



SRT observations of Local Group dwarf galaxies

Andrea Tarchi
INAF-Osservatorio Astronomico di Cagliari

Collaborators: P. Castangia, G. Surcis, A. Brunthaler, K. Menten, M. Pawlowski, A. Melis, S. Casu, M. Murgia, A. Trois, R. Concu, C. Henkel, J. Darling

SRT in a (pea)nutshell: receivers



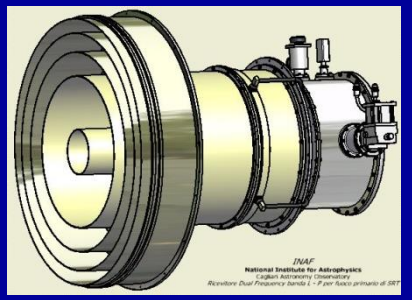
K-band (18-26.5 GHz)
7 feeds
Gregorian focus
Mechanical de-rotator





C-band (5.7-7.7 GHz)
single feed
BWG focus

Coaxial dual-feed
L-Band: 1.3-1.8 GHz
P-Band: 305-410 MHz
Primary focus



+ under constr.: S-band (7 feeds); C-band (low); Q band (7-19 feeds)
+ planned: C-band PAF (50px); W-band

SRT in a (pea)nutshell: Backends



SARDARA
Roach 2-based
BW: 300 MHz – 2 GHz
Full Stokes
Channels: up to 16384
Zoom modes and multi feed capabilities : under develop.





XARCOS
BW: 0.5-62.5 MHz
Channels: 2048
Max. res: 240 Hz
Up to 4 tunable sub-bands; Full Stokes
16 inputs (multi-feed)

+ DFB3 (mainly for pulsars); DBBC (mainly for VLBI); Total Power

SRT in a (pea)nutshell: Recent Milestones



Engineering Commissioning: 2013
Bolli+ 2015

Scientific Commissioning: 2016
Prandoni+ 2017

- **VLBI observations**: Feb 2015 (regular EVN sessions) e.g., **Paola's talk**
- **Sanna+ 2017**

Single dish observations:
Early Science Program Feb-Aug 2016

- **Active Surface Repair Work and migration to final Ctrl Rm building** Jan-Aug 2017 : **completed!**

SRT Early Science Program (ESP)

13 large projects accepted
2000 hours observing time allocated in 6 months

ID	Project Name	PI
S0001	SRT Multi-frequency Observations of Galaxy Clusters	Matteo Murgia
S0003	Proper motions and star formation activity of Local Group dwarf galaxies	Andrea Tarchi
S0004	Class I methanol masers: shock tracers in deeply embedded sources	Silvia Leurini
S0005	A new view on the family of the eclipsing pulsars	Andrea Possenti
S0006	Radio follow-up of gravitational radiation sources with SRT	Andrea Possenti
S0007	Mapping the microwave emission of Andromeda: filling the gap between radio and IR emission	Elia Stefano Battistelli
S0008	Searching for pulsars at high frequency in the Galactic Center region	Maria Noemi Iacolina
S0009	Constraining Cosmic Rays Production in Supernova Remnants with SRT	Alberto Pellizzoni
S0010	The Large European Array for Pulsars	Delphine Perrodin
S0011	Determining the kinetic temperature of star-forming molecular clouds across the outer Galaxy	Jan Brand
S0013	Monitoring of neutron star and black hole X-ray binaries with the SRT	Elise Egron
S0014	Polarimetric multi-frequency observations of a complete sample of radio sources	Roberto Ricci
S0015	Launching a radio pulsar timing program at SRT	Marta Burgay

Extragalactic maser proper motions

'…If the orbital speed (rotation curve) and inclination of the galaxy are known, then measurement of the proper motion directly yields the galaxy'e distance. A maser located …'

Reid & Moran in 'Galactic and Extragalactic Radio Astronomy' by Vershuur & Kellermann (1988, if not before)

Comparing the relative angular motion with the expected linear motion one derives (with a model in mind):

