GRA4MAT and the next steps for AGN research with the VLTI

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The Circinus galaxy on sub-parsec scale
## Where is the torus?

3 component model of the dust emission in the Circinus galaxy

Jud+ 2016

$\lambda = 12\,\mu m$

$\theta = 70°$ $\phi = 60°$

Offset δDEC [mas]

Offset δRA [mas]

N

E

ionization cone

maser disk

MIDI model image (Tristram, LB+ 2014)

1 pc

offset δRA [mas]
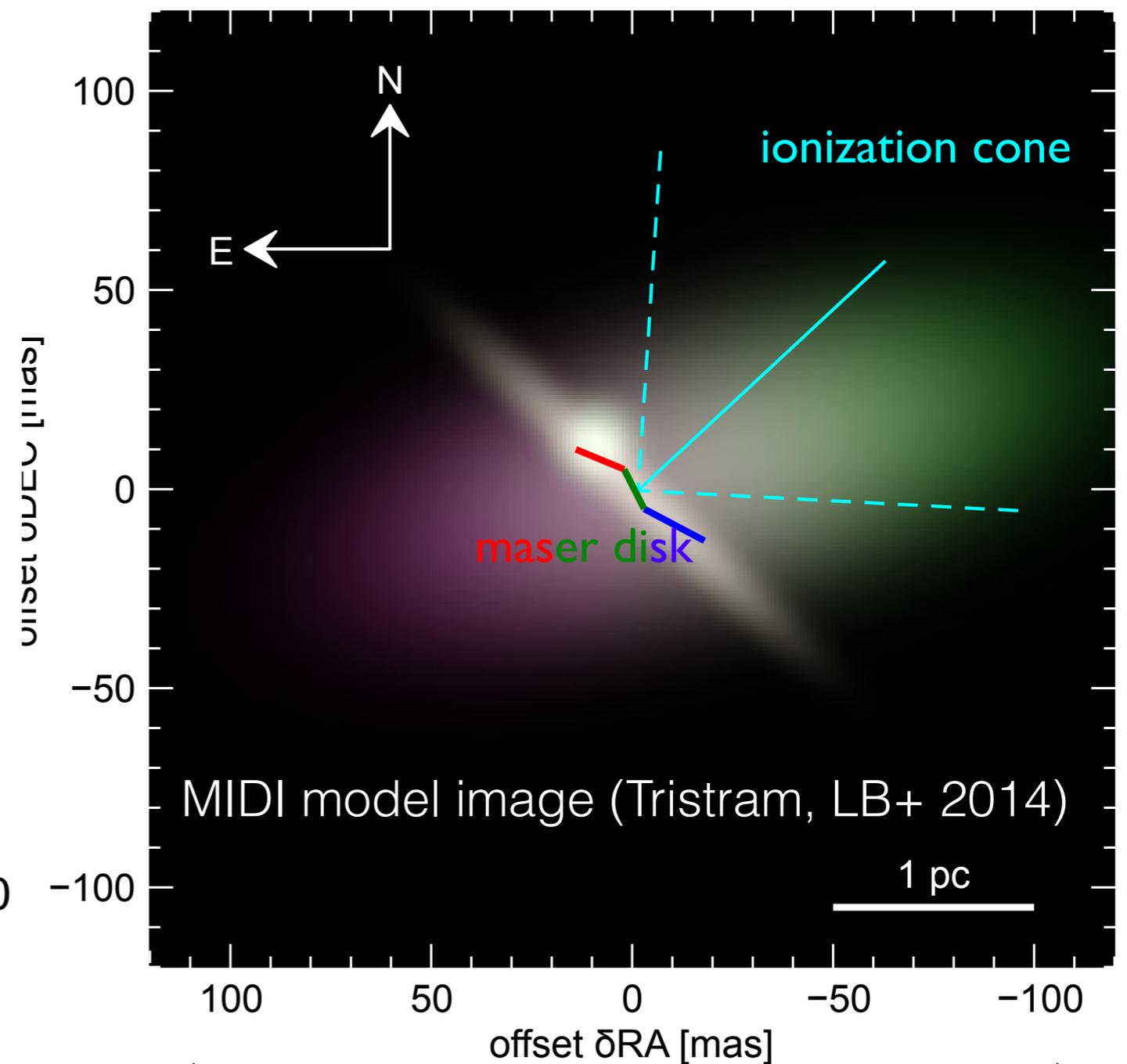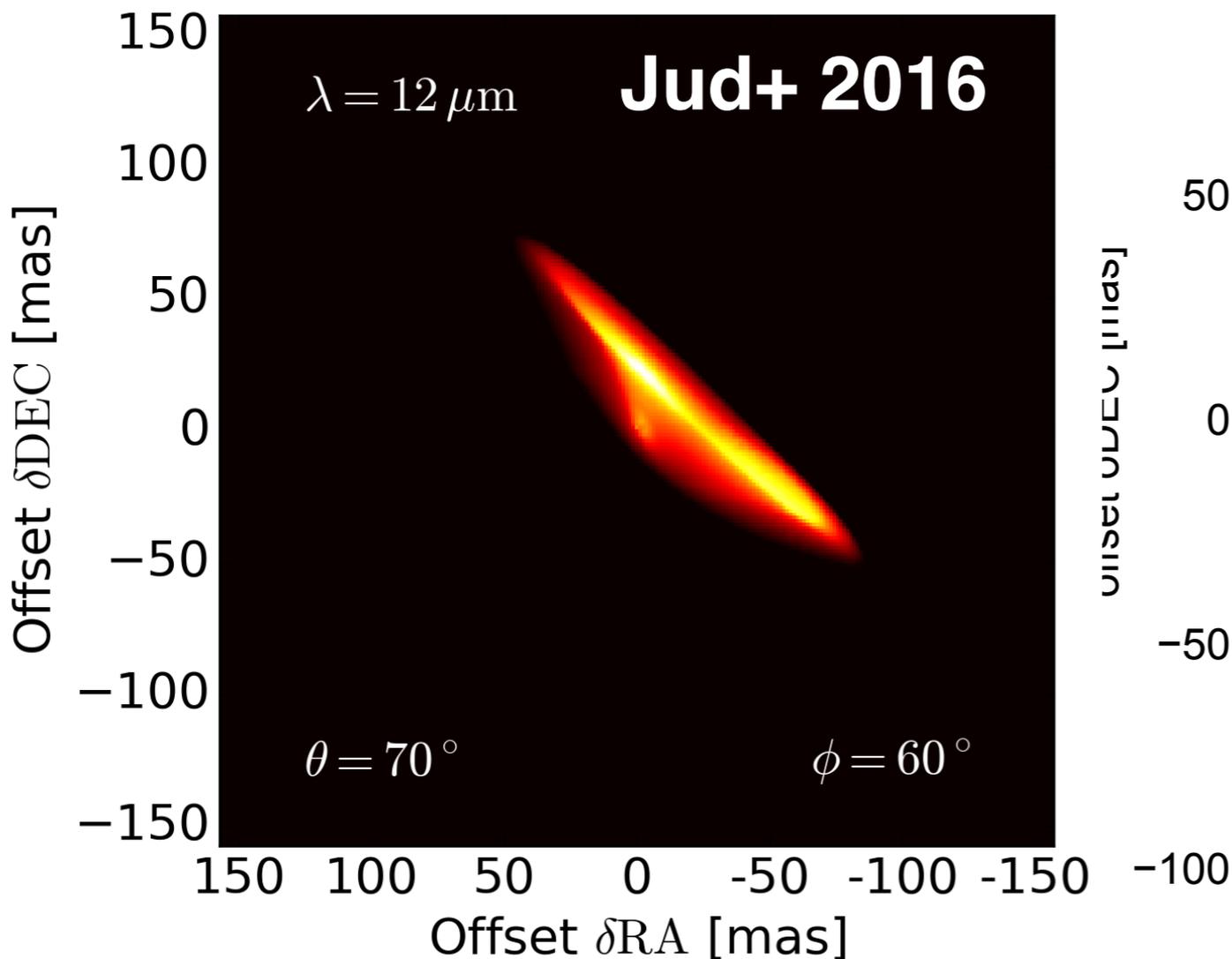
0.2 arcsec (4 pc)

