Masses of M• in low mass early-type galaxies using LGS AO

Krajnović (Oxford), McDermid (Gemini North),
Cappellari (Oxford), Davies (Oxford), MNRAS, submitted

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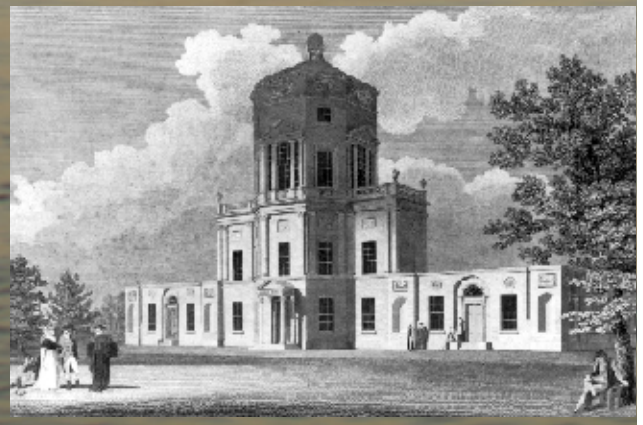
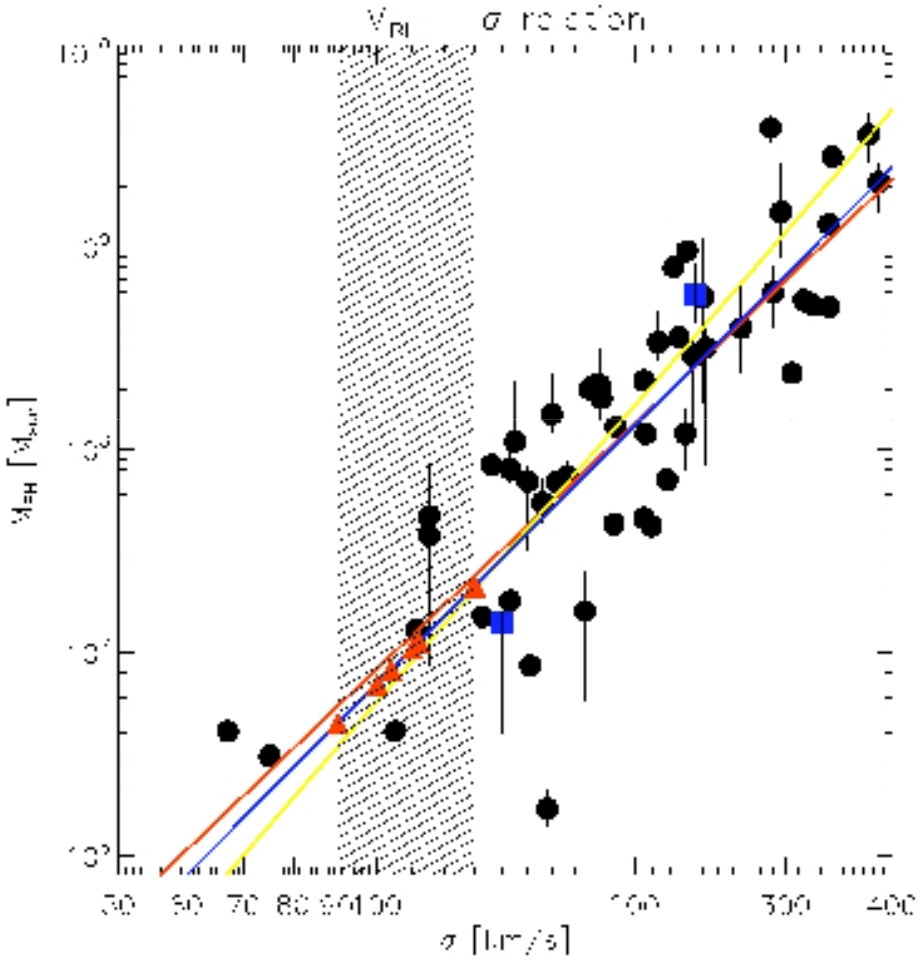
Oxford



Atlas^{3D} Black Hole project

- Goal: derive a representative M_{BH} - σ_e relation for early-type galaxies!
- Target under-populated regions of M_{BH} - σ_e relation
  - σ_e < 130 km/s
- Large scale IFU observations in hand!! –SAURON IFU
- Stellar dynamical models
  - Schwarzschild's method
- High resolution campaign:
  - Gemini + NIFS
  - LGS AO in 'open loop' mode

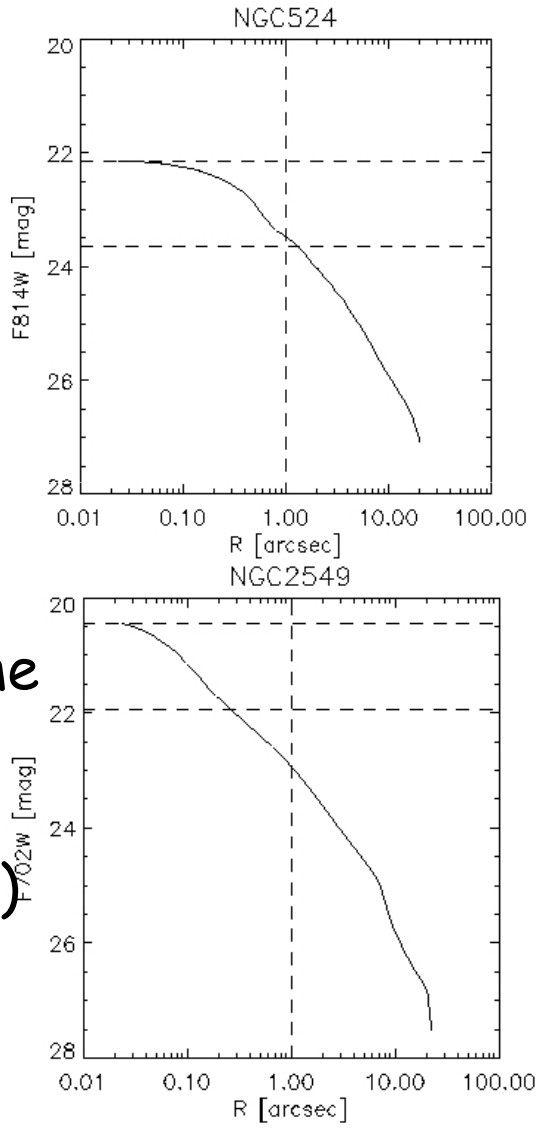


Gebhardt et al. (2000) & Merritt& Ferrarese (2000), Graham et al. (2008), Gültekin et al. (2009)

