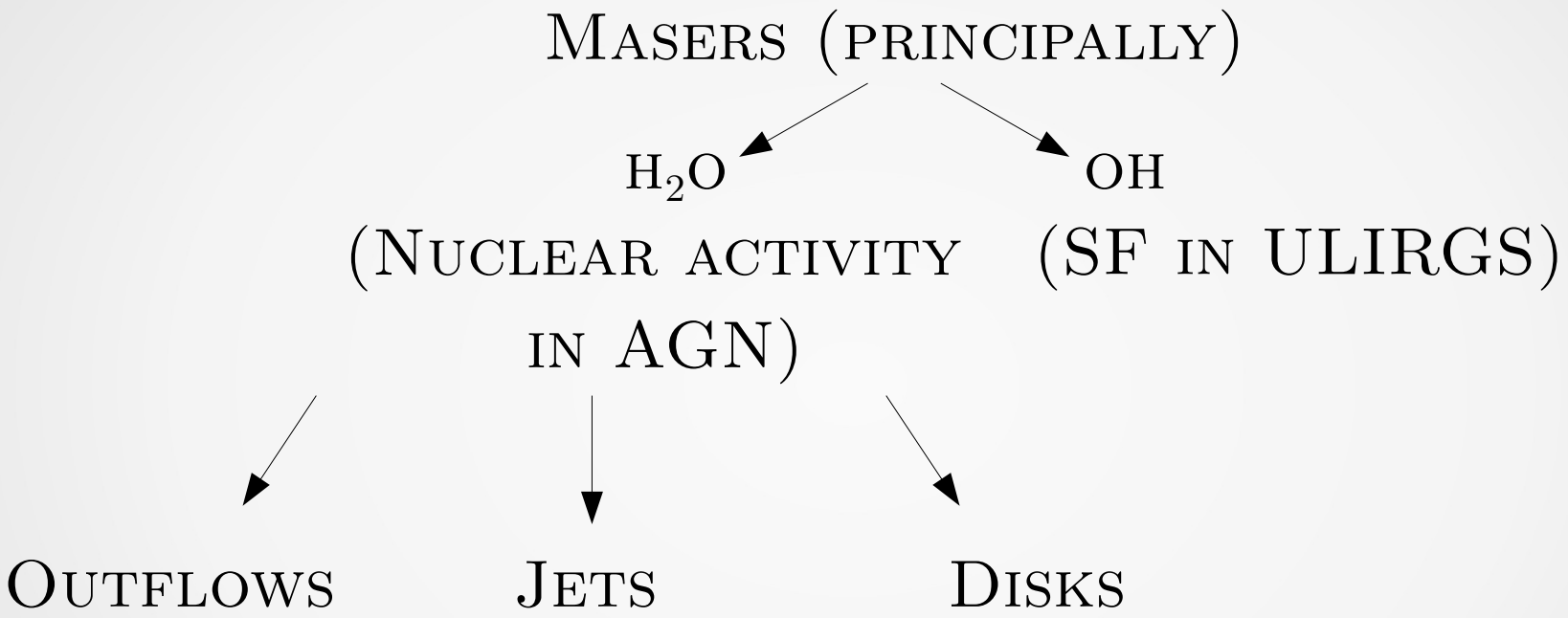
NuSTAR observations of water maser AGN

A. Masini, A. Comastri and the NuSTAR team

Contents

- Introduction
- The sample
- Results
- Conclusions

Introduction (or, what we know)



