Andrea Tarchi

Unveiling fine details of the (giga)maser source in TXS2226-184 with the VLBI

Collaborators:
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Extragal. water maser detection rates

~3500 galaxies surveyed → ~180 water maser sources found:

- in nearby starburst galaxies

- in LG galaxies (…more welcome)

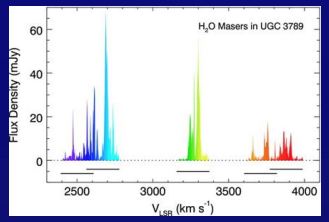
- in radio quiet AGN, mostly classified as Seyfert 2's or LINERs, in the local Universe ($z < 0.05$)

- some exceptions: NGC1052 (a radio galaxy at z=0.005), 3C403 (an FRII at z=0.06), SDSS J0804+3607 (a type 2 QSO SDSS J0804+3607 at z=0.66) and MG J0414+0534 (a type 1 quasar at z=2.64) … and maybe more.

Overall detection rates are of a few % in the full sample

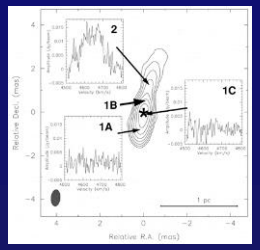
(see, e.g., Tarchi 2012, Braatz 2018, Tarchi+ 2020)

H_2O (mega)masers



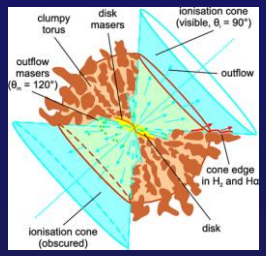
Disk-masers → **Disk geometry and BH masses**

(e.g. NGC 4258, UGC3789, …)



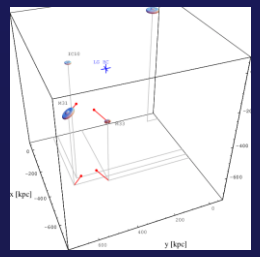
Jet-masers → **Evolution of the jet**

(e.g. Mrk348, NGC1052, …)



Outflow-masers → **Geometry of the outflow**

(e.g. Circinus)



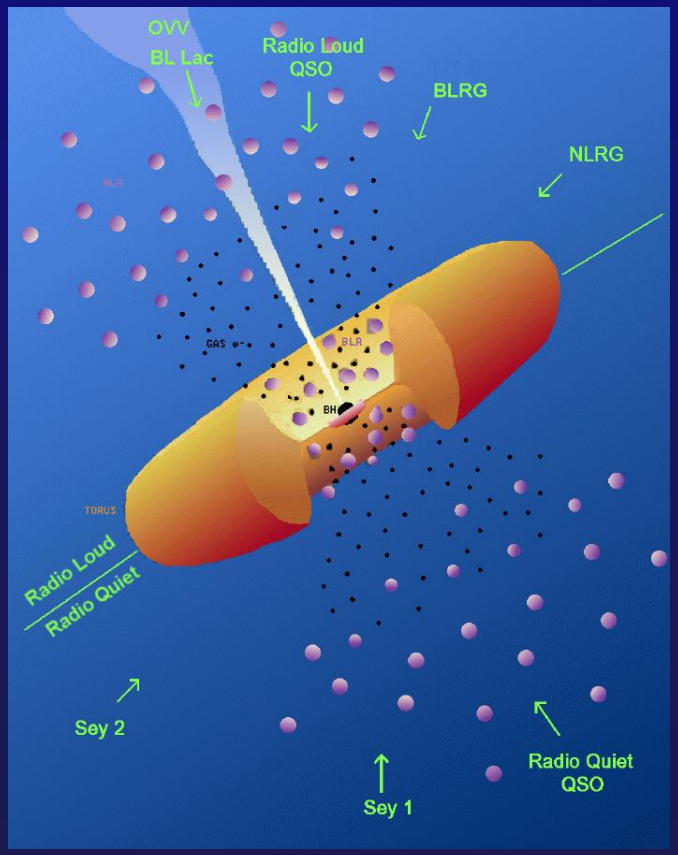
SF masers → **Proper motions and distances of LG members**

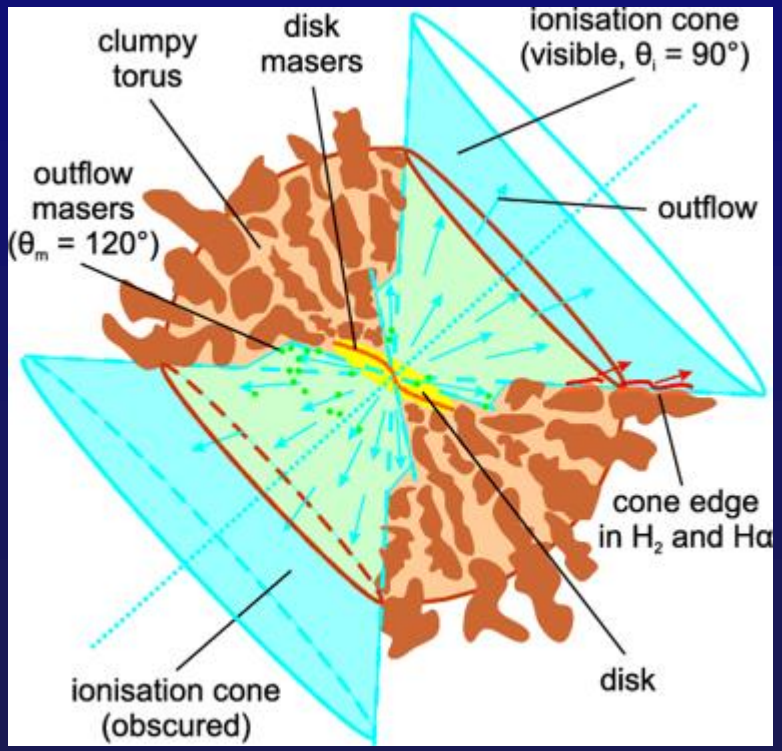
(e.g. IC10, M33)