$$\vec{v}_{prop} = \vec{v}_{rot} + \vec{v}_{sun} + \vec{v}_{galaxy}$$

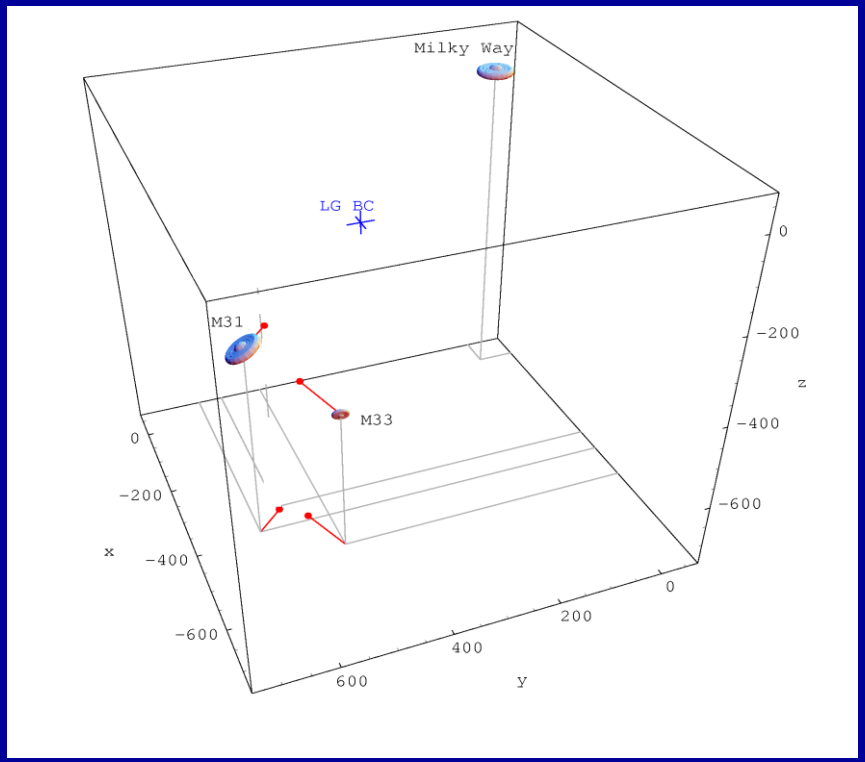
Courtesy: A. Brunthaler

Astrometry of M33

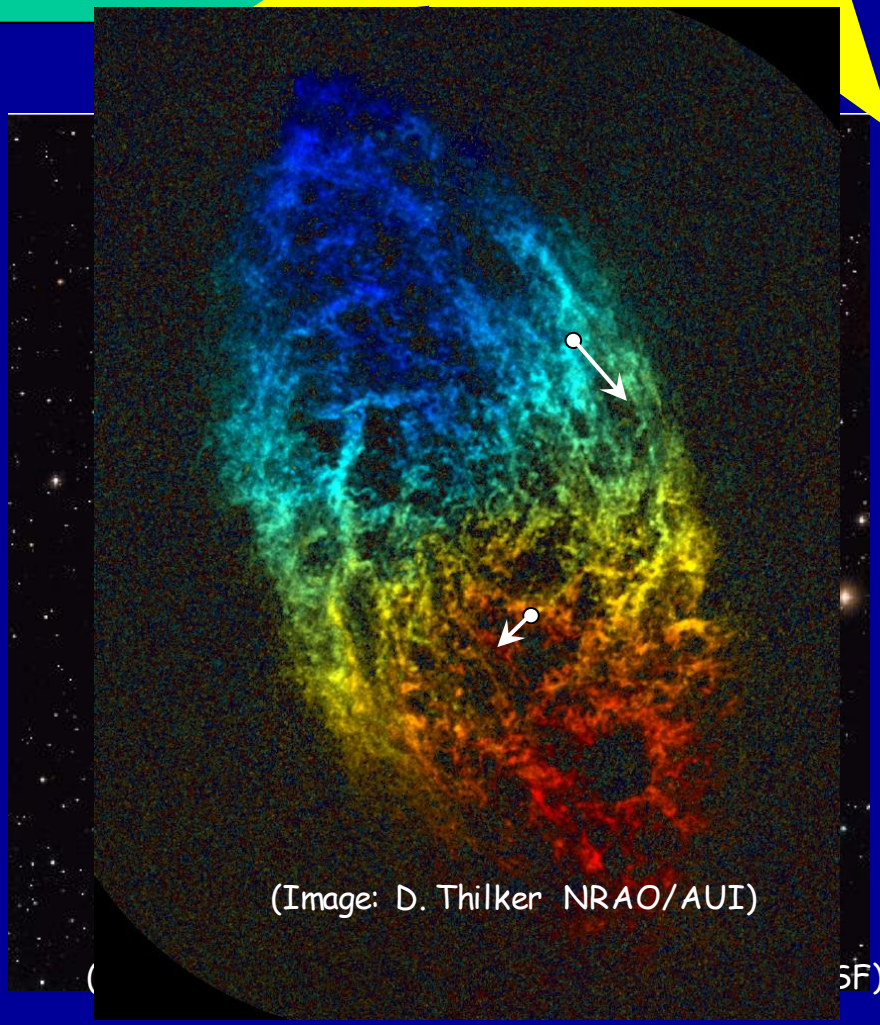
VLBA observations of water masers:

- 3d motion relative to Milky Way: v = 190 ± 59 km/s
- rotation known => geometric distance: 730 ± 168 kpc

3-8 μas/yr in 4.5 years



(Brunthaler et al. 2005, Science)

