18:00 JST, 31 December 2021

M2O Newsletter, No. 30

The theme this time is bookkeeping. Atypically material-dense because activity from Jan-March included

M2O website: Publications list and Members list updated.

SamePage A few additions and renovations:
(1) We now have a publication repository (Suggestion by Olga) of PDFs so that anyone can access the papers regardless of their institute's available subscriptions. See Workspace > Publications.
(2) Members page, if you havent already please go confirm your details at: Workspace > Everyone > List of Members

These monthly PDFs: I like making these and will continue to do so, ideally also transitioning back into occasional zoom telecoms too, im just very busy at the moment. Anyway, the M2O targets table (below) has been updaed with specific info about flare onsets and the dates they were reported (Suggestion by Bringfried)

Archive of Telecoms/Newsletters: I don't remember who suggested it, maybe Gabriele, but following the request Ive collated all the Telecom and Newsletter PDFs I could find on my current laptop and uploaded them to the Wiki page which we have on JIVE's server (big thanks to JIVE for allowing us to continue using this space). They can be found at this link. As a reminder. If you have presentation files or reports that you'd like to share - the Wiki is more suitable than SamePage which has a 2Gb space limit. The wiki has been cleaned up a little but needs further updating of the Timelines.

Reports: NRO45 eQ receiver commissioning and obs.; EVN mini symposium proceedings; G358-MM1 4-arm spiral

1 Activity since the previous Telecom

- **SamePage:** +5 (Luca Moscadelli, Mareki Honma, Johan van der Walt, Phrudth Jaroenjittichai, Jihyun Kang): total 84 members.
- **Papers accepted:** +0; Total: 19
- **Papers in revision:** None
- **Papers in prep:**
  - Burns et al., 6.7 GHz VLBI movie in G358. Drafting and further analyses (see Telecom18 Report)
  - Orosz et al., 7.6 and 7.8 GHz methanol masers in G358, aiming for ApJL
  - Hirota et al., G24.33+0.14 ALMA follow-up; pre- and post- flare phases. (see Telecom 20 Report)
  - Kobak et al., VLBI images and SD monitoring of G24.33 during the maser flare(s).
  - Gray et al., Two additions to the maser flare series: compression and skyplane overlap scenarios.
  - Volvach et al. "The powerful flare event of a water maser in the young protostellar system IRAS 16293-2422"
  - Volvach et al. "Powerful flare phenomena in water vapor maser lines in the emerging protostellar system with protoplanetary disks IRAS 16293-2422"
  - McCarthy et al. Ammonia masers observed in the G358 accretion burst
  - Stecklum et al. Simulations of heat propagation during the G358 accretion burst
- **New observing proposals:** None
- **M2O targets:** *** New 22 GHz water maser flare in V1318 Cyg S *** <– Should we follow it up?

Name	Maser line [GHz]	Pre-flare [Jy]	Date reported	Flare onset	Max Flux [Jy]	Current Flux [Jy]	Reported by	Reobserved by	Status
G25.65+1.05	22	850	08SEP17	08SEP17	60k	2150	Volvach	Hh, Sz, Mc	post-burst
W49N	22	5k	07SEP17	07SEP17	35k	?	Kramer, Ef	?	post-burst
NGC2071	22	1k	DEC18	18MAY18	7k	920	Sunada, Hh	Vr, Hh, Sz, Ib	post-burst
IRAS 16293-2422	22	<10	12DEC19	14APR19	30k	-	Sunada, Mc	Vr, Mc, Hh, Sz, Ib, Mc	-
G358.93-0.03	6.7	5	18JAN19	14JAN19	1000	15	Yonekura	Hh, Ib	decreasing
G53.22-0.08	22	3	31JAN20	12FEB19	800	30	Sunada	Vr, Hh, Ib	post-burst
G24.33+0.14	6.7	-	05SEP19	14AUG19	800	5	Olech	Hh, Ib, Vs, Mc	decreasing
Orion S6	6.7	3.1	10FEB20	09FEB20	9	2	Yonekura	Ib, Tr, Sz, Hh	variable
G85.411+0.002	6.7	12	28FEB20	18OCT19	95	80	Yonekura	Ib, Ef, Sz, Tr, Hh, Ky, Vs	decreasing
G33.641-0.228	6.7	periodic	MAR20	flutter	236	60	Bringfried	Hh, Ib, Vs	eruptive
G359.617-0.251	6.7	120	13JUL20	10JUL20	200	90	Yonekura	Ib, Hh,	decreasing
G034.196-0.592	22	<1	23OCT20	06OCT20	120	120	Ladeyschikov	Sz, Oa, Hh, Mc	?
G35.20-0.74	22	600	20JAN21	03JAN21	4k	4k	Volvach	Sz, Hh, Ib	?
G024.541+0.312	6.7	∼5	04NOV21	05JUL21	60	60	Durjasz	Ib, Hh, Vr	Active
G081.174-0.100	22	10	26NOV21	15OCT21	45	45	Ladeyschikov	Ef	Active
V1318 Cyg S	22	<10	05MAR22	27MAR21	330	330	Sunada		See SamePage

(Ib = Ibaraki) (Tr = Torun) (Sz = Simeiz) (Hh = HartRAO) (Ef = Effelsberg) (Ky = KVN Yonsei) (Vs = Ventspil) (Vr = VERA stations) (Mc = Medicina) (Ps = Puschino) (Oa = OAO-WFC)

- **Follow-up observations conducted (see Record Keeping for more details):**
  G081.174+0.100: VLA (PI: O Bayandina) and EAVN (PI: R Burns)
  G024.541+0.312: VLBA (PI: R Burns)

- **Active trigger proposals:**

Array	Code	Grade	Hours granted target x epoch x hour	Hours remaining	Active period	Resubmit deadline
EVN	EB083	1.2 / 5.0 (0 is best)	(3x2x8)x2 bands = 96	96	15/SEP/20 - 15/SEP/21	1/JUN/22 *
KaVA	EAVN21A-213	7.6 / 10.0 (10 is best)	2 x 1 x 8 = 16	16	16/JAN/21 - 15/JAN/22	15/NOV/21 #
EAVN	EAVN21A-214	8.3 / 10.0 (10 is best)	1 x 2 x 8 = 16	16	16/JAN/21 - 15/JAN/22	15/NOV/21 #
LBA	V581	4.1 / 5.0 (5 is best)	96	88	01/OCT/20 - 01/OCT/21	16/JUN/22 *
VLBA	BB428	0.59 / 10.0 (0 is best)	48	48	01/AUG/21 - 01/AUG/22	01/FEB/22
VLA	VLA/21B-082	B	12	12	29SEP21 - 31JAN22	-
SOFIA	90053	A	3.46	3.46	Rolled over	Rolled over
ATCA	C3321	[score]	50	50	[dates]	-
Subaru	S20B0051N	[score]	0.5*2 or 1 night	0.5*2 or 1 night	01/AUG/20 - 01/JAN/21	-
JWST	01906	1st quintile	24.9	24.9	Cycle 1	-
SMA	2021A-S010	A	1 track (split in 1/3s)	all	May-November 2021	March 2022
ALMA	2021.1.00455.T	A	11.2	all	01OCT21 - 01SEP22	Roll over?

(*/#) New proposals already (submitted/accepted) for the following observing semester

Blue coded proposals have public links (Ctr-F search the page for the code if it is not initially identifiable)

2 Reports

Short reports on specific activities, please send me an email (ross.burns@nao.ac.jp) in advance if you have something to report in an upcoming telecom.