LGS AO without NGS

Open-loop focus model

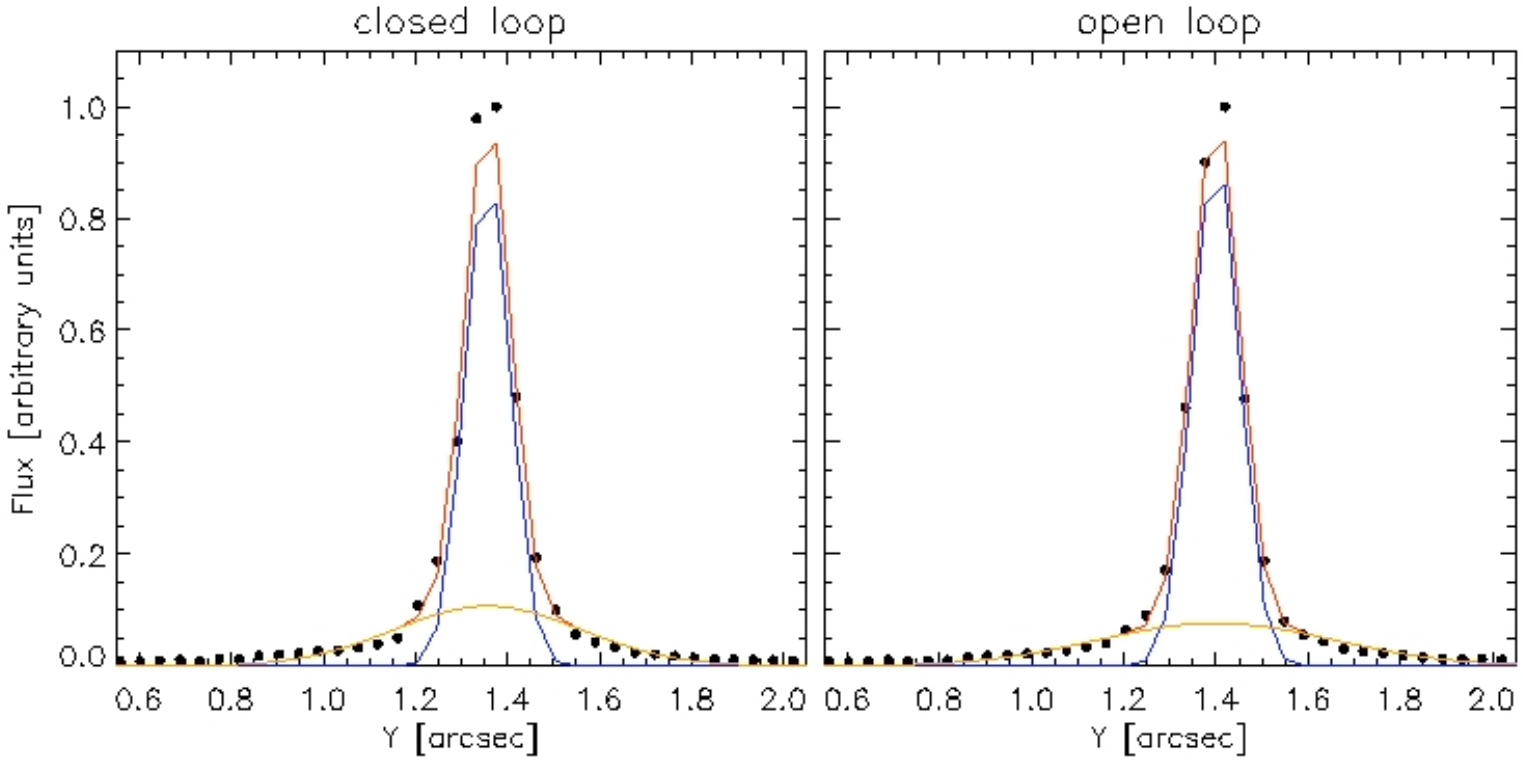
- No bright enough NGS nearby
- Tip-tilt correction on nucleus
- Test system capabilities
  - Different light profiles
- Adopted strategy (Thanks to GEMINI staff!!):
  - Tune LGS AO on a nearby (< 6 arcmin = same clearance window as science target) star
  - Open focus loop & move to target
  - Acquire target (LGS + tip-tilt from nucleus)
  - Focus is changed by following a model
  - Back to focus star to monitor PSF changes



