Masers as a Swiss army knife

in high-mass star formation

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1. Introduction
2. Basics of what produces the radiation we SEE
3. Where methanol masers fits in
4. OLD and NEW maser discoveries

1 Introduction

2 Basics of what produces the radiation we SEE

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4 OLD and NEW maser discoveries

Background and Motivation

- We have to understand the basics of
- Source of Radiation
- Source of Absorption
- Source of Emission
- But first a few Amazing pictures of what we look at.

Amazing pictures

Amazing pictures

Amazing pictures

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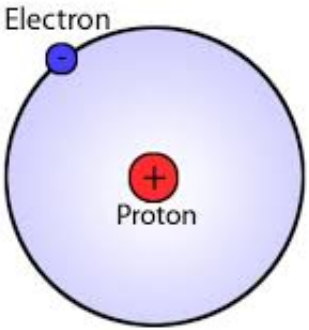
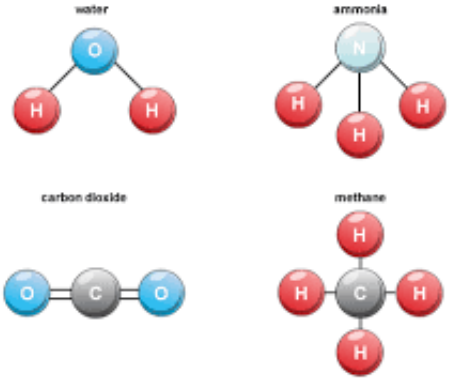
Atoms, Molecules and Dust

- Simplest atom Hydrogen with 1 proton and 1 electron



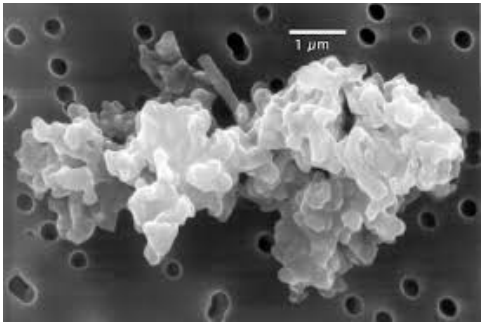
Atoms, **Molecules** and Dust

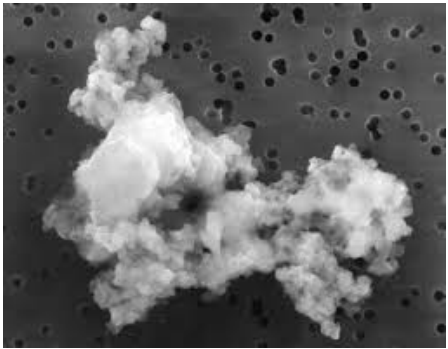
- Typical molecules form in the vicinity of High-mass star forming regions



Atoms, Molecules and **Dust**

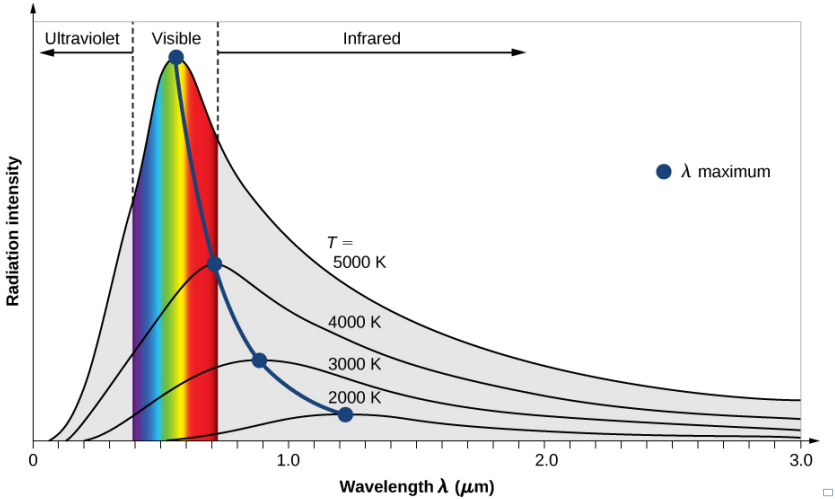
- Extremely small solidified particles made from heavy Metals and Silicates.





