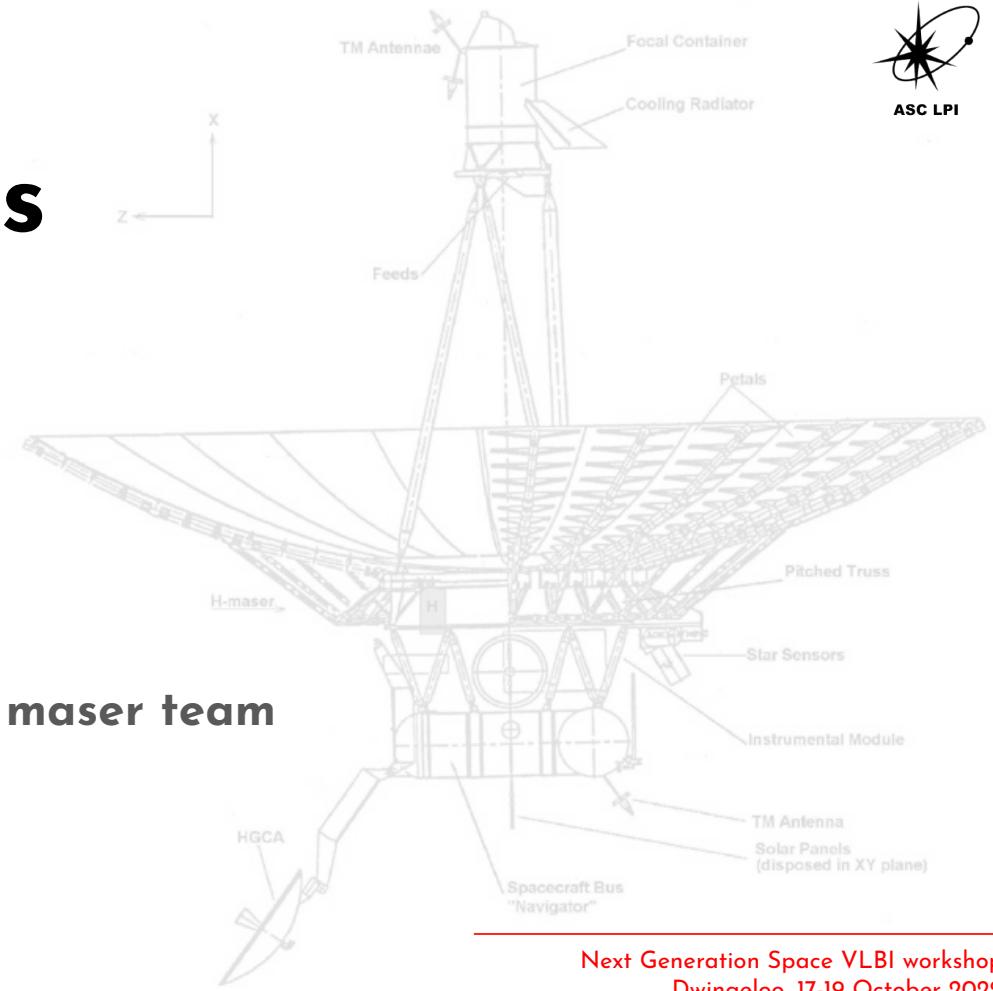
Cosmic masers as seen by RadioAstron

Olga Bayandina
on behalf of the RadioAstron maser team



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INAF
ISTITUTO NAZIONALE DI ASTROFISICA
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JIVE
Joint Institute for VLBI ERIC

Next Generation Space VLBI workshop
Dwingeloo, 17-19 October 2022

RadioAstron maser team

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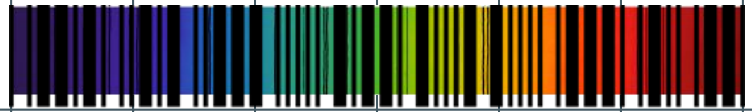
~1M$_\odot$



12345678

>8M$_\odot$

6.7 GHz methanol*

22 GHz water

44 GHz methanol

+ **Masers are compact:**
  features of a few AU
  structures of X00-X000 AU

+ **High flux densities:**
  up to tens kJy

+ **22 GHz H_2O masers:**
  ejection/young objects
  1665/1667 GHz OH masers:
  envelopes/evolved objects