(Mega)masers and the AGN Unified Model

More maser sources and more detailed studies are needed

Relevant for a better understanding of the Unified Scheme for AGN

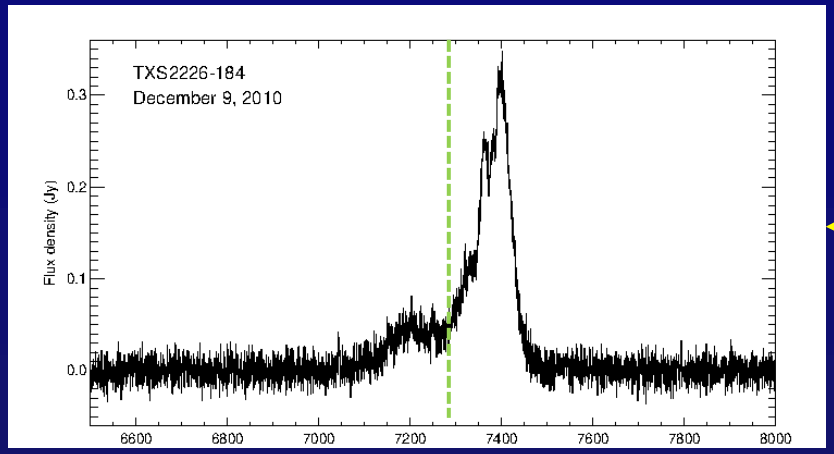




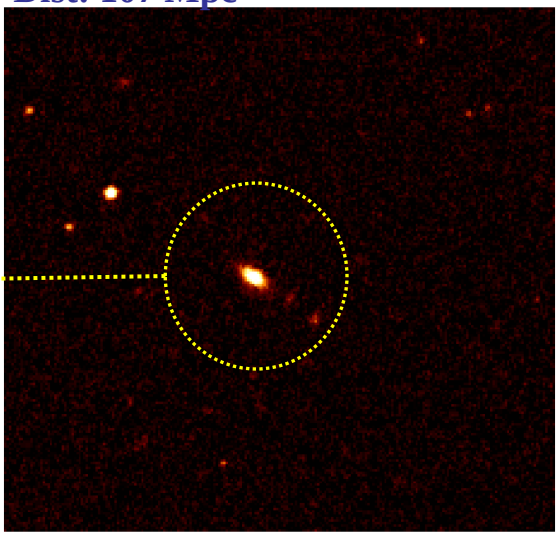
e.g.,
for Circinus: Tristram+ 2007;
for NGC1068: Impellizzeri+ 2019; Bannikova+ 2022

The gigamaser in TXS2226-184

GBT archival spectrum



Dist: 107 Mpc



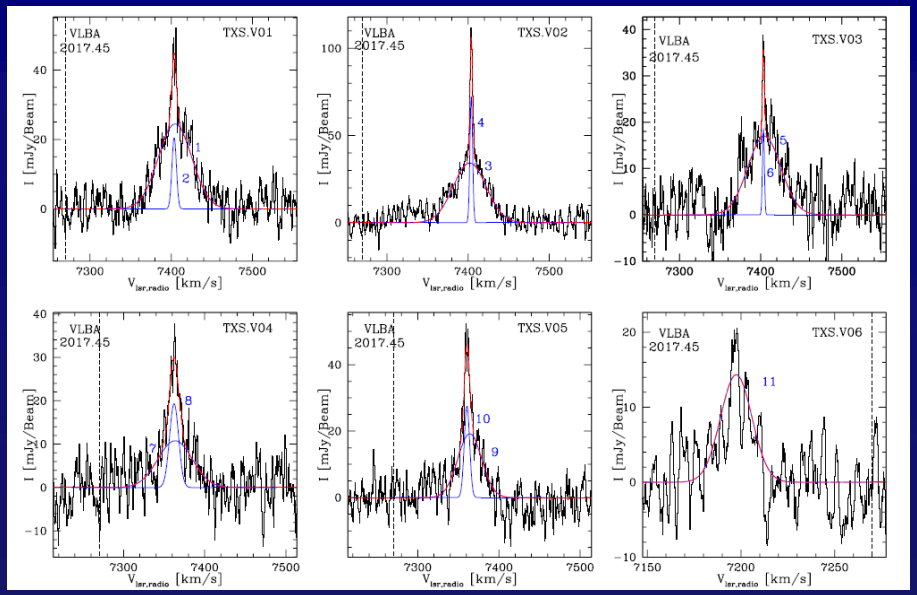
Class: LINER; E/S0 (or later-type)