Commissioning and test observations with the new wideband Qband (30-50 GHz) "eQ" receiver on the 45m Nobeyama radio telescope: R Burns

EVN mini symposium proceedings: R Burns

I had initially decided not to submit any proceedings but was asked to send a contribution after the deadline. I opted to write an update on the M2O which describes how we came about, our activities, how we operate and a case study centered on G358. There was a 5 page limit so focusing on the M2O group itself rather than trying to explain G358 was the priority. I decided to include all M2O members as co-authors. This meant that the author list got long and the affiliations list even longer. I asked the proceedings organisers what to do about this since including affiliations would have taken up several of our 5 page limit. The decision was that I should submit a separate page of affiliations (this is one of the reasons i asked everyone to input/check their details in the List of Members on SamePage. The submitted version (shown in the following pages) does not have specific affiliations but will be added later when ive compiled them all.

The 4-arm spiral in G358-MM1 traced by 6.7 GHz methanol masers: R Burns

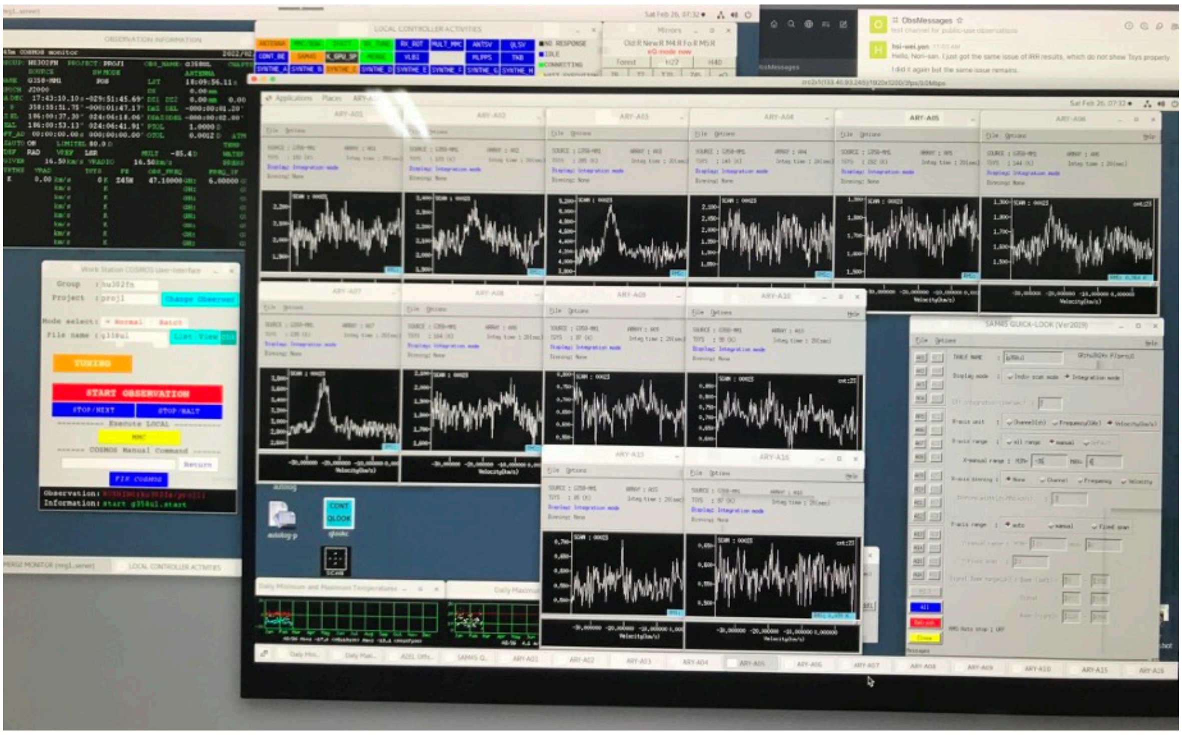
******* The full, individual reports will be shown on the following pages *******

Next Newsletter / Telecom: 30th Nov 2021, 18:00 JST

Extended Q-band (30-50 GHz) “eQ” Receiver installation on the Nobeyama 45m Radio telescope

Since December 2021 my main job changed to installing and commissioning a new receiver on the Nobeyama radio telescope. I previously reported that progress was being made so this time is more of a notification of completion of the commissioning and future prospects of using the system to map diffuse gas and some shock tracers around G358

We conducted a test of line detections (CCS thermal) in all spectral windows of both the upper (A1-8) and lower (A9,10,15,16) sidebands and confirmed that the LSR velocities of the lines match in the USB and LSB which was an issue we had to solve.
After this I used some spare telescope time to search near G358 for a suitable OFF point (emissionless region of sky used for calibration) as a pre-requisite for any future observations we might make of G358.
After finding a good off position I made a few scans of G358 to see which lines were detected in the 30-50 GHz range. There was only a few minutes available for this quick test but some lines were found:



USB
CCS [J=4-3] (45.379 GHz) no detection
HC3N [J=5-4] (45.490 GHz) detection
CS [J=1-0] (48.991 GHz) detection
HC5N (45.265 GHz) no detection
CH3CN [J=9-10] (new maser 45.844 GHz) no detection

LSB
SO (36.202 GHz) unclear
HC3N (36.392 GHz) unclear
H2CS (34.351 GHz) unclear
CC34S (33.112 GHz) unclear

Great to get some results, even though this was just a few mins on source. I’ll repeat this soon with more integration time. There may be a chance to map the SFR during telescope free time.

PROCEEDINGS OF SCIENCE

Recent updates on the Maser Monitoring Organisation

Ross A. Burns,[a,b,*] **Agnieszka Kobak ,**[c] **Alessio Caratti o Garatti ,**[c] **Alexander Tolmachev ,**[c] **Alexandr Volvach ,**[c] **Alexei Alakoz ,**[c] **Alwyn Wootten ,**[c] **Anastasia Bisyarina ,**[c] **Andrews Dzodzomenyo ,**[c] **Andrey Sobolev ,**[c] **Anna Bartkiewicz ,**[c] **Artis Aberfelds ,**[c] **Bringfried Stecklum ,**[c] **Busaba Kramer ,**[c] **Callum Macdonald ,**[c] **Claudia Cyganowski ,**[c] **Colomer Paco ,**[c] **Cristina Garcia Miro ,**[c] **Crystal Brogan ,**[c] **Dalei Li ,**[c] **Derck Smits ,**[c] **Dieter Engels ,**[c] **Dmitry Ladeyschikov ,**[c] **Doug Johnstone ,**[c] **Elena Popova ,**[c] **Emmanuel Proven-Adzri ,**[c] **Fanie van den Heever ,**[c] **Gabor Orosz ,**[c] **Gabriele Surcis ,**[c] **Gang Wu ,**[c] **Gordon MacLeod ,**[c] **Hendrik Linz ,**[c] **Hiroshi Imai ,**[c] **Huib van Langevelde ,**[c] **Irina Valtts ,**[c] **Ivar Shmeld ,**[c] **James O. Chibueze ,**[c] **Jan Brand ,**[c] **Jayender Kumar ,**[c] **Jimi Green ,**[c] **Job Vorster ,**[c] **Jochen Eislöffel ,**[c] **Jungha Kim ,**[c] **Koichiro Sugiyama ,**[c] **Karl Menten ,**[c] **Katharina Immer ,**[c] **Kazuyoshi Sunada ,**[c] **Kee-Tae Kim ,**[c] **Larisa Volvach ,**[c] **Luca Moscadelli ,**[c] **Lucas Jordan ,**[c] **Lucero Uscanga ,**[c] **Malcolm Gray ,**[c] **Marian Szymczak ,**[c] **Mateusz Olech ,**[c] **Melvin Hoare ,**[c] **Michał Durjasz ,**[c] **Mizuho Uchiyama ,**[c] **Nadya Shakhvorostova ,**[c] **Olga Bayandina ,**[c] **Pawel Wolak ,**[c] **Sergei Gulyaev ,**[c] **Sergey Khaibrakhmanov ,**[c] **Shari Breen ,**[c] **Sharmila Goedhart ,**[c] **Silvia Casu ,**[c] **Simon Ellingsen ,**[c] **Stan Kurtz ,**[c] **Stuart Weston ,**[c] **Tanabe Yoshihiro ,**[c] **Tim Natusch ,**[c] **Todd Hunter ,**[c] **Tomoya Hirota ,**[c] **Willem BAAN ,**[c] **Wouter Vlemmings ,**[c] **Xi Chen ,**[c] **Yan Gong ,**[c] **Yoshinori Yonekura ,**[c] **Zsófia Marianna Szabó** [c] **and Zulema Abraham** [c]

