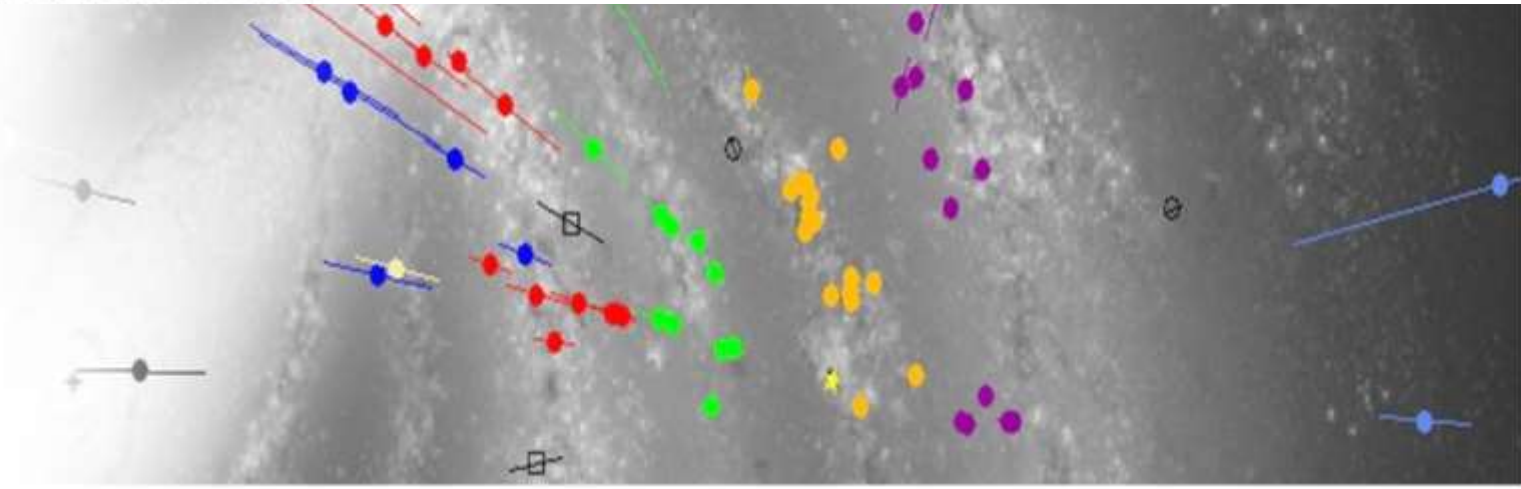
Astrophysical Masers: Unlocking the Mysteries of the Universe
IAU Symposium 336 | Cagliari, 4-8 September 2017



Radio properties of H_2O megamaser galaxies
Guide for H_2O megamaser survey

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Outline

- Introduction
- Radio properties of H_2O Megamasers
- Summary

Introduction

- Extragalactic H_2O masers

  M33 in Churchwell et al. (1977) Similar to those in MW

  Unexpected luminous masers: NGC4945, Circinus,

  Dos Santos & Lepine 1979

- **Low detection rate**, ~160 out of >4000 galaxies <4%

  Directional & small emission solid angle

  Short lifetime

  limited sensitivity, SKA → 10^{5-6} ? *Morgan et al. 2004*

- **Sample selection** → high detection rate? Henkel's talk: MM surveys

  Bright IRAS sources, *large* N_H *or* L_{FIR}, *Henkel et al. 1986,2005, Zhang et al. 2006*

  Seyfert 2s & LINERs, distance or magnitude-limited *Braatz et al. 1996,1997*

  High *Lx* & N_H AGNs or OH galaxies, *Hagiwara+2016, Wagner 2013*

Castangia's talk
Poster 15 E. Ladu+

Introduction

- **Two main types:**

✓ **Star-formation related H_2O masers** (***L* <10 $L_\odot$ Kilomasers**)

E.g. IC10, M33, IC342, NGC2146, M82, NGC3359, He2-10, Antennae, NGC4214, NGC5253

e.g., Andrea's works

✓ **AGN-related masers** (***L* >10 $L_\odot$**, megamasers**)**

@inner most region of AGN (<1pc)
related to jet or outflow (Jet-maser),
or accretion disk (Disk-maser)