Fainter sources: What to expect

The Circinus galaxy

at 4 Mpc

How (we thought) to scale an AGN:
- inner radius: $r_{in} \sim L^{0.5}$
- observed angle: $\Theta \sim r_{in}/D$
- observed flux: $F \sim L/D^2$
➡ $\Theta \sim F^{0.5}$

Fainter sources: What to expect

The Circinus galaxy as a faint AGN

at 18 Mpc

maximum UT baseline

$\Theta \sim F^{0.5}$: expect fainter objects to be well resolved as well
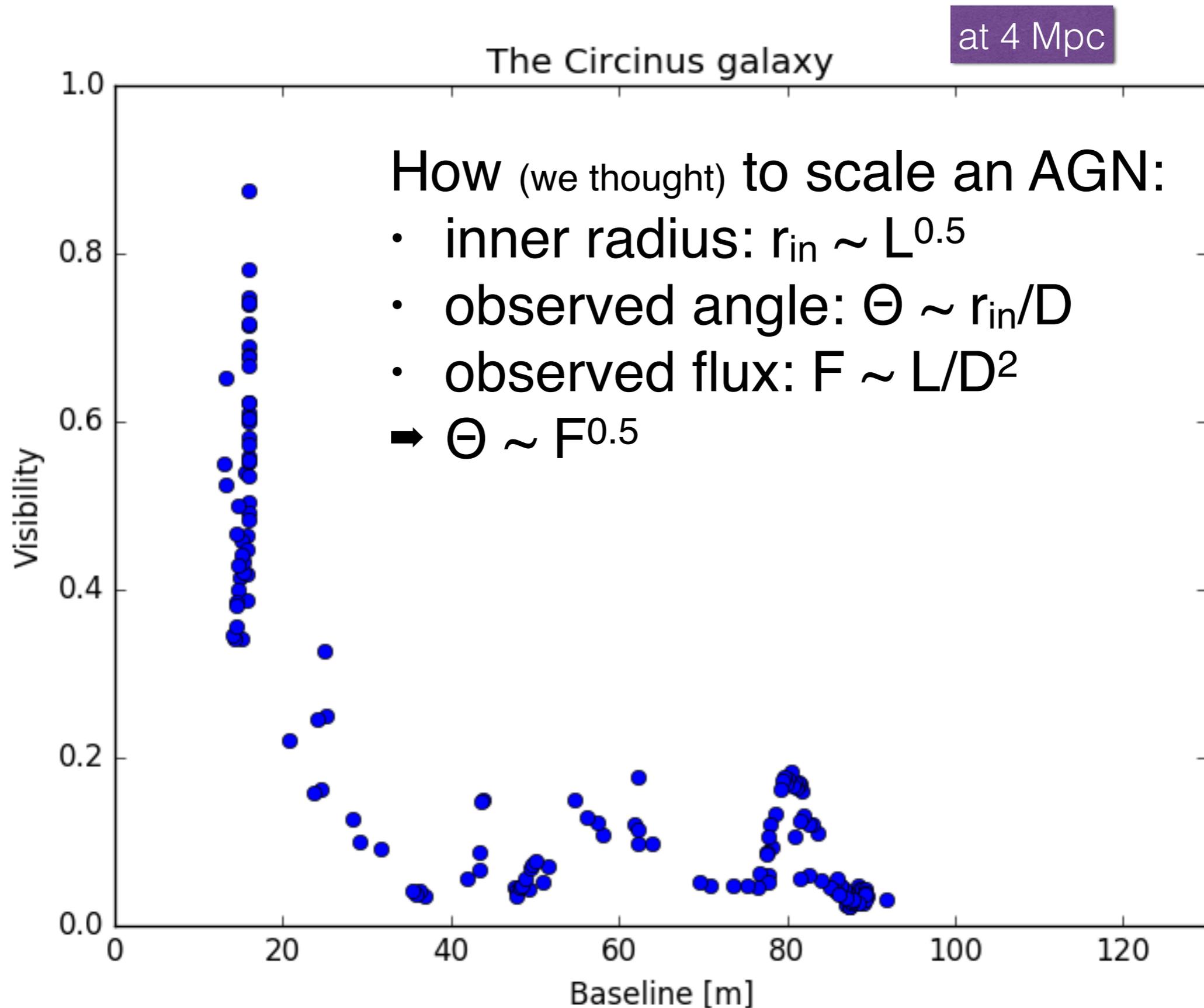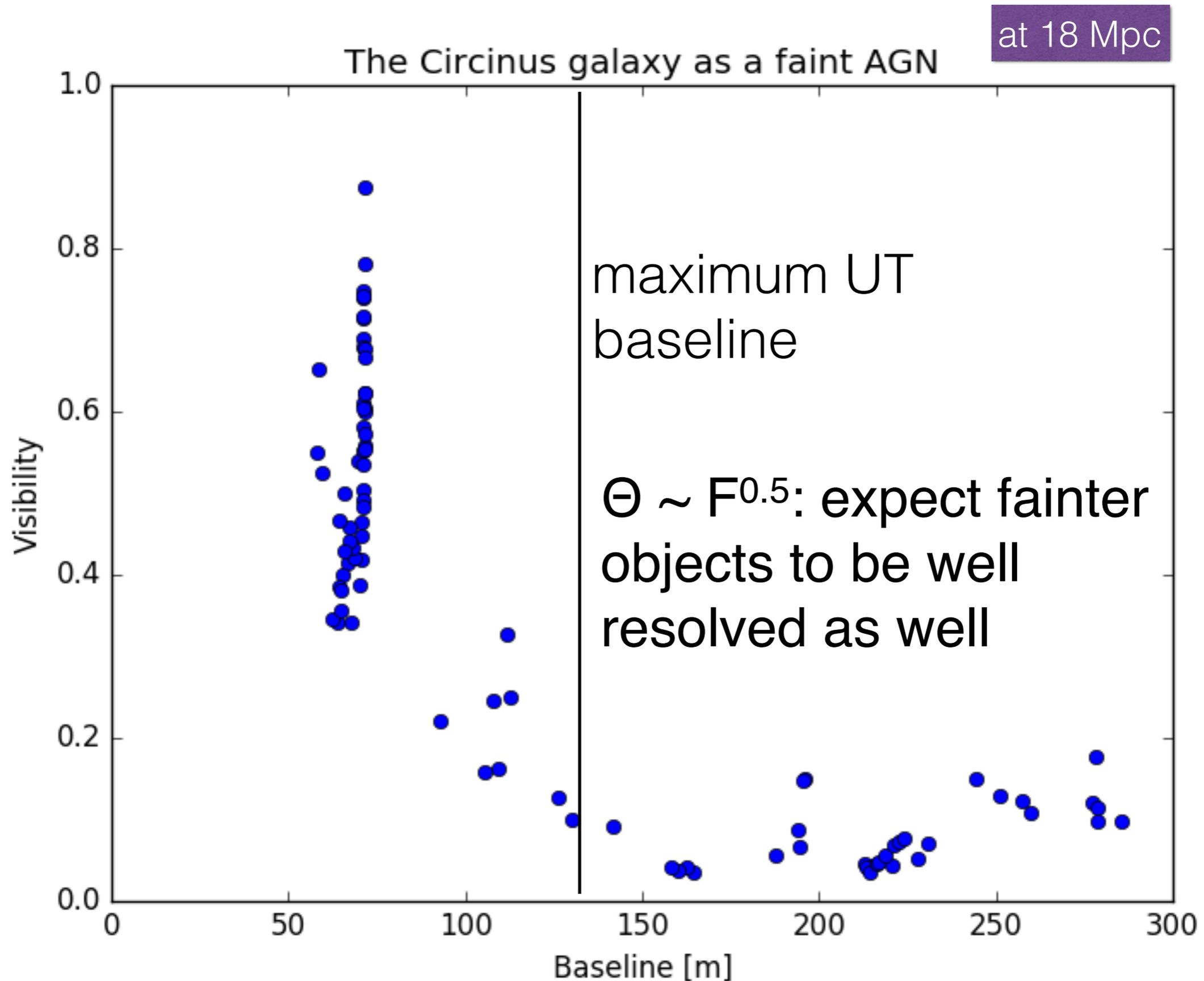
Faint sources are much smaller than expected

