

The nucleus of Centaurus A



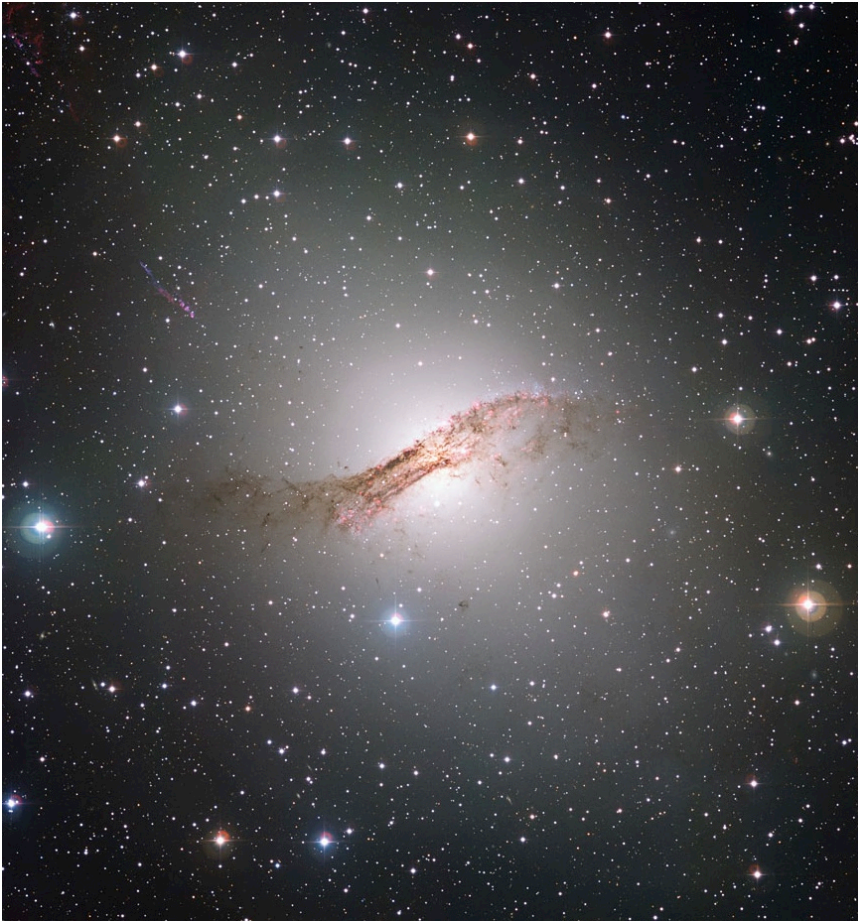
Nadine Neumayer

In collaboration with:

Michele Cappellari, Hans-Walter Rix, Juha Reunanen,
Paul van der Werf, Tim de Zeeuw, Ric Davies, Geoff Bicknell



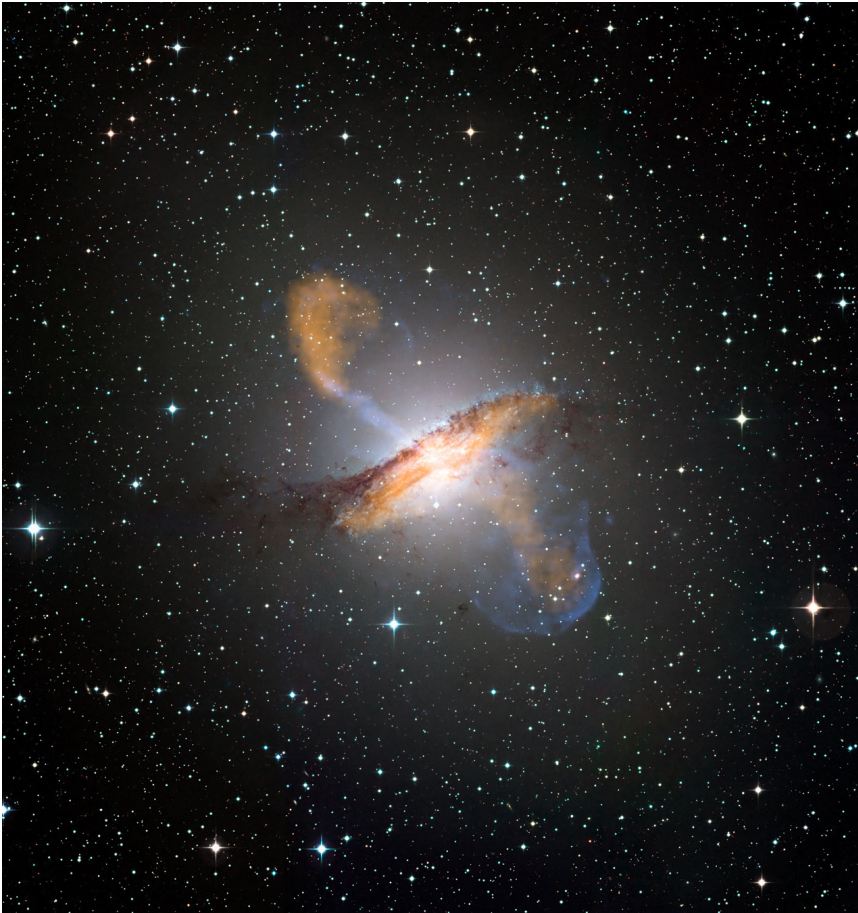
Motivation



- Nearest elliptical with AGN and jet ($1'' \sim 17\text{pc}$)

ESO/MPG 2.2m WFI

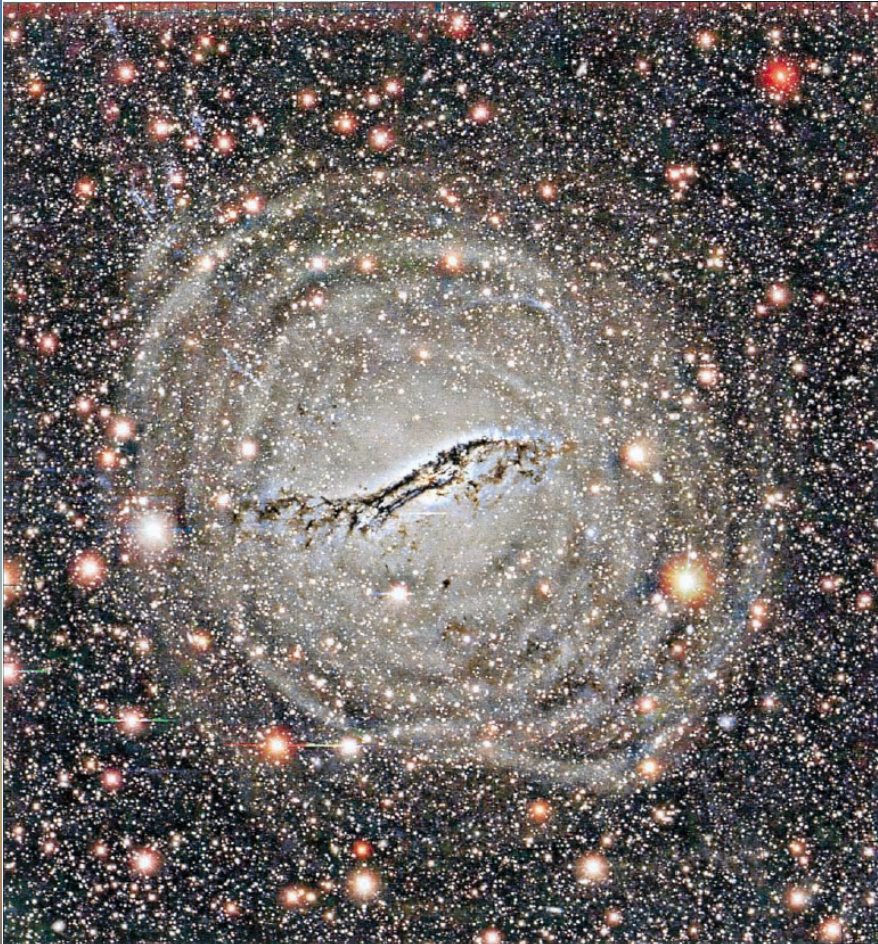
Motivation



- Nearest elliptical with AGN and jet ($1'' \sim 17\text{pc}$)
- Ideal laboratory to test AGN models

ESO/WFI; MPIfR/ESO/APEX/A.Weiss et al.;
NASA/CXC/CfA/R.Kraft et al. (X-ray)

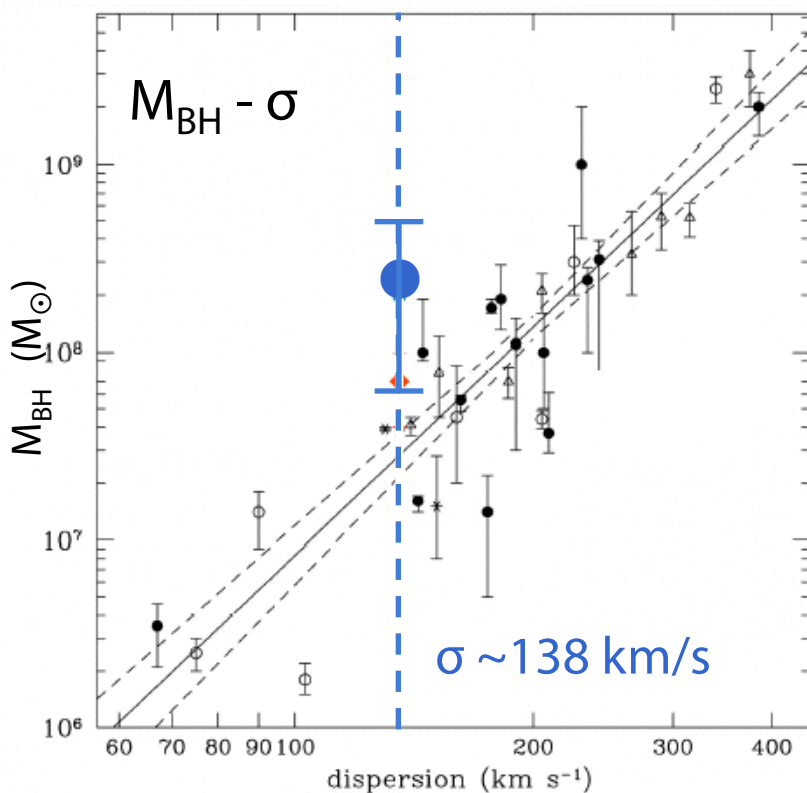
Motivation



CTIO / Peng et al. 2002

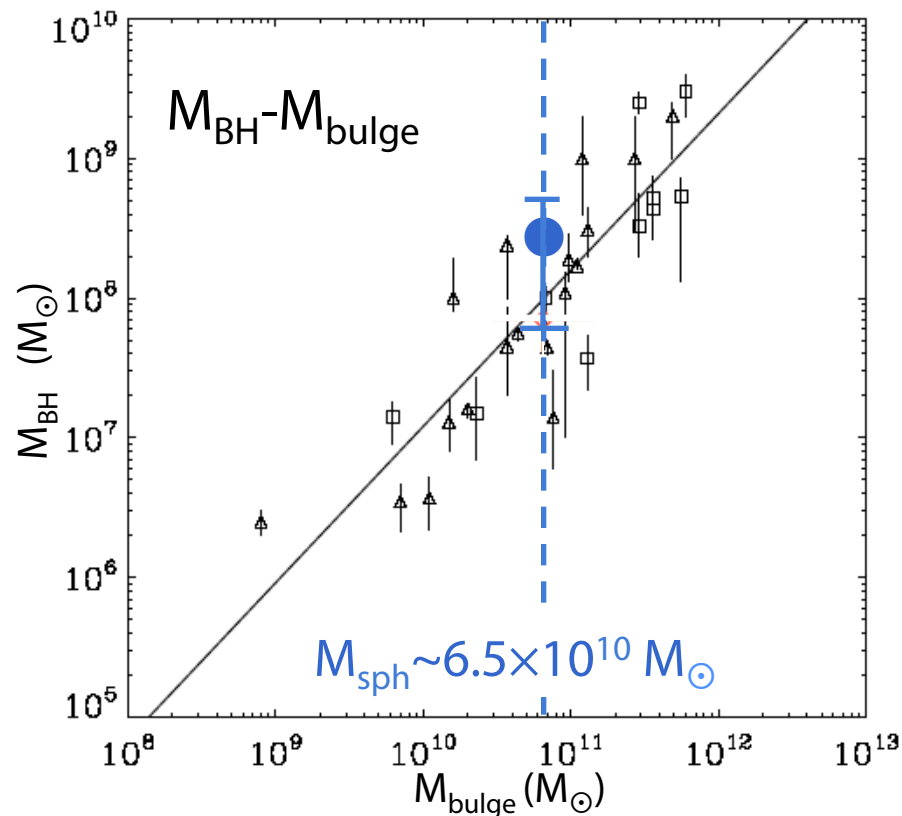
- Nearest elliptical with AGN and jet ($1'' \sim 17\text{pc}$)
- Ideal laboratory to test AGN models
- Evidence of recent merger (~ 0.5 Gyr ago)
- Binary black hole?

Cen A on the M_{BH} relations



Tremaine et al. 2002

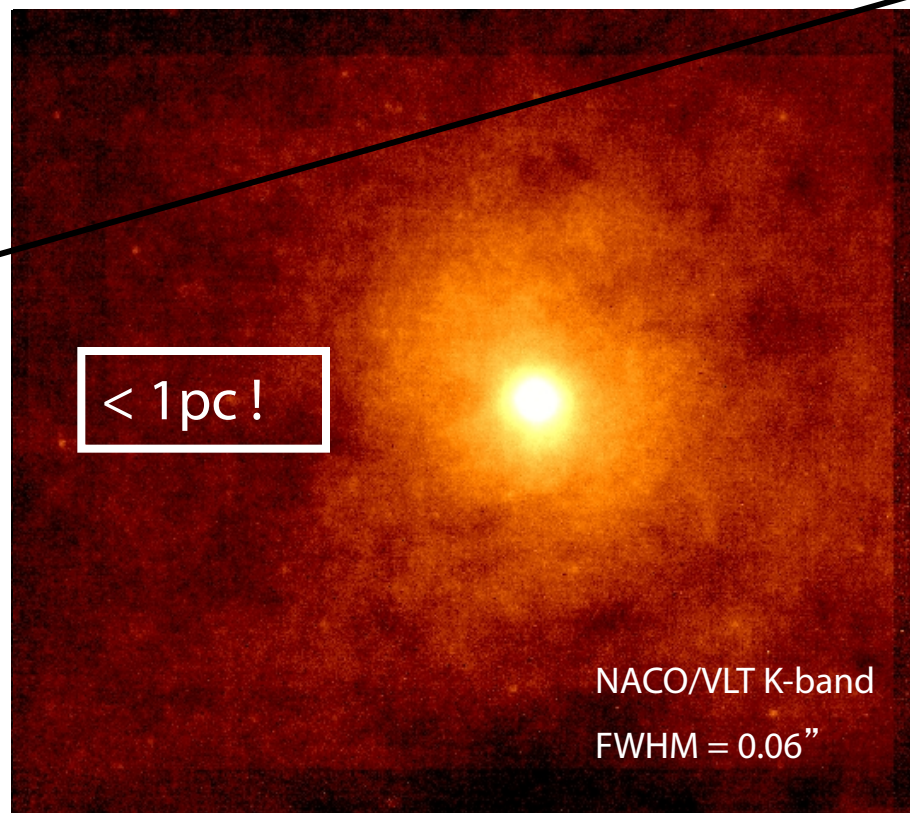
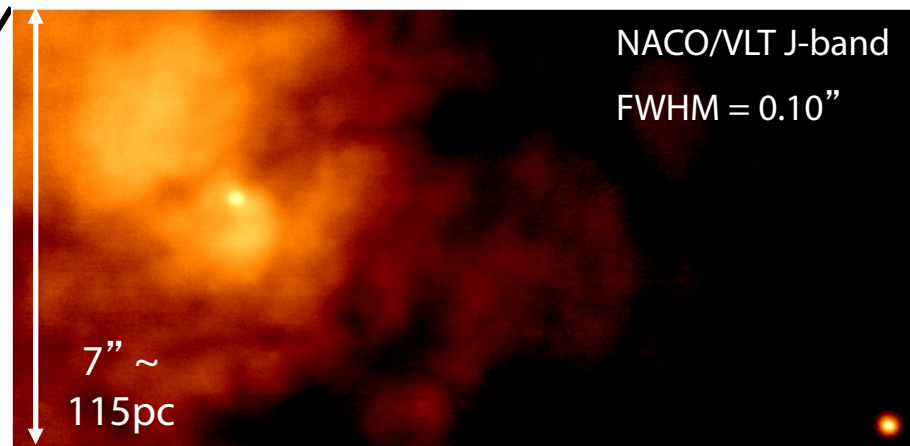
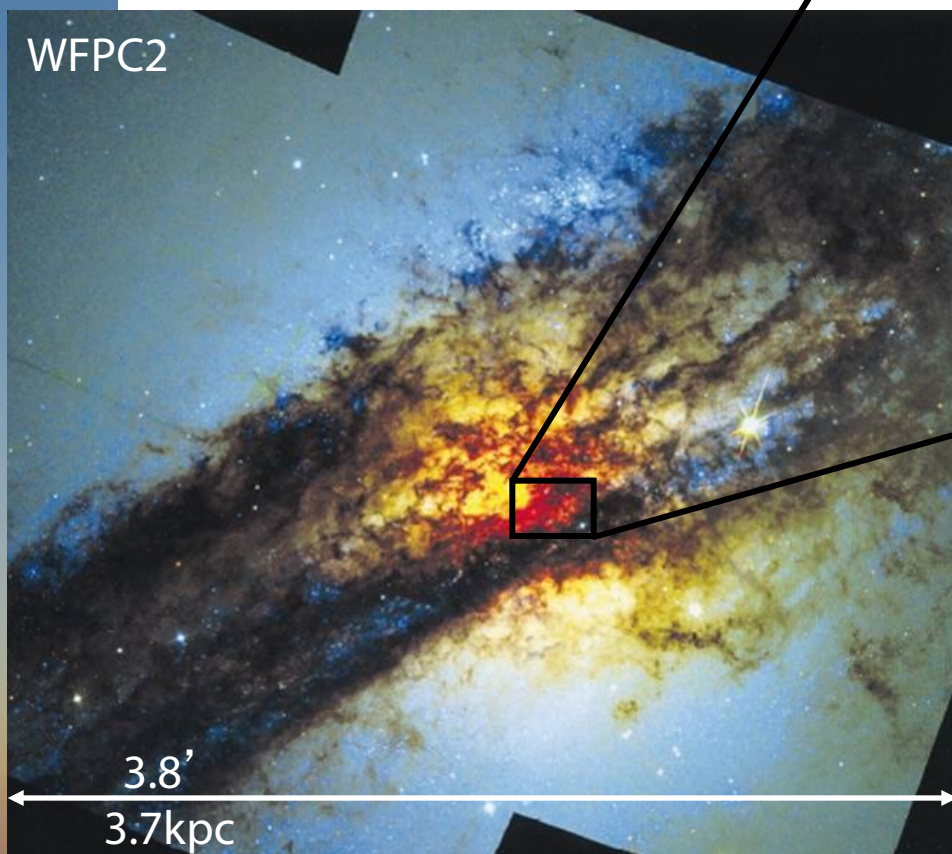
Silge et al. 2005



