Circularly polarized emission from the transient bursting radio source GCRT J1745-3009: Emission from magnetized dwarf ?

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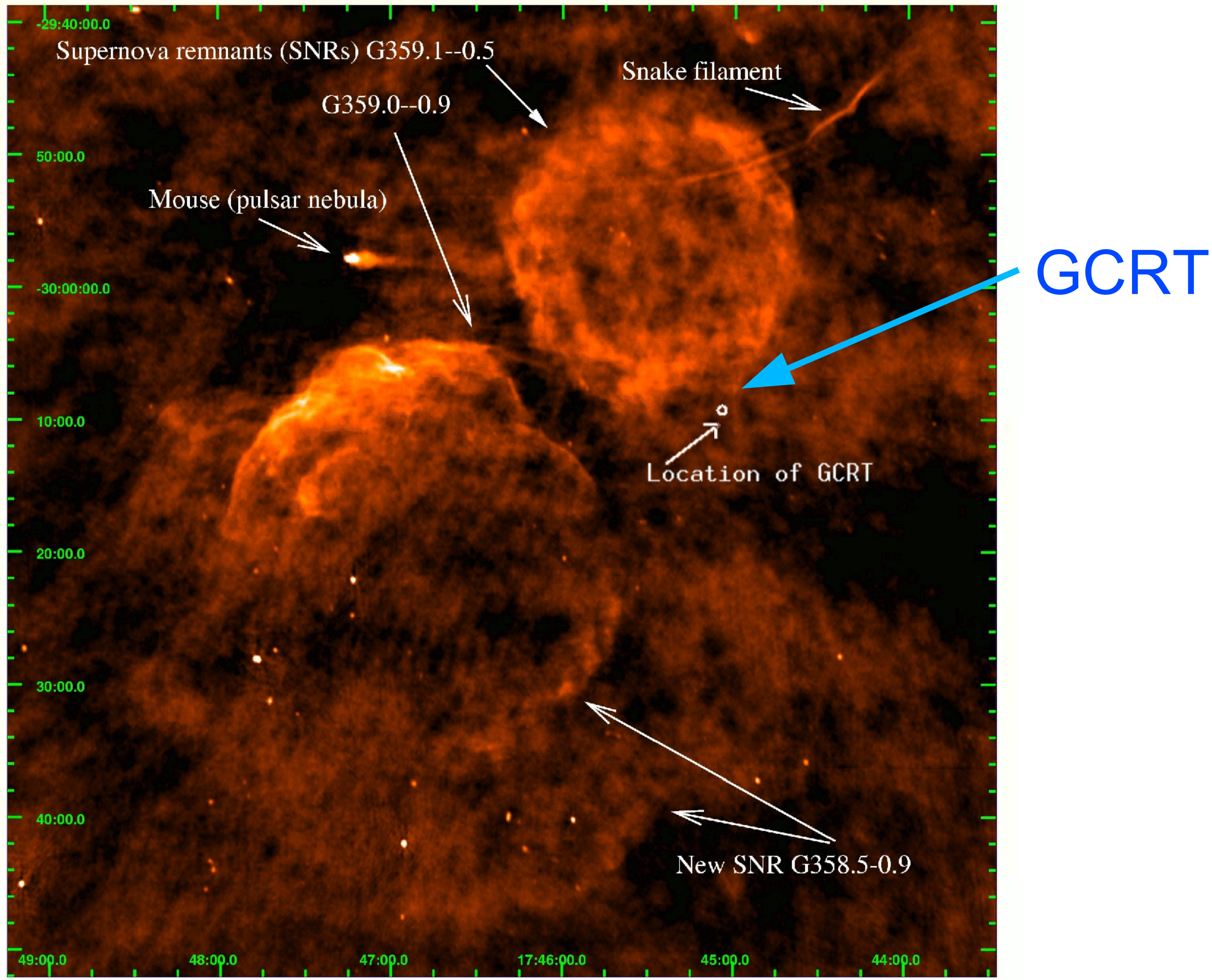
The GCRT: Introduction