Old K-band observations (Ball+ 2005)
No absolute position

New K-band observations (Surcis, Tarchi & Castangia 2020)

Array	Observation date	Beam size (mas × mas)	Position Angle (°)	rms[a] ($\frac{mJy}{beam}$)
VLBA	27 May 1998	1.81 × 0.54	−11.26	5.9[b] , **0.5**
VLBA	12 June 2017	1.42 × 0.36	−14.72	15.3[b] , **0.4**
EVN	29 October 2017	4.16 × 0.97	−26.99	21.7[b,d] , **0.2**
EVN	09 June 2018	2.11 × 1.41	+7.08	5.1[b] , **0.2**

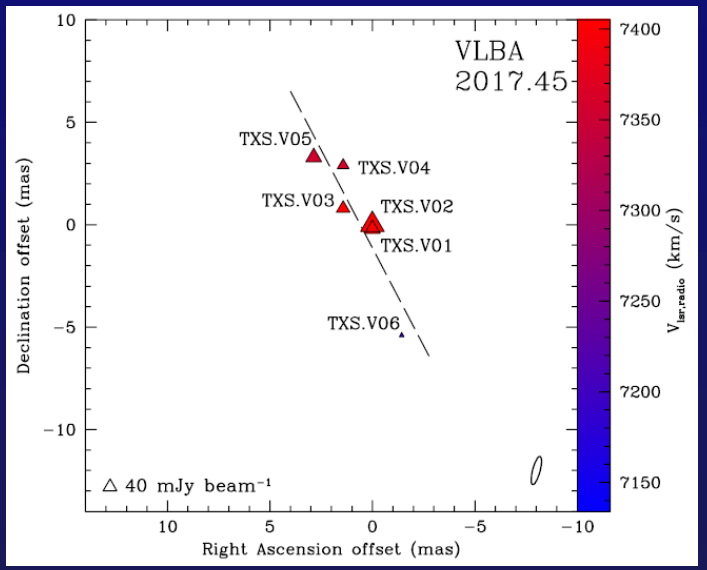
The gigamaser in TXS2226-184



maser features

K-BAND VLBA AND EVN RESULTS

- 6 water maser features (1 blue-shifted)
- maser absolute position
- linear/arc structure - no velocity gradient
- no continuum emission (rms = 0.2 mJy/b)
- no polarized emission (P < 15 %)

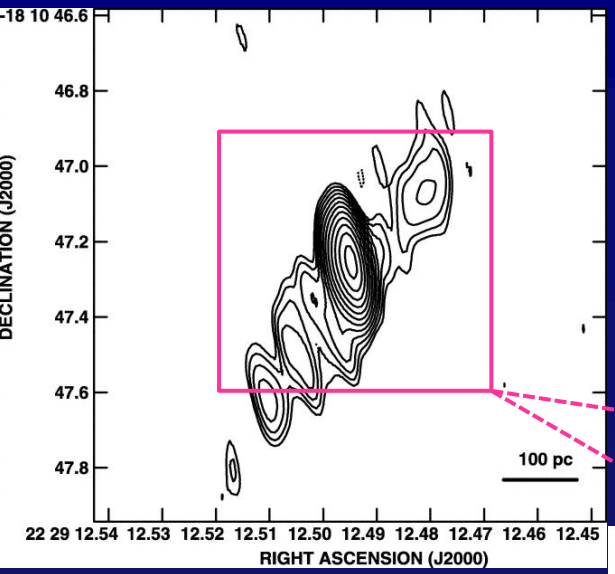


Distribution of maser emission

Surcis, Tarchi & Castangia (2020)

