Recent Status of the Maser Monitoring Organisation (M2O)

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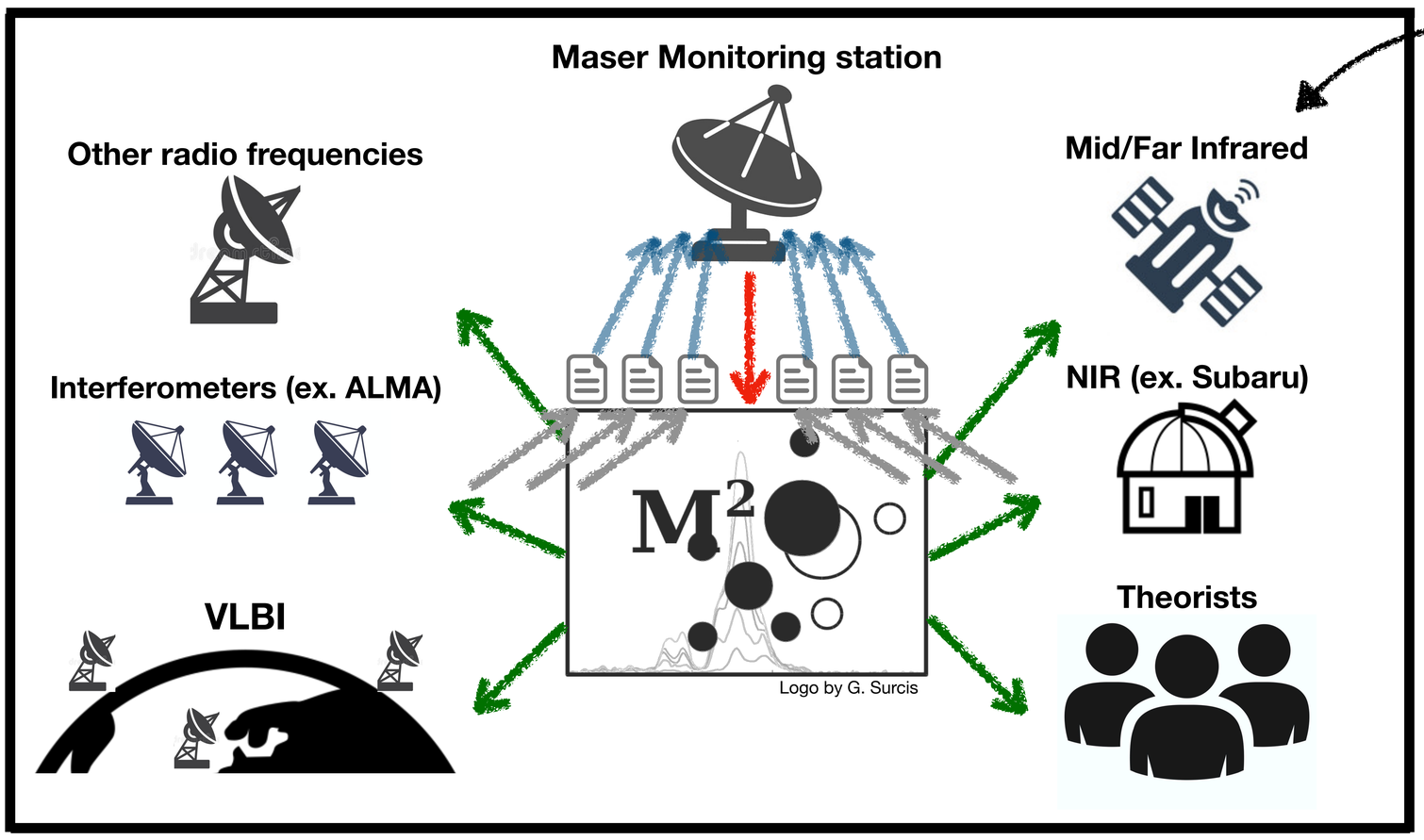
On behalf of the M2O (see website via QR code)

73 members
See website for full list

MaserMonitoring.org

Mission of the M2O

Maser emission is very sensitive to its environment; a change in physical conditions can selectively favor or unfavor the pumping/sink mechanism of different maser transitions. Due to this property, the appearance and temporal changes in maser emission can be used as indicators of the physical conditions in various astrophysical systems and can trace changes in those systems in an observationally accessible way - since maser emission can be readily monitored by standard radio telescopes even with short (~15min) integration time per source. Recognising this, several radio observatories monitor masers in the available time between PI-driven science observations.
These monitoring programs have occasionally identified flare events, where maser emission suddenly rises several orders of magnitude above their usual measured values, indicating the occurrence of energetic astrophysical events.
The Maser Monitoring Organisation (M2O) was established in late 2019 in order to follow up such events and investigate these events and identify their underlying phenomena - in addition to providing new insights into maser emission itself.