➢ **Extragalactic masers → good tools for probing galaxies**

Extragalactic H_2O masers (Kilomasers)---

Powerful tools for nearby galaxies

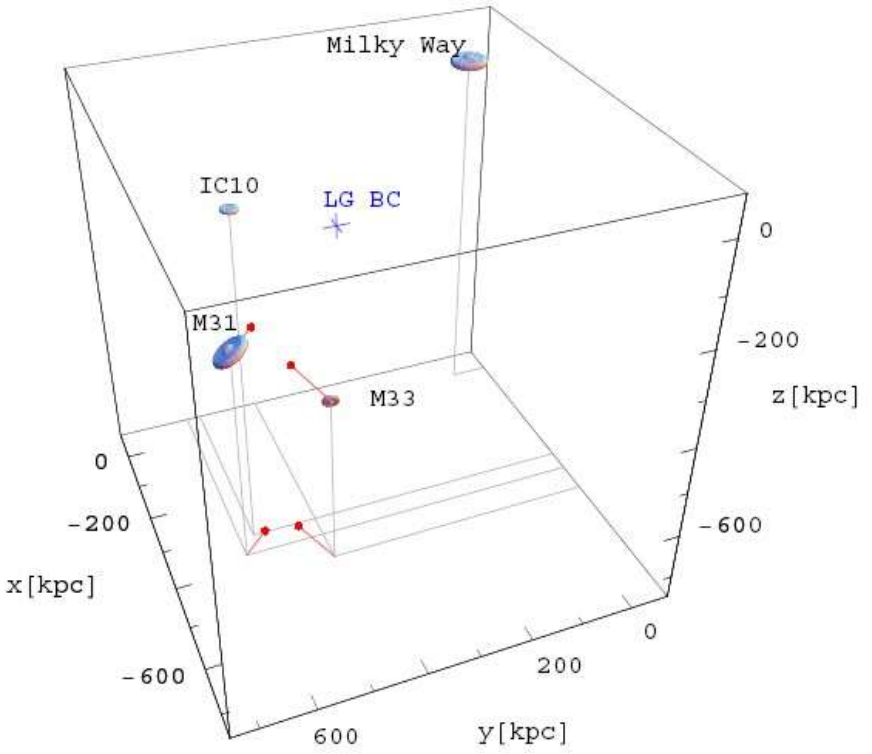
☐ SF-masers:

Nearby galaxies, similar properties to those in Galaxy

Sites of SFRs, radial velocity etc.

Proper motion, geometric distance,

Dynamical model of Local Group



Brunthaler+ 2005, Science, 307, 1440

Andrea's talk: Local Group dwarf galaxies

Disk-Megamasers:

Powerful tools for AGN/Cosmology

- Disk-maser science
  - High resolution mapping:
    - ✓ Mapping accretion disks
    - ✓ Weighing central engines:

      M_{BH}, $L_{Edd.}$, M-σ etc

      Greene's talk:
      To probe BH accretion
  - X-ray penetration

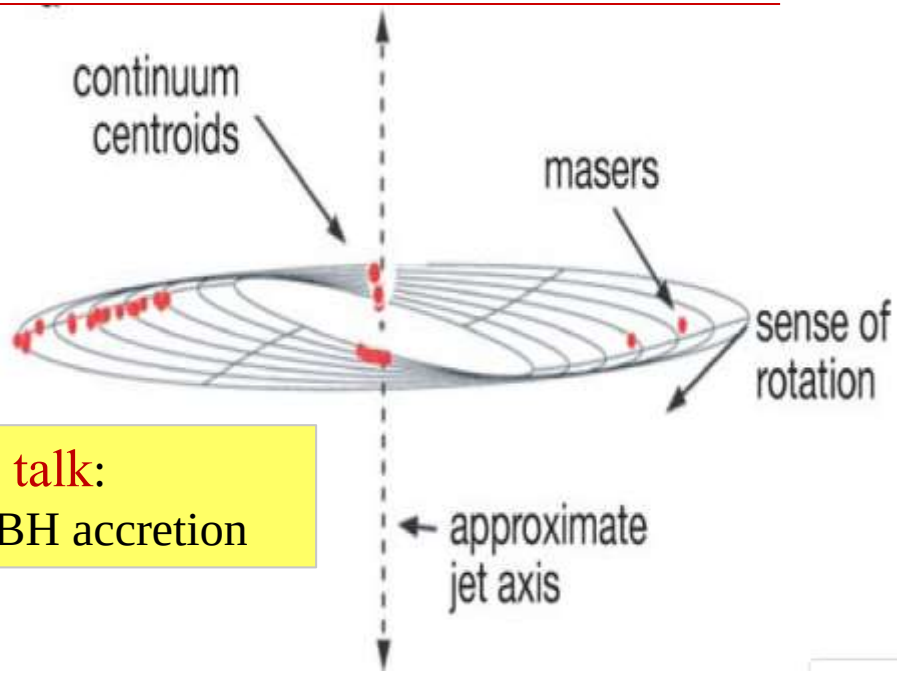
    Circumnuclear environment, L_X

    Poster 40 K. Leiter+
  - Cosmology

    Accurate geometric distance → H_0

    https://safe.nrao.edu/wiki/bin/view/Main/megamaserCosml

    Braatz's talk:
    The Megamaser Cosmology Project



H_2O Megamasers & AGN

AGN

(Ultimate energy source of H_2O megamasers)

H_2O meagmasers

Nuclear X-ray radiation

Activity of the central engine

AGN isotropic tracers

Megamaser hosts →Special?

- ***Low detection rate (~160/4000)***

  Megamaser sources → Some intrinsic properties?

Comparisons of megamasers & non-maser hosts:

- **Multi-wavelength properties of H_2O host AGN, galaxies**
- **Guide for H_2O megamaser survey**

→ Understanding better of megamaser

Megamaser hosts →Special?

Combine Fe Ka, [OIII] lines, X-ray & FIR data: Zhang et al. (2010)

- **Confirmed that H_2O masers prefer obscured hosts**
- **No obvious FIR/ H_2O luminosities correlation for AGN**

From [OIII], [OIV] lines & X-ray data: Ramolla et al. (2011)

- **H_2O masers reside primarily in X-ray absorbed sources**
- **No obvious difference between low & high-luminosity AGN-masers**

From optical data (imaging & spectroscopy): Zhu et al. (2012)

- **H_2O masers detection rate is higher, *wrt,* [OIII] & optcial Luminosity**
- **Extinction-corrected [OIII] flux: tracer of H_2O megamasers?**

Radio (6 & 20cm) data:

- **H_2O maser hosts tend to have large radio luminosity**
- **No obvious difference of radio spectral index Zhang et al. (2012)**