Pros & Cons

- No phase referencing

- Limited accumulation time

- Limited sensitivity
  up to ~15 Jy for H_2O and ~4 Jy for OH

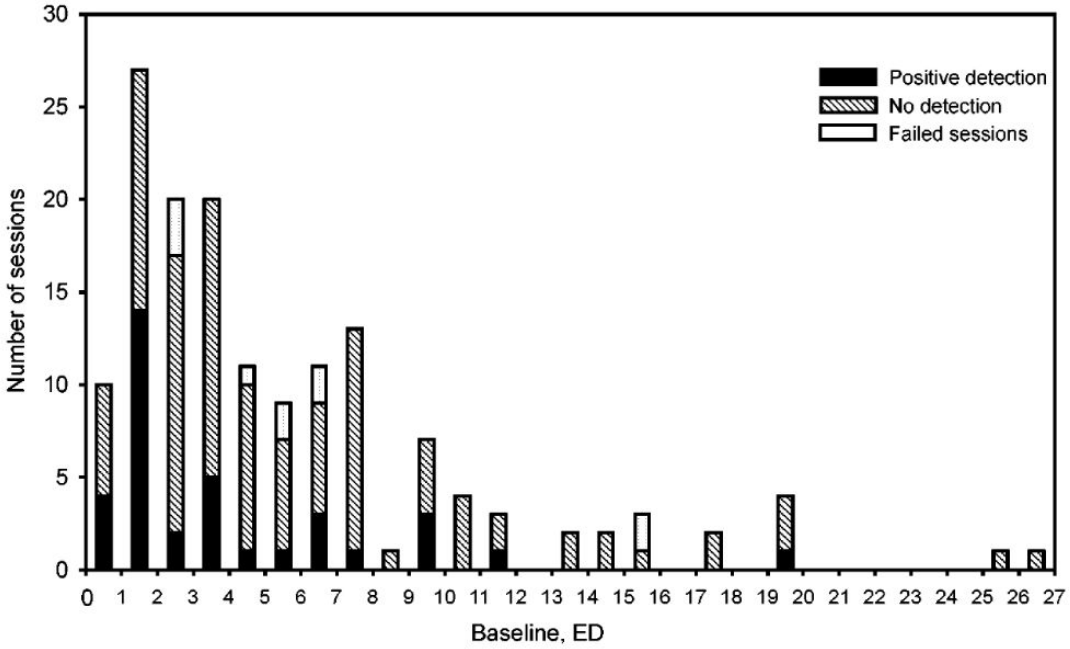
Statistics

In total **~200** maser observation sessions

~26% detection rate

Detected:
~12 SFR
~2 Extragalactic

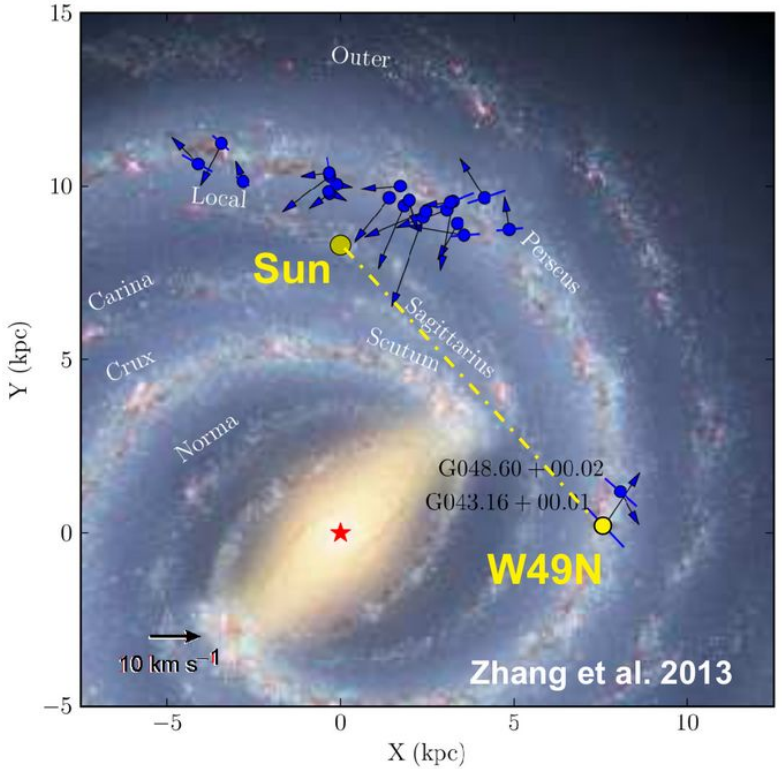
No detection:
Stellar masers



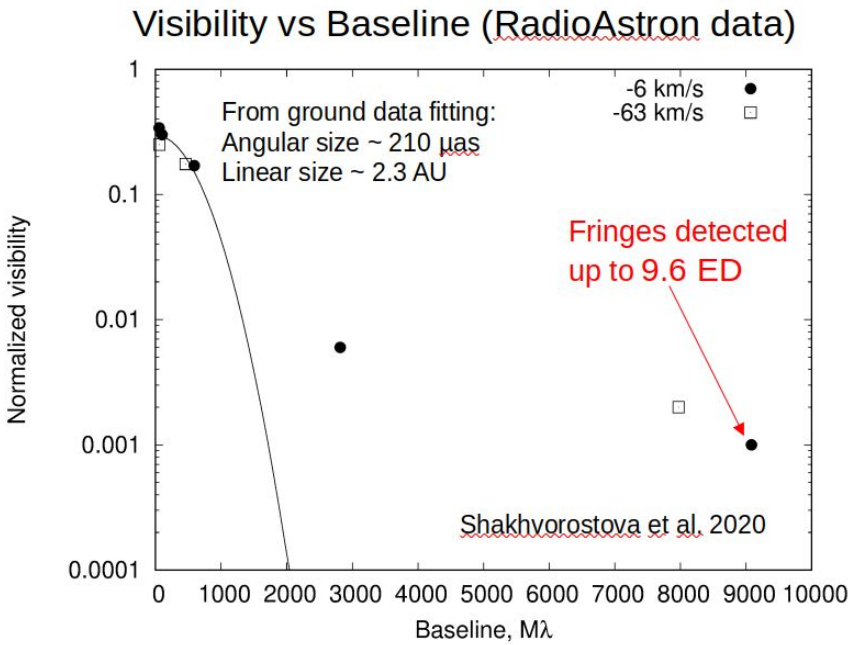
Sobolev+2017

W49N

- High brightness and complex structure