How the M2O operates

The M2O is primarily a communications network which connects radio observatories with eachother, with other follow-up facility users, with maser theorists who bring their understanding of the observed maser behaviour, and with experts of various astronomical systems such as star formation who consider the combined observational data in the context of their environments.

The fundamental flow of M2O operations is as follows:
1 A monitoring station reports a new maser flare to the M2O community.
2 Other radio observatories confirm the flare and search for flares of other masers.
3 Theorists asses these results and suggest other transitions which may be active.
4 VLBI and compact array observations are pursued of the detected lines.
5 Follow-up observations of a variety of facilities are pursued.
6 Data are shared and discussed in the M2O communications network.
7 The combined results are interpreted in their astrophysical contexts.
8 Iteration of the above steps until the event is over or the investigation is satisfied
9 Publications based on these results are drafted *

* One fundamental requirement is that all proposals and publications following from a reported flare event must credit the radio observatory who detected the initial event, and any subsequent contributors to the investigation. This is done by including the relevant individuals in all subsequent publications.

Current list of publications (+hyperlinks)

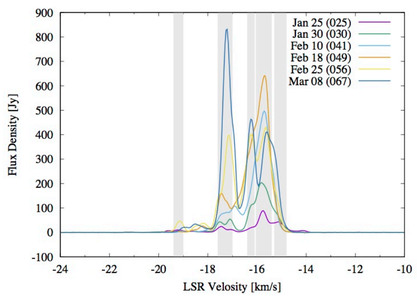
[3] Stecklum, B. et al. Stecklum, B. et al., 2021, A&A, in press
Infrared observations of the flaring maser source G358.93-0.03 – SOFIA confirms an accretion burst from a massive young stellar object.
Chen, X. et al., 2020, Nature Astronomy, 13 July
New maser species tracing spiral-arm accretion flows in a high-mass young stellar object
Volvach, A. E., et al., 2020, MNRAS, 496, L147–L151
Unusually powerful flare activity of the H2O maser feature near avelocity of -60 km s–1in W49N.
Volvach, A. E., et al., 2020, .MNRAS494, L59–L63
Monitoring a methanol maser flare associated with the massive star-forming region G358.93-0.03
Chen, X. et al., 2020, ApJL, 890
13CH3OH Masers Associated With a Transient Phenomenon in a High-mass Young Stellar Object.
[2] Burns R. A. et al. 2020, Nature Astronomy, 10B
A heatwave of accretion energy traced by masers in the G358-MM1 high-mass protostar
Burns R. A. et al. 2020, MNRAS, 491, 4069B
VLBI observations of the G25.65+1.05 water maser superburst
MacLeod G. C. et al., 2019, 489, 3981
Detection of new methanol maser transitions associated with G358.93-0.03
Bayandina O. S., et al. 2019, ApJ, 884, 140B
VLA Overview of the Bursting H2O Maser Source G25.65+1.05
Volvach L. N. et al., 2019, Astronomy Reports, 63, 652V
An Unusually Powerful Water-Maser Flare in the Galactic Source W49N
[1] Brogan C. L. et al., 2019, ApJL, 881, L39
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
Volvach L. N. et al., 2019, A&A, 628, 89
Flaring water masers associated with W49N
Volvach L. N. et al., 2019, MNRAS, 487, L77
Unusual flare activity in the extreme-velocity -81 km s-1 water-maser feature in W49N
Breen S. L. et al., 2019, ApJL, 876, L25
Discovery of Six New Class II Methanol Maser Transitions, Including the Unambiguous Detection of Three Torsionally Excited Lines toward G 358.931-0.030
Volvach L. N. et al., 2019, MNRAS, 482, L90
Powerful bursts of water masers towards G25.65+1.05
Volvach L. N. et al., 2019 Astronomy Reports, 63, 49
A Giant Water Maser Flare in the Galactic Source IRAS 18316-0602