Marconi et al. 2001

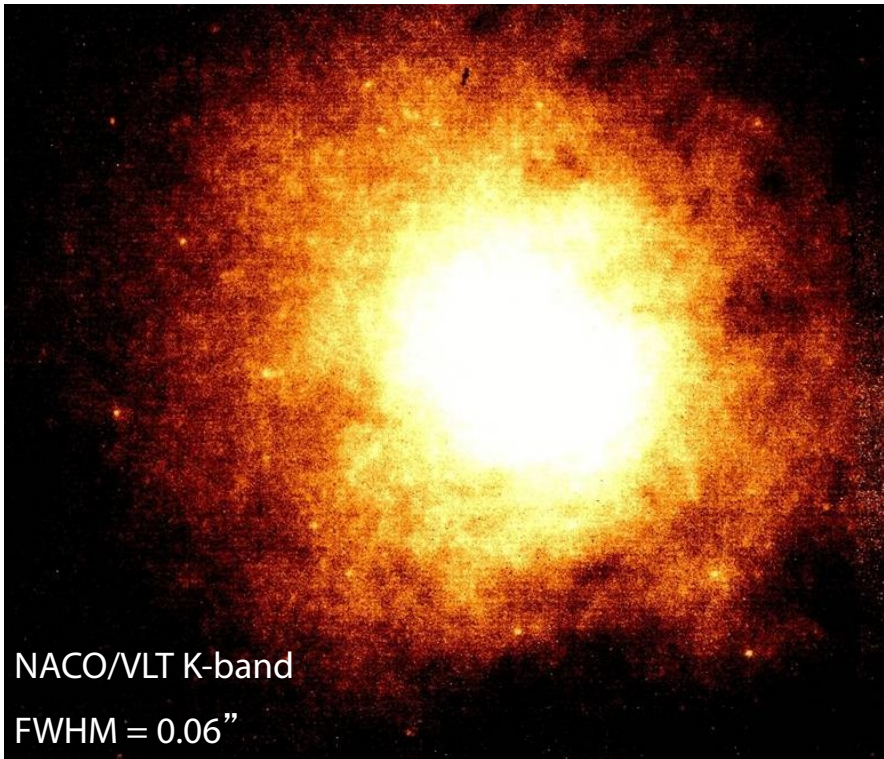
Häring & Rix 2004

Closer look



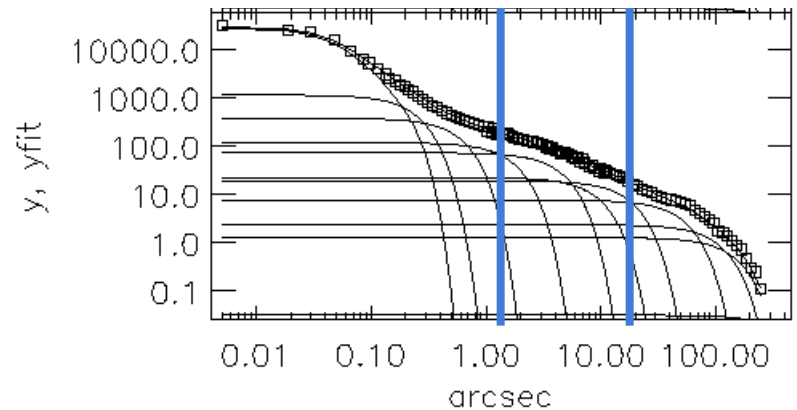
Core size: < 1 pc FWHM

Stellar mass model



Häring-Neumayer et al. 2006

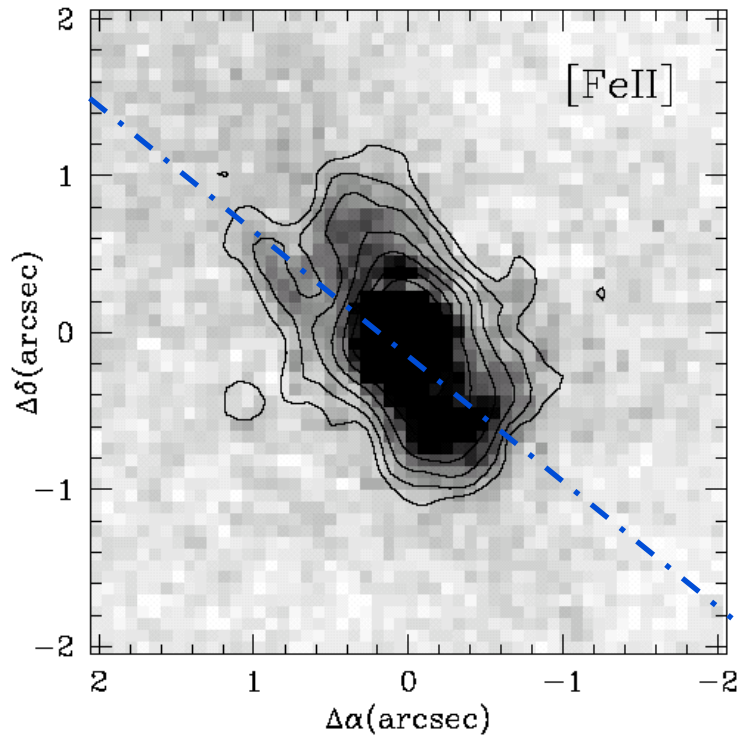
Multi-Gaussian Expansion



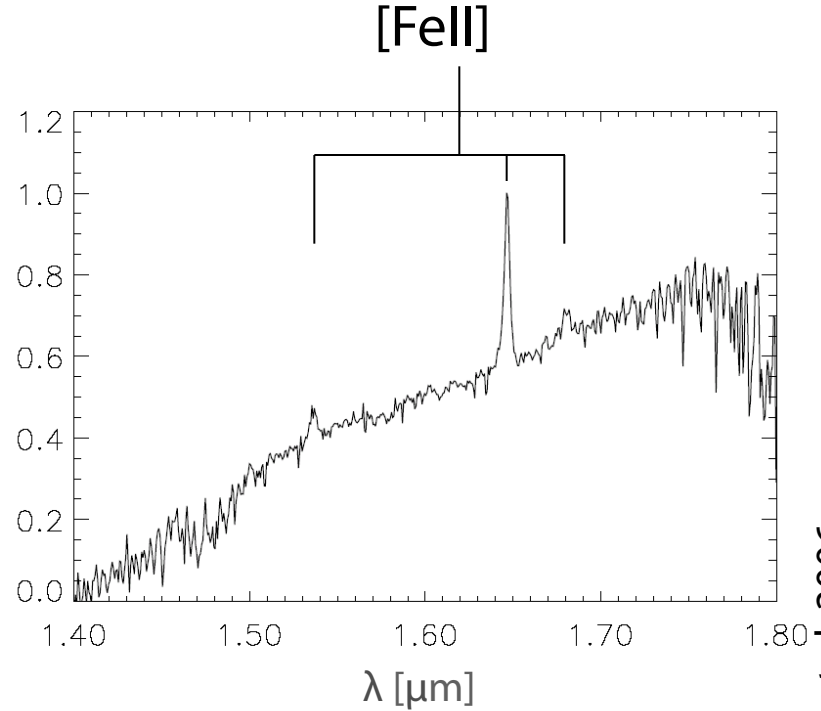
NACO + NICMOS + 2MASS

➔ stellar potential

Central kinematics - VLT/NACO



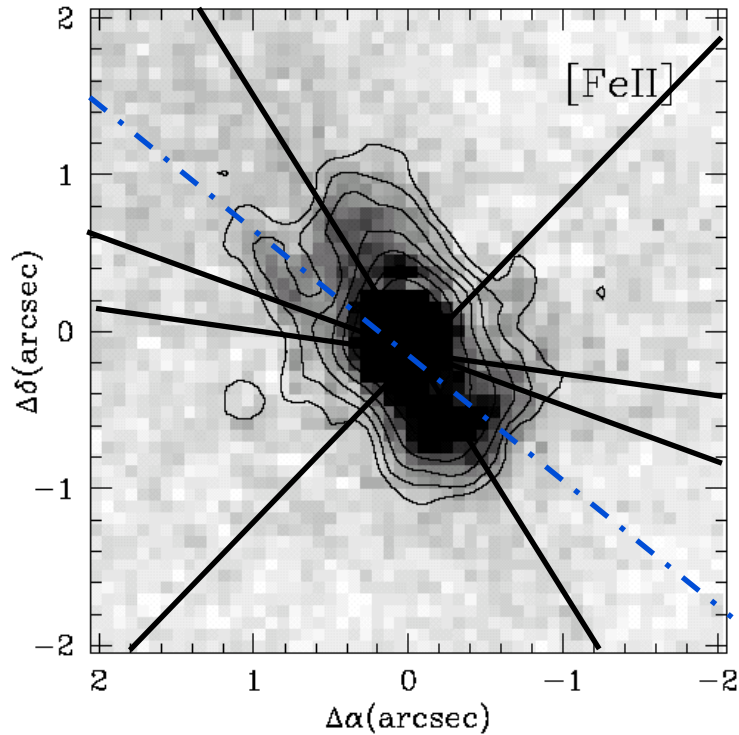
Marconi et al. 2001



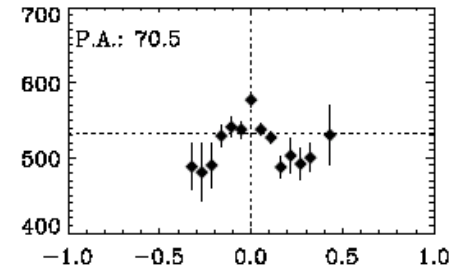
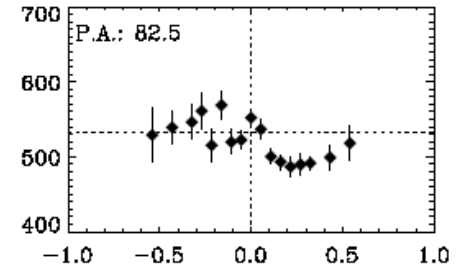
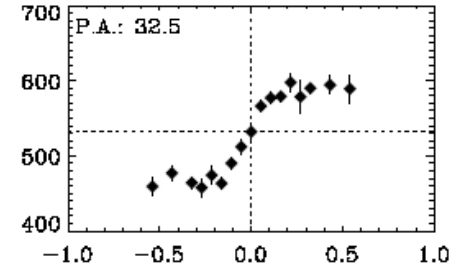
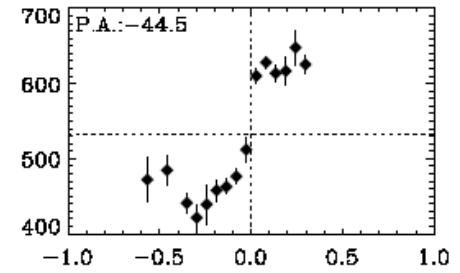
aperture: 86mas x 54mas

Häring-Neumayer et al. 2006

Central kinematics



Marconi et al. 2001

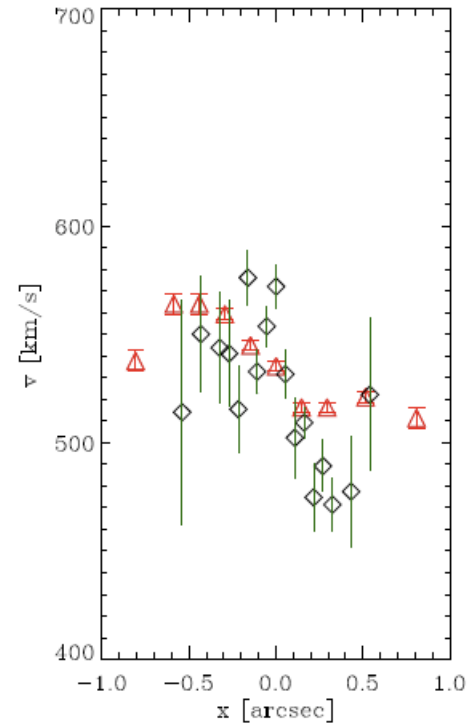
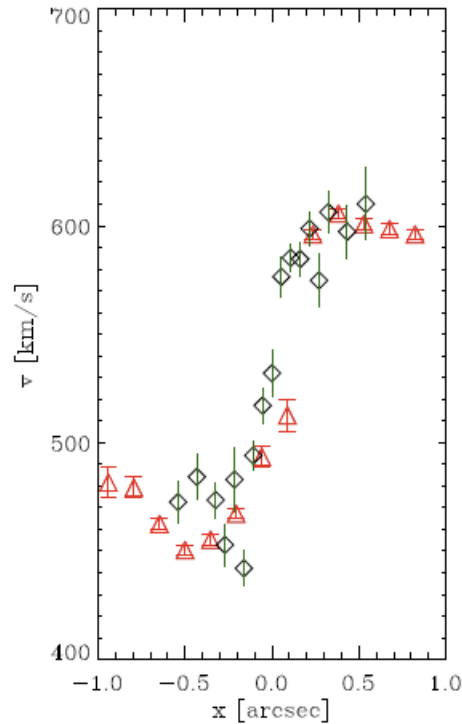
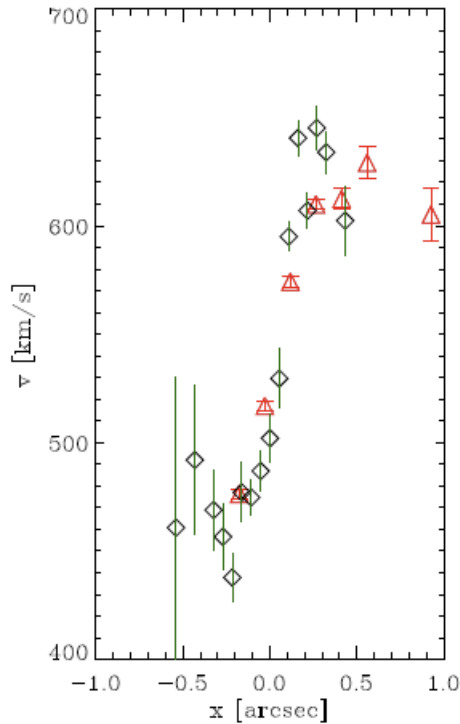


v [km/s]