- The most luminous H_2O maser in the Galaxy (L ~1 $L_\odot$)
- Located in the Perseus arm (11.1 ± 0.8 kpc, 3 pc above the galactic plane)
- Interstellar diffractive scattering affects the maser propagation



W49N

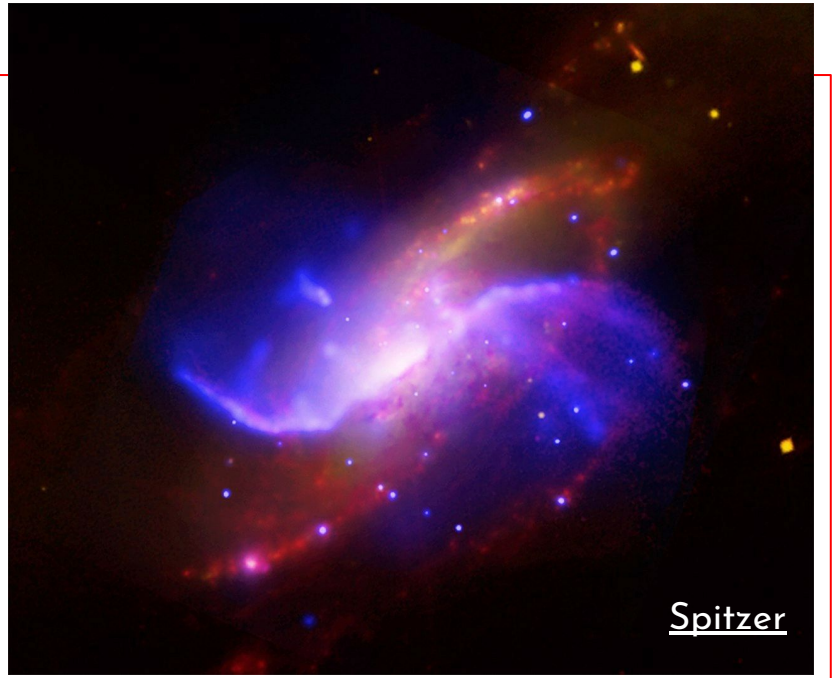


- ✓ Detection on the space-ground baselines of up to **9.6 ED**
- ✓ The correlated flux densities: **0.1-0.6%** of the total flux
- ✓ The low correlated flux is probably due to **turbulence** in the maser and/or in the interstellar medium