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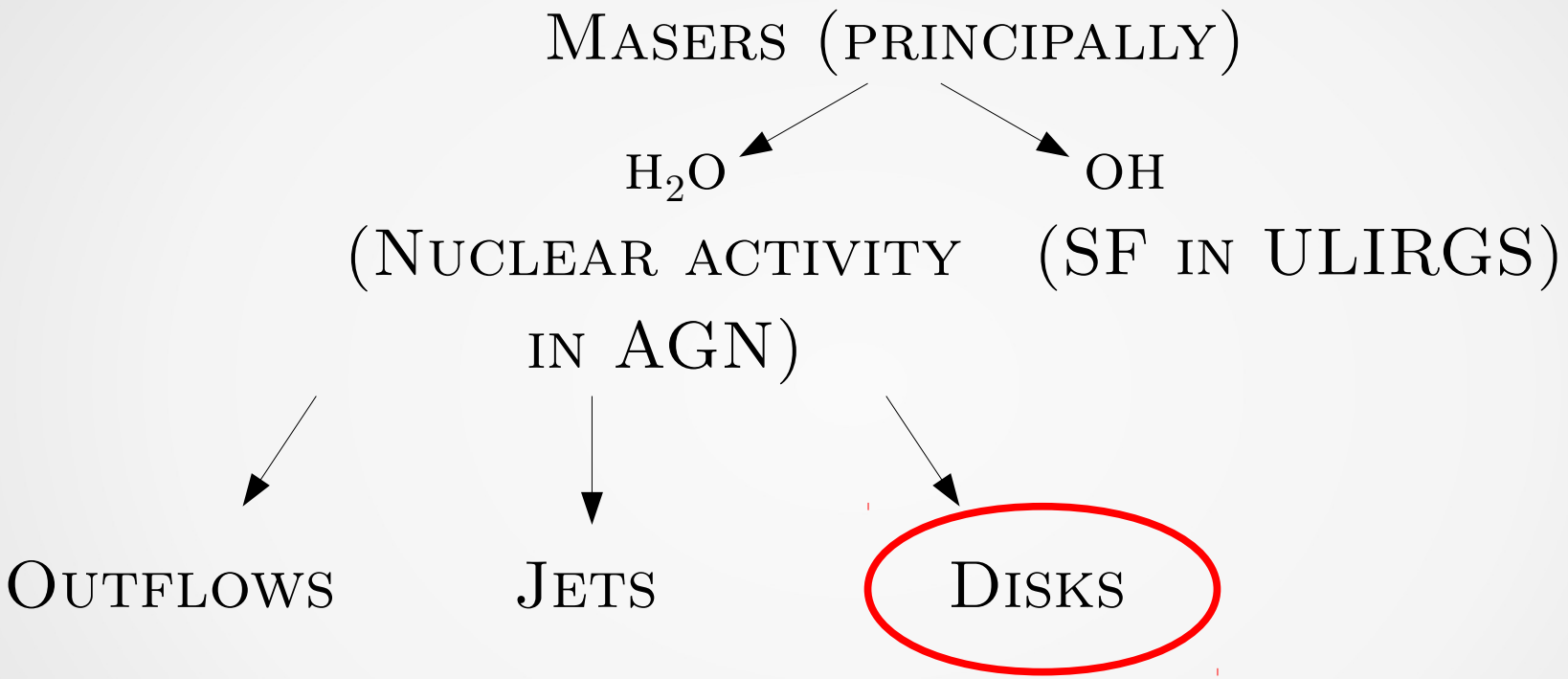

Introduction (or, what we know)

Subsample of disk water masers:

- Greenhill et al., 2008 – 76% are Compton thick
- Castangia et al., 2013 – 86% are Compton thick

obscuration ⟷ maser emission

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obscuration ⟷ maser emission

- Photon index
- Column density N_H
- Intrinsic luminosity
- …

- Most precise BH mass
- Disk parameters
- Geometric measurements of distances
- …

The sample

15 VLBI-mapped local ($z < 0.02$) Seyfert 2:

- 12 observed by NuSTAR: NGC 1194, NGC 1386, NGC 2273, NGC 2960, NGC 3079, NGC 3393, NGC 4388, IC 2560, MRK 1210 (Masini et al., in prep), NGC 1068 (Bauer et al., 2015), NGC 4945 (Puccetti et al., 2014) Circinus (Arévalo et al., 2014)
- 3 observed by XMM: NGC 4258, NGC 6264, UGC 3789 (Castangia et al., 2013)

Results

- NuSTAR hard X-ray (3-79 keV) spectral fitting using XSPEC to model heavy absorption and reflection (plcabs, pexrav, bntorus, mytorus)
- 6/9 Compton thick; in total,

  73% Compton thick, 27% Compton thin

  → **ALL OBSCURED** ($N_H > 10^{23}$ cm^{-2})
- Connection between maser emission and high obscuration confirmed

Results

- Why are disk maser AGN so much obscured?