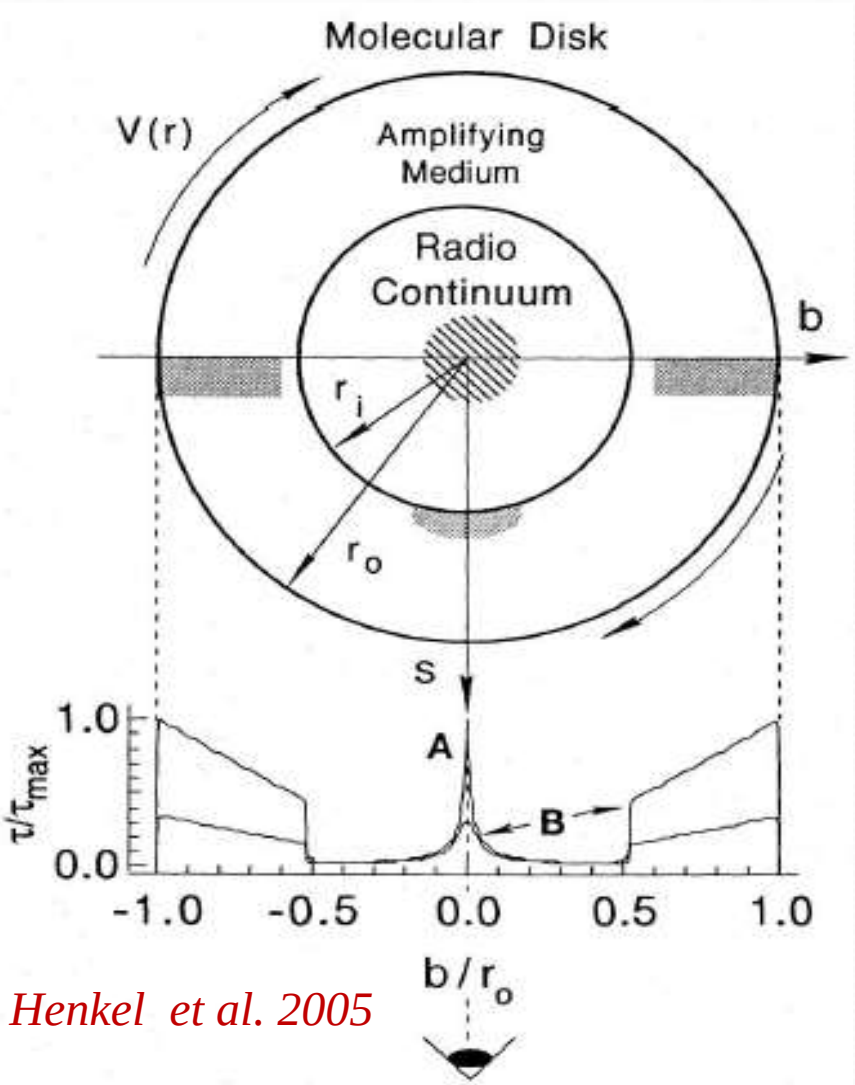
M_{BH}, L_X & Maser disk

- **No significant correlations** ***Kondratko et al. (2008); Su et al. (2008)***
- **M_{BH}-σ correlation @low mass** ***Greene et al. (2010, 2013), Bosch+(2016)***

