

The logo for the Osservatorio Astronomico di Cagliari (OAC) features the letters 'OAC' in a bold, blue, sans-serif font. The letter 'A' is stylized with a white horizontal bar through its center.

Osservatorio
Astronomico
di Cagliari



The faint radio nucleus of the megamaser galaxy IC485: AGN or SF activity?

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Collaborators:

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Extragalactic H₂O masers in brief

VLBI observations of H₂O megamasers are the only way to image the molecular gas at **< 1pc from SMBH**.

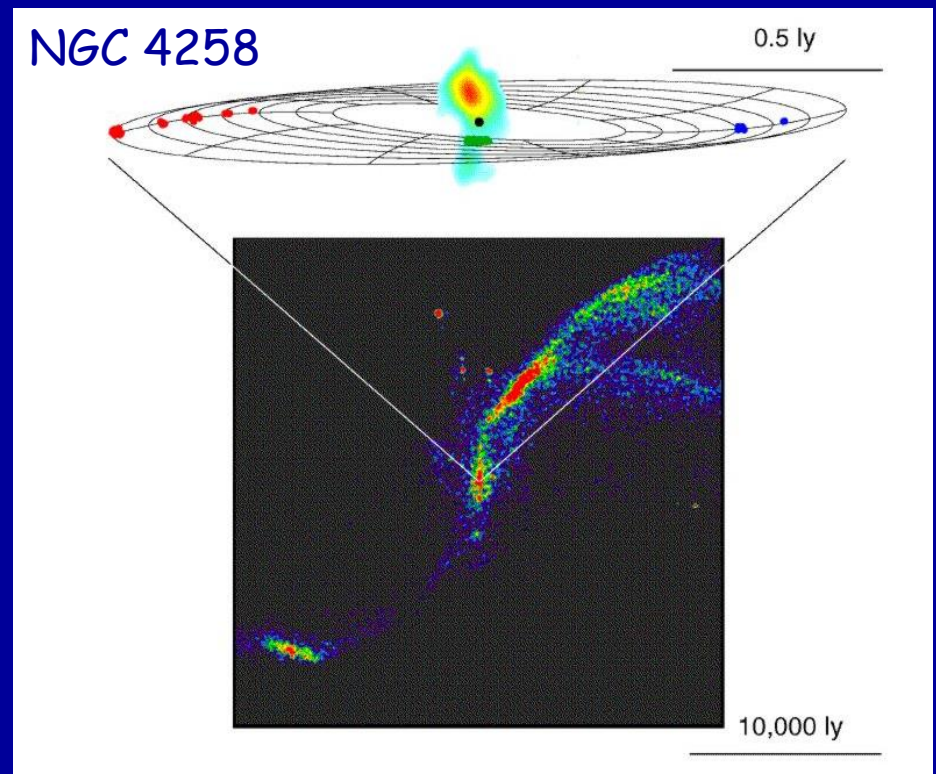
→ Structure and kinematics of the gas

Accretion discs

- **Geometry**
- **Dynamical masses**
- **Distances**

Recent works:

Kuo et al. (2011), Gao et al. (2017), Zhao et al. (2018)



Extragalactic H₂O masers in brief

Nuclear outflows

- Jets

Mrk 348

(Peck et al. 2003, Castangia et al. 2019)

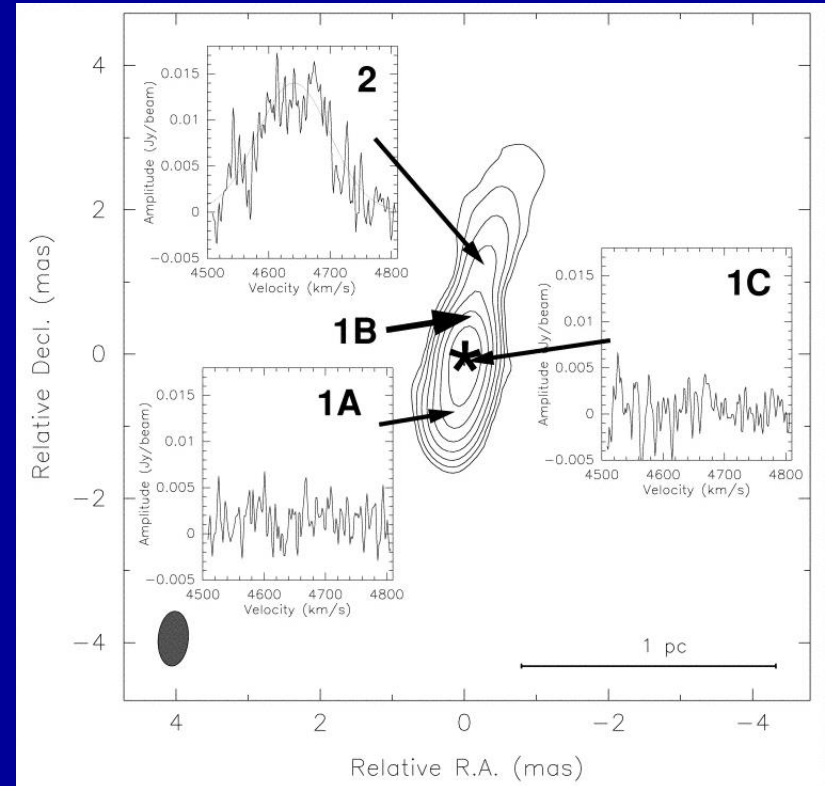
$$V_{\text{shock}}, \rho_j, \rho_0$$

- Winds

Circinus

(Greenhill et al. 2003)