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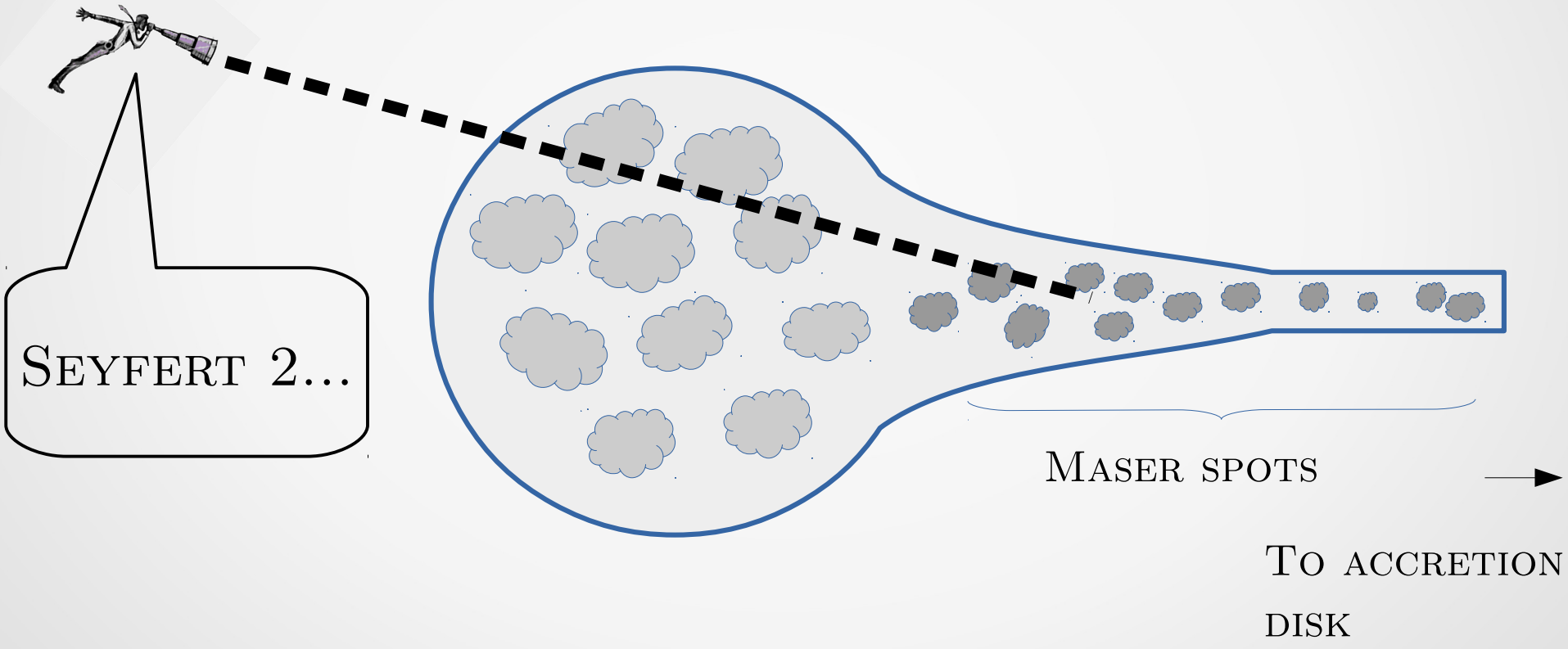

