

Searching for accretion bursts from young stellar objects with the Metsähovi Compact Array

Jakobus Vorster¹, D. McKay², Jere Raassina², Demian Aaltonen², Sonny Holman^{2,3}

¹University of Helsinki, Finland

²Aalto University Metsähovi Radio Observatory, Finland

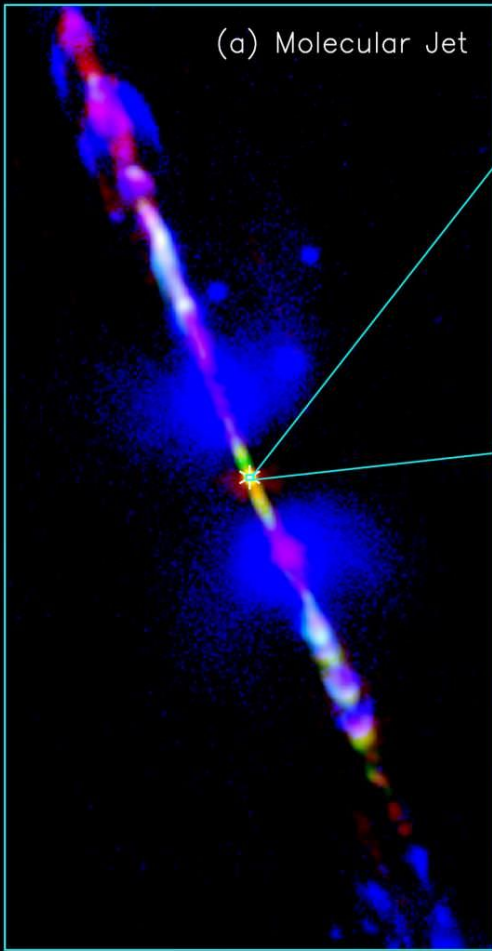
³Häme University of Applied Sciences HAMK, Finland

A? Aalto-yliopisto
Aalto-universitetet
Aalto University

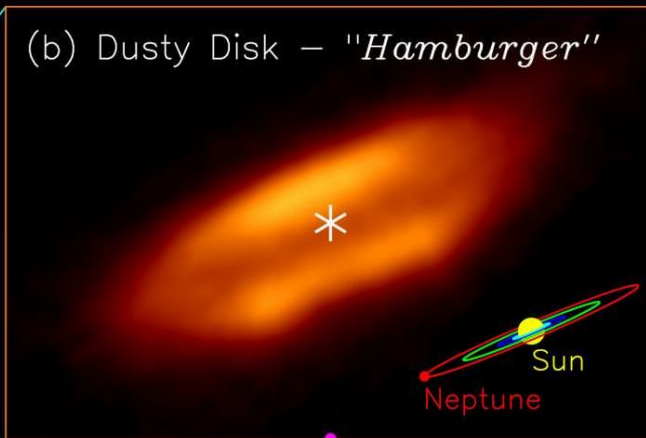


Young stars have disk-jet systems
that become planetary systems

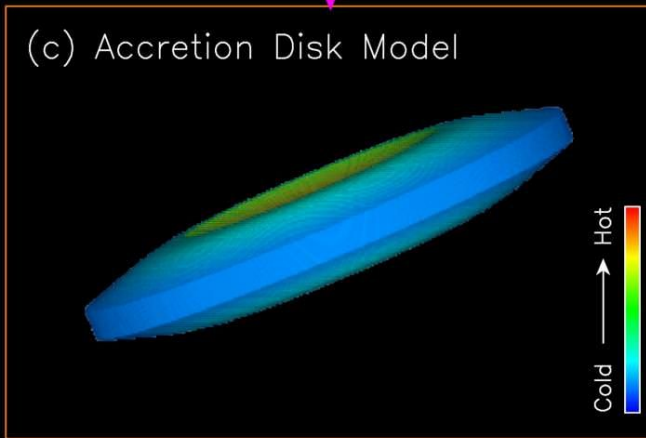
(a) Molecular Jet



(b) Dusty Disk – "Hamburger"



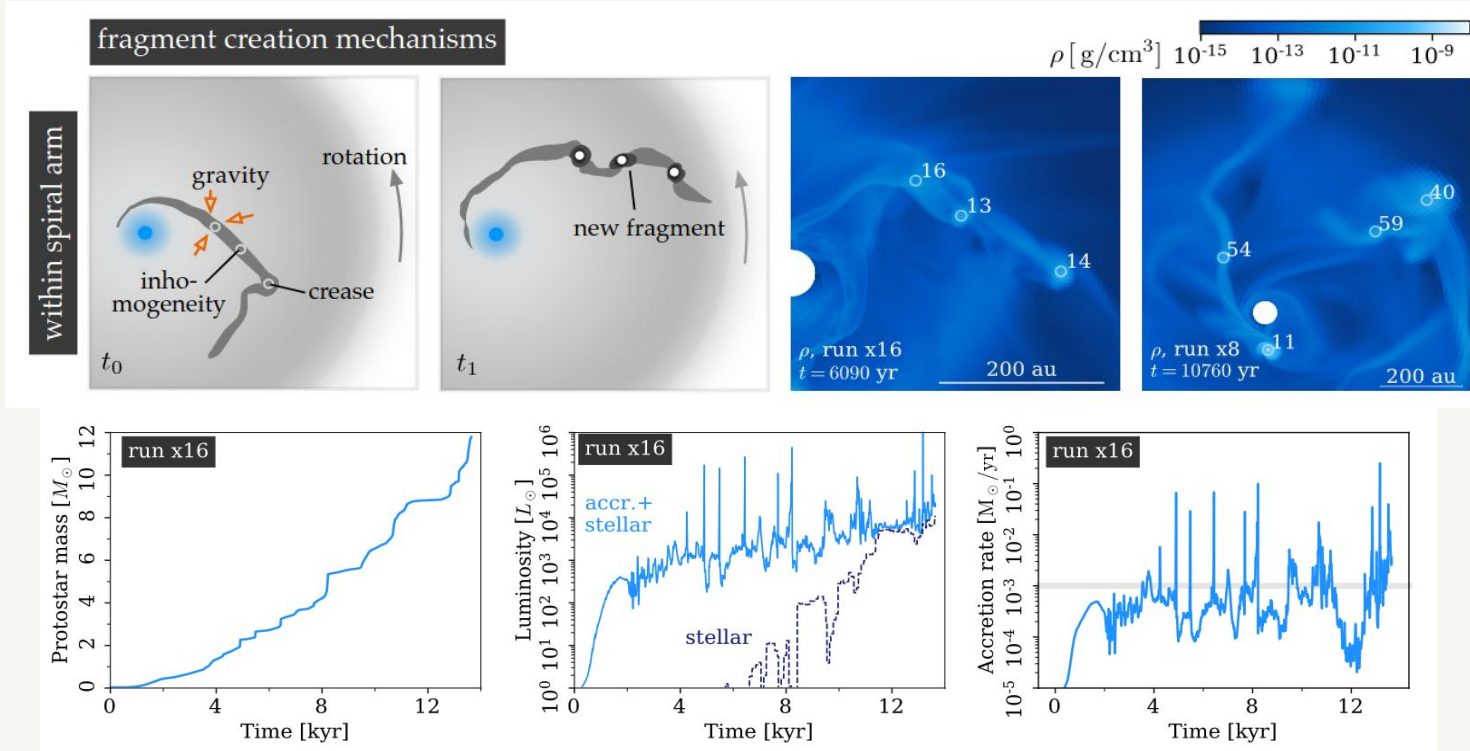
(c) Accretion Disk Model



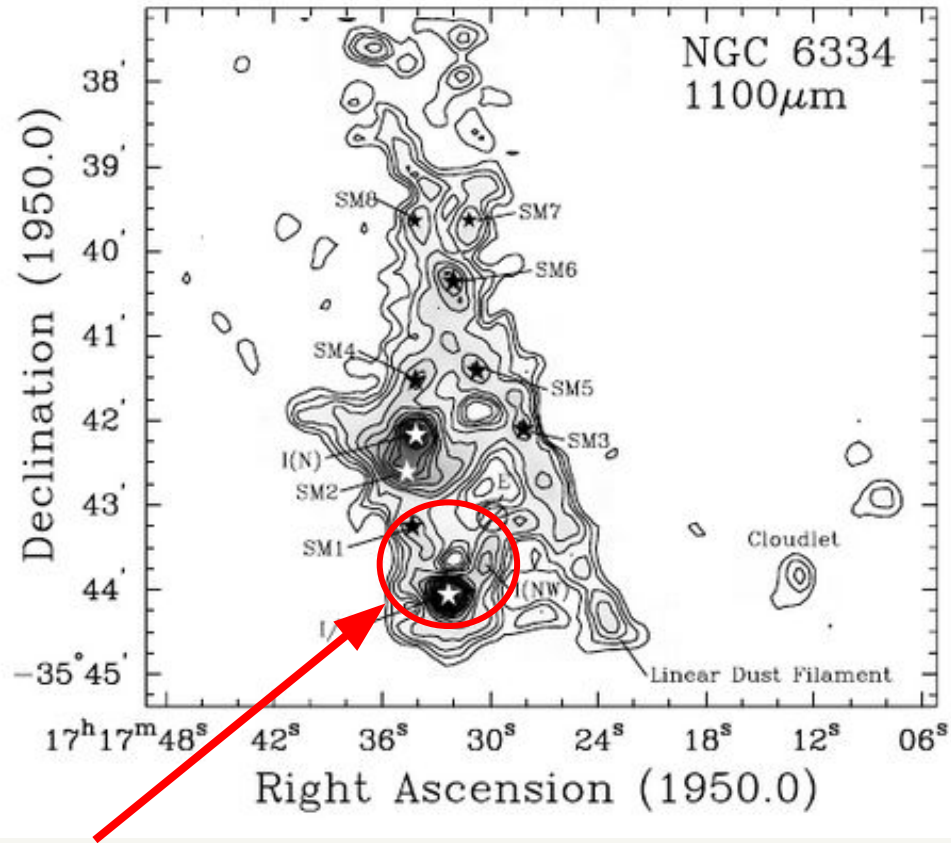
Credit: ALMA
(ESO/NAOJ/NRAO)/Lee et al.

Episodic Accretion

Hydrodynamic simulations, Olivia, G.A. and Kuiper, R. 2020

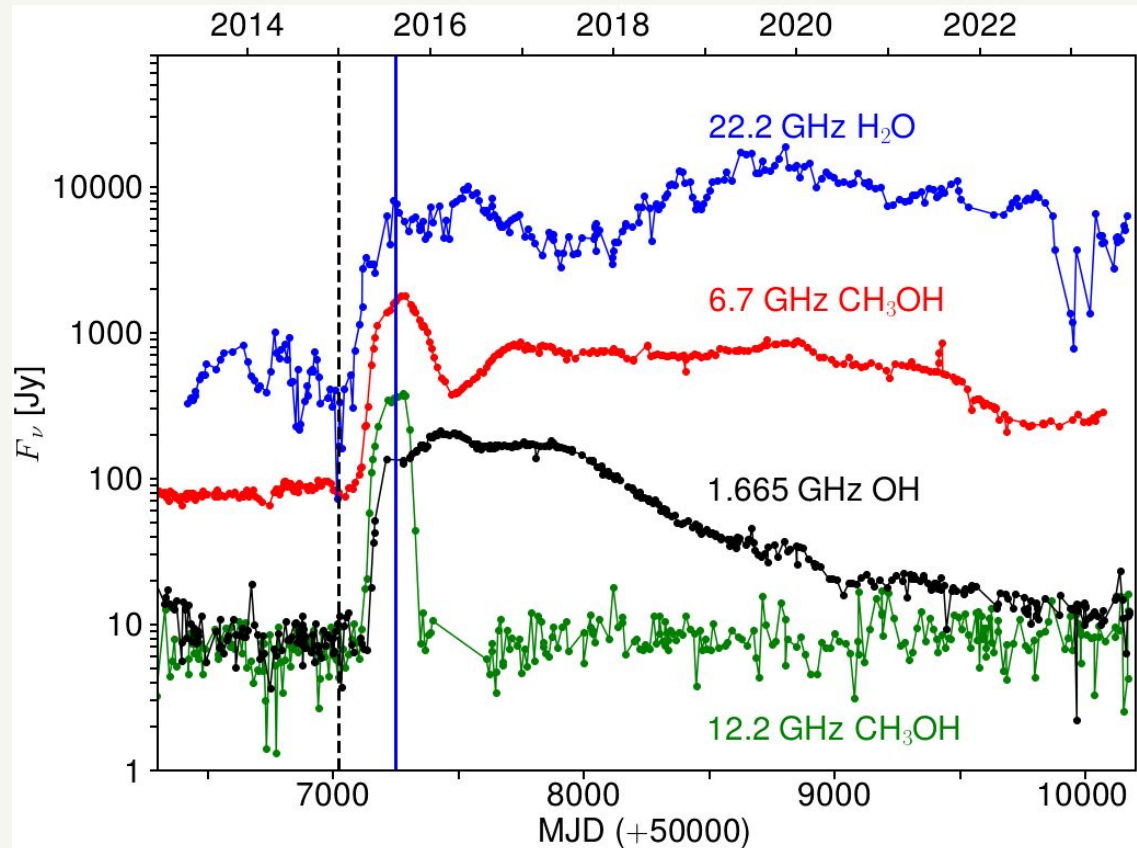


Quick Example: NGC6334I



Right: Sandell, G., et al. 2000

Single Dish Maser Monitoring with HartRAO (MacLeod et al. 2018)