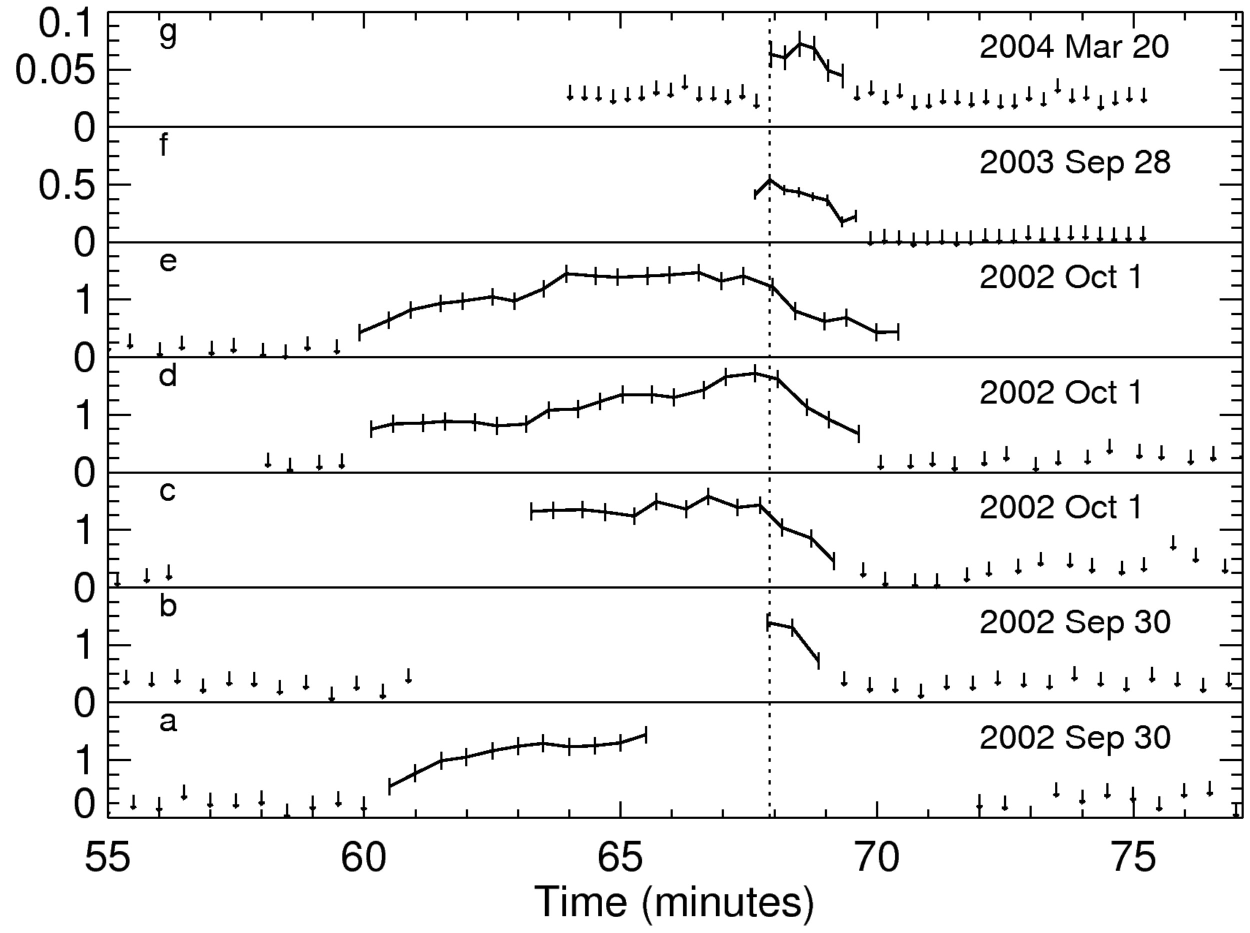
- Bursting transient radio source J1745-3009 discovered by Hyman et al. (2005) at 330 MHz.
- On 10 minutes, in each period of 77 minutes during discovery observation.
- **Brightness temp >10^{15} K if near the GC.**
- Likely to be coherent emission.
- 77 min too high for a typical pulsar.



