Precision near-IR spectroscopy for shedding light on the H_0 tension and understanding AGN physics

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H_0 tension

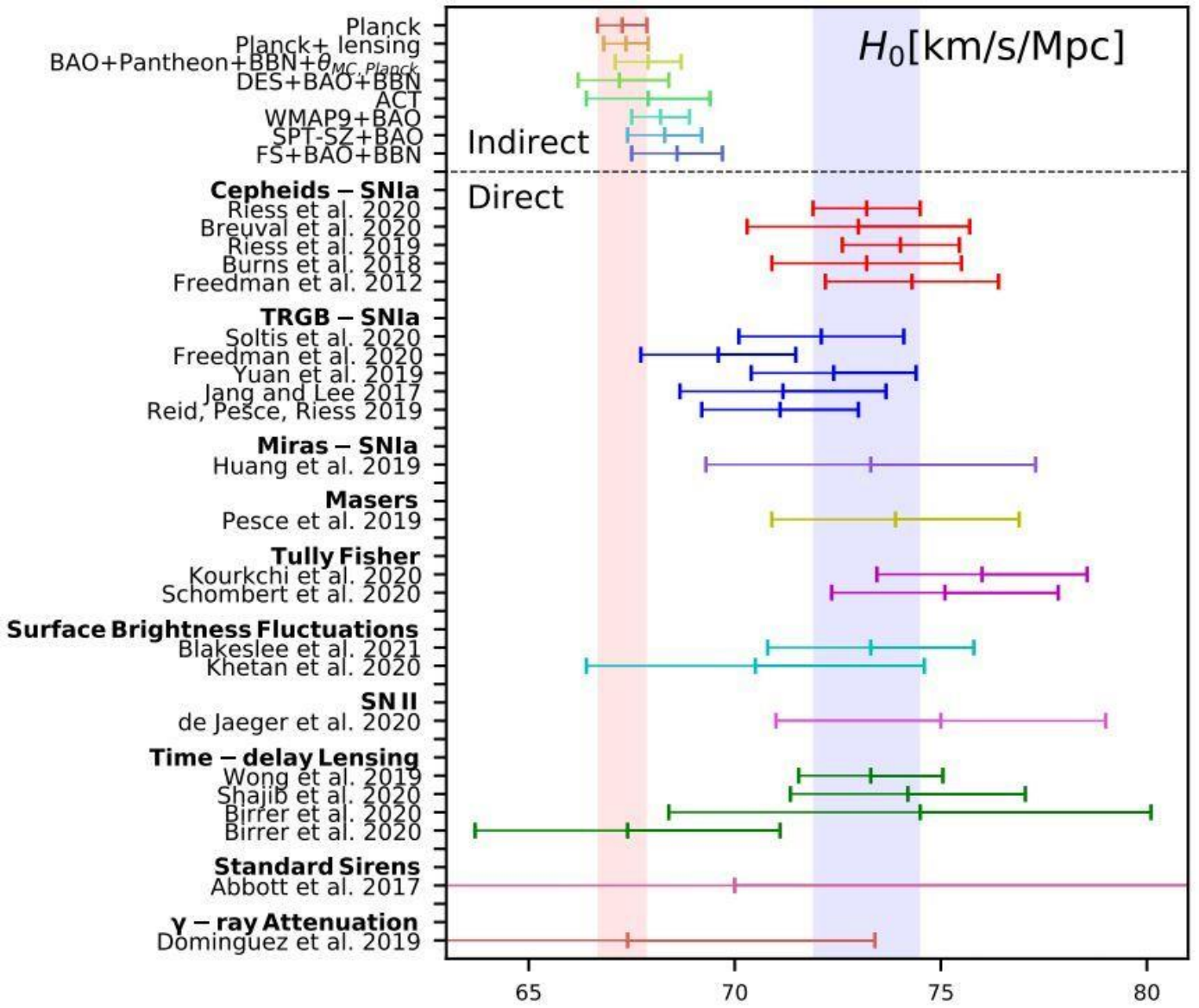
The Hubble constant H_0 is the current expansion rate of the Universe

4-5σ tension between early and late measurement

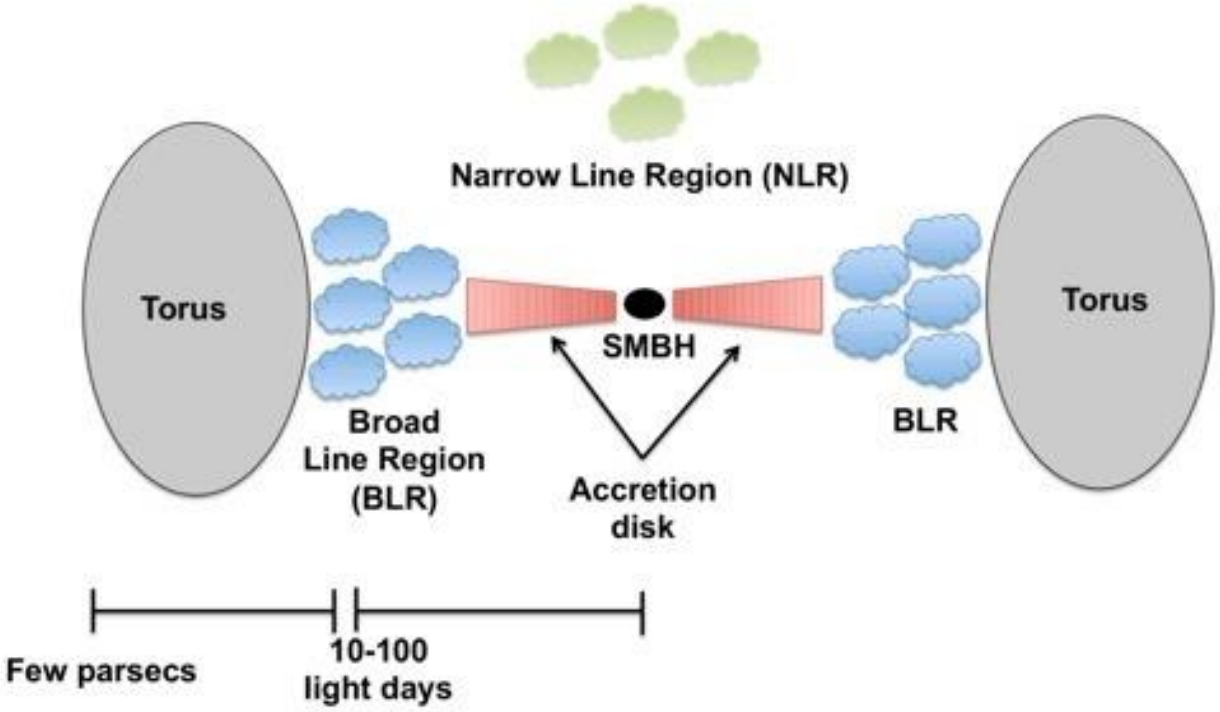
flat-ΛCDM needs extension?
systematics in local measurements?

We would like an additional <u>independent measurement of</u> H_0

Di Valentino+2020



AGN as standard candles with the SARM method



C. Ricci

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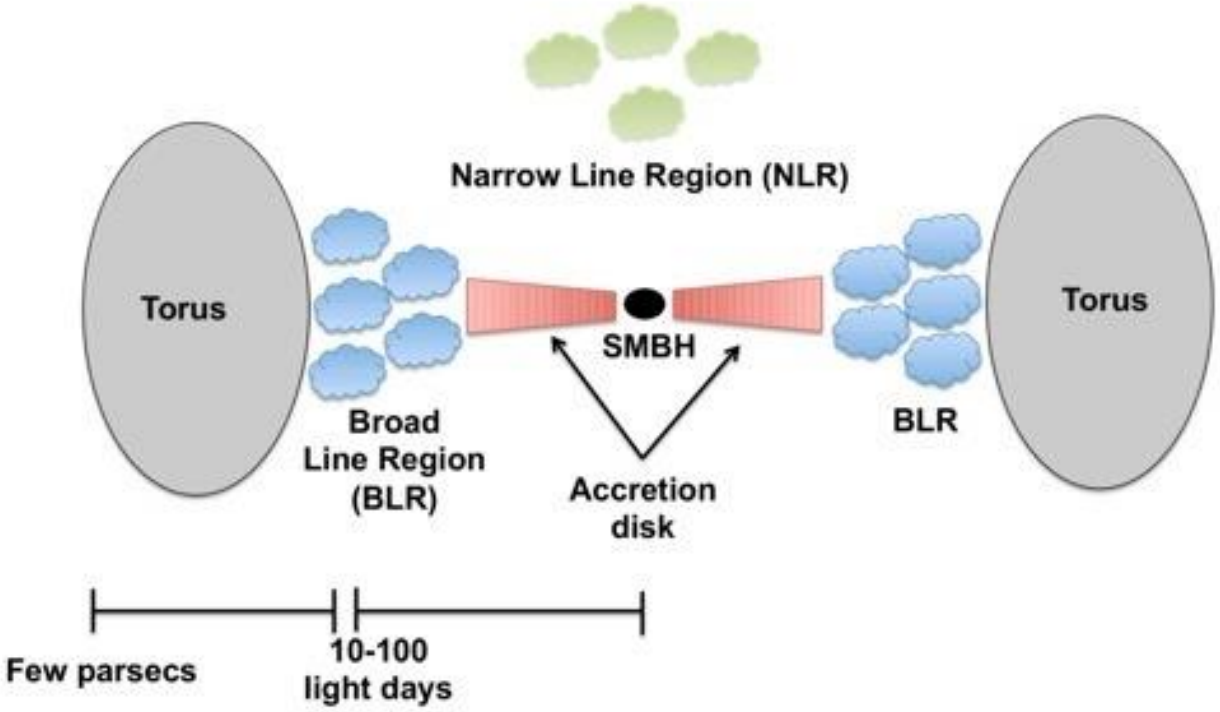