NGC 1068
Circinus

type 1 AGN ●
type 2 AGN ●

Visibility

Resolution / Inner radius r_{in}

Burtscher+ 2013
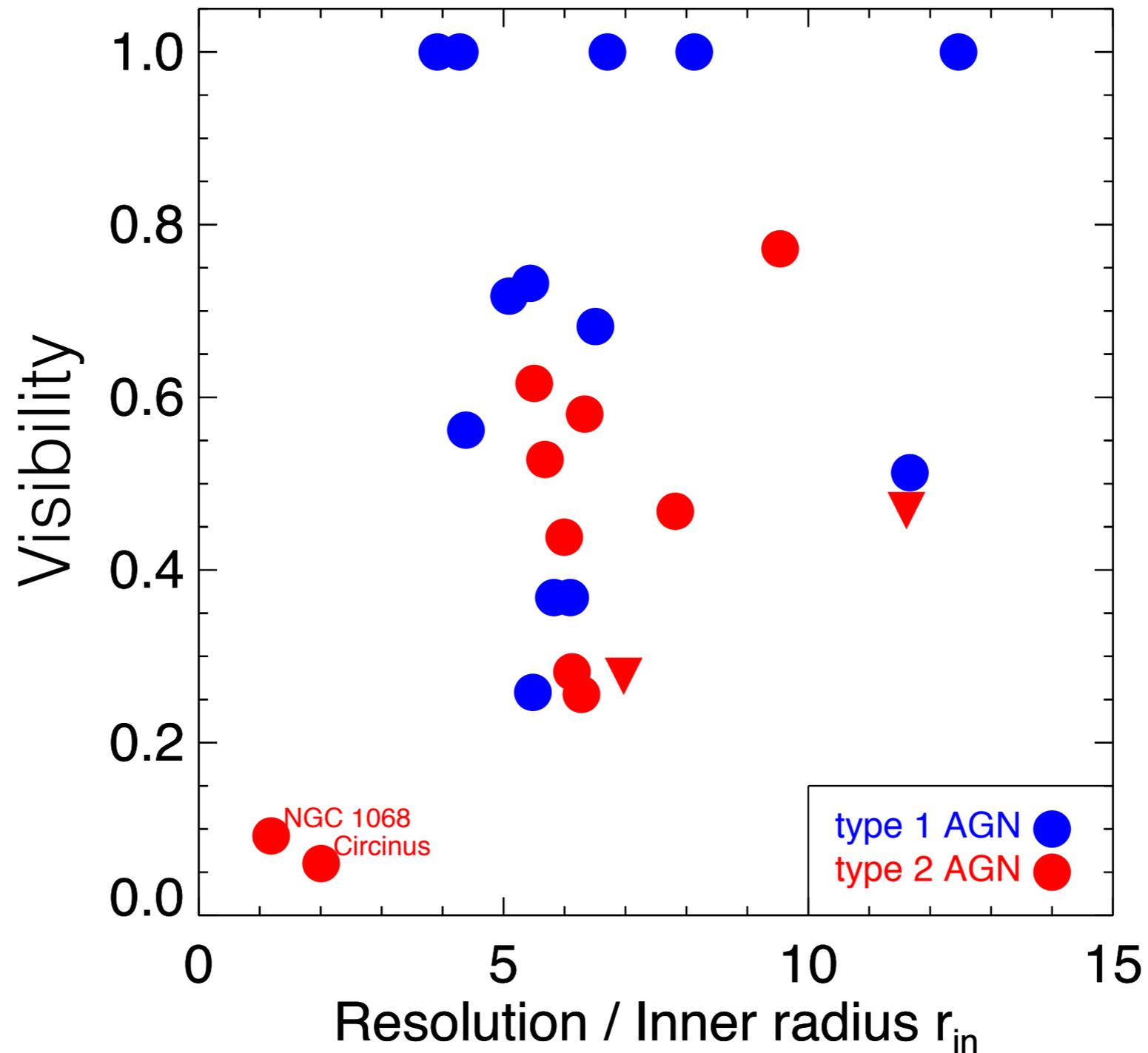
Most AGN tori "are oriented along the polar axis"

