The Ooty Radio Telescope

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A bit of history

- From the Kalyan Solar Array to the ORT.
- To build an equatorial-mount linear telescope.
- Find a slope parallel to earth's axis -> slope = latitude. Can't go too much to the north – why? Reasonably close to the equator.
- Completed in 1970.
- Built fully indigenously, all components designed and built in-house.

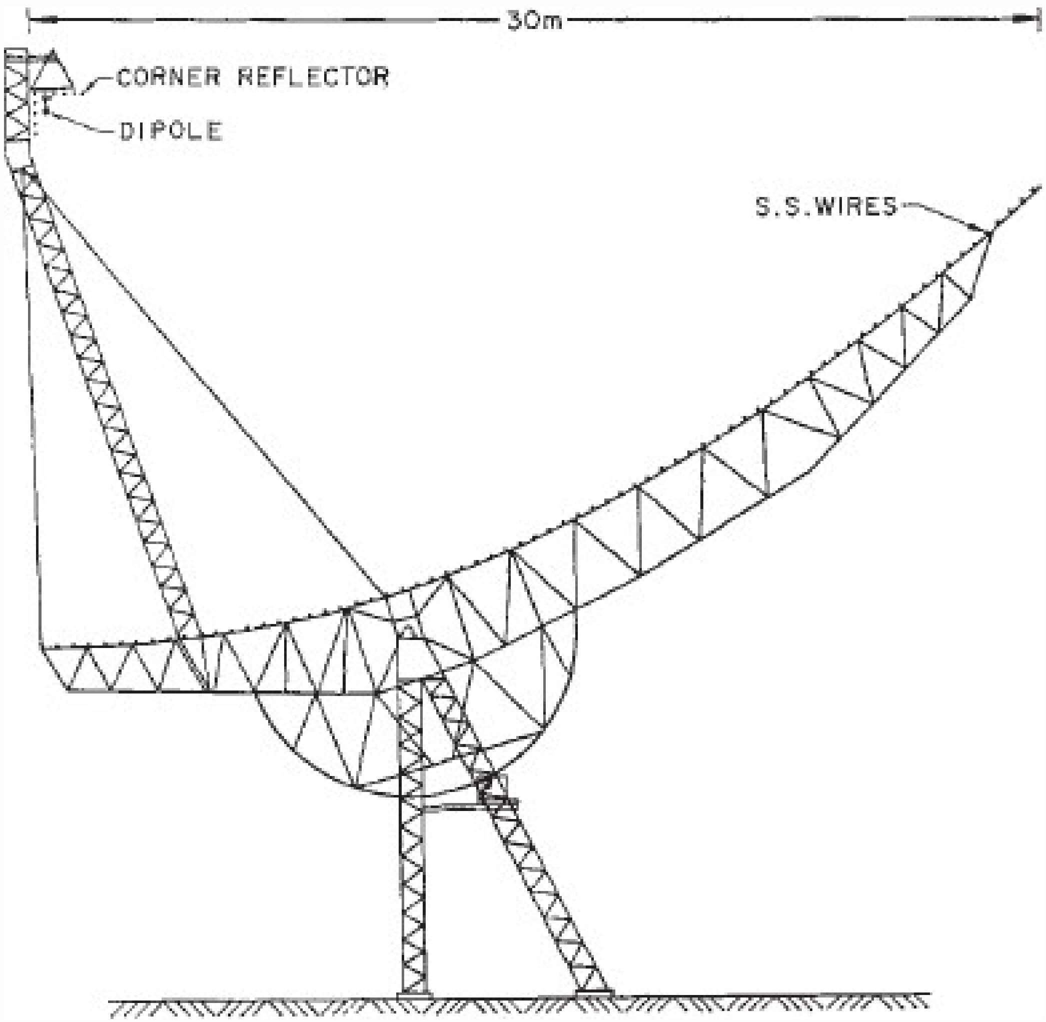
Some important numbers

- Half-wave dipoles
- 0.57λ spacing between dipoles
- Bandwidth – 4 MHz
- T_sys = 150 K(new array, 1990s).

  350K earlier
- A_eff = 0.6
- Area = 530m x 30 m
- RMS = T_sys / sqrt(Bt)