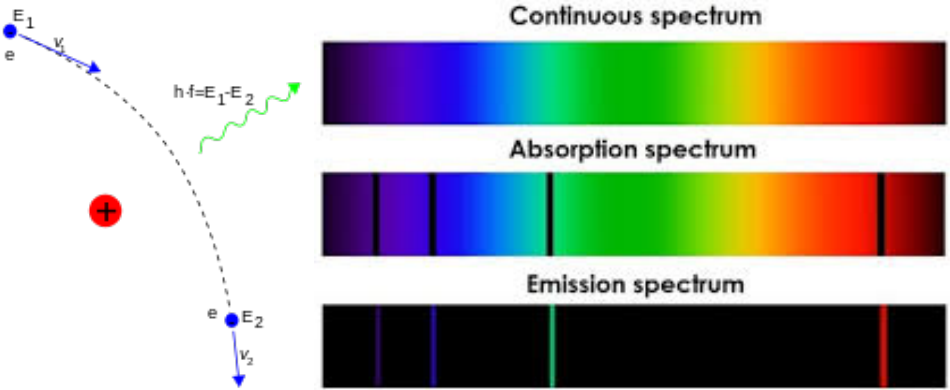
Source of Radiation

- All objects radiate, and it all depends on its Temperature, Black body spectrum.



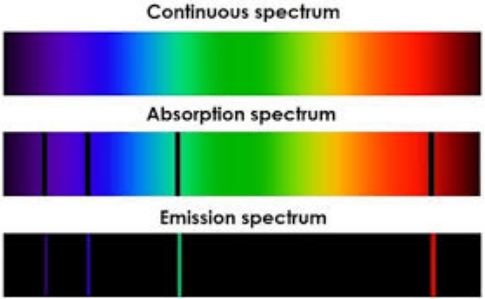
Source of Radiation

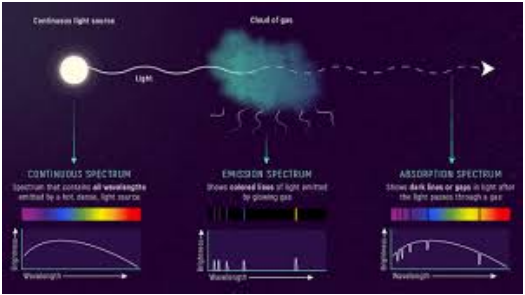
- Bremsstralung (Free-free emission), Top



Source of Absorption

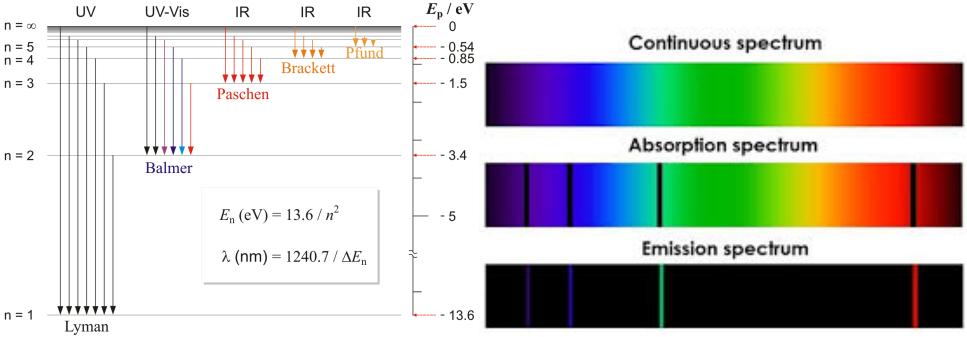
- Line radiation (Spectroscopic absorption), Middle