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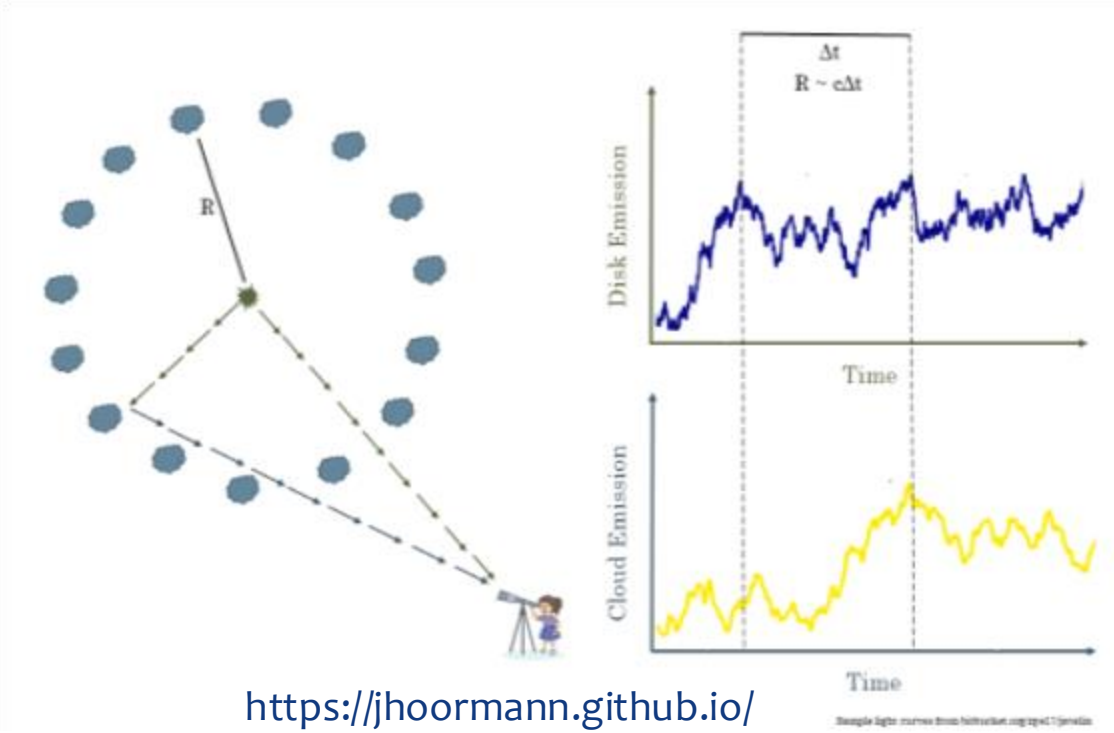
Reverberation **M**apping:
linear BLR dimension ΔR



https://jhoormann.github.io/

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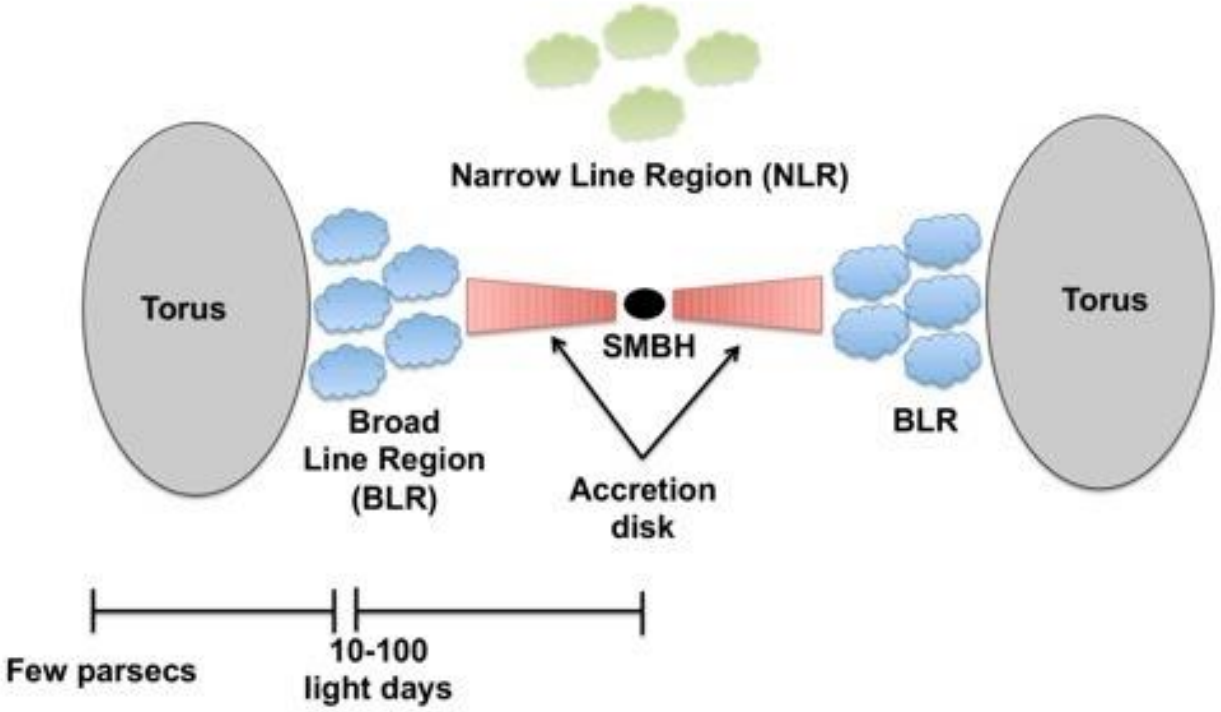

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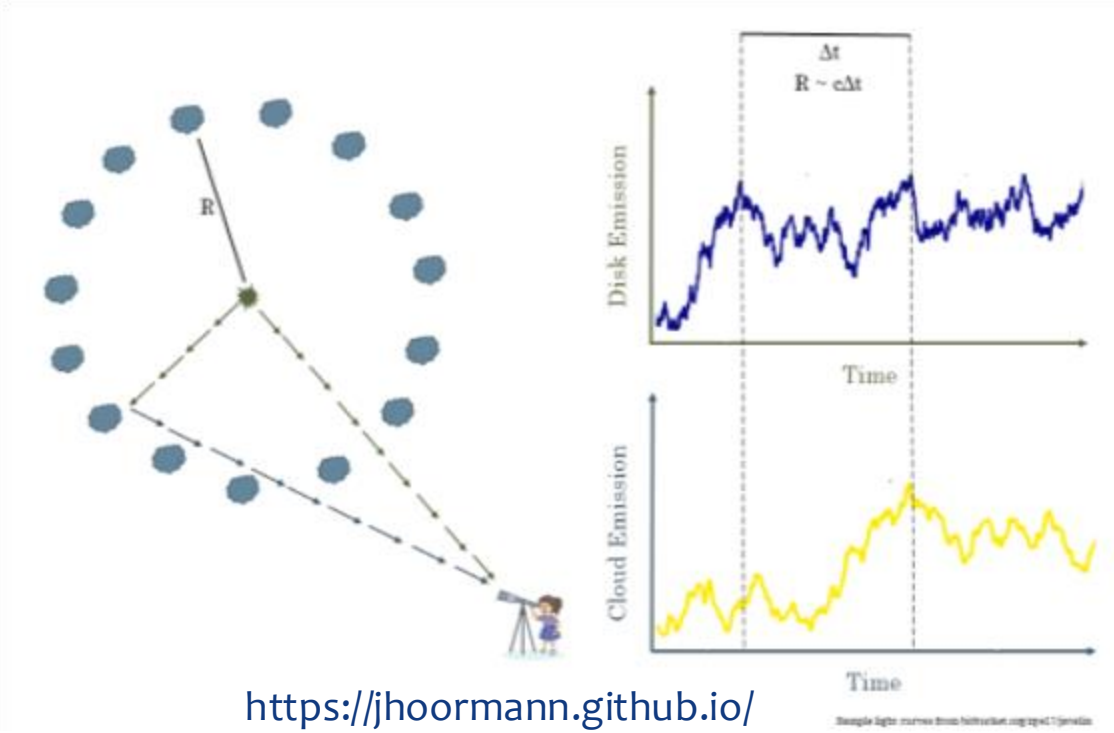