330 MHz image of the field G358.8--01 located about 1 degree south of the Galactic Centre. The resolution is ~14" and the rms noise ~1 mJy/beam. This is the highest sensitivity image of the region and is made from GMRT data. The map is used to confirm a faint barrel shaped SNR shown near the bottom.

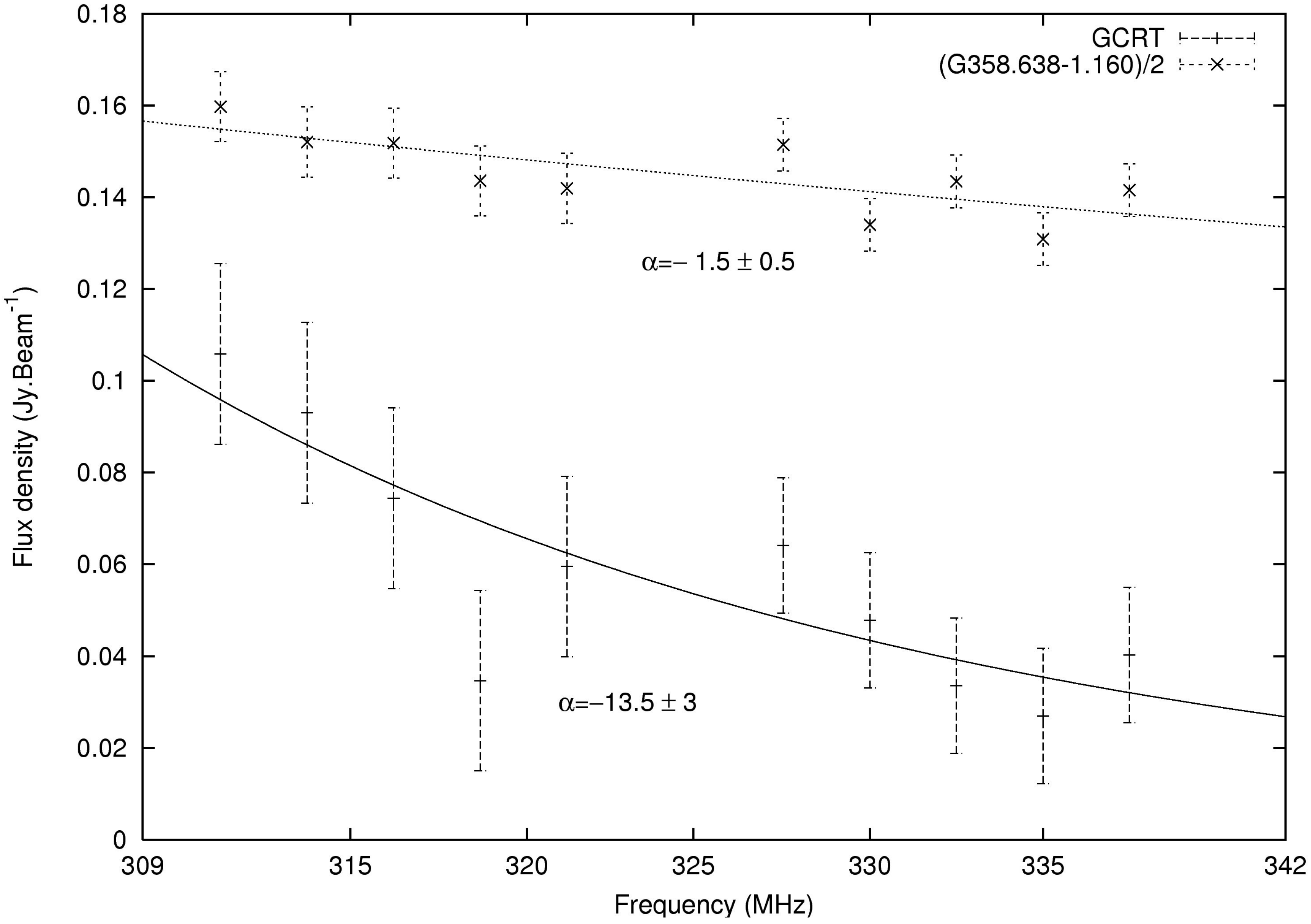
Radio detections

- GMRT observations in 2003.
- Serendipitous detection from 2004 SNR data.