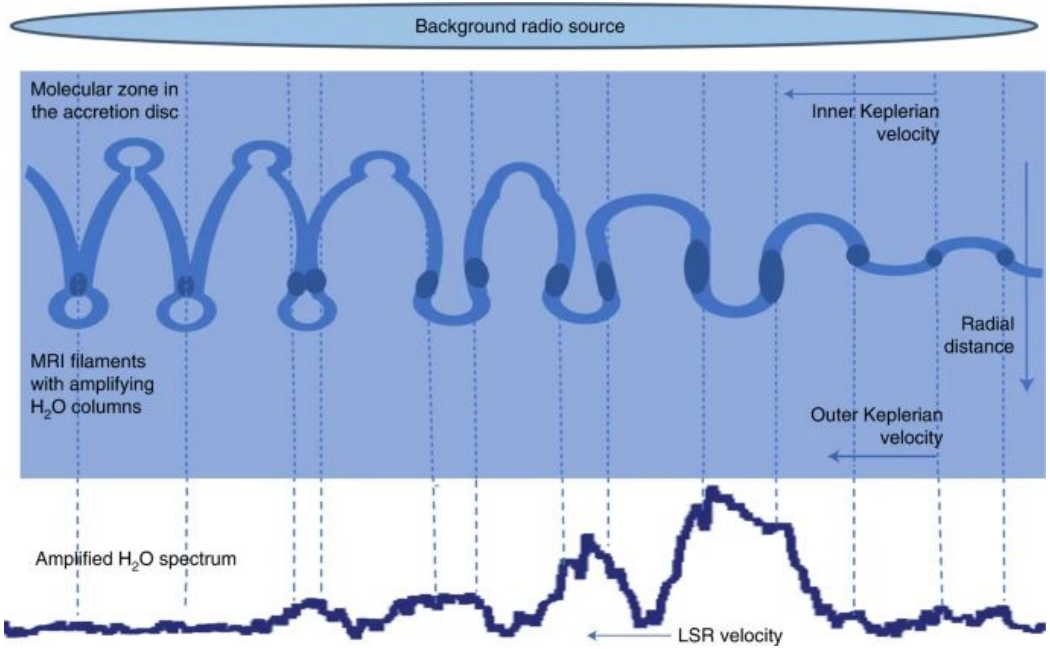
Shakhvorostova+2020

NGC 4258 (Messier 106)

- Extragalactic H_2O MegaMaser
- Nearby galaxy - the distance 7.6 Mpc
- H_2O emission originates from a fast rotating disc surrounding an active galactic nucleus (AGN)



NGC 4258

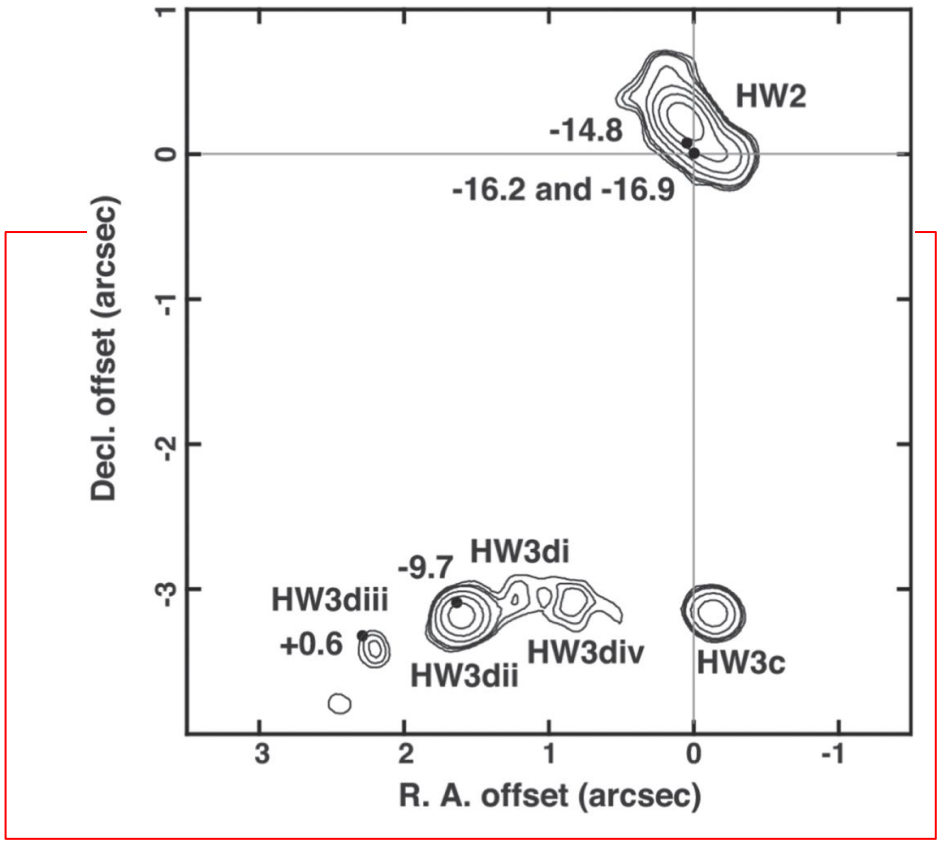


- ✓ Detections with Earth–space baselines of **1.3**, **9.5** and **19.5** ED
- ✓ Angular resolutions **11-23** μas
- ✓ **Distinct and regularly spaced regions** within the rotating disc are found at an orbital radius ~0.126 pc
- ✓ The emission regions are produced by a **periodic magneto-rotational instability** in the disc

Baan+2022 (Nat Ast)