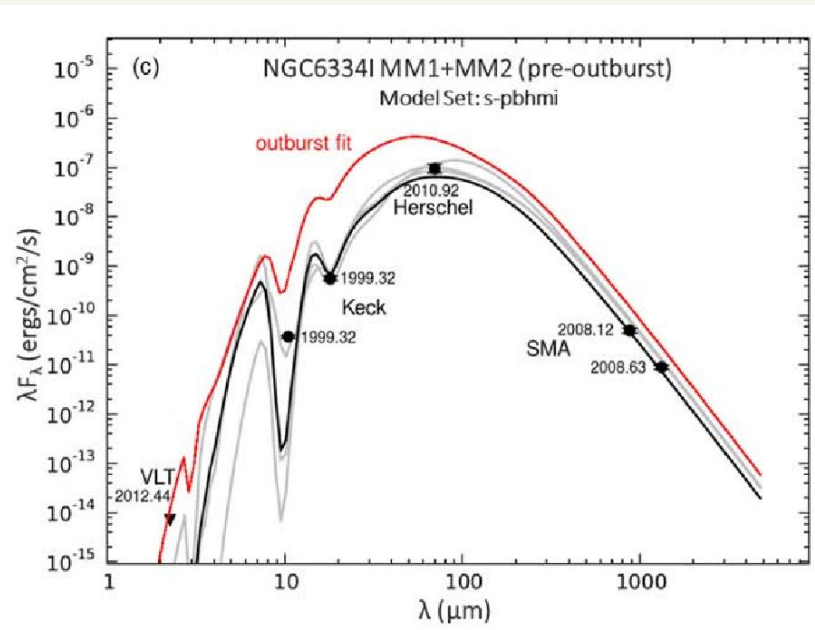
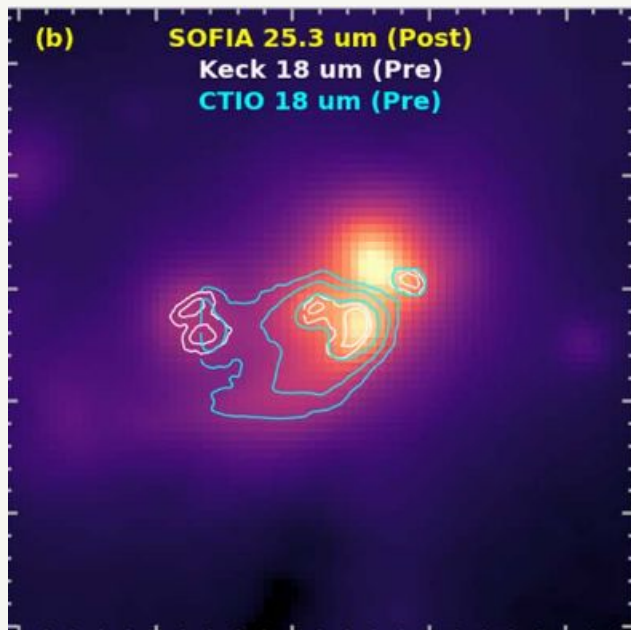


Accretion burst in 2015.1

6.7 GHz methanol masers flared from 100 Jy to 1100 Jy.

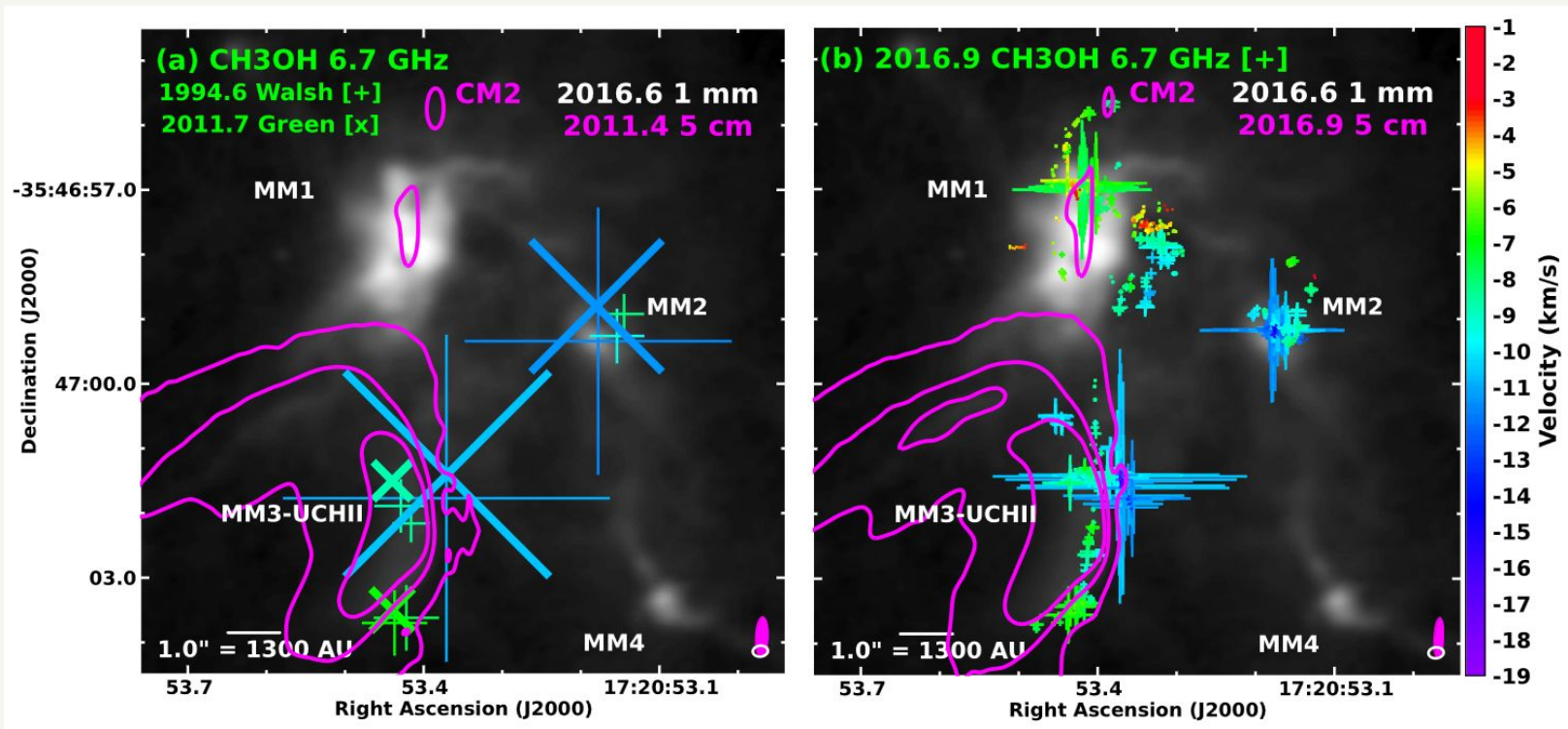
Flares in other maser species as well.

Infrared + Millimetre Outburst in NGC6334I

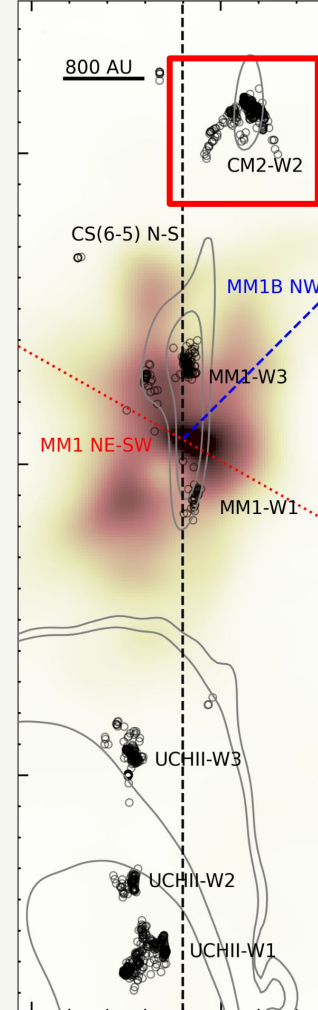
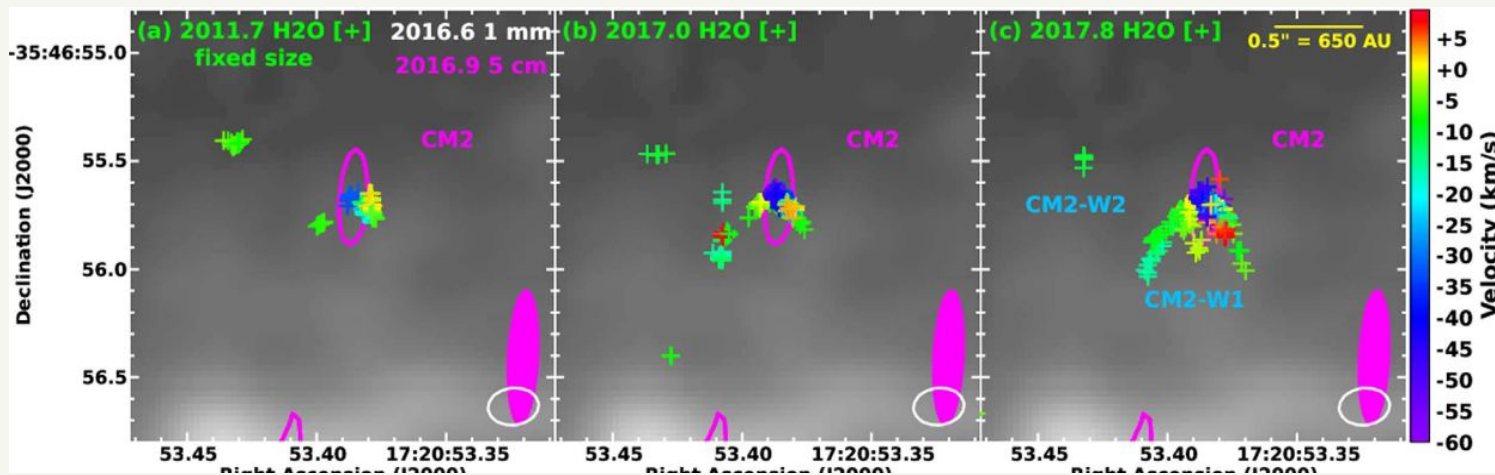
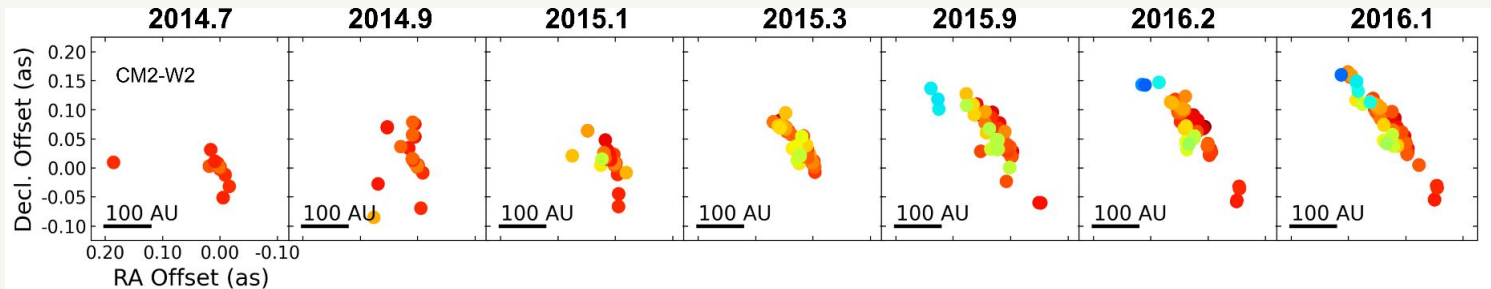


Hunter, et al. 2021

Methanol masers turned on with the burst (Hunter et al. 2018)



Masers tracking Bow-Shock Widened For >1 yr



Top: VLBI Monitoring of 22 GHz water masers, Vorster et al. 2024, bottom JVLA Brogan et al. 2018

Many effects of episodic accretion

Heat up the surrounding environment, melting ice off of dust (Jørgensen et al 2020).