[a] *National Astronomical Observatory of Japan,*
2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[b] *Korea Astronomy and Space Science Institute,*
776 Daedeokdae-ro, Yuseong-gu, Daejeon 34055, Republic of Korea
[c] *Various institutes,*
see the website for a full list

E-mail: ross.burns@nao.ac.jp

The Maser Monitoring Organisation (M2O) is a research community of observers, astronomers and theoreticians pursuing a joint goal of reaching a deeper understanding of maser emission and exploring their variety of uses as tracers of astrophysical events. These proceedings detail the origin, motivations and current status of the M2O, as was presented at the 2021 EVN symposium.

**** European VLBI Network Mini-Symposium and Users' Meeting (EVN2021) ****
**** 12-14 July, 2021 ****
**** Online ****

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*Speaker

1. The Maser Monitoring Organisation

Maser emission has long been used as an observational tracer of activity in astrophysical contexts, from solar system bodies, stellar births, stellar deaths and the disks of distant supermassive black holes. Their extreme brightness temperatures make them readily detectable by observational instruments, their narrow spectral line-widths make them excellent tracers of dynamical processes, additionally, knowledge of the required conditions of local densities, temperatures and radiation environments in which they arise make them effective indicators of physical conditions. Unsurprisingly, maser observations have contributed to an eclectic mix of topics in astronomy.

Maser emission is very sensitive to its environment; a change in physical conditions and the presence/lack of shocks can selectively favor or unfavor the pumping/sink mechanism of different maser transitions, effectively switching them *on* or *off*, or causing temporal variations as the local environment approaches or deviates from what is required to produce maser activity. This selectivity of masers results in specific transitions often found being found to associate with, and thus trace, specific astrophysical environments and structures; the 6.7 GHz methanol maser typically associates with high-mass protostellar disks, and the 22 GHz water maser typically associates with shocks in proto-/stellar jets. Multi-epoch radio observations of multiple maser species and transitions can thus locate disks, shocks, outflows and other structures in deeply embedded systems that are otherwise inaccessible to observation, in addition to tracing their evolution.

Many radio observatories conduct long-term monitoring of masers either as a main internal programme, via open-use proposals, or in the available time between PI-driven science observations, all in efforts to track flux variations. In addition to discovering periodic masers this way, monitoring programs have identified flare events where fluxes suddenly rises several orders of magnitude above their usual values, often indicating the occurrence of an energetic astrophysical event. In a case of extremely fortunate timing, during the IAUS 336 symposium on astrophysical masers in September 2019 reports surfaced of two large maser flares in high-mass star forming regions G25.65+1.05 and W49N. News of these events quickly became popular focal points at coffee breaks and ultimately the timely gathering of maser experts and observers facilitated the organisation of immediate requests of directors' discretionary time for follow-up maser imaging observations with several VLBI arrays. Presenters at the symposium had also reported several past maser flares witnessed in their monitoring campaigns, but had not been followed up at the time - an opportunity thereby missed since such flares proved to be short-lived. In light of the need for prompt and organised follow-up responses to maser flares, and in the excitement of the G25.65+1.05 and W49N events, the Maser Monitoring Organisation (M2O) was established during an interlude between talks. Its initial goal was of providing a communications platform where monitoring stations could report new flare events that could then be confirmed by other radio observatories, and followed up using VLBI observations. Activities since then have rapidly expanded beyond this initial scope.

2. M2O: General operation

In practice, and at its core, the M2O is a communications platform which connects radio observatories with each other, with follow-up facility users, with maser theorists who contribute knowledge of maser production and behaviour, and with experts of various astrophysical systems,

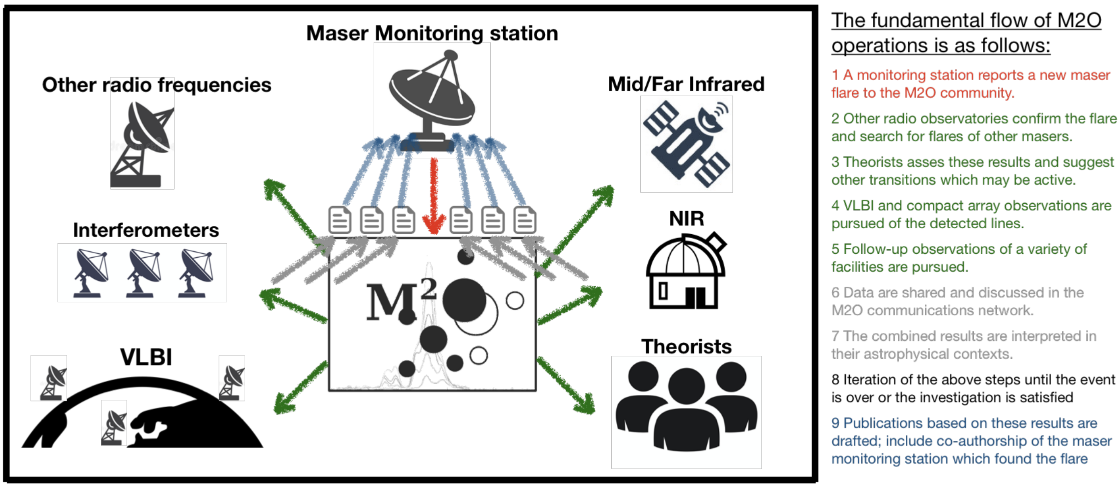


Figure 1: General flow of an M2O response to a new maser flare, coloured arrows match coloured text

such as star forming regions, who consider the available information in the context of its environment. Observational resources acquired for use in quick-response follow-ups are available and their use determined collectively by the community, in that if a maser flare event appears to be interesting then a proportional investment of resources is undertaken. This can range from zero to up to around 100 hours across many facilities as was the case for G358.93-0.03 (see below). Furthermore, the monitoring station that reports a maser flare event is given acknowledgment via their inclusion in all subsequent publications, as thanks, since without such reports there would be nothing to follow-up in the first place. Prompt communication of flare alerts and the sharing of information and observing resources seems to have been key to the recent success of the M2O.