LGS AO without NGS

Focus star before and after 1h: ~30% strehl

fwhm1 = 0.11″	fwhm1 = 0.12″
fwhm2 = 0.48″	fwhm2 = 0.60″

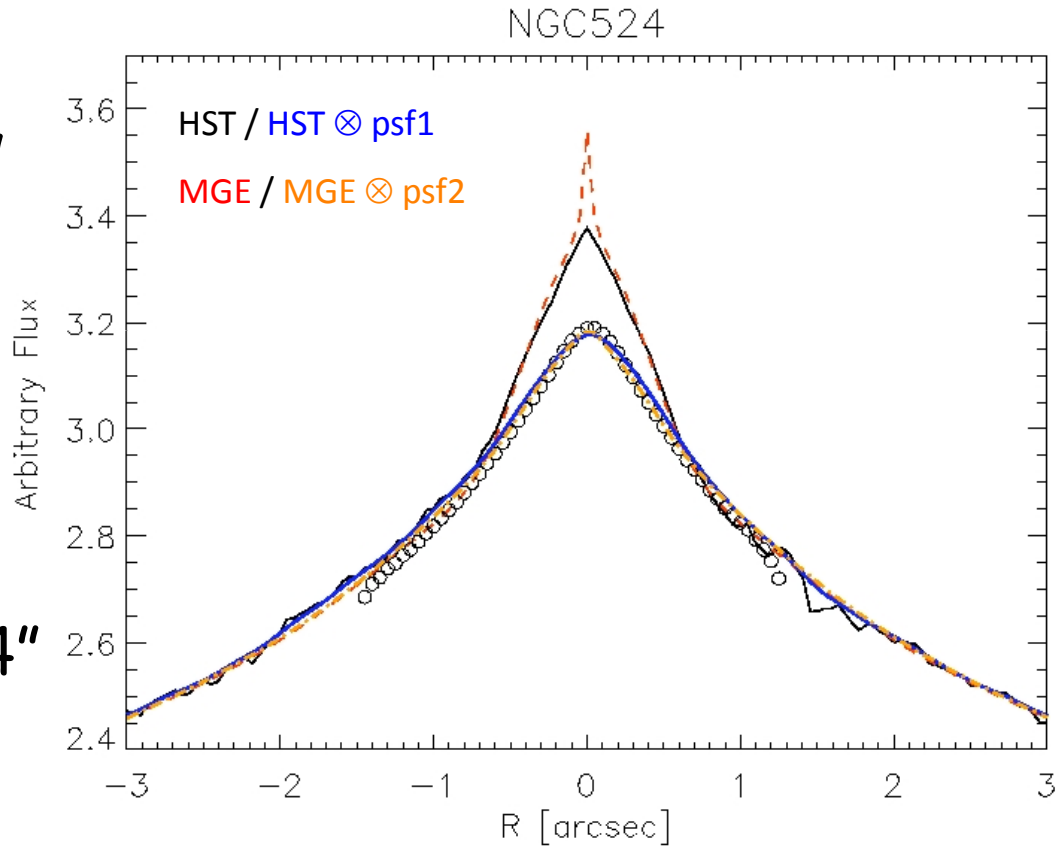


Estimating PSF

- Diffraction limit: fwhm ~ 0".1
- Comparison with HST image (psf~0".05)
- Comparison with Multi-Gussian-Expansion model (deconvolved) (Emsellem et al. 1994, Cappellari 2002)
- Convolve test image with a double Gaussian
- Compare with NIFS data cube
- Used for non-AO data: Emsellem et al. (2004), McDermid et al. (2006), Shapiro et al. (2006)

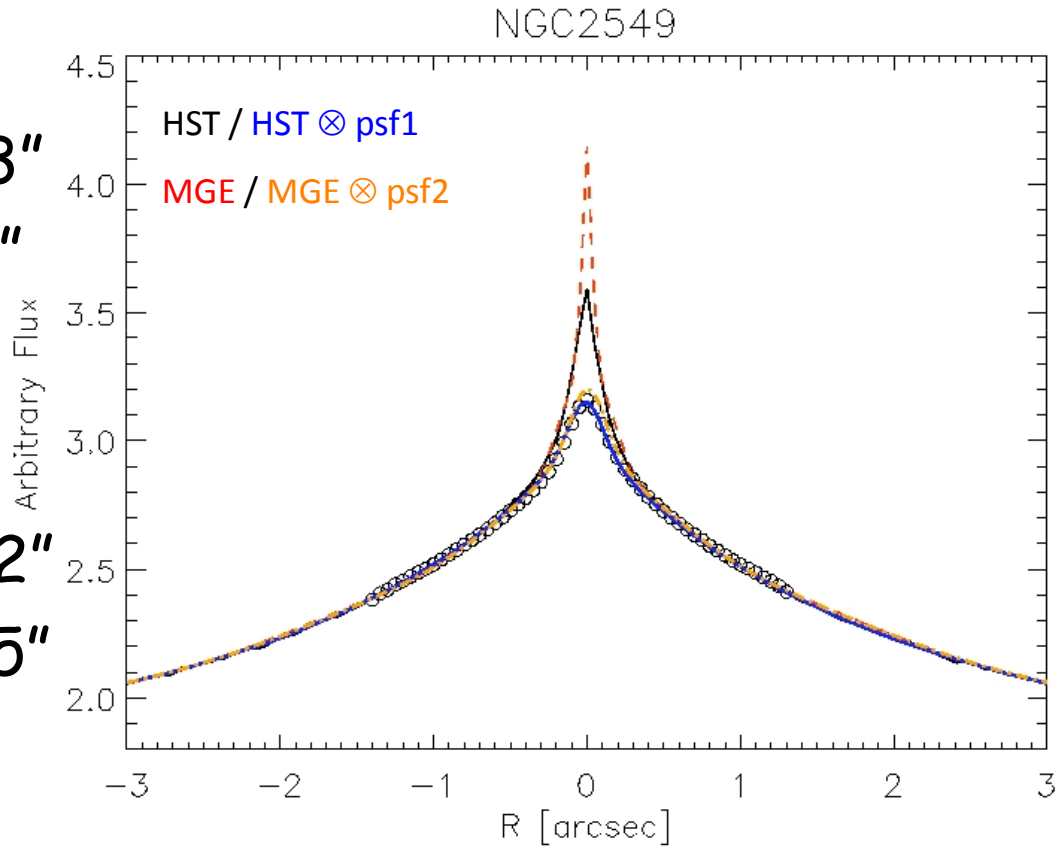
Estimating PSF - NGC524

- HST (psf1):
  - $Fwhm_1$ = 0.23″ ± 0.1″
  - $Fwhm_2$=1.25″ ± 0.1″
  - I_1=0.39 ± 0.08
- MGE (psf2)
  - $Fwhm_1$ = 0.16″ ± 0.1″
  - $Fwhm_2$ = 1.36″ ± 0.14″
  - I_1 = 0.33 ± 0.09