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$$M_{BH} = f\frac{R_{BLR}\Delta V^2}{G}$$

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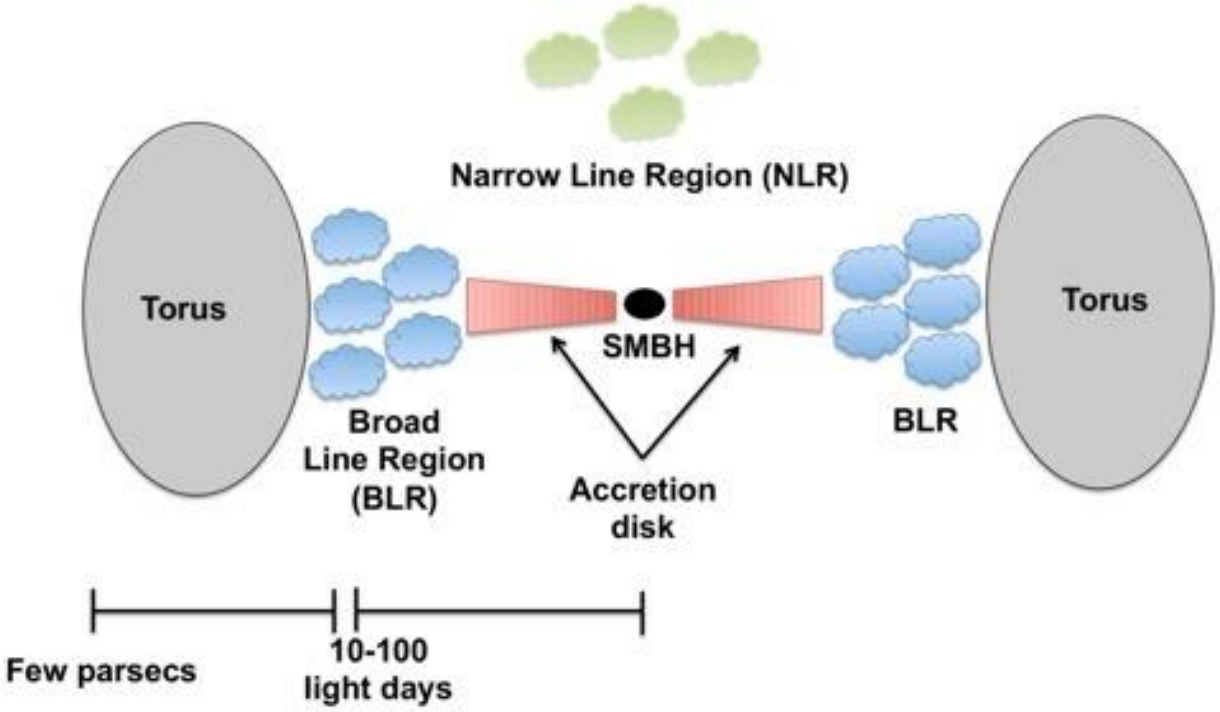
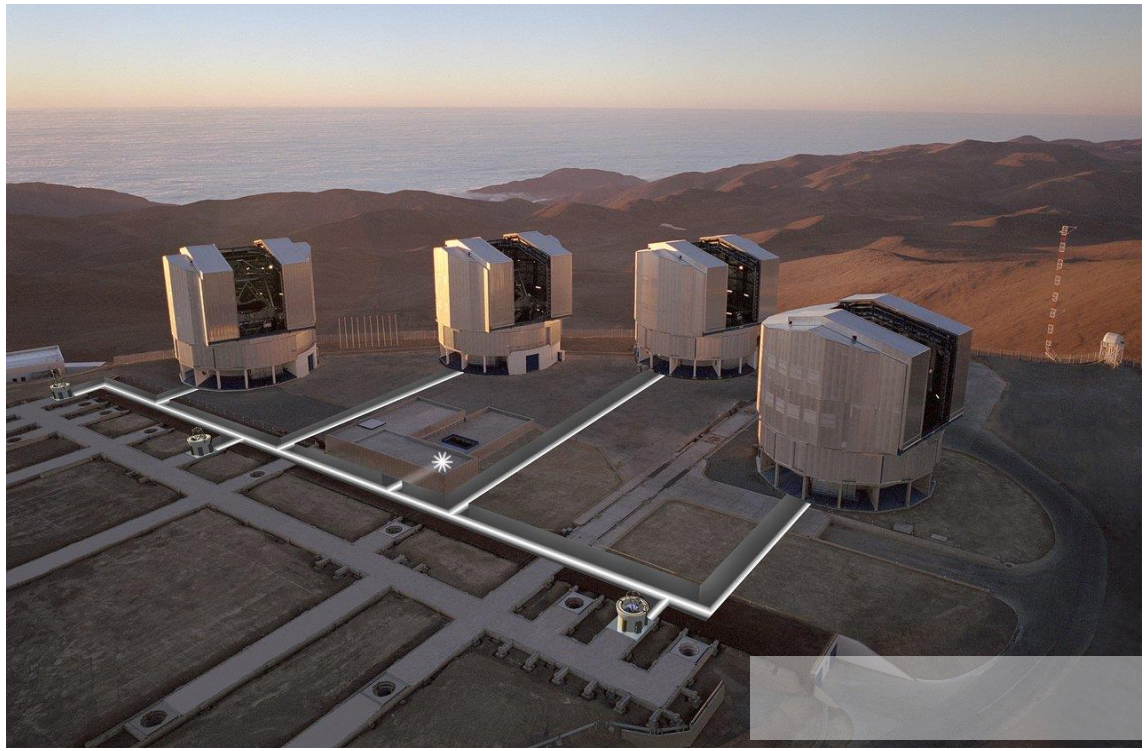


C. Ricci

Spectro**A**strometry
angular BLR dimension $\Delta\theta$:
GRAVITY@VLTI 1.98-2.4μm



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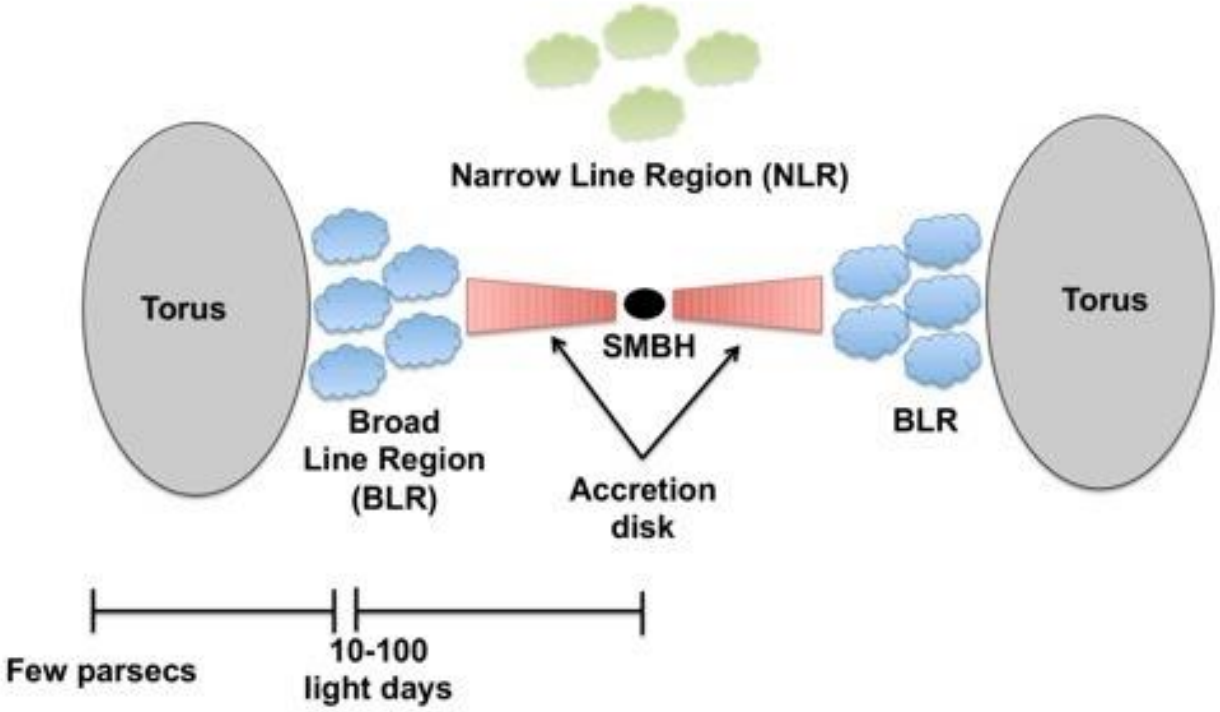