3. The G358.93-0.03 maser flare

The G358.93-0.03 maser flare event and follow-up campaign became the first large-scale and focused flare pursuit of the M2O into which more than 20 follow-up observing requests were invested. G358.93-0.03 is a high-mass star forming region in the Galactic centre direction, which was first identified by its 6.7 GHz methanol maser emission. This maser had been monitored by the Hitachi 32-m radio telescope team operated by Ibaraki University, who reported maser flare activity to the M2O on the 18th of Jan 2019. Tracking the evolution of the 6.7 GHz methanol maser transition showed that the burst reached peak brightness some 70 days later [1] followed by a brightness reduction over $\sim$ 4 months, at which time the main flare phase appeared to have subsided.

Follow-up ALMA observations revealed a cluster of 7 millimeter cores, of which G358-MM1 was identified as the progenitor of the maser flare. It exhibited hot core chemistry and spatio-kinematics indicative of rotation [2] and spiral-like substructures [3]. During the flare state, high-resolution imaging of the 6.7 GHz methanol maser revealed a 'heat-wave' of accretion energy propagating outward from G358-MM1 at subluminal speeds [4]. Measurements of the pre-, mid- and post-burst phase infrared spectral energy distribution enabled by SOFIA observations concluded that G358-MM1 gained $M_{acc} = 5.3^{+11.1}_{-4.4} \times 10^{-4} M_{\odot}$ of mass during the accretion burst

[5], and independent agreement was obtained for estimates of the stellar mass ($\sim 9M_{\odot}$) and system inclination (22 degrees from face-on) in analyses of dynamics traced by spectral line data with the VLA [3] and ALMA [2], and in infrared radiative transfer modelling analyses [5]. At the time of writing 27 new maser transitions have been discovered in association with the accretion burst whose utility as possible new astrophysical tracers is now being explored [1–3, 6, 7] The M2O-led investigations into G358-MM1 produced to what is at present the most recently identified, and most intensely studied accretion burst event of a high-mass protostar. More results from G358-MM1 and other targets are in preparation.

4. Current Status of the M2O: Membership, Flares, Publications, Resources

The M2O currently has 80 members, spanning Europe, Asia, the Americas and Australasia, and includes individuals at all levels of academic progression from students, through postdocs and professors, to directors of research institutes. To date, 15 flares have been reported to the M2O, comprising events identified by seven flares of 6.7 GHz methanol masers and eight 22 GHz water masers. Follow-up campaigns were initiated for 12 of these flares, of which 6 targets have generated publications: W49N, G25.65+1.05, G358.93-0.03, G24.33+0.14, G359.617-0.251, IRAS16293-2422, with more on the way (see the website[1] for an up-to-date list of publications).

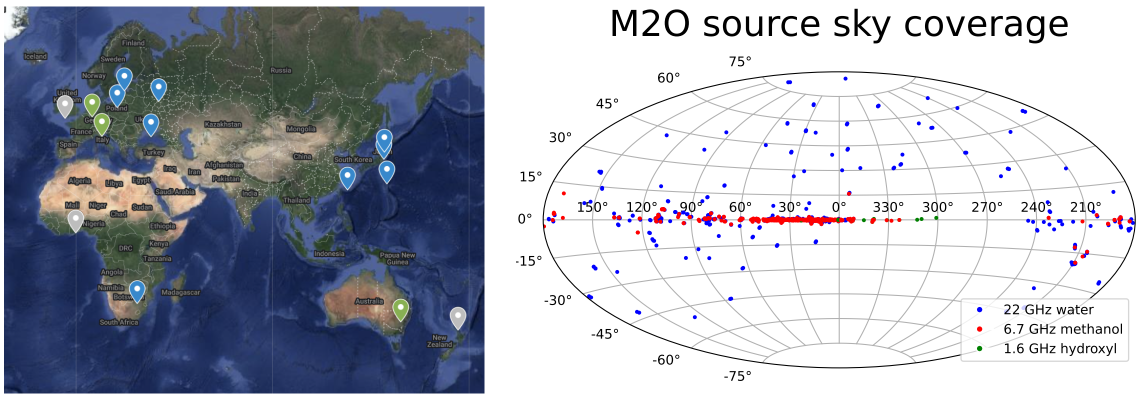


Figure 2: *Left:* Global distribution maser monitoring observatories with internal programmes (blue icons), those used as open-use (green icons), and those indicating interest in contributing in the future (grey icons). *Right:* Distribution of maser targets monitored by the cumulative of M2O participating stations.

The most vital resource of the M2O is the maser monitoring stations which search, identify and report new maser flare events by monitoring large numbers of maser targets at observing cadences typically between days and weeks. Most of the observatories' monitoring programs predate the M2O by years or even decades, as indeed the M2O is merely the collaboration of efforts amongst observatories and other maser enthusiasts. At present 9 observatories monitor as part of their internal programmes, 3 observatories are used for monitoring as part of open-use proposals, 3 more stations have shown interest in joining. These are shown in Figure 2, *left*. At present around 1000 maser targets are being monitored by the cumulative efforts of M2O monitoring stations.

[1]https://www.masermonitoring.org

Uniquenesses in hardware, latitudes and time available gives rise to an arbitrary sky coverage of targets where biases toward the Galactic plane and northern hemispheres can be seen in the 1.6 GHz hydroxyl and 6.7 GHz methanol, and the 22 GHz water masers, respectively (Figure 2, *right*).

Another important resource is access to follow-up facilities, especially those providing imaging. To facilitate rapid responses to new maser flare alerts the M2O maintains access to this resource through triggerable Target of Opportunity proposals on the VLA, SMA, ATCA, ALMA, EVN, LBA, VLBA, KaVA, EAVN, Subaru, SOFIA and the JWST. Additionally the M2O also collaborates with other large programs by sharing flare information, expertise (another key resource) and in certain conditions observational resources - with teams such as the JCMT Transients Program[2] and the KaVA Star Formation Large Program[3], driven by a shared goal of broadening the wavelength coverage of follow-up investigations into episodic astrophysical phenomena.

References

[1] G.C. MacLeod, K. Sugiyama, T.R. Hunter, J. Quick, W. Baan, S.L. Breen et al., *Detection of new methanol maser transitions associated with G358.93-0.03*, **489** (2019) 3981 [1910.00685].

[2] C.L. Brogan, T.R. Hunter, A.P.M. Towner, B.A. McGuire, G.C. MacLeod, M.A. Gurwell et al., *Sub-arcsecond (Sub)millimeter Imaging of the Massive Protocluster G358.93−0.03: Discovery of 14 New Methanol Maser Lines Associated with a Hot Core*, **881** (2019) L39 [1907.02470].

[3] X. Chen, A.M. Sobolev, Z.-Y. Ren, S. Parfenov, S.L. Breen, S.P. Ellingsen et al., *New maser species tracing spiral-arm accretion flows in a high-mass young stellar object*, *Nature Astronomy* (2020) .

[4] R.A. Burns, K. Sugiyama, T. Hirota, K.-T. Kim, A.M. Sobolev, B. Stecklum et al., *A heatwave of accretion energy traced by masers in the G358-MM1 high-mass protostar*, *Nature Astronomy* (2020) 10.

[5] B. Stecklum, V. Wolf, H. Linz, A. Caratti o Garatti, S. Schmidl, S. Klose et al., *Infrared observations of the flaring maser source G358.93-0.03. SOFIA confirms an accretion burst from a massive young stellar object*, **646** (2021) A161 [2101.01812].