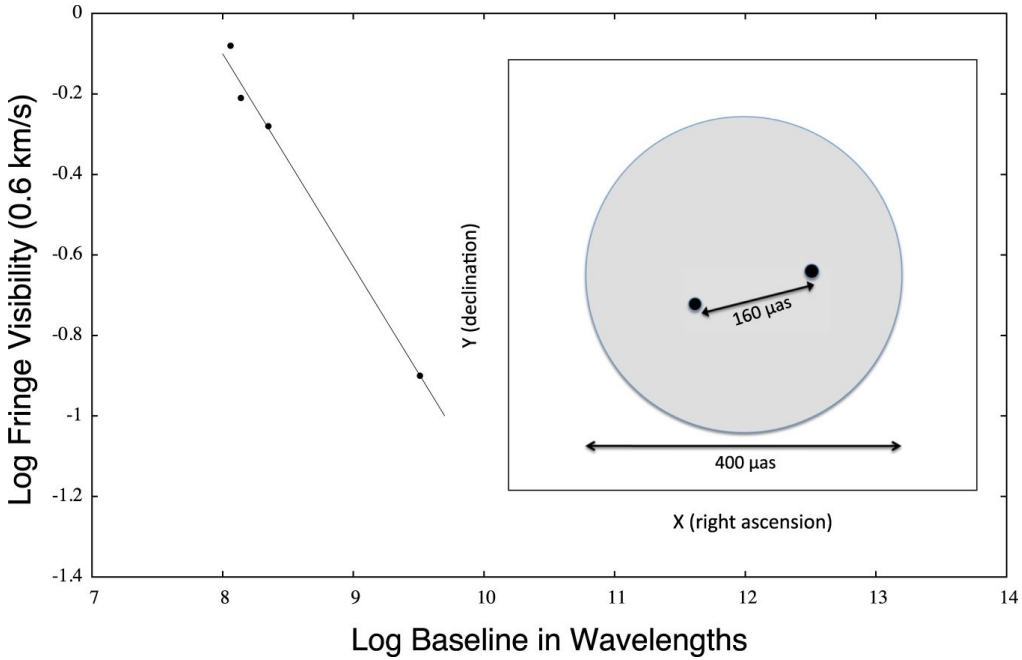
Cepheus A

- MSFR: ~16 cores at ~700 pc
- Multiple H_2O masers associated with disk/outflows/jets



Sobolev+2018

Cepheus A

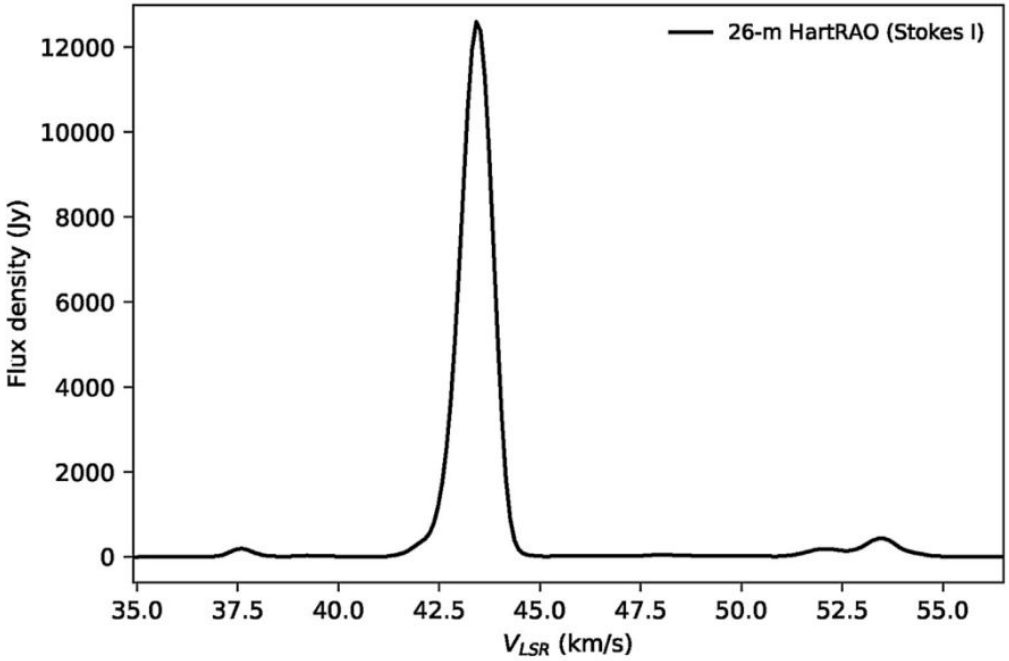


- ✓ Resolution of **66 μas** on a baseline of **3.3 ED**
- ✓ Two **Sun-sized (15 μas)** components separated by 160 μas are detected
- ✓ **Models:**
  (1) Keplerian motion around a central object,
  (2) two overlapping clouds,
  (3) vortices caused by flow around an obstacle