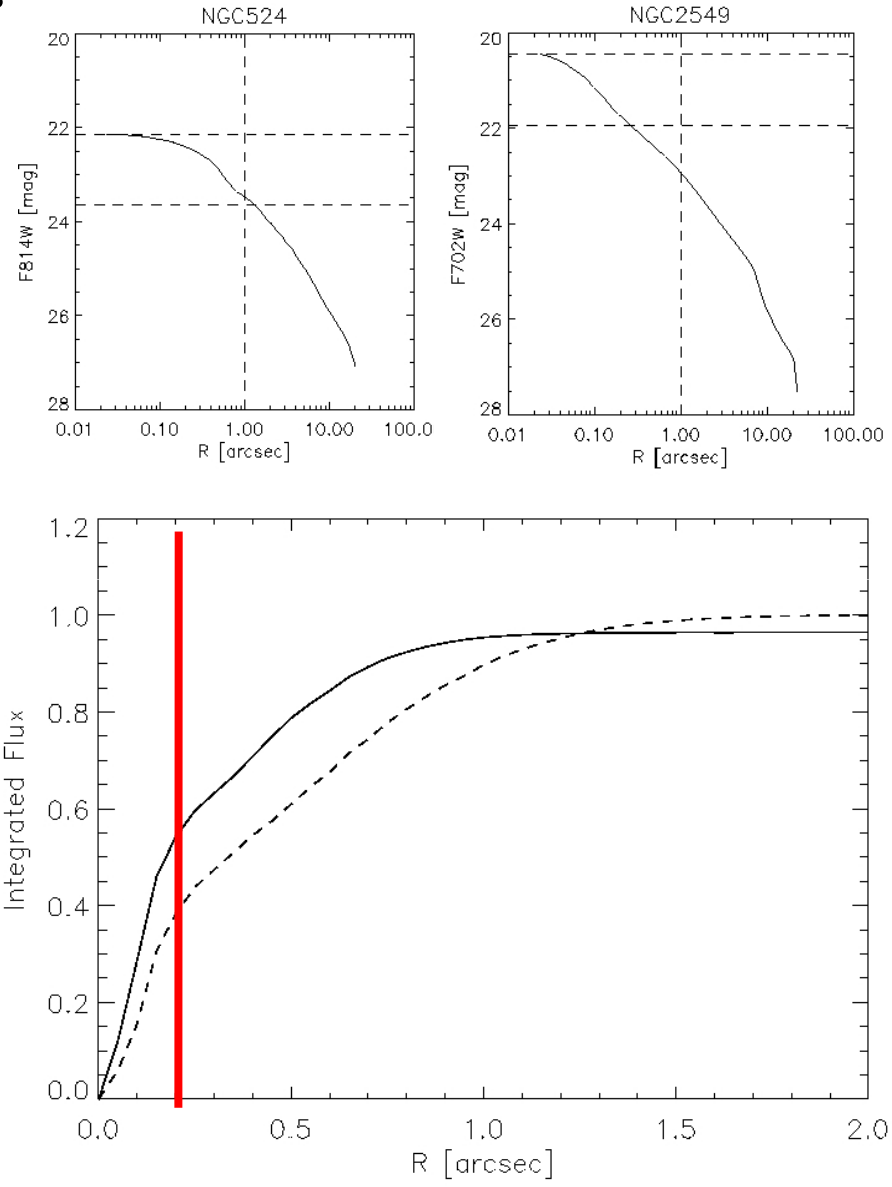
Estimating PSF - NGC2549

- HST (psf1):
  - $Fwhm_1$ = 0.17″ ± 0.03″
  - $Fwhm_2$=0.84″ ± 0.08″
  - I_1=0.53 ± 0.08
- MGE (psf2)
  - $Fwhm_1$ = 0.20″ ± 0.02″
  - $Fwhm_2$ = 0.81″ ± 0.05″
  - I_1 = 0.47 ± 0.05