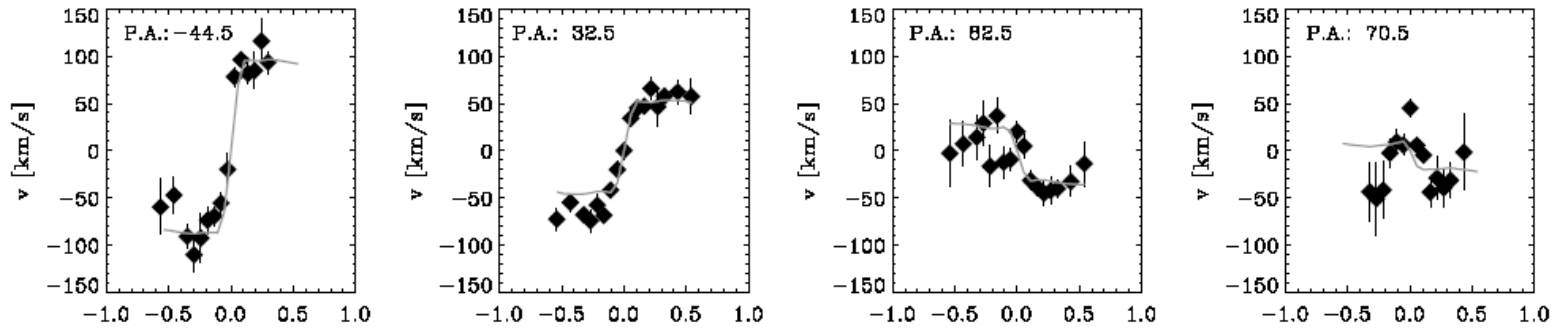
position along the slit [arcsec]

Häring-Neumayer et al. 2006

Comparison of NACO & ISAAC



Best-fitting model



“Hot disk” model

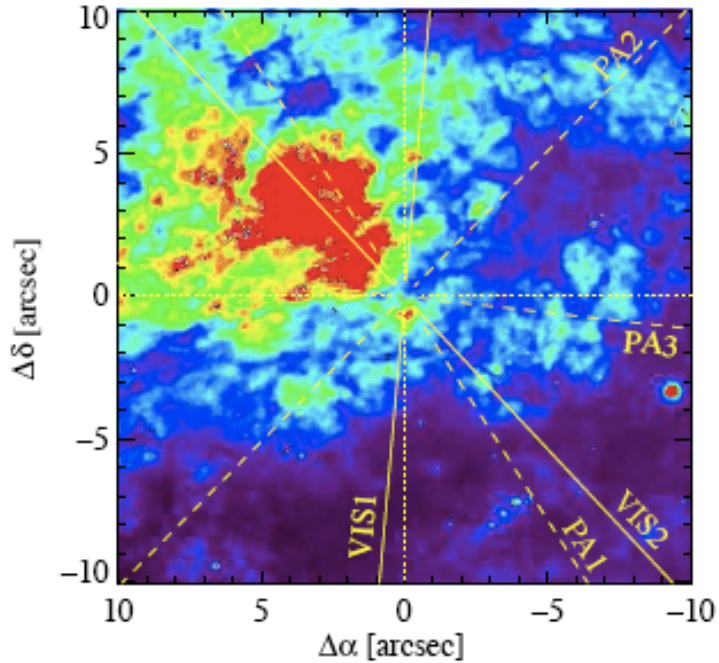
$$M_{\text{bh}} = (6.1 \pm 0.8) \times 10^7 M_{\odot}$$

$$i = 45^{\circ}$$

$$\zeta = -27^{\circ}$$

Häring-Neumayer et al. 2006

Study with STIS/HST

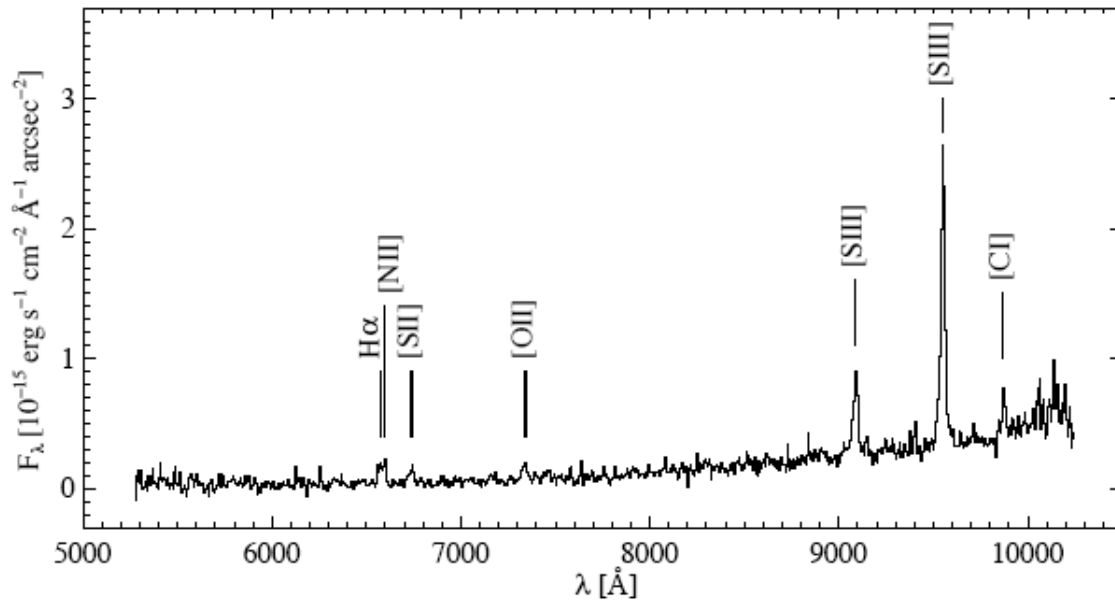


- Pushed STIS to the reddest limit

Marconi et al. 06

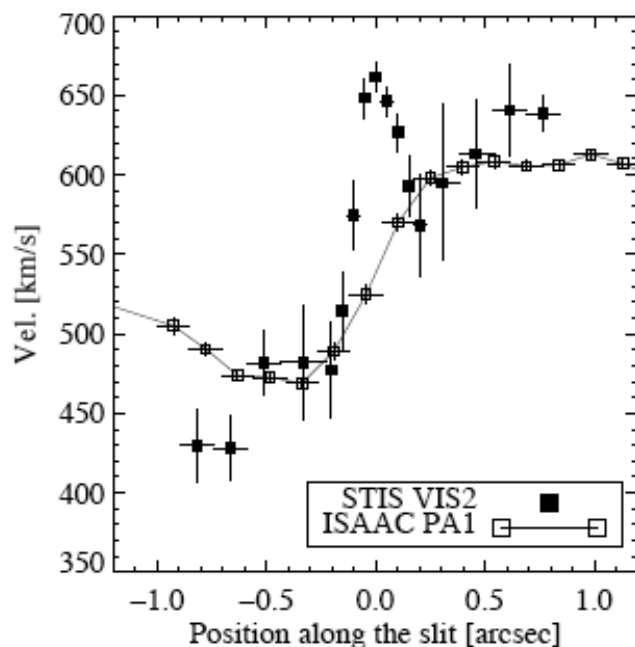
Study with STIS/HST

- Pushed STIS to the reddest limit



Marconi et al. 06

Study with STIS/HST

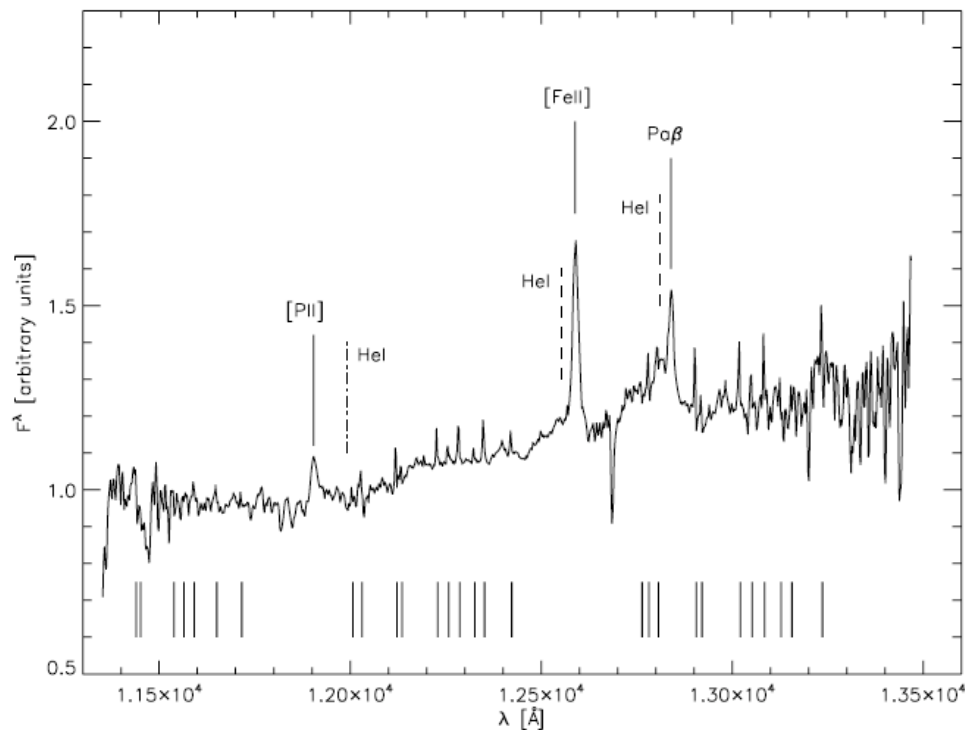


- Pushed STIS to the reddest limit
- Find M_{BH} in agreement with our NACO study
- Still, inclination angle is not well constrained

Marconi et al. 06

IFU to the rescue!

- CIRPASS at Gemini S
- IFU data in J-band
- [FeII], Pa β & [PII]
- 0.6" seeing
- With 0.25"/pix
- fov 9.3" x 3.5"

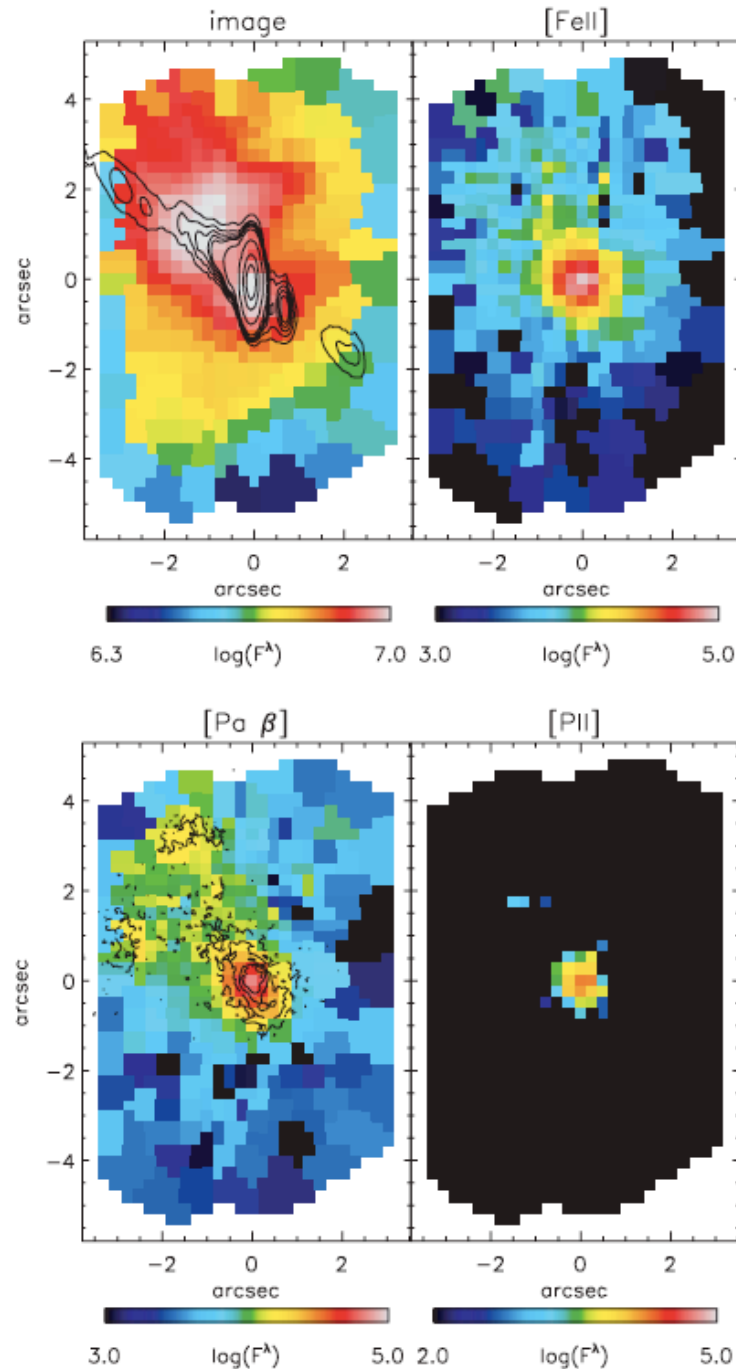


Krajnović, Sharp & Thatte 2007

IFU to the rescue!

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- IFU data in J-band
- [FeII], Pa β & [P11]
- 0.6" seeing
- With 0.25"/pix
- fov 9.3" x 3.5"