Sobolev+2018

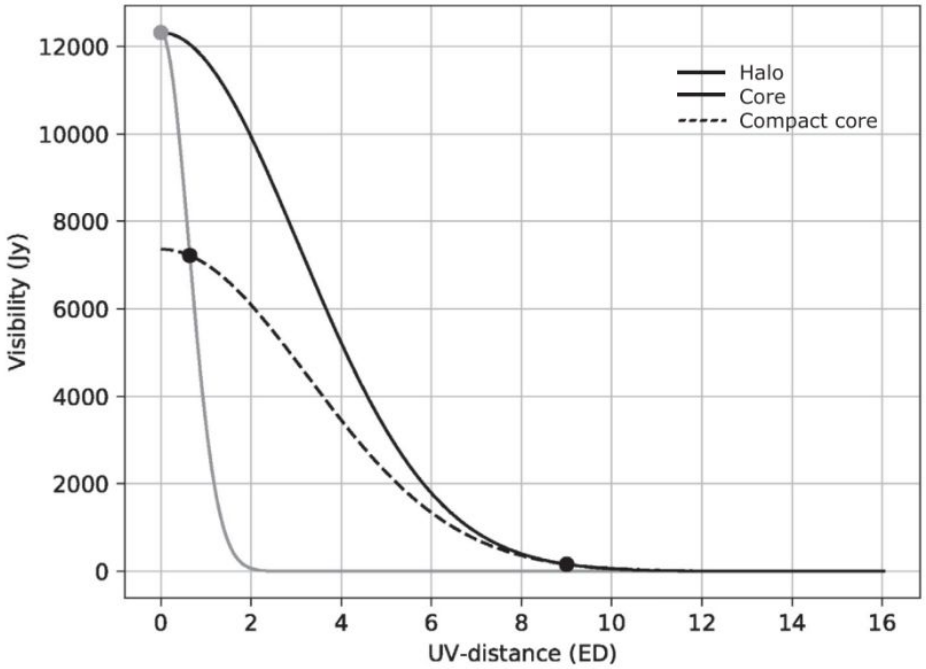
G25.65+1.05

- One of only 3 Galactic water masers known to flare to **10^5-10^6 Jy (T_B ~ 10^{17} K)**
- Flares:
  2002 - 3 kJy,
  2010 - 19 kJy,
  2016 - 46 kJy,
  2017 - **76 kJy**



Bayandina+2020

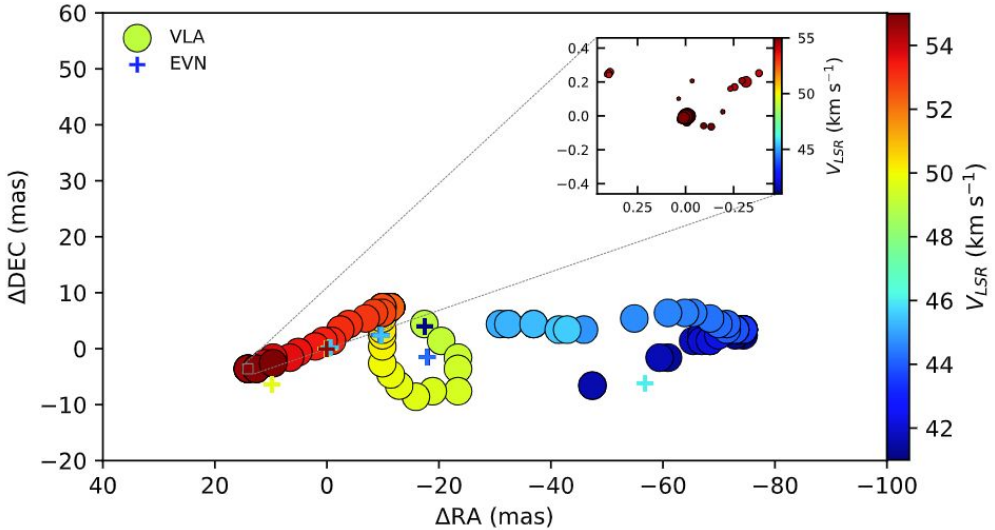
G25.65+1.05



- ✓ Active phase of the source's activity
- ✓ Baselines of ~9 ED
  (only 2 ground telescopes)
- ✓ Only **1%** of the flare flux:
  a very compact structure - **25 μas**
  (**0.05 AU or 5 $D_{\odot}$** at 2.08 kpc),
  brightness temperature of **3 x 10^{16} K**

Bayandina+2020

G25.65+1.05



- ✓ Stable state
- ✓ Baselines of **~2.7 ED** (VLBA)
- ✓ **The flare feature is not detected**
- ✓ Red-shifted spectral feature is detected with the flux of ~30 Jy