Source of Absorption

- Line radiation (Spectroscopic emission), Bottom



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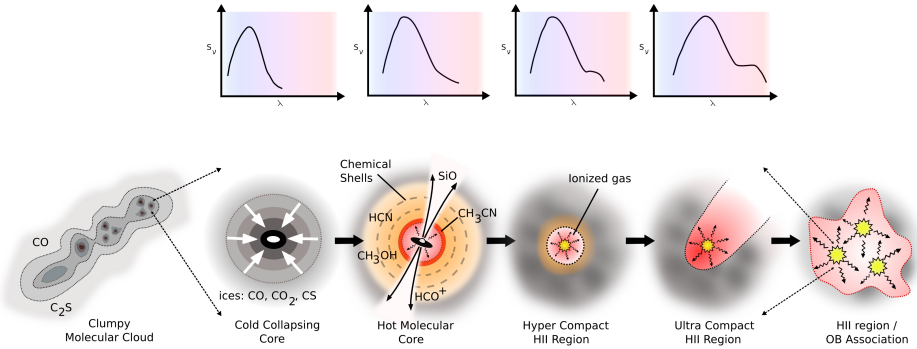
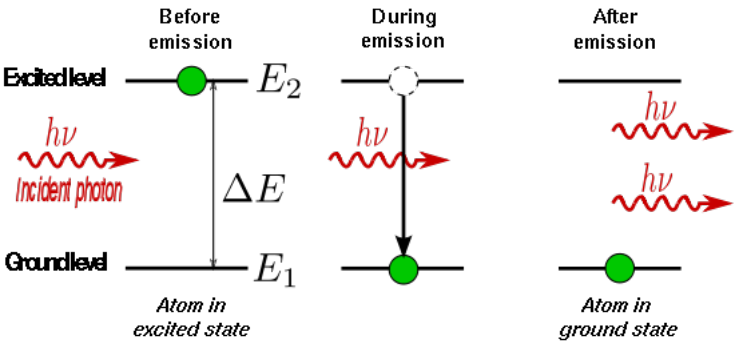
High mass star formation and masers

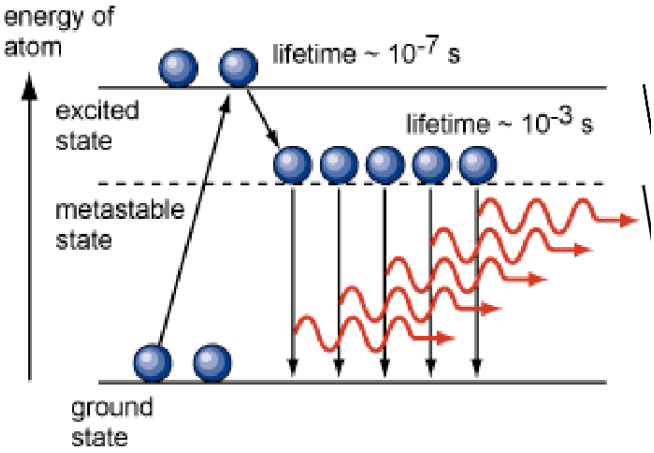


MASERS



$$E_2 - E_1 = \Delta E = h\nu$$

Pumping and Rate equations



$$\frac{dN_i}{dt} = \sum_{j<i}\left[\left(-N_i + \left(\frac{g_i}{g_j}N_j - N_i\right)W\mathcal{N}_{ij}\right)\beta_{ij}A_{ij} + C_{ij}\left(N_j\frac{g_i}{g_j}e^{-E_{ij}/kT} - N_i\right)\right] + \sum_{j>i}\left[N_j + \left(N_j - \frac{g_j}{g_i}N_i\right)W\mathcal{N}_{ji}\right)\beta_{ji}A_{ji} + C_{ji}\left(N_j - N_i\frac{g_j}{g_i}e^{-E_{ji}/kT}\right)\right]$$

