Tick Tock - The 12.2 GHz Methanol Masers in G9.62+0.20

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Abstract

The bright interstellar methanol masers at 12.2 GHz and 6.7 GHz were discovered in 1987 and 1991 respectively. It was soon established that many were quite variable. In 2003 Goedhart et al. reported that one source, G9.62+0.20E, exhibited flares at 12.2 and 6.7 GHz that appeared to be periodic, repeating every 246 days. This was an unanticipated result. A subsequent flare was observed with the VLBA (Goedhart et al. 2005) at 12.2 GHz at the time predicted from single-dish monitoring at HartRAO.

Since then, monitoring of this and other possibly periodic sources has continued with the 26-m Hartebeesthoek telescope. During this time, the main reflecting surface of the telescope was upgraded, the receiver rebuilt to provide dual polarization, and the spectrometer, telescope control system, observing and reduction software all replaced. Has the apparent periodic behaviour persisted in the face of these radical changes to the observing system?

We present here the full 12.2 GHz time series data through 2006. The data quality was much improved by the upgrades. Flares in the main maser peak continued to be observed during this interval. The repetition rate of the flares has been refined using the extra data, and remains close to that originally determined. At 6.7-GHz the flares have smaller amplitude but also continue; twelve have now been observed. The data sets at 6.7 and 12 GHz now cover 7.5 and 7 years respectively. The flaring behaviour is clearly not transient, indicating that a persistent driving mechanism is active.

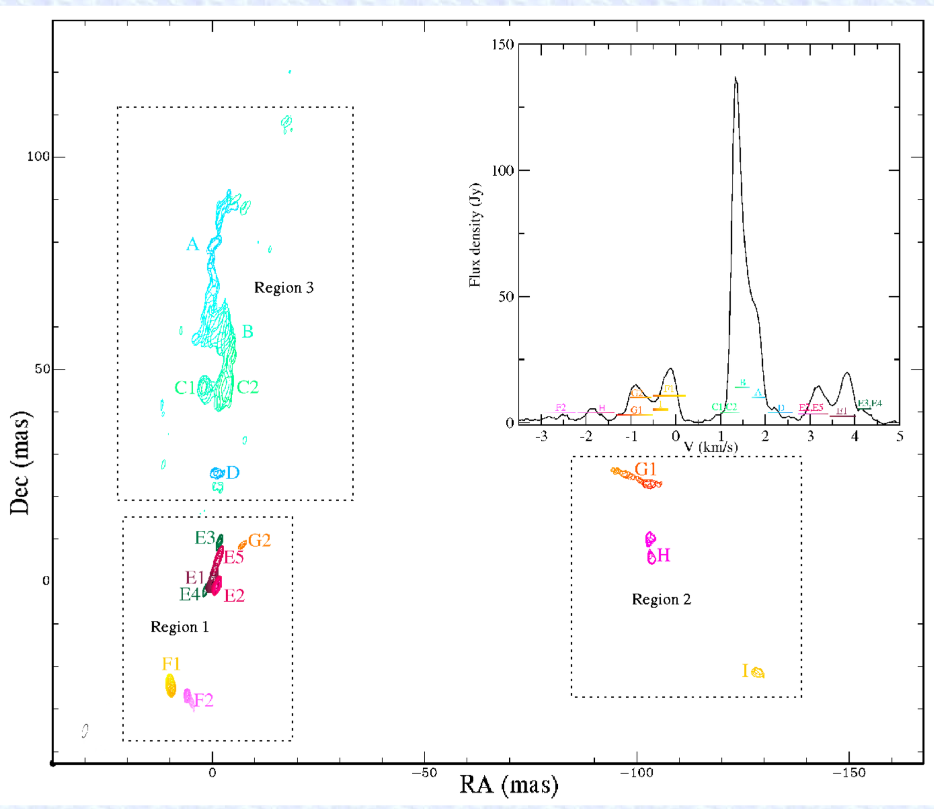

Figure 1: G9.62+0.20 12.2 GHz maser spot map made using the VLBA, from Goedhart et al. (2005).