Coexist with OHMs

- **Merging system: evolution?** ***Wagner (2013), Wiggins et al. (2015)***

Radio properties of megamaser hosts

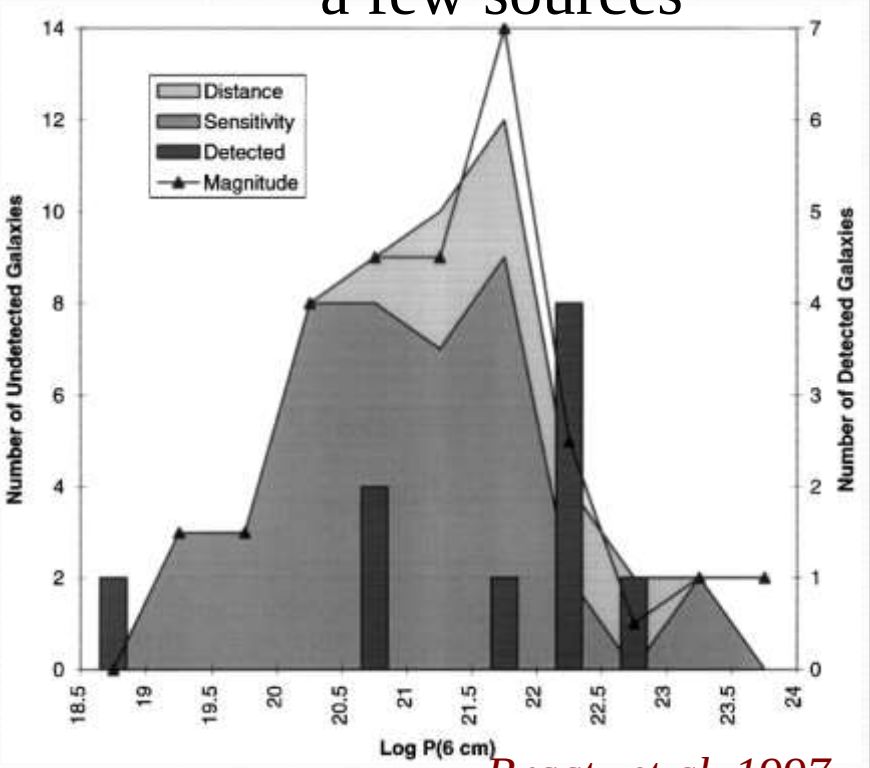


Henkel et al. 2005

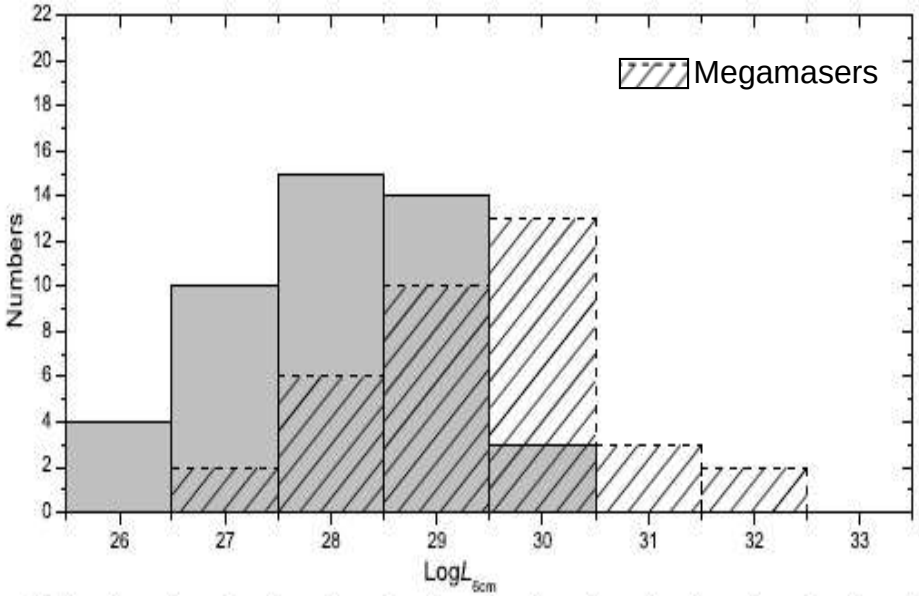
Megamasers

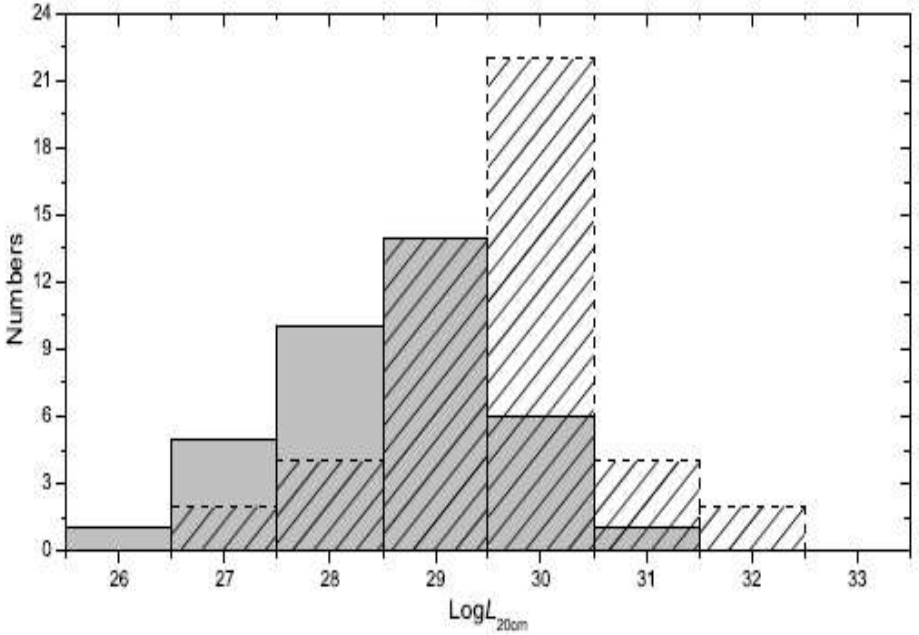
- Sy2/LINERs
- Tend to stronger radio power

a few sources



Braatz et al. 1997





✓ Maser galaxies tend to have higher nuclear radio continuum luminosities

Maser v.s. non-masing Seyfert 2s

- Collected radio obs. data
- Comparisons of radio properties between maser & non-masing Sy2s
- Maser galaxy tend to have larger radio luminosity

Zhang et al. 2012, A&A, 538, 152

Megamaser emission v.s. nuclear radio emission

→Maser galaxy tend to have larger radio luminosity

Uncertainties:

- **Data from different telescopes, ~beam size**
- **Observations at different periods ~variable**
- **…….**

To apply observations from the same telescope, for both maser and non-maser galaxy samples