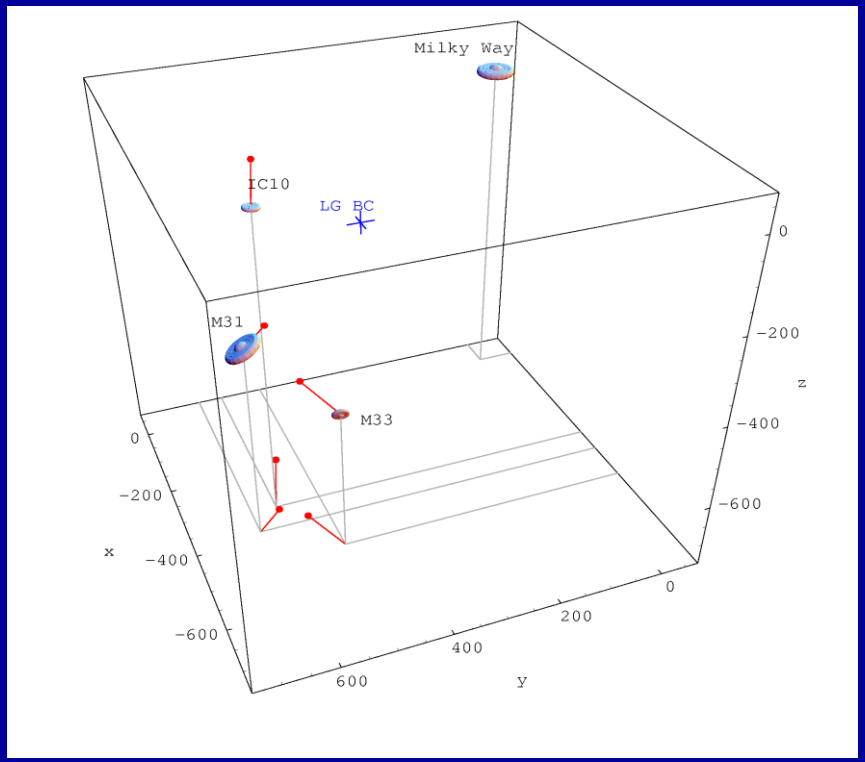


Courtesy: A. Brunthaler

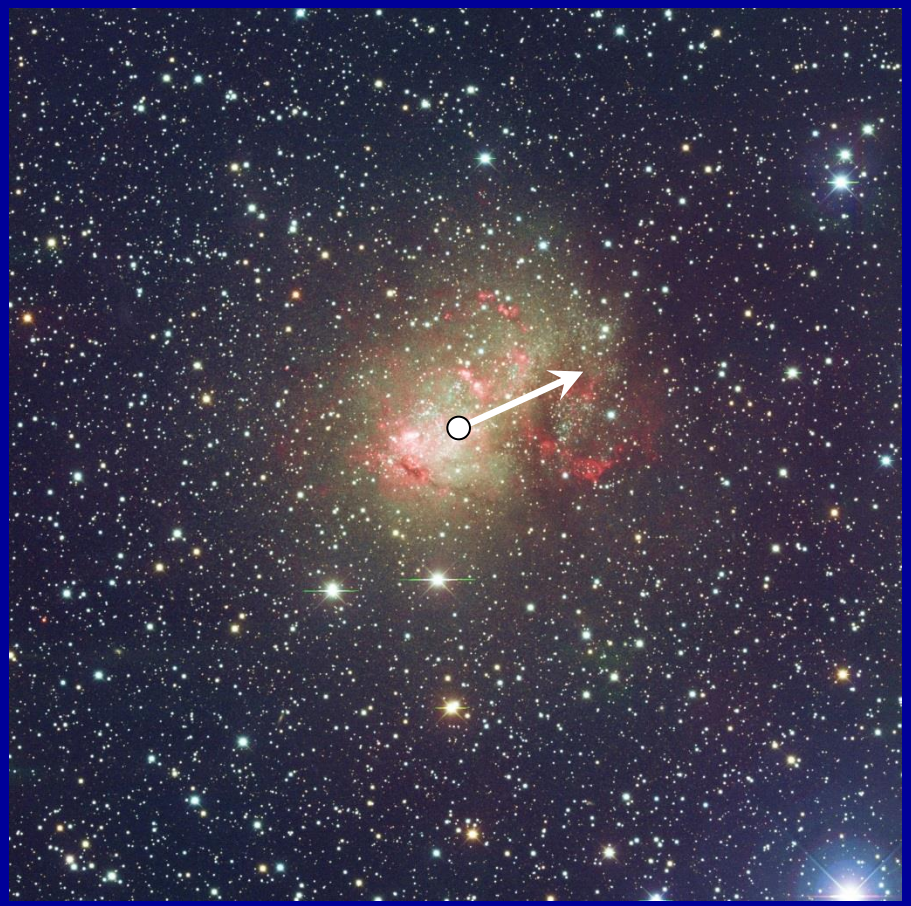
Astrometry of IC 10

VLBA observations of water masers:

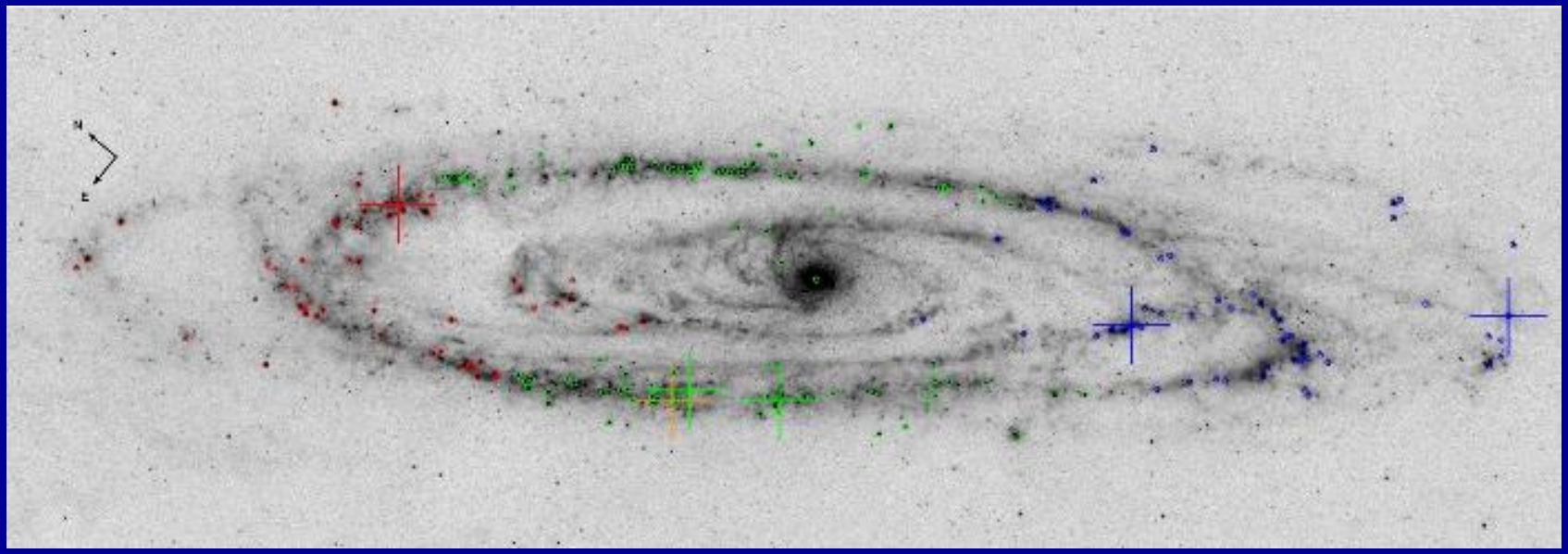
- One H_2O maser in IC10 (660 kpc)
- 3d motion relative to Milky Way: v = 215 ± 42 km/s



(Brunthaler et al. 2007, A&A)