Wind geometry



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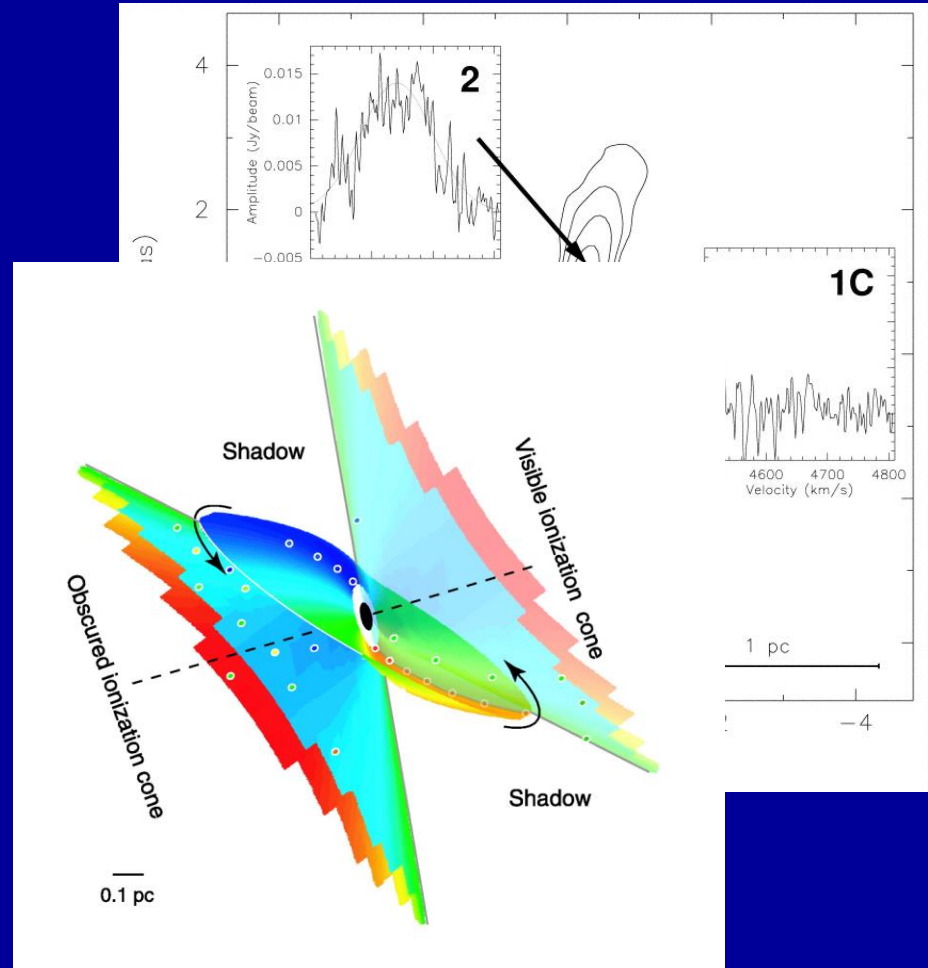
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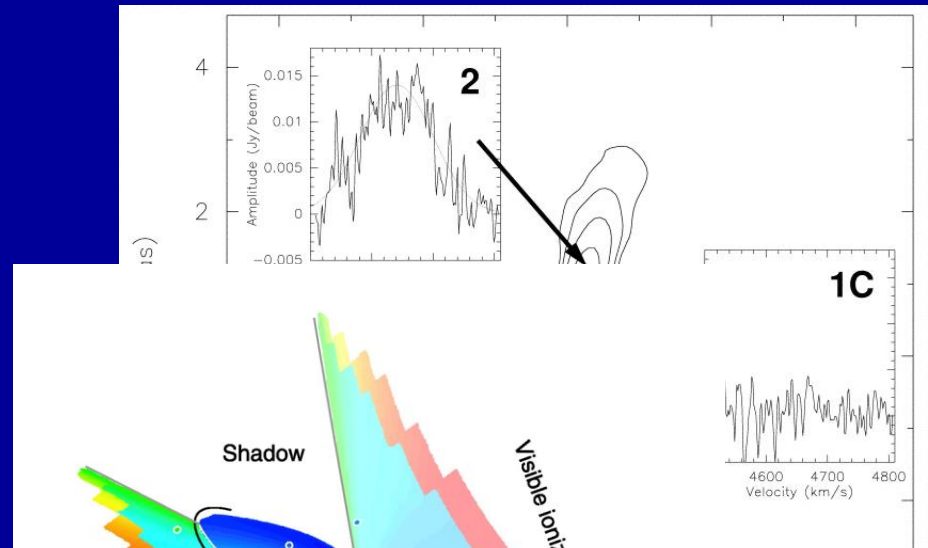
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$$V_{\text{shock}}, \rho_{\text{ij}}, \rho_0$$

VLBI radio continuum and maser observations have been used to test the alignment of the radio jets and the rotation axis of accretion disks and to pinpoint regions of strong interaction of low power jets and/or nuclear outflows with the interstellar medium in radio quiet AGNs.