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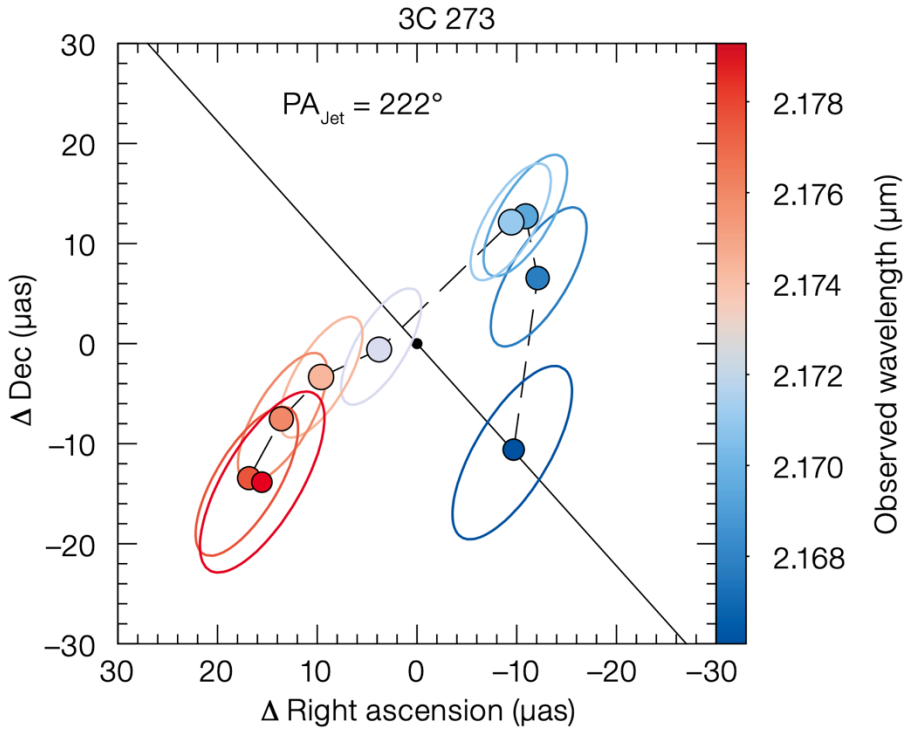
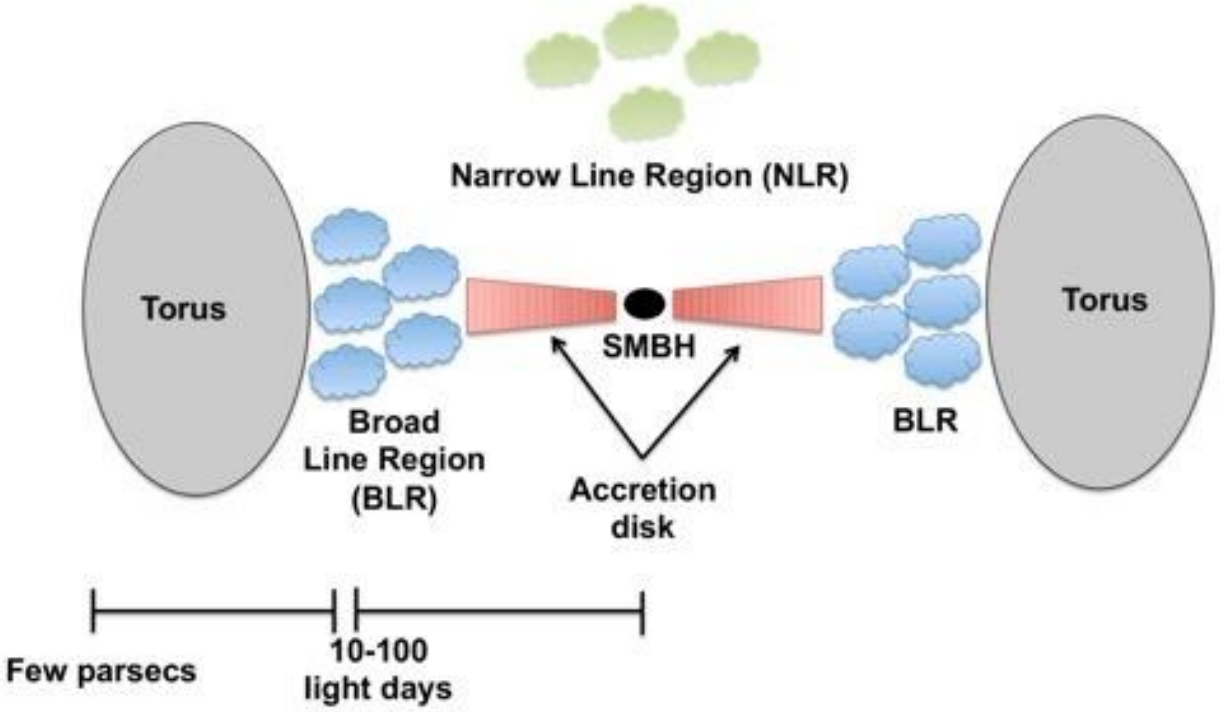


Sturm+22 (GRAVITY collaboration)

AGN as standard candles with the SARM method



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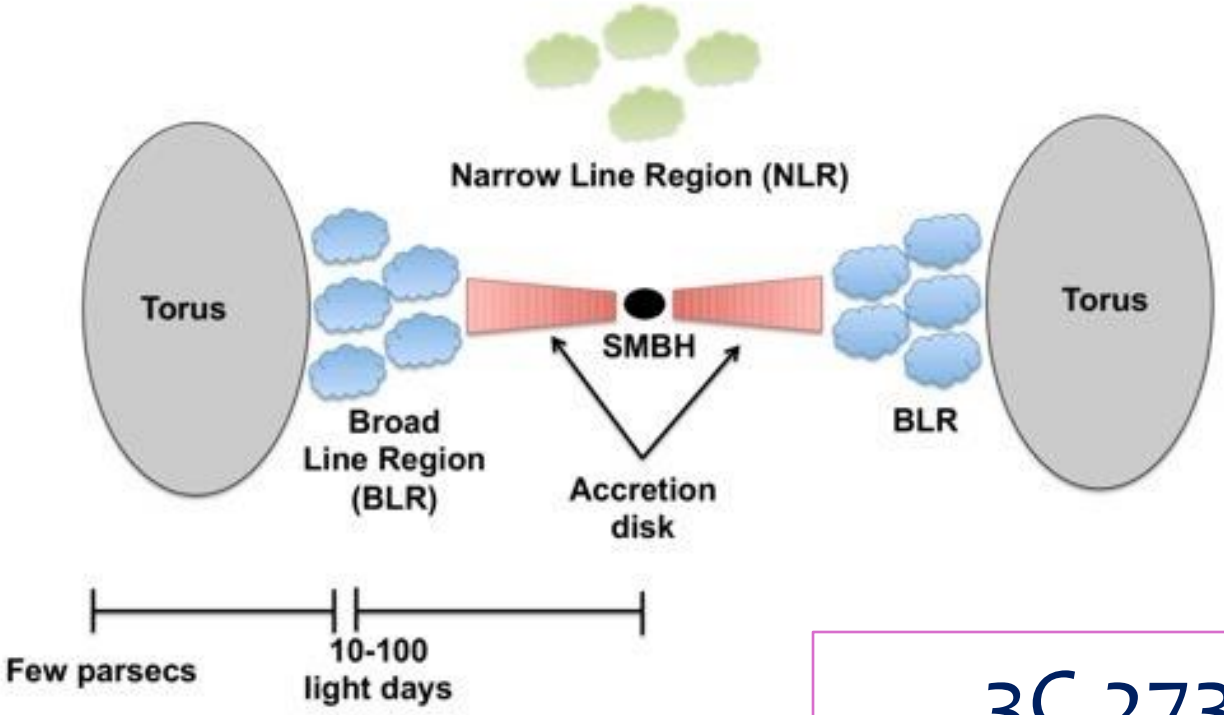
With both measurements for the same object:

$$D_A = \Delta R / \Delta \theta$$

$\rightarrow$ $\mathbf{H_0}$

AGN as standard candles with the SARM method



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3C 273 – Wang+2020

$H_0 = 71.5^{+11.9}_{-10.6}$ km s^{-1} Mpc^{-1}

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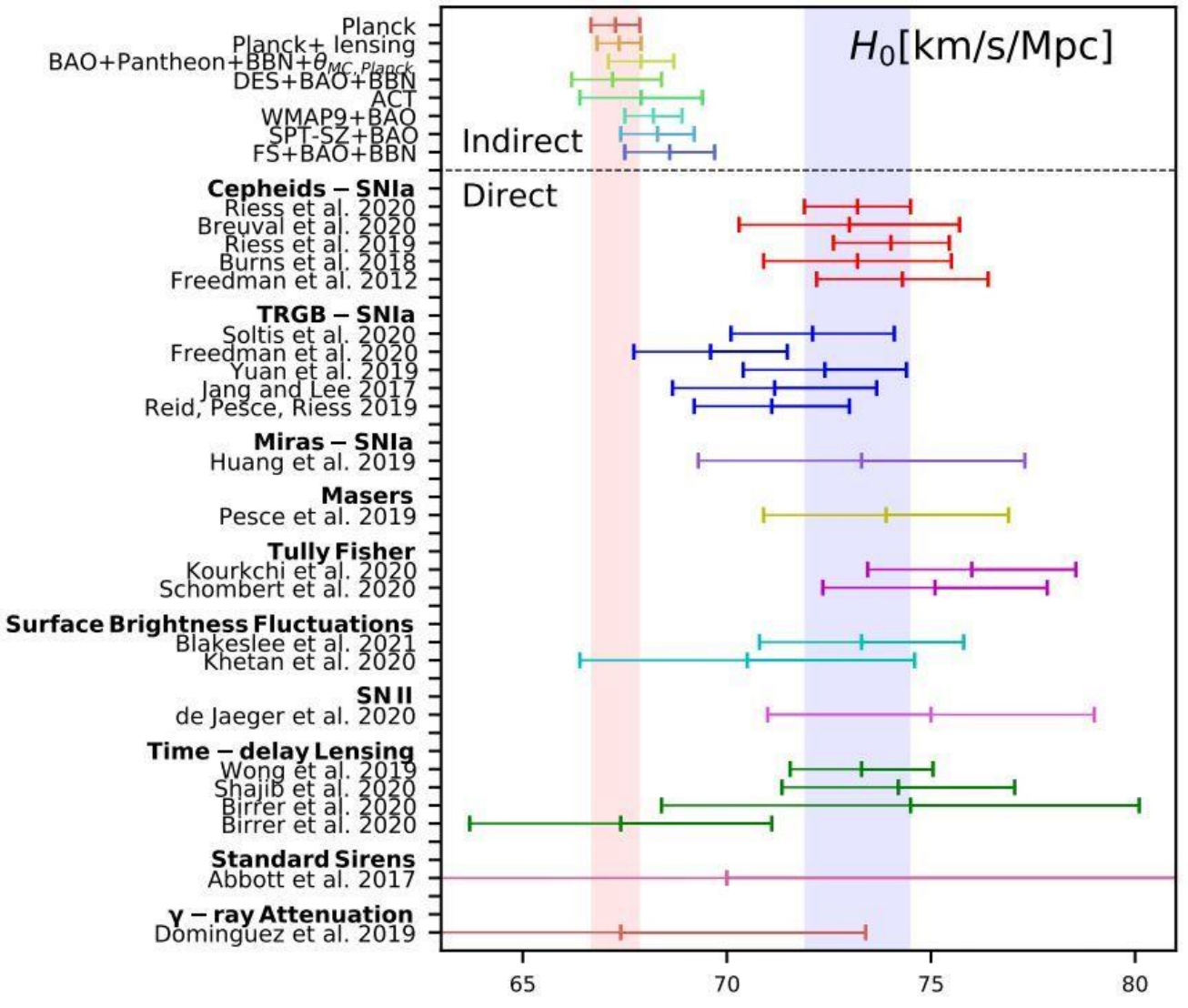
Main uncertainty source:

RM performed on the Hβ line, while SA on the Brγ

Are we looking at the same region?



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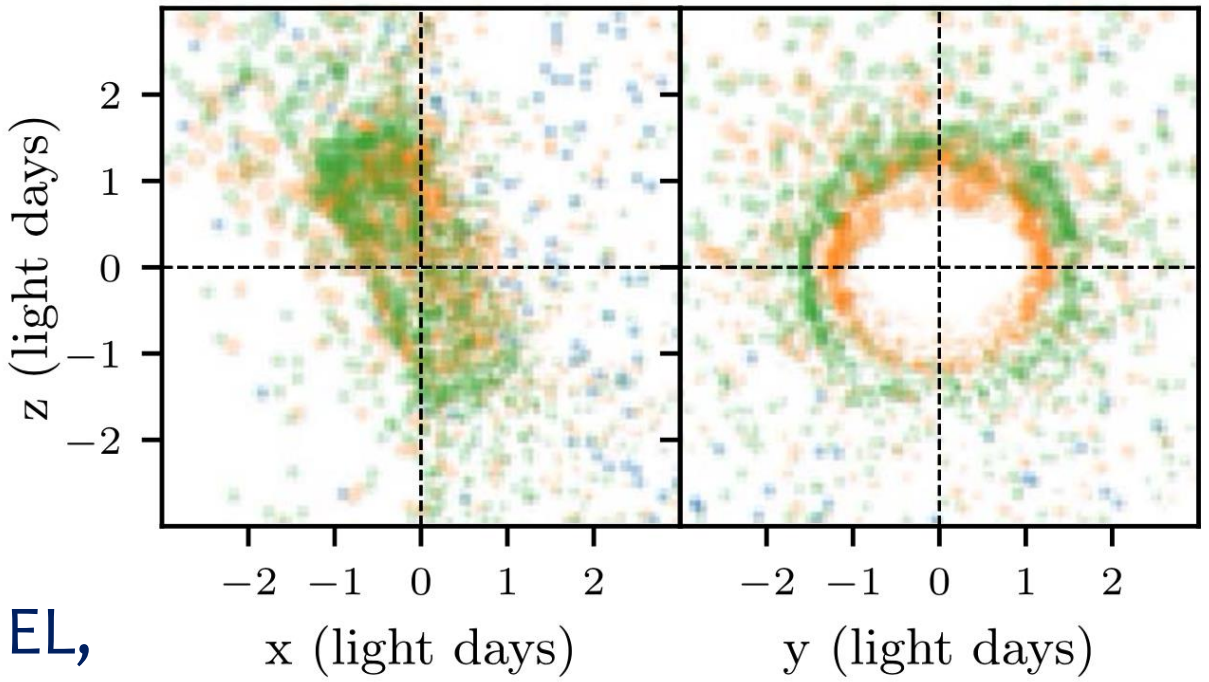
Are we looking at the same region?

Codes for detailed BLR modelling (CARAMEL, CARAMEL-gas) – now possible for very local objects only!

$$M_{BH} = f \frac{R_{BLR} \Delta V^2}{G}$$

BLR modeling
For NGC5548



Williams+20
Hβ in blue, C IV in orange, Lyα in green

Infrared RM

International collaboration perform nearIR Reverberation Mapping on GRAVITY objects

A. Barth, V. Bennert, B. Boizelle, M. Brotherton, E. Cackett, P. Du, J. Hernandez Santisteban, K. Horne, H. Landt, M. Malkan, J. Montano, J. Montano, Y. Chan Taak, T. Treu S. Valenti, L. Villafana
(USA, UK, Germany, Italy, China)