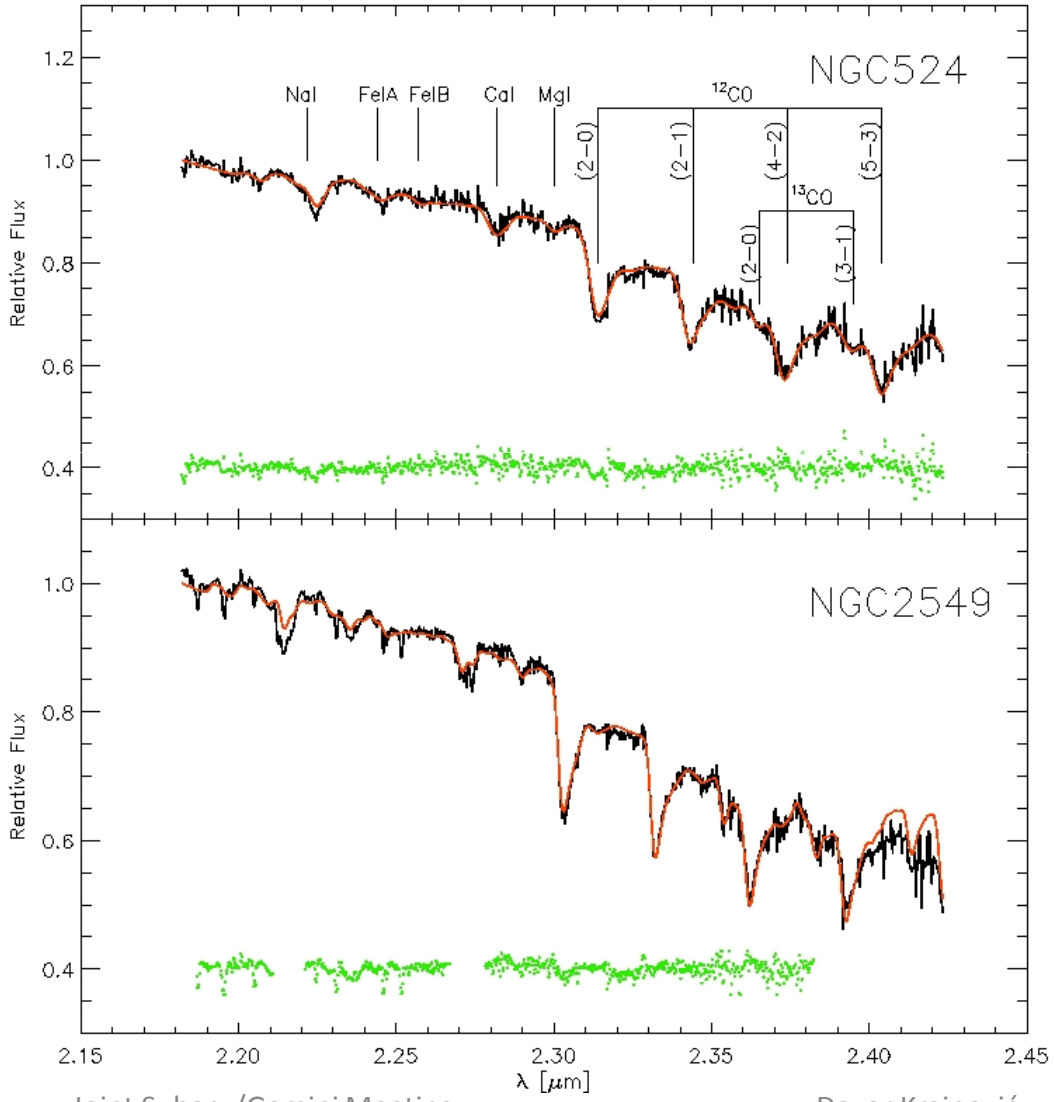


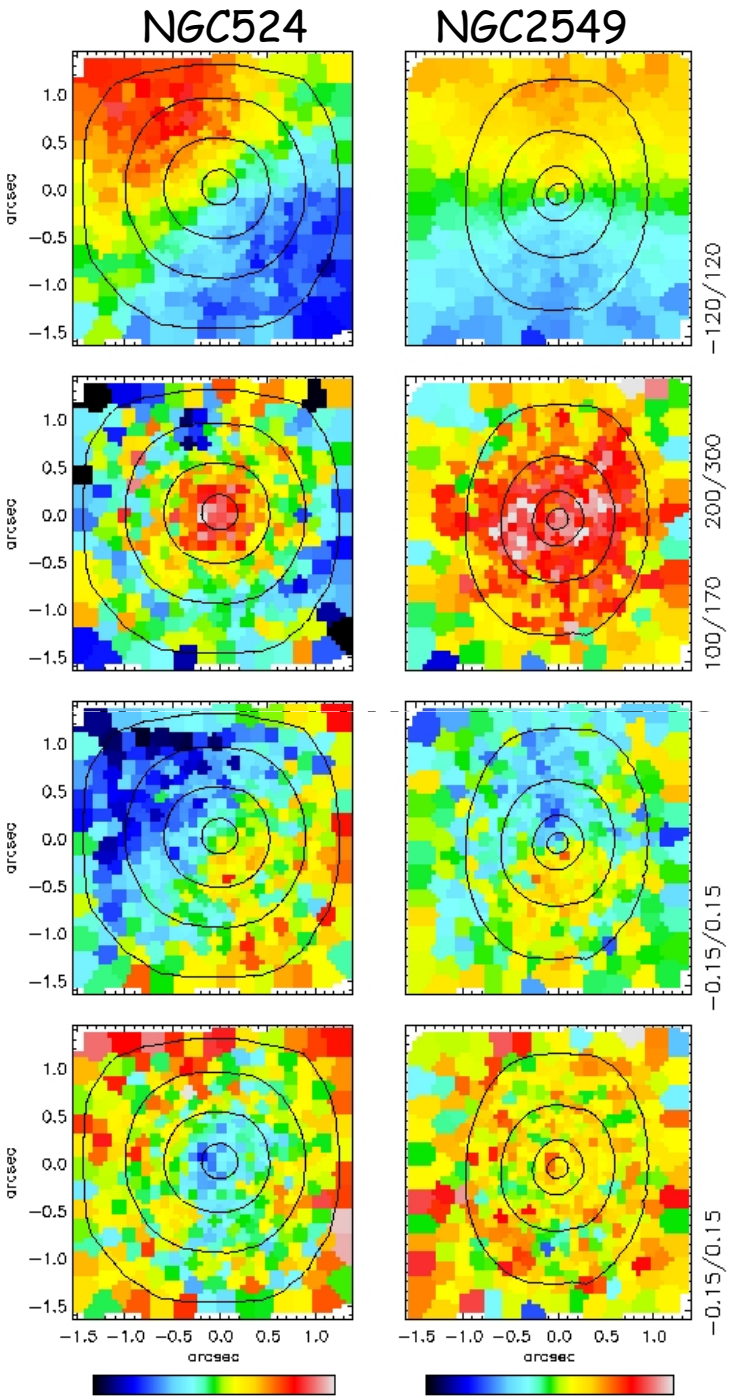
Influence of PSF

- LGS correction
  - SFO star: 0.12″/0.60″
  - NGC524: 0.23″/1.25″
  - NGC2549: 0.17″/0.84″
- Tip-tilt jitter responsible for broad component
- Integrated flux
  - NGC524: ~40% within 0.2″
  - NGC2549: ~55% within 0.2″



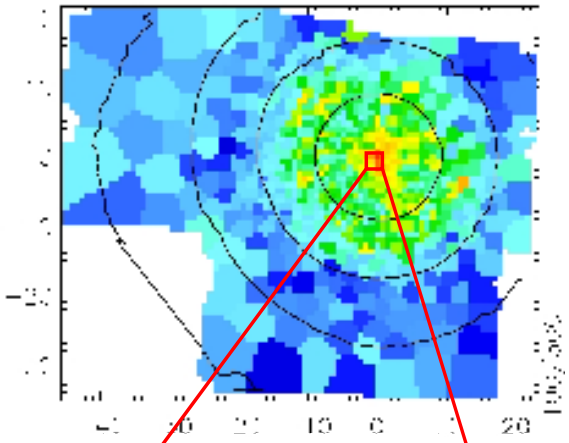
Kinematics


NGC524
NaI
FeIA
FeIB
CaI
MgI
^{12}CO
(2–0)
(2–1)
(4–2)
(5–3)
^{13}CO
(2–0)
(3–1)
Relative Flux
NGC2549
Relative Flux
λ [μm]