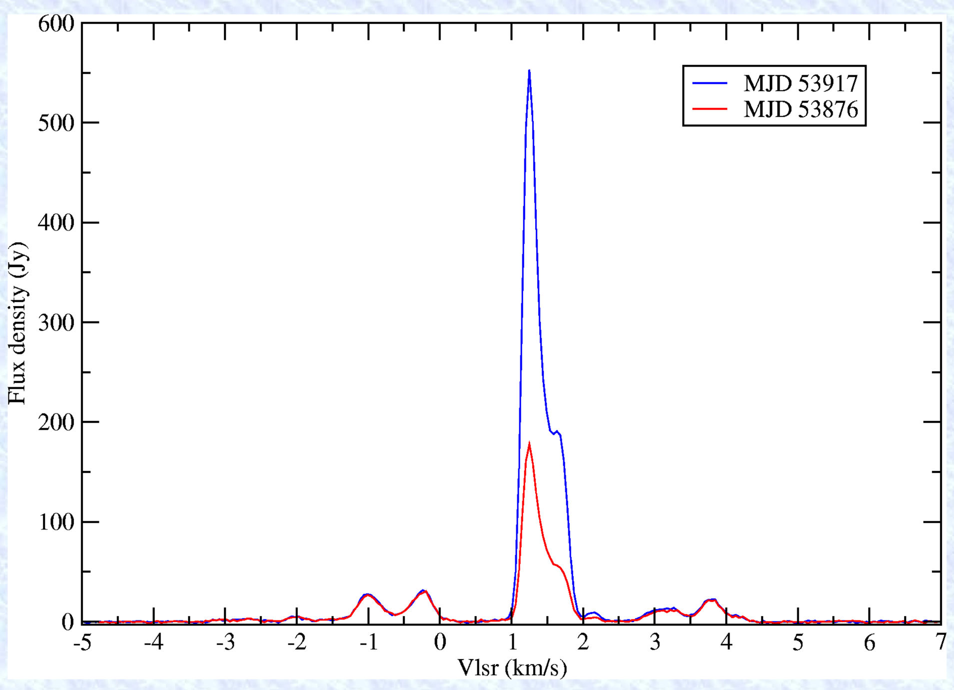

Figure 2: Spectra of G9.62+0.20 at 12.2 GHz taken with the 26-m Hartebeesthoek telescope at flare minimum and maximum during 2006. The increased aperture efficiency with new antenna surface and the dual polarization receiver have improved data quality by nearly an order of magnitude since the beginning of monitoring this source.