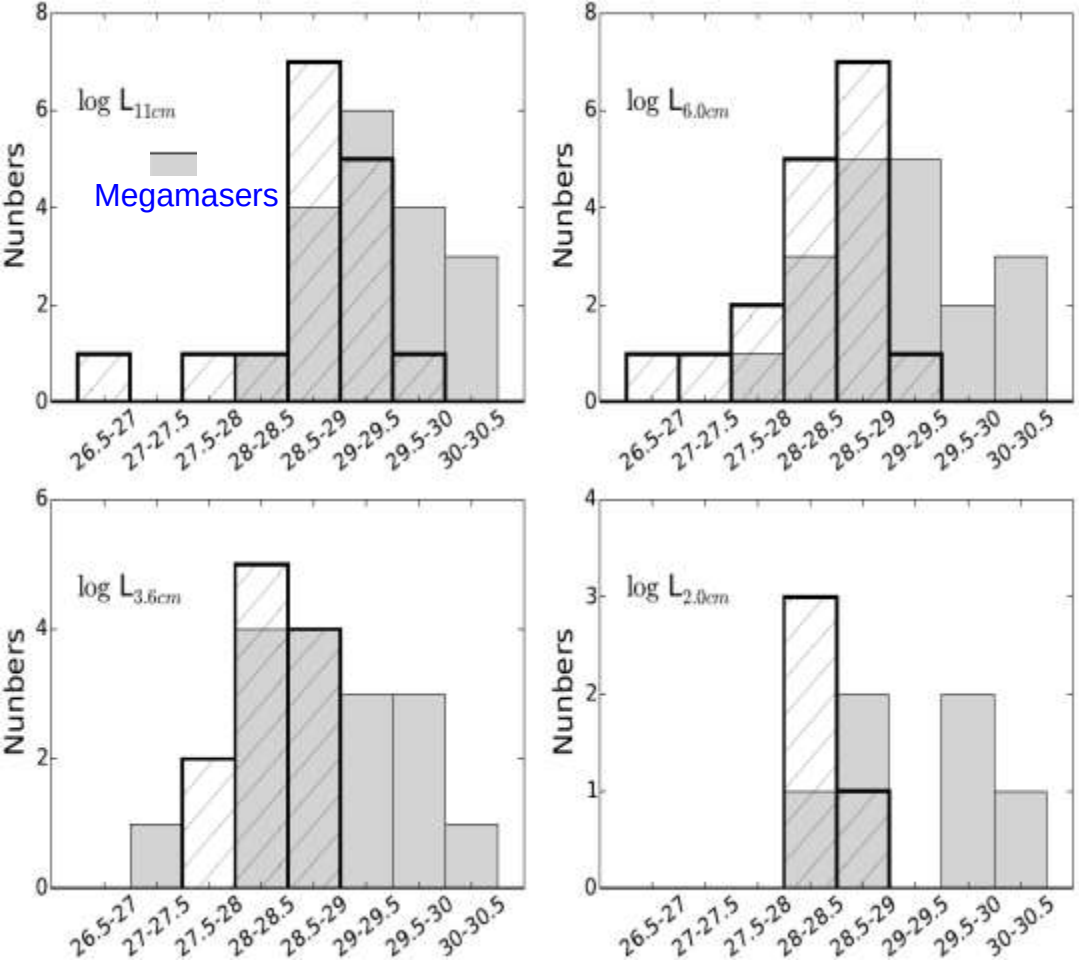
Aims:

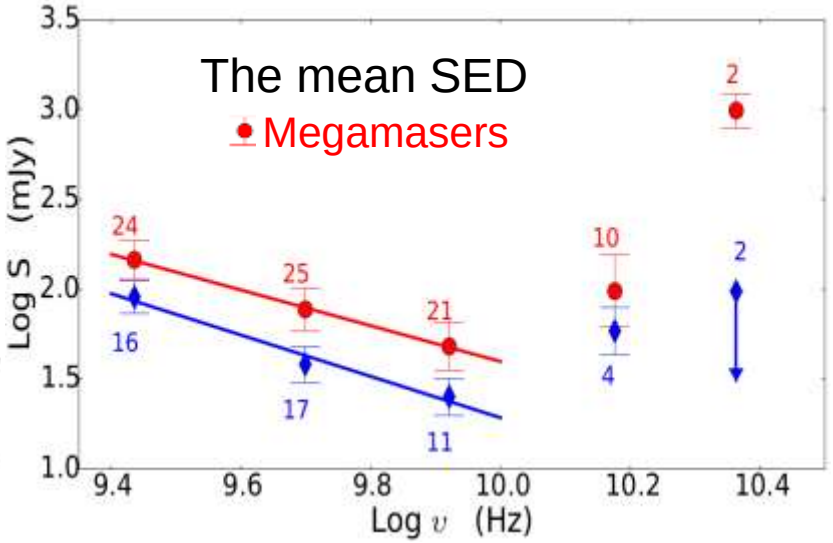
- ✓ **Multiband radio properties of H_2O galaxies**
  i.e. fluxes, spectral indices
- ✓ **Maser v.s. non-masing Sy2s**
- ✓ **H_2O megamasers v.s. radio emission of the maser hosts**