Lopez-Gonzaga, LB et al. 2016; see also Hönig+ 2012, 2013, Tristram+ 2014, Lopez-Gonzaga+ 2014
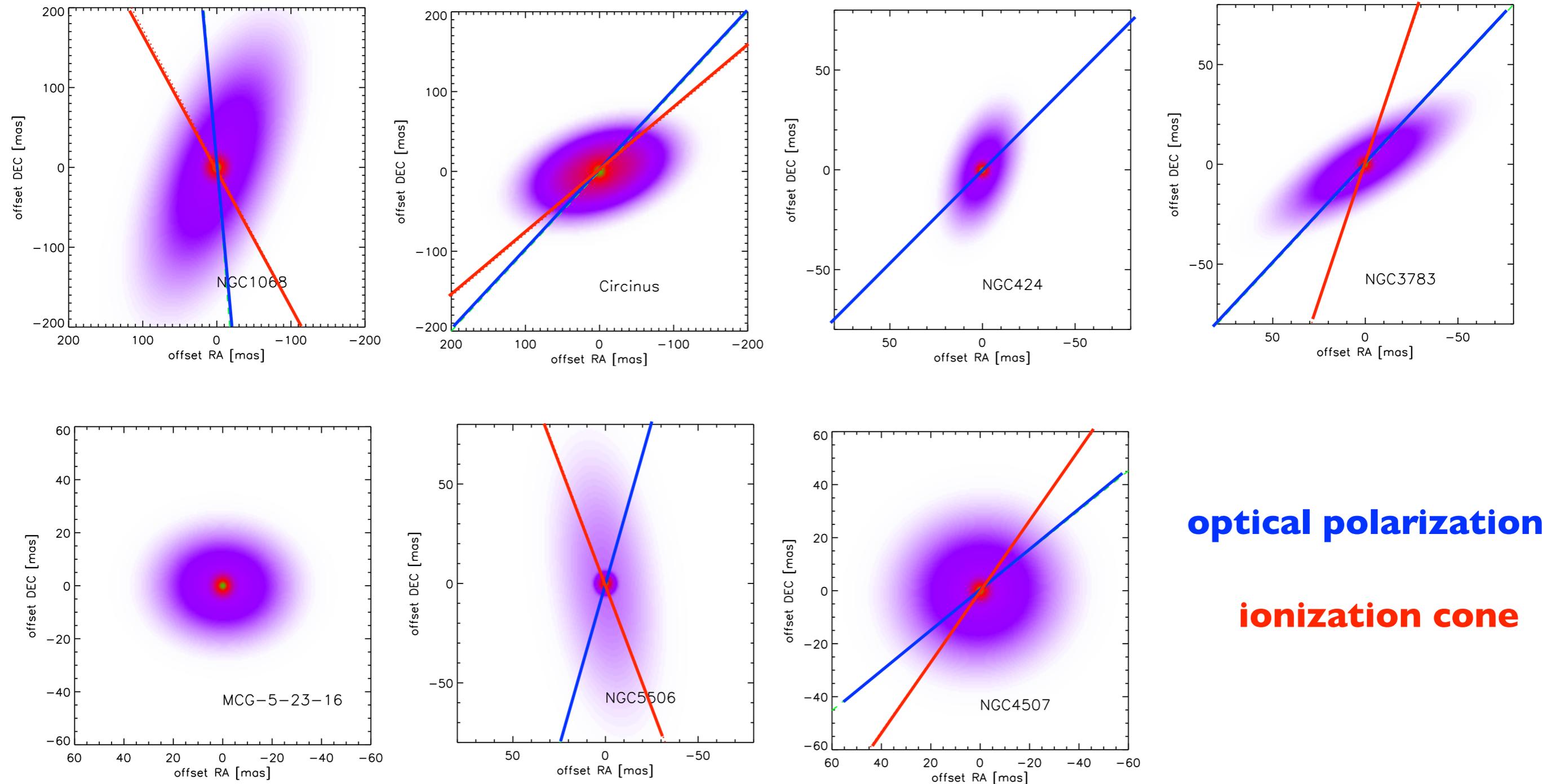
Probing AGN outflows at the base
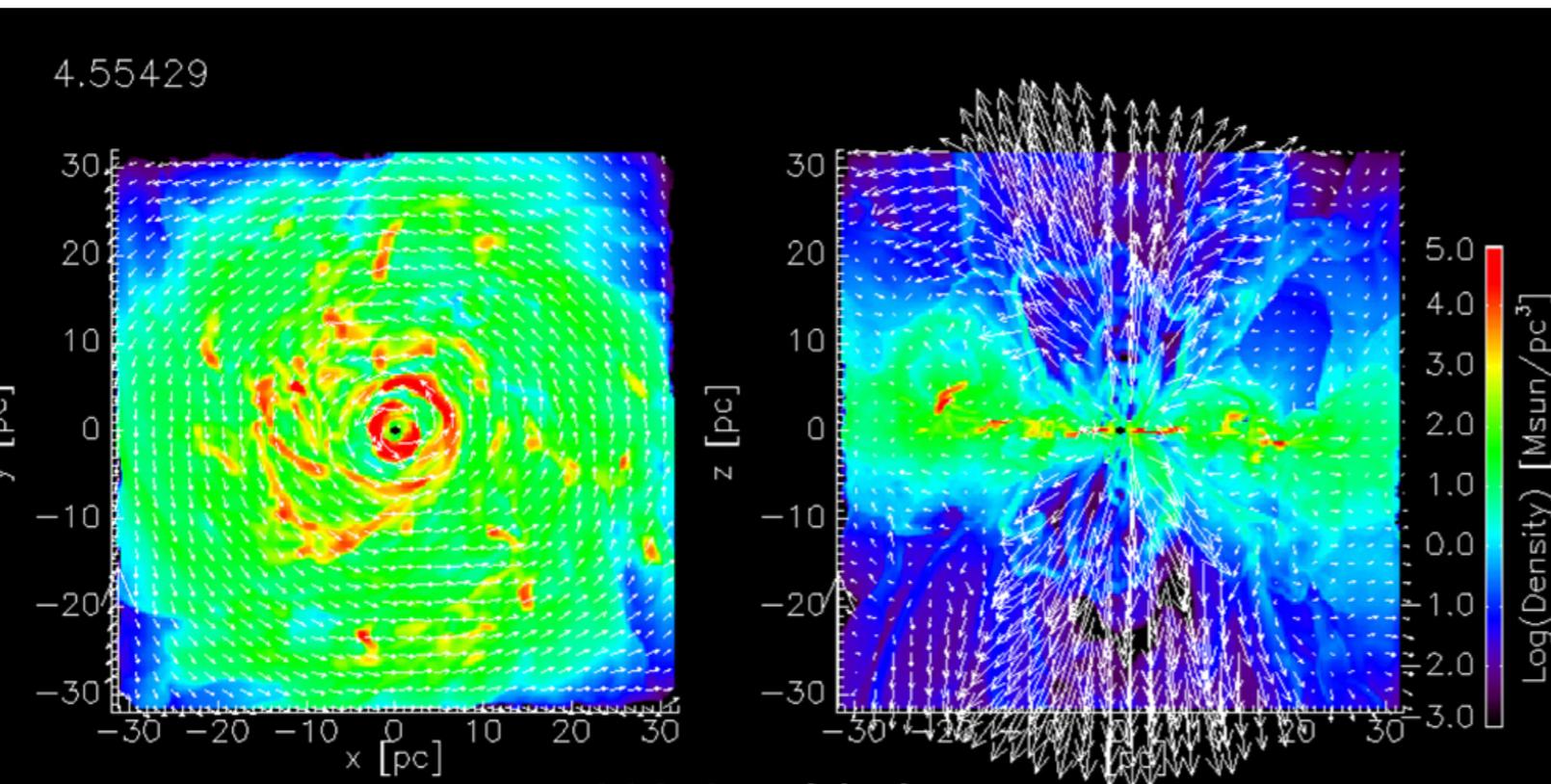

Wada+ 2012

10% Eddington rate
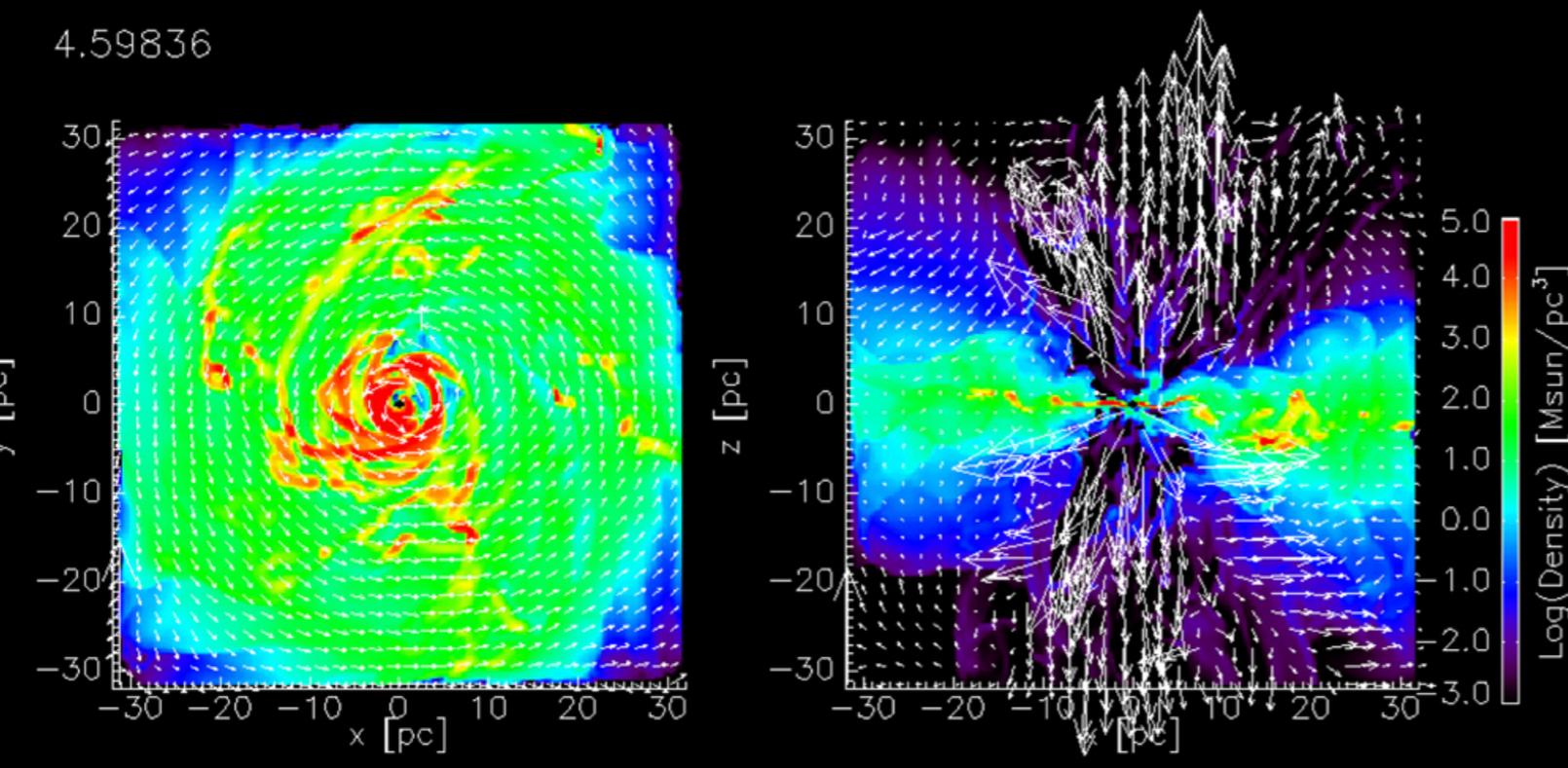
1% Eddington rate

Broad line region studies: Brγ / Brα

"velocity-resolved delay maps"
show how the broad line region
reacts to continuum variations