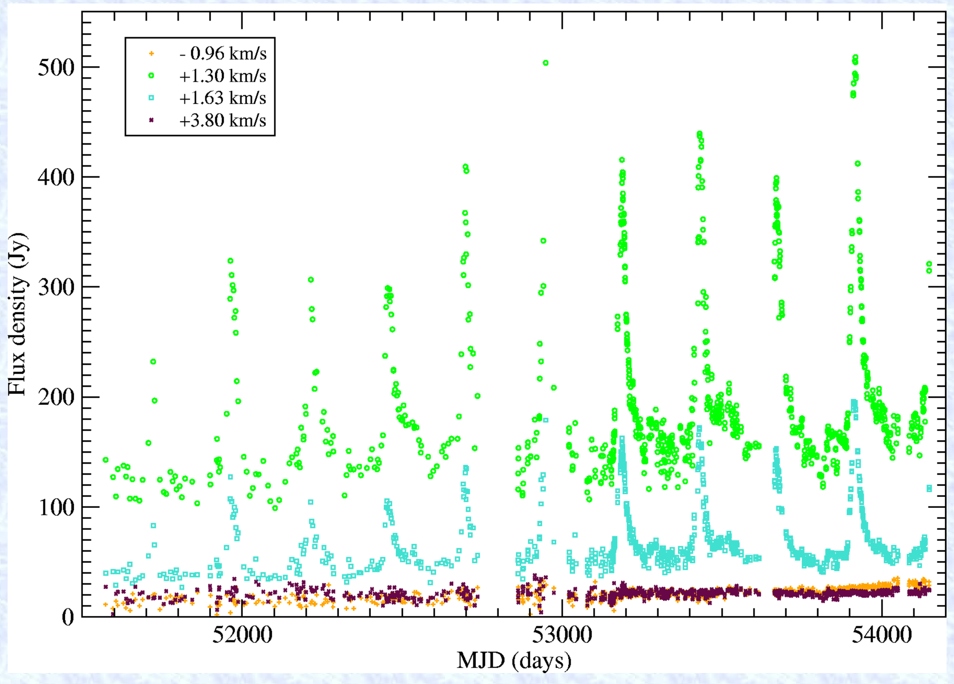

Figure 3: Time series of the two brightest peaks at 12.2 GHz, with two weaker peaks shown for comparison . The left half of the data are from the single polarization receiver before the antenna surface upgrade, The right half are from the dual polarization receiver, during and after the surface upgrade. Colours approximately match those used in Fig. 1.

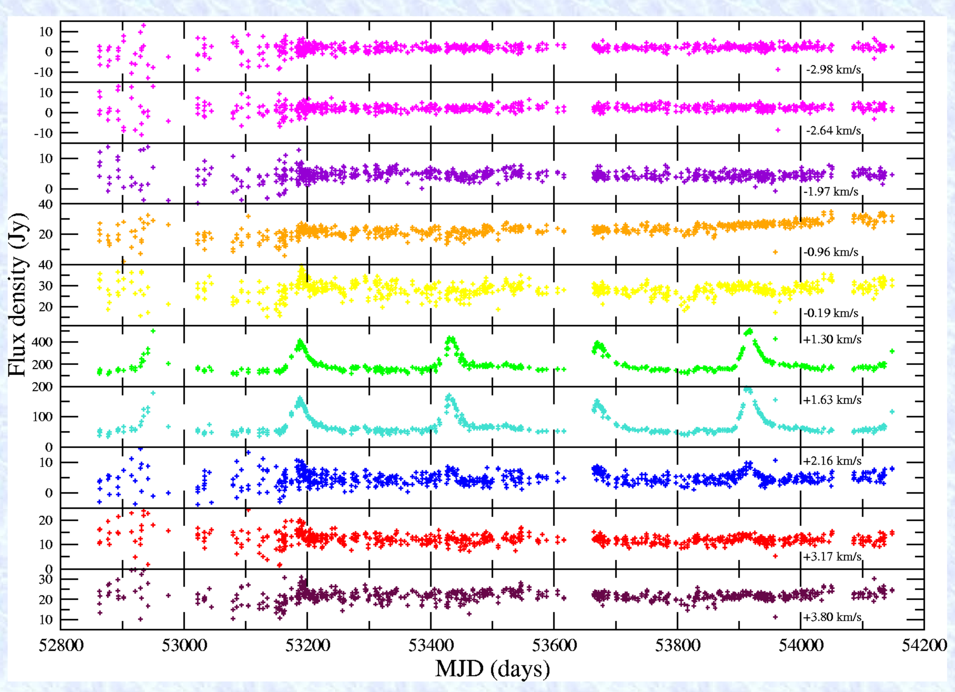

Figure 4: Time series of the maser peaks, obtained with the dual polarization receiver. Colours approximately match those used in Fig.1.

Introduction

The discovery by Goedhart et. al (2003, 2004) that some Class II methanol masers appeared to exhibit regular variations came as a surprise. In the case of the first such source to be identified, G9.62+0.20, the variations were found in the brightest peaks of the 6.7-GHz masers. These are the brightest such masers known, and the fractional variation was quite small.

Monitoring of the source at 12.2 GHz showed that the relative amplitude of the variations was much greater. Several flare cycles showed no sign of being repetitive but aperiodic, as in G351.78-0.54 (MacLeod & Gaylard 1996), and a period of 246 days gave the best fit to the available data. This period determination permitted the mapping of the the source during a flare by Goedhart et al. (2005) at 12.2 GHz using the VLBA, and this map is shown in Fig. 1. No changes in morphology were seen in the VLBA maps during the flare.