M31



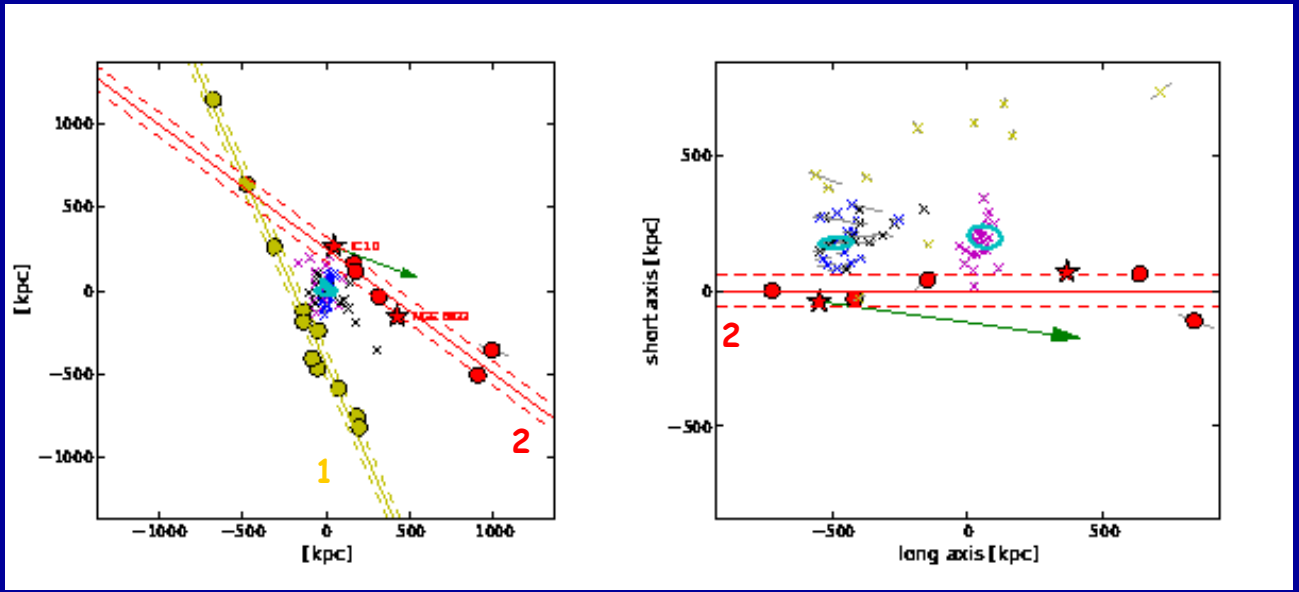
Darling 2011

5 water masers detected, so far **(Darling+ 2016)**

Ongoing effort to derive water masers proper motions in M31

1 Methanol maser **(Sjouwerman+ 2010)** **…see also next talk by Ylva!**

ESP S0003: Motivation(s)



Created using Pawlowski+ 2012,2013,2015; Ibata+ 2013

- To detect, for the first time, water and/or methanol maser emission in non satellite dwarfs (but IC10) associated with Planes 1 and 2

- To derive (with VLBI follow-ups) full velocity vectors for these galaxies
  →Origin of dwarfs structures, total mass of matter (also dark) of the LG

- Sensitive radio continuum maps of these galaxies
  → Spectral indices, SFRs

ESP S0003: Sample & Setup

Sample: 14 Local Group dwarf galaxies 'associated' with Planes 1 and 2

Time: about 200 hours in total (C and K bands)

Backend: SARDARA
BW: 1.5 GHz (2 GHz were not proposed at that time)
Channels: 16384
Res=91 kHz; 4 km/s@6.7-GHz; 1.2 Km/s@22-GHz
Full Polarization

Mapping technique: On-The-Fly (RA-DEC)
scanning speed 3'/sec (for all, but small K-band maps)

Data reduction: SCUBE **(Murgia & Govoni)**

…a few preliminary results…

Masers search: method and criteria

We:
-produced the averaged cubes at C and K band for three galaxies: NGC6822, IC1613, and WLM.

-searched for the 6.7-GHz methanol and 22-GHz water maser emission, Using the 'maser finder' method by S. Curiel with and described in Surcis+ 2011, with the following constraints:

- 5 sigma limit
- A channel range corresponding to ±200 km/s, centered on the lines doppler shifted by the systemic velocity of the galaxy

-derived the peak to noise ratio (SNR) in the spectrum at the position of the features found

-cosidered detections (SNR > 5) and tentative detections (3<SNR<5)

...and ...

Masers search: results

No maser emission above 5 sigma has been detected in the three targets analysed, so far: NGC6822, IC1613, and WLM

In principle, **not surprising**, though:

epected masers number: $N = 10^{[-0.6x(1 + \log(L_{H2O})]} \times SFR_{gal}/SFR_{MW}$

with $L_{H2O} = 0.0023 \times \int Sdv \times D2$ **(Brunthaler+ 2006)**

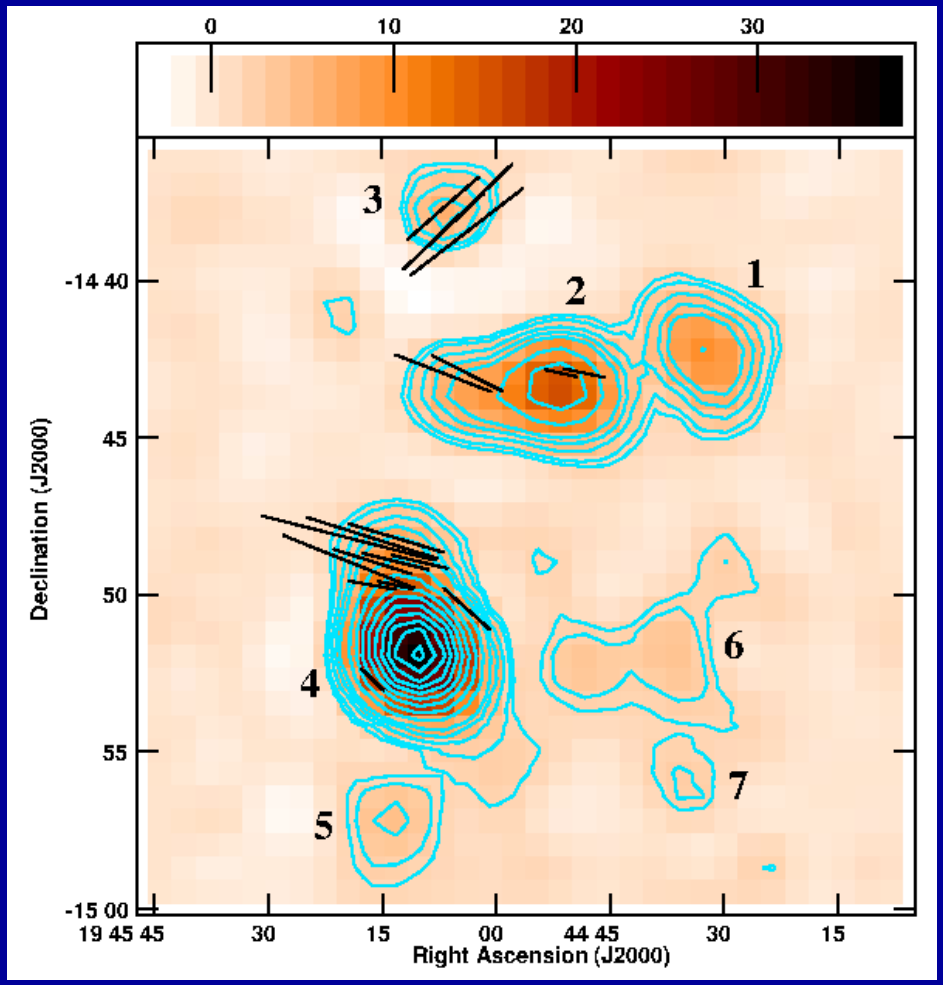
Noise in the SRT cubes
NGC6822: 20 mJy@C-band and 90 mJy/beam@@k-band
IC1613: 30 mJy and 70 mJy/beam@K-band