The case of G358

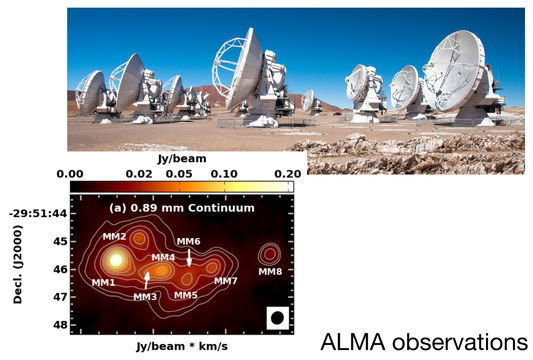
G358.93-0.03 is a high-mass star forming region in the Galactic centre direction, which was first identified by its 6.7 GHz methanol maser emission in the maser multibeam (MMB) survey in 2006.

This maser has long been monitored by the Hitachi 32 meter radio telescope operated by Ibaraki University.

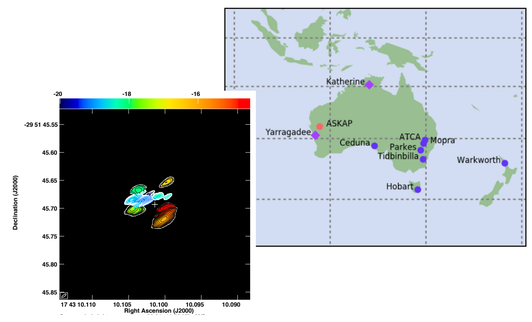
In January 2019 the Ibaraki team (courtesy of Y. Yonekura and K. Sugiyama, see ATEL #12446) reported maser flare activity to the M2O, which initiated an intense series of follow-up observations of this region.



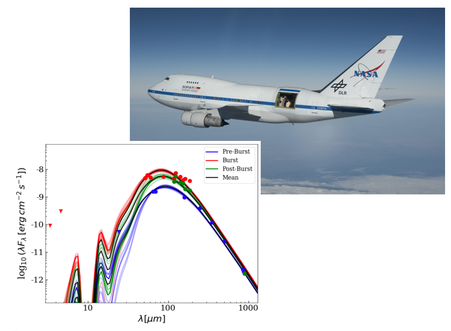
The spectra above (Y. Yonekura) show the temporal evolution of the 6.7 GHz maser emission, which is pumped by radiation from warm dust, and therefore indicates a sudden increase in the intensity of the infrared radiation field in this high-mass star forming region.



ALMA observations revealed the maser to be associated with a millimetre core, MM1, one member of a protocluster - in addition to discovering 14 new maser transitions which had not been seen before. The observations also characterised the hot core environment and revealed a rotating structure [1].



VLBI observations with the Australian Long Baseline Array (LBA) revealed a ring-like structure of 6.7 GHz methanol masers around the position of the MM1 core [2]. Results of the full VLBI observational campaign (6 epochs) at 6.7 GHz will be presented in a talk on March 4th, 9:22 UTC.



SED analyses by the airborne FIR observatory, SOFIA, confirmed that maser activity exhibited by G358-MM1 was due to a sudden accretion burst [3]. This now the third known observationally studied case of an accretion burst in a high-mass protostar and is providing valuable insights into the mechanism by which such stars form.

Observational resources

Main monitoring observatories:

Ibaraki
Monitoring almost all 6.7 GHz methanol masers above -30 Dec (~500 sources)

Parkes
monitoring 15 OH and CH masers

Hart
monitoring ~30 sources at 1.6, 6.7, 12.2 and 22 GHz (OH, CH3OH, CH3OH, H2O)