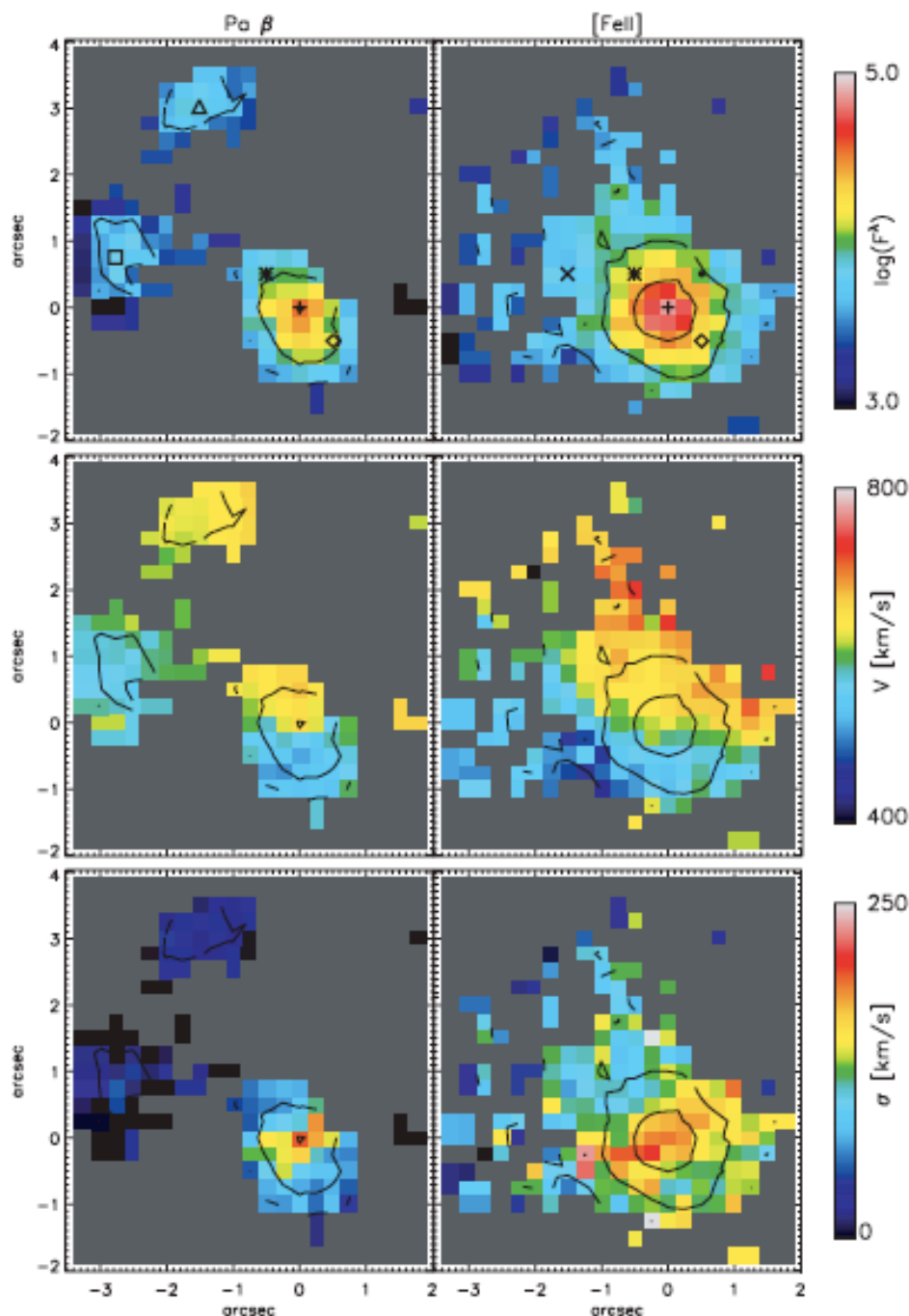
Krajnović, Sharp & Thatte 2007



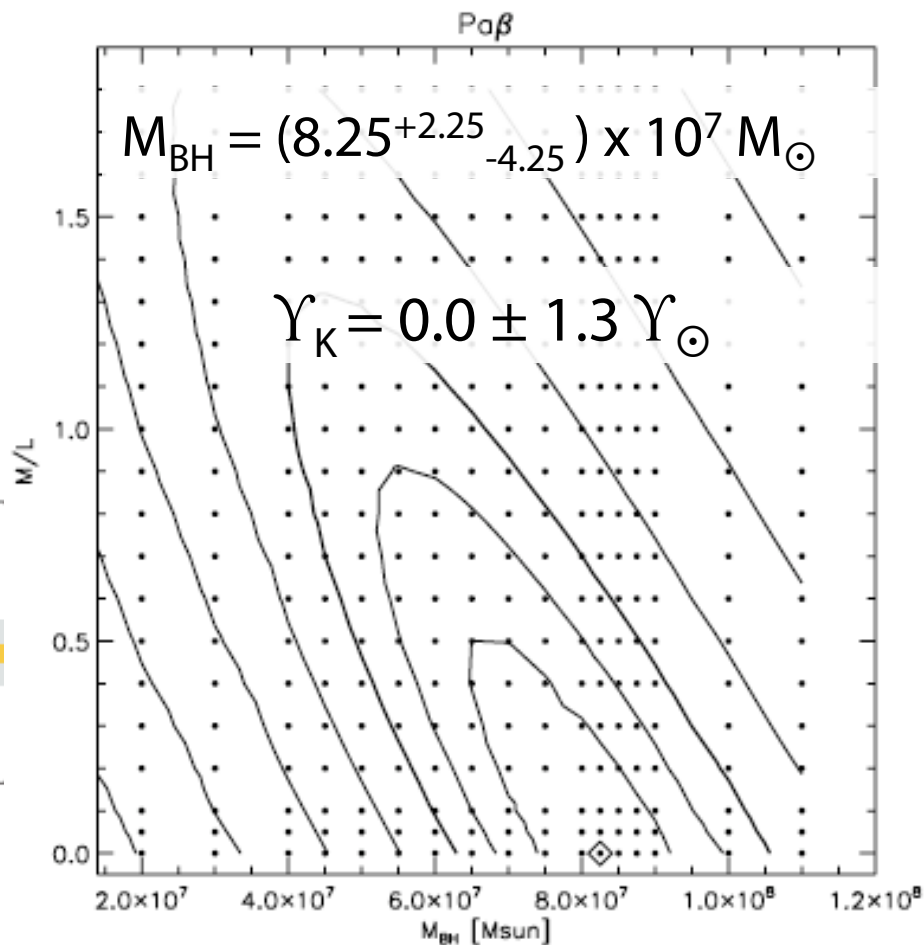
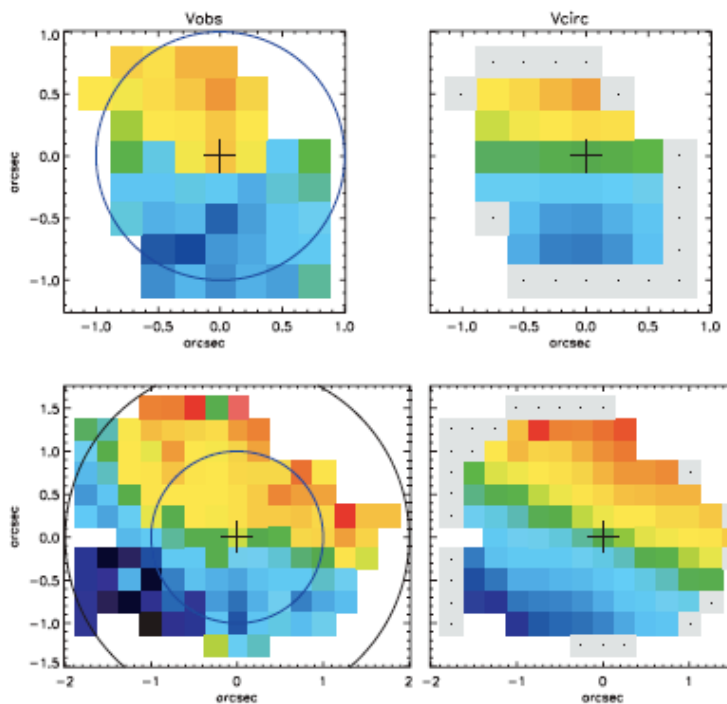
IFU to the rescue!

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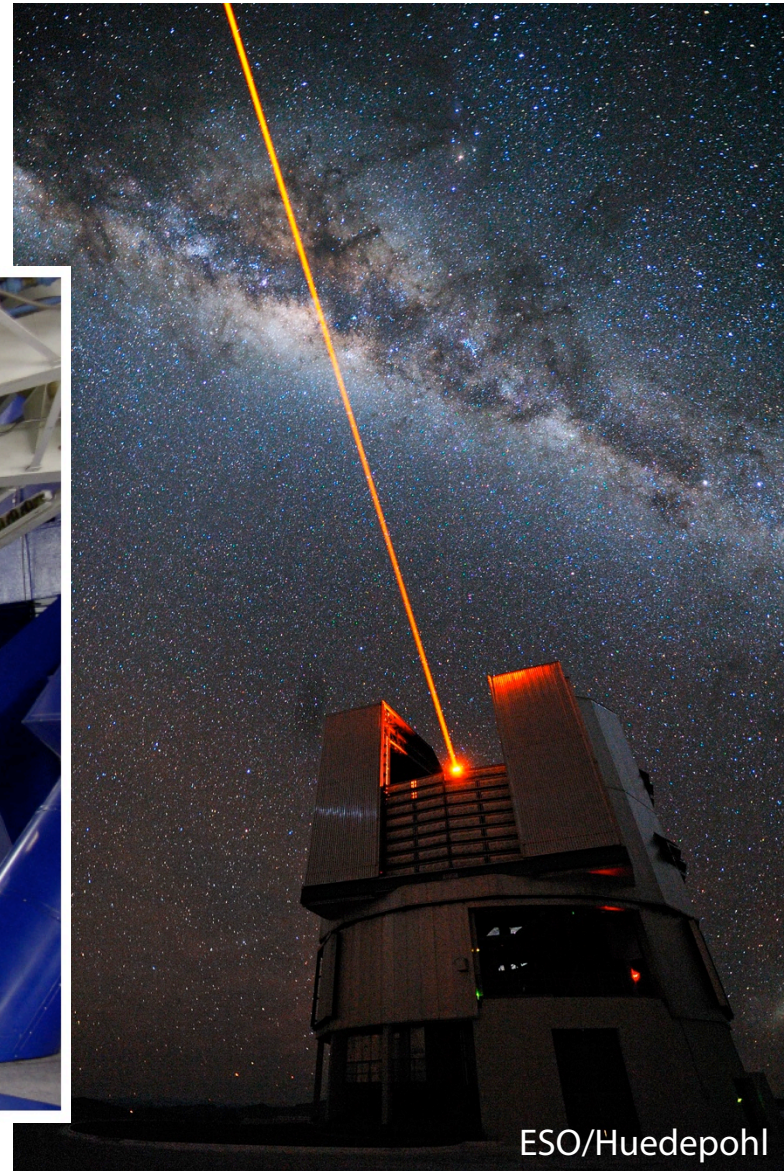
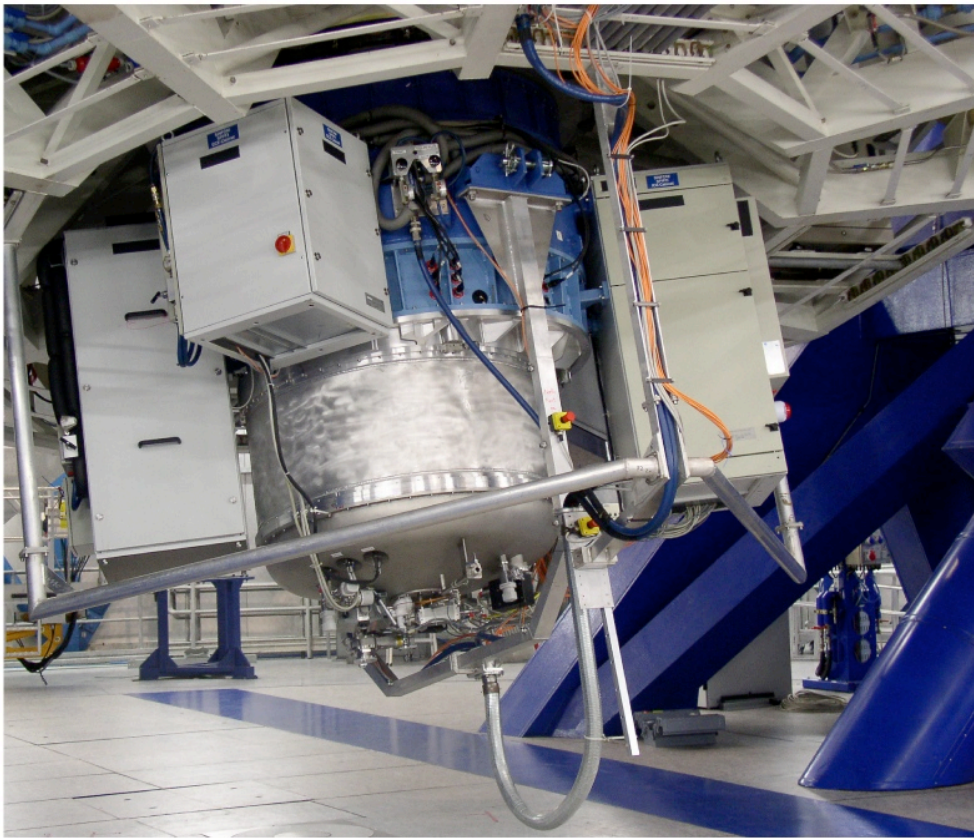
CIRPASS data and model



Krajnović, Sharp & Thatte 2007

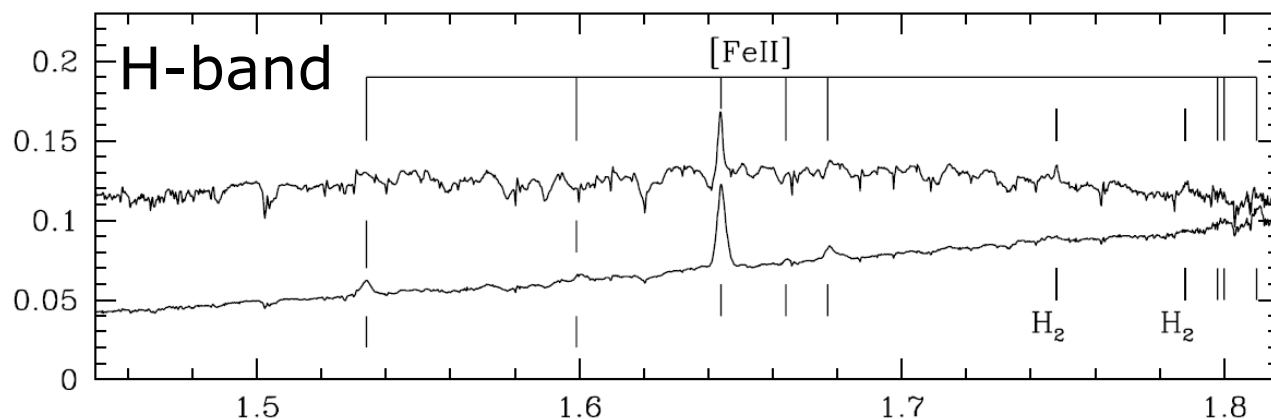
SINFONI/VLT

Combines IFU and adaptive optics

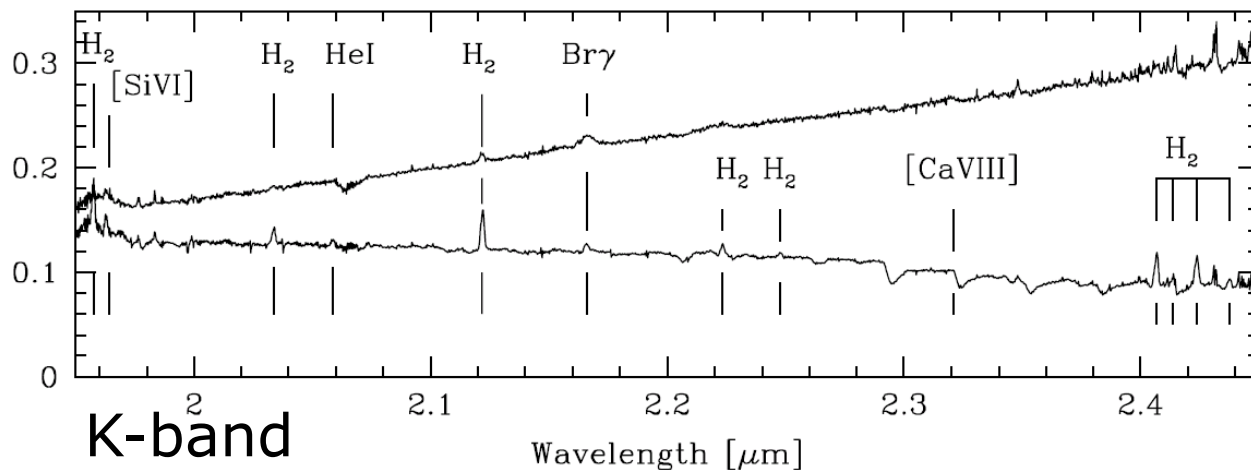


ESO/Huedepohl

IFU data – SINFONI/VLT



Spatial resolution:
0.12" FWHM
~ 2pc for CenA

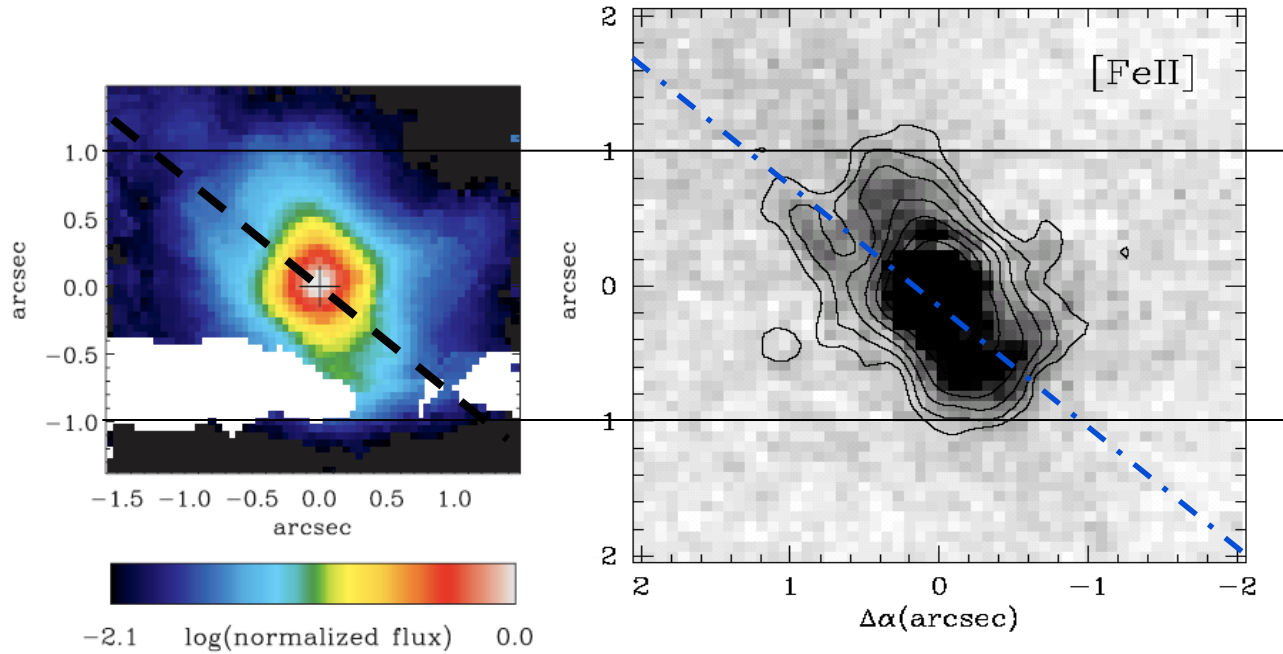


Spectral
resolution:
R ~ 4800
 $\sigma_{\text{ins}} = 27 \text{ km/s}$

Neumayer et al. 2007

[FeII]