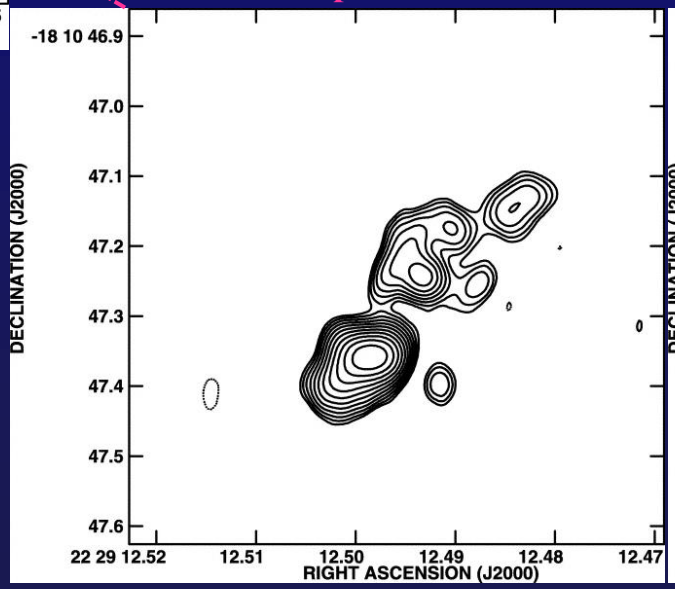
Nuclear radio continuum in TXS2226-184

… @ 2020

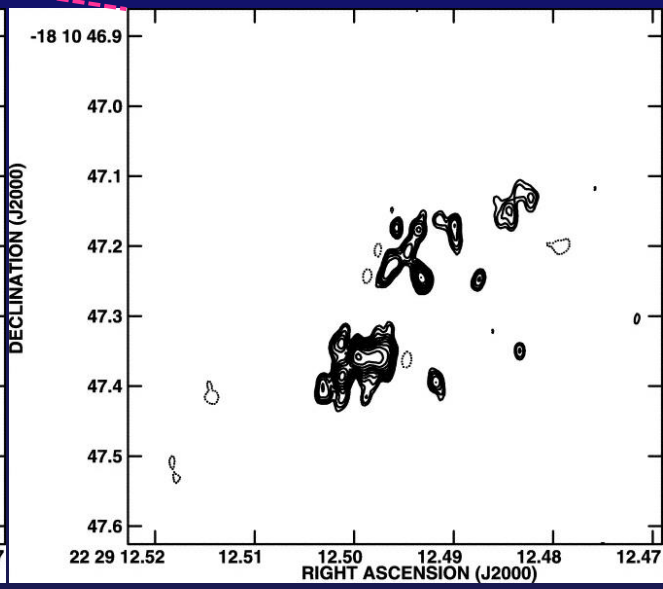


MERLIN 5 GHz
Res. 179x41 mas

20 mas ≈ 10 pc



VLBA+GBT 1.4 GHz – Heavy Tap.
Res. 45 x 45 mas



VLBA+GBT 1.4 GHz – Light Tap.
Res. 20 x 12 mas

From Taylor+ (2004)

The nature of the gigamaser in TXS2226-184

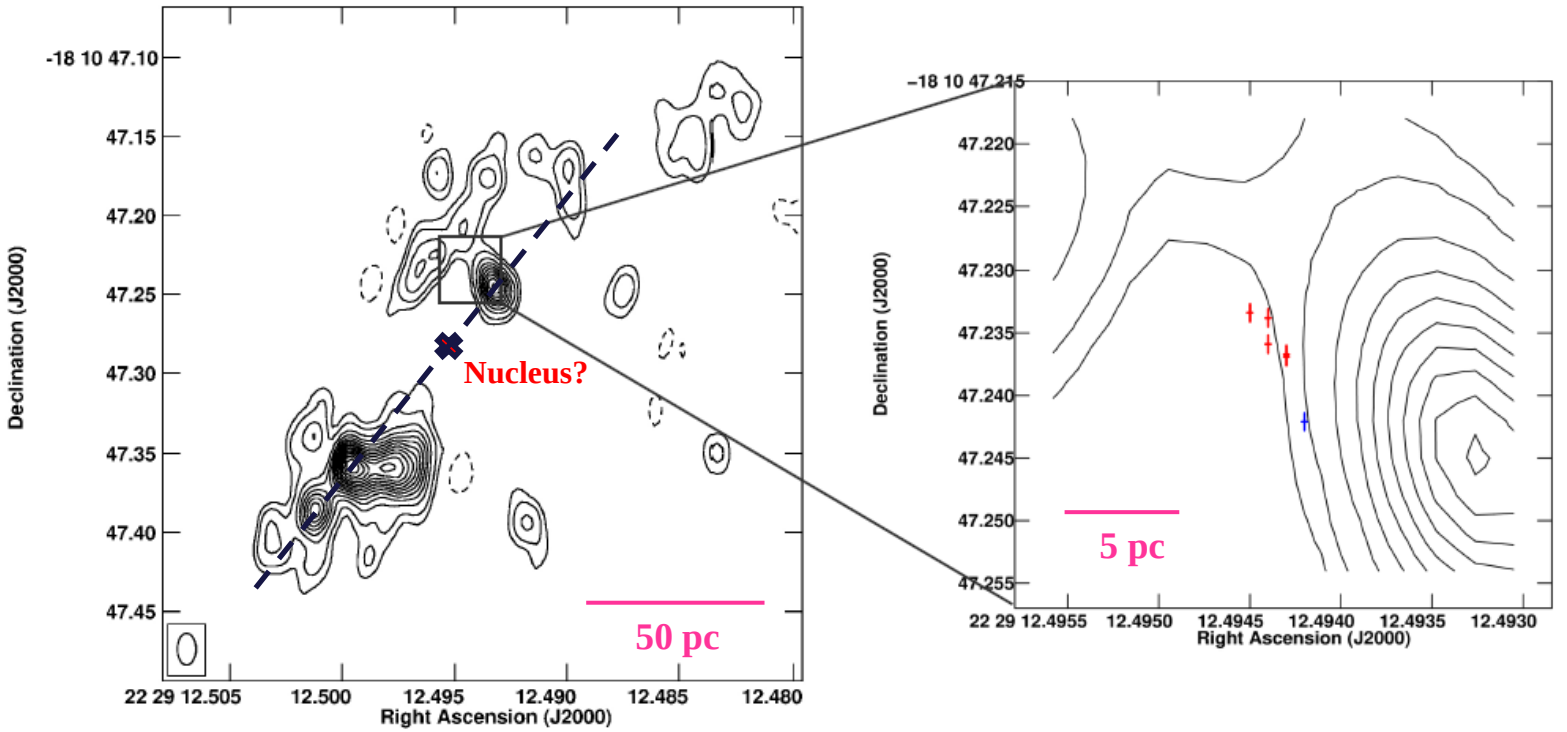


Fig. 9. Continuum emission of 1.4 GHz from the nuclear region of TXS 2226-184 as observed with the VLBA in 2002 (Taylor et al. 2004). Contours are $-1, 1, 2, 4, 6, 8, ..., 26 \times 3\sigma$, where $\sigma = 43.23\ \mu$Jy beam^{-1}. The red and blue crosses indicate the positions of the red-shifted and blue-shifted H_2O masers with respect to the systemic velocity of the galaxy ($V^{TXS}_{lsr,radio} = 7270$ km s^{-1}), respectively, detected with the VLBA in epoch 2017.45 (see Sect. 4.2). The size of each cross corresponds to the absolute position error.