Torun
Monitoring ~140 sources at 6.7 GHz

Irbene
Monitoring ~40 sources at 6.7 GHz

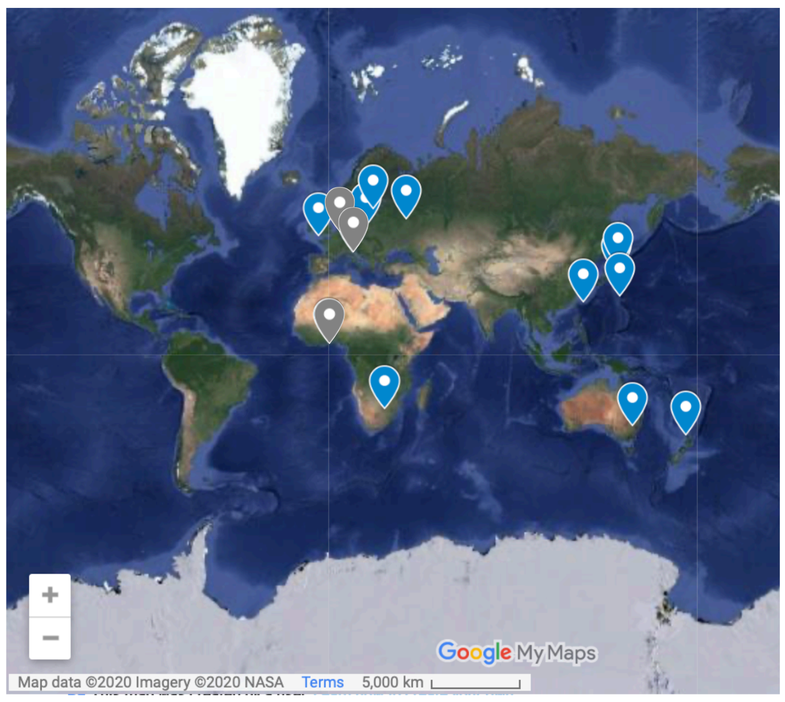
Simeiz
Monitoring ~90 sources at 22 GHz

Puschino
Monitoring ~200 sources at 22 GHz

Additional stations also occasionally provide alerts and follow-up observations of new maser flares

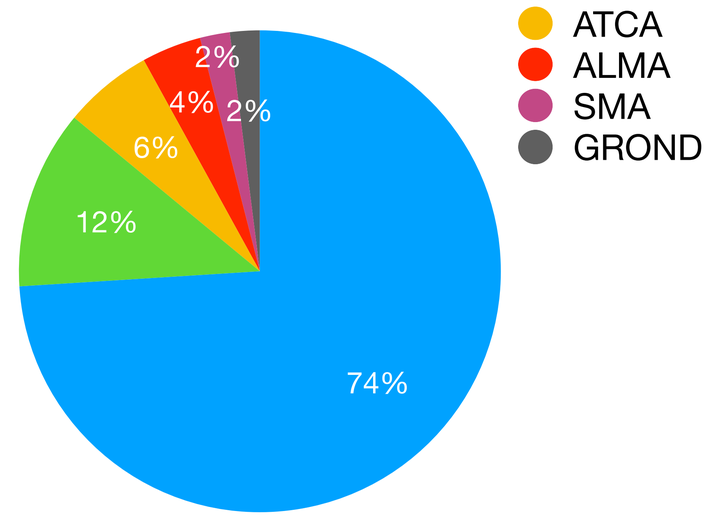
Currently, ~800 unique masers monitored by M2O member observatories together

Map of monitoring stations



Follow-up imaging

11 Maser flares reported since Sep 2019
52 follow-up observations including:



Flare alerts are also followed up by most single-dish observatories covering a variety of frequency bands and providing temporal sampling

Current proposals

In order to reduce the number of requests for Director's Discretionary Time (DDTs) following the detection of new flare events, we have moved focus to triggerable Target of Opportunity (ToO) proposals.
Currently we have been granted ToO triggers on the following facilities

EVN	KaVA	LBA
VLBA	EAVN	Subaru

Observations from multiple arrays are combined to achieve better temporal coverage than is realistic to request to a single VLBI array.

Furthermore, new proposals to more ground-based and space-based facilities are currently in evaluation.

Developing facilities / services

We have recently invested efforts into the development of new observational facilities, including single-baseline interferometers for monitoring both the masers, and the brightness temperatures of continuum sources associated with maser emission.

We also provide cross-checking of measured fluxes between stations for their calibration purposes.

Considering the combined list of all maser targets monitored by the M2O it is also possible to suggest new maser source lists to radio observatories who wish to contribute to the global effort of maser monitoring.

VLBI data reduction and training

In view of the large volume of follow-up data acquired, especially for VLBI investigations, we emphasise data access to all M2O members for any VLBI data which has not already been reserved by another member/team. Data reduction help is also available in one-to-one sessions over zoom to increase the output rate of results and publications.

Future plans

The major plans for the M2O in 2021 will be:
- Accelerate publications to match that of data acquisition.
- Expand the number of maser monitoring stations and optimise coordination.
- Expand the reach of follow-ups via ToO proposals and project collaborations.
- Host an M2O conference.