recent observations indicate a
variety of geometries from
infall to disks
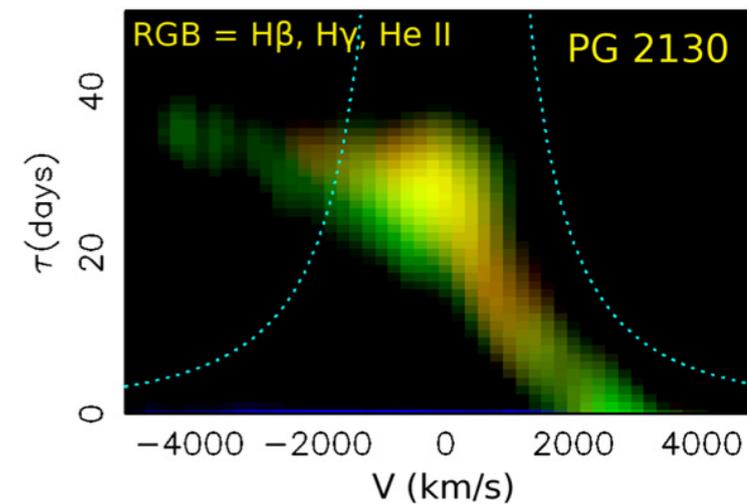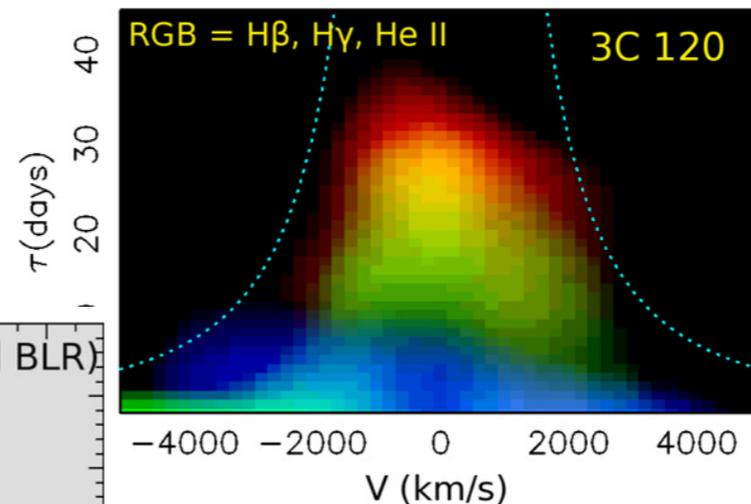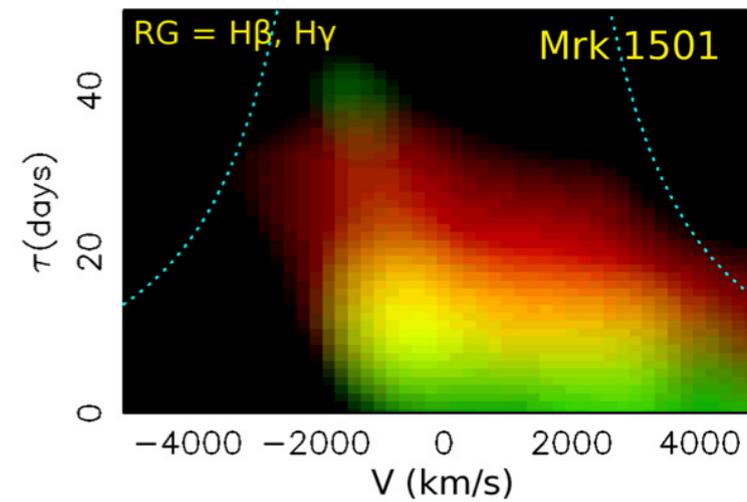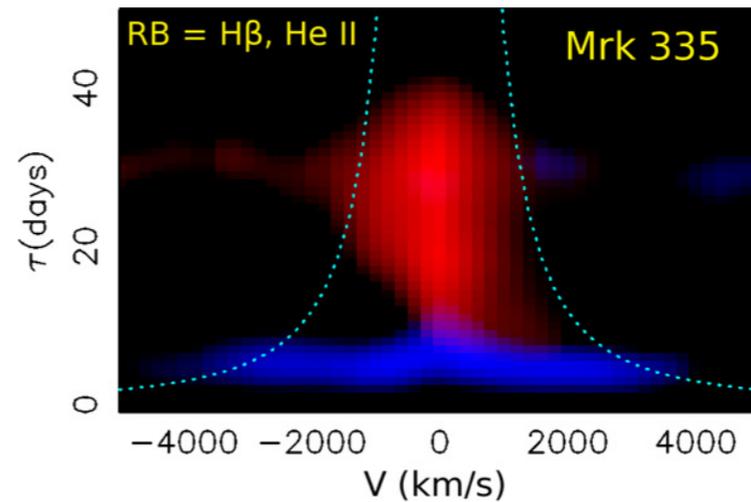
Grier+ 2013
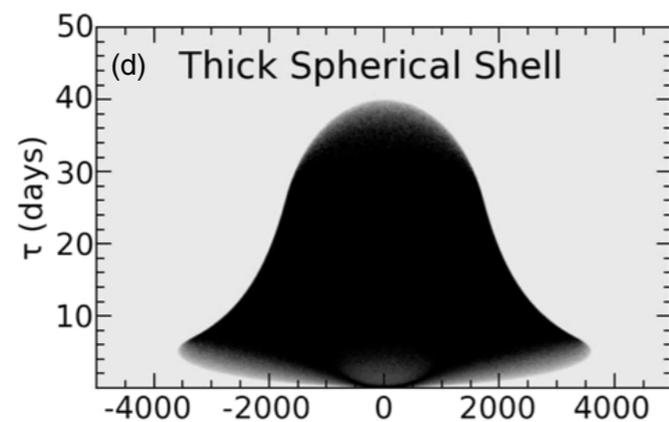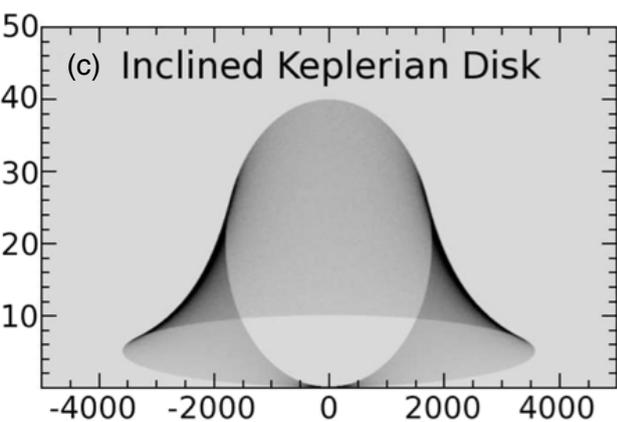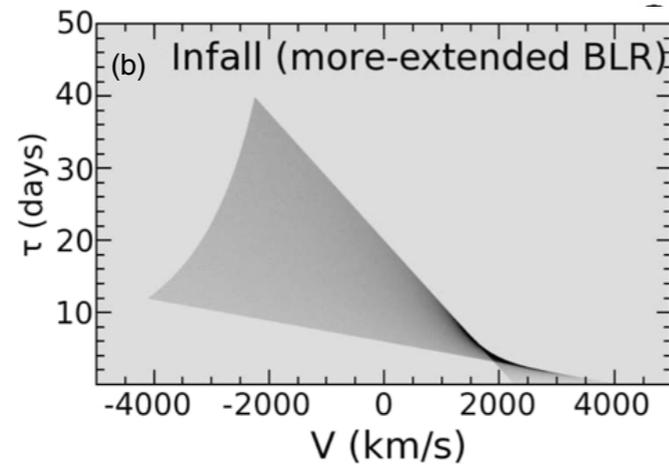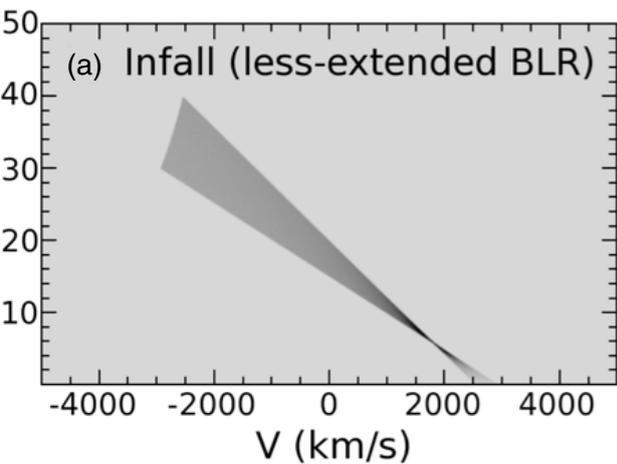
$$v_{\mathrm{BLR}} = f \cdot \mathrm{FWHM}$$