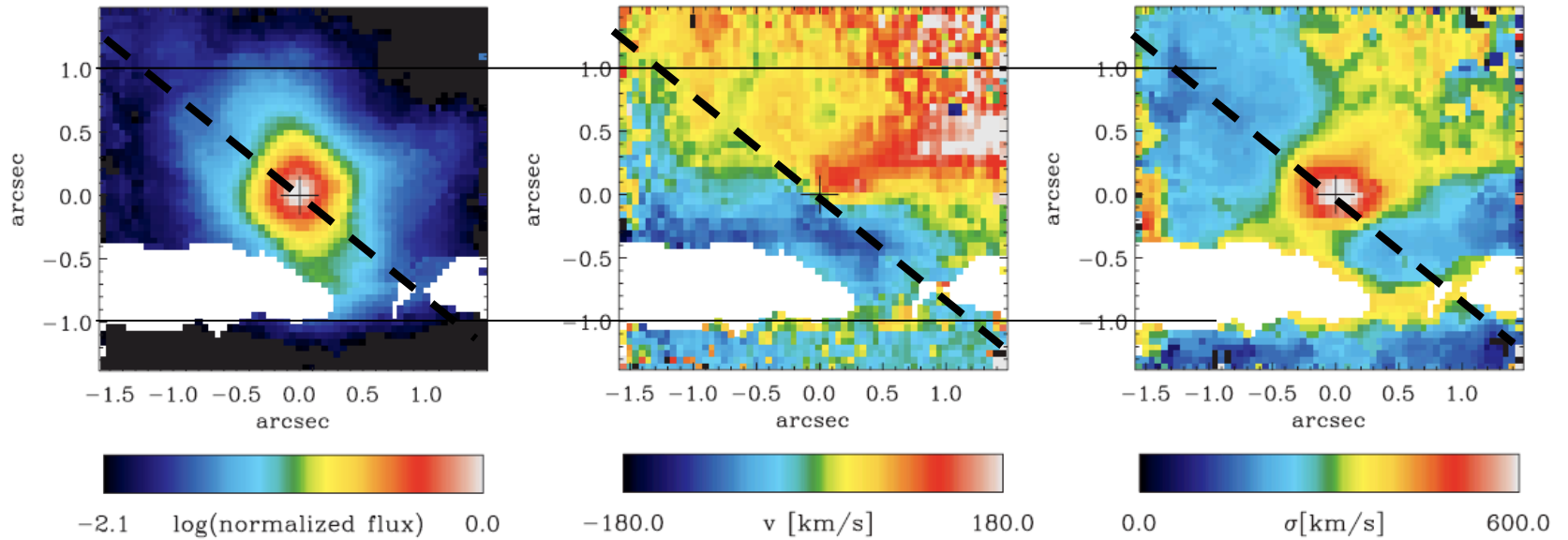
$\lambda=1.644\mu\text{m}$



Neumayer et al. 2007

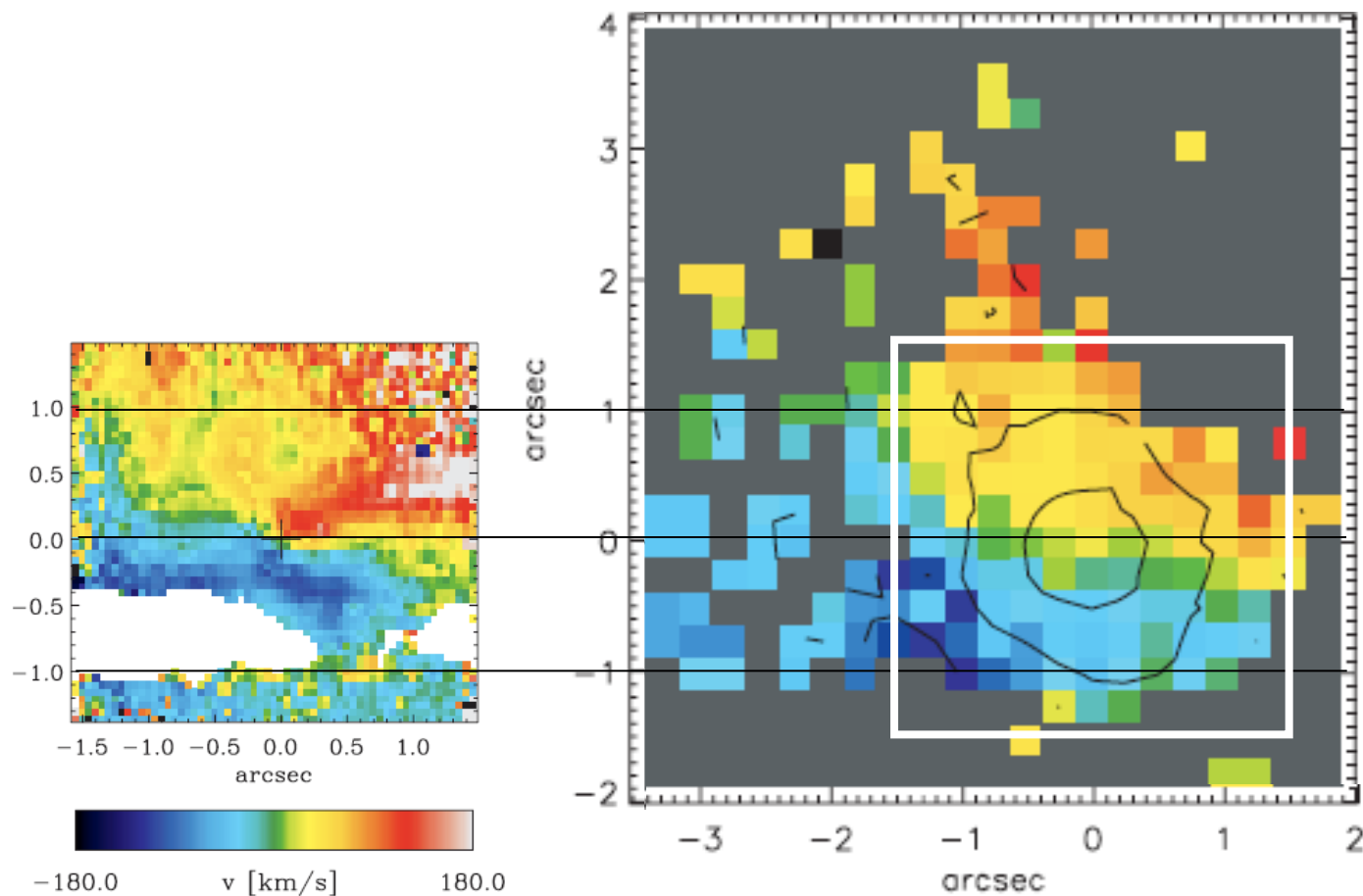
[FeII]

$\lambda=1.644\mu\text{m}$



Neumayer et al. 2007

[FeII] - SINFONI vs. CIRPASS



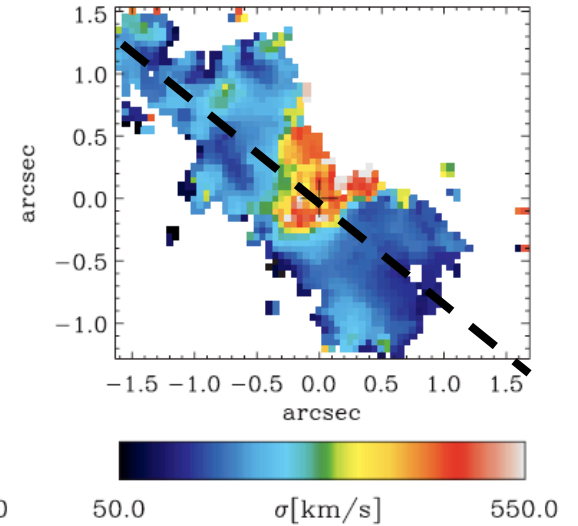
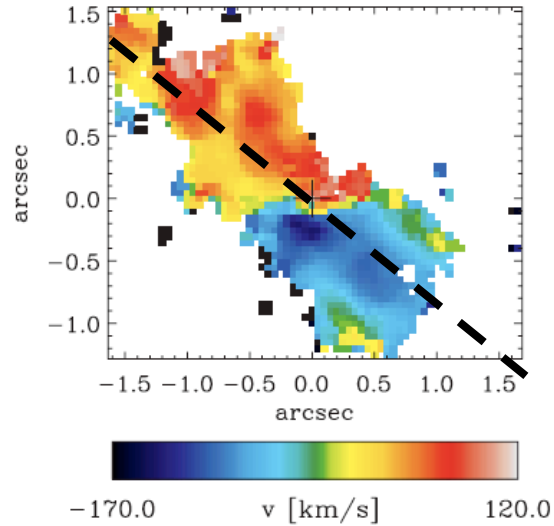
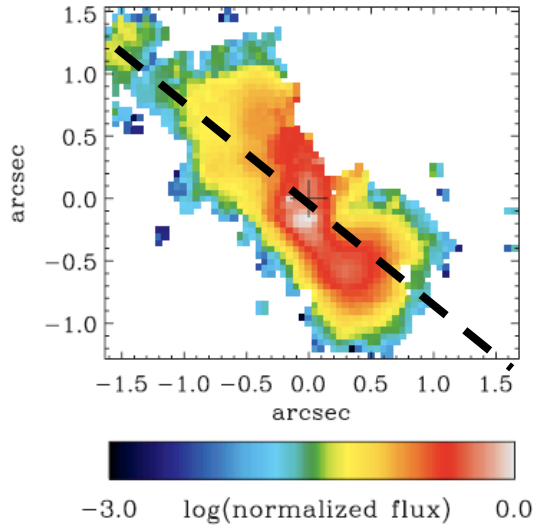
Adaptive optics

vs.

Seeing limited

[SiVI]

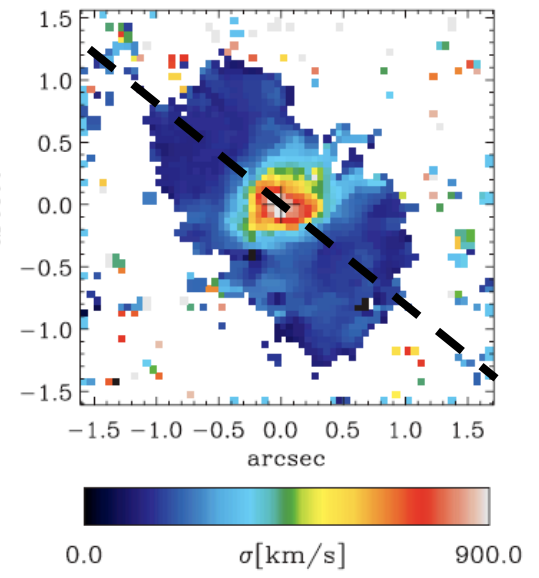
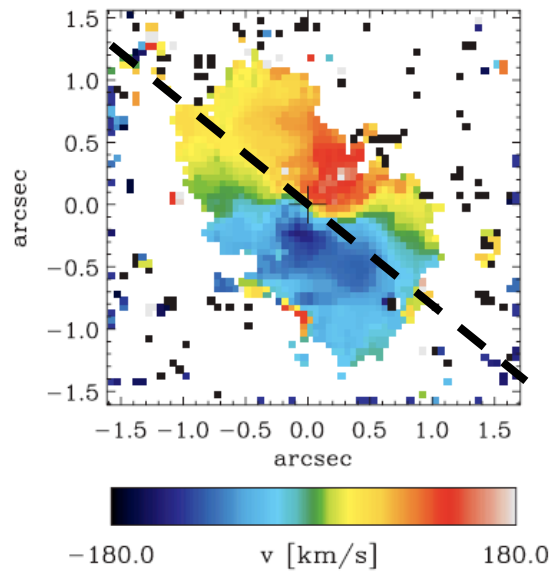
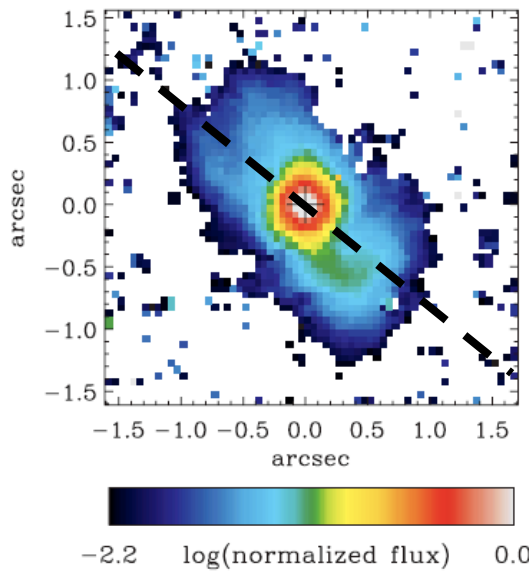
$\lambda=1.964\mu\text{m}$