[6] S.L. Breen, A.M. Sobolev, J.F. Kaczmarek, S.P. Ellingsen, T.P. McCarthy and M.A. Voronkov, *Discovery of Six New Class II Methanol Maser Transitions, Including the Unambiguous Detection of Three Torsionally Excited Lines toward G 358.9310.030*, **876** (2019) L25 [1904.06853].

[7] O.S. Bayandina, C.L. Brogan, R.A. Burns, X. Chen, T.R. Hunter, S.E. Kurtz et al., *A Multitransition Methanol Maser Study of the Accretion Burst Source G358.93-0.03-MM1*, **163** (2022) 83 [2201.12075].

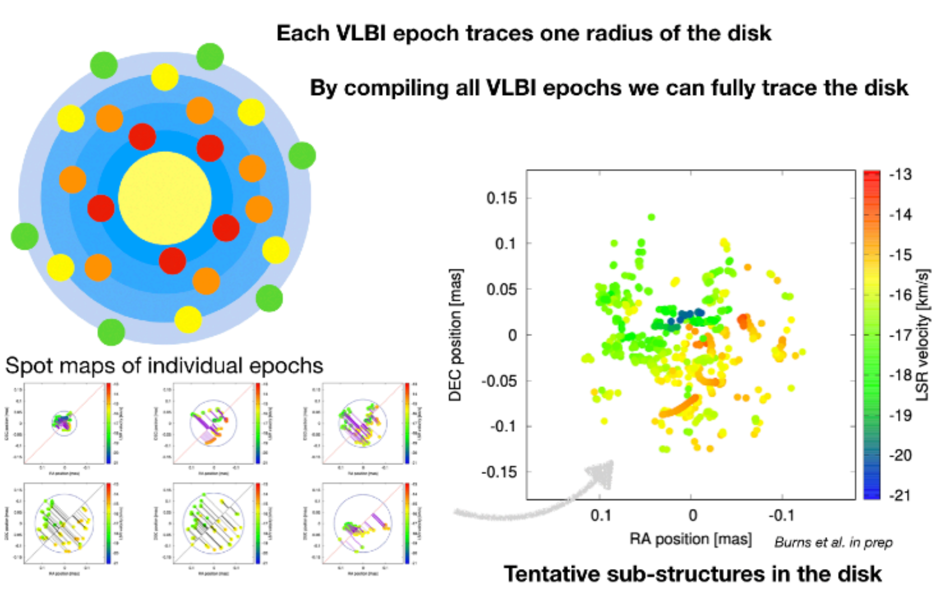
[2]https://www.eaobservatory.org/jcmt/science/large-programs/transient/

[3]https://radio.kasi.re.kr/kava/large_programs.php#sh3

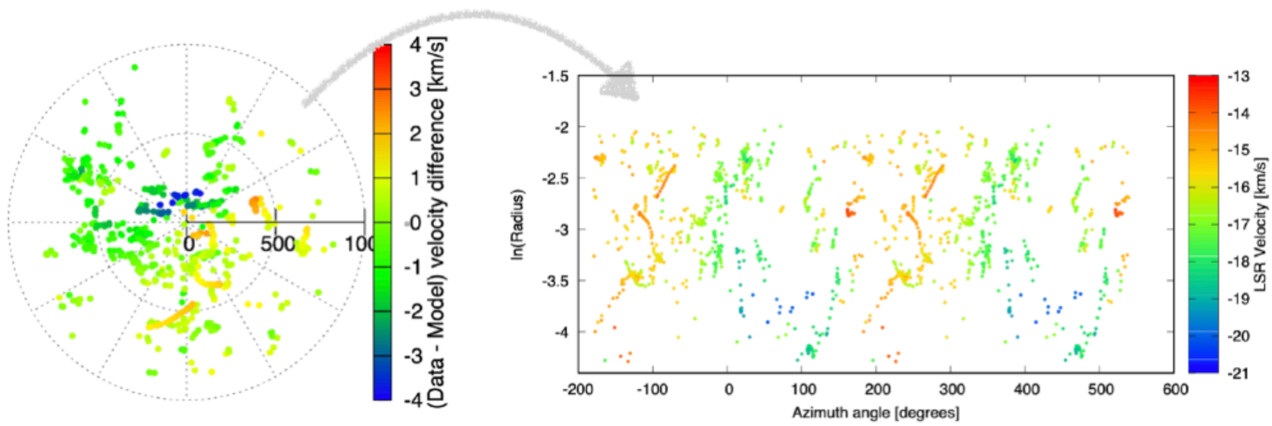
The 4-arm spiral system in G358-MM1

<u>Note that this is just an update. Im working on the Methods section of this paper right now</u>

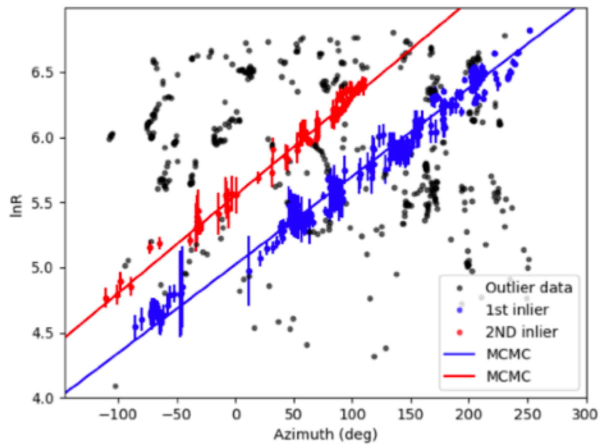
Technique: “Heat-wave mapping”
The heat-wave caused by accretion energy ignites a ring of 6.7 GHz methanol masers at the radius where the temperature (and other physical-) conditions are suitable for producing maser emission (~150 K and the right intensity of ~25 micron radiation). As the heat-wave moves through the disk it ignites masers at larger and larger radii producing concentric rings that get larger over time. By overlaying all the spot maps from the 6 VLBI epochs which were taken during the accretion burst you therefore get a discreetly sampled view of the entire disk out to ~900 AU, beyond which the masers switched off (probably because there was no more dust beyond this radius to produce the 25micron radiation needed for the maser [based on what ive seen from the ALMA data]).
Anyway, using the heat-wave to map the disk surface with maser VLBI is a great way to get the spatio-kinematics of the disk at milliarcsecond angular resolution and sub km/s spectral resolution thanks to it being masers with narrow emission spectra. Below is a visual explanation of this where the coloured points in the schematic represent maser spot maps at different epochs. The individual spot maps are shown on the bottom left of the image and the disk, viewed by heatwave mapping is shown on the right.