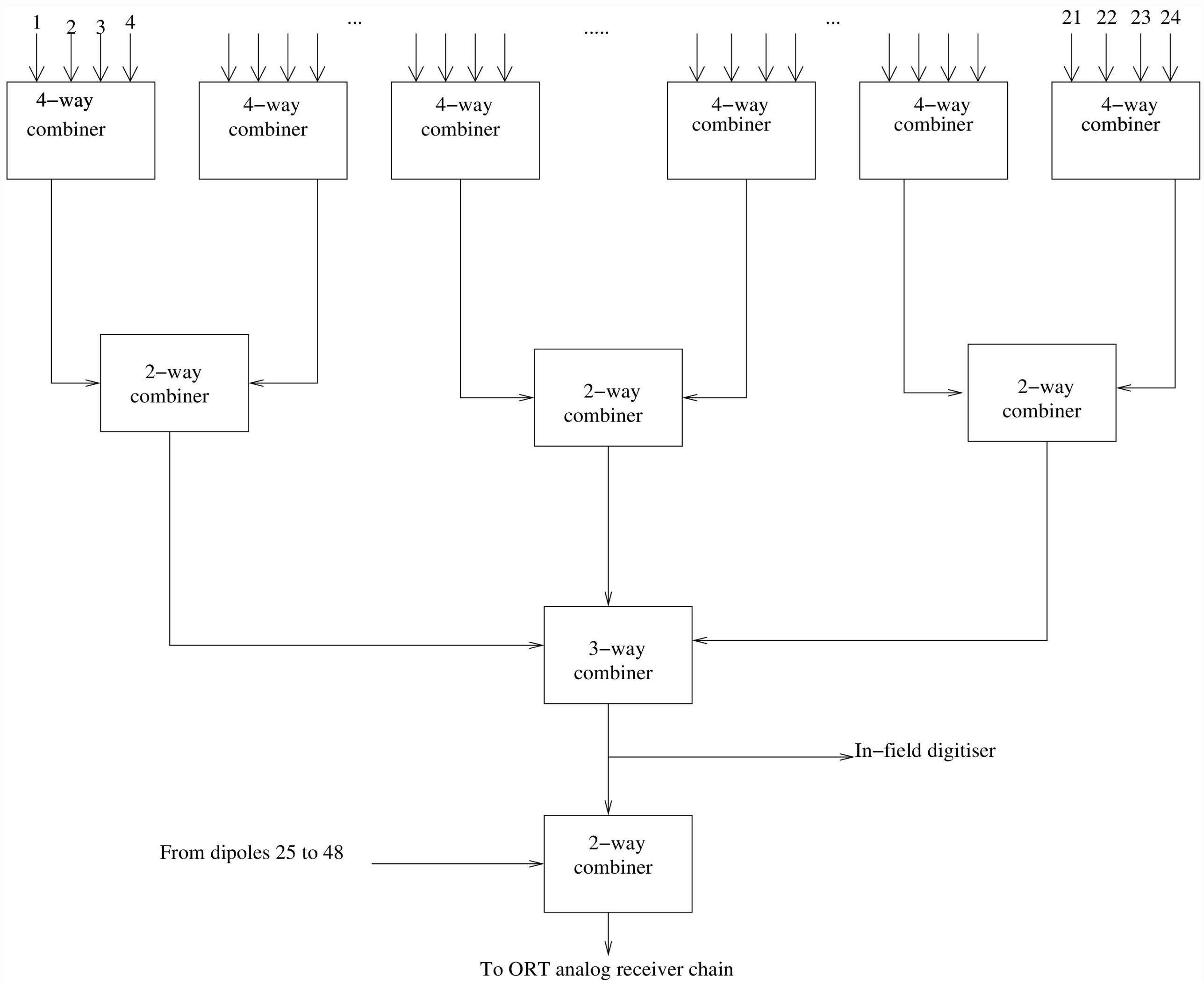
  = 150 / √(4e6*1) = 75 mK

  Gain = 3 K/Jy -> 25 mJy (~40 mJy in practice)
- Confusion limited at ~ 1Jy



Swarup et al, 1971, Nature Phy. Sci., 230, 185

The RF chain



1
2
3
4
...
.....
...
21
22
23
24
4−way combiner
4−way combiner
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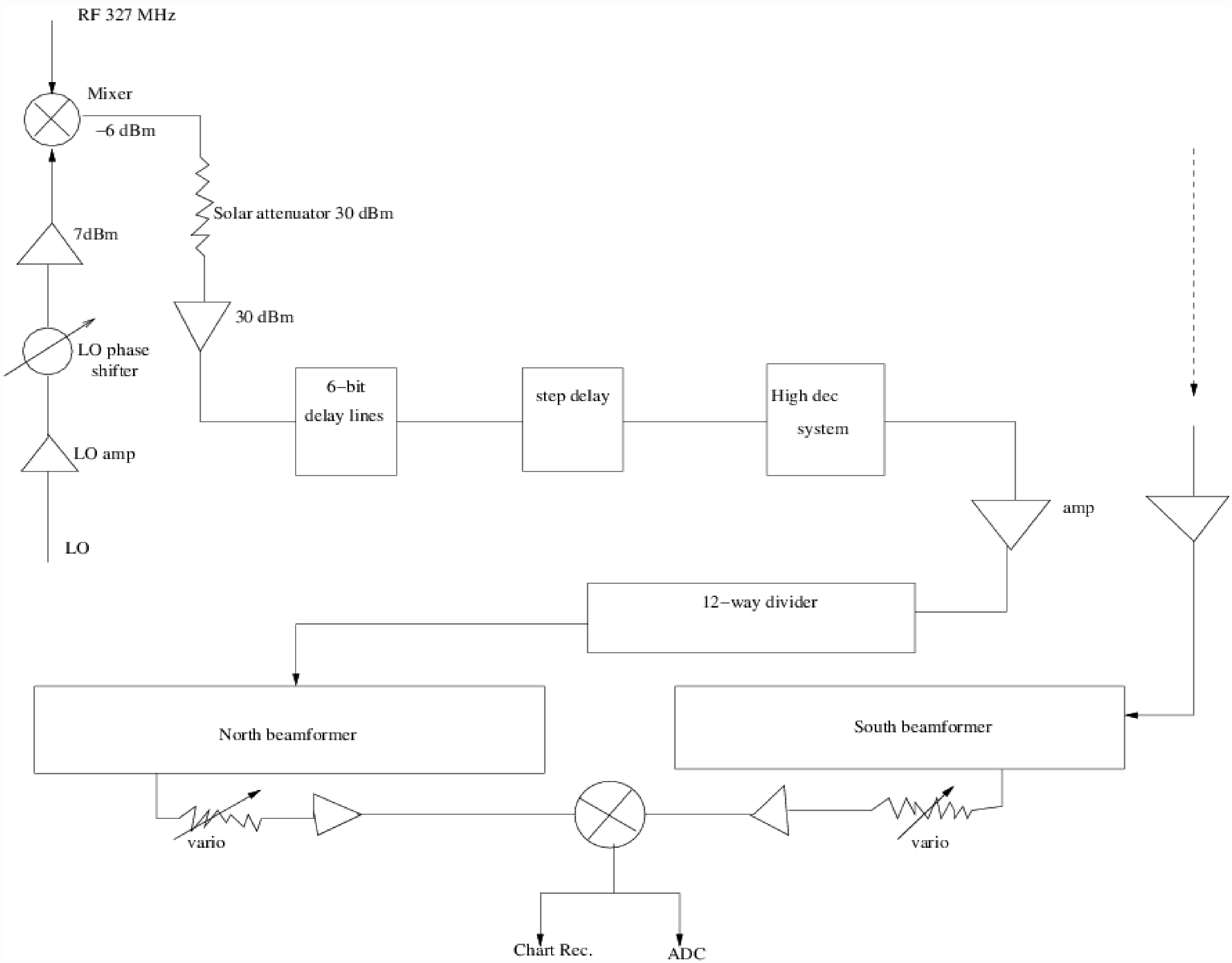
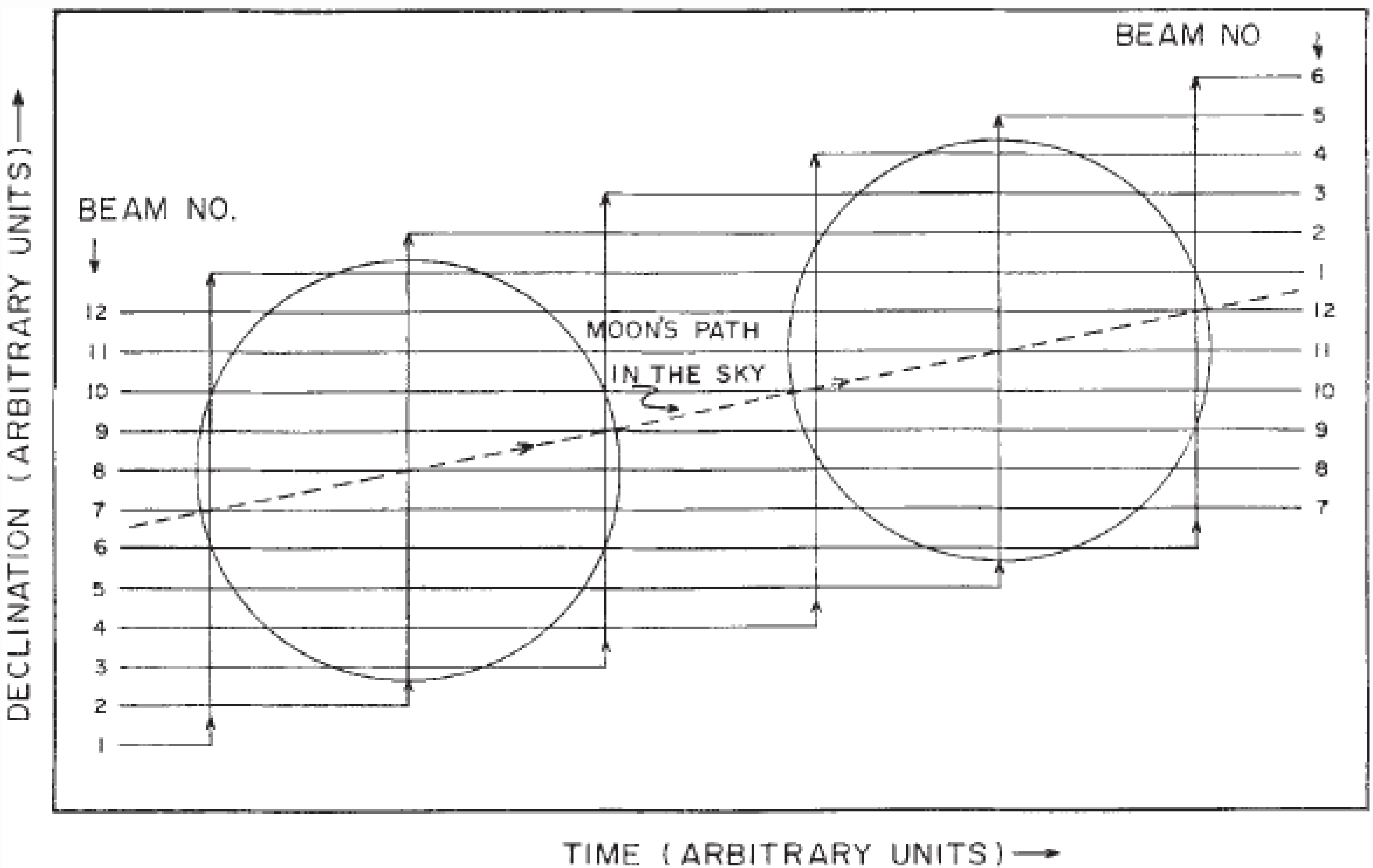
4−way combiner
4−way combiner
2−way combiner
2−way combiner
2−way combiner
3−way combiner
In−field digitiser
From dipoles 25 to 48
2−way combiner
To ORT analog receiver chain