Results

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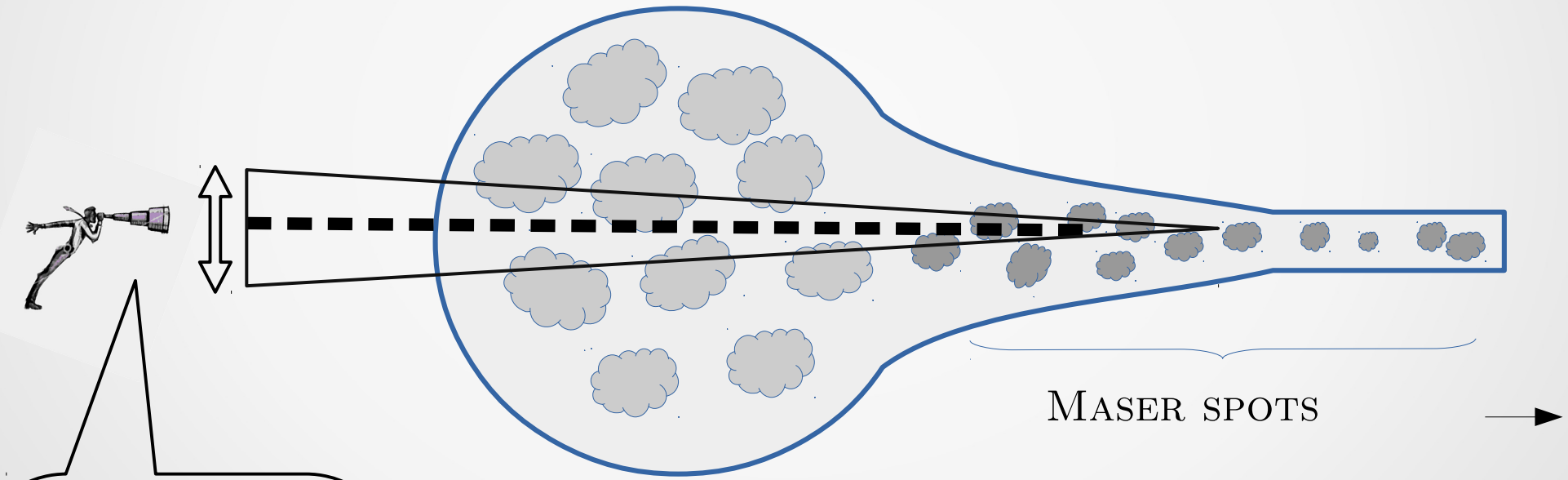
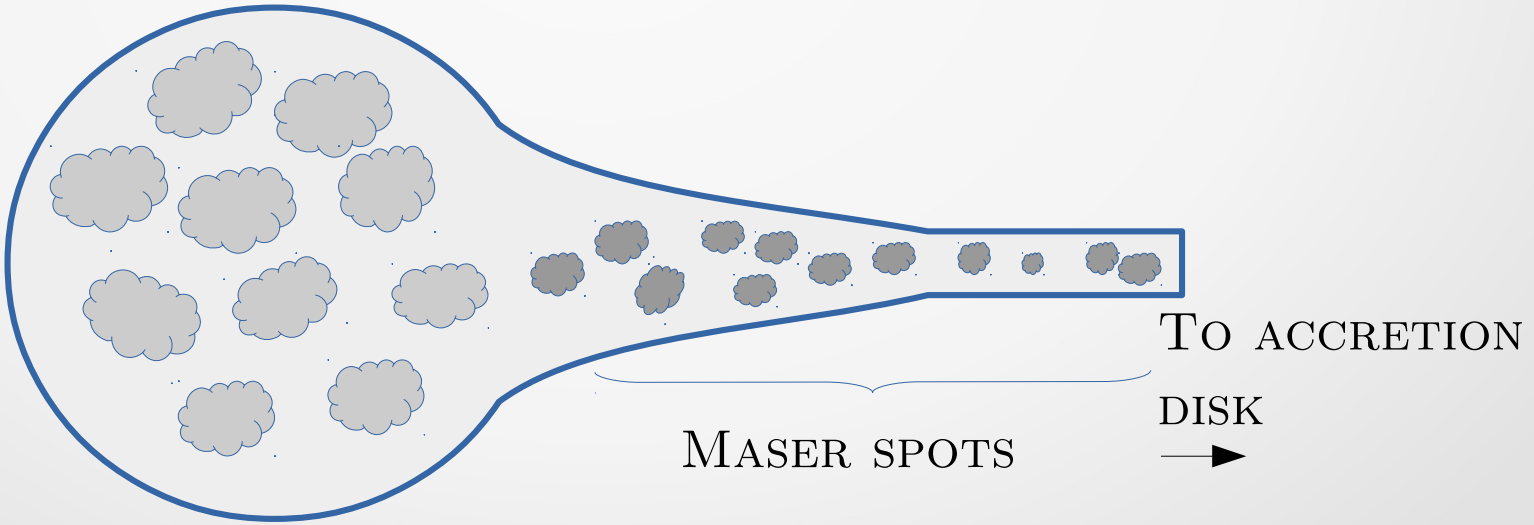


Results

Maser emission needs

- ~ edge-on geometry
- High density ($10^7 < \rho < 10^{11}$ cm^{-3}; Lo 2005, Tarchi 2012)