I thought that the extensions at about 2 o-clock, 6 o-clock and 10 o-clock looked like spiral arms. To fit this and get some real numbers I ‘unwound’ the disk in the azimuth direction and plotted the radial data in log space. Any logarithmic spiral arms would show as straight lines in such a plot. Below is said plot. I can see some straight lines which was encouraging:



Nobuyuki Sakai then helped me with fitting these lines. He tried using a RANSAC algorithm and also MonteCarlo Markov Chain. His conclusions were that two of the arms were real but could not confirm whether the other arms were real or not since its quite hard to do this kind of fitting. His results are summarised visually in the next figure:



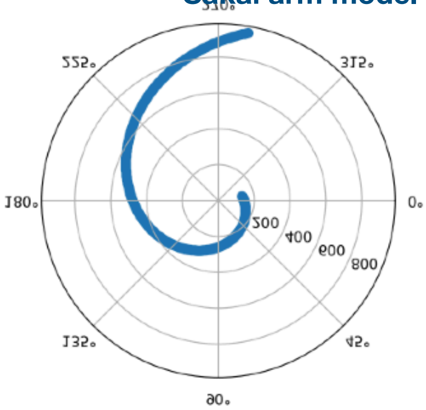
Arm #	Pitch angle (deg)	Rref, Az-ref (AU, deg)
1	21.2+/-0.2	(265.7+/-1.7, 82.9)
2	23.2+/-0.4	(256.2+/-3.0, -0.7)

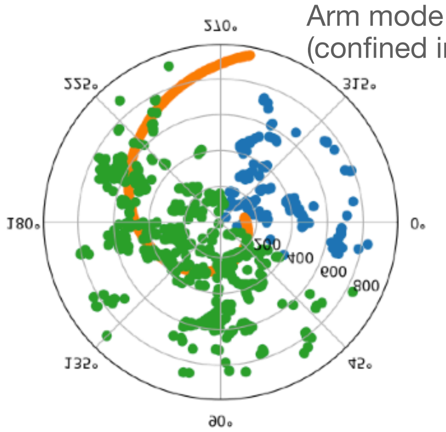
Another formula (y=ax+b)
Arm 1 : 0.00678336 x + 5.02047126

Arm2 : 0.00748049 x + 5.55104219

Initially I decided to give up on trying to fit the residuals, but then Jay Blanchard suggested trying a 2-d spatial correlation approach to fitting the data. Essentially we took the arm function determined by Sakai-san and cross correlated the shape with the data.

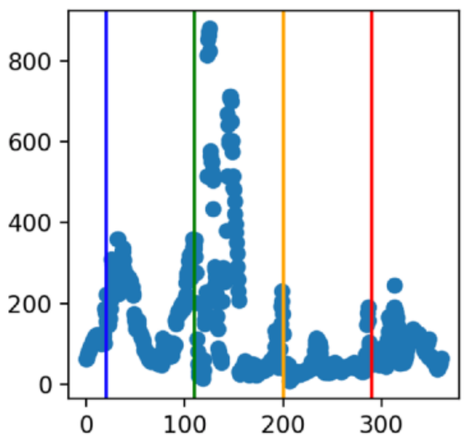
Sakai arm model





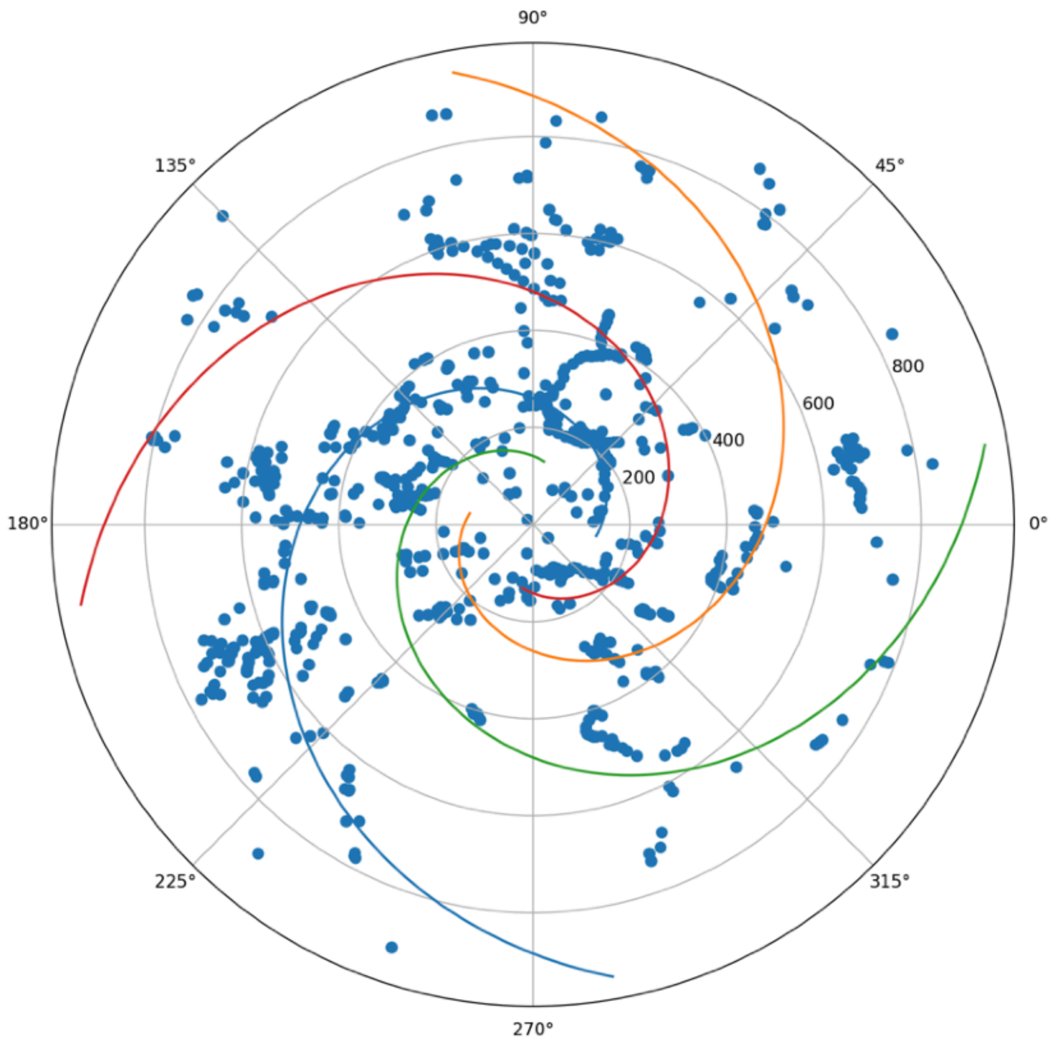
Arm mode vs data, data used for the fit (confined in Az around the arm) shown in green

This approach is not dissimilar to a Beysian fit since the arm model acts as a prior. This 2d spatial cross-correlation approach has the benefit of being able to confine the Azimuth range of the data used in the fit. The results are as follows:



There were higher correlations of the model and data at 4 points along the azimuth direction. The best thing about the result is that there is a 180 degree symmetry of the two main arms found by N. Sakai-san:
Symmetric pair 1: Blue and Orange
Symmetric pair 2: Green and Red.
In the plot (left) the x-axis is the azimuth range while the y-axis is the crosscorrelation coefficient. The vertical lines show the rough locations of correlation peaks (arms) which where symmetric pairs are colour matched on the plot on the next page.
(note, the narrow vertical streaks are from clumps in the data with a lot of spots which spike the correlation coefficient. They wash out with binning)

Below is what is seen when plotting the arms back on the data.
As mentioned, the write-up is still in progress, I just wanted to keep you informed. The write up will of course have more details and interpretations. As such, please keep this somewhat confidential until the draft is submitted. I'll circulate a draft hopefully sometime this month. The main reason for the delay has been that further insights into the data/results keep spurring on more work and analyses (such as these shown). However, I dont think there is anything else we can squeeze out of this data set so Im closing the analyses and focusing on the write-up.