$$M_{\mathrm{BH}} \sim \frac{R_{\mathrm{BLR}} \cdot v_{\mathrm{BLR}}^2}{G}$$

f ~ 0.7 - 5

Distance measurements

Hönig+ 2014

NGC 4151	Distance Modulus (mag)	Metric Distance (Mpc)
Mean	30.29	14.066
Std. Dev.	1.55	8.694
Min.	27.95	3.890
Max.	32.33	29.200
Median	31.04	16.200

$D_A = 19.0^{+2.4}_{-2.6}$ Mpc
(68% confidence interval)

Angular size of inner boundary

Time lag to inner boundary

Probability distribution

Marginal posterior

Distance (Mpc)

„Nodules"   NGC 1068

H₂ (1-0) S(1)

Müller-Sanchez+ 2009

[OIII] + ground-based M band

HST-D
HST-E
HST-C
HST-F
HST-B
HST-A

Gratadour+ 2006
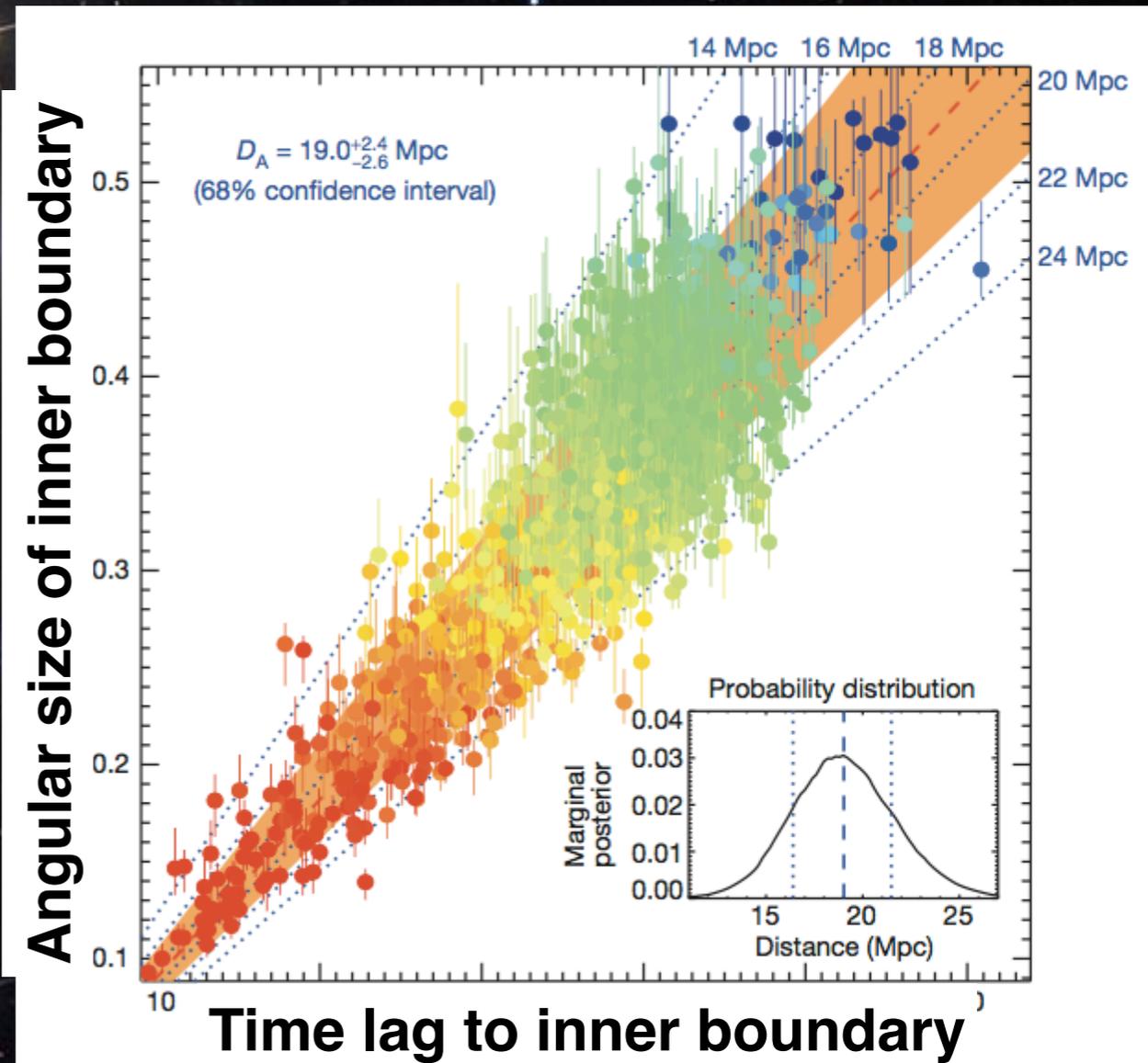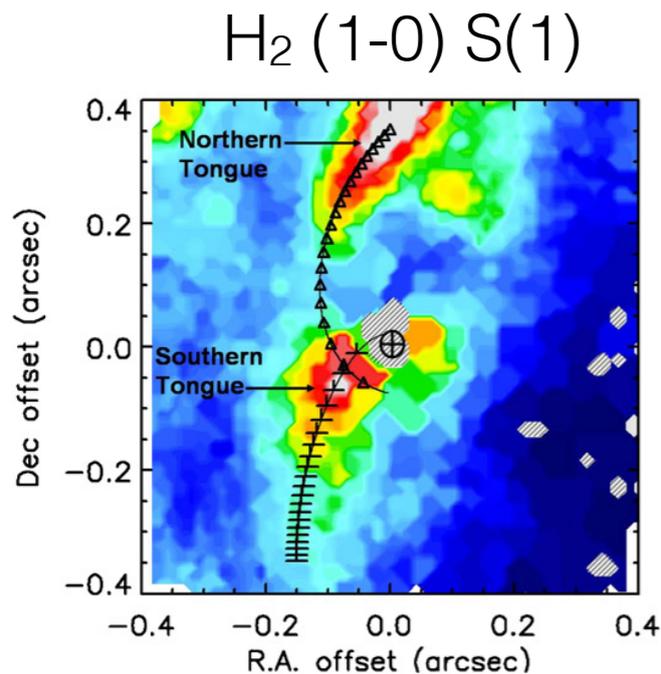
Molecular and stellar lines very close to the AGN?