Monitoring has continued at both 6.7 and 12.2 GHz, and we report on the latter here.

Observations

During the monitoring period the surface of the 26-m Hartebeesthoek telescope was replaced with more accurate solid aluminium panels. The aperture efficiency at 12 GHz fell from 0.20 to 0.10 before rising to 0.45 when the new panels were aligned. There was a gap in monitoring around MJD 52800, due to the replacement of the single polarized receiver with a dual polarized one, the introduction of a new 2x1024 channel spectrometer, and the replacement of the minicomputer telescope control system with one based on PC's running Linux.

Calibration was based on contemporaneous monitoring of Virgo A (which is partly resolved), 3C123, 3C218 and the maser source G351.42+0.64, which was previously found to show little variation. Internally, the minimal variation in weaker peaks of G9.62+0.20 provided a consistency check.

Results

Typical spectra obtained with the upgraded 26-m telescope are shown in Fig. 2. Only the maser peaks in region 3 of Fig. 1 flare strongly at 12.2 GHz. Time series of the two brightest peaks and two of the weaker peaks are shown in Fig. 3, which shows all day from the start of monitoring to 2007 February. The strongest peaks are getting brighter, the the flares are now up to 50% brighter than in the first few cycles monitored.

To show more clearly the behaviour of the individual maser peaks, the time series post-MJD52800 are shown in stacked plots in Fig. 4. These are colour-coded similarly to Fig. 1. The peak at -0.96 km/s has started increasing, but the negative velocity peaks do not appear to respond to whatever is causing the flares.

Period determination and analysis

The program Period04 (Lenz & Breger 2005) was used to obtain the periodogram of the strongest peak (Fig. 5). The full data set gives a period of 243.040 days, the first half 242.237 days and the second half 242.532 days. The three periodograms are very similar, with the noise being lowest in the full data set.

Epoch-folding was used as an alternative period tester, the L-statistic of Davies (1990) being employed (Fig. 6). The test is sensitive to the number of phase bins M employed per test period. Inspection of Fig. 6 suggested that averaging the results over ranges of M would be more stable, and these are illustrated in Fig. 7. These are consistent with a period of 243 to 244 days, which is similar to the Period04 result.

The time series folded on test periods of 242 to 245 days are shown in Fig. 8. This clarifies why determining the period to better than a day is difficult – a shorter period, such as 242 days, provides the best alignment of the rising edges of the flares, but a longer period, such as 244 days, best aligns the falling edges. This is a symptom of the flares not having an identical duration, and inspection of Fig.3 is suggestive of this.

Discussion

Despite almost every piece of hardware and software involved in the monitoring having changed, the large amplitude flares remain. Within present experimental uncertainty they appear to to have an unchanging period, but their amplitude has increased over the monitoring period.

The extreme regularity of the phenomenon over seven years argues for a strongly deterministic cause. The length of the interval between flares suggest orbital motion of an object around the primary could be the origin of the regular variations, but it also needs to be seen in the context of the other objects showing similar behaviour.

References

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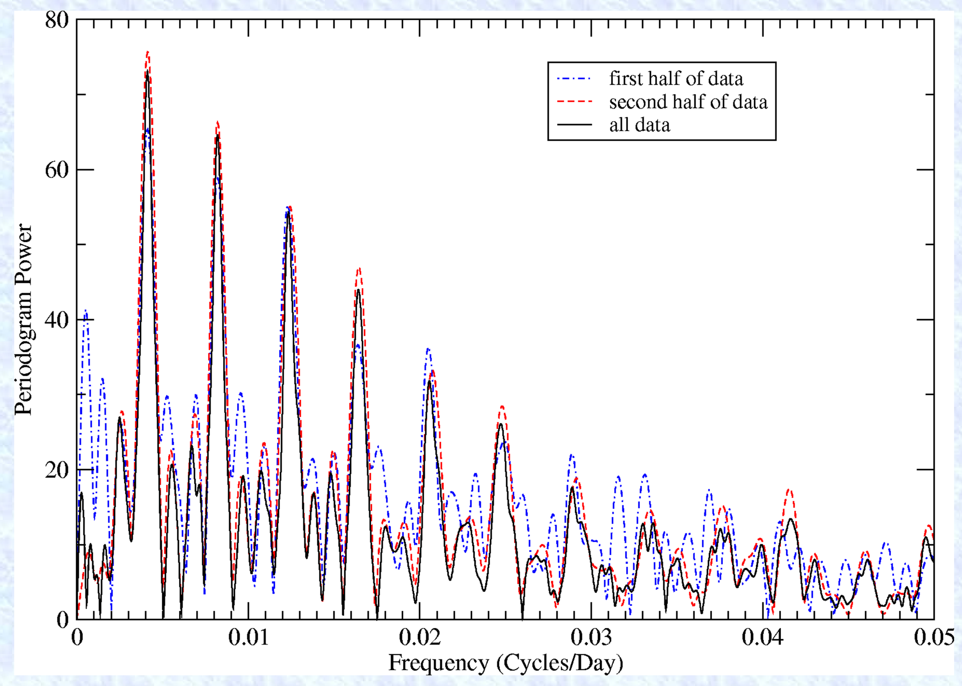