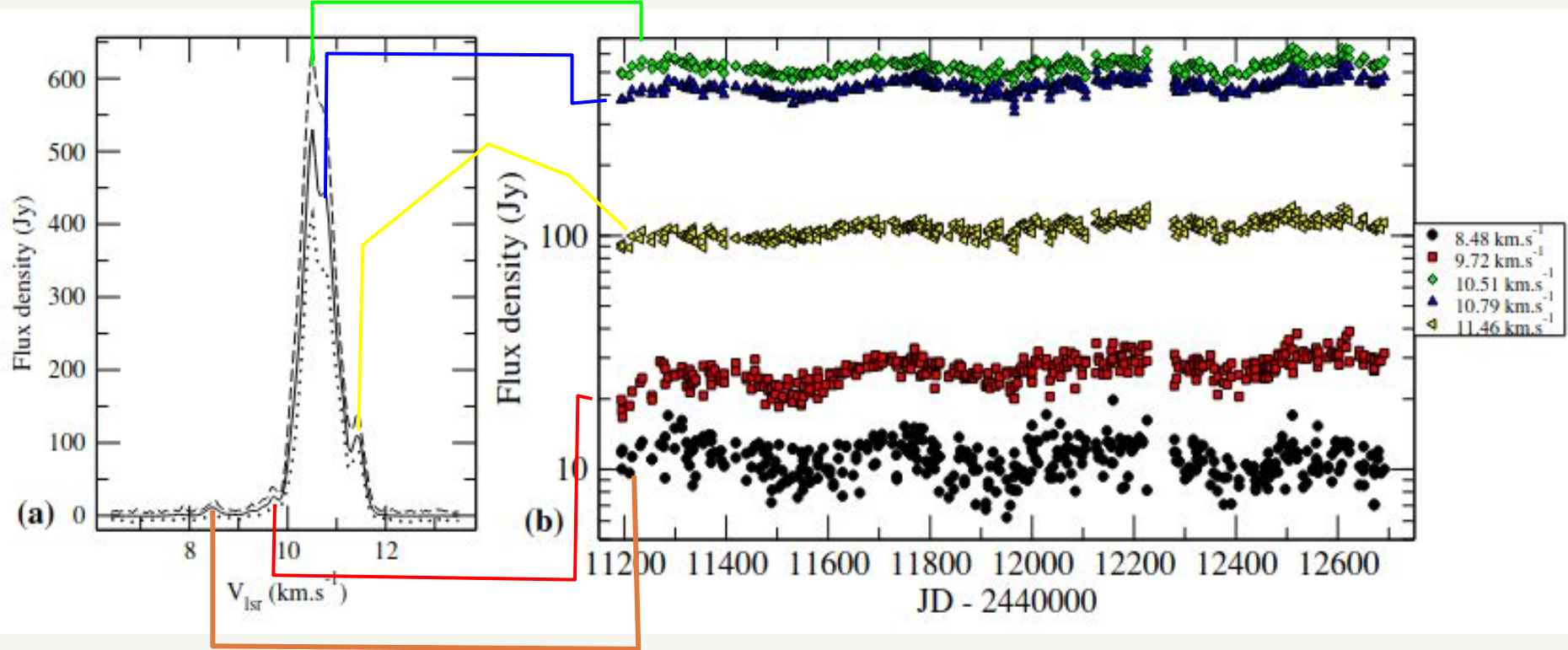
Change the initial conditions for planet formation by annealing dust from amorphous to crystalline (Abraham et al 2009).

Eject gas (Cesaroni et al., 2018, 2023, 2024).
and dust (Kadam, K et al 2025).

May hinder planet formation in $M > 3 M_{\text{sun}}$ stars (Das, I et al. 2025).

How are they detected?
6.7 GHz methanol maser monitoring

Single Dish Maser Monitoring

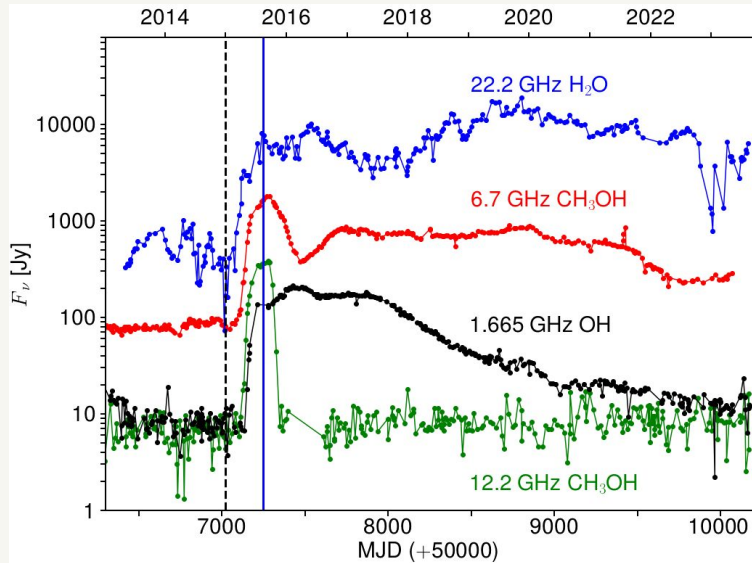


Goedhart, S., Gaylard, M. J., & Van Der Walt, D. J. (2004). Long-term monitoring of 6.7-GHz methanol masers. *Monthly Notices of the Royal Astronomical Society*, 355(2), 553-584.

Flare Alert and Follow-Up

Single-dish flare alert → Target of Opportunity proposals at international facilities (JVLA, ALMA, VLBI).

Post-flare, single-dish functions as a burst “clock”.



MacLeod, G et al., 2018



Metsähovi Compact Array (MCA)