ALMA CO(6-5) and continuum

7pc

Garcia-Burillo+ 2016

Advantages of

GRA   4   MAT
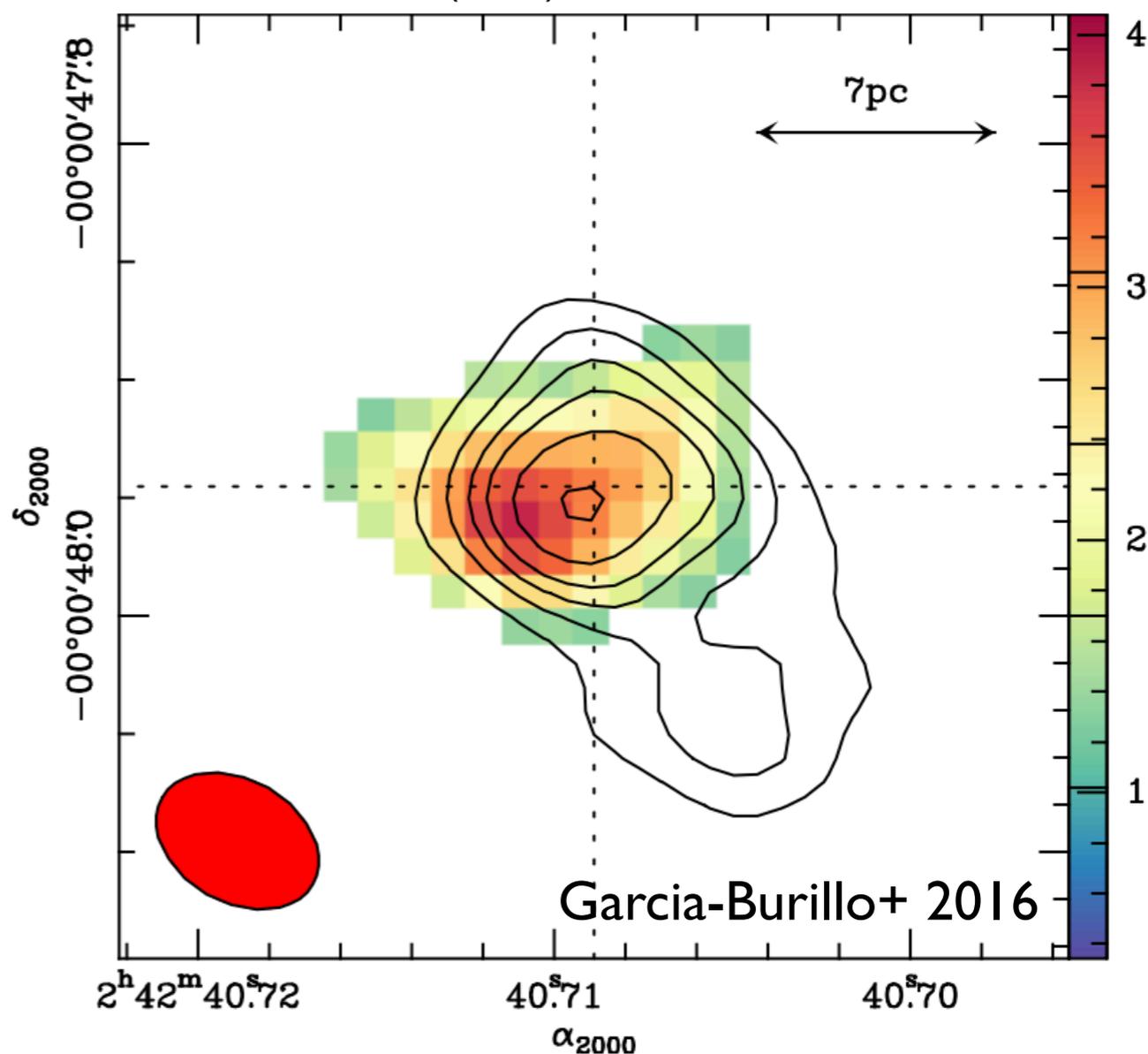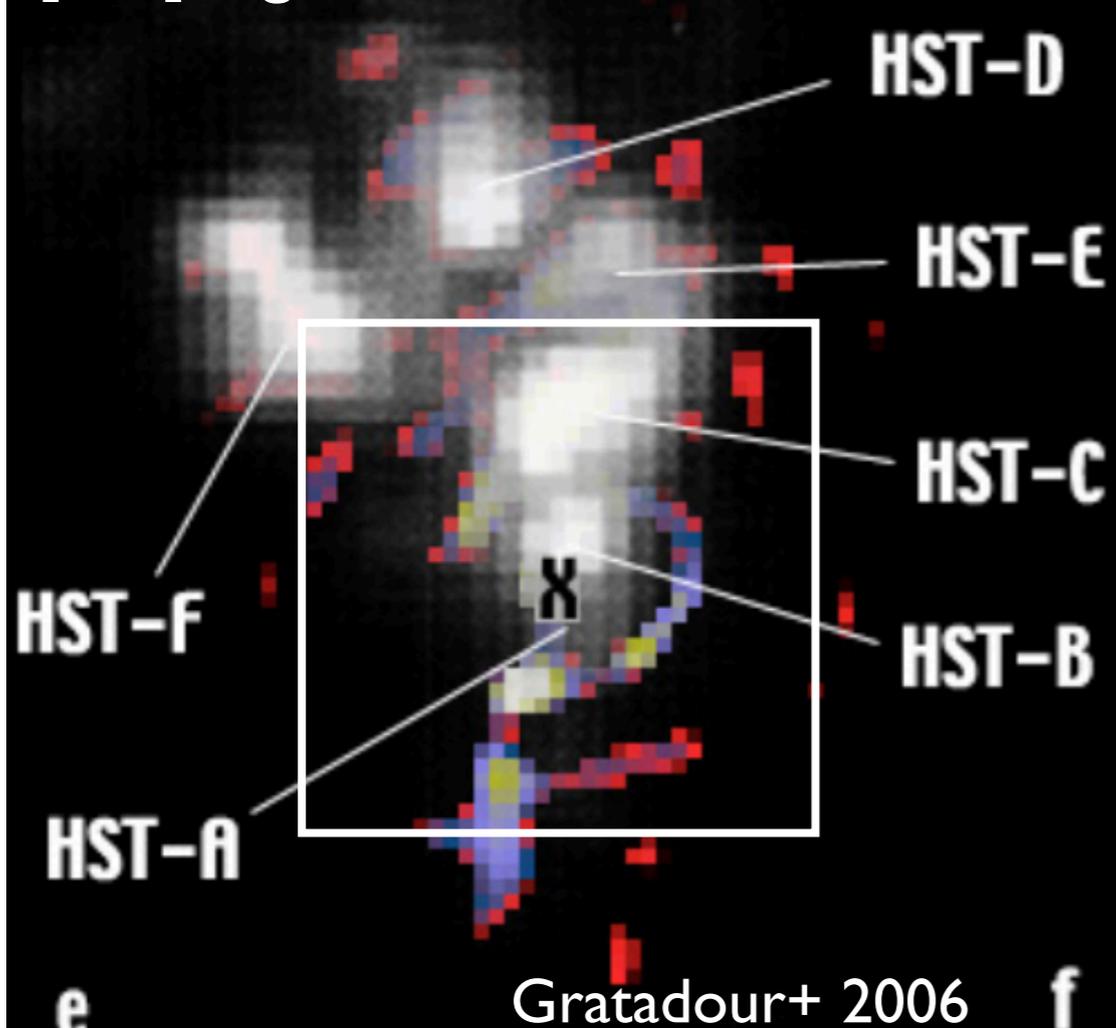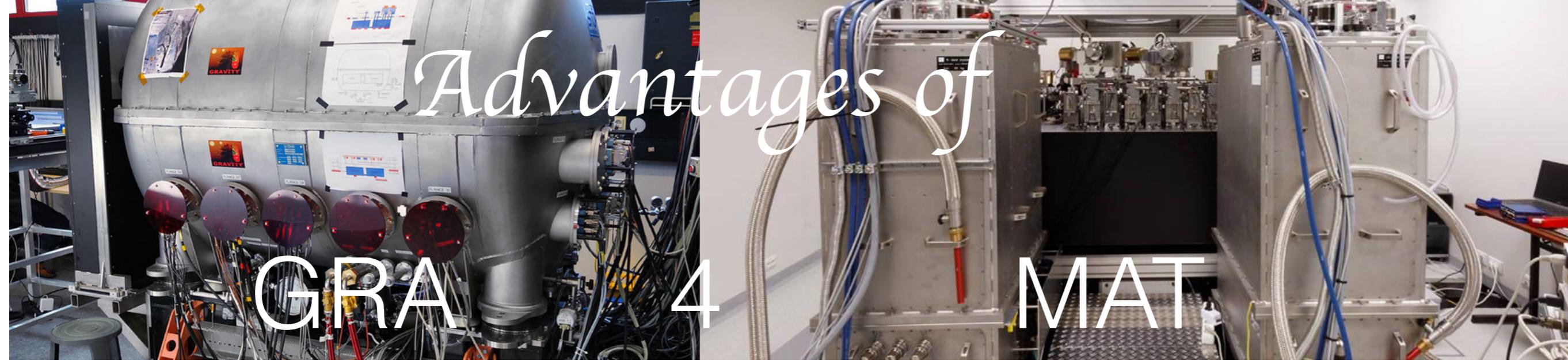
- **Longer coherence / integration times in MATISSE**