Figure 5: Periodograms of the time series for the maser peak at +1.30 km/s, for the two halves of the data independently and combined, from Period04.

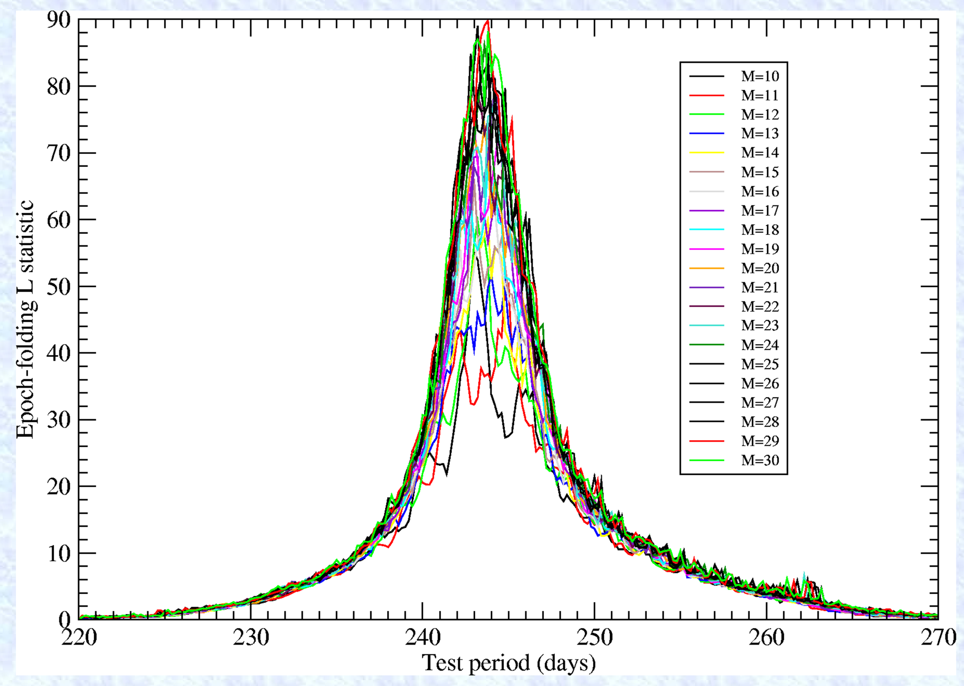

Figure 6: Epoch-folding L-statistic of the time series for the maser peak at +1.30 km/s, for number of phase bins per test period M ranging from 10 to 30.