Light curve of GCRT emissions at different epochs. These have been folded with a periodicity of 77 minutes.

Results...

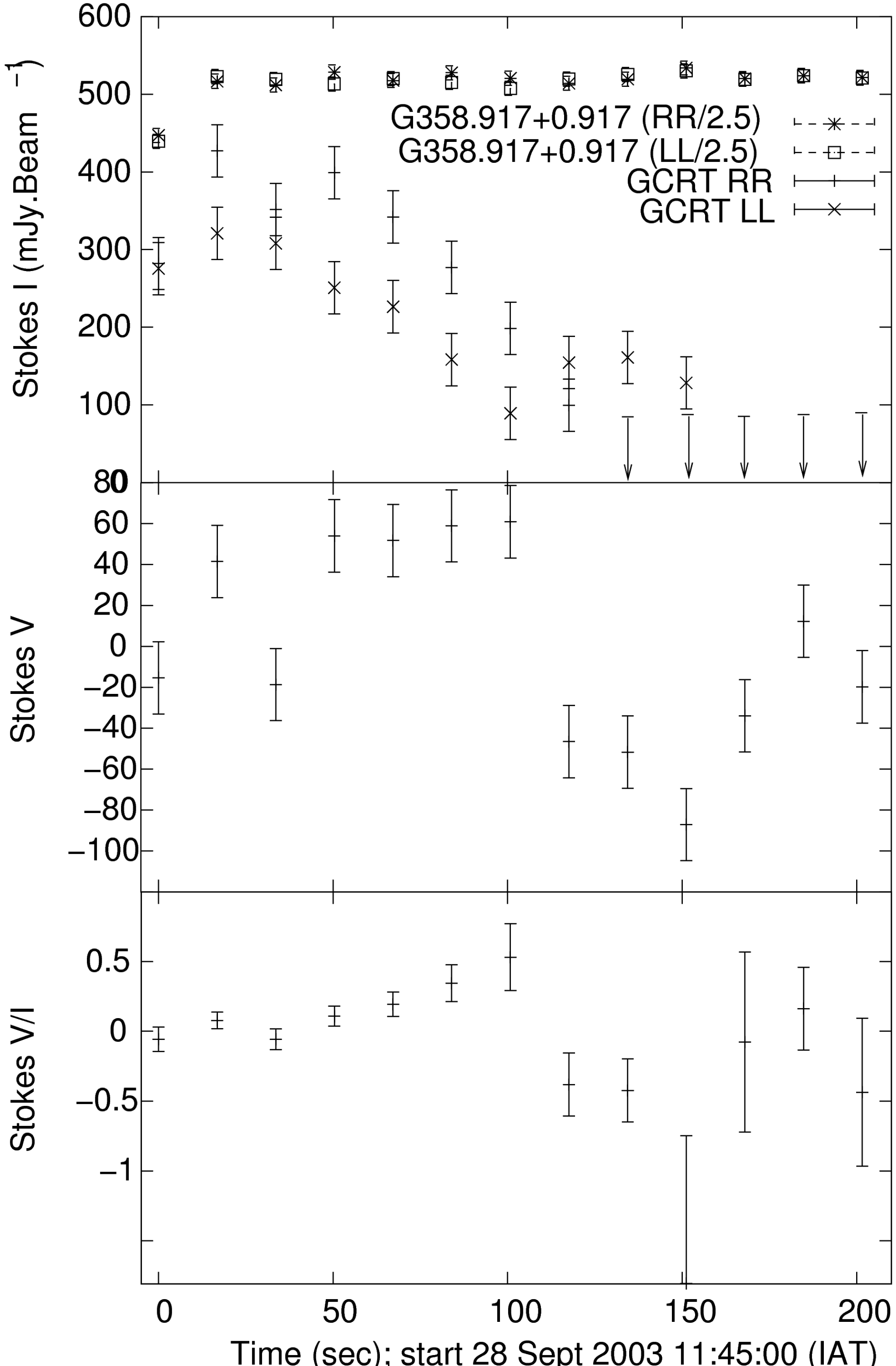


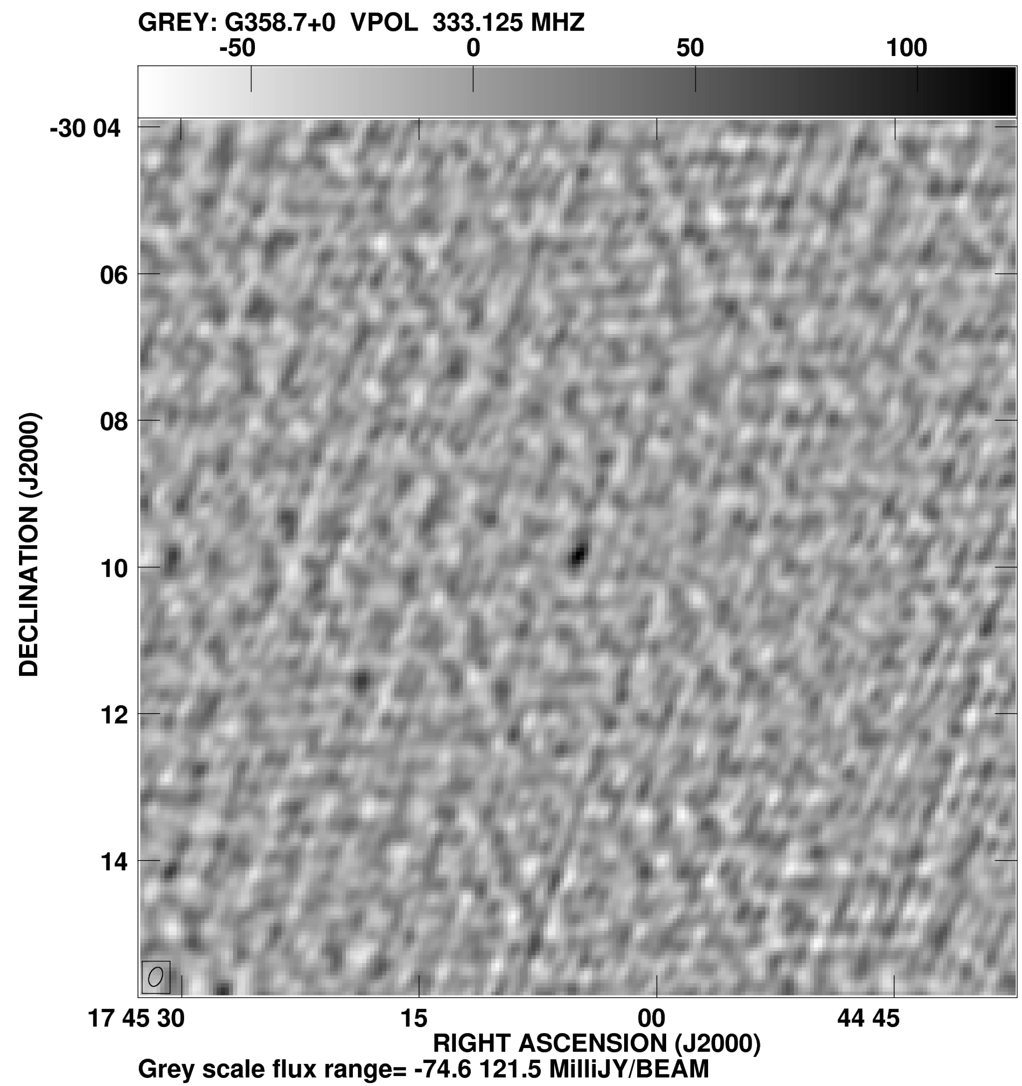
GCRT
(G358.638-1.160)/2
α=− 1.5 ± 0.5
α=−13.5 ± 3
Flux density (Jy.Beam^{-1})
Frequency (MHz)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
309
315
320
325
330
335
342

Results ...