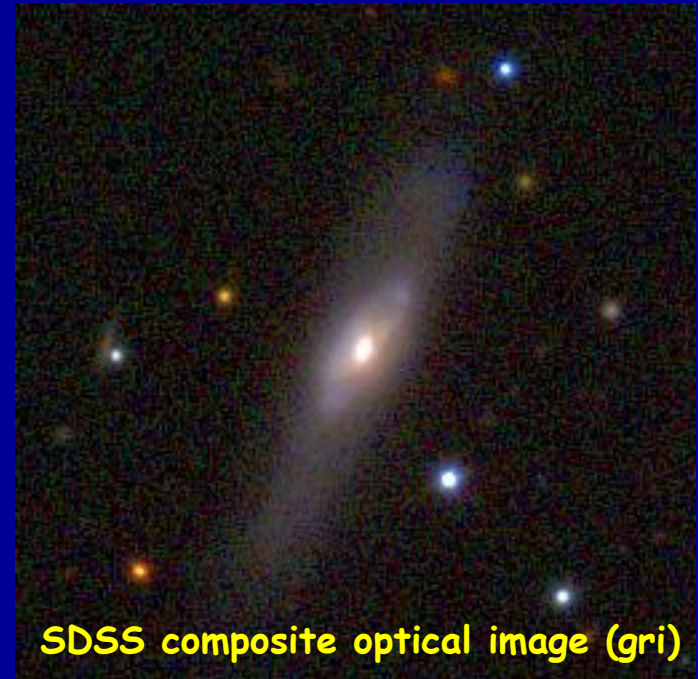


IC 485

A spiral **Sa** galaxy at ~ 122 Mpc

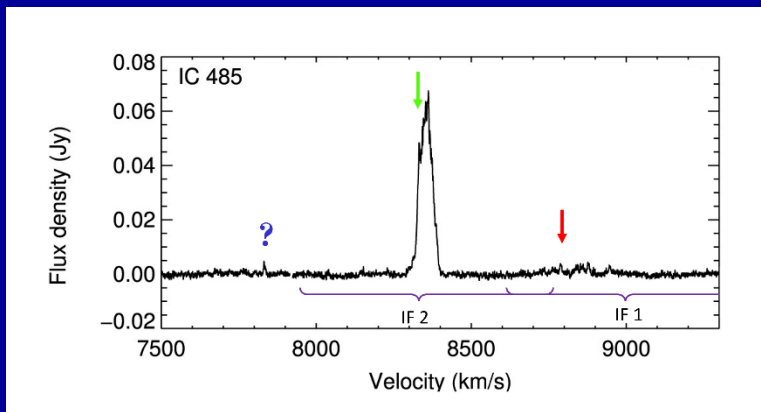
The nucleus:

- **LINER** (Liu et al. 2011)
But alternative classifications exist!
(e.g. **Sy**; Jeong et al. 2013)
- Unresolved and faint radio source
1.4 GHz \rightarrow NVSS, FIRST
20 GHz \rightarrow VLA A, Darling (2017)
- Marginally detected at high energy
 $L_x \sim 10^{40} \text{ erg s}^{-1}$ (XMM; Bassani privat. comm.)
- It is a **galaxy pair** (CGC 148-085)
Separation ~ 1.4 arcmin (~ 50 kpc)



IC 485: line emission

A luminous ($\sim 1000 L_{\text{SUN}}$) water maser was detected with the GBT:



VLBI observations in 2018

2 x 64 MHz IFs

$\Theta_{\text{beam}} = 0.9 \times 0.4 \text{ mas}$

rms $\sim 6 \text{ mJy/beam}$

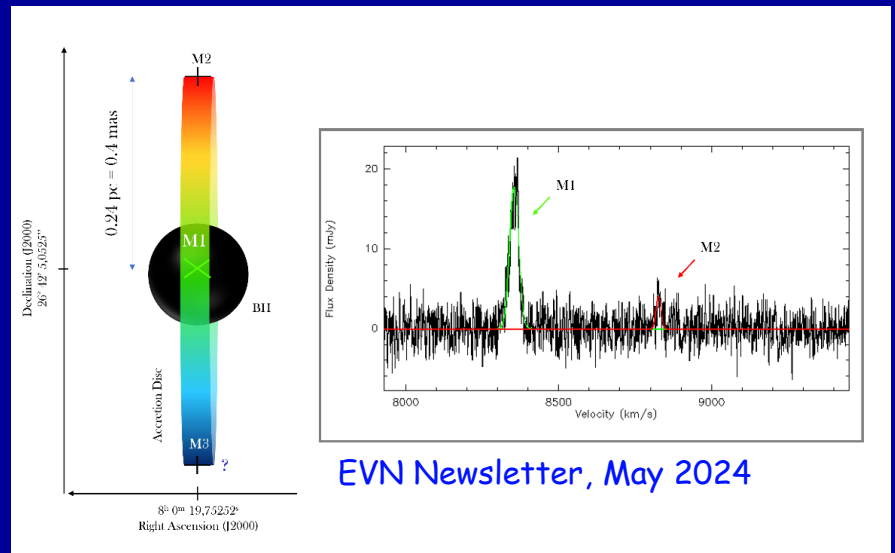
(Average GBT spectrum; Pesce et al. 2015)