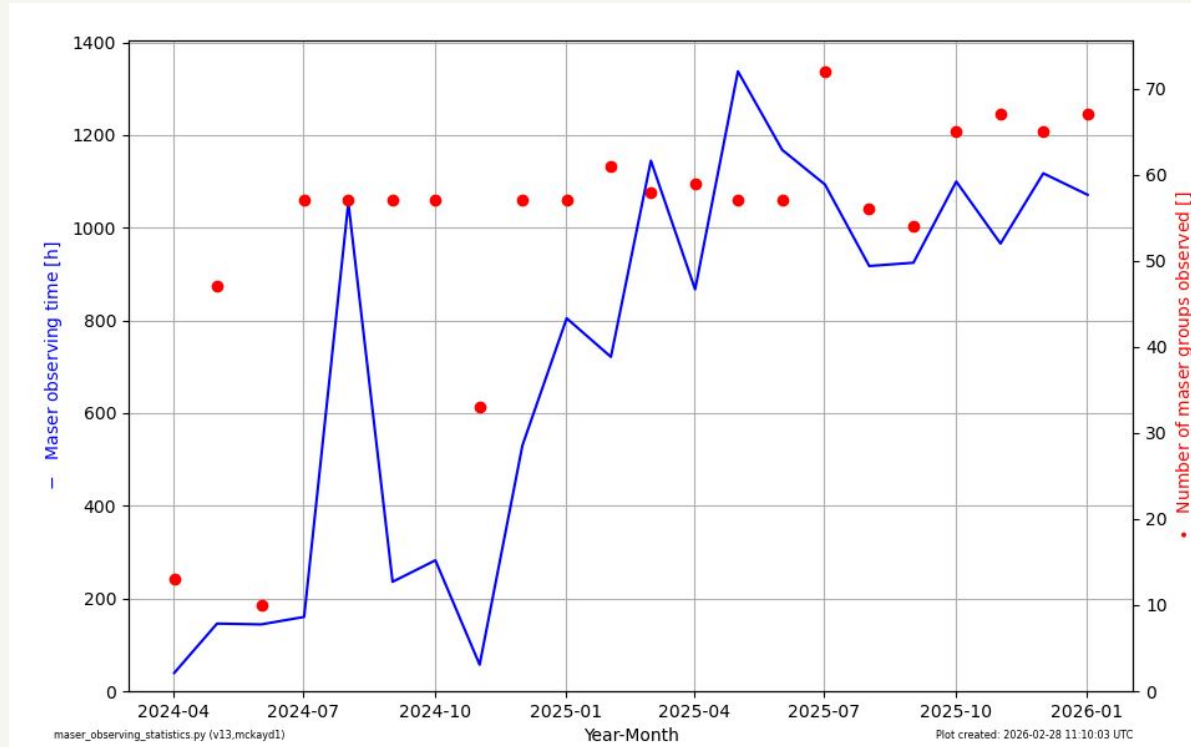


A? Aalto-yliopisto
Aalto-universitetet
Aalto University

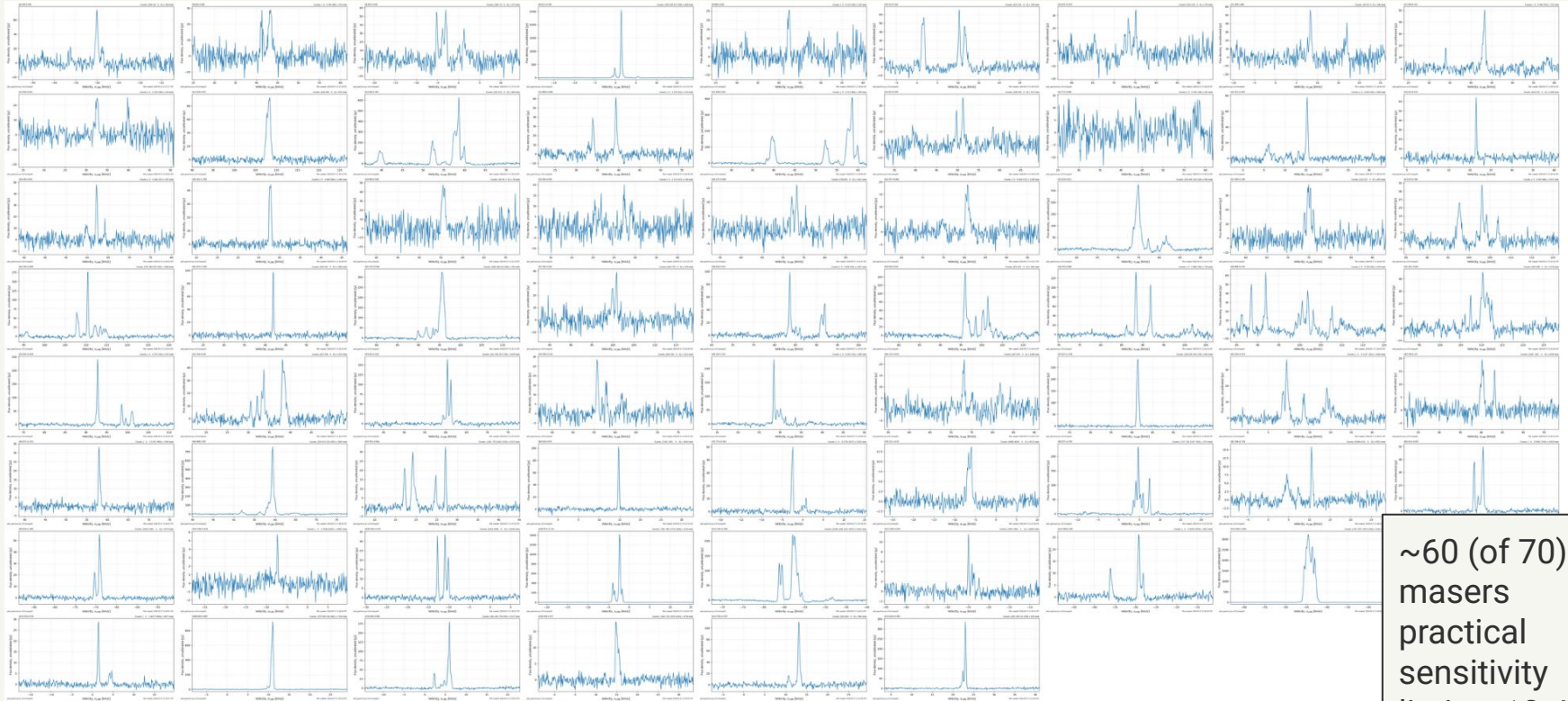
Single Dish Monitoring with the MCA

Brief history of the project

- First maser tests in late 2023
- Monitoring started in earnest in mid 2024.
- Automated observations.
- January 2025, average of a ~1000 hours of observations per month (between two antennae).
- We cover 150 high mass star forming regions with 60 pointings.

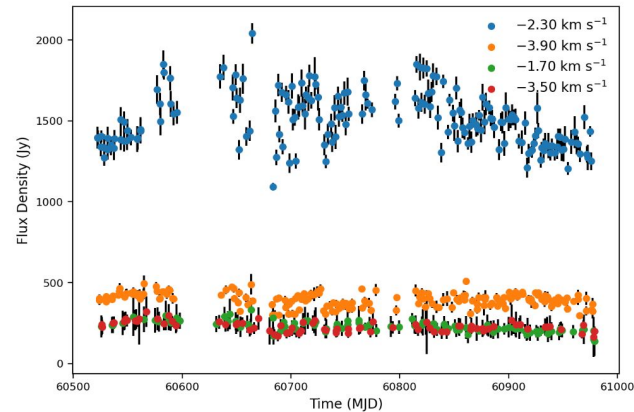
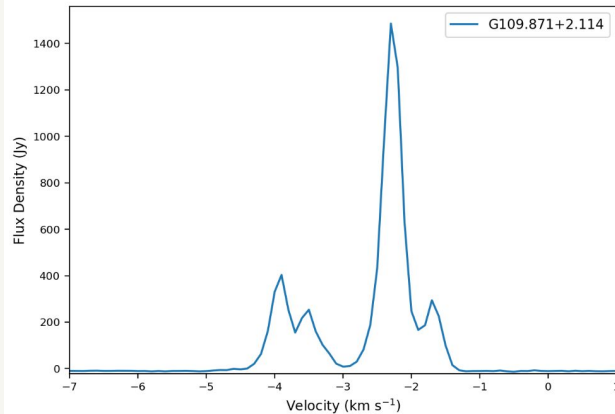
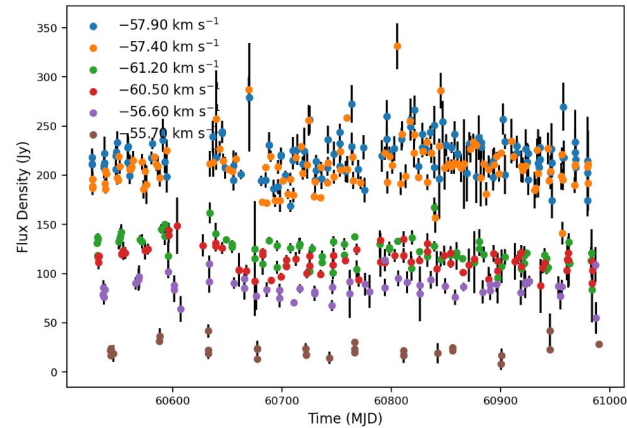
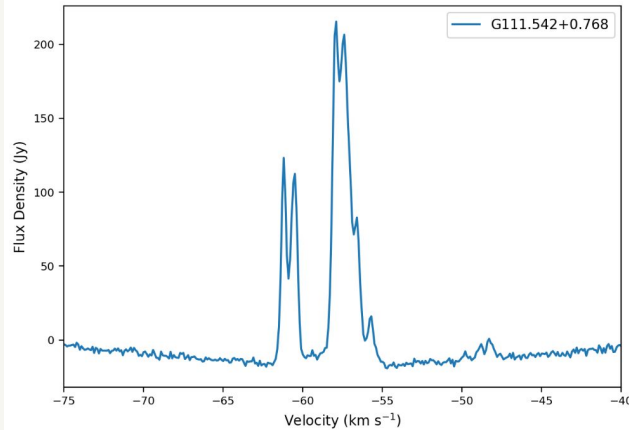


MCA Maser Monitoring Programme



~60 (of 70)
masers
practical
sensitivity
limit ~10 Jy.

Monitoring Data Examples

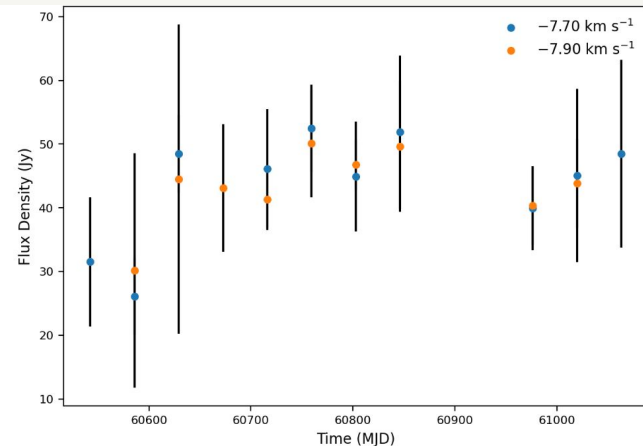


Detecting faint masers with a 5.5 m dish.

We want to keep an eye on the masers.

However, with small dishes we do not always detect faint features.

We therefore **dynamically average** each maser feature according to its average brightness.

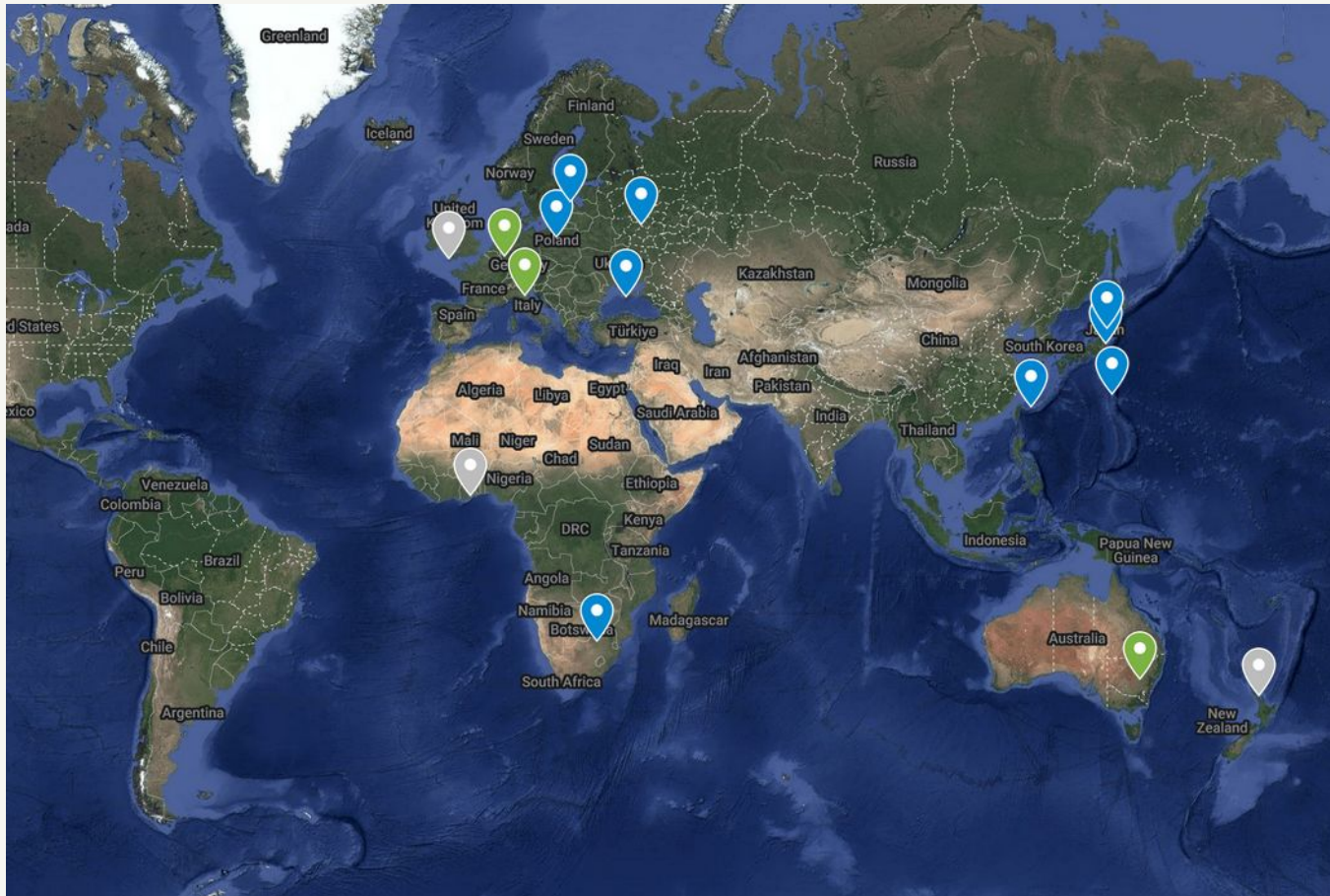


$$\begin{aligned} \text{if } F_v > F_{\text{upper}} &\rightarrow N_{\text{time}} = \Delta t/3 + 1 \\ \text{elif } F_v < F_{\text{lower}} &\rightarrow N_{\text{time}} = \Delta t/40 + 1 \\ \text{else } N_{\text{time}} &= \overline{F}_v/5 \end{aligned}$$

Reconsidering the problem

Worldwide maser monitoring with 25m class single dishes.