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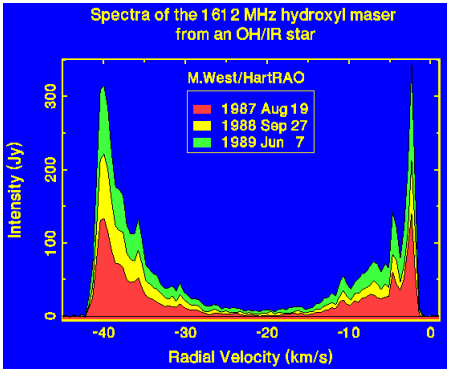
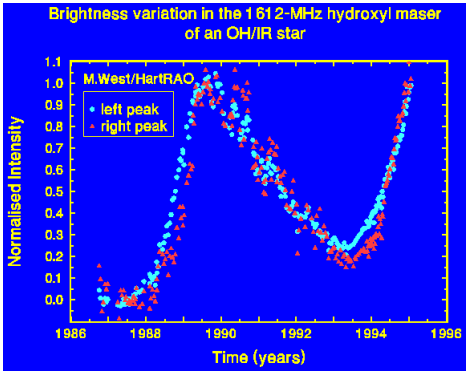
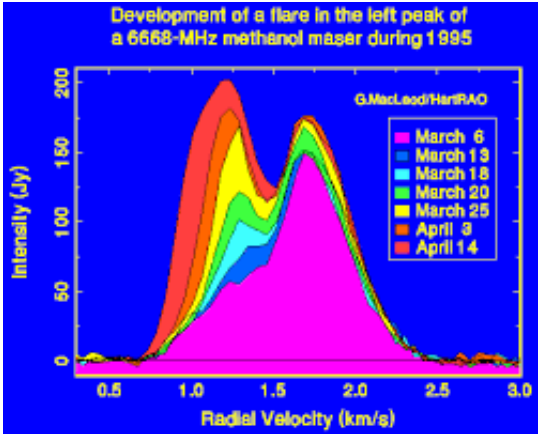
OH IR stars

- Although not classified as high-mass stars, they possibly were..