Neumayer et al. 2007

B γ

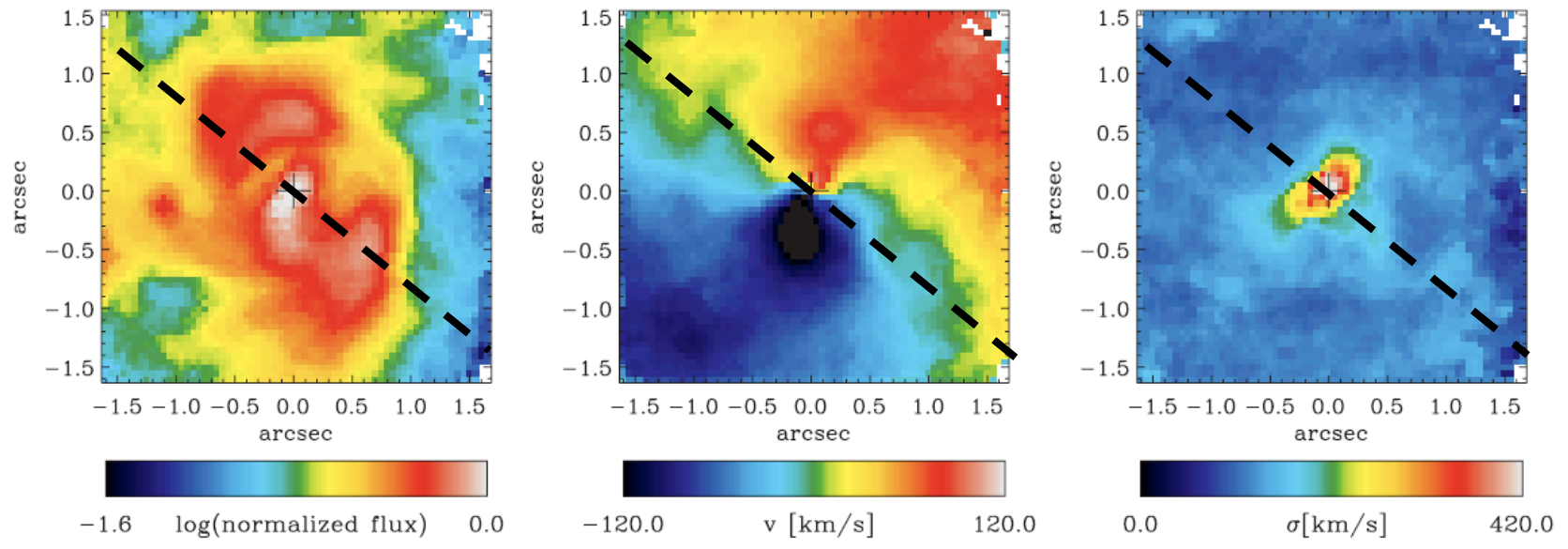
$\lambda=2.166\mu\text{m}$



Neumayer et al. 2007

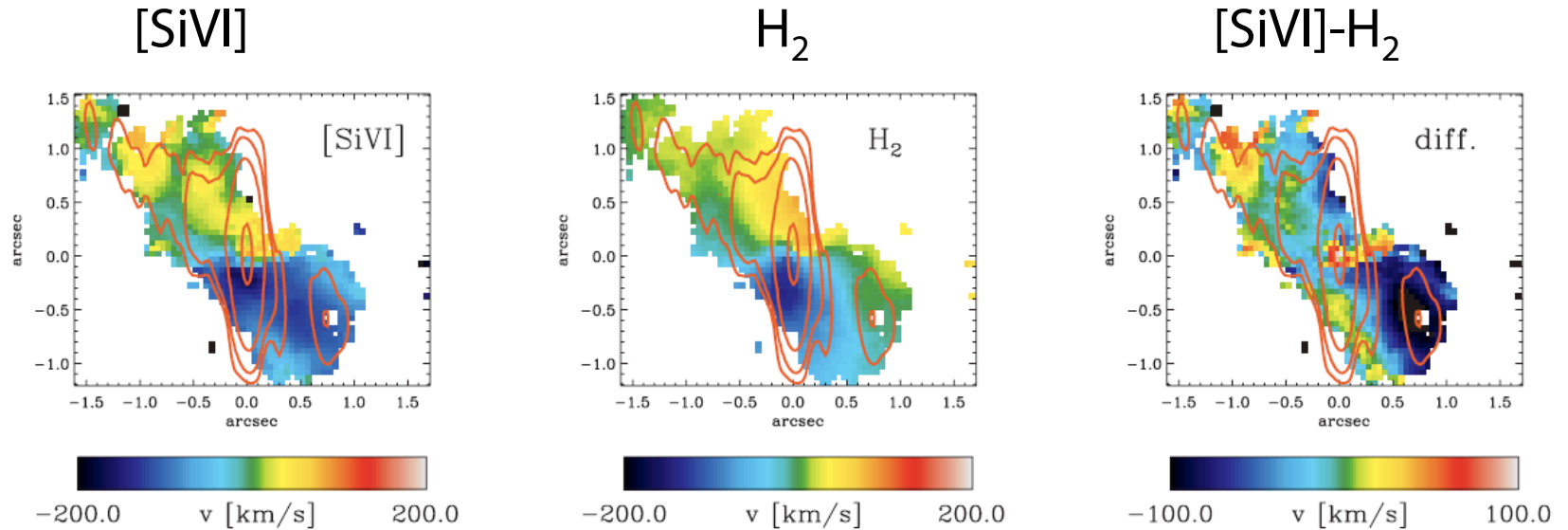
H₂

$\lambda=2.121\mu\text{m}$



Neumayer et al. 2007

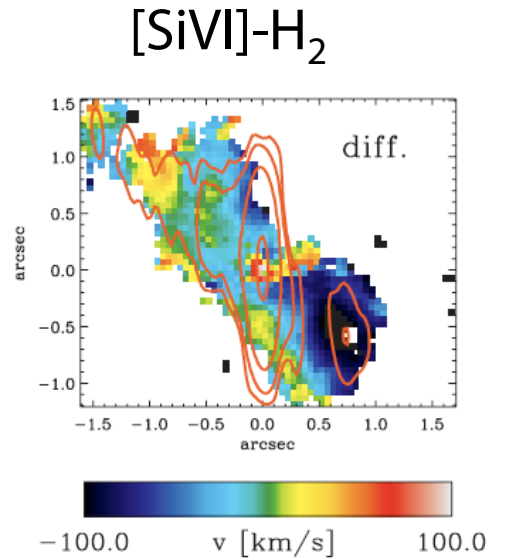
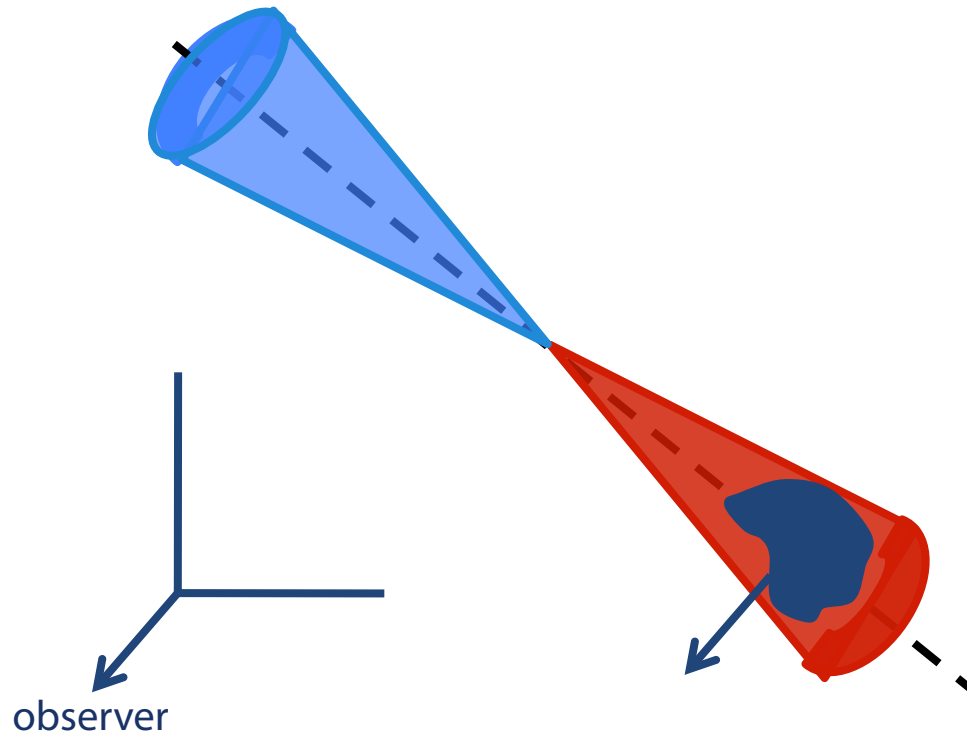
Jet-gas interaction?



Red overlay: VLA contours (M. Hardcastle et al.)

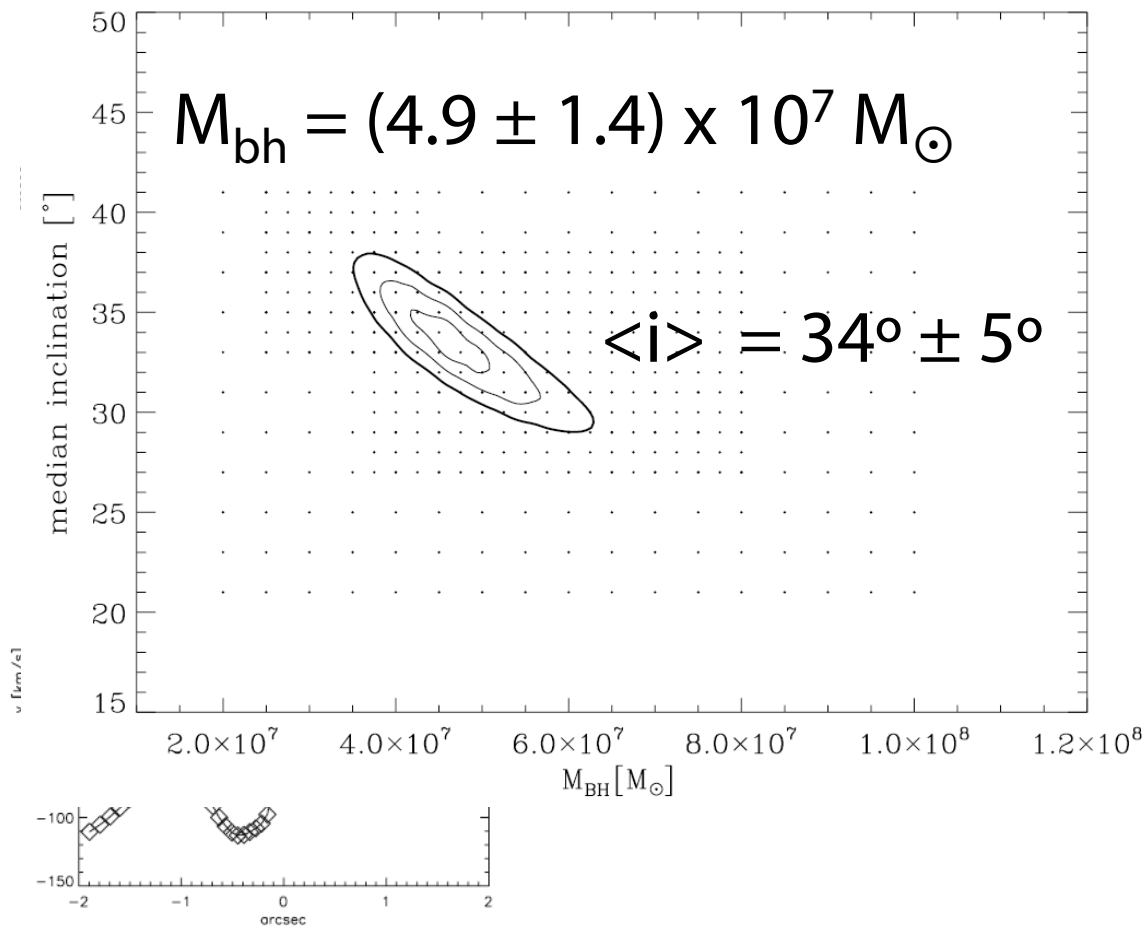
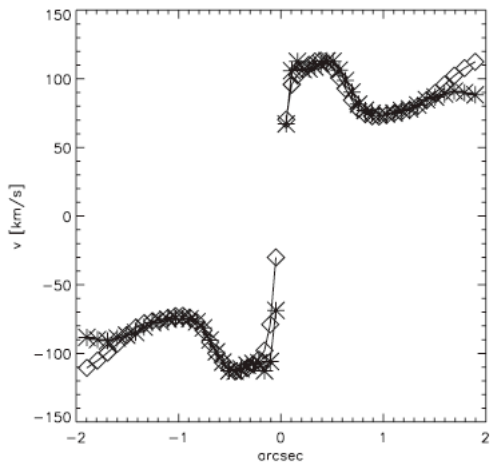
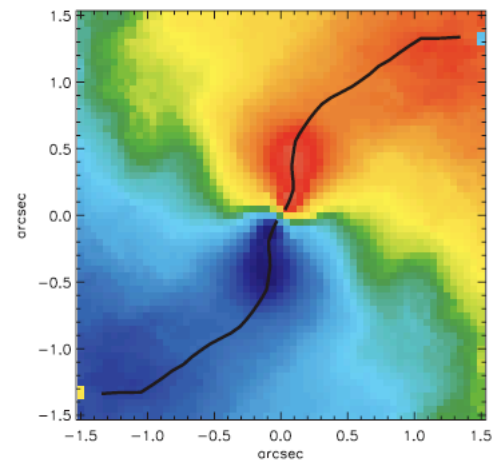
Neumayer et al. 2007

Jet-gas interaction?



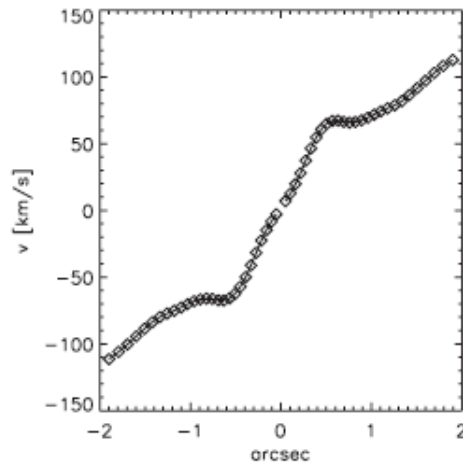
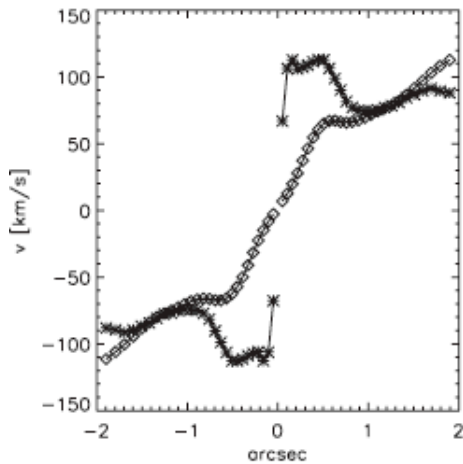
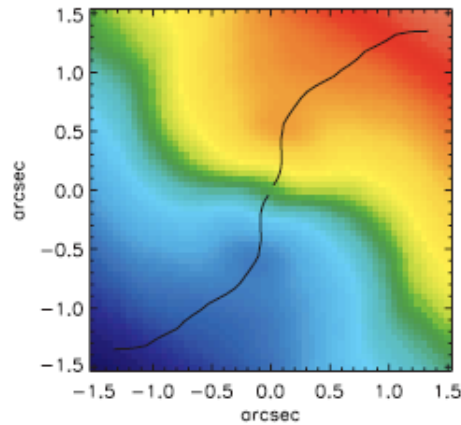
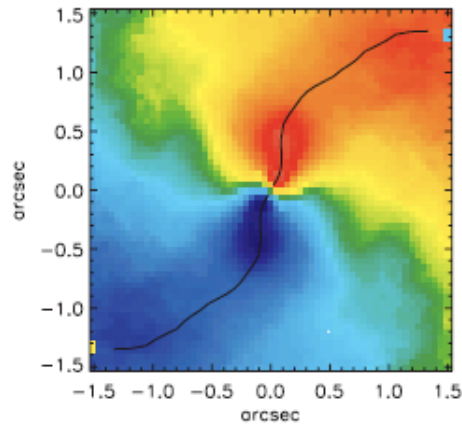
Bicknell, Sutherland & Neumayer 2013

IFU data and model



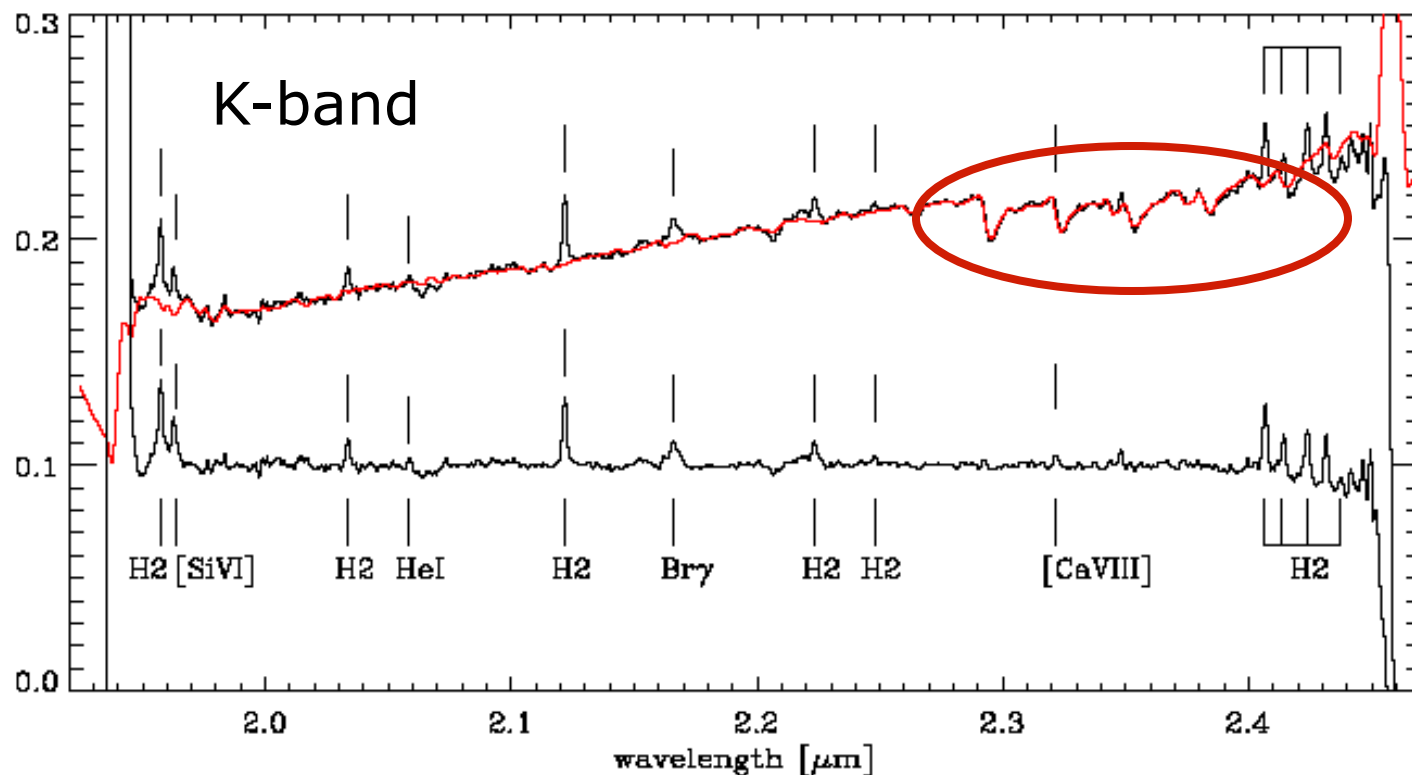
Neumayer et al. 2007

No black hole?