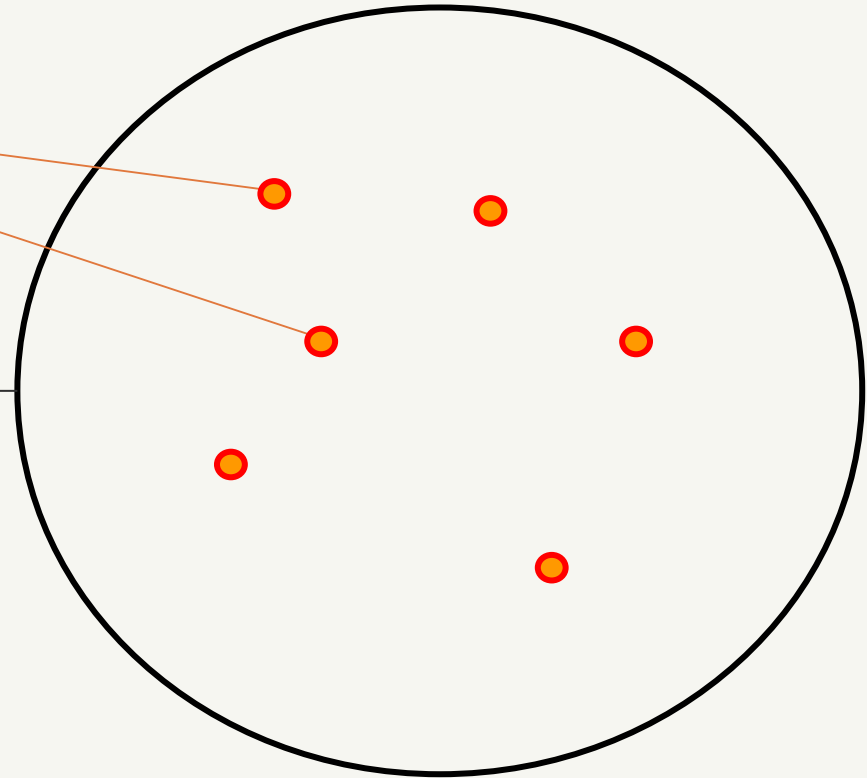
What can we do with three 5.5 m dishes in Finland?

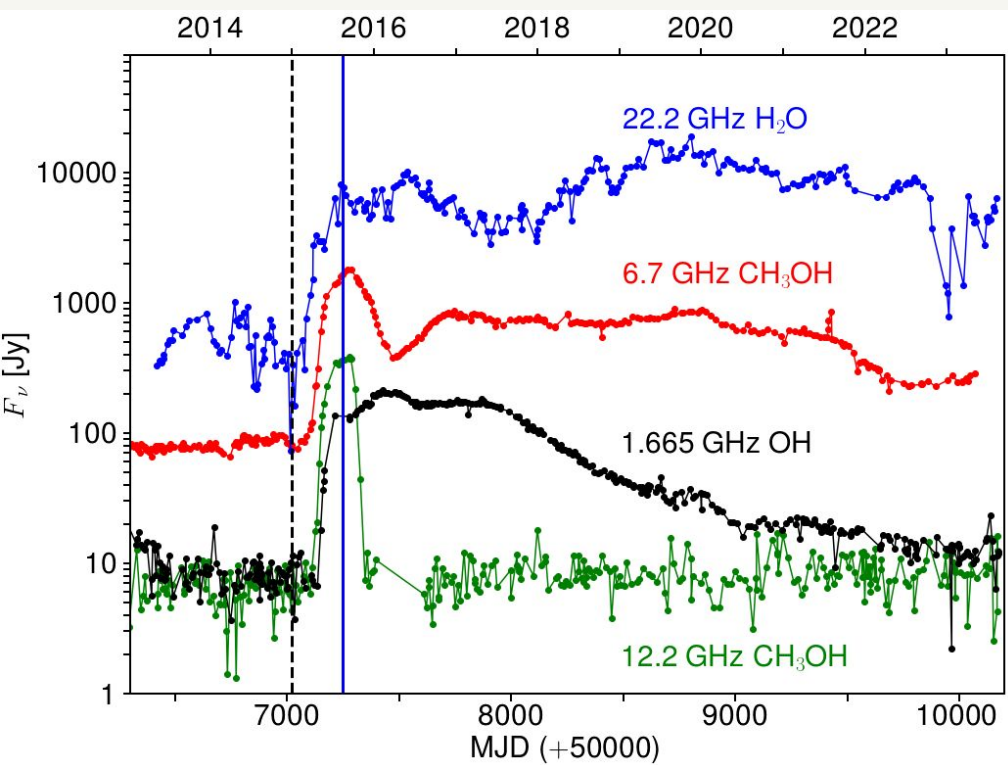


Small dish → Better spatial coverage

High mass star forming regions

0.5° Single dish primary beam





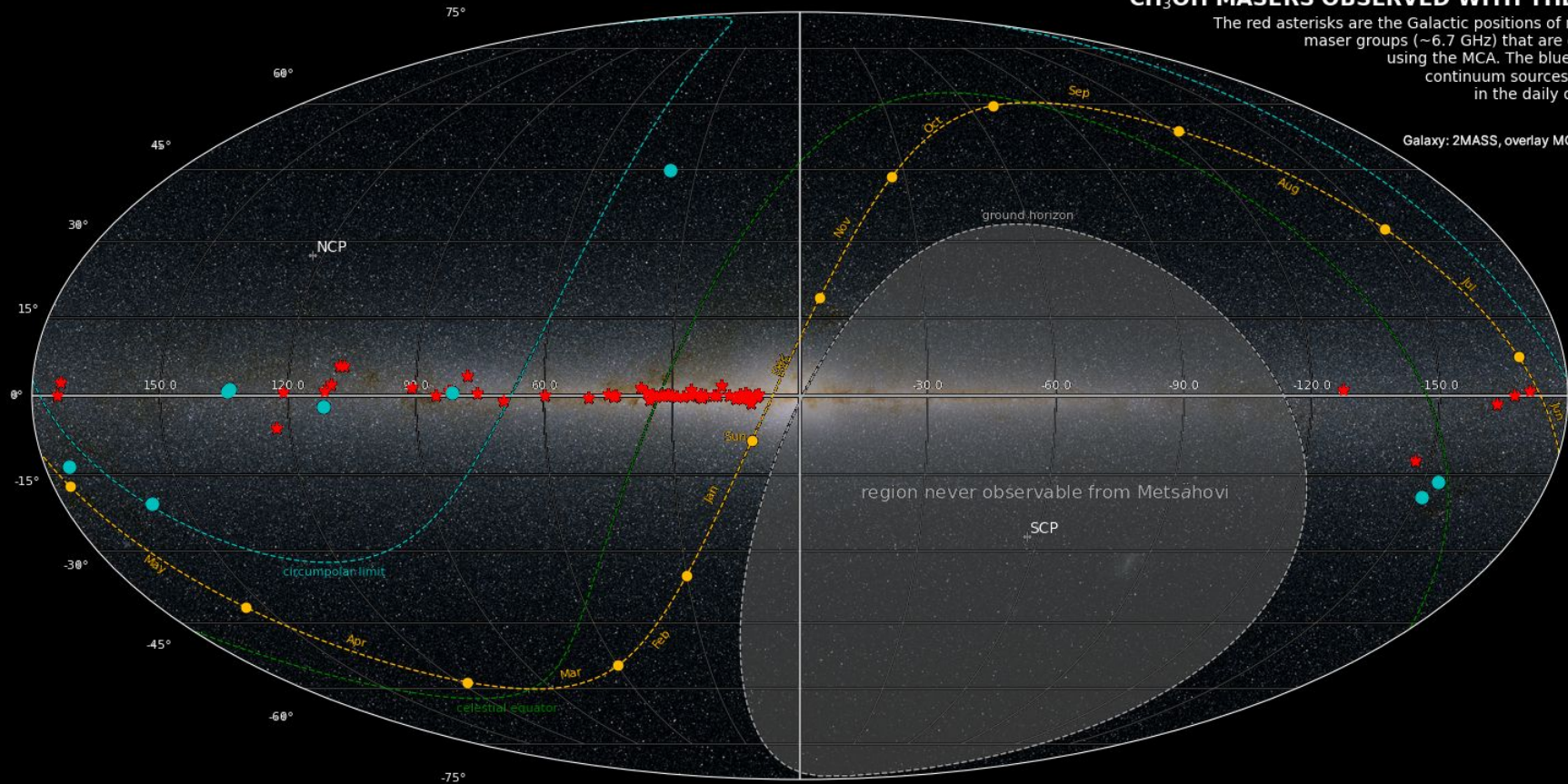
Of the eight detected flares, ~70% were > 100 Jy methanol masers (Wolf et al. 2024).

These flares are bright (~ 10x for 6.7 GHz) and happen over < month timescales.

CH₃OH MASERS OBSERVED WITH THE MCA

The red asterisks are the Galactic positions of methanol maser groups (~6.7 GHz) that are observed using the MCA. The blue dots are continuum sources included in the daily observing

Galaxy: 2MASS, overlay MCA (McKay)

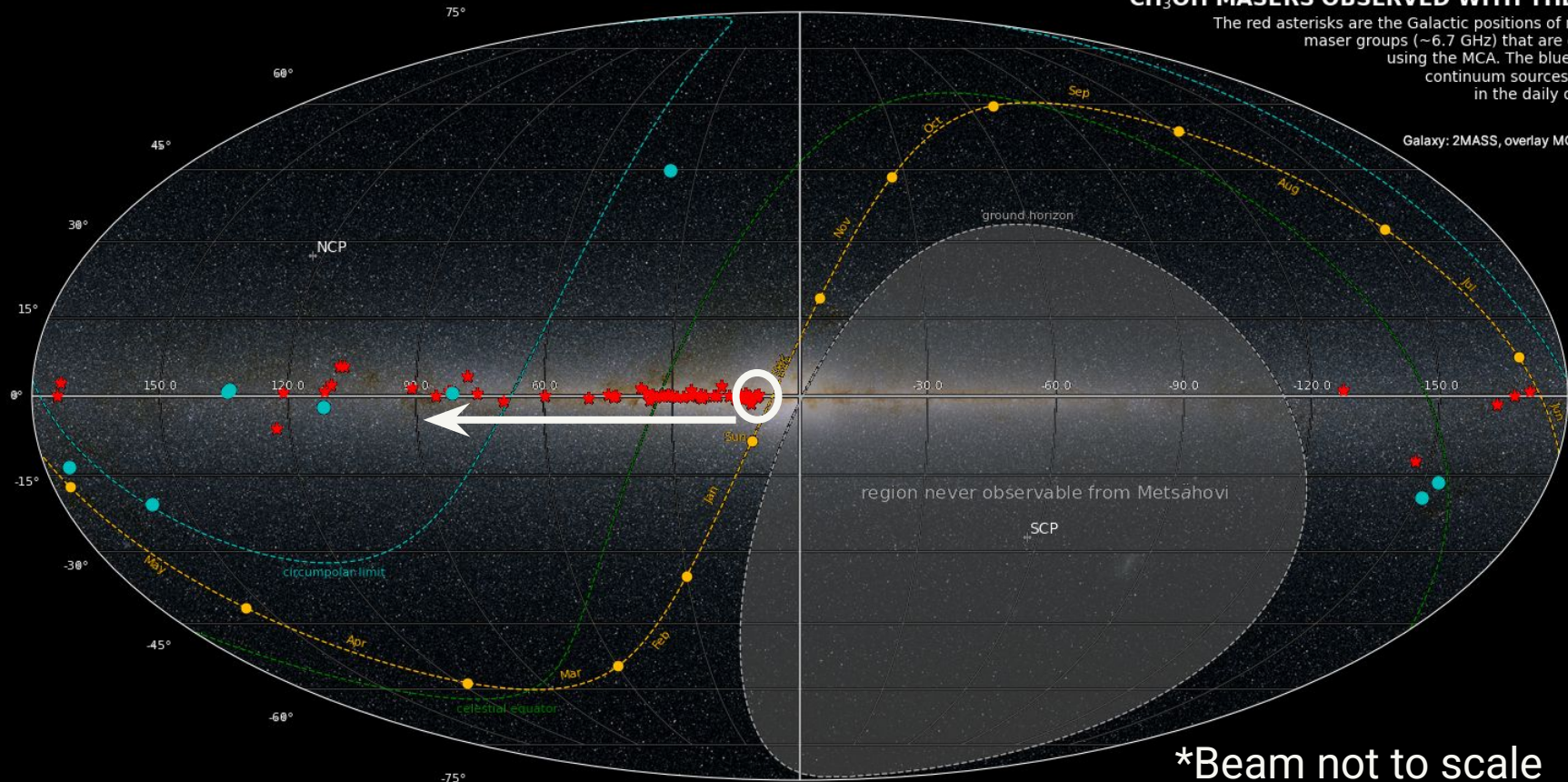


Constant Galactic Latitude Drift Monitoring

CH₃OH MASERS OBSERVED WITH THE MCA

The red asterisks are the Galactic positions of methanol maser groups (~6.7 GHz) that are observed using the MCA. The blue dots are continuum sources included in the daily observing