Further down...



Lunar occultation observing



Early key science

- Precise measurement of radio source angular sizes and positions: high resolution in declination due to occultation. Res = 4 arcsec.
- Evolution of radio source linear size with redshift and luminosity: an importrant contribution to our understanding of the standard model of the evolving cosmos.
- Interplanetary scintillation (IPS) observations against compact sources to study the intervening medium.
- Observation of radio recombination lines(RRLs)

Source identification

Swarup et al., 1971 ApJL, 9, 53.

TABLE 1

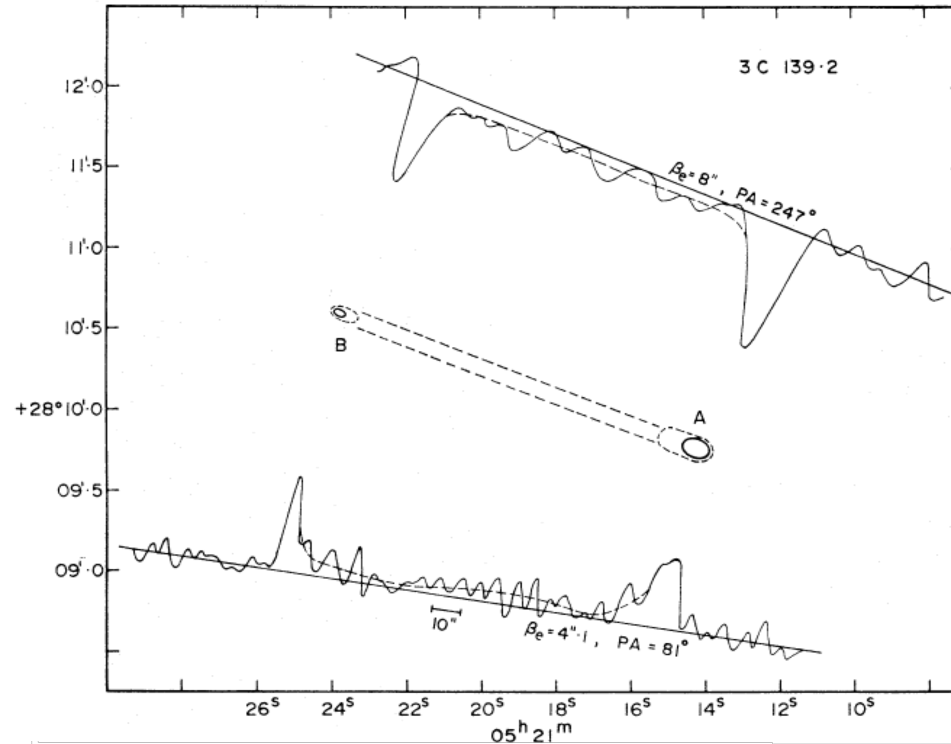
Structural data at 327 MHz for 25 radio sources