At 5 sigma: for water, in NGC6822, N~0.1 and in IC1613, N~0

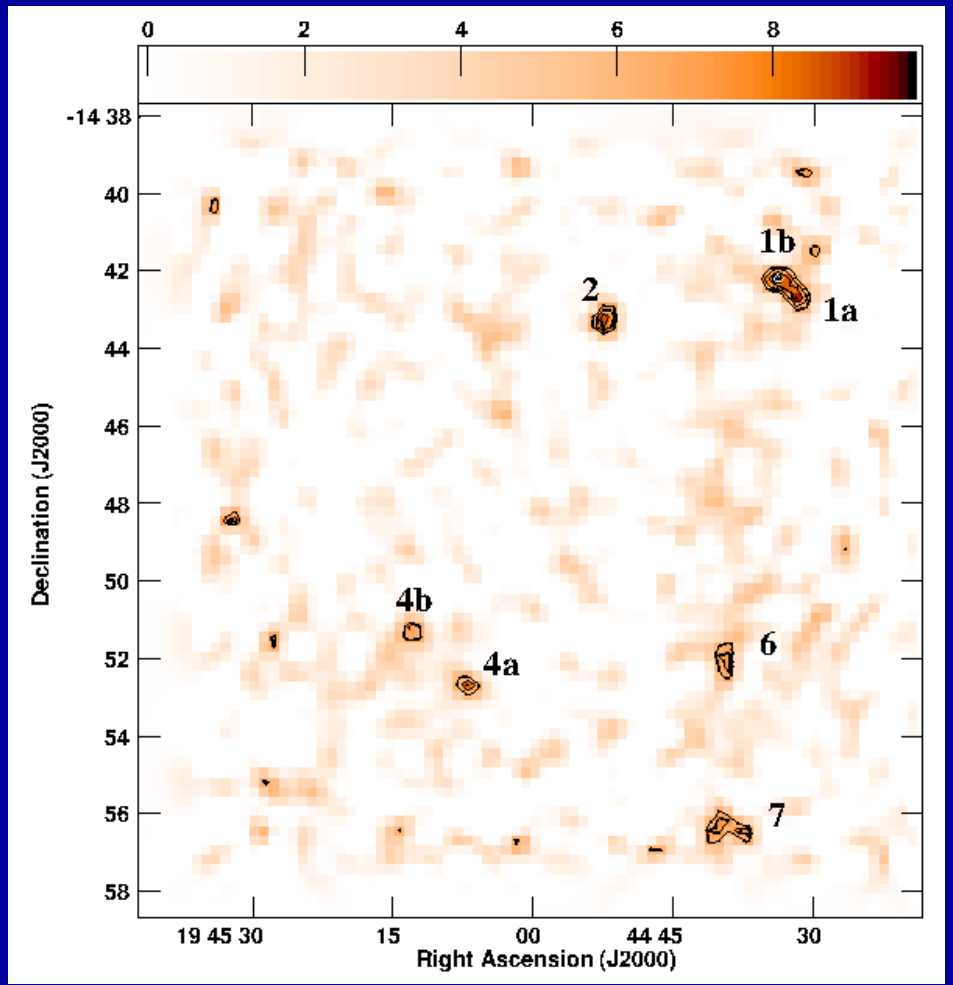
But: for IC10, N~0.3, 2 masers has been found, though (flares?, wrong SFRs?)…see later slides