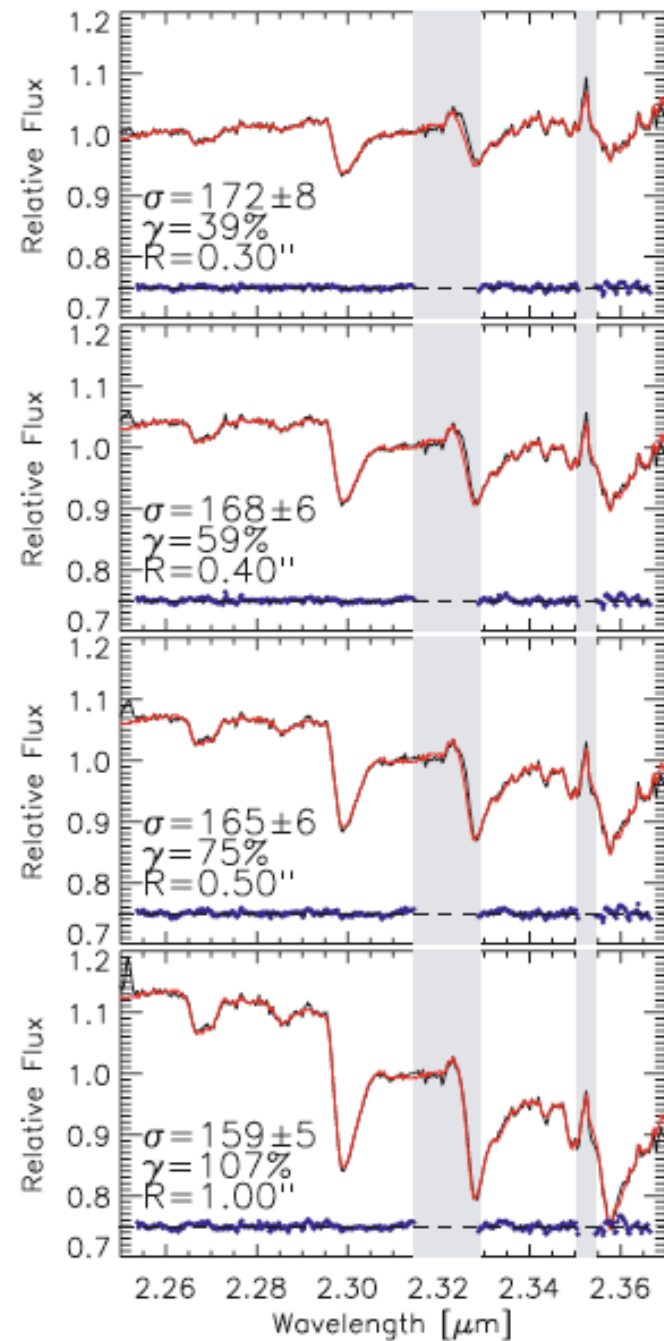
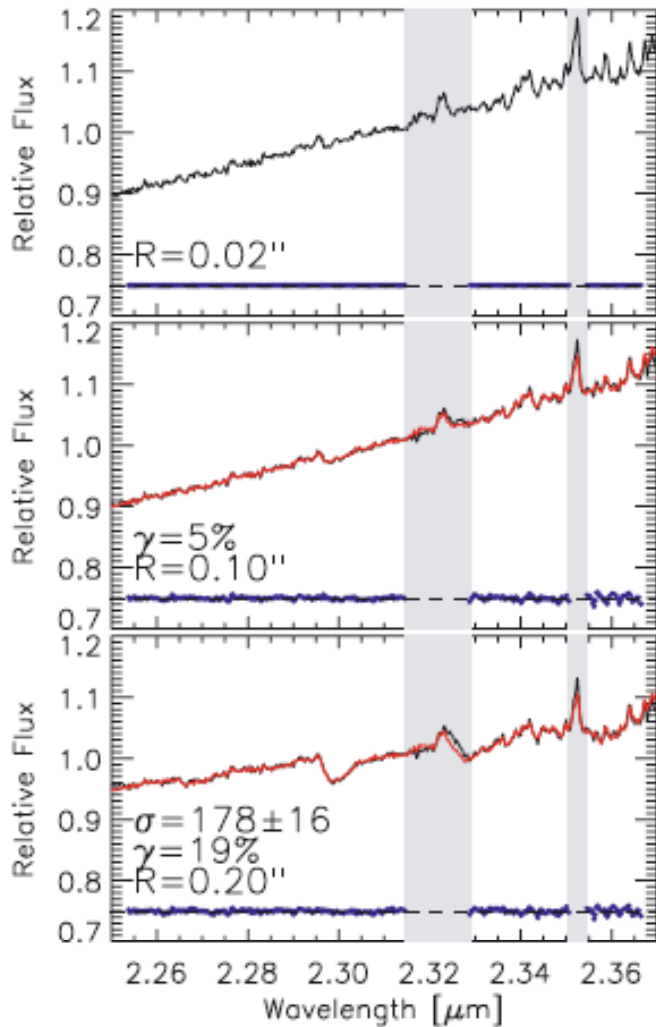
ruled out to very high accuracy

Stellar kinematics - Template fitting

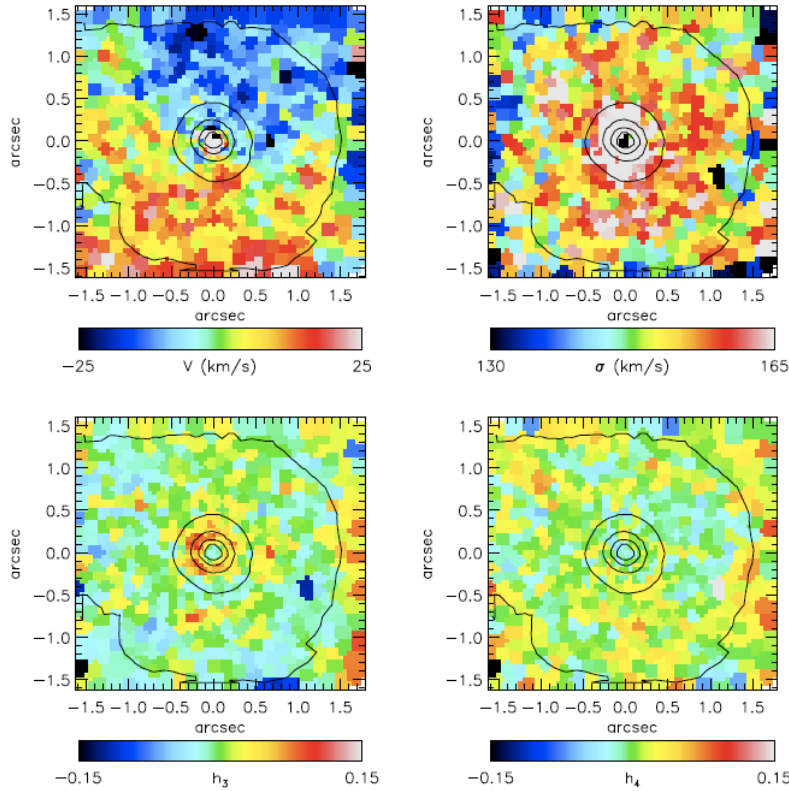


using pPXF routine by Cappellari & Emsellem 2004

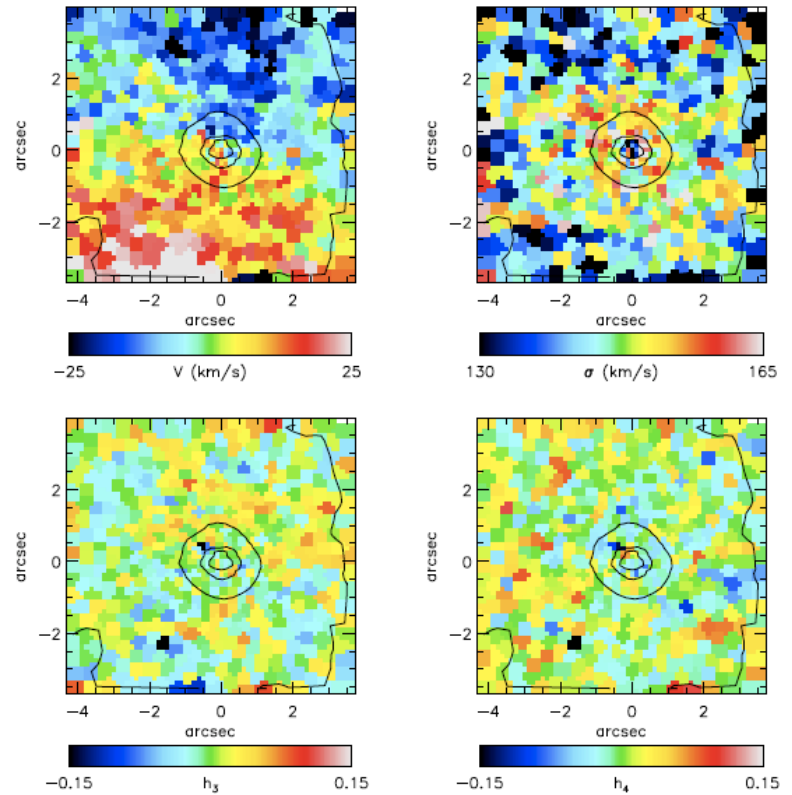
Template fitting



Stellar kinematics

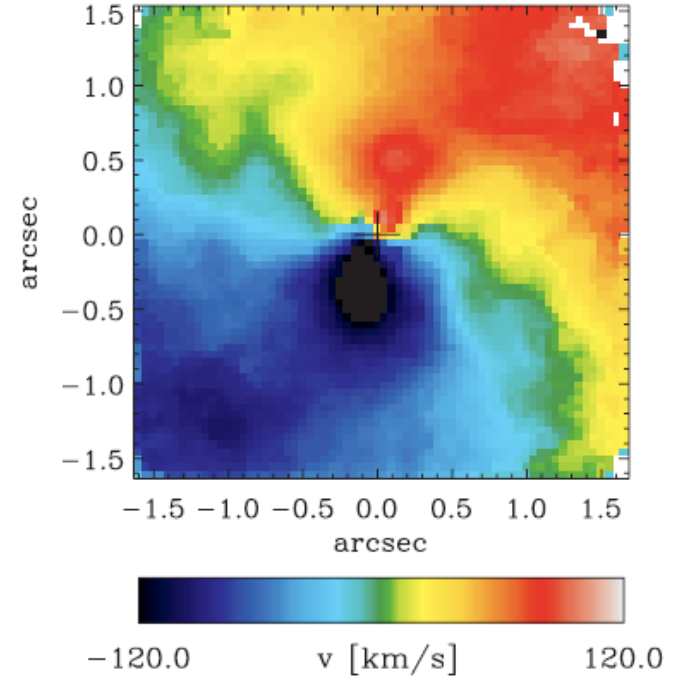
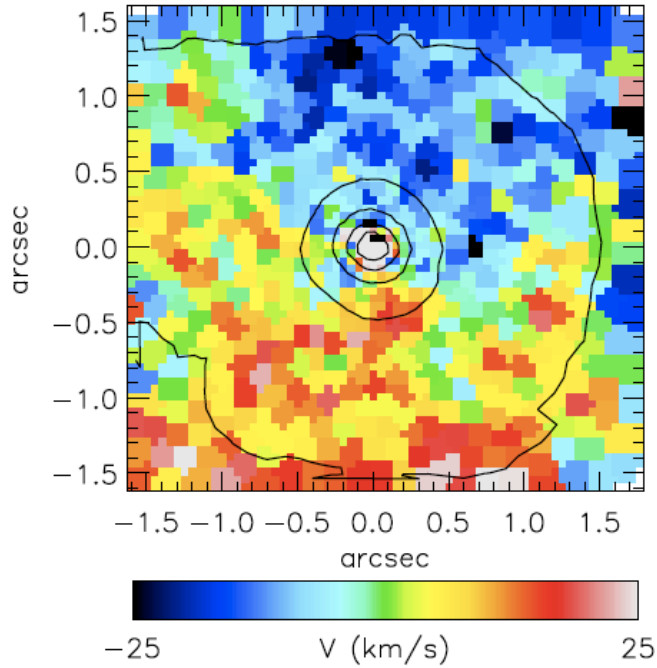


100mas/pix - fov 3'' x 3''

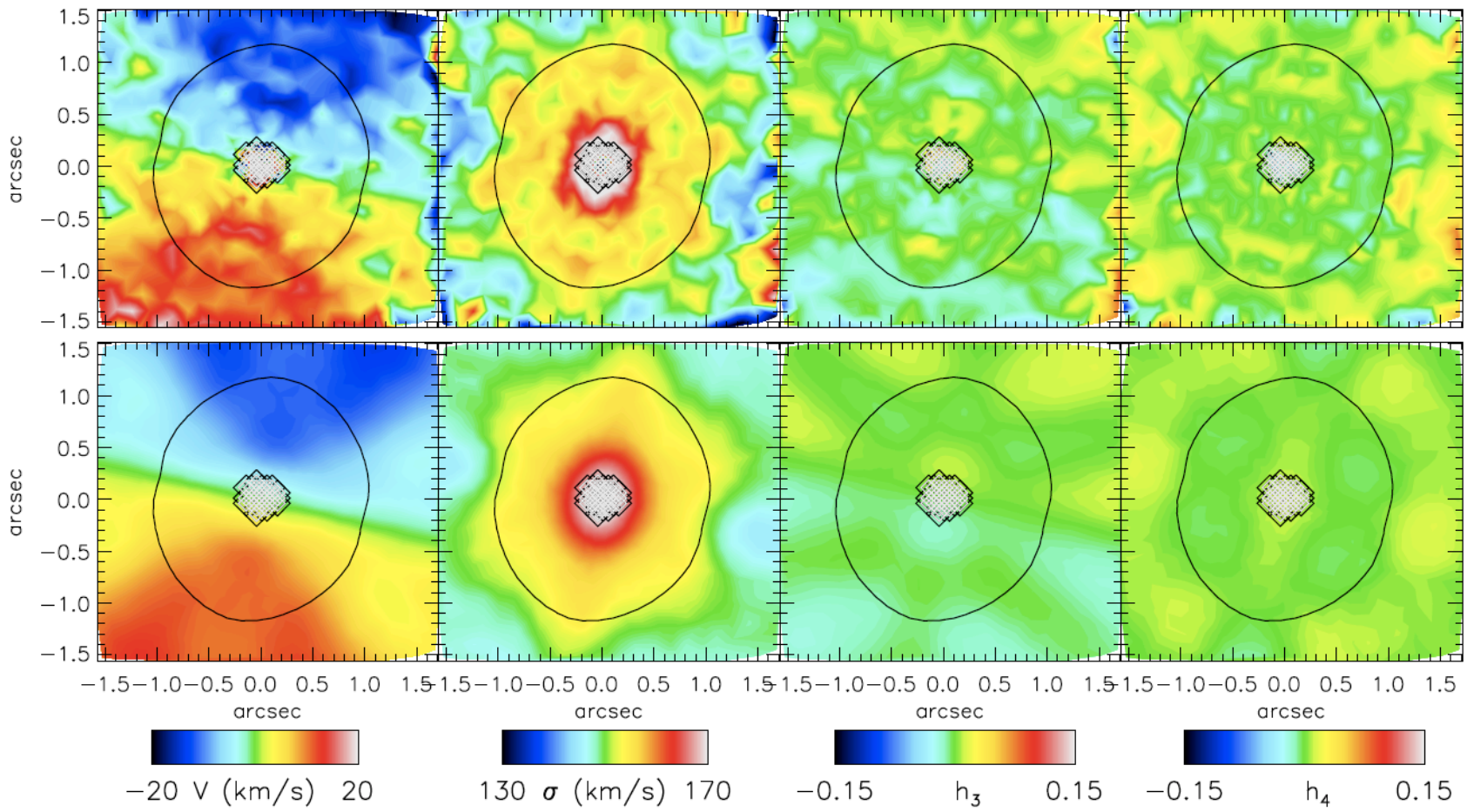


250mas/pix - fov 8'' x 8''