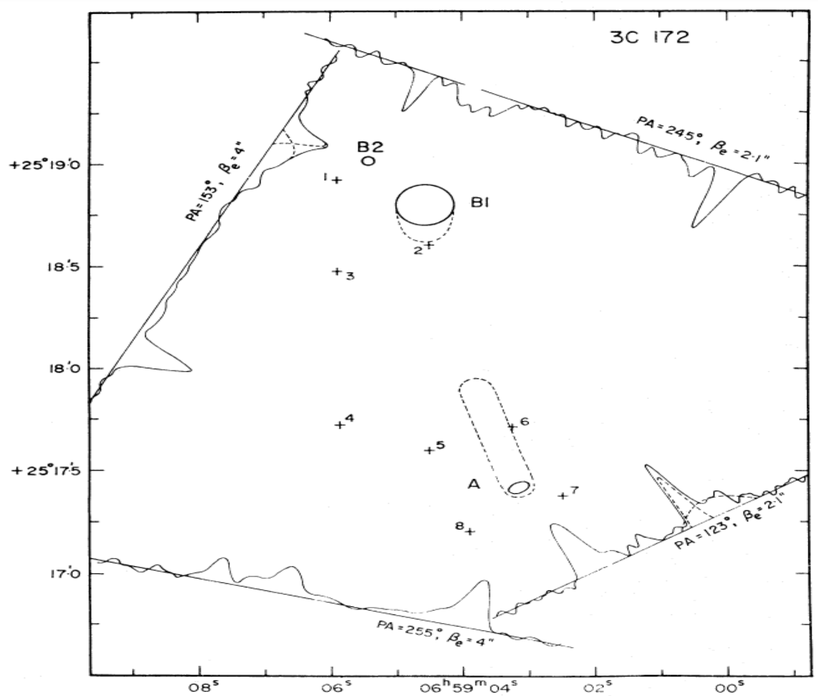
1	2	3	4	5	6	7		8	9	10	11
				Observed data				Derived structure			
Source OTL	Other cat. number	Flux at 327 MHz fu	No. of scans	β_r	PA of scan	Angular size of components A	B	PA A to B	Comp. sep.	Flux ratio A/B	Remarks
0018 +05	4C05.04	2.0	3	1.0″	12°	≦1.3″	~4″	25°	8″	1.0	
				1.0	198	≦1.4	~4				
0133 +14		0.8	4	2.6	35	≦2.0					
				2.6	269	~2.5					
0139 +15		0.8	2	1.9	352	≦1.8					
				4.1	310	≦3.5					
0142 +15		0.6	4	2.0	126	~4.0					
				2.0	187	~12.0					Possibly double.
0150 +16	4C16.04	1.9	4	2.0	42	~4.0	~3	90	8	1.5	
				1.0	239	~4.0	~2				
0248 +21	4C21.10	1.5	2	1.0	65	< 1.2					
				1.0	225	≦0.8					
0410 +26	4C26.15	2.1	4	1.0	17	~2.0	~1	108	3	0.6	
				1.0	290	~1.5	~1.5				
0556 +28		1.2	2	1.0	82	< 1					Possibly double.
				1.0	307	< 1					

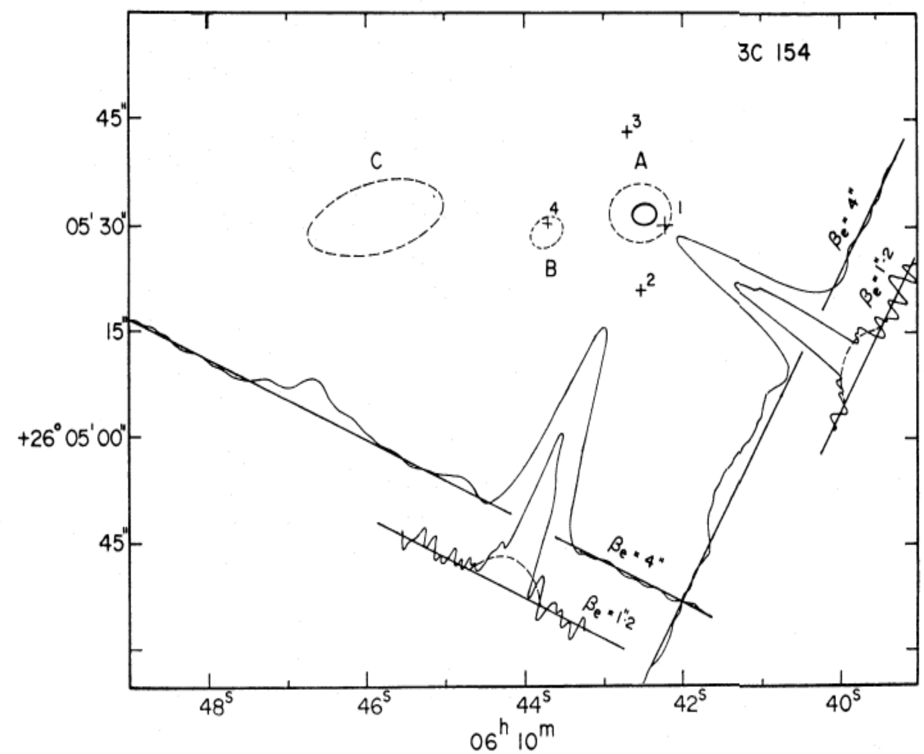
Table I

Summary of occultations

Source	Flux density 327 MHz	Date of occultation	Phase and PA of occultation
3C 139.2	6	08.05.70	I (126°), E (247°)
		29.07.70	I (81°)
3C 154	15	04.12.71	I (150°), E (247°)
3C 172	9	27.05.71	I (153°), E (255°)
		11.10.71	I (123°), E (245°)
3C 215	6	16.09.71	I (138°), E (268°)