In case of Keplerian rotation:

$R_{\text{disk}} \sim 0.24 \text{ pc}$

$M_{\text{BH}} \sim 1.2 \times 10^7 M_{\text{SUN}}$

(Ladu et al. 2024)



IC 485: radio continuum

Unresolved and faint radio continuum emission was detected toward IC485 at **kpc scale**:

- **1.4 GHz VLA**

NVSS, $S_{\text{peak}} = 4.4 \text{ mJy}$ (Condon et al. 2002)

FIRST, $S_{\text{peak}} = 3.01 \text{ mJy}$

According to Condon, Mathheus, & Broderick (2019) the radio emission is powered by young massive stars rather than by the AGN

A radio-compact source was detected also at **smaller scale scale**:

- **20 GHz, VLA-A** (res. 0.08" (50 pc))
- $S_{\text{peak}} = 77 \pm 15 \text{ } \mu\text{Jy}$ (Darling 2017)

IC 485: nuclear radio continuum

We observed the radio continuum emission of IC485 with the EVN in May 2018 at **1.4 and 5.0 GHz** (for details see Ladu et al. 2024)

- **No continuum source was detected above the 5σ noise level** neither at 1.4 nor at 5.0 GHz
- A **tentative source** is visible in the L band map with a peak flux density of **$68\ \mu\text{Jy}$** (3.8σ ; Ladu et al. 2024) coincident in position with the VLA source detected at 20 GHz by Darling (2017) and the main maser line

Our EVN results suggest that the **kpc-scale radio emission is mostly resolved out at pc scale, indicating a diffuse morphology \rightarrow extremely weak or radio-silent AGN?**

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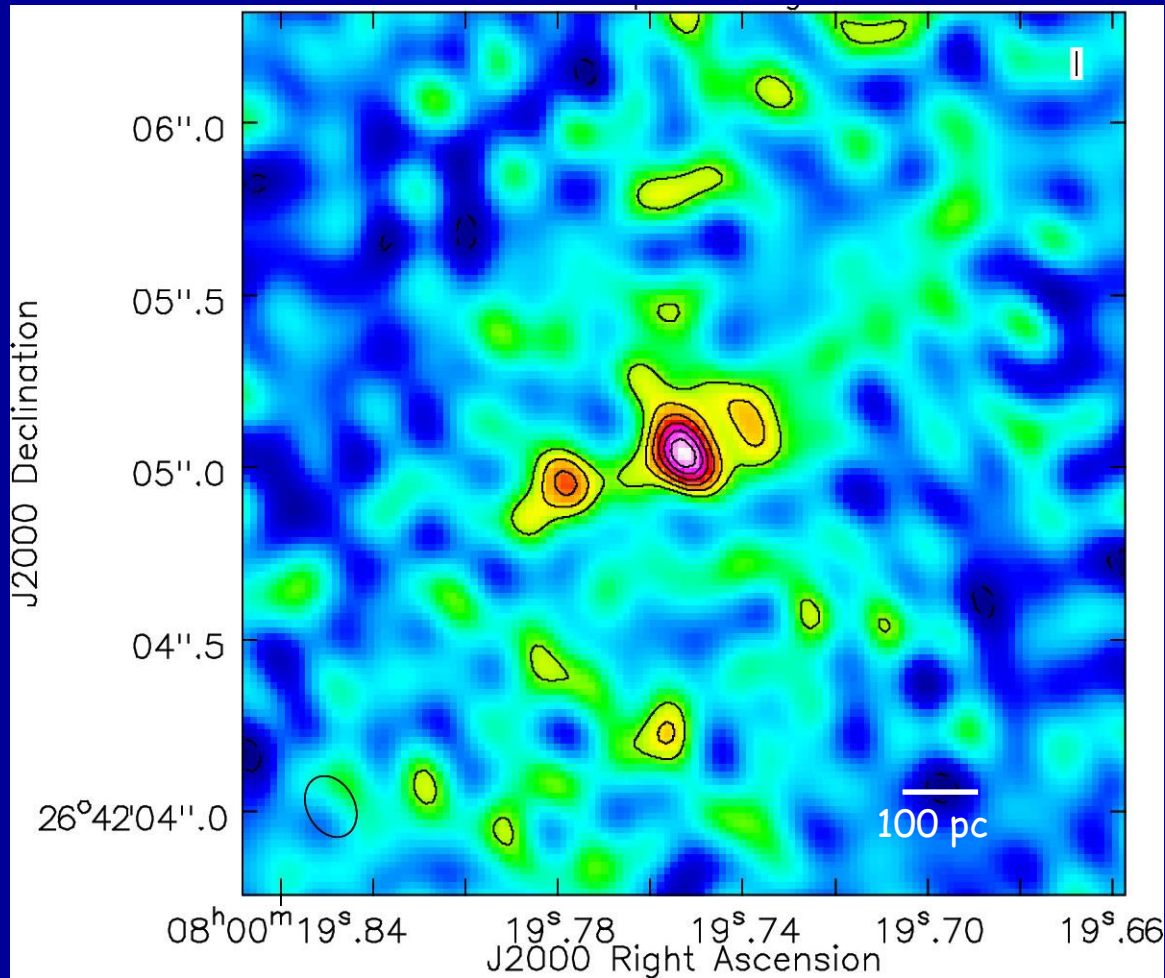
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Our EVN results suggest that the **kpc-scale radio emission is mostly resolved out at pc scale, indicating a diffuse morphology** → extremely