…in the meanwhile…

Radio continuum maps of NGC6822

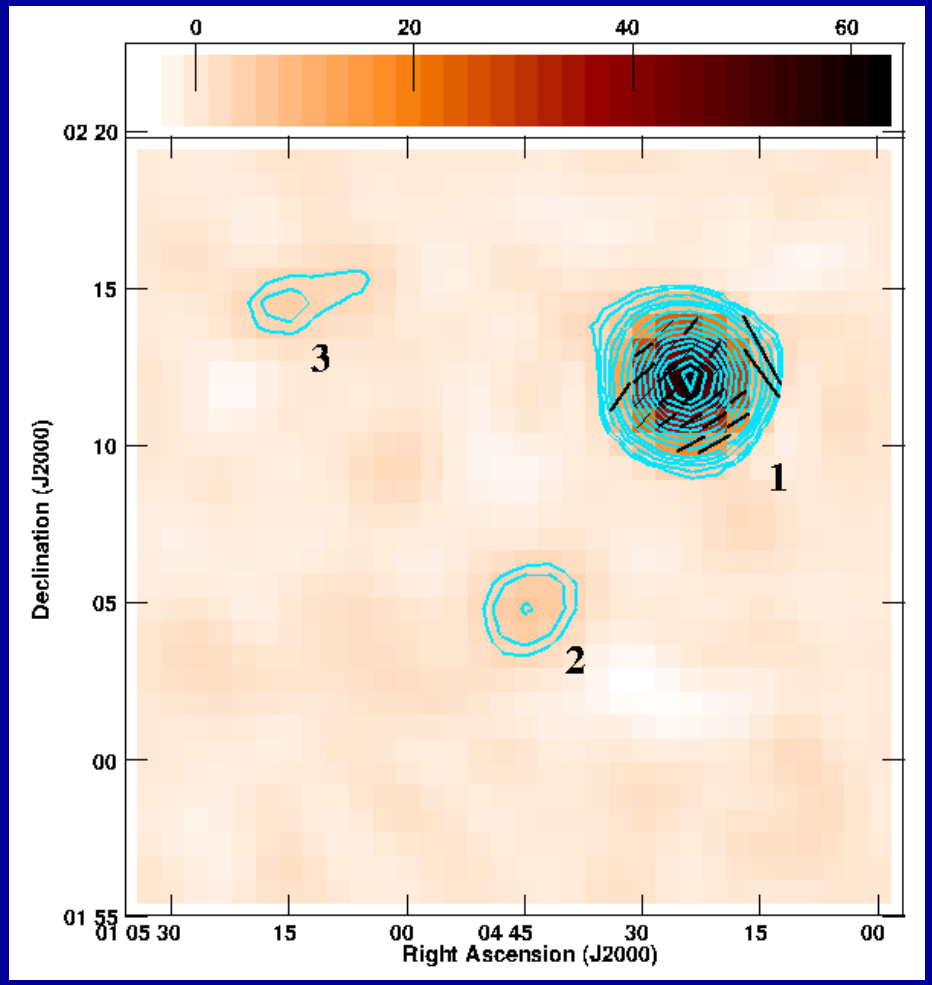


C-Band; 21′x21′; 19RAx19DEC; 5 h;
Noise 0.65 mJy/beam ((beam 2′.9)
Polarization: 2′.1 10%

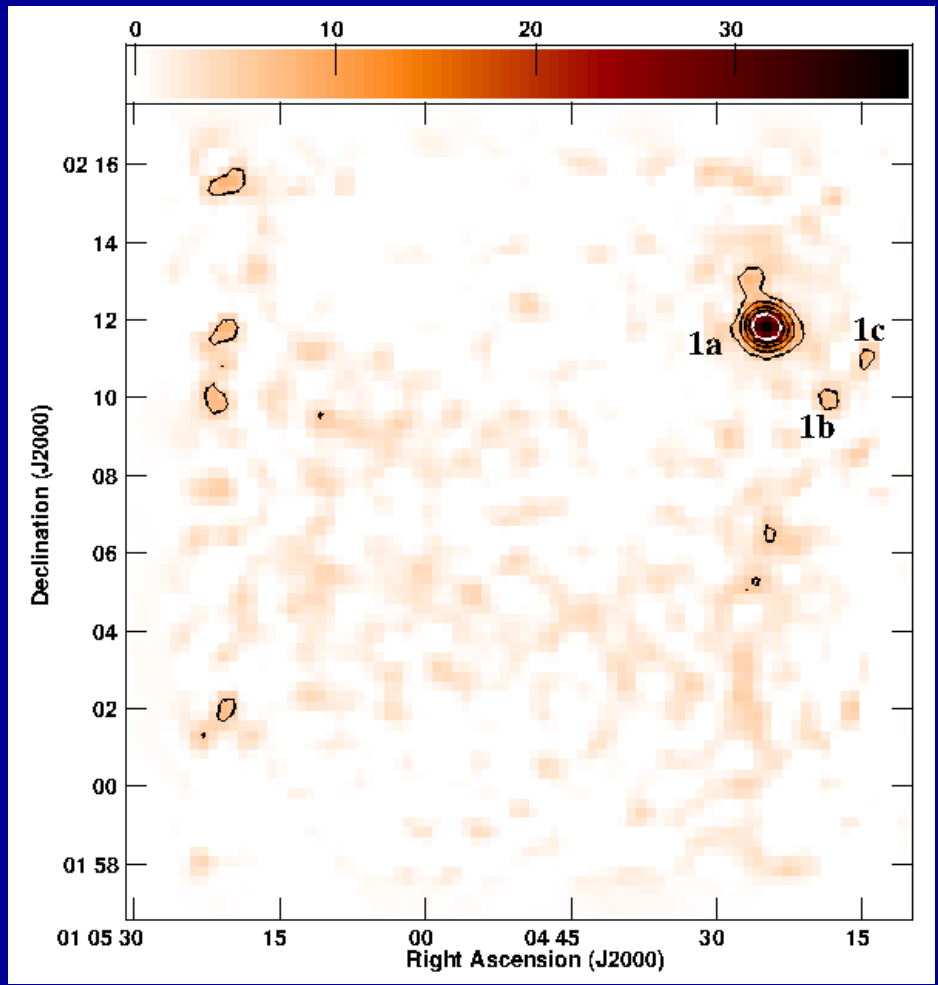


K-Band; 18′x18′; 60RAx60DEC; 38 h;
Noise 2 mJy/beam ((beam 0′.9)

