The variability of cosmic methanol masers in massive star-forming regions

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Talk overview

- Introduction.
- Methodology.
- Results.
- Toy model.
- Summary and future prospects.

- *MASER* is an acronym for Microwave Amplification by Stimulation Emission of Radiation.
- In order to form maser there must be population inverse and velocity Coherence.
- For maser to exist for a certain period, there must be a pumping mechanism.
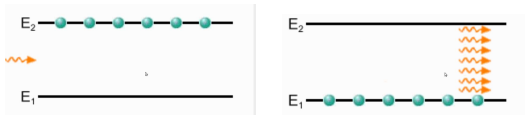- There are a small number of astronomical masers. **viz, water vapour, hydroxyl, methanol, ammonia, etc**

Figure: The photon stimulate an excited states to emit the radiation at the same frequency as it moves across.

Methanol maser spectroscopy and star formations

▶ Methanol (CH_3OH) is formed in a molecular cloud by the process of grain surface reactions (H, O and CO are primary species) (Das et al. 2008).

▶ Class I methanol maser (MMI) are offset to ultra-compact ionized hydrogen (UCHII) whereas Class II methanol maser (MMII) are close to UCHII.

▶ 6668 MHz ($J_k = 5_1 - 6_0$ A^+) and 12178 MHz ($J_k = 2_0 - 3_{-1}$ E) are two brightest MMII.

▶ Stars are formed from giant molecular clouds (GMCs), which collapse to form a protostar. A protostar accrete matter to form a star.
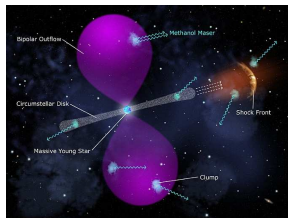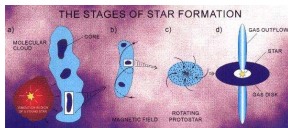

Figure: Left Image credit: Arizona Radio Observatory and right image: Yvonne Kei-Nam Tang (Cornell University)

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Methodology

- After the repair of HartRAO 26 meter telescope bearing, receivers were brought down for service and they were calibrated using Hot-Cold Y-factor method.
- $P_1 = \Upsilon (T_{rec} + T_{sky})$, $P_2 = \Upsilon (T_{rec} + T_{sky} + T_{ND})$, $P_3 = \Upsilon (T_{rec} + T_{eccosorb})$ and $P_4 = \Upsilon (T_{rec} + T_{eccosorb} + T_{ND})$
- The 26 meter HartRAO telescope sensitivities were calibrated at 12178 and 6667 MHz by radio sources *Hydra A*, *Virgo A* and *3C123* (Ott et al. 1994).
- Spectra were observed with a spectrometer producing 1024 channels in each polarization, and the frequency-switching observing method was used.

Methodology continue.....

- Since the data was unevenly sampled. The Lomb-Scargle period searching method (Press et al. 1989) was used to searching for periods and to test the significance of weak periods.

- $P_N(\omega) = \frac{1}{2\sigma} \left[\frac{\left[\sum_j (h_j - \bar{h}) \cos \omega(t_j - \tau) \right]^2}{\sum_j \cos^2 \omega(t_j - \tau)} + \frac{\left[\sum_j (h_j - \bar{h}) \sin \omega(t_j - \tau) \right]^2}{\sum_j \sin^2 \omega(t_j - \tau)} \right]$

- τ makes $P_N(\omega)$ to be completely independent of any t_j shift by any constant.
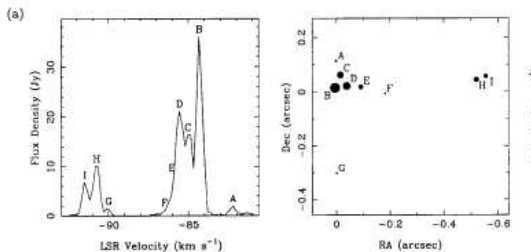
Results and discussion