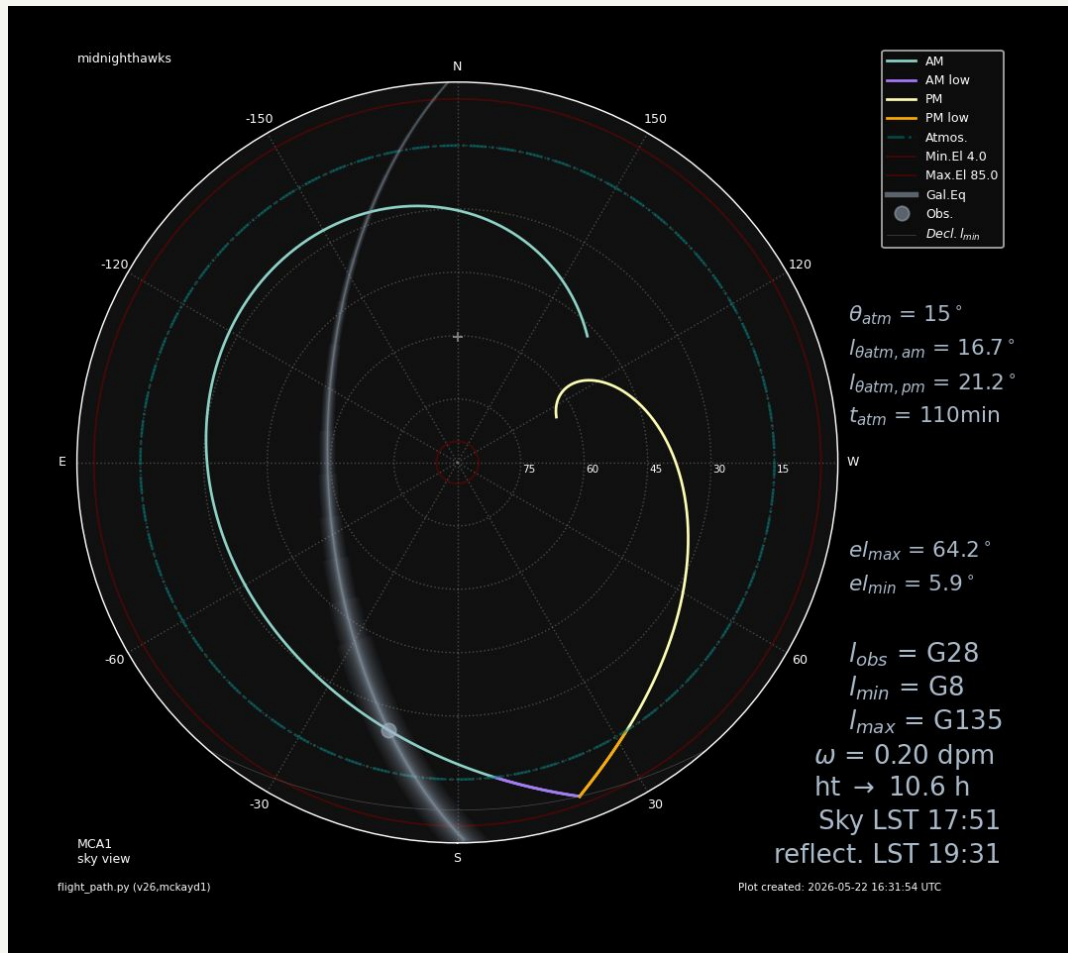
Galaxy: 2MASS, overlay MCA (McKay)



*Beam not to scale



Midnight Hawks

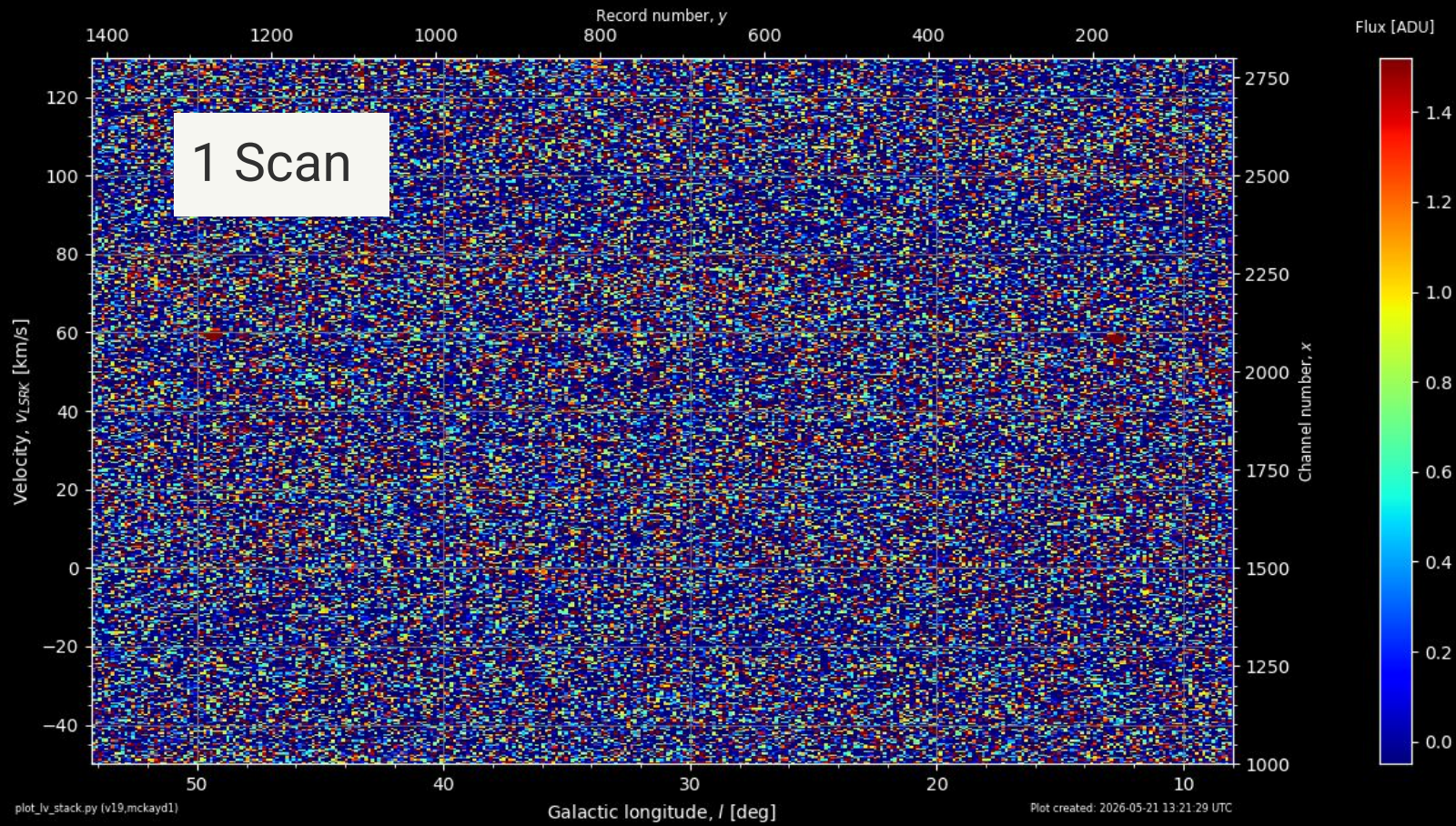


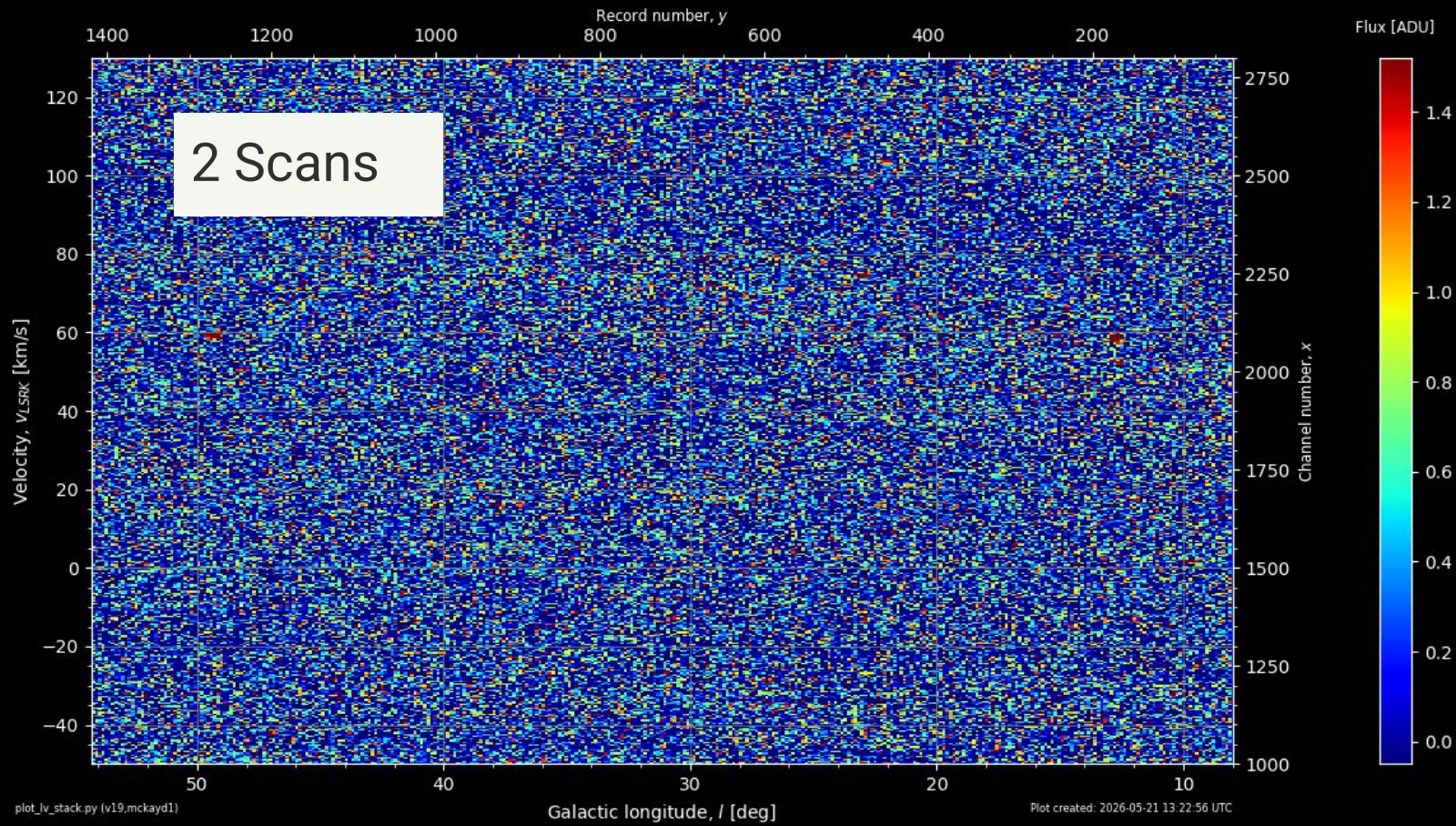
We can use our 0.5 deg beams to do a scan of the lowest galactic latitudes.