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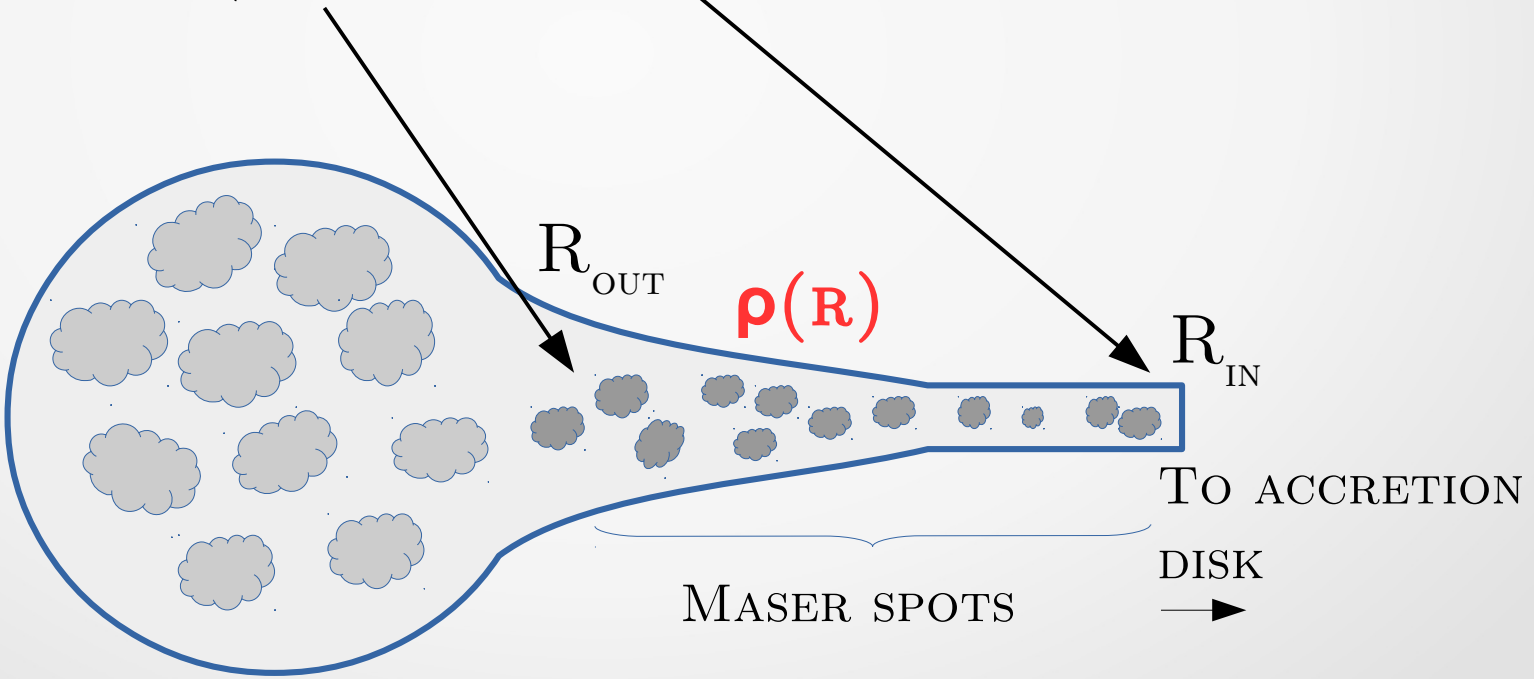
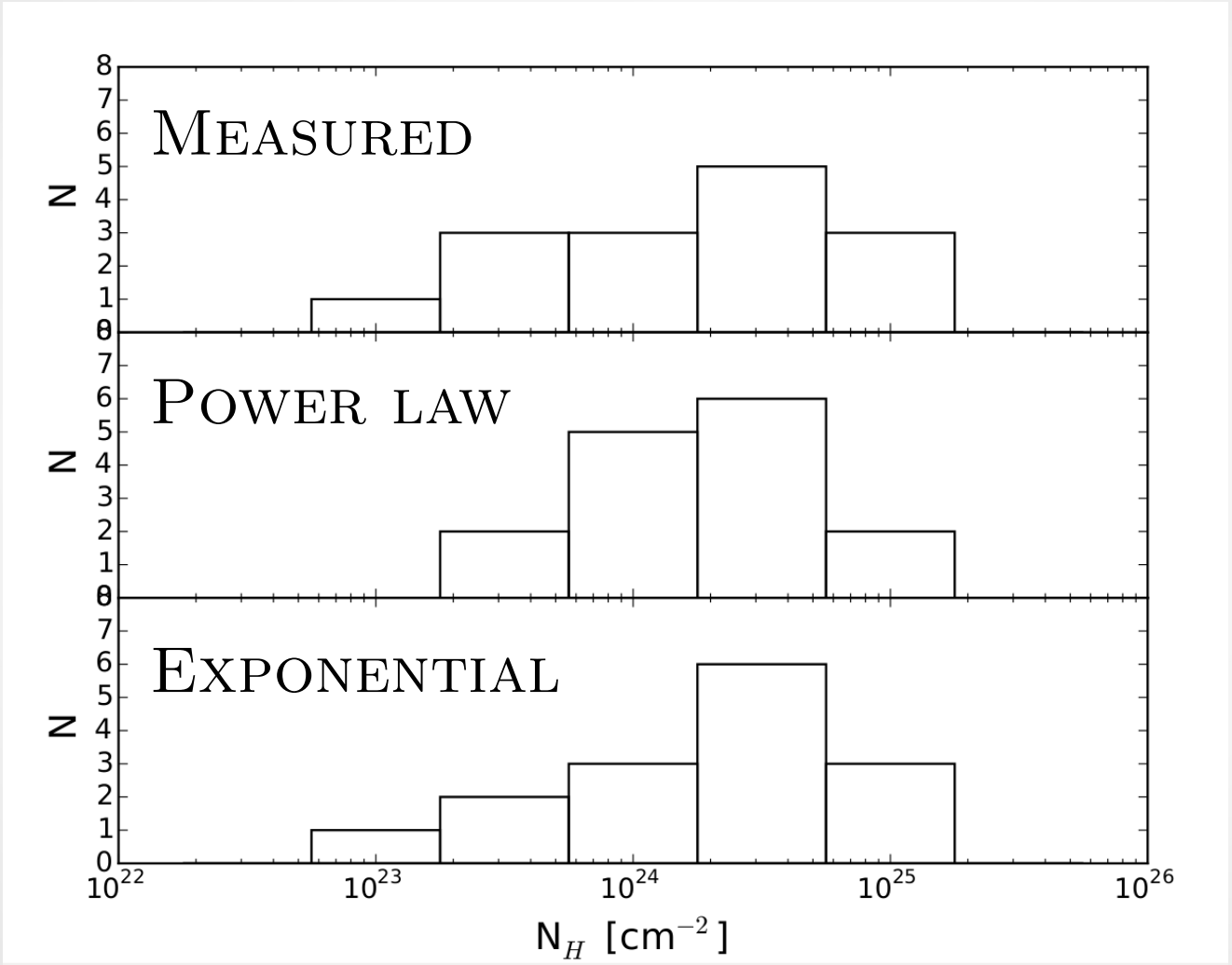