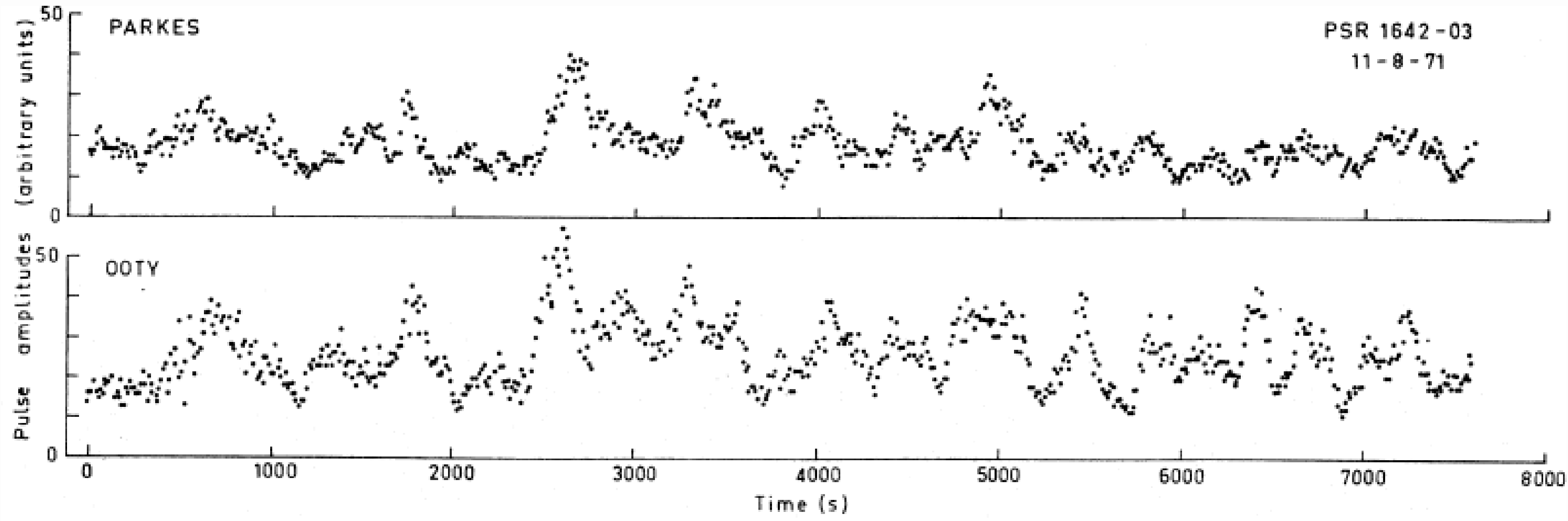




Kapahi et al., 1974, MNRAS, 167,299.

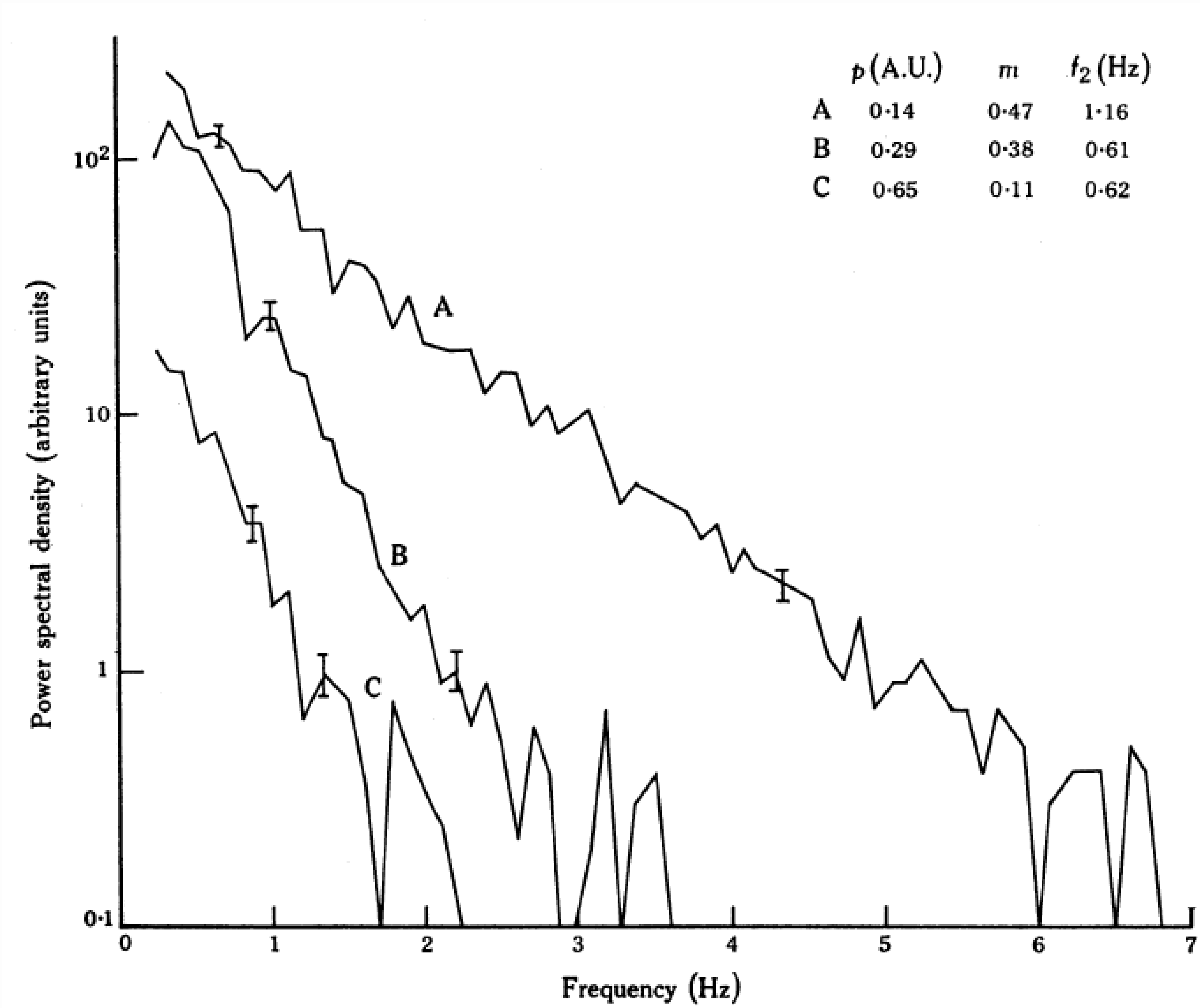
Pulsar intensity variation

Slee et al., 1974, MNRAS, 167, 31.