IRTF (3.2 meters) campaigns

- Mrk1239, z=0.0199
- IC4329a, z=0.0161
- Ark120, z=0.0327

Infrared RM

IRTF (3.2 meters, 0.7-2.6μm) campaigns

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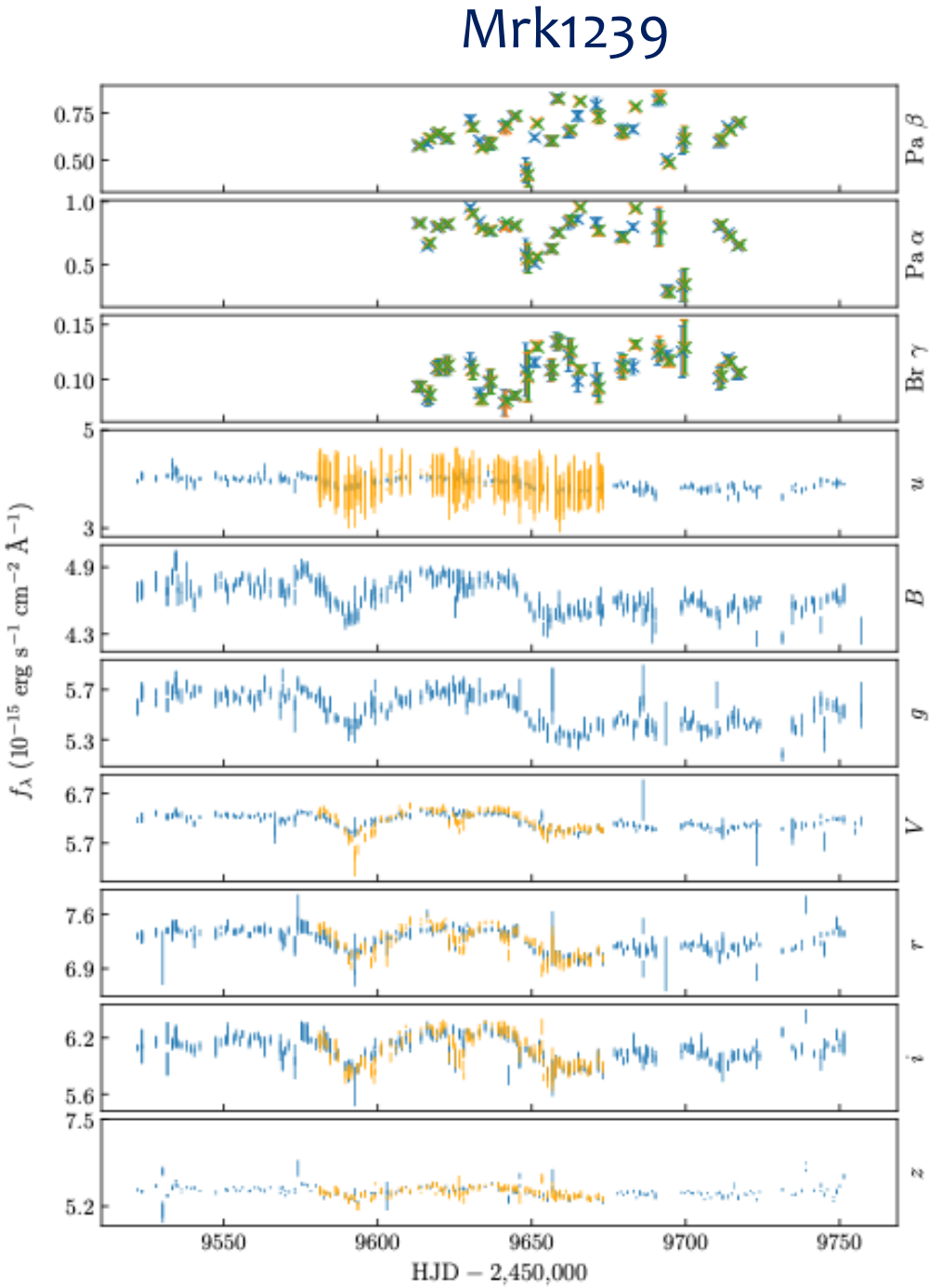
- IC4329a, z=0.0161

24 epochs over 4 months
No significant flux variation + uncertainties on flux estimates

No time lag recovered



Infrared RM

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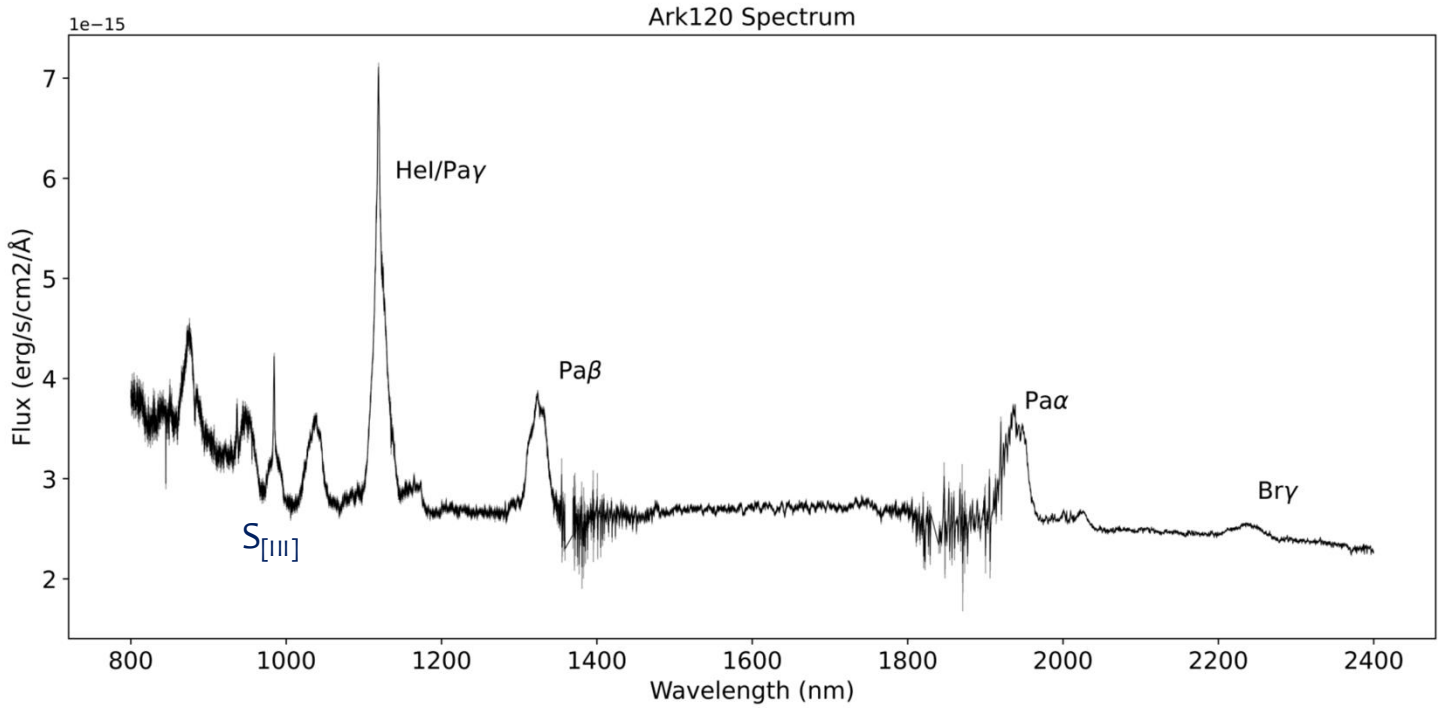
ongoing monitoring, total of 3 semesters with ~20 observations each… stay tuned!

SNR ≃ 25 for Brγ



Infrared RM

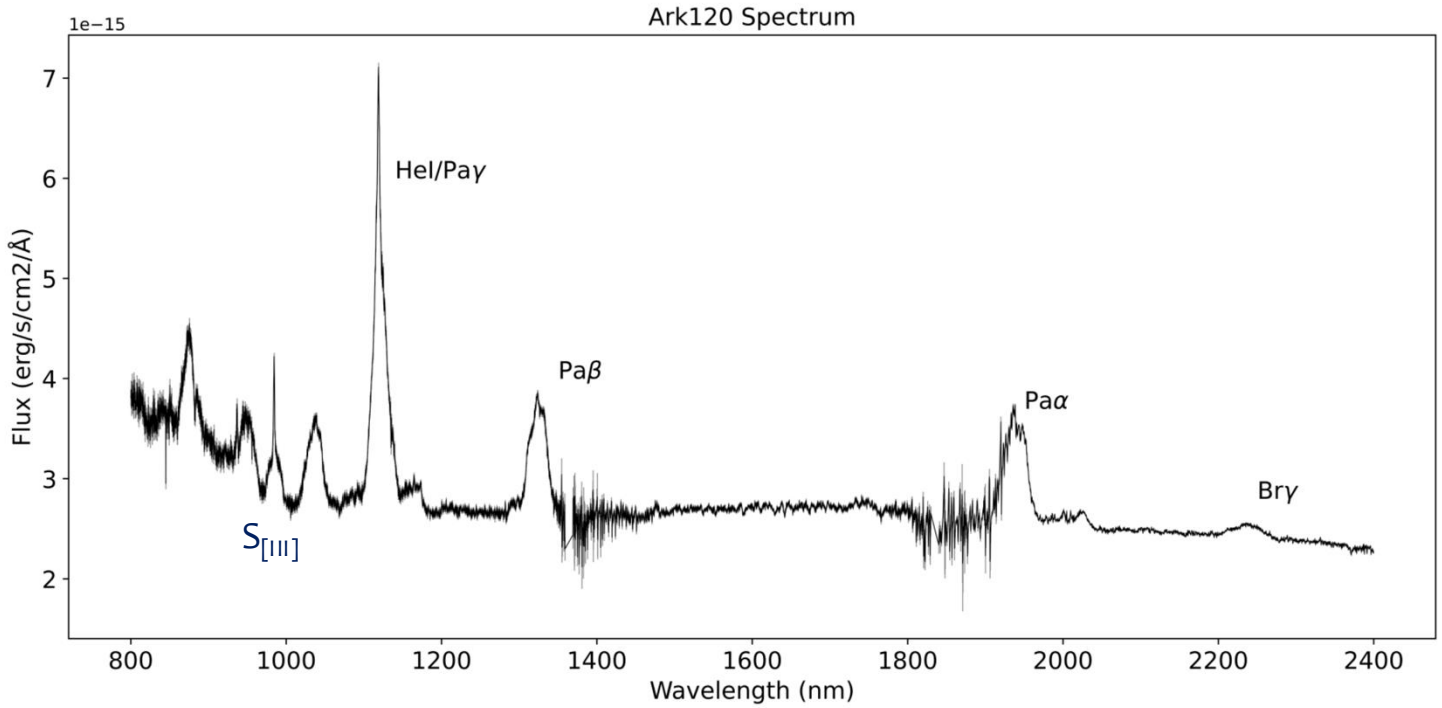
We hope to obtain an H_0 estimate with less than 10% uncertainties
We still need to combine multiple objects to say something about the H0 tension

IRTF (3.2 meters, 0.7-2.6μm) campaigns

- Ark120, z=0.0327

ongoing monitoring, total of 3 semesters with ~20 observations each… stay tuned!