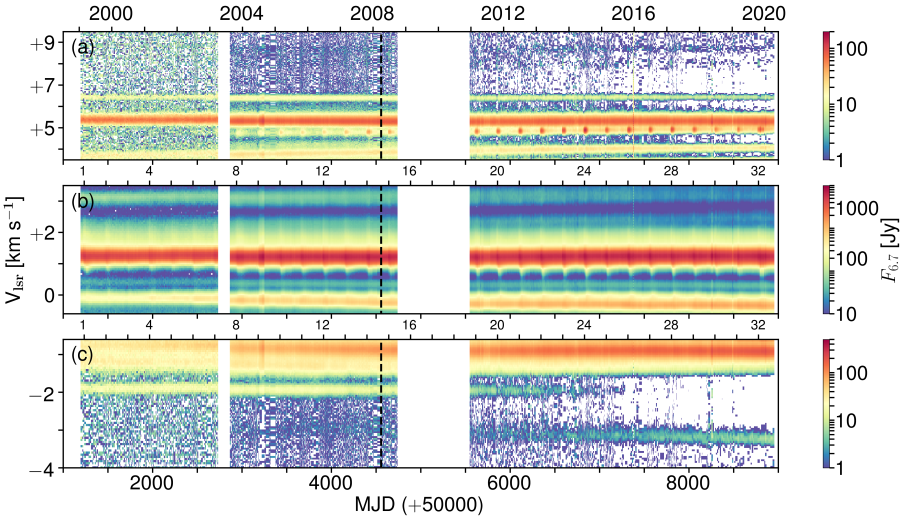




Mexican wave



Periodic masers



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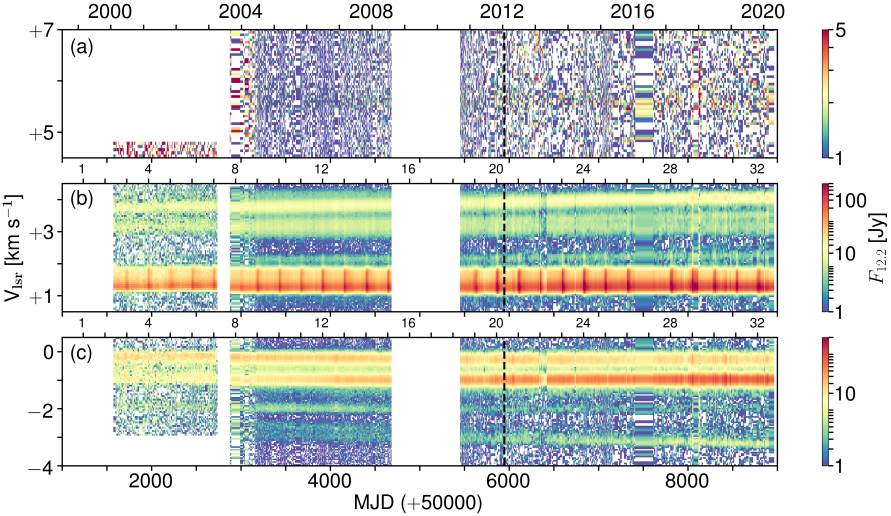
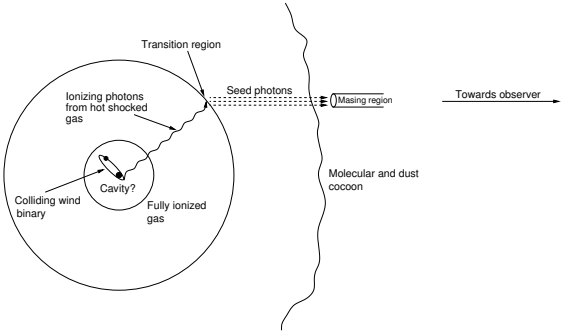
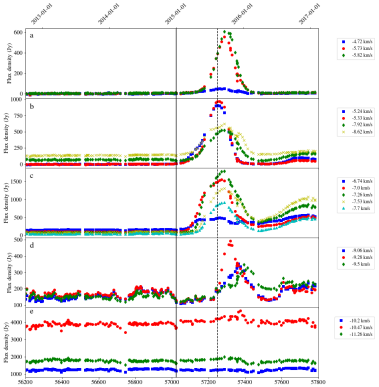
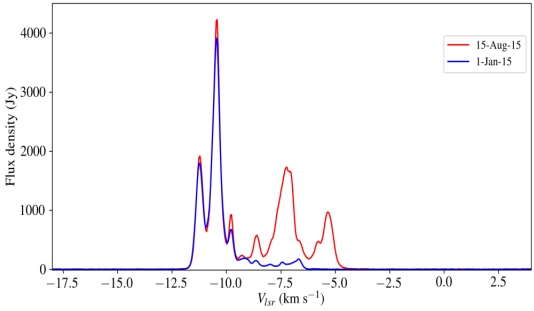


Periodic masers – Colliding wind binary hypothesis



Maser flares – G351.42 (Kitty)





Maser flares – G323.46

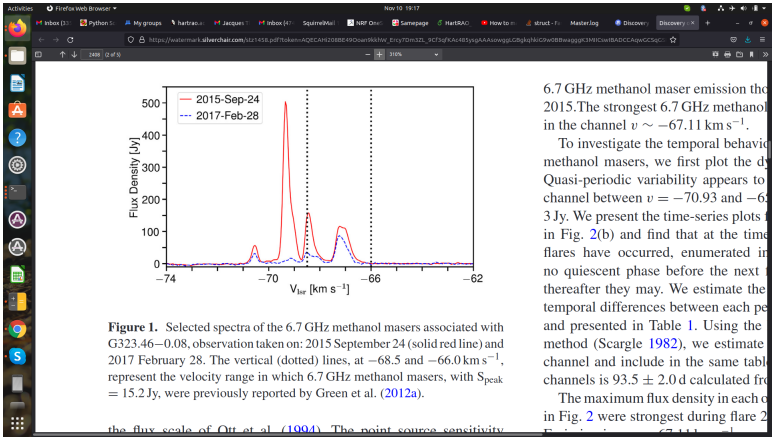


Figure 1. Selected spectra of the 6.7 GHz methanol masers associated with G323.46−0.08, observation taken on: 2015 September 24 (solid red line) and 2017 February 28. The vertical (dotted) lines, at −68.5 and −66.0 km s^{-1}, represent the velocity range in which 6.7 GHz methanol masers, with S_{peak} = 15.2 Jy, were previously reported by Green et al. (2012a).