Surcis, Tarchi & Castangia (2020)

Jet Origin?

One group of relatively-broad lines

However, quite stable for jet-masers…may resemble MGJ0414+0534 @z=2.64 (Impellizzeri+ 2008; Castangia+ 2011)

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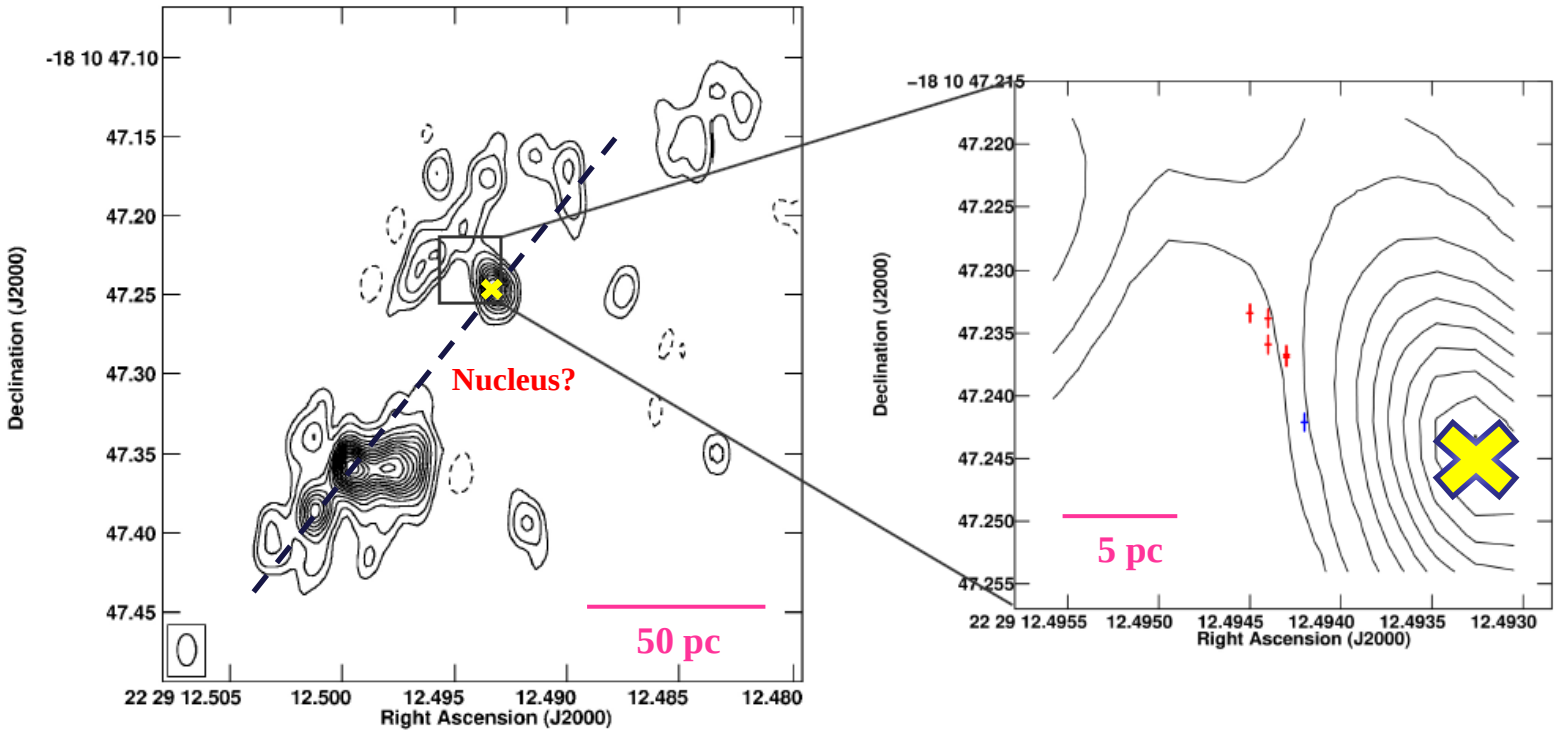