Bayandina+ in prep

G25.65+1.05

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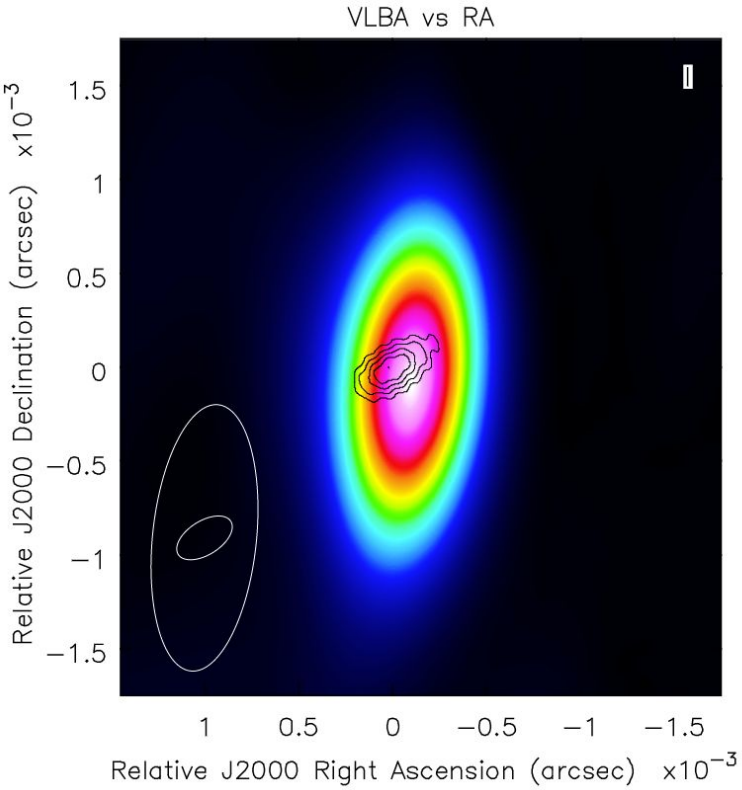
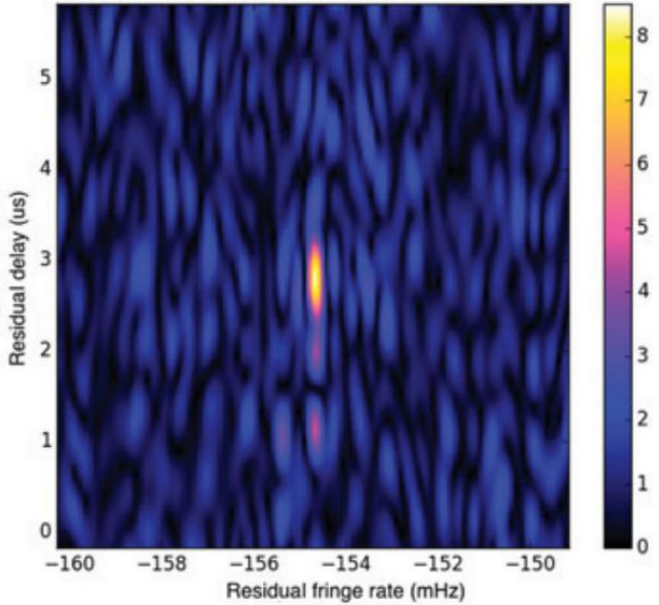


Bayandina+ in prep

The record resolution!

NGC 4258

- ✓ Extragalactic H_2O MegaMaser
- ✓ At a distance of ~7 Mpc
- ✓ **26.7 Earth Diameters**
- ✓ **Angular resolution ~8 μas**