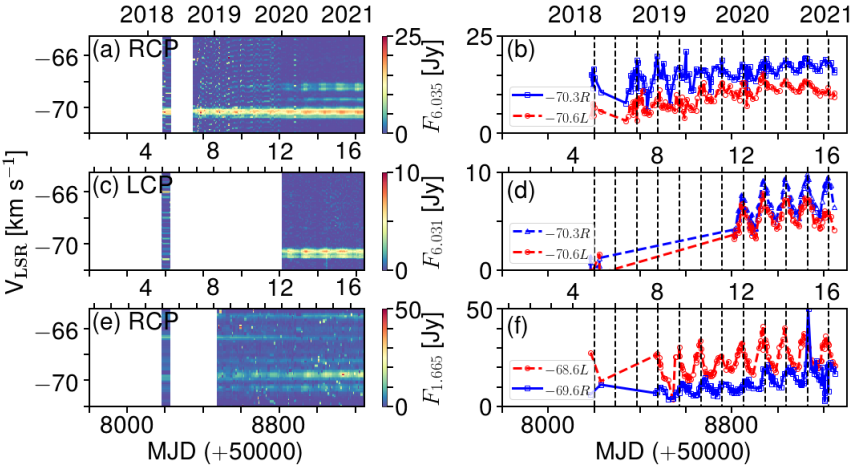
the flux scale of Ott et al. (1994). The point source sensitivity

6.7 GHz methanol maser emission thc
2015.The strongest 6.7 GHz methanol
in the channel $v \sim -67.11$ km s^{-1}.

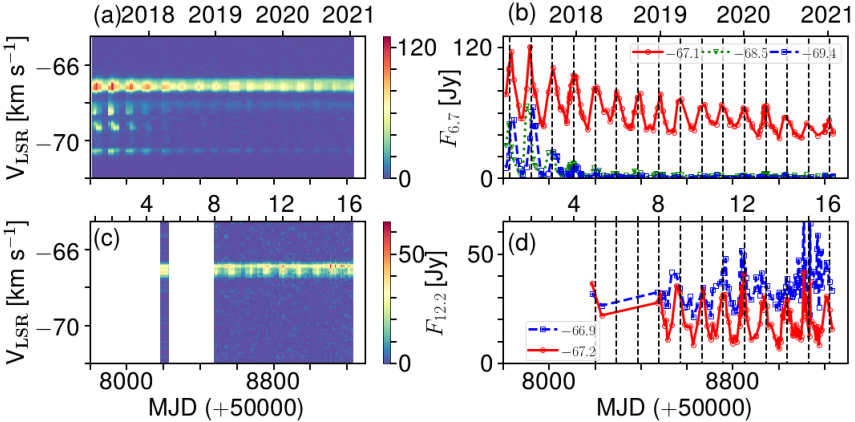
To investigate the temporal behavic
methanol masers, we first plot the dy
Quasi-periodic variability appears to
channel between $v = -70.93$ and -6
3 Jy. We present the time-series plots
in Fig. 2(b) and find that at the time
flares have occurred, enumerated ir
no quiescent phase before the next
thereafter they may. We estimate the
temporal differences between each pe
and presented in Table 1. Using the
method (Scargle 1982), we estimate
channel and include in the same tabl
channels is 93.5 ± 2.0 d calculated fr