Samples: maser and non-masing Sy2s
Bands: 1.3 cm, 2 cm, 3.6 cm, 6 cm, 11cm

Observations: 2014-01-18 ~ 2014-01-20

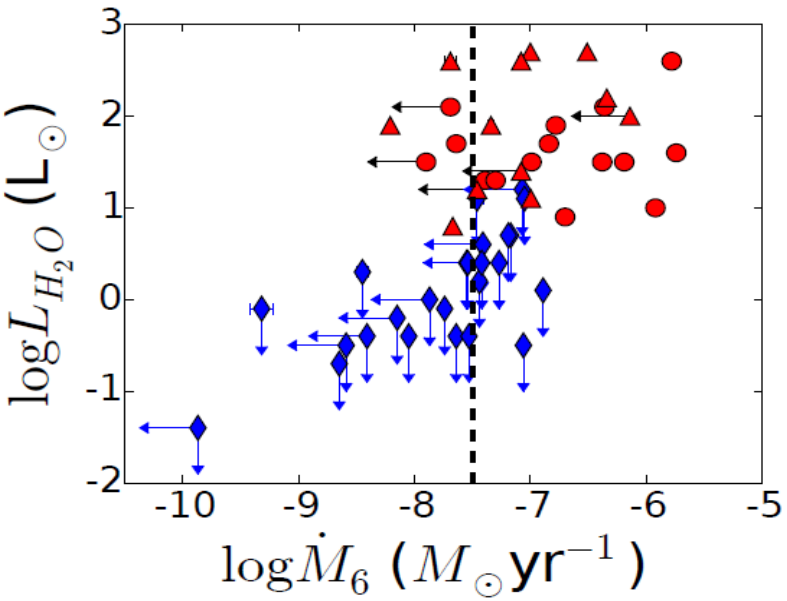






Confirmation:

Maser Sy2s have larger radio luminosity.



Liu, Zhang+ 2017, MNRAS, 466, 1608

Maser Sy2s: larger accretion rate

Maser Sy2s have larger radio luminosity

Guide for H_2O megamaser searching?

Application for observations

One pilot survey on H_2O megamaser toward one small sample of Seyfert 2 galaxy with strong radio emission



Observations (2016-01-29 ~ 2016-01-31)

- **Samples**: *from one large Seyfert 2 sample (derived from SDSS-DR7, z>0.04* Coldwell et al. 2013*)*