Radio continuum maps of IC1613

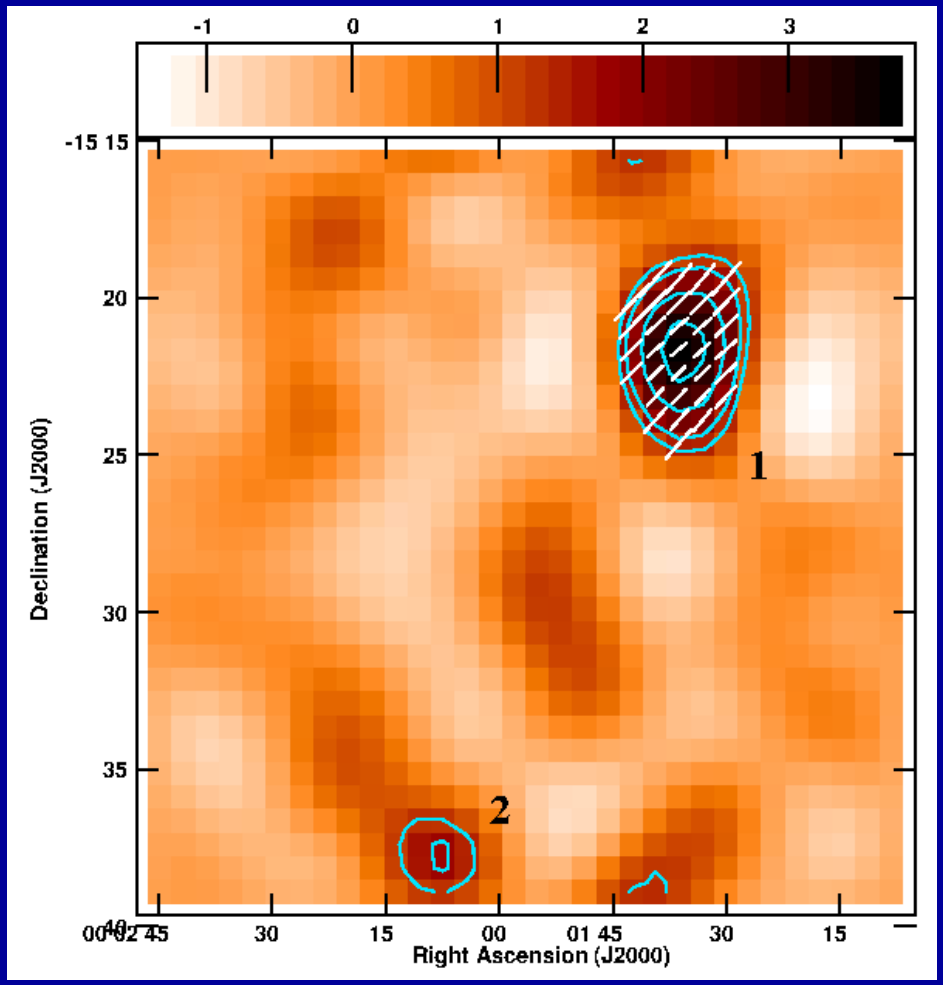


C-Band; 21′x21′; 16RAx16DEC; 4 h;
Noise: 1 mJy/beam ((beam 2′.9)
Polarization: 2′.1 = 10%

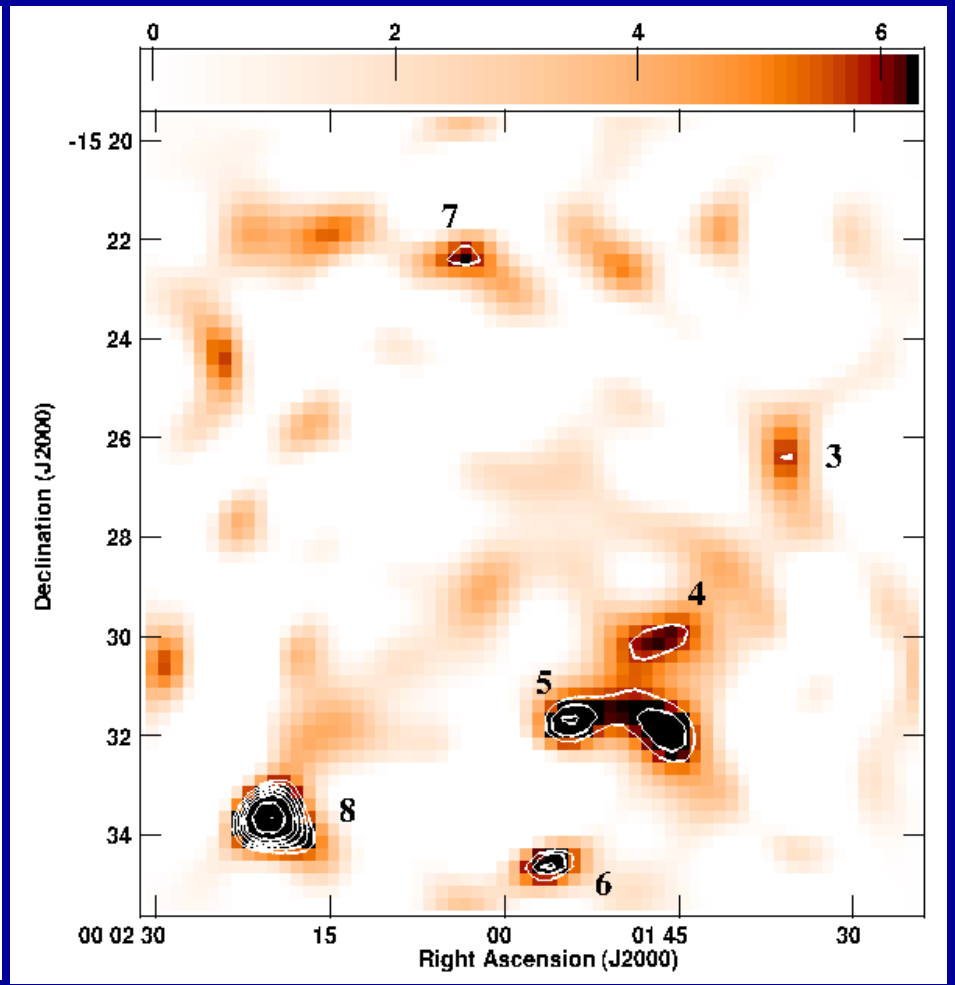


K-Band; 18′x18′; 55RAx55DEC; 35 h;
Noise 1.7 mJy/beam ((beam 0′.9)

Radio continuum maps of WLM



C-Band; 21′x21′; 17RAx17DEC; 4.5 h;
Noise 0.4 mJy/beam ((beam 2′.9)
Polarization: 0′.75 = 50%



K-Band; 12′x12′; 34RAx34DEC; 14.5 h;
Noise 1.9 mJy/beam ((beam 0′.9)

Summary

We performed spectropolarimetric maps at C and K bands with the SRT of the full optical body of all non-satellite dwarfs in the LG, belonging to Plane 1 and 2

No confident (>5 sigma) maser sources have been detected in NGC6822, IC1613, and WLM, so far, while some interesting tentative (3-4 sigma) detections deserve confirmation

Deep radio continuum maps for the thre dwarfs have been obtained that will provide spectral index and SFR infos

The SRT is indeed suitable to perform sensitive searches for masers in extended extragalactic (and Galactic) sources (along with surveys and monitoring programs)