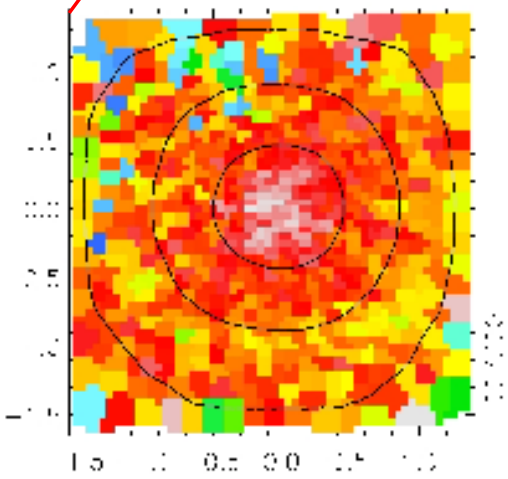

NGC524
NGC2549
arcsec
−120/120
200/300
100/170
−0.15/0.15
−0.15/0.15

Comparison with SAURON

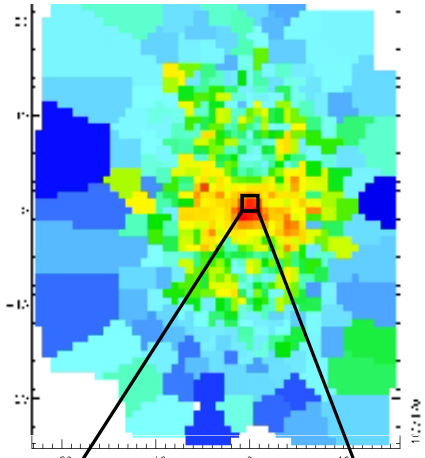
NGC524 SAURON



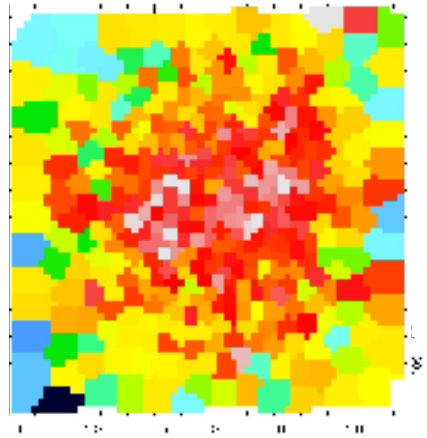
NIFS

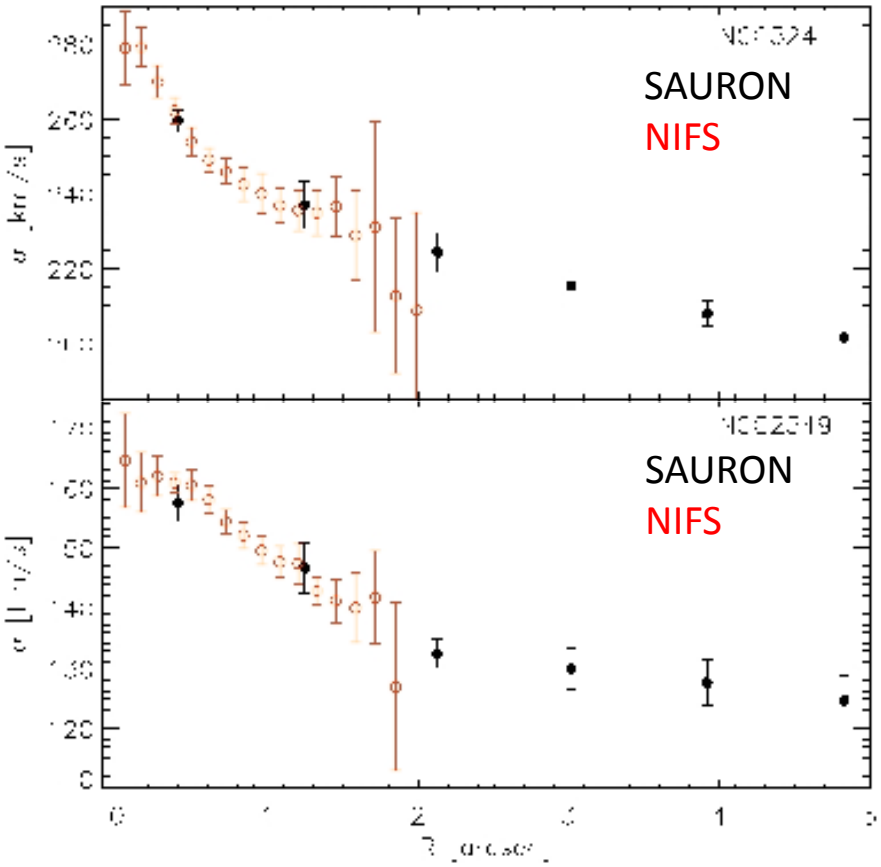


NGC2549 SAURON



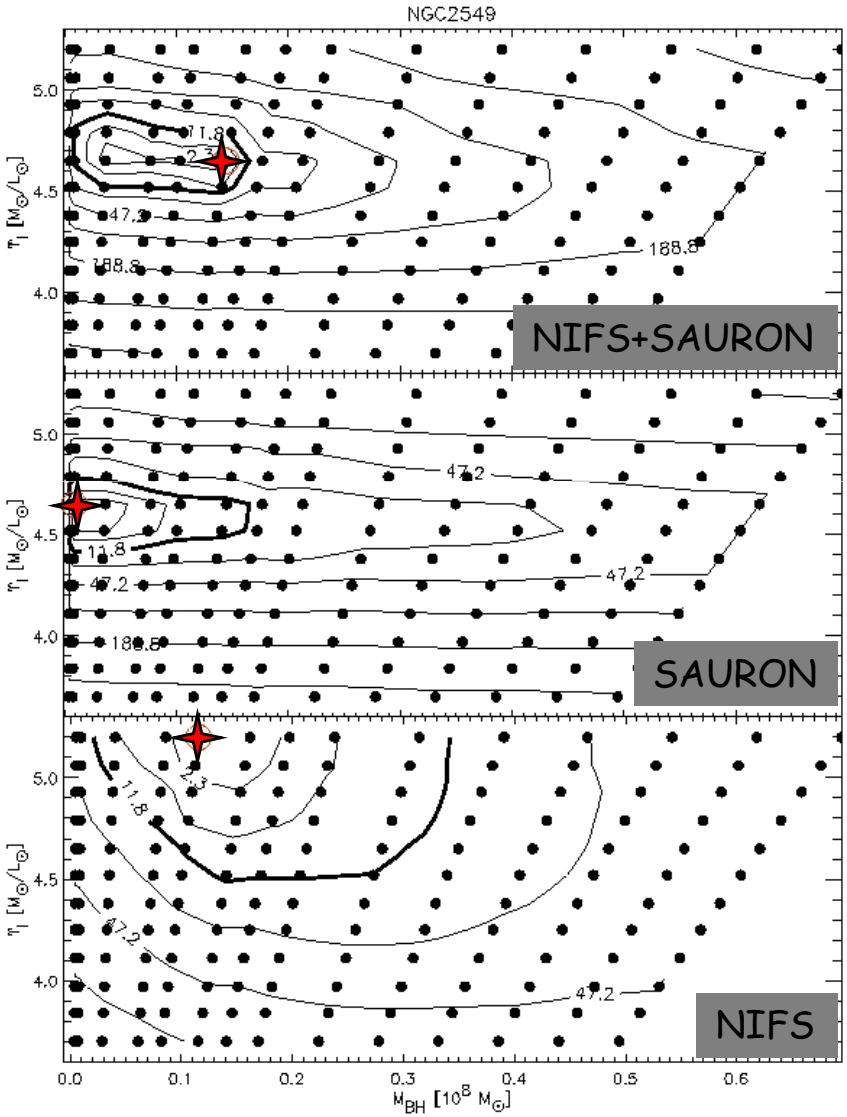
NIFS

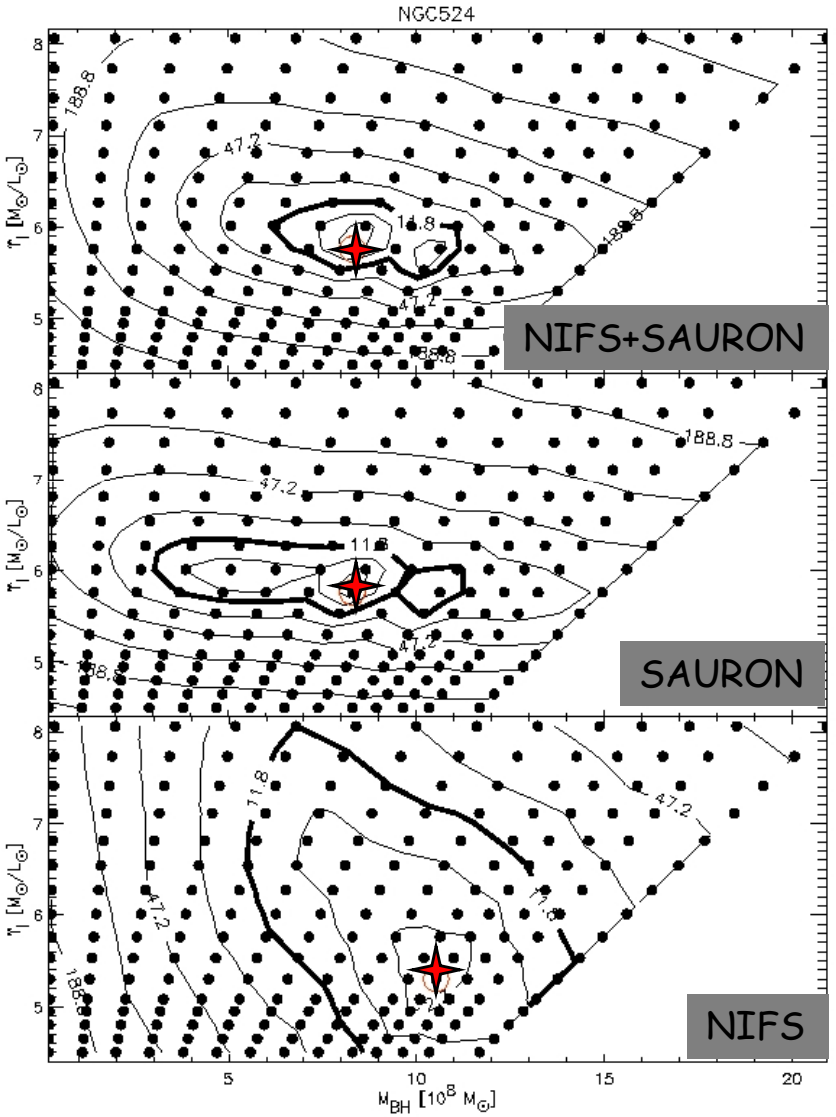




NGC524: NIFS σ ~ 4% higher
NGC2549: NIFS σ ~ 1% higher

Importance of NIFS and SAURON

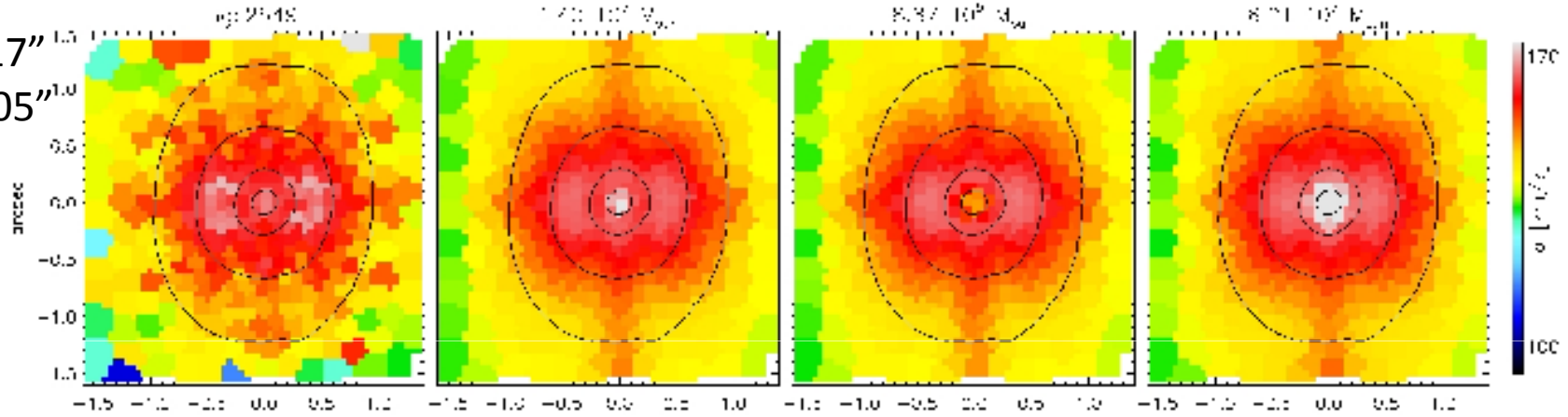