Baan+2018

Future projects

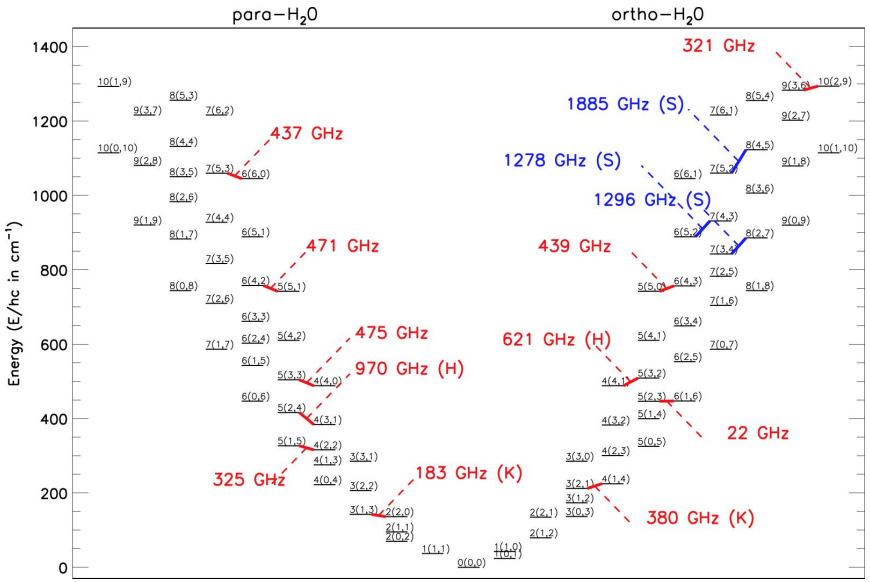
Frequency range

183 GHz and 380 GHz Masers

- Detected with
  the Kuiper Airborne Observatory

Terahertz Water Masers

- Detected only with SOFIA
- Evolved stars



Neufeld+2017

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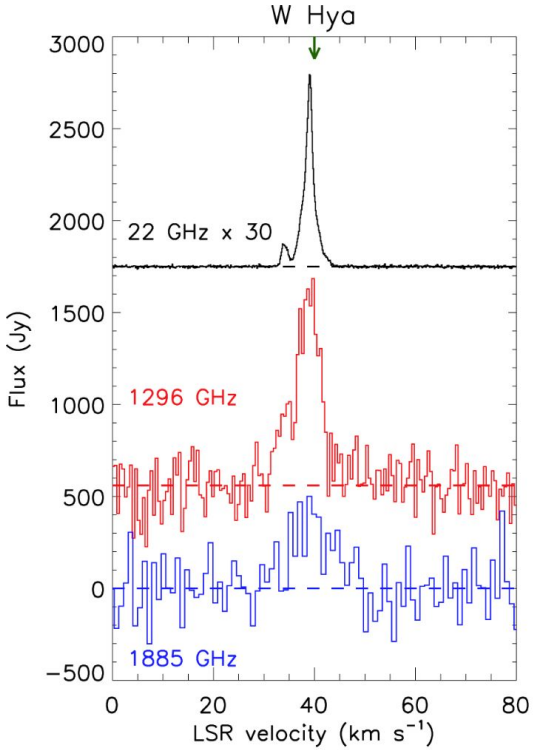


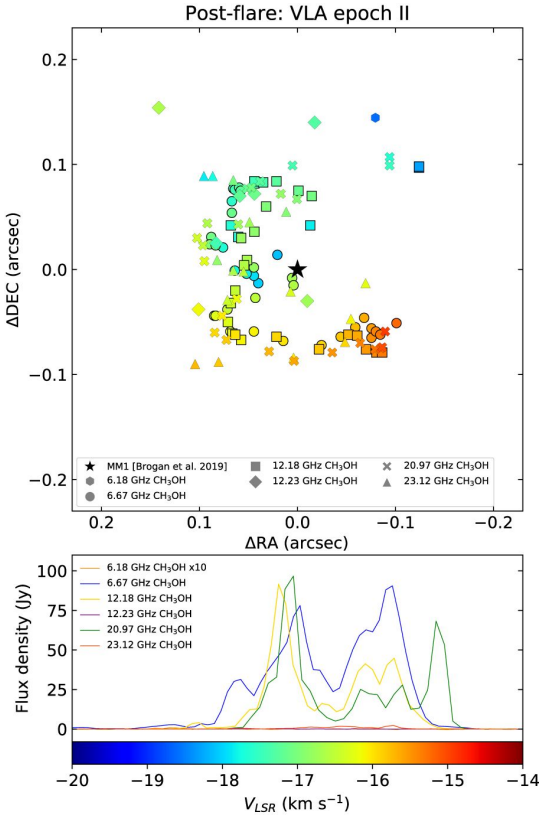
Neufeld+2017

Future projects

- Episodic accretion bursts
- Only three cases:
  S255IR, NGC 6334I, G358.93–0.03

G358.93–0.03

- **>20** new methanol maser transitions discovered



Bayandina+2022

Thanks!

Do you have any questions?

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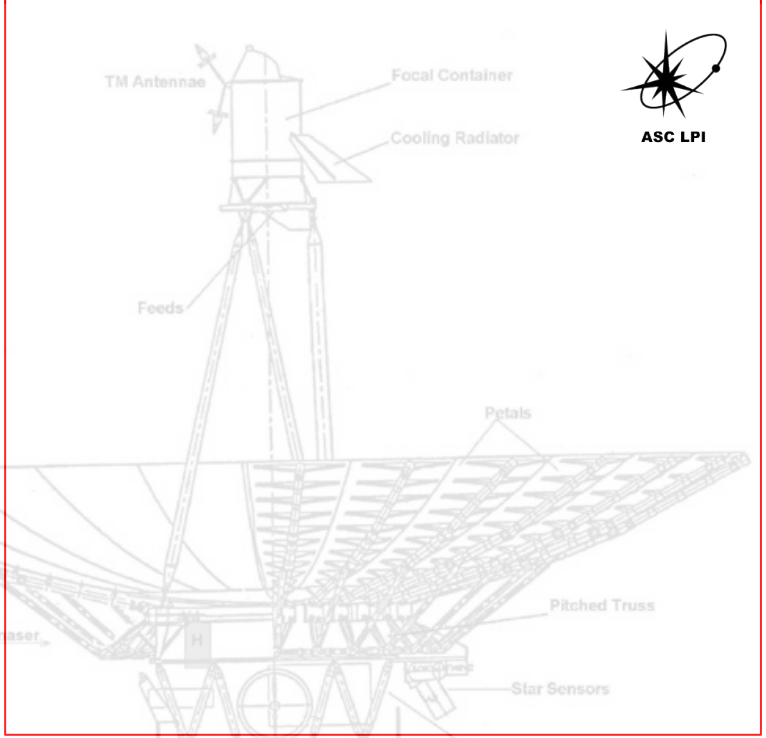

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Bologna VLBI: Life begins at 40!
New frontiers and scientific challenges for VLBI with enhanced frequency/time/space dynamic ranges
Bologna, CNR Research Area
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