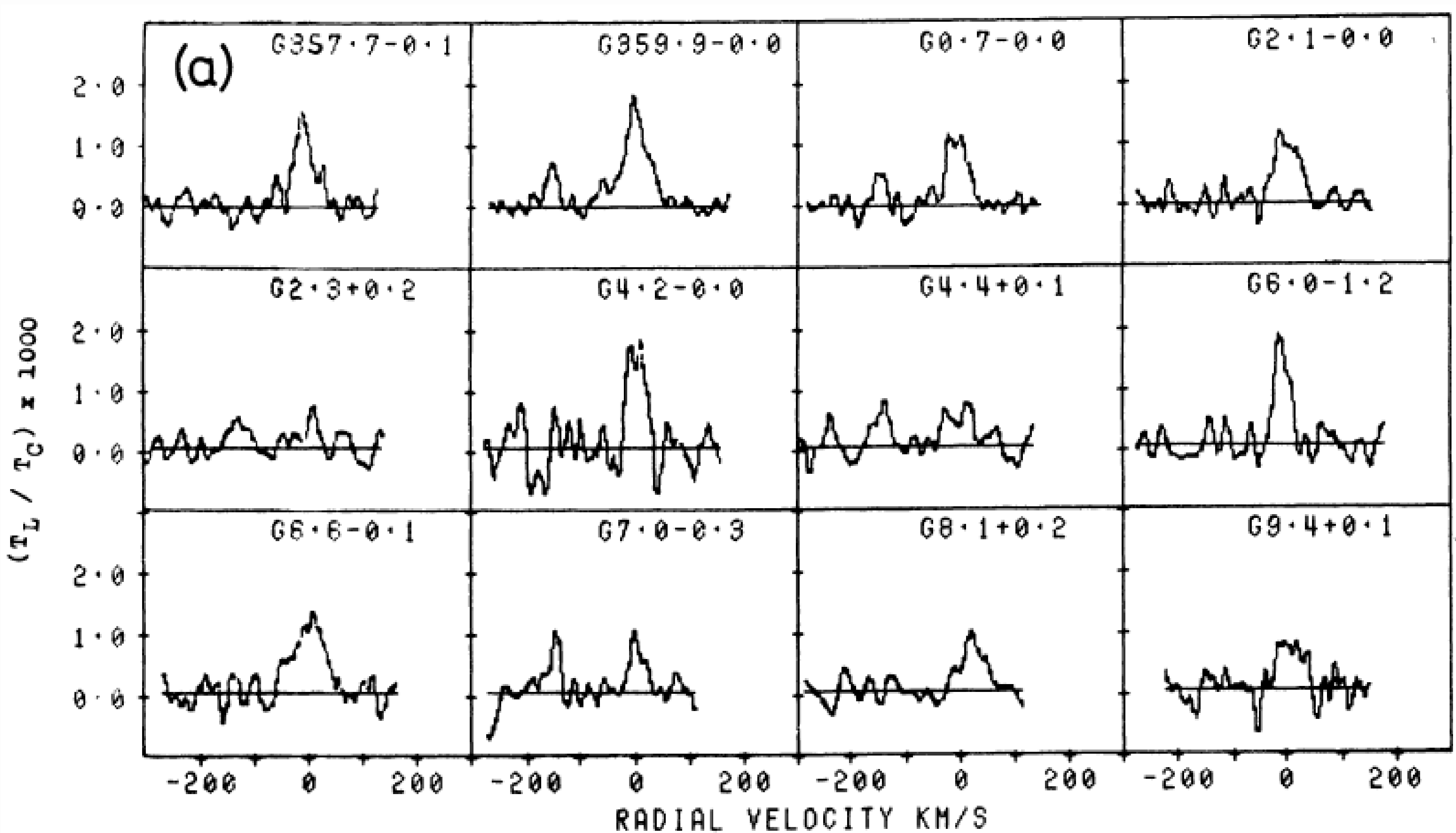
IPS measurements

Rao et al., 1974, Aust. J. Phys., 27, 105.



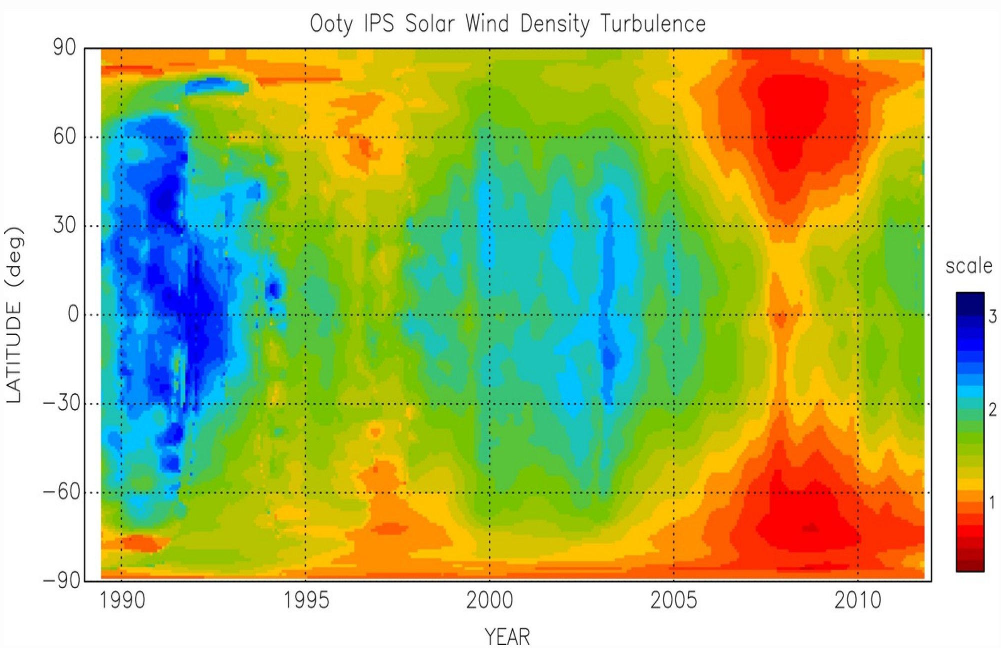
Radio Recombination lines

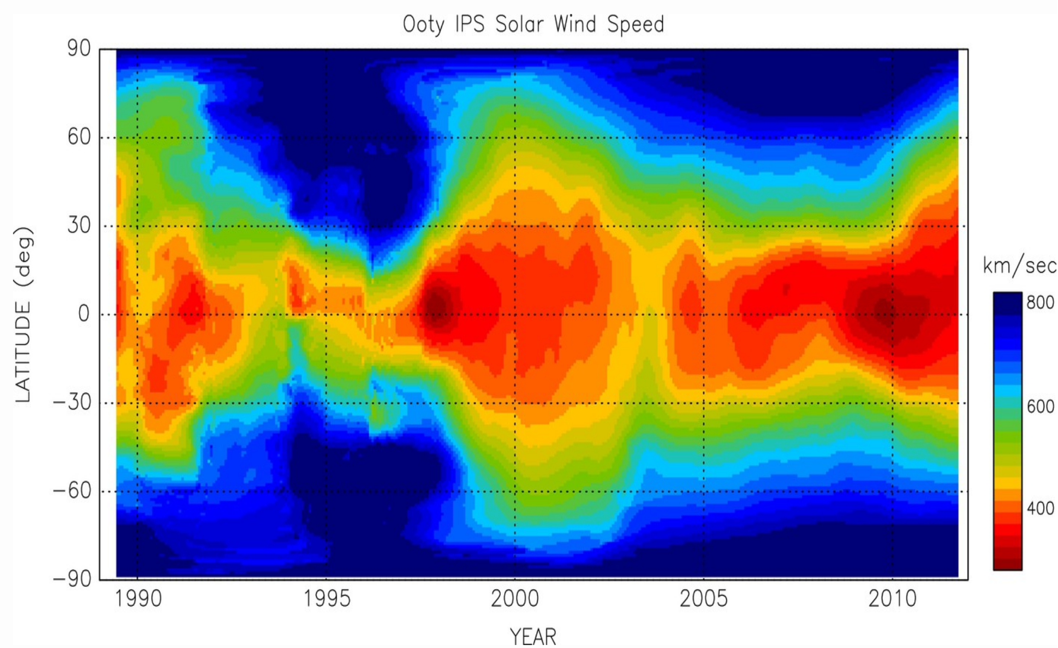
Anantharamaiah, 1985, JApA, 6, 177.