SNR ≃ 25 for Brγ over the continuum



Infrared RM

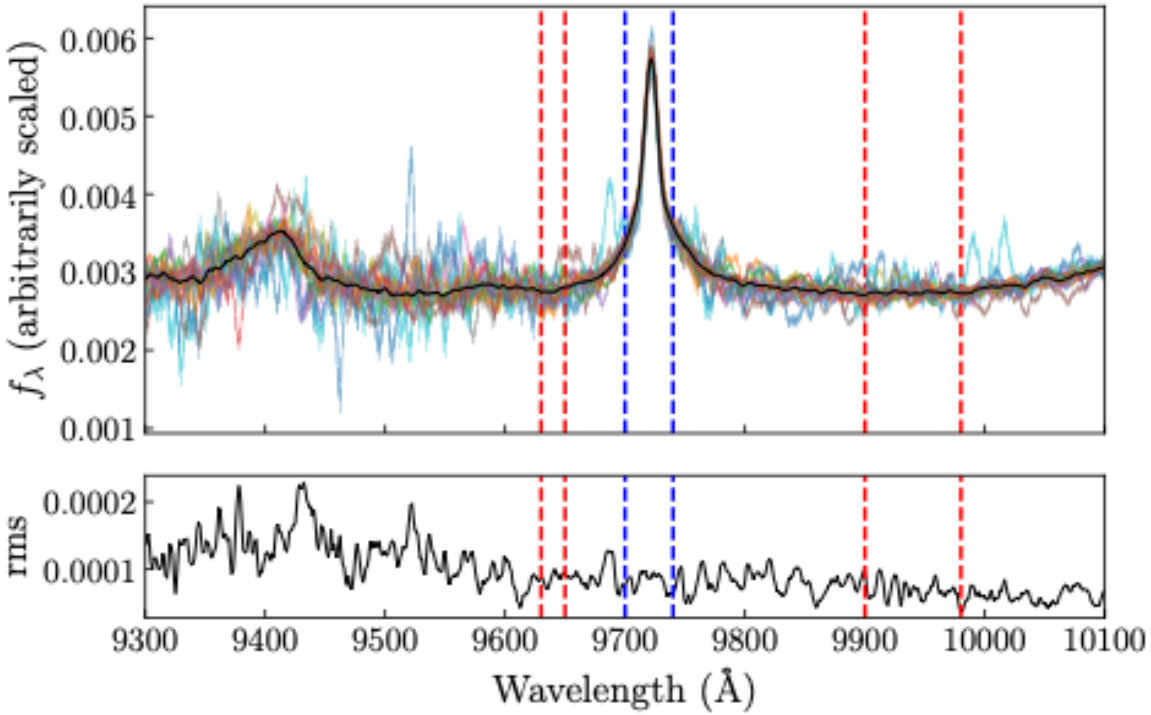
Flux calibration between different epochs:

“traditionally” done with the [OIII] line

We use the S[III]λ9531 line, with the *mapspec* code (Fausnaugh+2017)

We need two continuum windows next to the line, but on the blue side there is FeII emission that needs to be modelled and subtracted

At best, 3-4% uncertainties on flux calibration



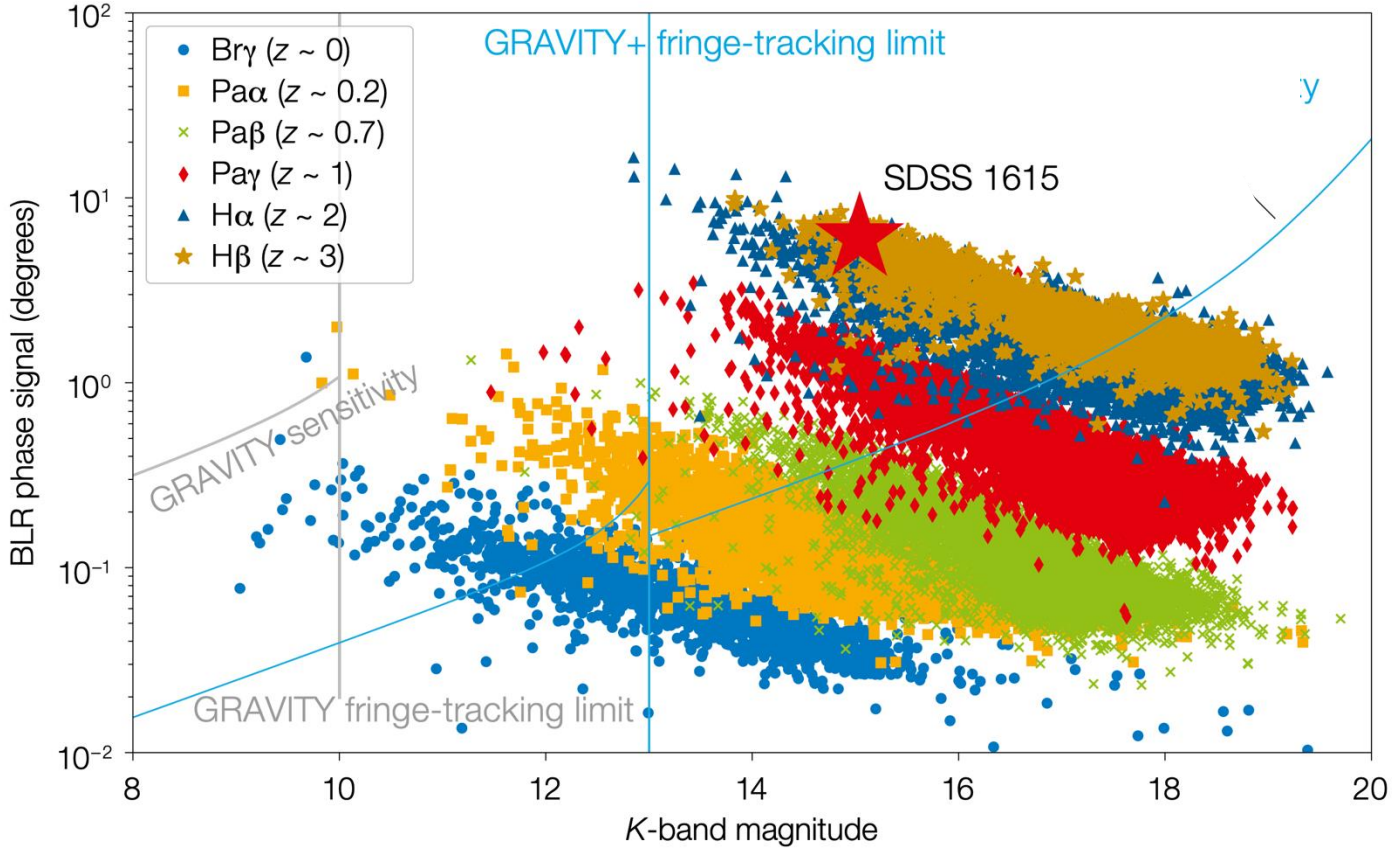
GRAVITY+

It will observe hundreds of additional AGN at K magnitudes up to 13

BLR angular size and SMBH masses:

- with different lines
- at different redshifts

But we cannot perform IR Reverberation Mapping for these objects with the current telescopes! (6-7 hours per epoch at IRTF)