Results

- Assume a density profile for the disk, $\rho(r)$
- Assume the same profile holds for the torus
- Assume the outer torus density (e.g., 10^4 cm^{-3})
- Get the torus outer radius
- Integrate $\rho(r)$ inside the torus to obtain N_H

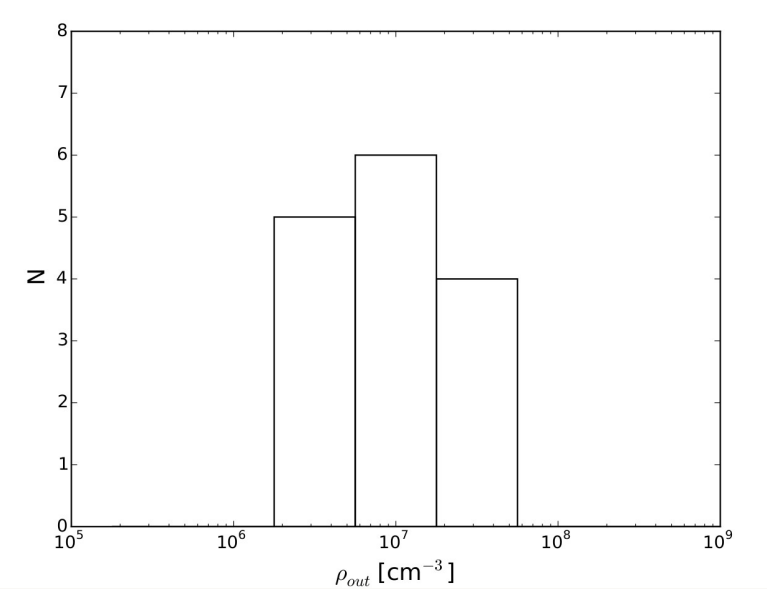
  → comparable with NuSTAR one!