Record keeping

M2O Publications

No.	Target	Facility	Author	Frequency (GHz)	Status	Ref	Journal
1	W49N	Sm, Tr	Volvach+	22.2	Published	(1)	MNRAS_L
2	W49N	Sm, Tr, Mc, Ef	Volvach+	22.2	Published	(2)	A&A
3	W49N	Sm, Tr, Mc, Ef, Kvazar	Volvach+	22.2	Published	(3)	Ast.Rep.
4	W49N	Sm	Volvach+	22.2	Published	(4)	MNRAS
5	G25	VLA	Bayandina+	6.7, 12.2, 22	Published	(5)	ApJ
6	G25	Sim/Hh/Tr	Volvach+	22	Published	(6)	MNRAS_L
7	G25	KVASAR	Volvach+	22	Published	(7)	Ast.Rep.
8	G25	EVN	Burns+	22	Published	(8)	MNRAS
9	G25		Aberfelds+	6.7	in prep		-
10	G25		Bayandina+	12.2, 23.1	in prep		-
11	G25		MacLeod+	6.7, 22	in prep		-
12	G358	ATCA	Breen+	mm	Published	(9)	ApJ
13	G358	ALMA-SMA	Brogan+	mm	Published	(10)	ApJL
14	G358	Hh	MacLeod+	New Methanol masers	Published	(11)	MNRAS
15	G358	LBA	Burns+	6.7	Published	(12)	Nat.Ast.
16	G358	Various VLBI	Burns+	6.7 movie	in prep		-
17	G358	Various VLBI	Burns+	Maps of rare masers	in prep		
18	G358	VLBA	Burns+	6.7 and 12.18	in prep		
19	G358	Asia-Pacific VLBI	Orosz+	7.6, 7.8	in prep.		ApJL
20	G358	VLA	Chen+	multiple lines methanol	Published	(13)	ApJL
21	G358	VLA	Chen+	New lines + Methanol	Published	(14)	Nat. Ast.
22	G358		MacLeod+	6.7 GHz monitoring	in prep		
23	G358		MacLeod+	6.2, 12.2, 20.3, 20.9	in prep		-
24	G358	VLA	Bayandina+	6.18,6.7,12.18,12.23,20.97,23.12	Published	(15)	AJ
25	G358	SOFIA	Stecklum+	FIR	Published	(16)	A&A
26	G358	Sm and Hh	Volvach+	19.9, 20.9	Published	(17)	MNRASL
27	G24.33	EVN, VLBA	Kobak+	6.7, 12.2, 22.2	in prep		-
28	G24.33	Tr	Olech+	OH, Meth	in prep		-
29	G24.33	Hh	v. d. Heever+		in prep		-
30	G24.33	ALMA	Hirota+	Thermal and maser	in prep		-
31	G24.33 + G359	ATCA	MacCarthy+	6.7. 22. Rare transitions	Published	(18)	MNRAS
32	IRAS16293-2422	Simeiz	Volvach+	Water maser flare	Published	(19)	MNRAS

[1] Volvach, L. N., Volvach, A. E., Larionov, M. G., MacLeod, G. C. & Wolak, P. Unusual flare activity in the extreme-velocity 81 kms1 water-maser feature in W49N. *Monthly Notices of the Royal Astronomical Society: Letters* **487**, L77–L80 (2019). URL https://doi.org/10.1093/mnrasl/slz088.

[2] Volvach, L. N. *et al.* Flaring water masers associated with W49N. A&A **628**, A89 (2019).

[3] Volvach, L. N. *et al.* An unusually powerful water-maser flare in the galactic source w49n. *Astronomy Reports* **63**, 652–665 (2019). URL https://doi.org/10.1134/S1063772919080067.

[4] Volvach, A. E., Volvach, L. N. & Larionov, M. G. Unusually powerful flare activity of the H_2O maser feature near a velocity of -60 km s^{-1} in W49N. MNRAS **496**, L147–L151 (2020).

[5] Bayandina, O. S., Burns, R. A., Kurtz, S. E., Shakhvorostova, N. N. & Val'tts, I. E. JVLA overview of the bursting H$_2$O maser source G25.65+1.05. *arXiv e-prints* arXiv:1812.11353 (2018).

[6] Volvach, L. N. *et al.* Powerful bursts of water masers towards G25.65+1.05. MNRAS **482**, L90–L92 (2019).

[7] Vol'vach, L. N. *et al.* A Giant Water Maser Flare in the Galactic Source IRAS 18316-0602. *Astronomy Reports* **63**, 49–65 (2019).

[8] Burns, R. A. *et al.* VLBI observations of the G25.65+1.05 water maser superburst. MNRAS **491**, 4069–4075 (2020).

[9] Breen, S. L. *et al.* Discovery of Six New Class II Methanol Maser Transitions, Including the Unambiguous Detection of Three Torsionally Excited Lines toward G 358.9310.030. ApJ **876**, L25 (2019).

[10] Brogan, C. L. *et al.* Sub-arcsecond (Sub)millimeter Imaging of the Massive Protocluster G358.93−0.03: Discovery of 14 New Methanol Maser Lines Associated with a Hot Core. ApJL **881**, L39 (2019).

[11] MacLeod, G. C. *et al.* Detection of new methanol maser transitions associated with G358.93-0.03. MNRAS **489**, 3981–3989 (2019).

[12] Burns, R. A. *et al.* A heatwave of accretion energy traced by masers in the G358-MM1 high-mass protostar. *Nature Astronomy* 10 (2020). URL https://ui.adsabs.harvard.edu/abs/2020NatAs.tmp...10B.

[13] Chen, X. *et al.* $^{13}CH_3OH$ Masers Associated With a Transient Phenomenon in a High-mass Young Stellar Object. ApJL **890**, L22 (2020). URL https://ui.adsabs.harvard.edu/abs/2020ApJ...890L..22C.

[14] Chen, X. *et al.* New maser species tracing spiral-arm accretion flows in a high-mass young stellar object. *Nature Astronomy* (2020). URL https://ui.adsabs.harvard.edu/abs/2020NatAs.tmp..144C.

[15] Bayandina, O. S. *et al.* A Multitransition Methanol Maser Study of the Accretion Burst Source G358.93-0.03-MM1. AJ **163**, 83 (2022).

[16] Stecklum, B. *et al.* Infrared observations of the flaring maser source G358.93-0.03. SOFIA confirms an accretion burst from a massive young stellar object. A&A **646**, A161 (2021).

[17] Volvach, A. E. *et al.* Monitoring a methanol maser flare associated with the massive star-forming region G358.93-0.03. MNRAS **494**, L59–L63 (2020).

[18] McCarthy, T. P. *et al.* Molecular line search towards the flaring 6.7-GHz methanol masers of G 24.33+0.13 and G 359.62-0.24: rare maser transitions detected. MNRAS **509**, 1681–1689 (2022).

[19] Volvach, A. E., Volvach, L. N. & Larionov, M. G. Composite powerful short flare of water maser emission in IRAS 16293-2422. MNRAS **507**, L52–L56 (2021).