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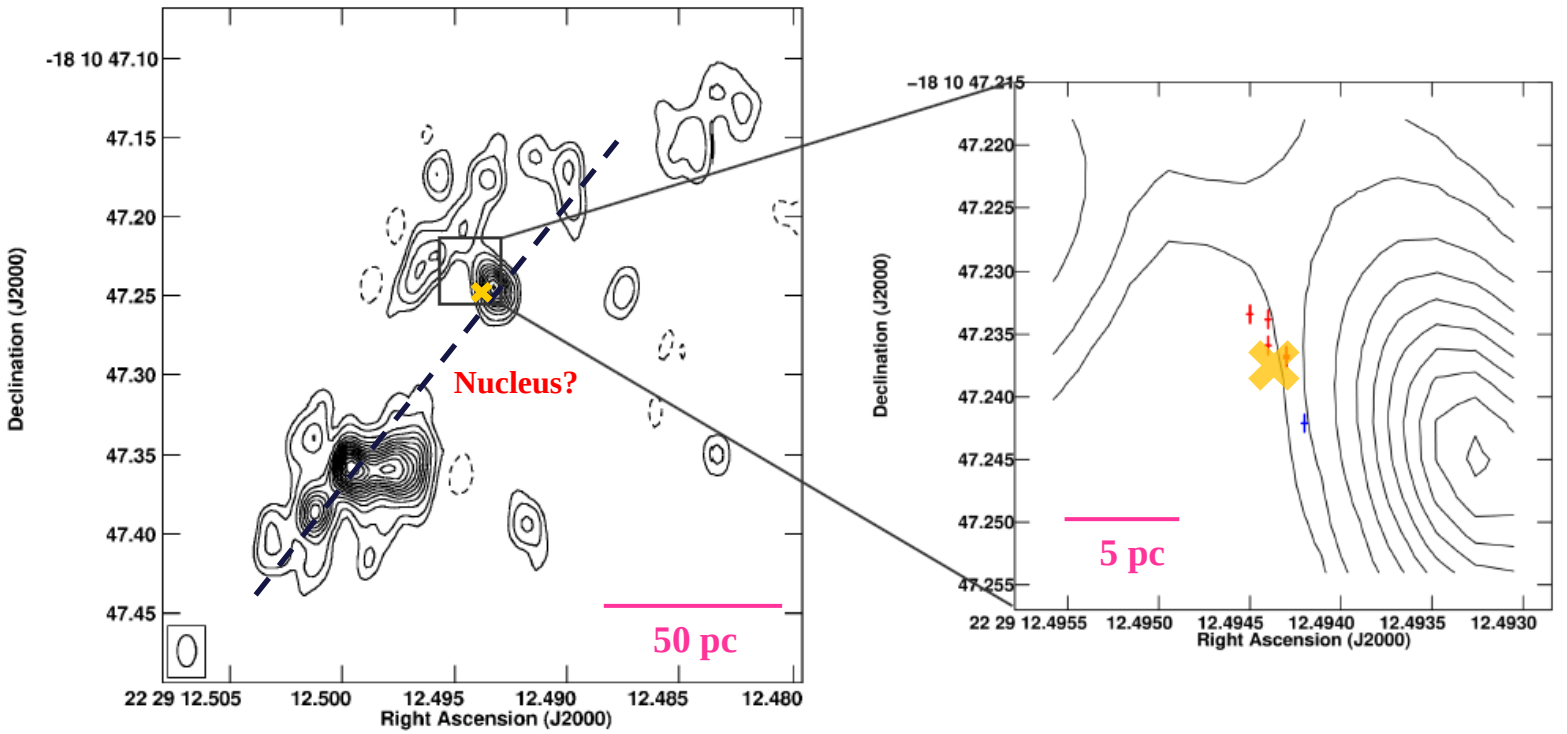

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Surcis, Tarchi & Castangia (2020)

Disk Origin?
Quite stable for jet-masers
What about the line profile (no triple peak)

Where is the nucleus in TXS2226-184?

New observations with the EVN

...work in progress...

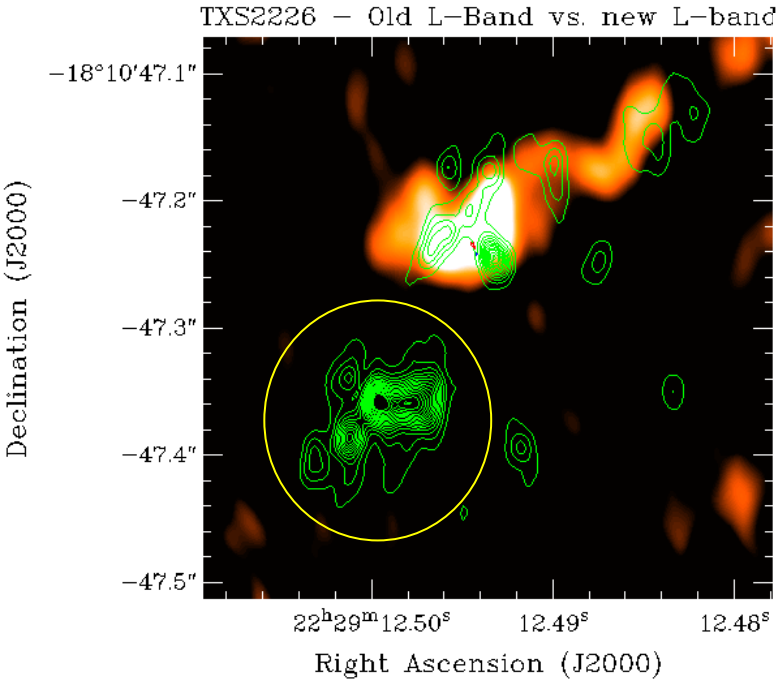
Target (T): TXS2226-184 **Phase reference J2232-1659**