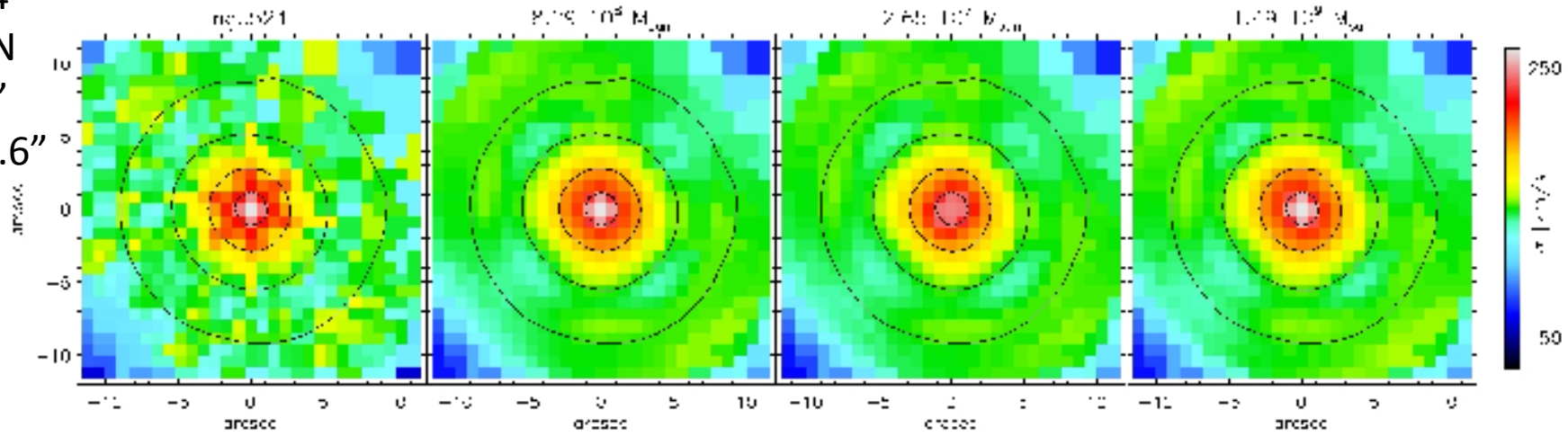
Data model comparison

NGC2549
NIFS
PSF ~ 0.17”
Rbh ~ 0.05”

Best M_{BH} Small M_{BH} Big M_{BH}

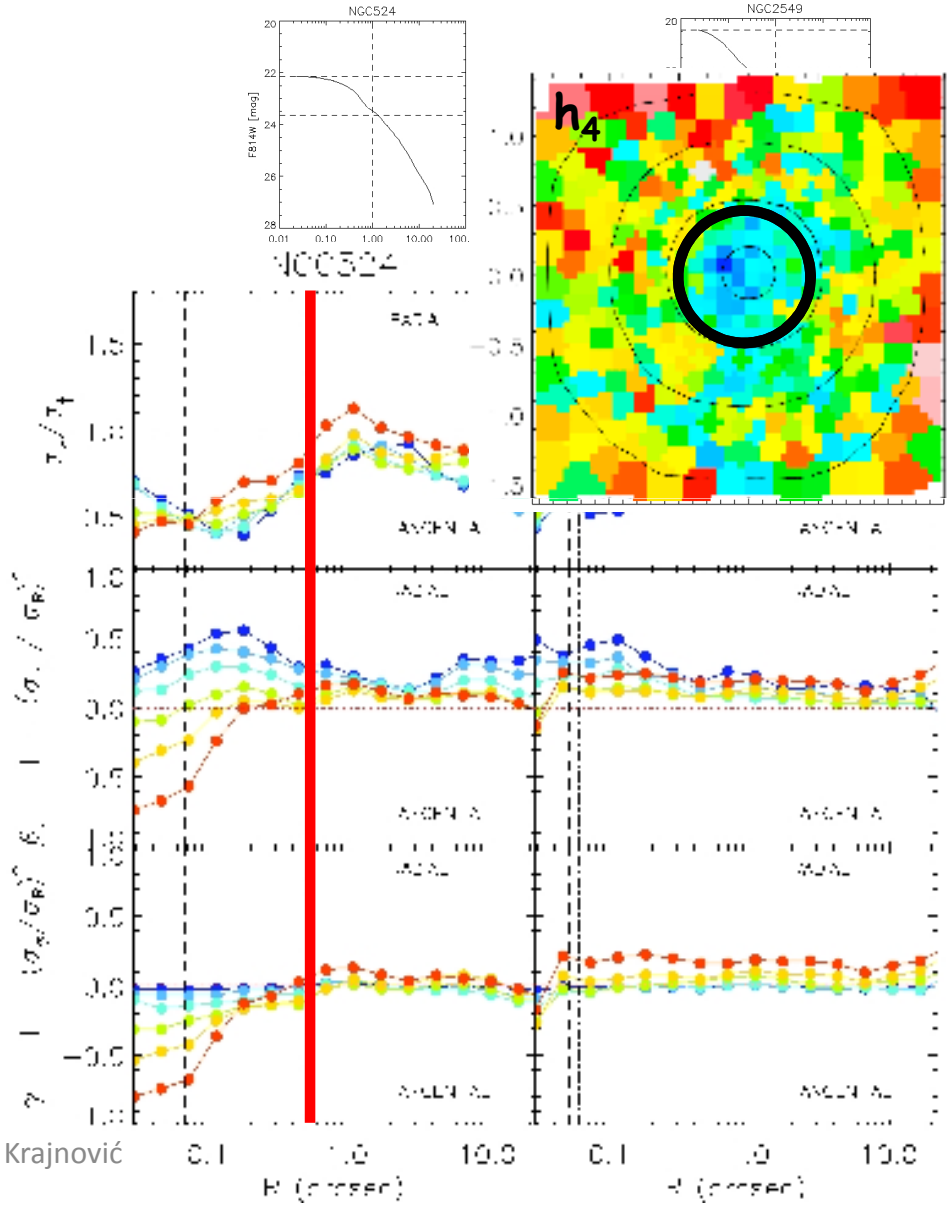


NGC524
SAURON
PSF ~ 1”
Rbh ~ 0.6”



Orbital structure

- Core light profiles -> dry mergers -> binary BH mergers -> tangential anisotropy ($\sigma_r/\sigma_t < 1$) Faber+97, Hopkin+09, Kormendy+08, Milosavljević&Merritt01+
- Cuspy light profiles -> wet mergers -> gas accretion onto BH -> tangential anisotropy ($\sigma_r/\sigma_t < 1$) (!!) Mihos&Hernquist94, Hopkins+09, Kormendy+08
- NGC524: tangential
- NGC2549: radial



Conclusions

- Limited LGS AO can deliver considerable correction to PSF
  - 0".1- 0".2 resolution
  - Suitable for cuspy light profiles (smaller objects)
- Relative importance of large scale and high resolution IFUs:
  - Breaking M/L -Mbh degeneracy
  - IFU data – beyond sphere of influence
- Our method opens skies for similar studies => ***Atlas^{3D} Black Hole Project***
- NGC 524: $M_{BH} = (8.5 \pm 2) \times 10^8\ M_{sun}$
- NGC2549: $M_{BH} = (1.4 \pm 1) \times 10^7\ M_{sun}$