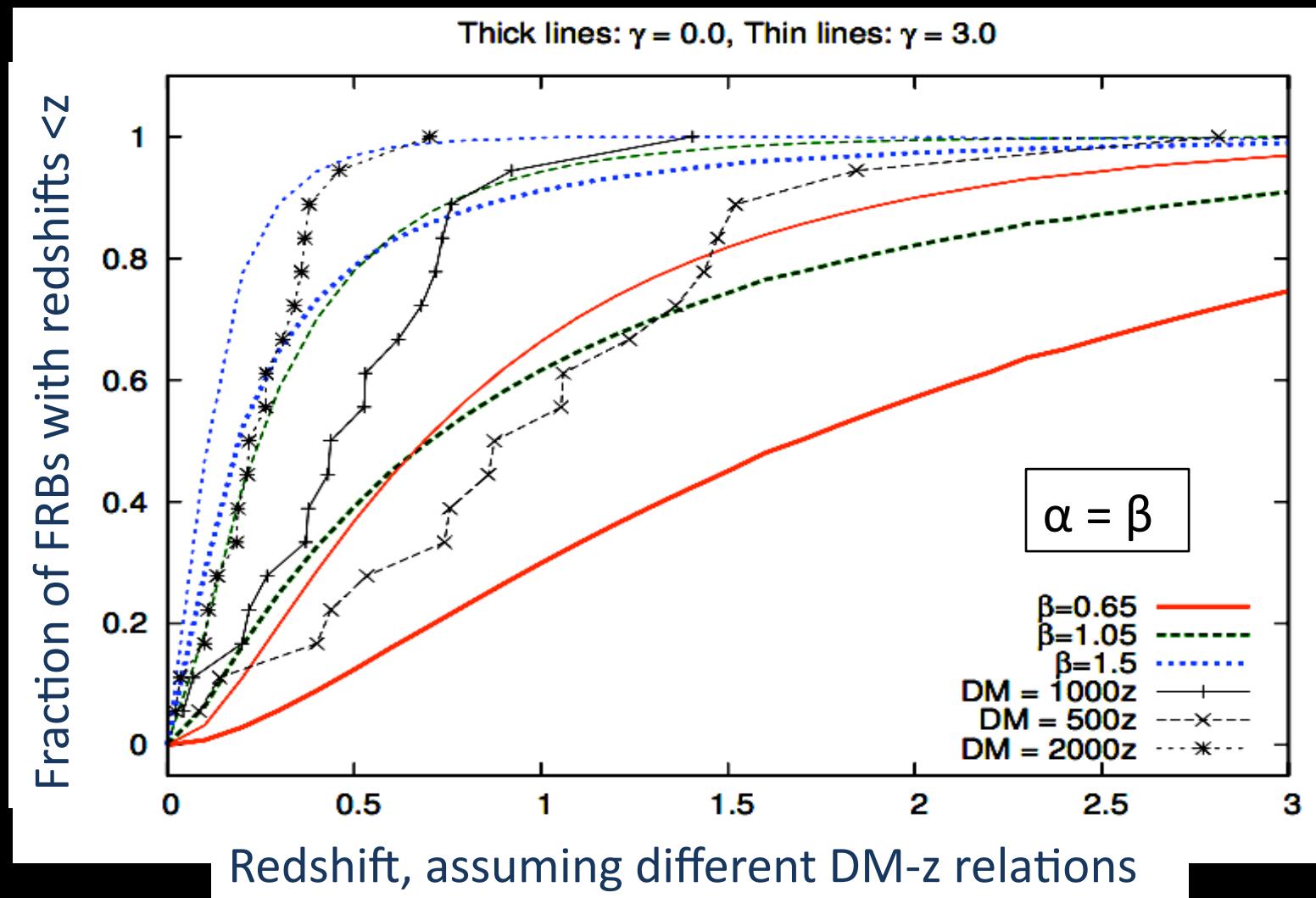


Number of FRBs at  $\text{DMs} < \text{DM}$ , with correction for Galactic contribution

PDFs and CDFs of DM from an individual host galaxy, and the IGM assuming standard candles



# Cumulative FRB DM/z distribution



**Gamma:** spectral index; **Beta:** cumulative luminosity function index

Vedantham, Ravi et al., submitted