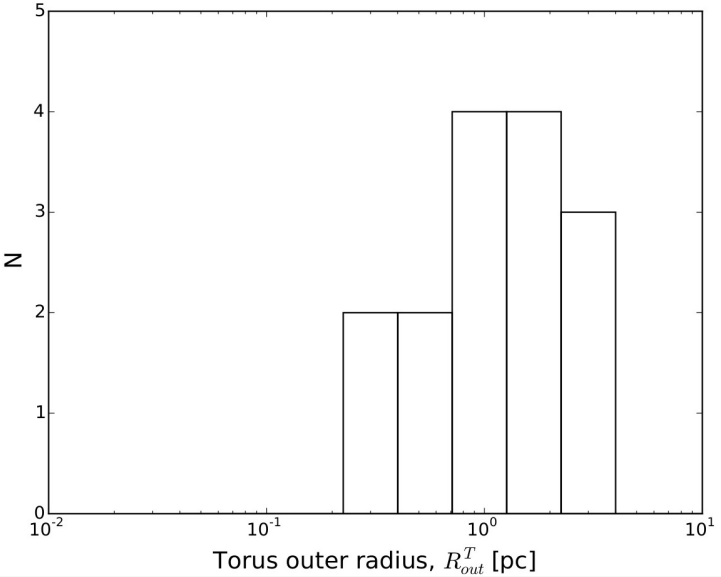
Results


Measured
Power law
Exponential
N
0
1
2
3
4
5
6
7
8
10^{22}
10^{23}
10^{24}
10^{25}
10^{26}
N_H [cm^{-2}]

Results

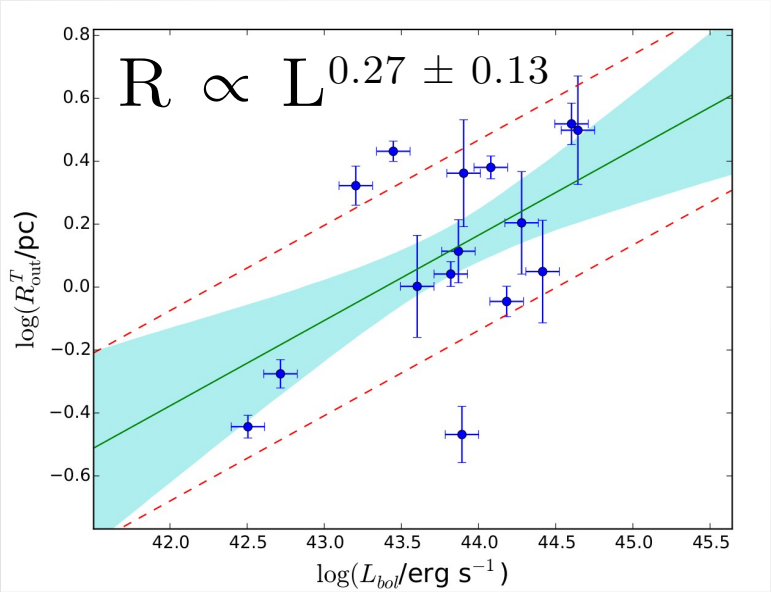
- The crucial parameter is ρ_{out}
- Reverse the problem and solve for it, using the measured N_H → distribution peaked at 10^7 cm^{-3}
- Get the torus outer radius → pc-scale size!

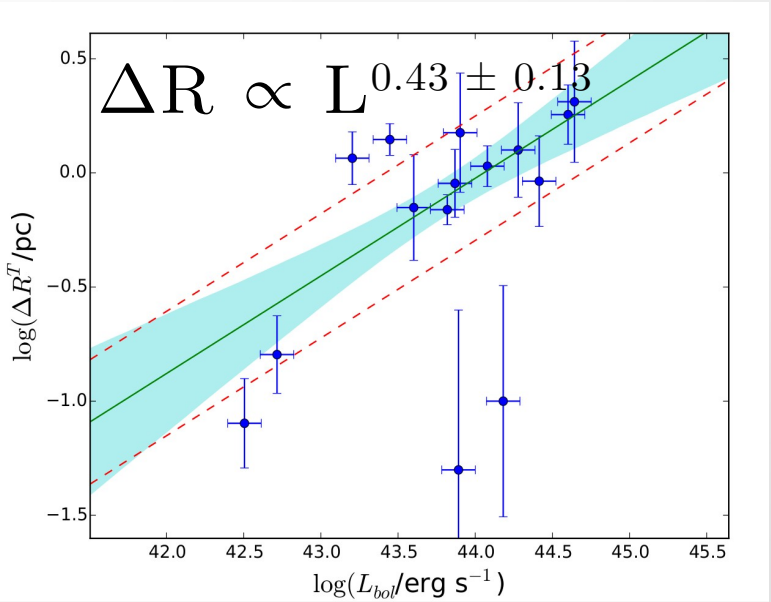




Results

- For Circinus and NGC 1068 mid-IR interferometry is available (not clear comparison – double dusty structure, projection effects)
- More interesting is the comparison with the half-light radius
- Trend with bolometric luminosity (warps?)