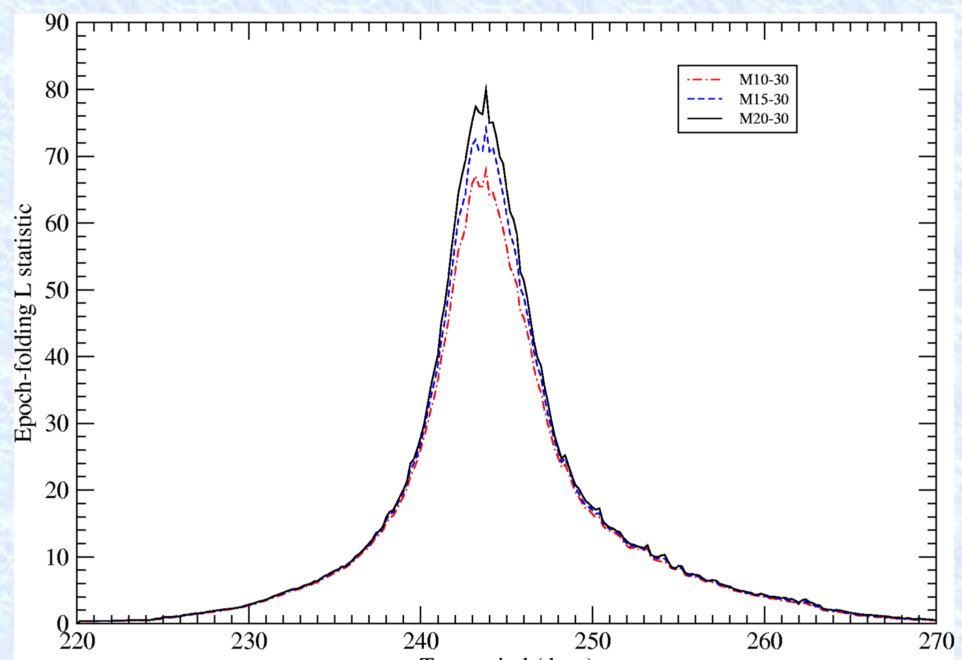

Figure 7: Epoch-folding L-statistic of the time series for the maser peak at +1.30 km/s, for three averages over the bin size.

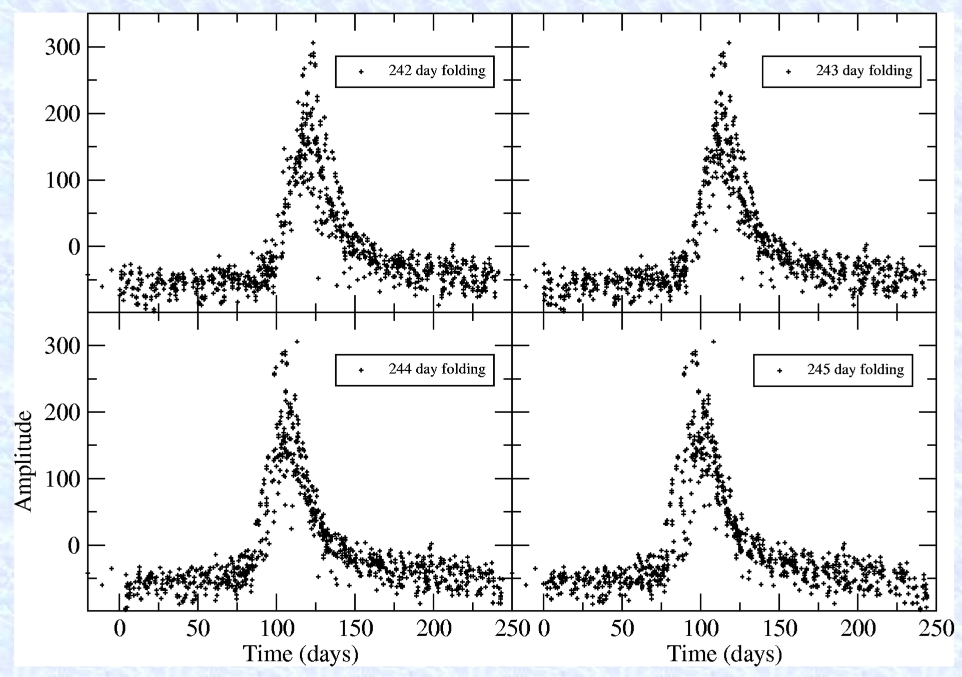

Figure 8: The time series for the maser peak at +1.30 km/s, epoch-folded for test periods of 242 to 245 days.