Intermediate resolution/scale? → **e-MERLIN** observations:

- **L-band**, March-July 2023
- **C-band**, March-April 2023

e-MERLIN maps



L-band, tapered

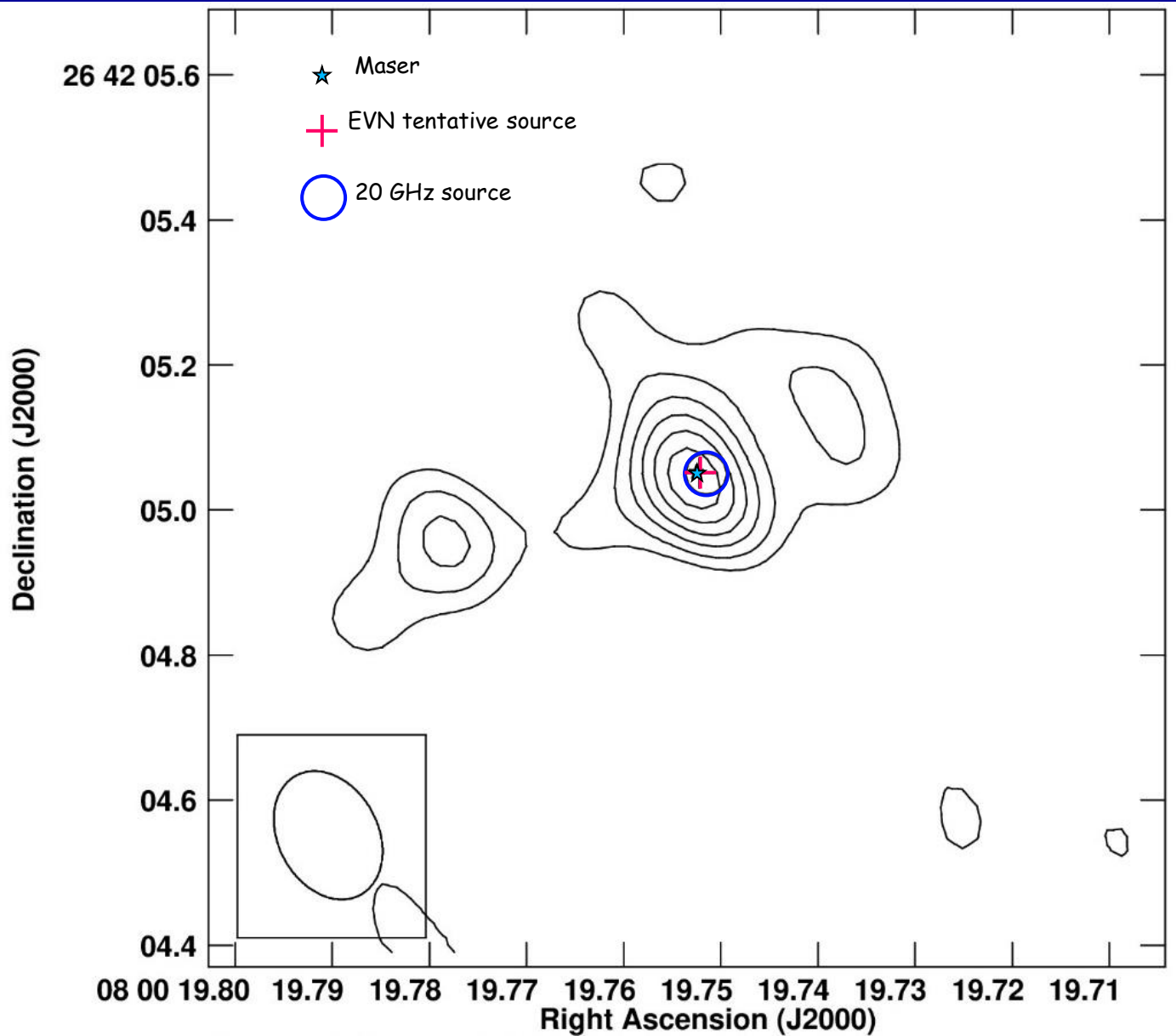
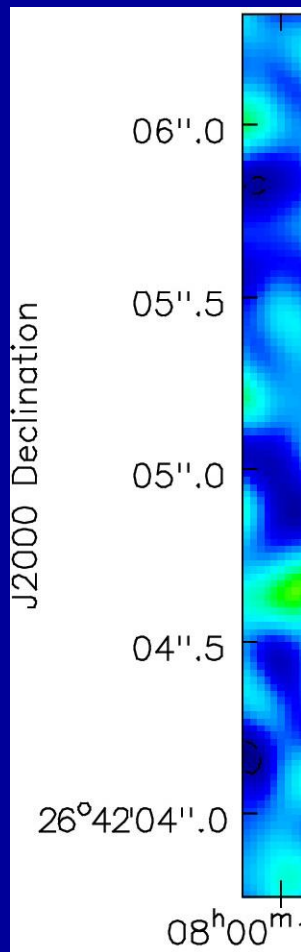
$$\Theta_{\text{beam}} = 0.19'' \times 0.14''$$