The maximum flux density in each c
in Fig. 2 were strongest during flare 2

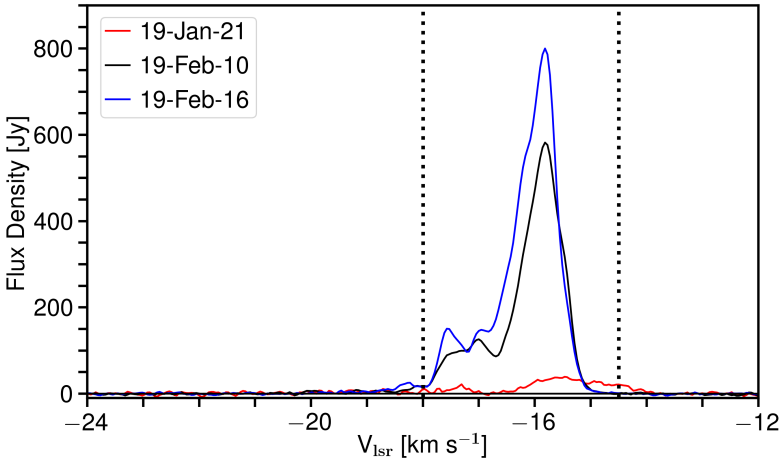
Maser flares – G323.46 (periodicity after the flare



Maser flares – G323.46 (periodicity after the flare



Maser flares – G358.93 (possible accretion burst)



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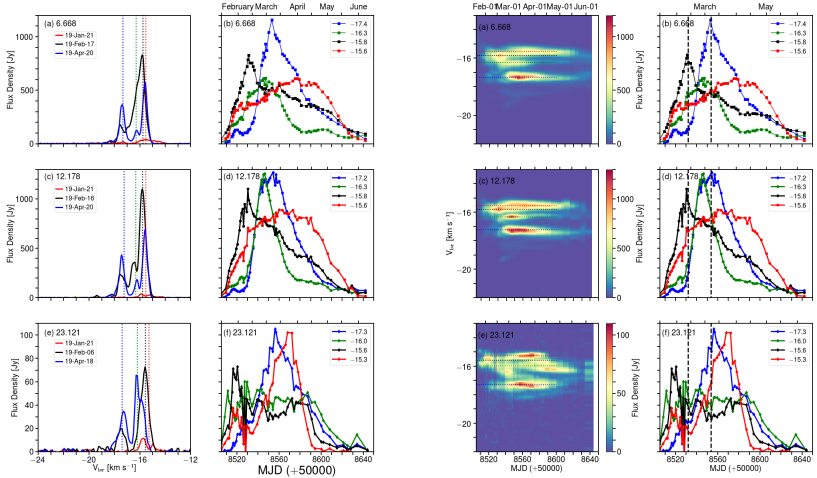

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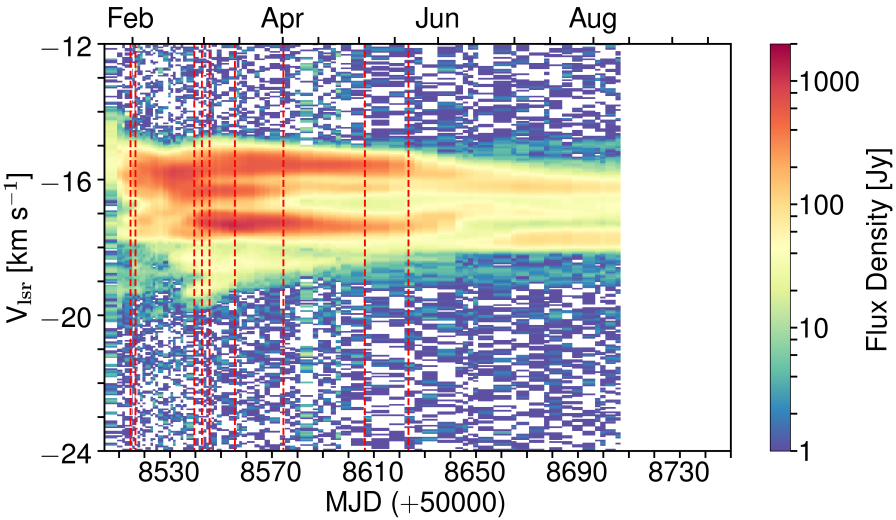