  $0.04>z>0.05$

  $Decl.\ \delta > -20^\circ$

  $L_{20cm} \geq 10^{29}$ erg s^{-1} Hz^{-1}

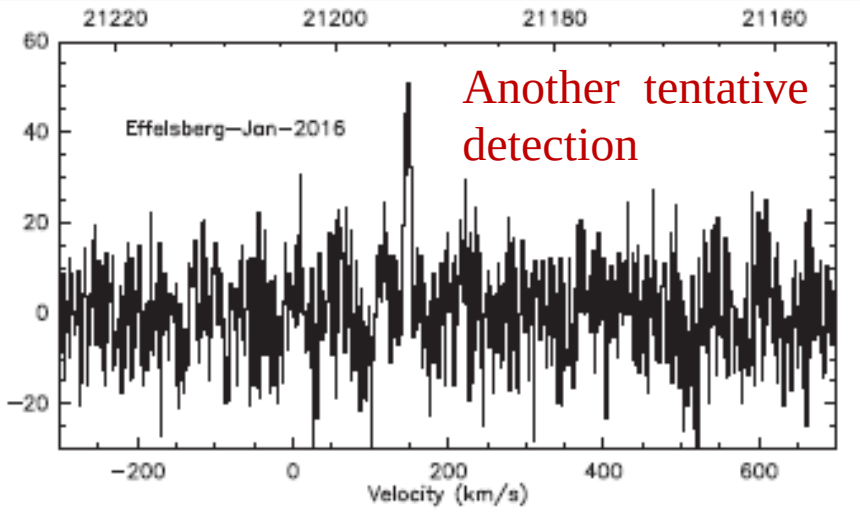


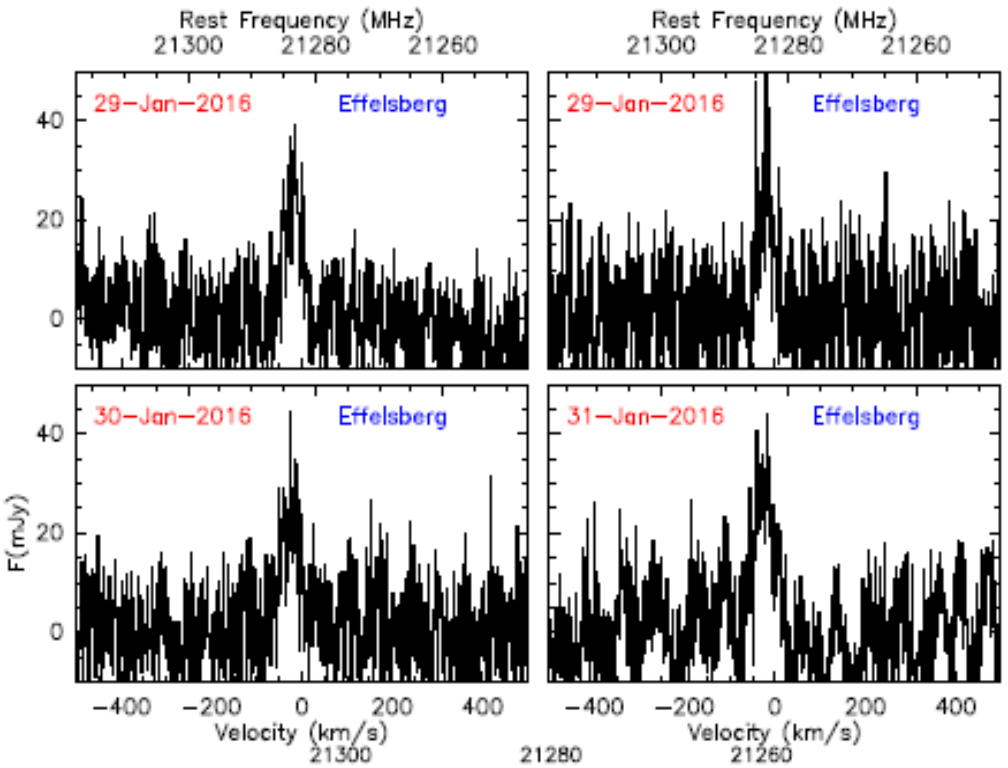
Targets:

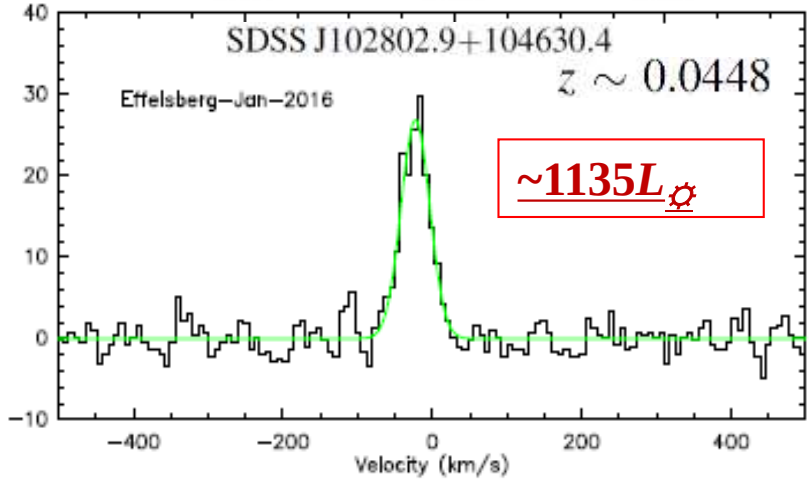
18 Seyfert 2 with radio-bright nuclei

Successful pilot survey!!

- Relative high detection rate
  ~5.5%/11%
- @Large distance







Thus, Story to be continued…

Zhang et al. 2017, ApJL, 836, L20

Successful selection technique → guiding for H_2O megamaser surveys

→A large proposal to Effelsberg

H_2O Megamasers survey toward the large Seyfert 2 sample

Proj_ID	PI	Title	Community	Category	Status
			100-m-Radiotelescope Effelsberg Proposals		
64-17	Zhang	A survey for H2O megamasers...	Everyone	regular	accepted

Expectations:

- More new distant H_2O megamasers (z>0.04, >15?)
- New megamasers --- follow-up mapping?

→highly obscured, active nuclei region
• megamaser formation





Summary

- ✓ **H_2O megamasers tend to locate in radio-bright Sy2s**

  Statistical analysis on both archival data (Zhang et al. 2012) and systematic observations (Liu et al. 2017) .

- ✓ **Successful pilot survey toward 18 radio-bright Sy2s**

  Zhang et al. (2017)

- ✓ **Expecting survey toward large radio-bright Sy2 sample**


Thanks
all~