The ORT now

- Used mainly for IPS-based observations of the solar wind
  - > Solar wind speed, density and turbulence
  - > Propagation of solar flares and CMEs
  - > 3D tomography of the solar wind

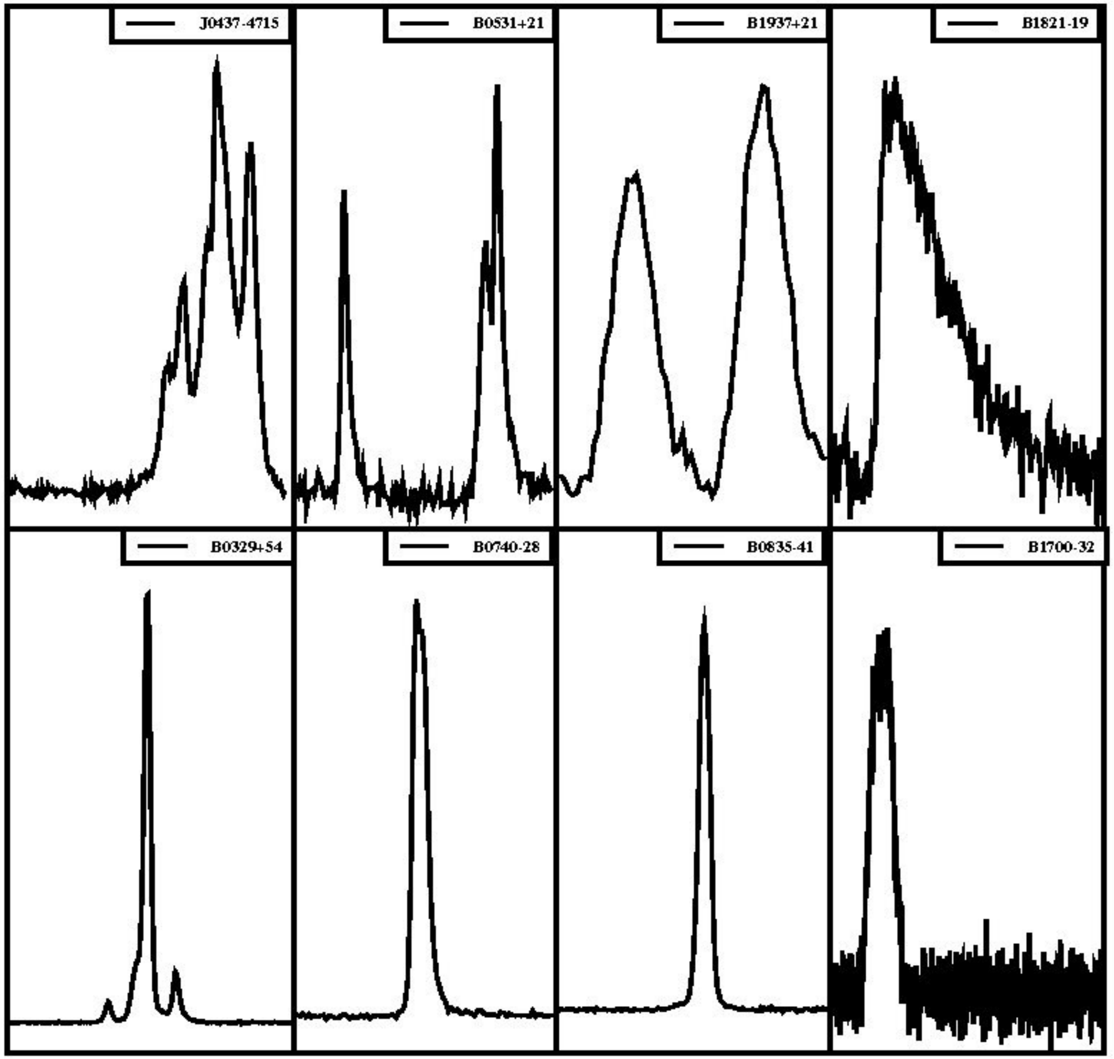




Manoharan, 2012, ApJ, 751, 128.

Pulsar observations

- Pulsar observations with more recent receivers.
- Sampled total power(beam 7), followed by dedispersion.
- Ideal for searches, but modest sensitivity.