M2O follow-up data

No.	Target	Facility	Date	Frequency (GHz)	Code	PI/comment
1	G25	VLA	Oct 2017	6.7, 12.2, 22	17B-408	OB / Reduced
2	G25+W49N	EVN	Oct 2017	22	RB004	RB / Reduced
3	G25+W49N	KaVA	Oct 2017	22	K17RB01A	RB / Reduced
4	G25+W49N	VLBA	Oct 2017	22	BO058	GO / Reduced
5	G25	VERA	2007-2013	22, 16 x epochs	[archival]	K. Motogi / On hold
6	G358	VERA	31 Jan 2019	6.7	-	SY / Reduced
7	G358	VERA	3 Mar 2019	6.7	-	SY / Reduced
8	G358	VERA	1 Apr 2019	6.7	-	SY / Reduced
9	G358	VERA	3 May 2019	6.7	-	SY / Reduced
10	G358	LBA	2 Feb 2019	6.7	vc026a	RB / Published
11	G358	LBA	3 Feb 2019	23.1	vc026b	GO / Abandoned
12	G358	LBA	28 Feb 2019	6.7	vc026c	RB / Published
13	G358	EVN	13 Mar 2019	6.7, <u>6.18</u>	RB005	RB / Reduced
14	G358	KVN	25 Mar 2019	22, 44, 95, 120	n19rb01a	RB / Reduced
15	G358	VLBA	19 May 2019	6.7, 12.2, 23.1	BB414	RB / Reduced
16	G358	VLBA	7 Jun 2019	6.7, 12.2, 20.7	BB412	RB / Reduced
17	G358	LBA+E.Asia	17 May 2019	7.6, 7.8	vx028a	GO,SE / Reduced
18	G358	LBA+AusSCOPE	28 Sep 2019	6.7	v581a	RB / Reduced
19	G358	LBA+AusSCOPE	18 Aug 2020	6.7	v581b	RB / Reduced
20	G358	SOFIA	30 April 2019	50...120 μm		BS,JE / Published
21	G358	GROND	8 Feb 2019	NIR		HL,BS,AC / Published
22	G358	SMA	several 2019	mm		THunter,CB / Published
23	G358	ALMA	several 2019	Bands 5,6,7		CB / Published
24	G358	VLA	25FEB19	X/S/C/U/K	19A-448	OB / Published
25	G358	VLA	04JUN19	X/S/C/U/K	19A-476	OB / Published
26	G358	VLA	2019	HNCO	-	XC,AS
27	G24	LBA	8 Sep 2019	6.7	vx026d	RB,MO / Correlated
28	G24	LBA	13 Sep 2019	6.7	s002a	RB,MO / Correlated
29	G24	LBA	28 Sep 2019	6.7	v581a	RB,MO / Correlated
30	G24	EVN	22 Sep 2019	22	RB006A	RB,MO / QuickLook
31	G24	EVN+Merlin	7 Oct 2019	6.7	RB006B	RB,MO / QuickLook
32	G24	EVN+Merlin	17 Nov 2019	1.667	RB007	RB,MO / correlated
33	G24	VLBA	27 Sep 2019	6.7, 12.2, 22	BB416A	RB,MO / QuickLook
34	G24	VLBA	27 Oct 2019	6.7, 12.2, 22	BB416B	RB,MO / correlated
35	G24	VLBA	02 Dec 2019	6.7, 12.2, 22	BB416C	RB,MO / correlated
36	G24	ALMA	26 Sep 2019	Band6	-	THirota / Reduced
37	G24	SOFIA	25 Oct 2019	FIR		BS,JE
38	G24	ATCA	26 Nov 2019	K-band	C3321	GO,SB
39	G24	ATCA	27 Nov 2019	C-band	C3321	GO,SB
40	NGC2071, Ori-S6	KaVA	13 Mar 2020	22/44/95/130	a20d3a	RB / QuickLook
41	NGC2071, Ori-S6	KaVA	16 Apr 2020	22/44/95/130	a20d3b	RB / QuickLook
42	NGC2071, Ori-S6	KaVA	11 May 2020	22/44/95/130	a20d3c	RB / Quick Look
43	G85.411+0.002	VLBA	24/Apr/2020	L/C/Ku/K	BB421B	RB / QuickLook
44	G85.411+0.002	VLBA	22/May/2020	L/C/Ku/K	BB421A	RB / QuickLook
45	G85.411+0.002	VLBA	22/June/2020	L/C/Ku/K	BB421C	RB / Quick Look
46	G359.617-0.251	LBA	18/Aug/2020	6.7	V581B	RB / Quick Look
47	G359.617-0.251	VLBA	21/Aug/2020	6.7 / 12.2 / 22	BB418A	RB / Quick Look
48	G359.617-0.251	ATCA	25-26/July/2020	6-10 GHz	C3321	GO / Submitted
49	G034.196-0.592	VLA	19/NOV/2020	C	VLA/20B-441	DL / Calibrated
50	G034.196-0.592	VLA	29/NOV/2020	K	VLA/20B-441	DL / Calibrated
51	G034.196-0.592	KaVA	12/DEC/2020	K(QWD)	a20d4a	RB / Quick Look
52	G034.196-0.592	KaVA	23/JAN/2021	K(QWD)	a21d1a	RB / Quick Look
53	G034.196-0.592	KaVA	18/FEB/2021	K(QWD)	a21d1b	RB / Quick Look
54	G35.200.74	KaVA	23/JAN/2021	K(QWD)	a21d1a	RB / Quick Look
55	G35.200.74	KaVA	18/FEB/2021	K(QWD)	a21d1b	RB / Quick Look
56	S255 and G188	EVN	3/NOV/2021	C	EB087	RB / Correlated
57	G024.541+0.312	VLBA	16/NOV/2021	C/Ku/K	BB428A	RB / Correlated
58	G024.541+0.312	VLBA	30/DEC/2021	C/Ku/K	BB428B	RB / Correlated
59	G024.541+0.312	VLBA	25/JAN/2022	C/Ku/K	BB428C	RB / Correlated
60	G081.174-0.100	EAVN	9/DEC/2021	K	a21d2a	RB / observed
61	G081.174-0.100	VLA	19/DEC/2021	X/S/C/K/U	21B-082	OB / reduced
62	G081.174-0.100	VLA	03/JAN/2022	X/S/C/K/U	21B-082	OB / reduced

Reminders:

Please consult the original reporters of flare events on how they request their input to be acknowledged in follow-up proposals and publications.

All G25.65+0.15 papers : include a member from the Volvach et al. group in the author list and an acknowledgement of their funding.
All W49N papers : include a member from the Kramer et al. group in the author list and an acknowledgement of their funding.
All NGC2071 papers : include a member from the VERA / Sunada team in the author list and an acknowledgement of their funding.
All G358.93-0.03 papers : include a member from the Ibaraki team in the author list and an acknowledgement of their funding.
All G53.22-0.08 papers : include a member from the VERA / Sunada team in the author list and an acknowledgement of their funding.
All G24.33 papers : include a member from the Torun team in the author list and an acknowledgement of their funding.
All Orion-S6 papers : include a member from the Ibaraki team in the author list and an acknowledgement of their funding.
All G85.411+0.0002 papers : include a member from the Ibaraki team in the author list and an acknowledgement of their funding.
All G33.641-0.228 papers : not follow-up'd yet. Best consult SamePage > Workspace > G33.641-0.228 if you're planning to work on this source
All G359.617-0.251 papers : include a member from the Ibaraki team in the author list and an acknowledgement of their funding.
All G034.196-0.592 papers : include a member from the Ladeyschikov et al. group in the author list and an acknowledgement of their funding.
All G35.200.74 papers : include a member from the Volvach et al. group in the author list and an acknowledgement of their funding.
All G024.541+0.312 papers : include a member from the Torun team in the author list and an acknowledgement of their funding.
All G081.174-0.100 papers : include a member from the Ladeyschikov et al. team in the author list and an acknowledgement of their funding.