$$\text{Rms} = 14 \mu\text{Jy}$$

$$S_{\text{peak}} = 113 \mu\text{Jy}$$

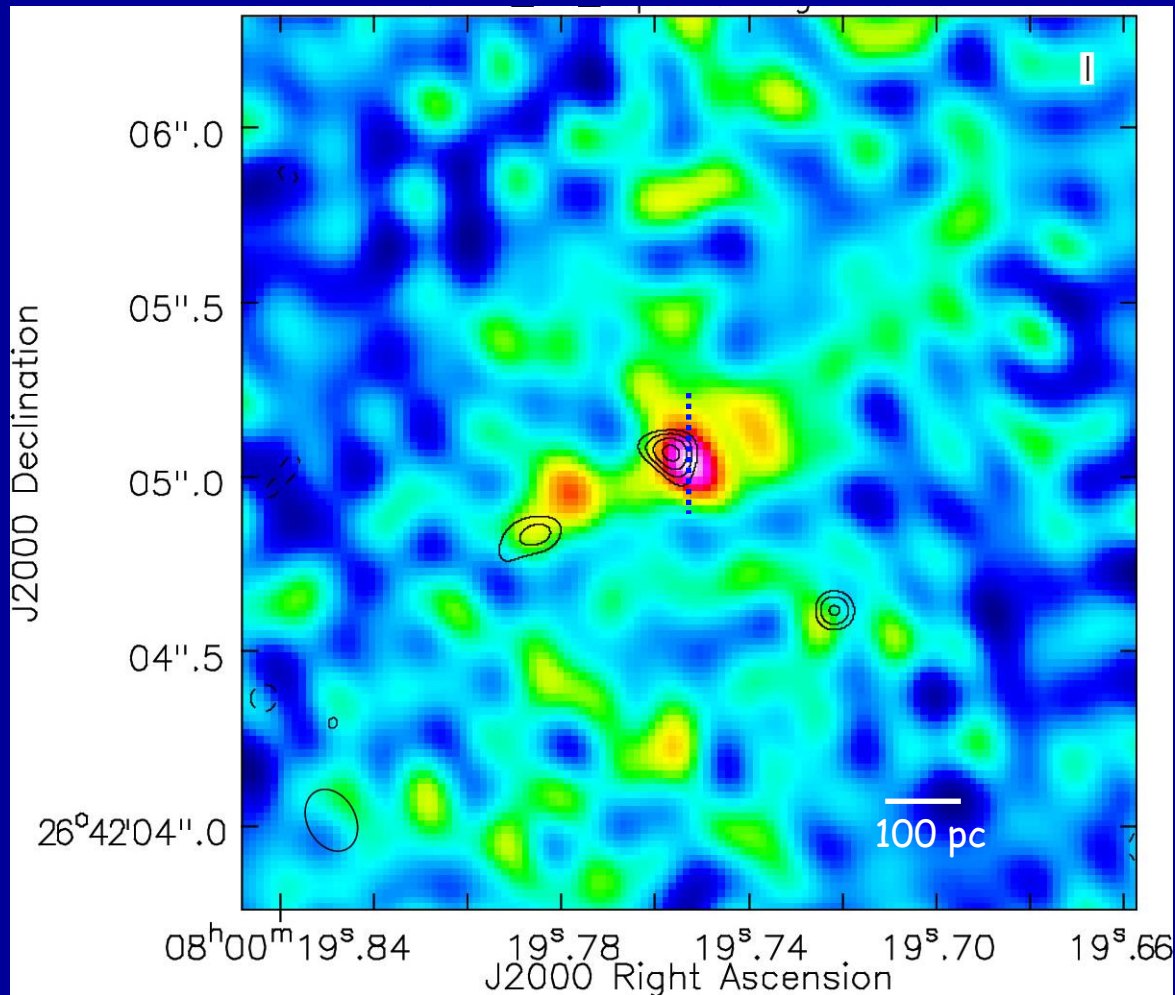
$$\text{SNR} \sim 8$$

(Castangia et al. in prep.)



(Castangia et al. in prep.)

e-MERLIN maps



Contours

C-band, tapered

$\theta_{\text{beam}} = 0.19'' \times 0.15''$

Rms = 24 μJy

$S_{\text{peak}} = 113 \mu\text{Jy}$

SNR ~ 5

(Castangia et al. in prep.)

AGN or SF activity?

Morphology of the radio emission at 100 pc scale

- A compact source surrounded by extended emission approximately in the east-west direction
 - morphology suggests it can be a weak jet or an outflow
- Orientation of the extended emission approximately perpendicular to the putative accretion disk
 - consistent to what is found in other disk-maser systems
 - Jet orientation is confined to a cone within 32° of the maser disk's normal (Kamali et al. 2019)

AGN or SF activity?