Figure: On the left: it is a spectrum for G331.13-0.24 at 6668 MHz and on the right it is a VLBI Image (Phillips et al. 1998).
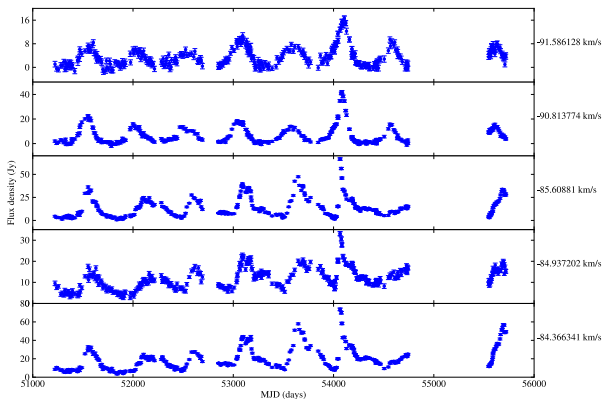
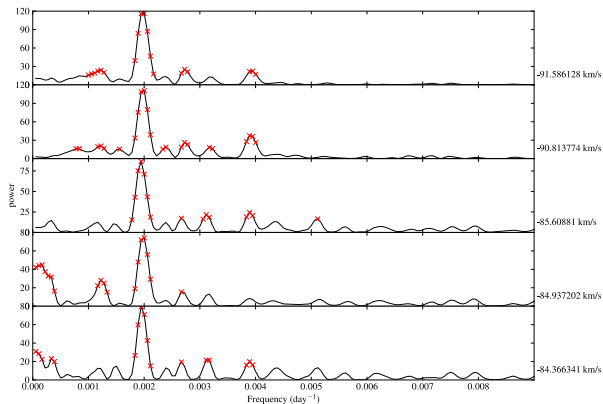Figure: Time series for five G331.13-0.24 maser spots at 6668 MHz.

Figure: Lomb–Scargle periodogram (maser group around -91 km.s^{-1} exhibit the 499 days period; -84.366 and 85.608 km.s^{-1} have 513 days period).

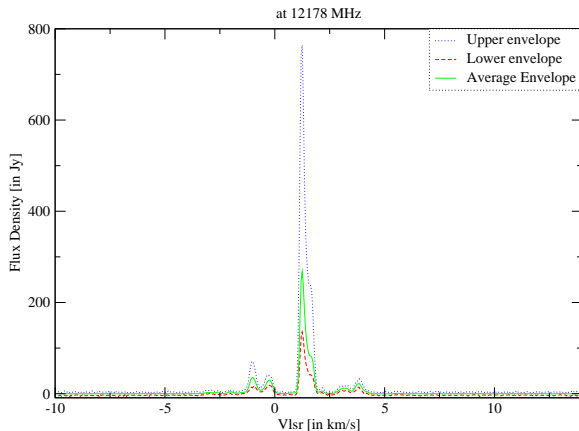# Results and discussion continue....

Figure: It is a spectrum for G9.62+0.20 at 12178 MHz.

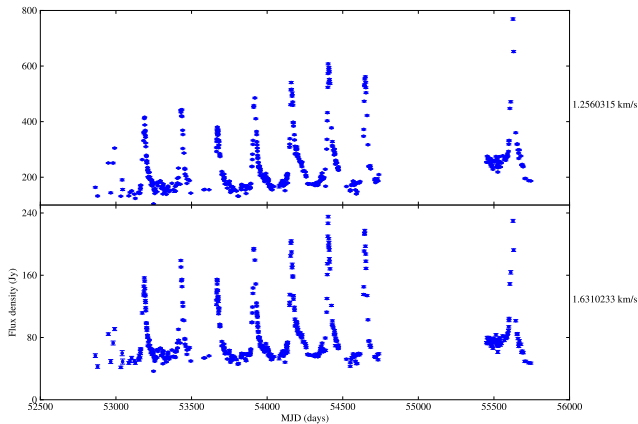J.P. Maswanganye[1] M.J. Gaylard[1] and S. Goedhart[2]   Hartebeesthoek Radio Astronomy Observatory