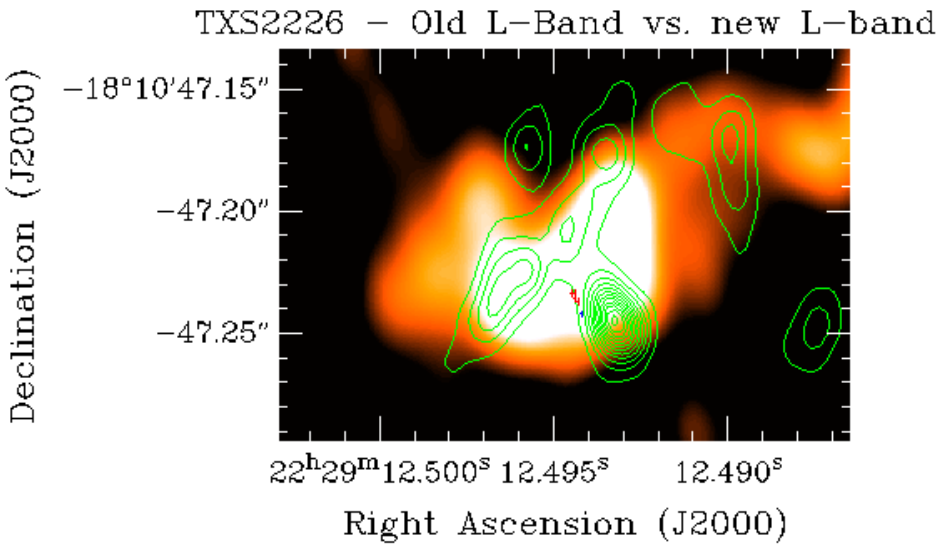
	ET045A	ET045B	ET045C
Project name			
Band	L (1.6 GHz)	C (5 GHz)	K (22 GHz)
Date	Feb. 26, 2021	Mar. 7, 2021	Mar. 9, 2021
Bandwidth	4 IF of 32 MHz, 2 pol	8 IF of 32 MHz, 2 pol	8 IF each of 32 MHz, 2 pol
Total time	7 hours	7 hours	7 hours
Sensitivity - rms	$0.05\ mJy/beam$	$0.03\ mJy/beam$	N/A
Resolution	30 x 15 mas	5 x 4 mas	N/A

Reduction and analysis: AIPS (NRAO) and Kvis (ATNF)