- Very steep spectrum (-13 ±3) (Hyman et al. 2007).
- Reanalysis of 2003 outburst.

Circularly polarised emission





Stokes V difference image made from data integrated between 35 to 103 and 103 to 155 seconds respectively from the scan start and bridging the polarisation reversal. Rms noise 19.2 mJy.Beam^{-1}.

Discussions

- Stokes V reversal within 17sec. **Size < 8.$R_\odot$**.
- Brightness temperature $>10^{10}$ K for distance **>1 pc**, and **circular poln.** rules out thermal and incoherent synchrotron emission.
- Integration time > known pulsar periods.
- Pulse averaged Pulsar Cir. Poln. frac. <<100%.
- Pulsar based scenario ruled out.

Discussions ...

- **Cyclotron or plasma emission** produces high circular polarisation.
- Bandwidth $\lesssim$ 0.1.ν (~30 MHz).
- Cyclotron -- magnetic field ≤120 Gauss, typical in **stellar corona**.
- Plasma emission – 10^9 ions.cm^{-3}, less likely in brown dwarf corona.

Discussions ...

Distance and Classification:

- T_B of cyclotron emission could reach up to **~10^{20} K** (Melnik 1994, Slee 1969).
- Distance upper limit **100 kpc** (<EG distance).

Limits from IR observation:

- Near IR observation with Magellan and Gemini.
- 3 *I*-band objects within its 3σ positional uncertainty.
- Spectrum of 1 of them (C) is of late K / early M type star at **>1 kpc**, or a cool dwarf L5 star at ~200 pc (Kaplan et al. 2008).

Distance limits ...

- **Flare stars** (typically dwarf stars of class G to M) in the Galaxy could emit strong **high Cir. Pol.** radio emission.

<u>History</u>: More than 50 obs. from 1958 (Gershberg 2005) in ~tens of MHz to ~GHz frequency.

- Mostly **M dwarfs** (e.g., V 371 Ori, UV Cet, YZ CMi, EV Lac and AD Leo).
- Highest known luminosity: **230 Jy** at 136 MHz from **Orion** nebula (400 pc away) (Slee & Higgins 1969).
- Comparable GCRT luminosity (2002 outbursts) places it **~4 kpc** away (similar to IR limit).

Comparison with flare star Cir. Poln.

- Cir. Poln. from flare stars 0 to 100% (Abada-Simon et al. 1994).
- 40-60% of Cir. Poln. in 8 cases (Nelson et al. 1979).

  Lang et al. (1983) -- 15% Cir. Poln. from AD Leo.
- *Reversal* in Cir. Poln. seen from AD Leo (Jackson et al. 1989).
- Varying mode coupling → change Poln. fraction and poln. *sense reversal* (Dulk 1985, Melrose 1980).