Morphology of the radio emission at 100 pc scale

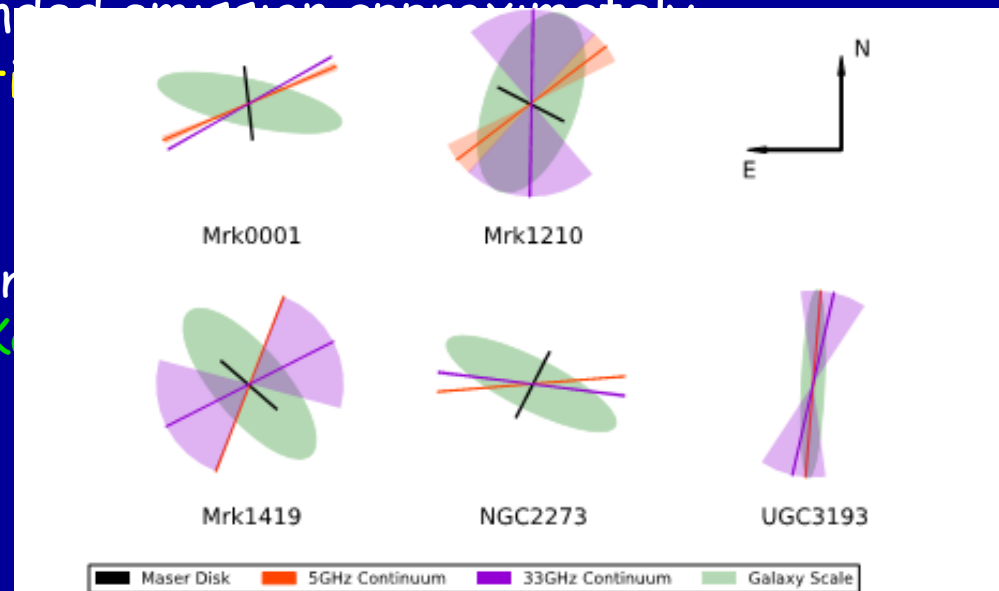
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- Orientation of the extended emission approximately **perpendicular to the putative**

→ consistent to what is

Jet orientation is consistent with maser disk's normal (K



AGN or SF activity?

Properties (L and α) of the central radio source

- $L_{1.5} = 3.2 \times 10^{20} \text{ W Hz}^{-1}$

- $L_5 = 1.8 \times 10^{20} \text{ W Hz}^{-1}$

→ too large to be produced by HII regions

→ consistent the luminosity of bright RSNs or SNRs (Arp299 or Arp220)

- Flat spectrum (S prop. to $\nu^{-\alpha}$)

$$\alpha_{1.5-5} = 0.04 \text{ (peak)}$$

$$= -0.2 \text{ (int.)}$$

$$\alpha_{5-20} = -0.17 \text{ (peak)}$$

$$= 0.02 \text{ (int.)}$$

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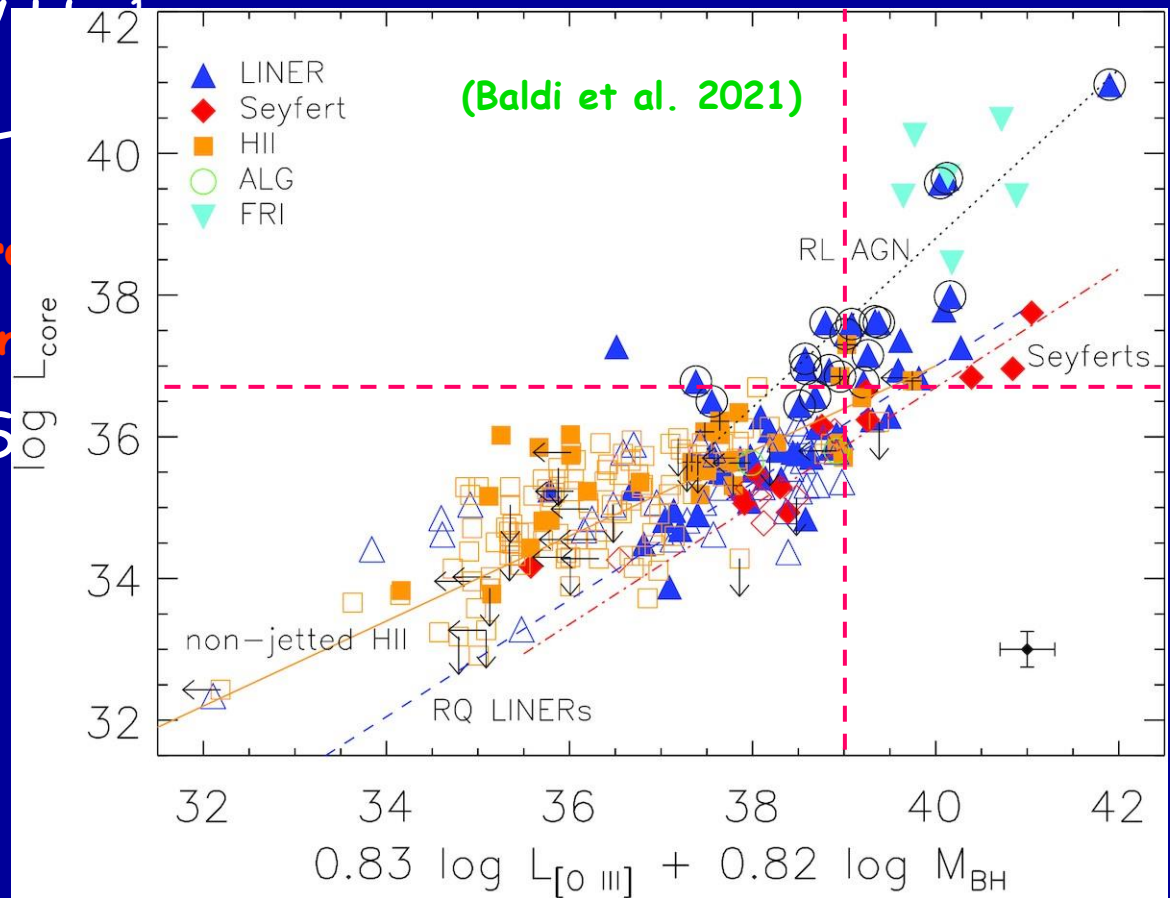
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Summary and future plans