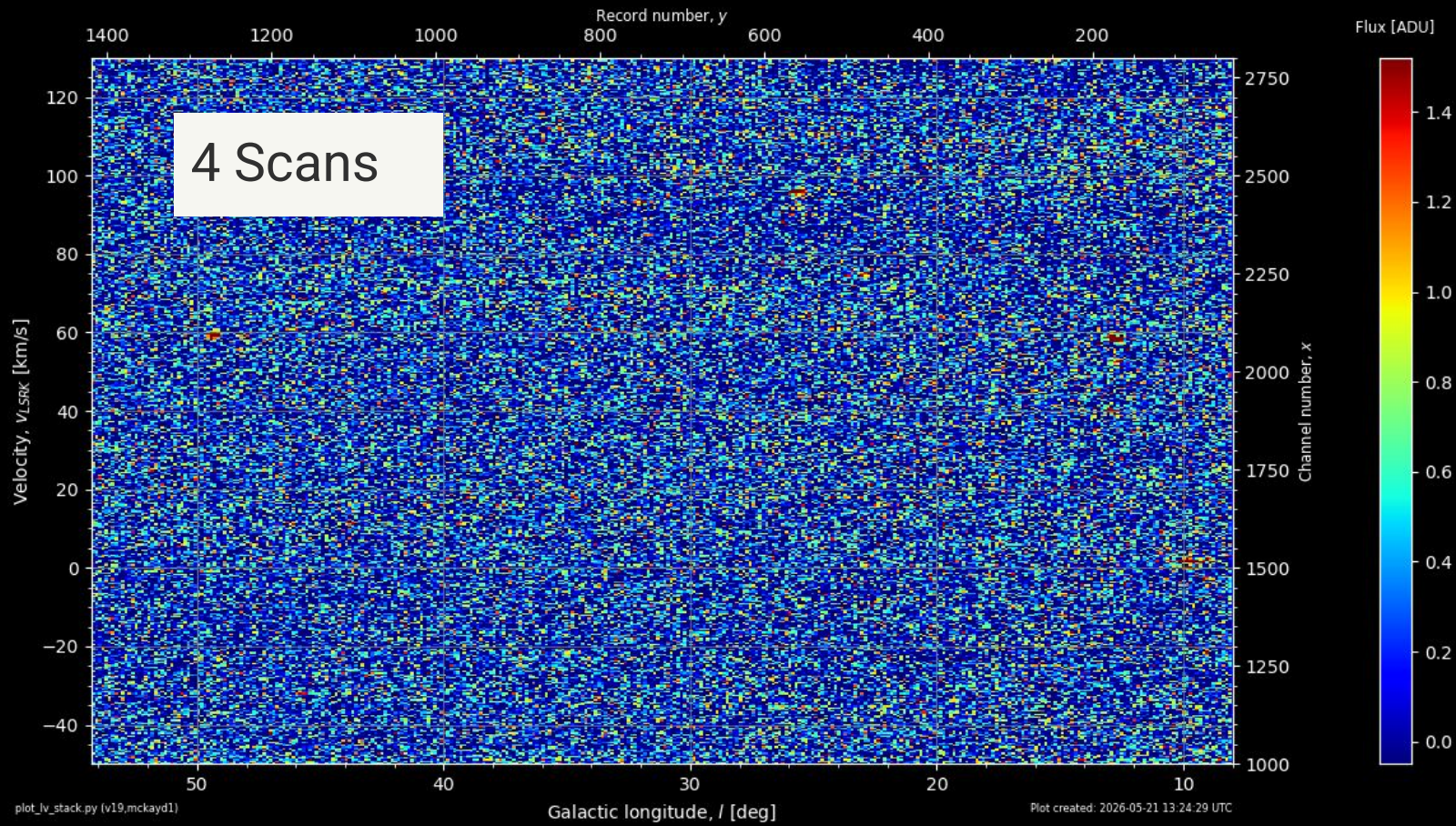
Our aim is to cover the maximum galactic volume
 Longitudes: 8 - 135 deg
 Latitudes: -2 - 2 deg.

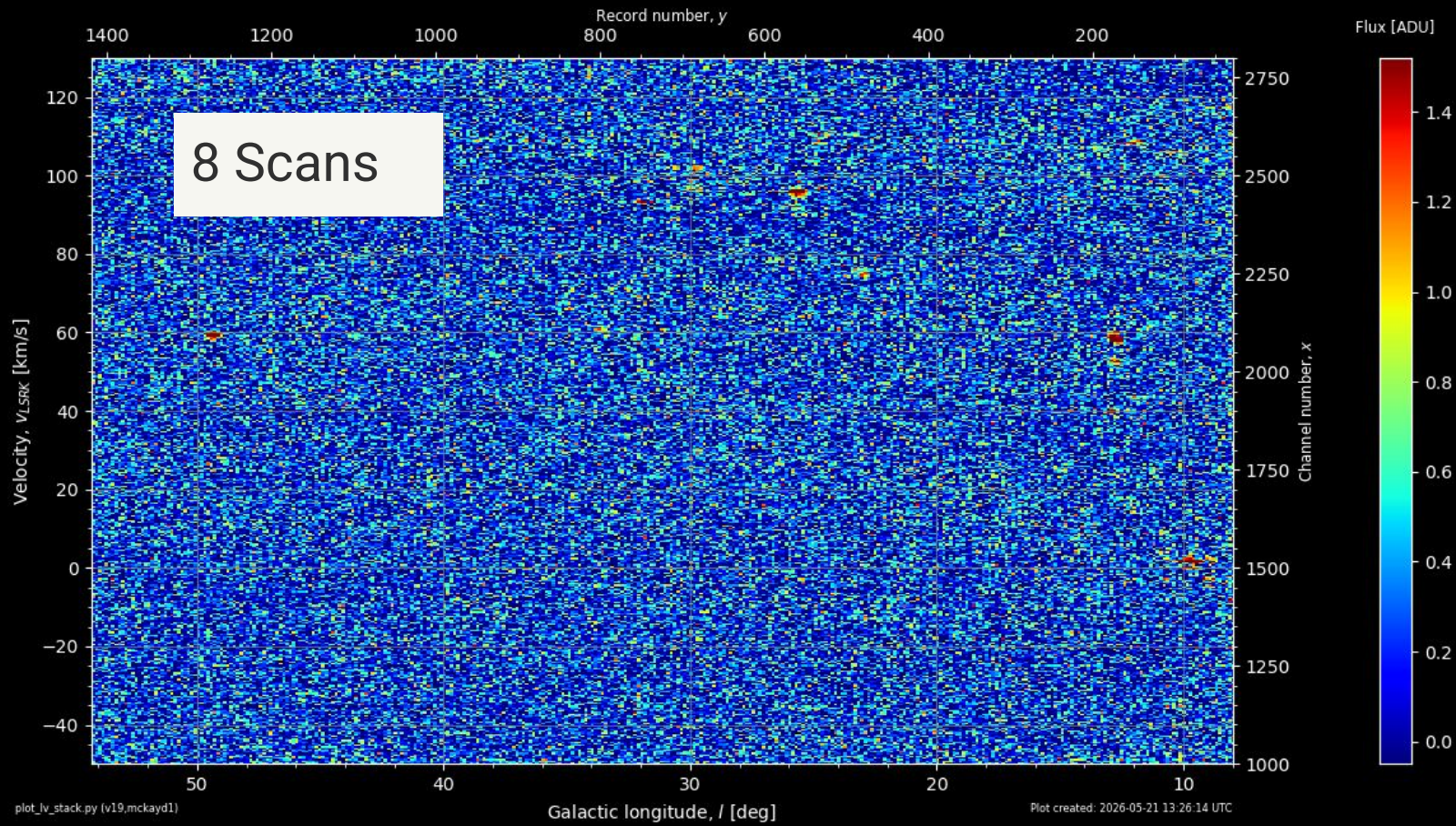
With a <100 Jy sensitivity and a 1 week cadence.

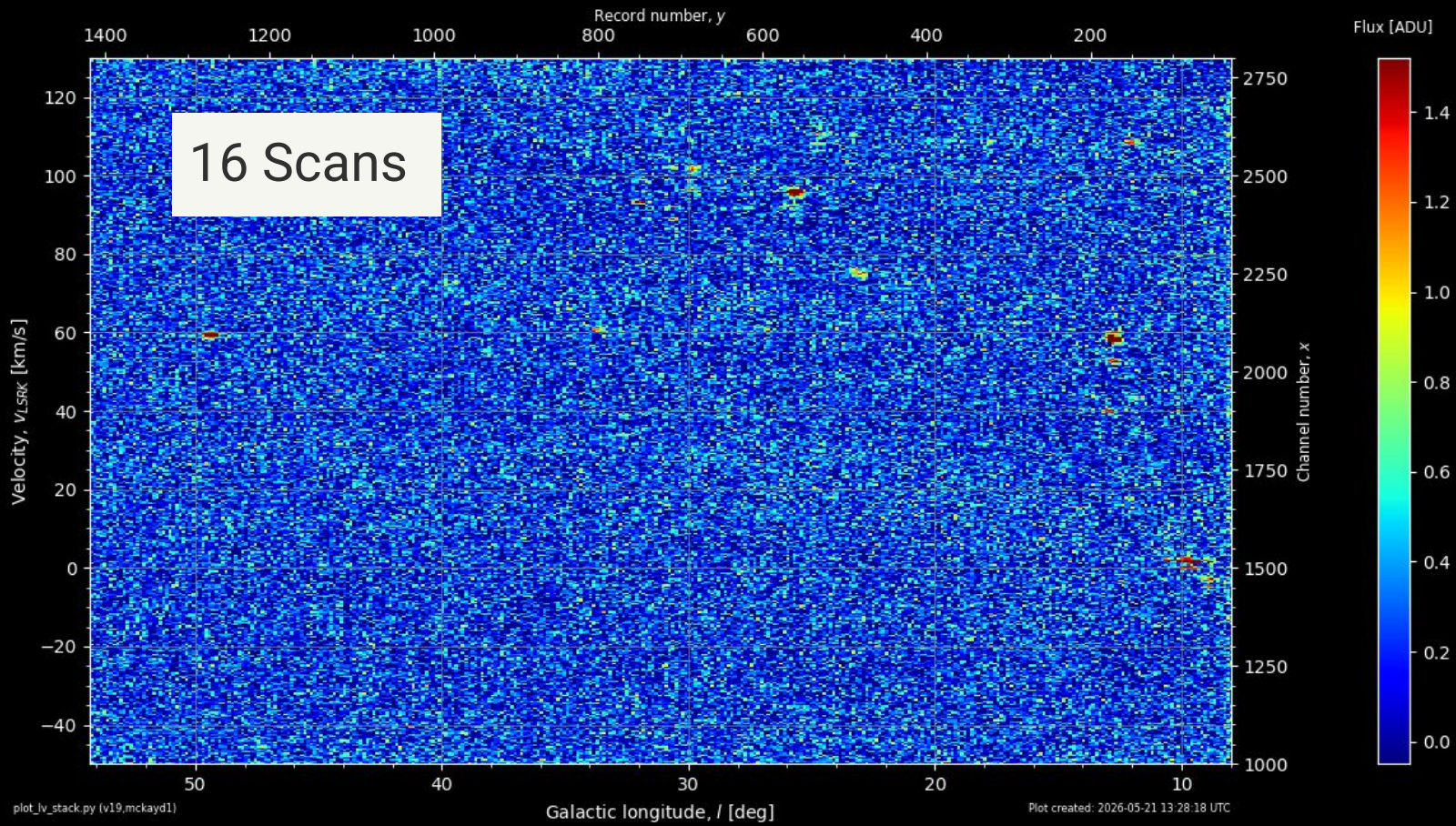
This will allow us to catch flares in sources outside our monitoring list.