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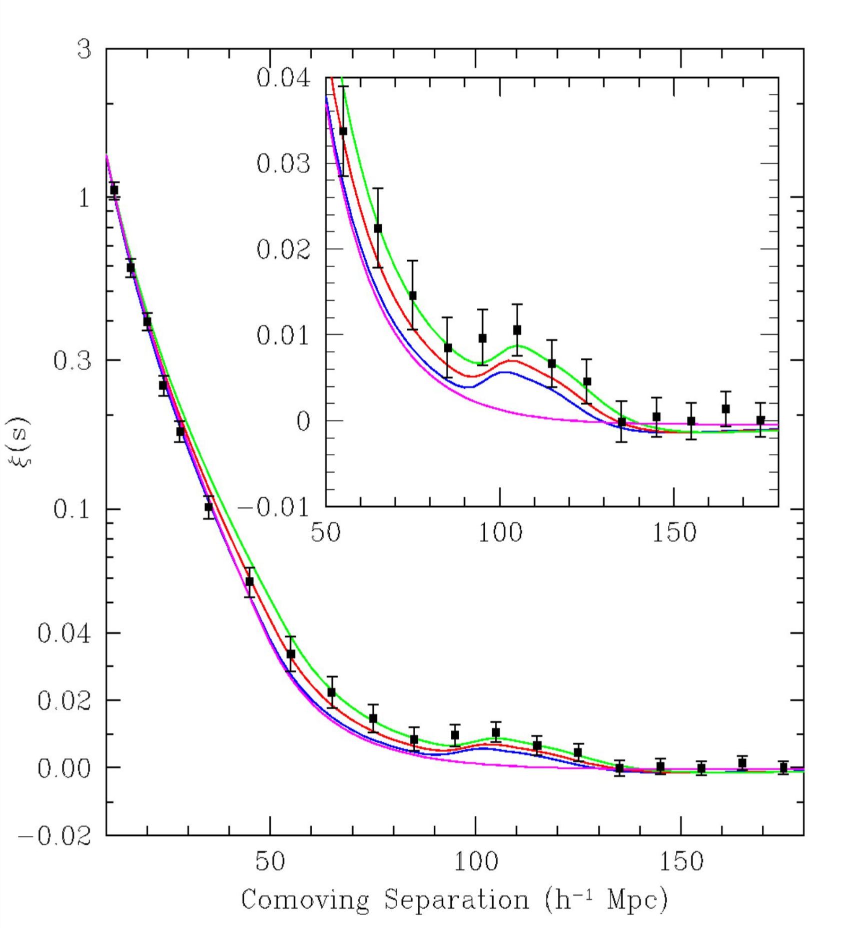
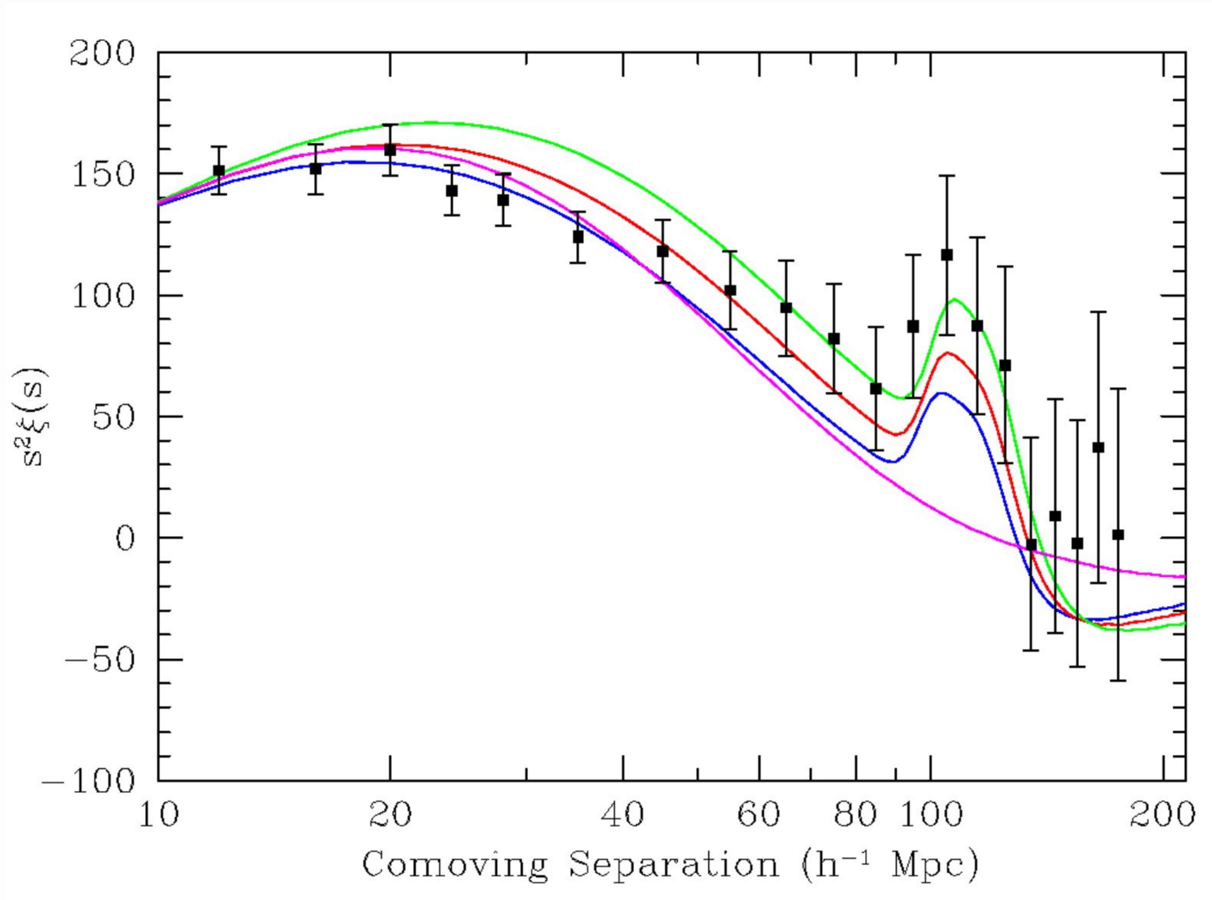
Motivations for modernization of the ORT

- From a beamformer to an interferometer.
- Regular, linearly aligned, highly redundant baselines.
- Certain cosmology experiments require very high-precision calibration, enabled by redundancy.
- The upgrade to the ORT receiving system is tailored to a specific cosmology experiment, vis. the detection of the matter power spectrum weak BAO signature at 100 h^{-1} Mpc.
- Available detection in optical to low redshifts(z ~ 0.47) from ~3800 sq deg; 0.72 h^{-1} GPc^3 volume of universe observed.
- Attempts to detect the BAO peak in intermediate redshifts in progress in radio.





Eisenstein et al., 2005, ApJ, 633, 560.

Upgrade to the ORT

- Happening in two phases – to exist in parallel.
- In phase-I, 40 groups of 24 dipoles each – 40-element interferometer. BW = 19 MHz. FoV = 4.5º, 780 baselines, 39 unique baselines.
- In phase-II, 264 groups of 4 dipoles each – 264-element interferometer. BW = 40 MHz. FoV = 27º. > 34000 baselines. 263 unique baselines.
- Resolution = 1.75º x 0.1º.
- Digitized in-field, signals transported on optical fiber.
- Programmable digital receiver for recording and correlation.

Numbers for the ORT BAO expt.

- RF = 327 MHz -> $z = 3.35$.
- BW = 40 MHz -> $z \sim 3.1 - 3.63$.
- Beam = 1.75 deg x 27 deg.
- Volume = 1.4×10^7 Mpc^3.
- $\Omega_{HI} = 0.001$, $h = 0.72$, ΛCDM cosmology.
- $M_{HI} = 1.96 \times 10^{15} M_{sun}$ ~ 200000 *Milky ways*.
- ~10 Jy from HI within the band.

Unique advantages of the ORT

- Equatorial mount – coherent addition of visibility
- Multiple, highly redundant measurement of unique visibilities – overdetermined system of equations, enables precision calibration
- Enhanced sensitivity: Phase-I : 12.6 mJy
Phase-II : 9 mJy
- Larger field of view – fast surveys + better resolution(from lunar occultation)
- Theoretically, BAO achievable in ~1000 hours of integration
- w-term can be completely avoided – the vanishing elephant
- Compact array – ionosphere tractable
- Amenable to embarrassingly parallel realization of data lines
- Virutally unlimited observing time

Ongoing efforts at the ORT

- Work underway for the software correlator.
- Calibration using Phase-I receiver and system characterization.
- Routine IPS observations with the legacy receiver.
- New pulsar backends for routine pulsar observing and POS. Doubles up for IPS.
- New algorithms for third generation calibration techniques being devised.

Questions?