Investigating the nucleus of IC485

• Radio Continuum emission

- e-MERLIN maps reveal a nuclear source possibly extended in the east-west direction.
- The characteristics of emission (morphology and spectral index) suggest radio emission is produced by a weak jet.
- More sensitive VLBI observations to possibly detect the core
- X-ray observations to measure the column density and derive the intrinsic luminosity

• Maser emission

- HSA observations to detect more spots
- Monitoring campaign to measure velocity drifts and a possible flare of the blueshifted lines

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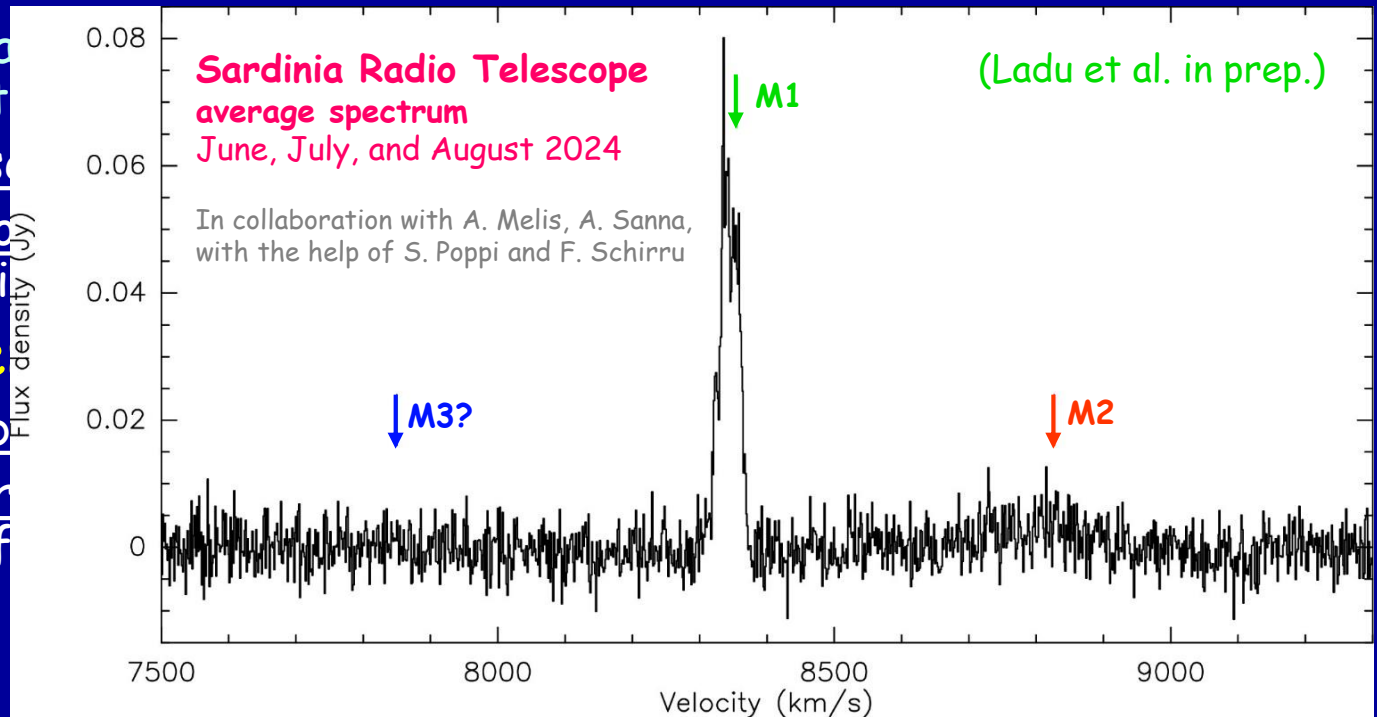
- More studies

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Our results highlight the potential of maser and radio continuum studies to shed light on the radio emission mechanism at work in radio quiet AGN