Figure: It is a time series for G9.62+0.20 at 12178 MHz.
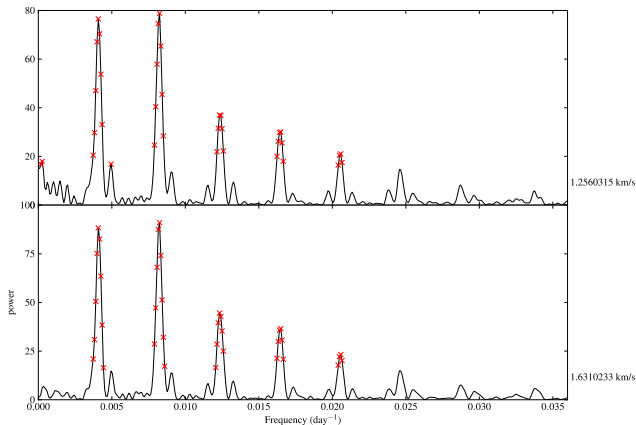
Figure: It is Lomb-Scargle periodogram (245.1 days period) for G9.62+0.20 at 12178 MHz .
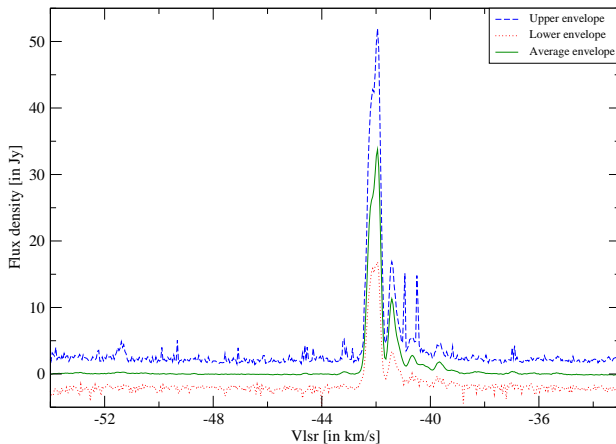
Figure: It is a spectrum for G338.93-0.06 at 6668 MHz.

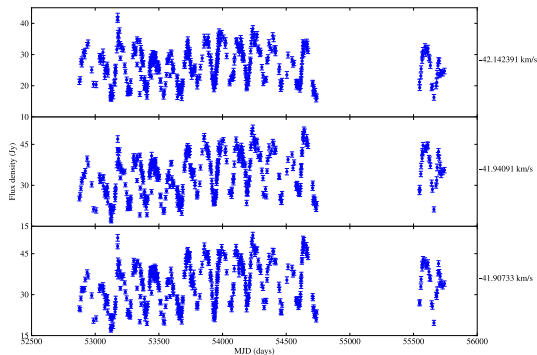J.P. Maswanganye[1] M.J. Gaylard[1] and S. Goedhart[2]   Hartebeesthoek Radio Astronomy Observatory

Figure: It is a time series for G338.93-0.06 maser spots at 6668 MHz.
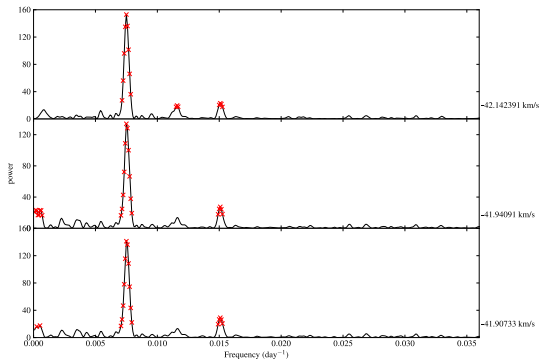
Figure: Lomb-Scargle periodogram (133.4 days period) for G338.93-0.06 at 6668 MHz.

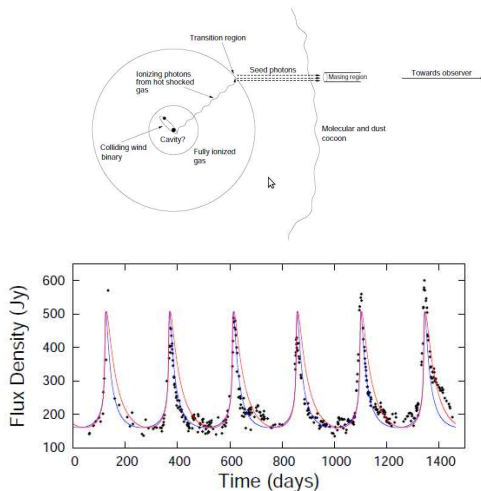# Attempting to explain the variability

Figure: The top diagram is van der Walt (2011) toy model for G9.62+0.20 and the bottom is a best fit to the time series.

Summary and future prospects

- G9.62+0.20 at 12178 MHz exhibit a very strong periodic and the measured period by Lomb-Scargle method is 245.1 days period. Its intensity is increasing.
- Why is it so?
- G338.93-0.06 at 6668 MHz also show a strong variability. It is periodic but it is not a sinusoidal variation.
- Why is it the case?
- G331.13-0.24 at 6668 MHz shows a strong variation but it does not look periodic but quasi-periodic.
- Why such a behaviour?
- What causes this variability in methanol masers?
- What is unique about methanol masers in massive star forming regions that allows this kind of behaviour to occur?
- How regular or periodic are these methanol maser emission sources?
- The monitoring programme will continue with a hope to put more constraints in maser model.

Acknowledgements

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Reference

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