Future steps

Data reduction for the remaining observed dwarf galaxies in the sample

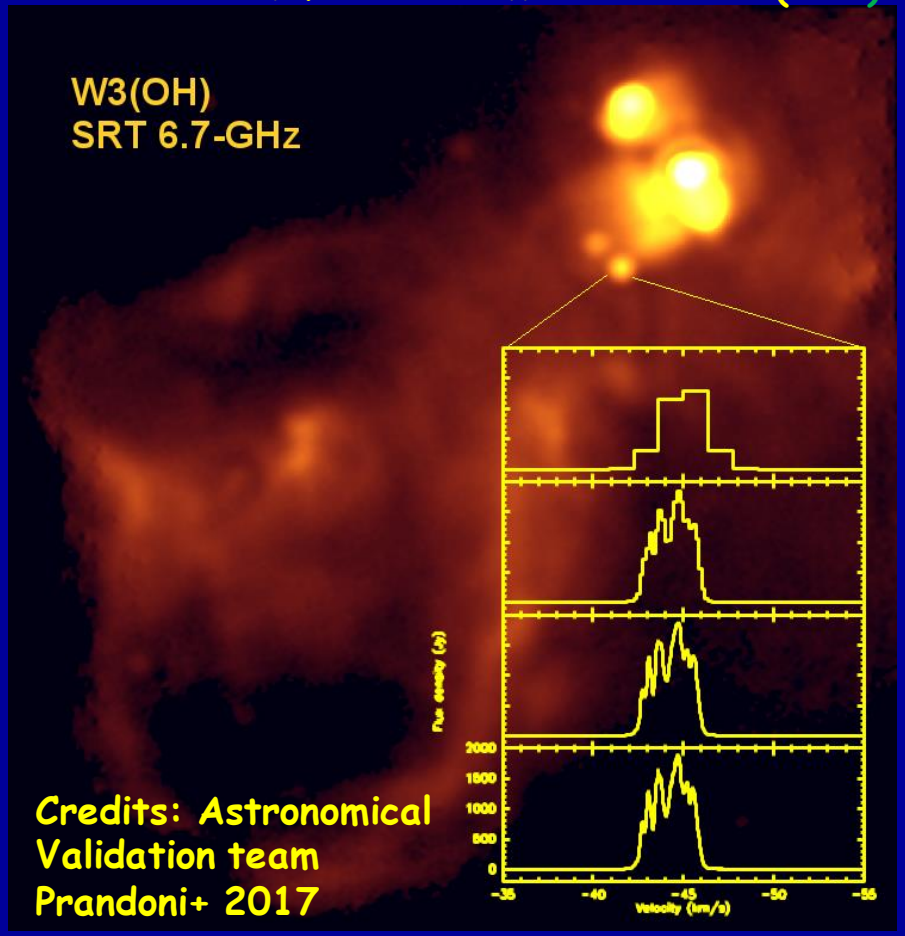
Confirmation of tentative maser detections (with the SRT, 32-m @Medicina, or else)

Extension of SARDARA toward multi-feed capabilities to speed-up spectro-polarimetric mapping and maser searches

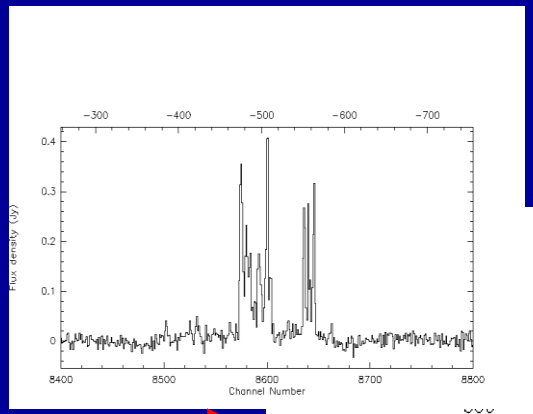
Masers @ SRT

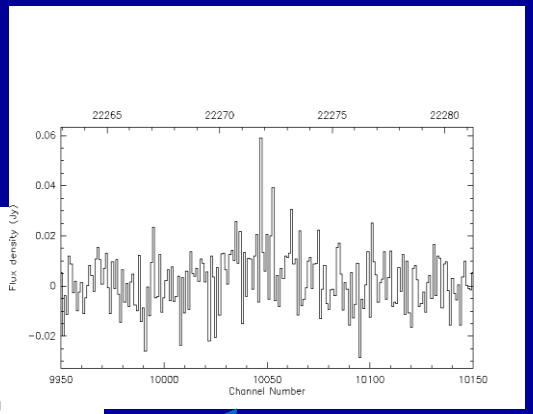


Methanol maser in W3(OH)

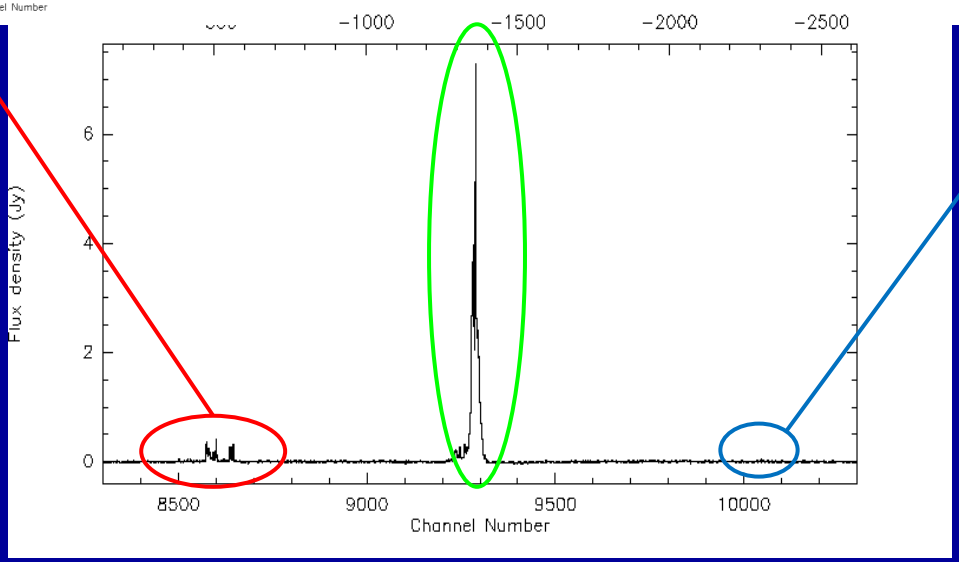


Megamasers @ SRT





NGC4258 22-GHz





Credits: A. Tarchi, P. Castangia, and the Tender RAS team