Stellar vs. gas motion

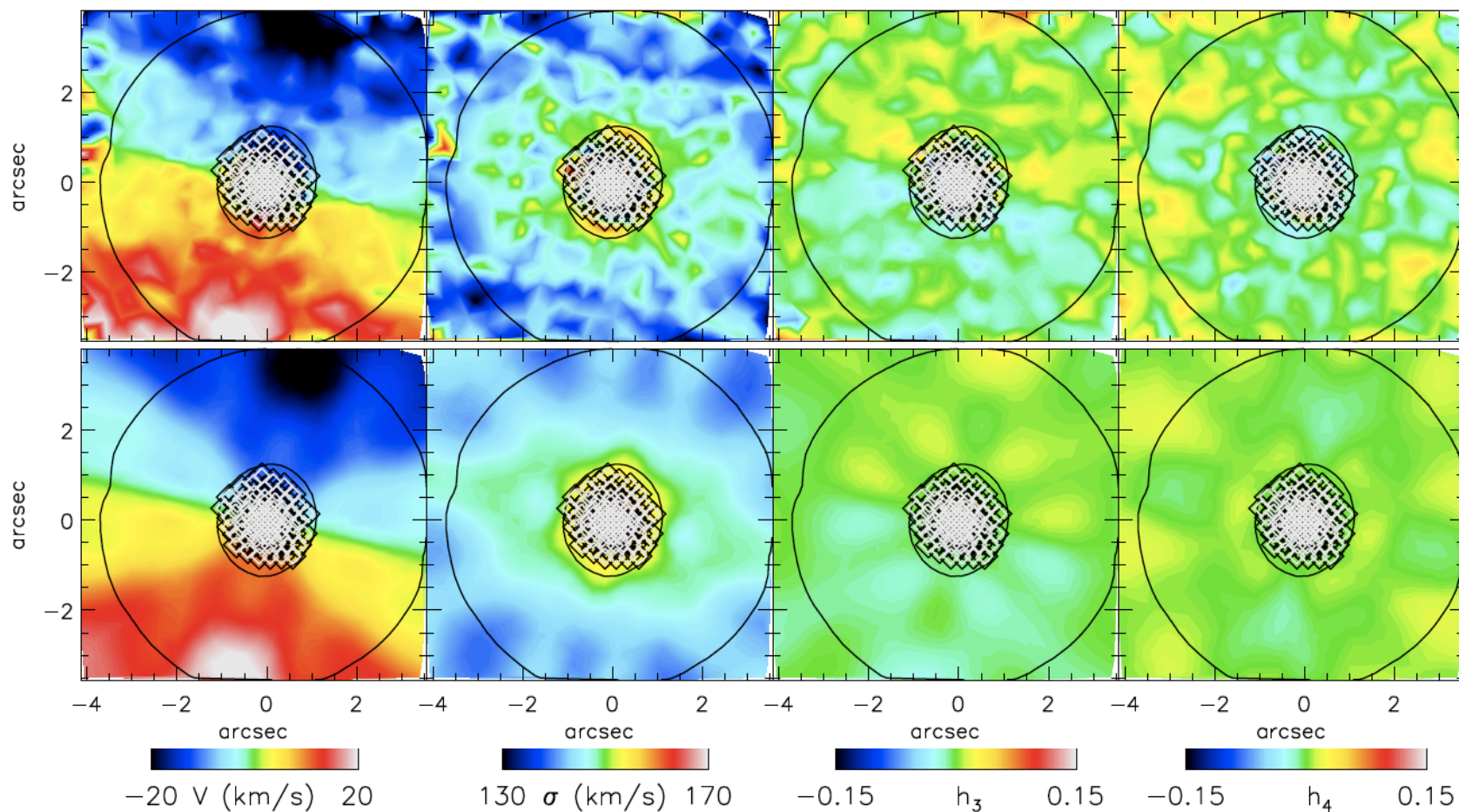


Stellar kinematics - data and model



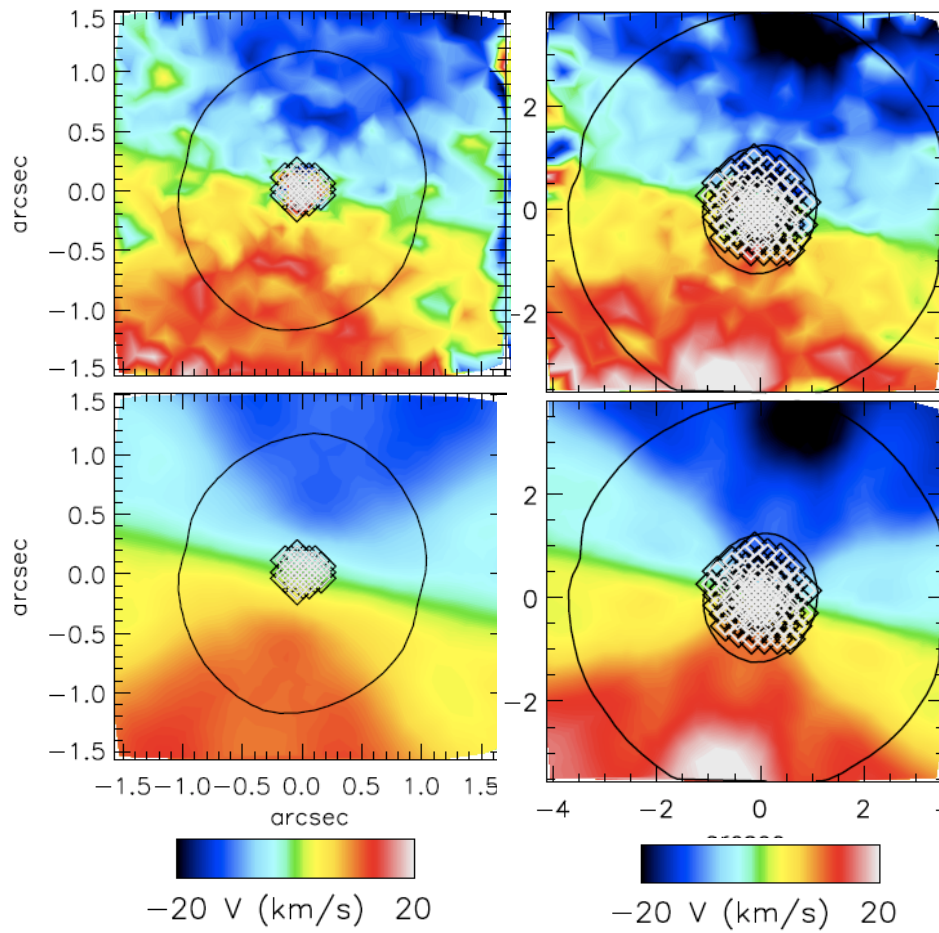
Cappellari, Neumayer et al. 2009

Stellar kinematics - data and model



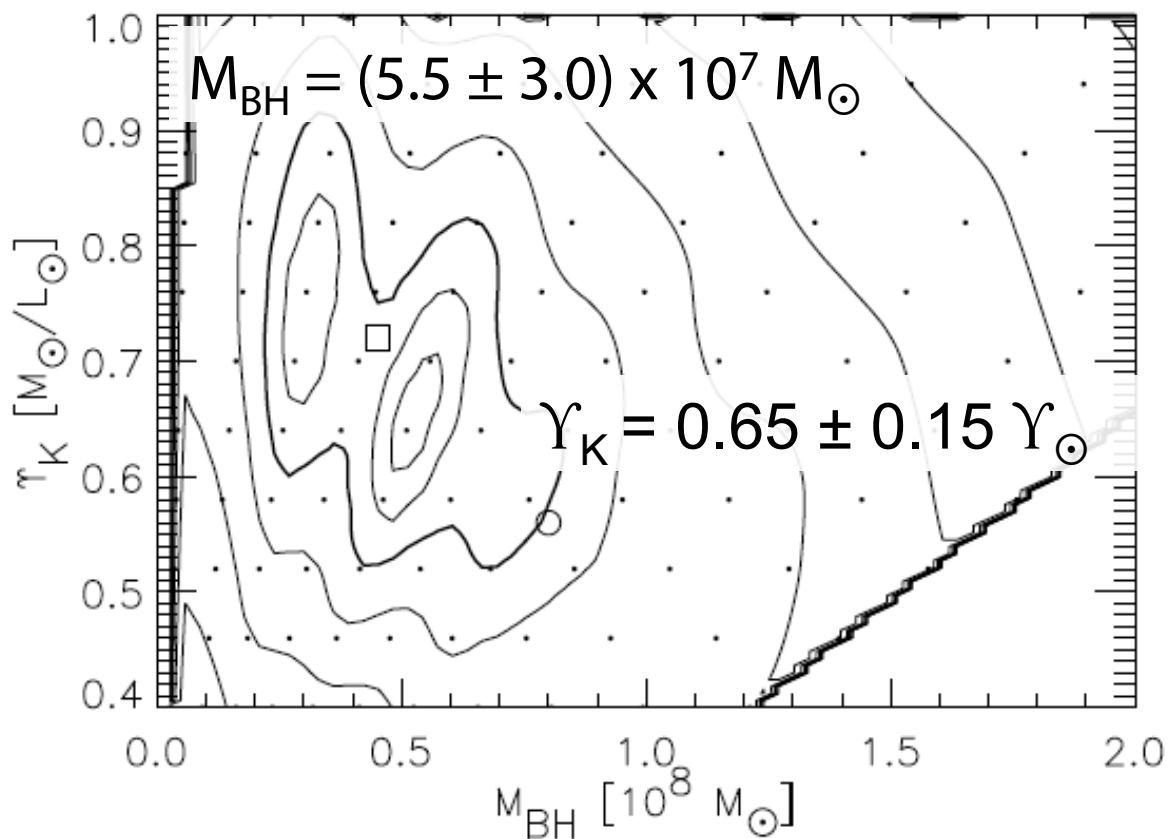
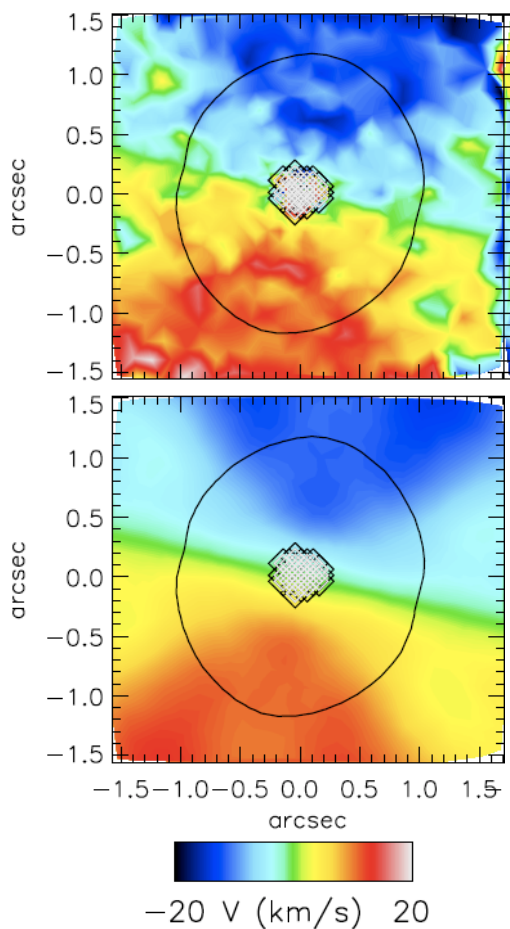
Cappellari, Neumayer et al. 2009

Stellar kinematics - best fit



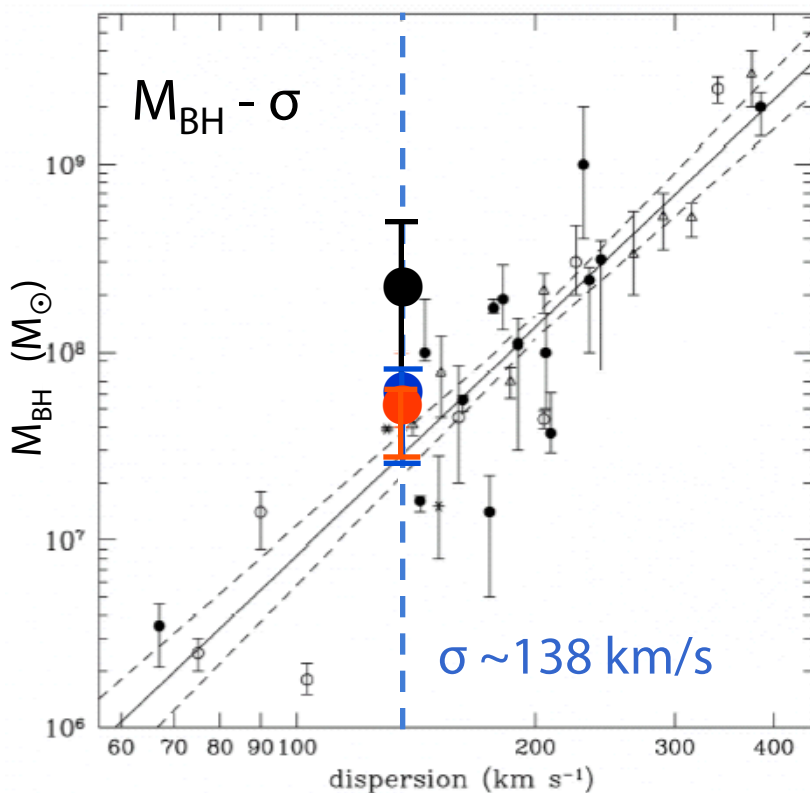
Cappellari, Neumayer et al. 2009

Stellar kinematics - best fit



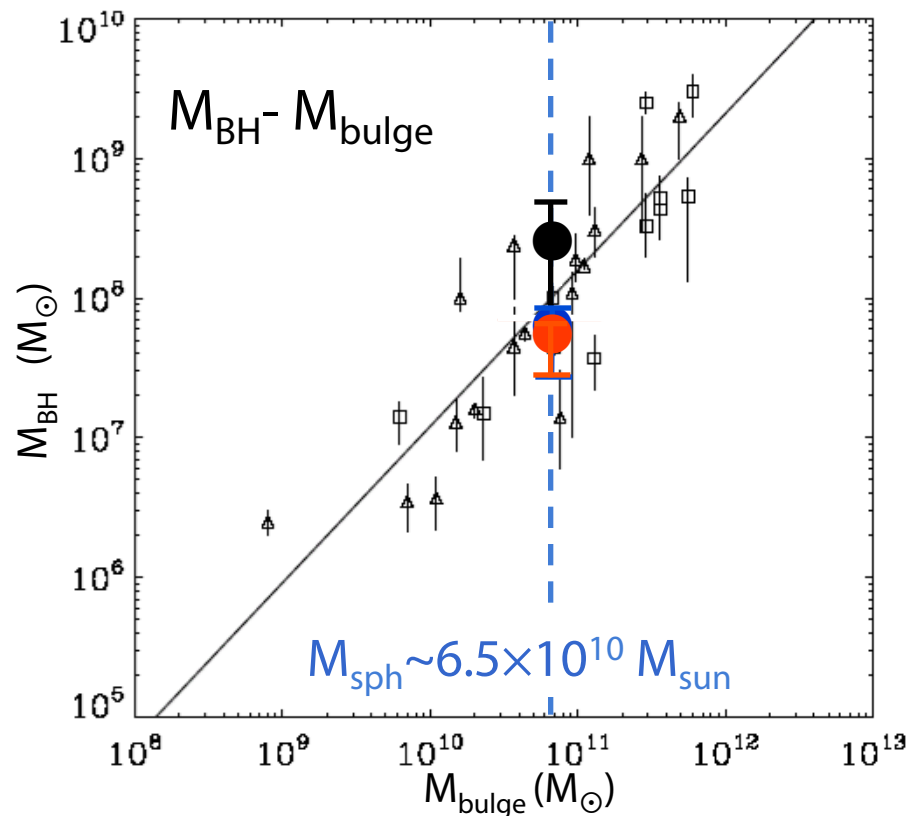
Cappellari, Neumayer et al. 2009

Cen A on the M_{BH} relations



Tremaine et al. 2002

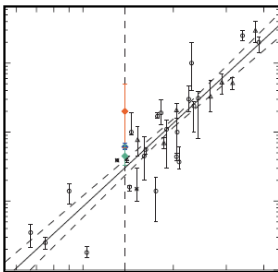
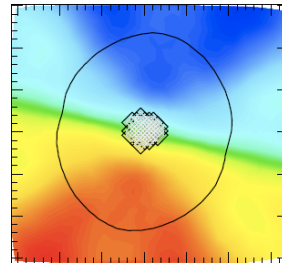
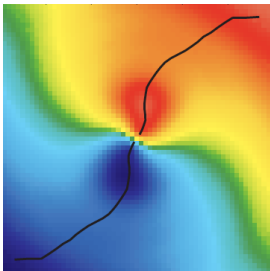
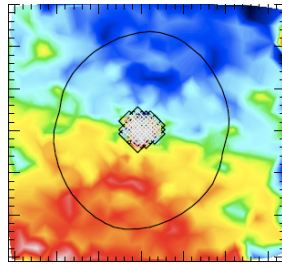
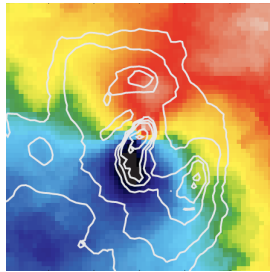
Silge et al. 2005



Marconi et al. 2001

Häring & Rix 2004

Summary



- high resolution gas and stellar kinematics
- counter-rotation
- warped disk model (gas)
 $M_{\text{BH}} = 4.9 \times 10^7 M_{\text{sun}}$
- Schwarzschild model (stars)
 $M_{\text{BH}} = 5.5 \times 10^7 M_{\text{sun}}$
- in agreement with $M-\sigma$

Lessons learned

- Need high spatial resolution
- Adaptive Optics works!
- 2D data is crucial
- Take into account the dispersion of the gas
- Be cautious when having an AGN
 - Extraction of stellar kinematics gets complicated
 - Ionized gas is likely influenced by the AGN