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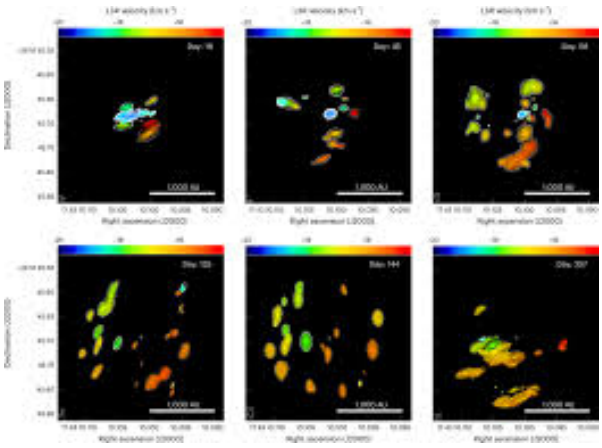

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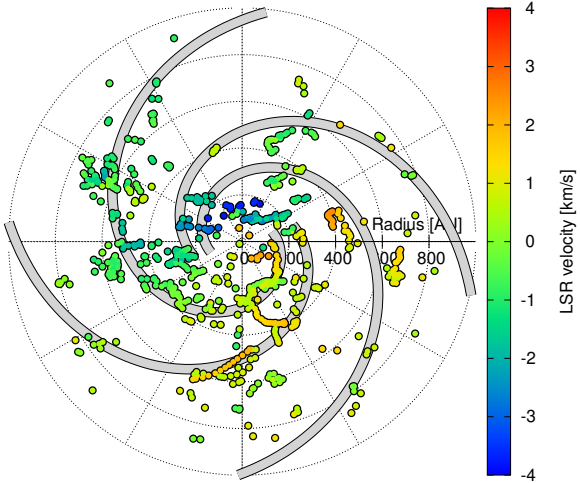
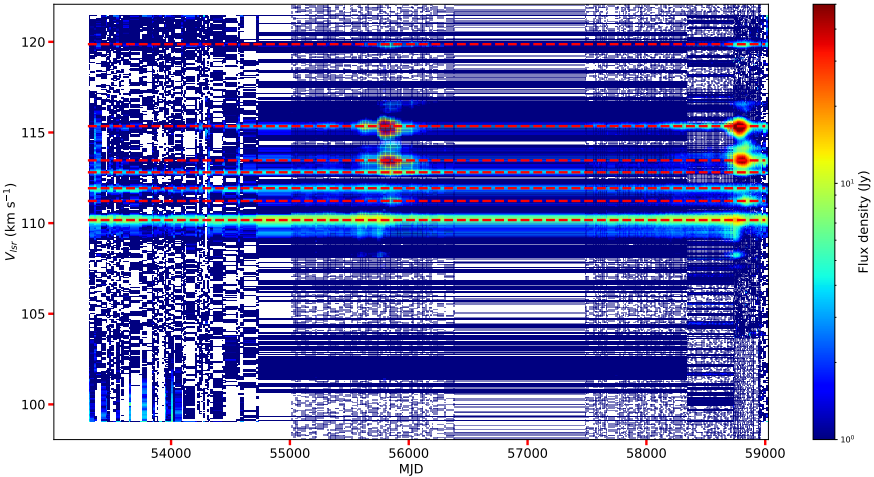


Maser flares – G024.33 (possible 3000 day period)



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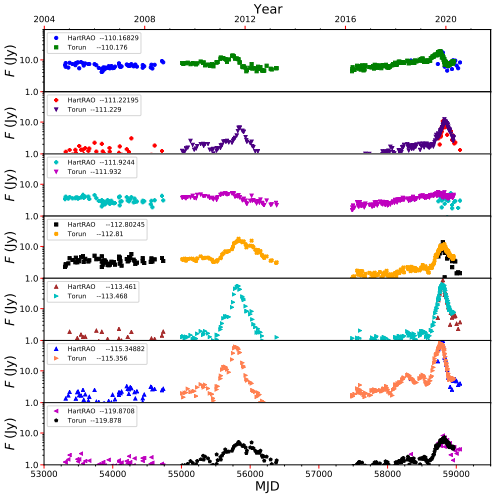

Thank you

Thanks for Listening