Periodicity of 2002 outbursts

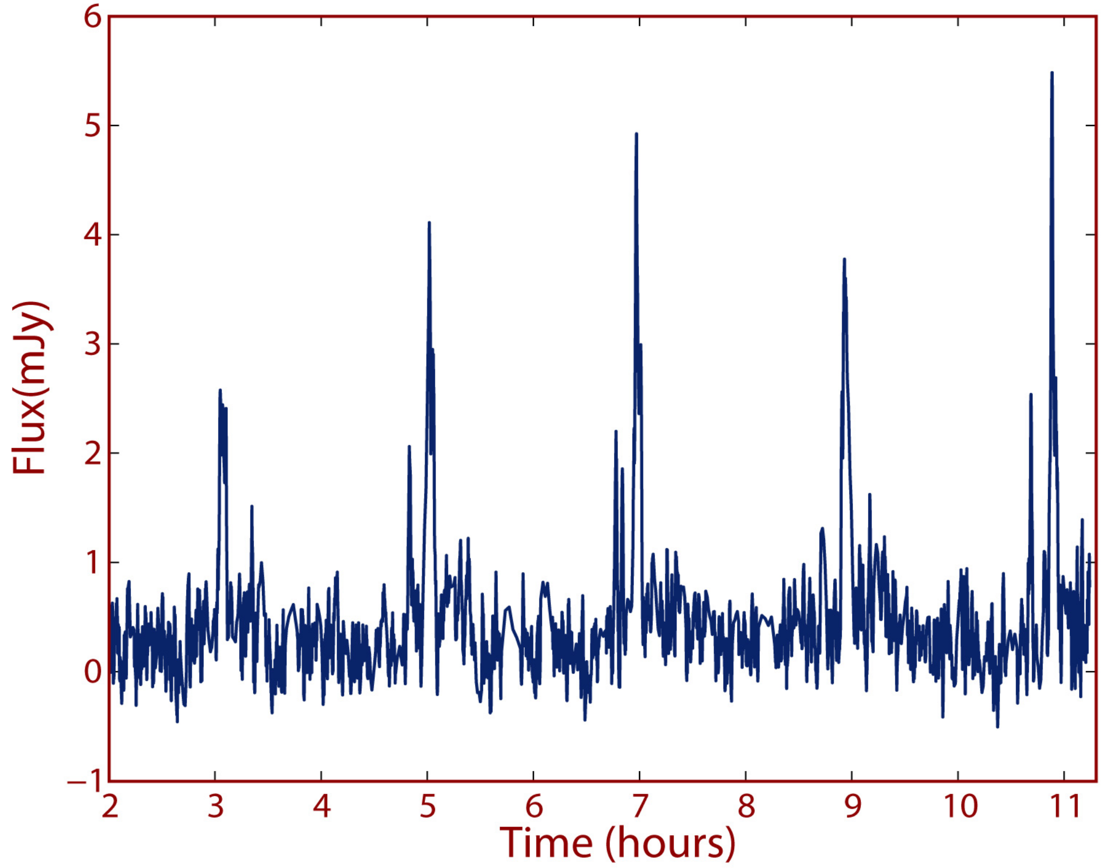
- Stellar flares not known to occur periodically.
- Rotation period 77 min. of the spot of emission ?
- Measured rotation period decreases toward lower mass ($0.1.M_{\odot}$) stars to ~0.1 day [e.g., in Pleaides, Irwin et al. (2008)].
- Few of these ultracool dwarfs produce flares at radio frequencies (Burgasser & Putman 2005).
- Within one rotation there could be two pulses.
- One detected with radio flare varying with a time period of 2 hours (Hallinan et al. 2007).

Candidate progenitor of the GCRT

- Kaplan et al. (2008) IR observation identified one object (C) as a possible counterpart.
- IR flux densities are not well fitted by emission from an ultracool dwarf (L4.5V).
- Goodness of the fit remains similar if their K7V star is replaced by a ~0.1.$M_\odot$ star ~0.1 Gyr old (young mid to late M type of star) with Av ~3.5 (distance ~4 kpc).

Conclusions

- Detection of time varying high (up to 100%) circular poln. from the GCRT J1745-3009.
- $T_B > 10^{10}$ K for distance >1 pc shows coherent emission.
- Properties inconsistent with Pulsar, but could result from cyclotron or plasma emission.
- Radius $<8.R_\odot$.
- 77 min periodicity could correspond to half of rotation period.
- GCRT could be outbursts from a highly subsolar flare star with a distance $\lesssim$4 kpc.



Time series of radio emission from M9 dwarf TVLM 513-46546 (Hallinan et al.)