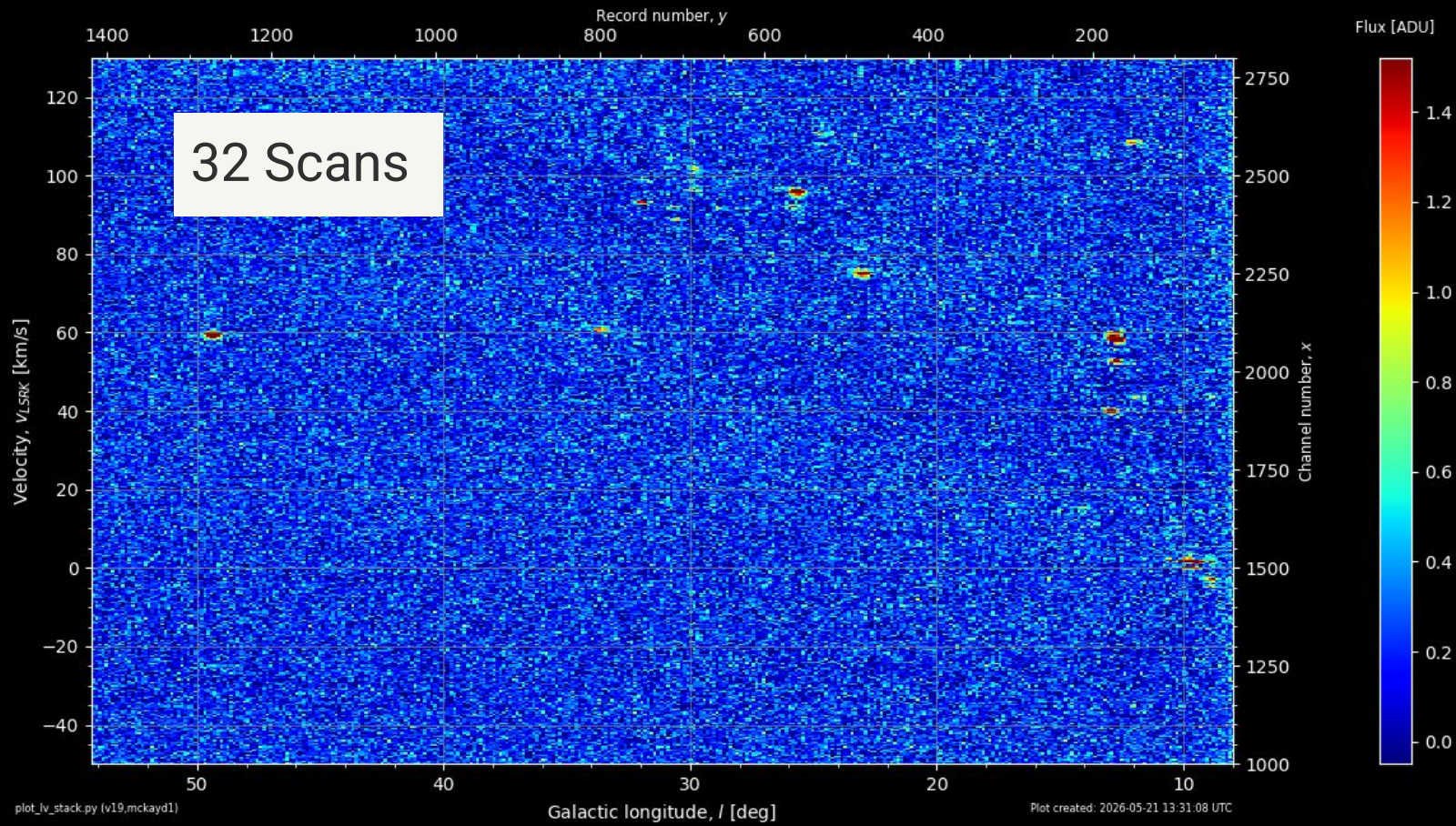


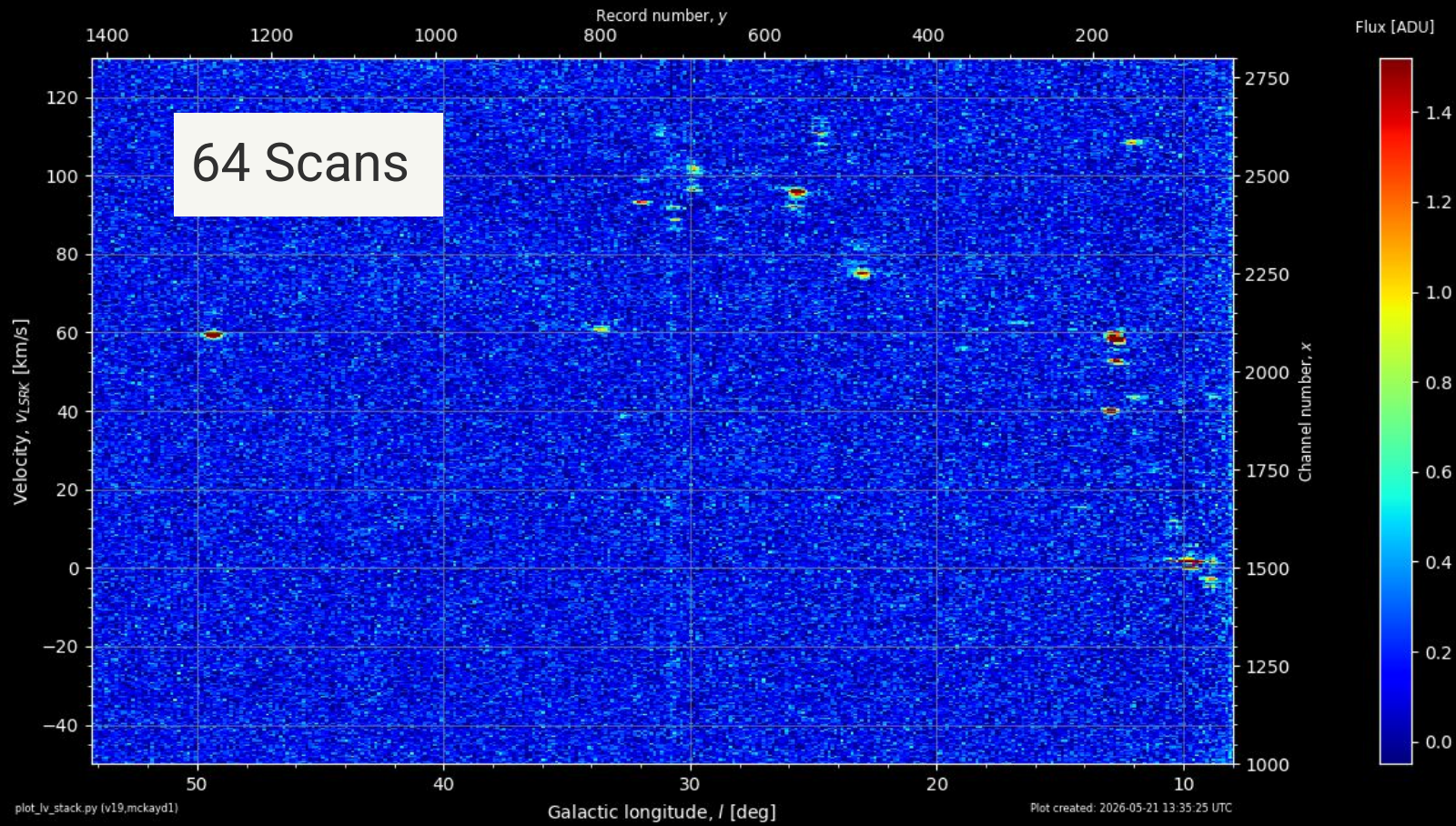


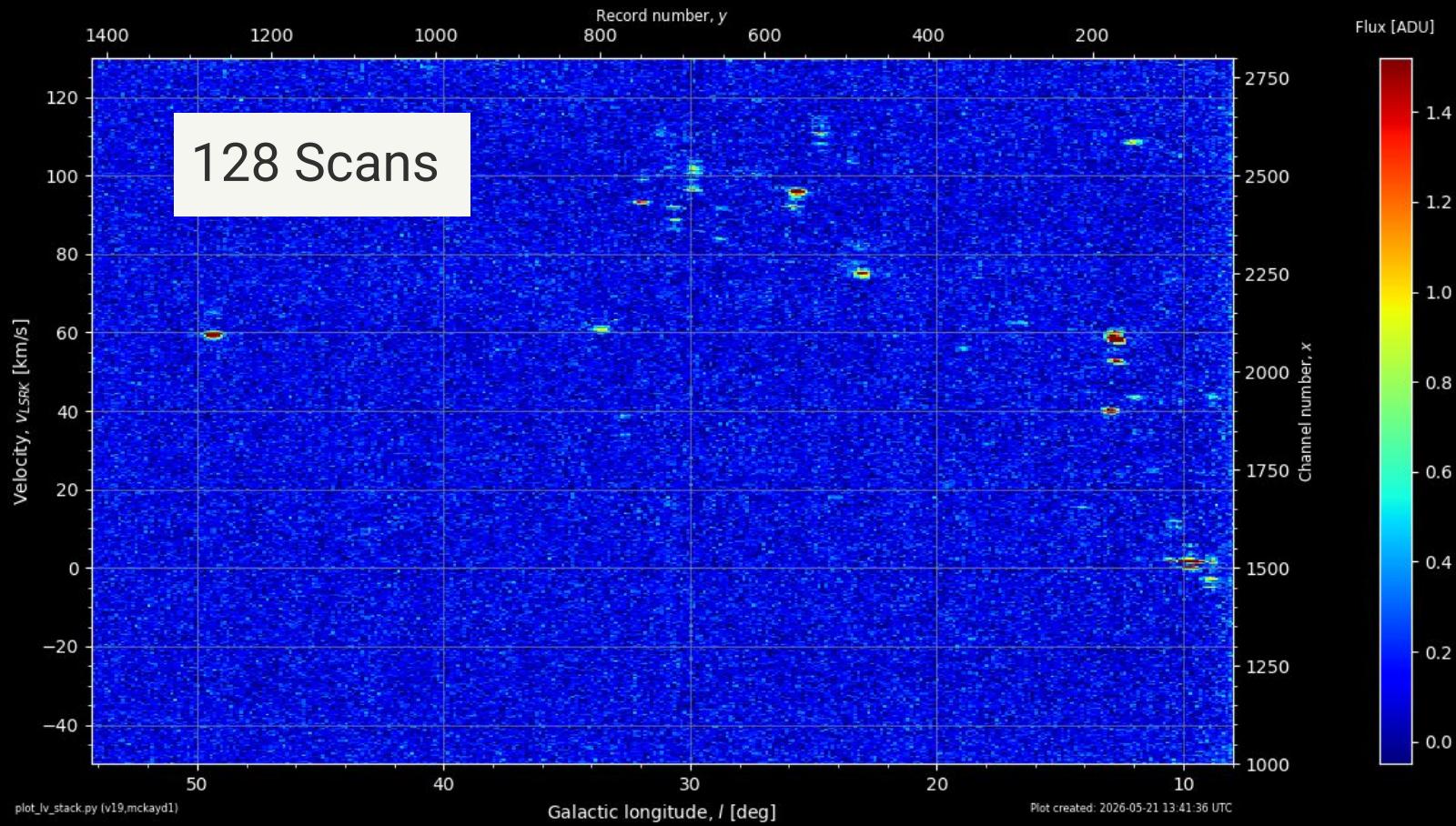












Conclusion

We want to identify accretion bursts from high-mass star forming regions through maser monitoring.

“Standard” single dish monitoring: With two MCA 5.5 m dishes

We have monitored ~ 60 high mass star forming regions

With cadences 1d - 30d depending on source brightness, down to 10 Jy.

Midnight hawks:

We are developing a novel monitoring method with regular scans across the galactic plane to do blind flare detection.

Very early stages.

Planned backend upgrades will also allow us to monitor all lines between 4-8 GHz in single dish (and later interferometrically).

Thank you for your attention!

Jakobus Vorster¹, D. McKay², Jere Raassina², Demian Aaltonen², Sonny Holman^{2,3}

¹University of Helsinki, Finland

²Aalto University Metsähovi Radio Observatory, Finland

³Häme University of Applied Sciences HAMK, Finland

Contact me: Jakobus.vorster@helsinki.fi

Contact Derek: derek.mckay@aalto.fi

A? Aalto-yliopisto
Aalto-universitetet
Aalto University



The logo of Häme University of Applied Sciences (HAMK), consisting of a stylized geometric design of four triangles meeting at a central point.
HAMK
Hämeen ammatti-
korkeakoulu