Conclusions

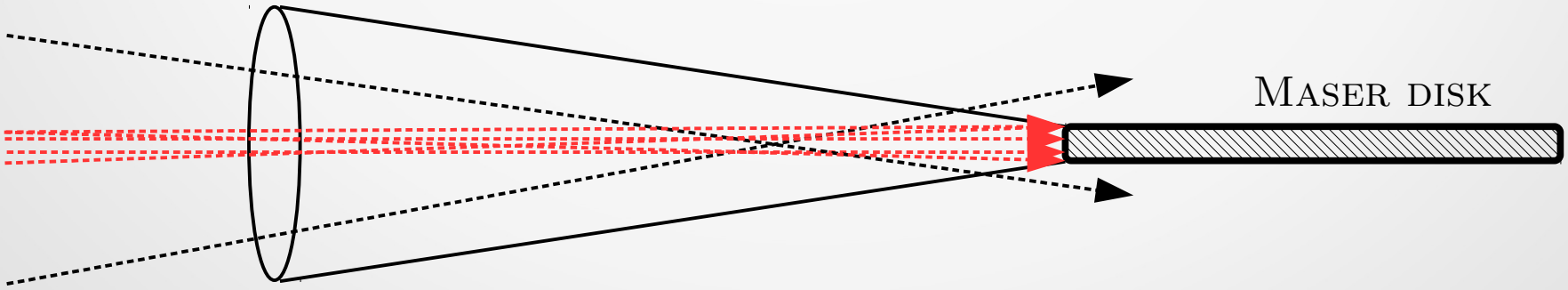
- Subsample of local disk maser: ~ 70% are Compton thick
- Could be due to a geometrical effect, with the torus inflating from the disk: co-alignment between the two
- Assuming a single density profile, one can get

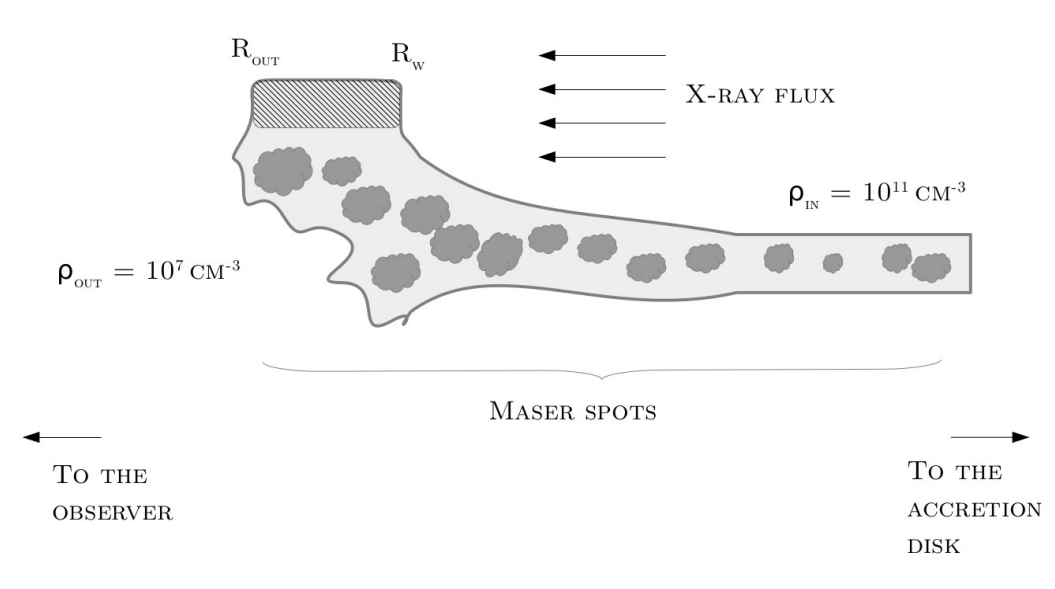
  1) N_H distribution for a sample

  2) Torus outer radius

Appendix: Super-obscuration?

- If the source is seen perfectly edge-on, the column density must be very high because of the presence of the maser disk ($\sim 10^{26} - 10^{27}$ cm^{-2})
- If the solid beaming angle allows for L.O.S. in which the maser emission is seen but the disk is not intercepted, the issue is solved



Appendix: Warps

- In some cases, warps in maser disks could provide low covering factor and/or fast N_H variability
- warps of depths 0.003 – 0.1 pc could provide enough obscuration → no torus needed