20 mas ≈ 10 pc @ 107 Mpc

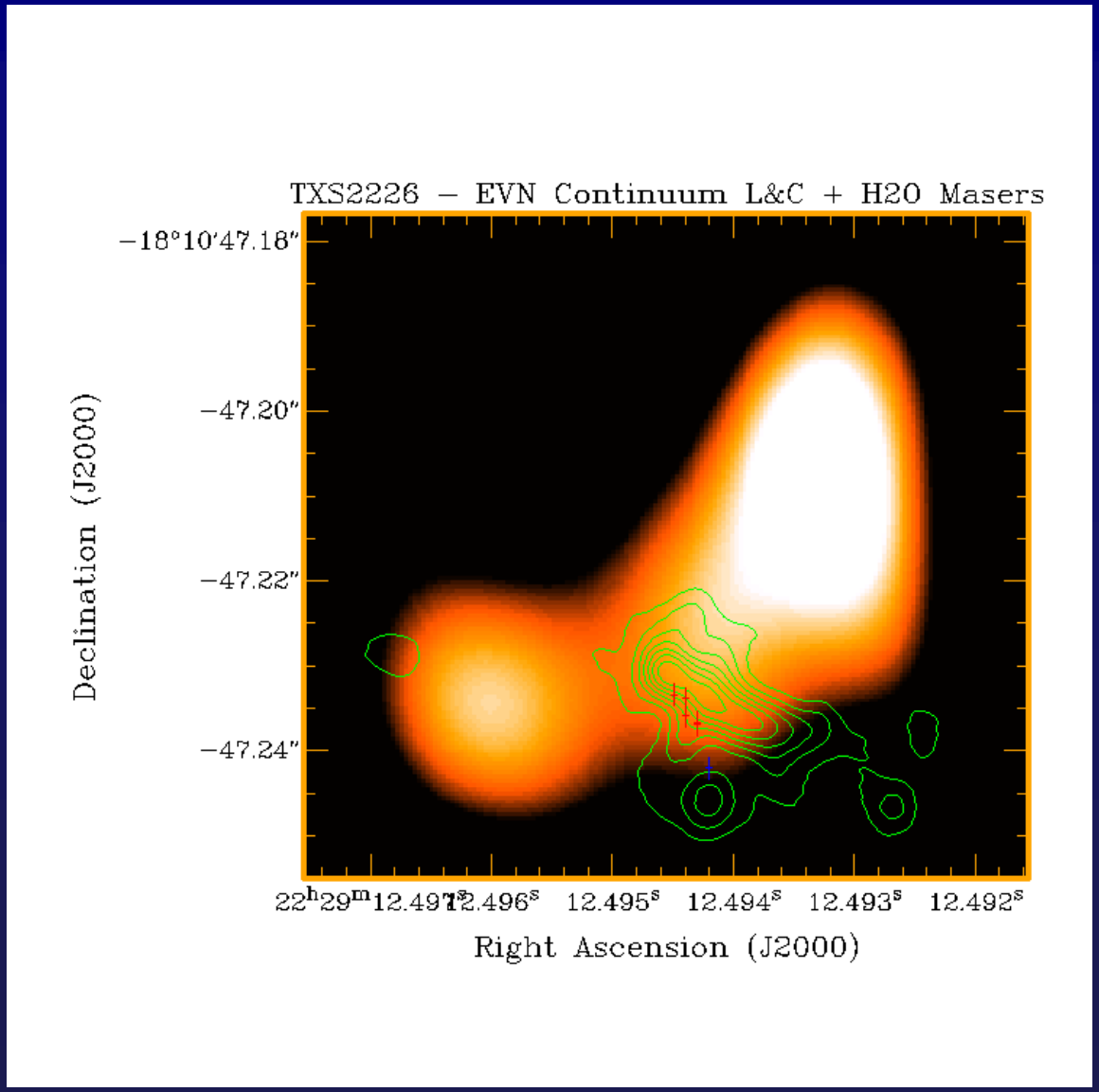
RC in TXS2226-184: past vs. present





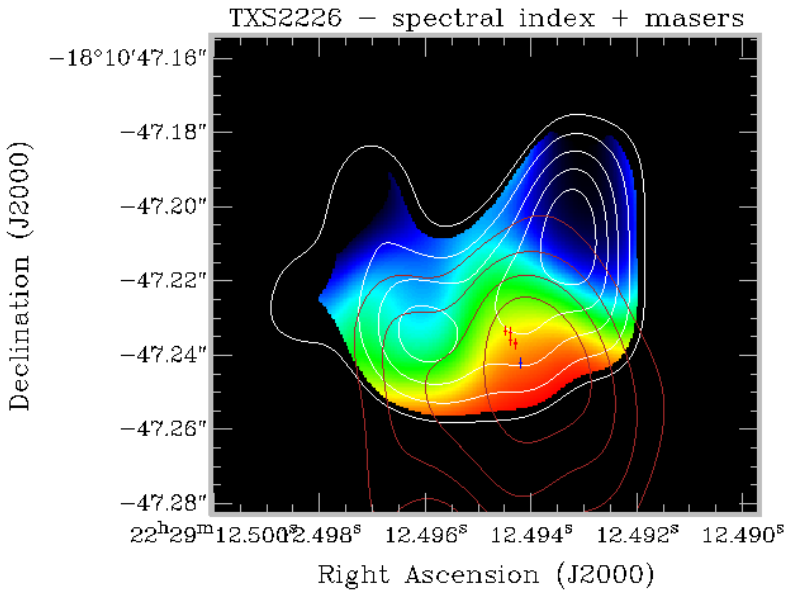
Significant changes from Taylor+ 2004 (green contours)
Similar resolution and sensitivity
… but 20 years gap -> fading jet knot? Else?

RC in TXS2226-184: new L&C VLBI maps

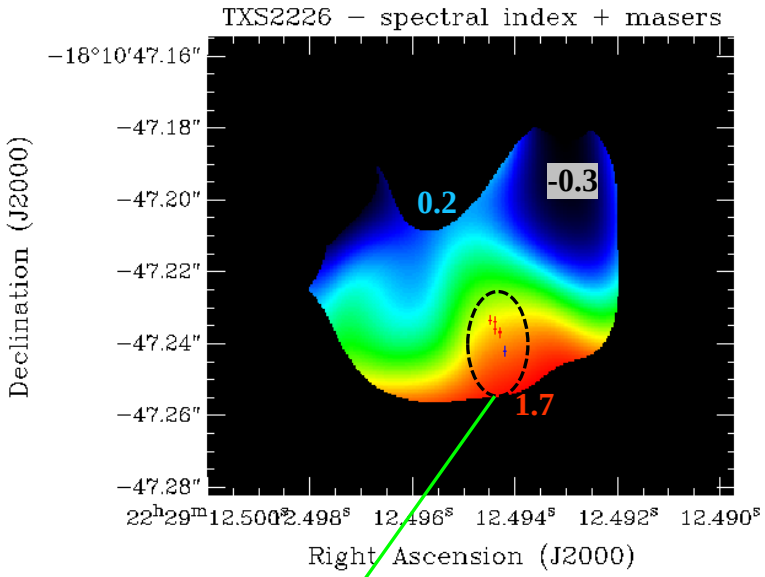


RC in TXS2226-184: the nuclear spix

$S \alpha \nu^{\alpha}$



preliminary



Masers are located where the spectral index is strongly 'inverted'!
(…and HI optical depth is larger)

→ Nucleus?

Final remarks

Individually each (mega)maser is a unique tool to derive detailed information on AGN (accretion disks, jets/outflows and molecular tori) and estimate fundamental astronomical quantities, such as distances and black-hole masses

As a class, megamasers provide a very relevant support, in particular if and when complemented by studies at other frequencies (e.g., mm/sub-mm, X-ray, etc…), to our understanding of the Unified Model of AGN

For the case of TXS2226-184, our VLBI studies allowed us to:
- Detect the maser spots with (sub)mas accuracy and derive their absolute position
- Produce multi-frequency continuum maps of the nuclear region
- Use the radio continuum scenario (distribution and spectral index) to infer the nucleus location
- Shed light on the possible maser origin, likely associated with the very base of the jet or a 'peculiar' accretion disk

Sensitive arrays with VLBI options are mandatory: SKA and ngVLA!
(see e.g. contributions to the 'VLBI in the SKA era')