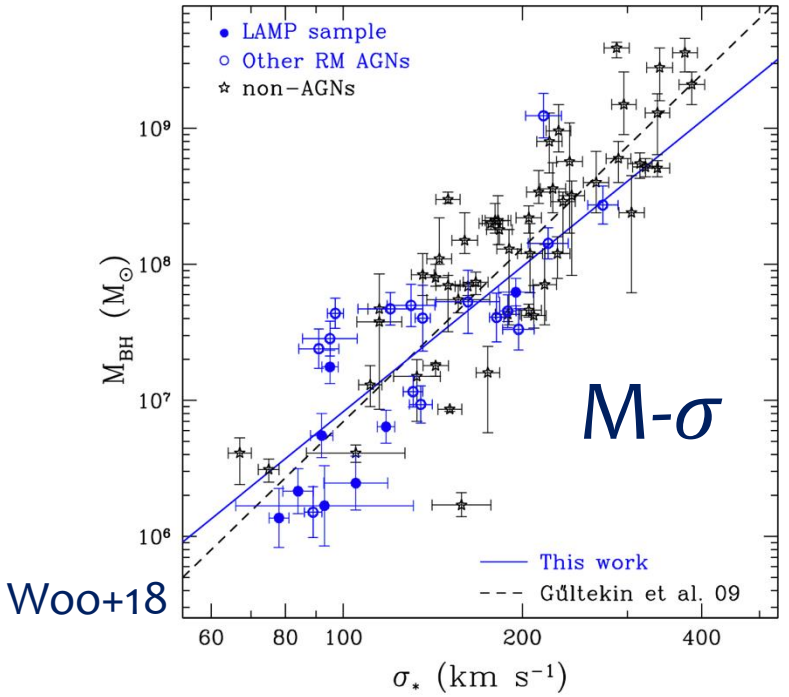


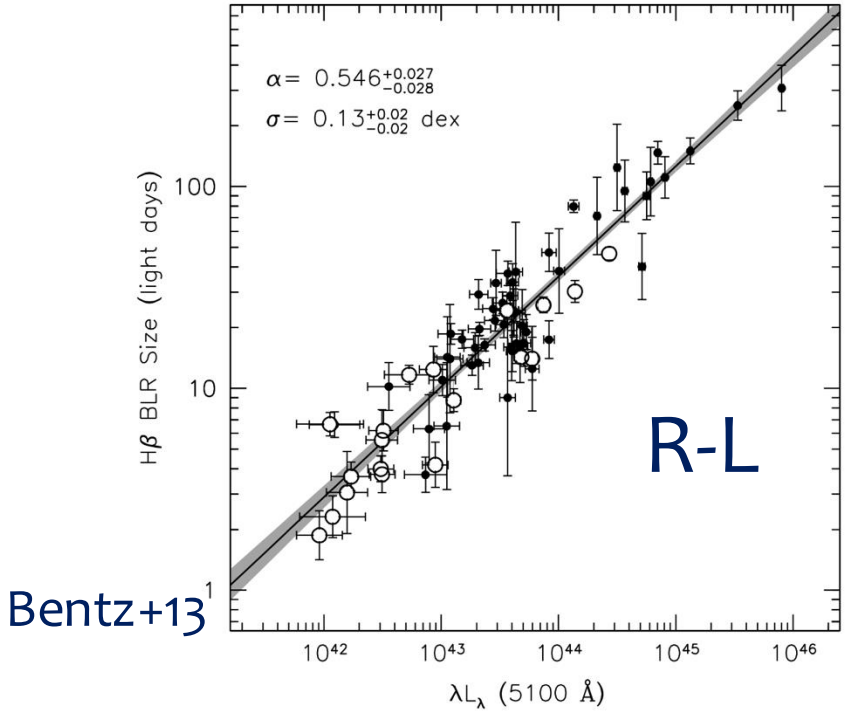
GRAVITY+ collaboration

Current issues

- With narrow-lines flux calibration is hard to get 1% flux precision and derive time lags
- Current instruments require very long observing times to perform RM on the coming GRAVITY+ objects
- We still lack a complete understanding of BLR shape, geometry and kinematic, which means uncertainties in SMBH mass estimates
- BLR modeling is possible only for very local objects with current instruments

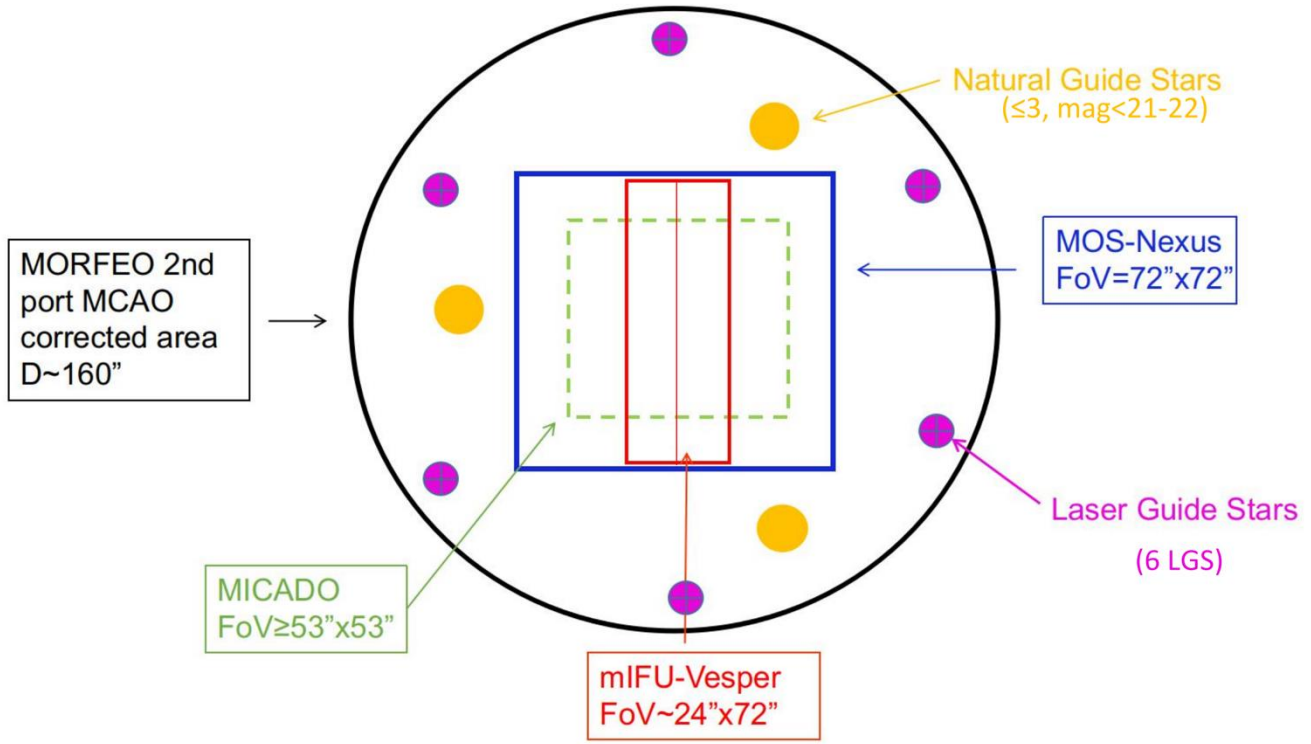
$$M_{BH} = f\frac{R_{BLR}\Delta V^2}{G} = f\frac{L^{0.5}FWHM^2}{G}$$





NEXUS

- MOS: we can use stars in the field for flux calibration and reach <1% precision on fluxes



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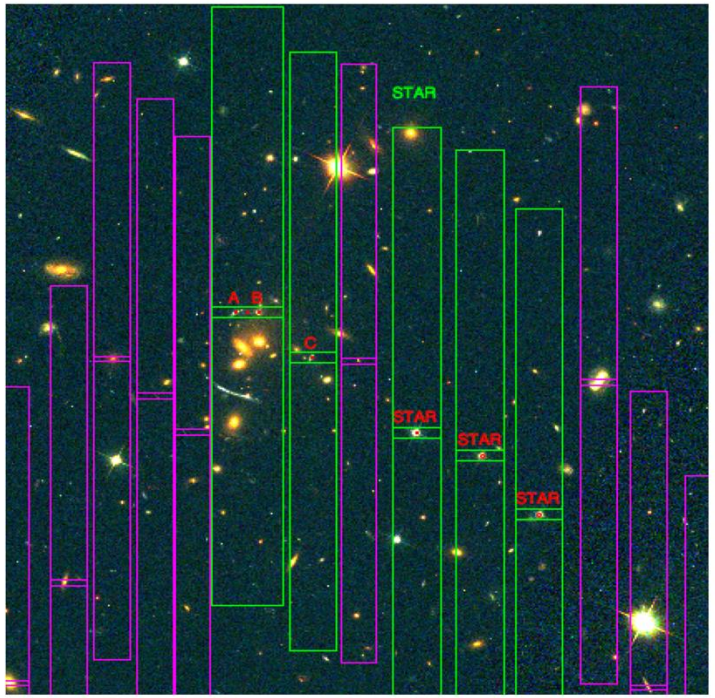
- MOS: we can use stars in the field for flux calibration and reach <1% precision on fluxes
  (Method used in Williams+21 for the RM of a quadruply lensed quasar with Flamingo2)



NEXUS

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- With the spectral range up **to 2.45 μm**, we can monitor GRAVITY+ lines
- High spectral resolution means more accurate telluric corrections
- We could obtain SNR of Brγ of 50-100 above the continuum in *tens of minutes for* objects that would require 20 hours per epoch at IRTF

NEXUS

Measure H0 with 1-2% precision combining GRAVITY+ and reverberation mapping

Use high resolution IR spectra to understand the physics, geometry and kinematics of the BLR

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Thank you!

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