  - higher sensitivity

  - more efficient since H2RG is currently read-out noise limited

  - allows to observe larger bandwidth high-res spectra

Advantages of GRA 4 MAT
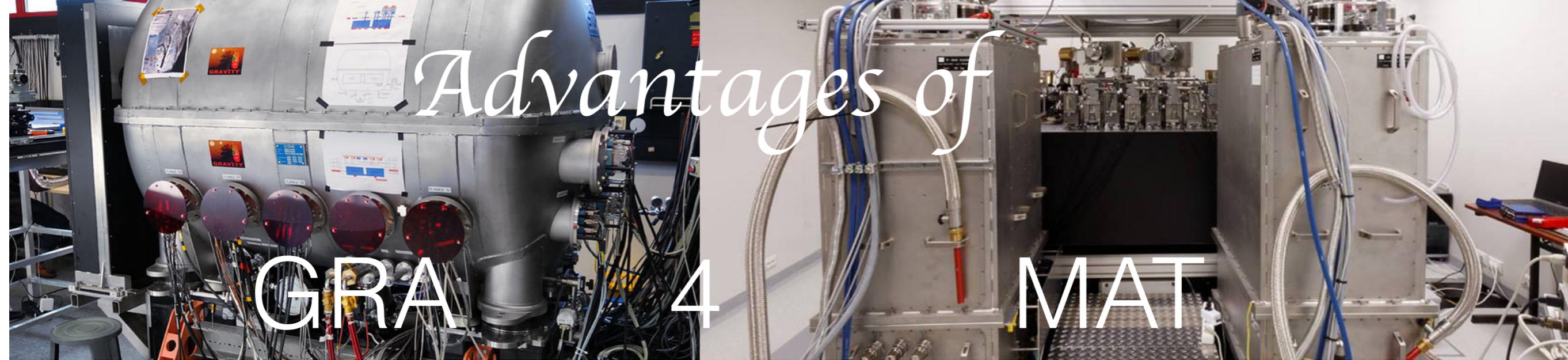
- **Transfer some UT observations to ATs**

  - better (u,v) coverage

  - pays for GRA4MAT if just 1.5 nights of UT observations can be shifted to ATs (assuming 5-6 FTE for GRA4MAT as estimated by ESO)

How many sources?



on-axis

2"
VLTI field of view

AGN

off-axis

star

AGN
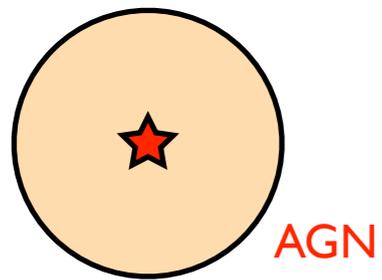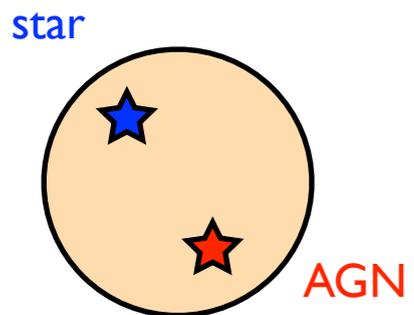
2"
VLTI field of view

Veron-Cetty & Veron 2010
167566 AGNs + QSOs

X

2MASS PSC
K < 10.5, dist < 2", DEC < +30, Sy 1

Burtscher+ 2015

Fraction of AGN light within 1"

log L$_{AGN}$ (NIR)

Seyfert 1
Seyfert 1i
Seyfert 2
LINER

didates
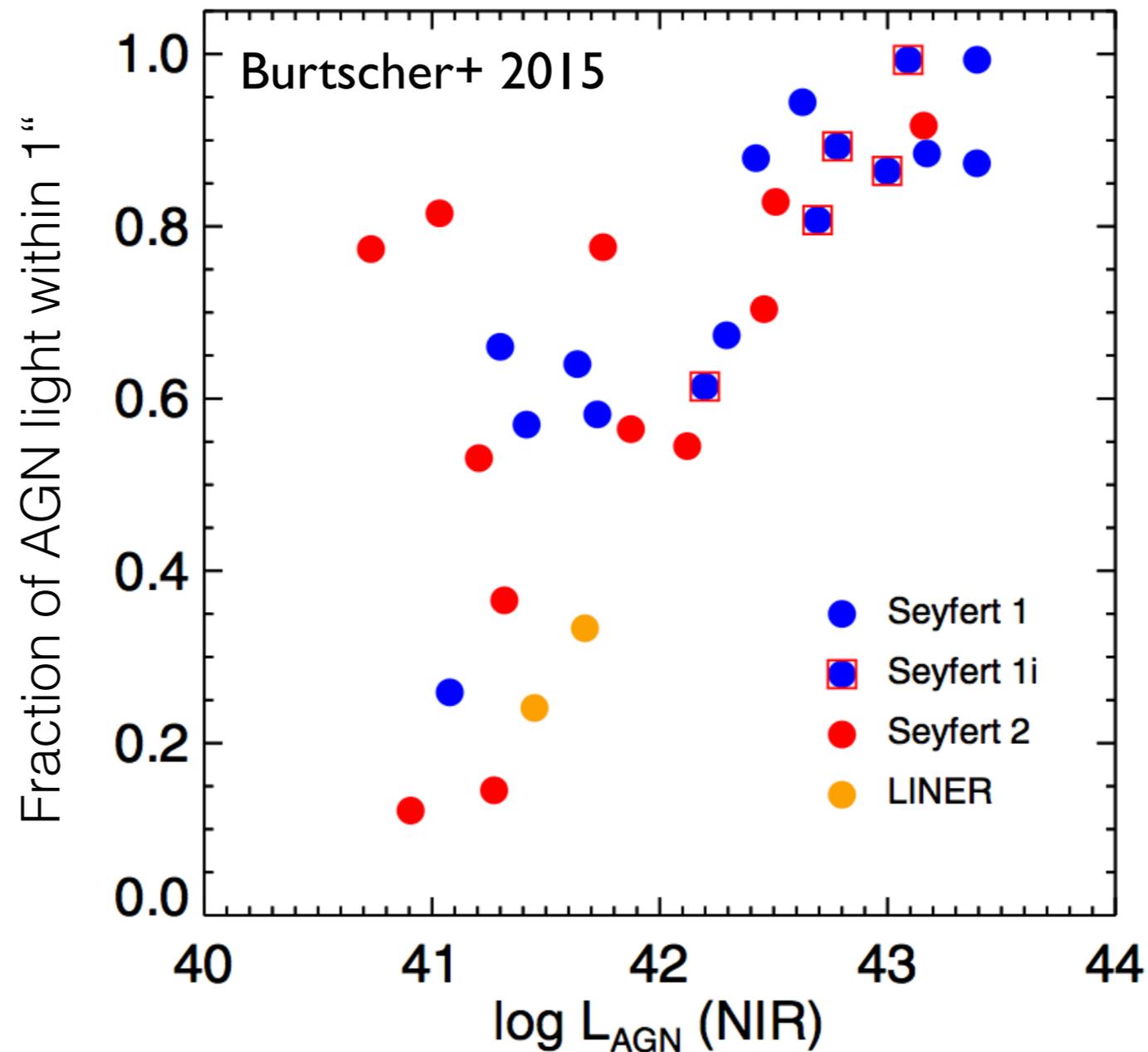
- use DDLs for GRA4MAT off-axis use

- dedicated 2GFT to reach K~12.5 mag