Observing Supermassive Blackholes with E-ELT

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ESO

DRM Case G9: A Survey of Black Holes in Different Environments

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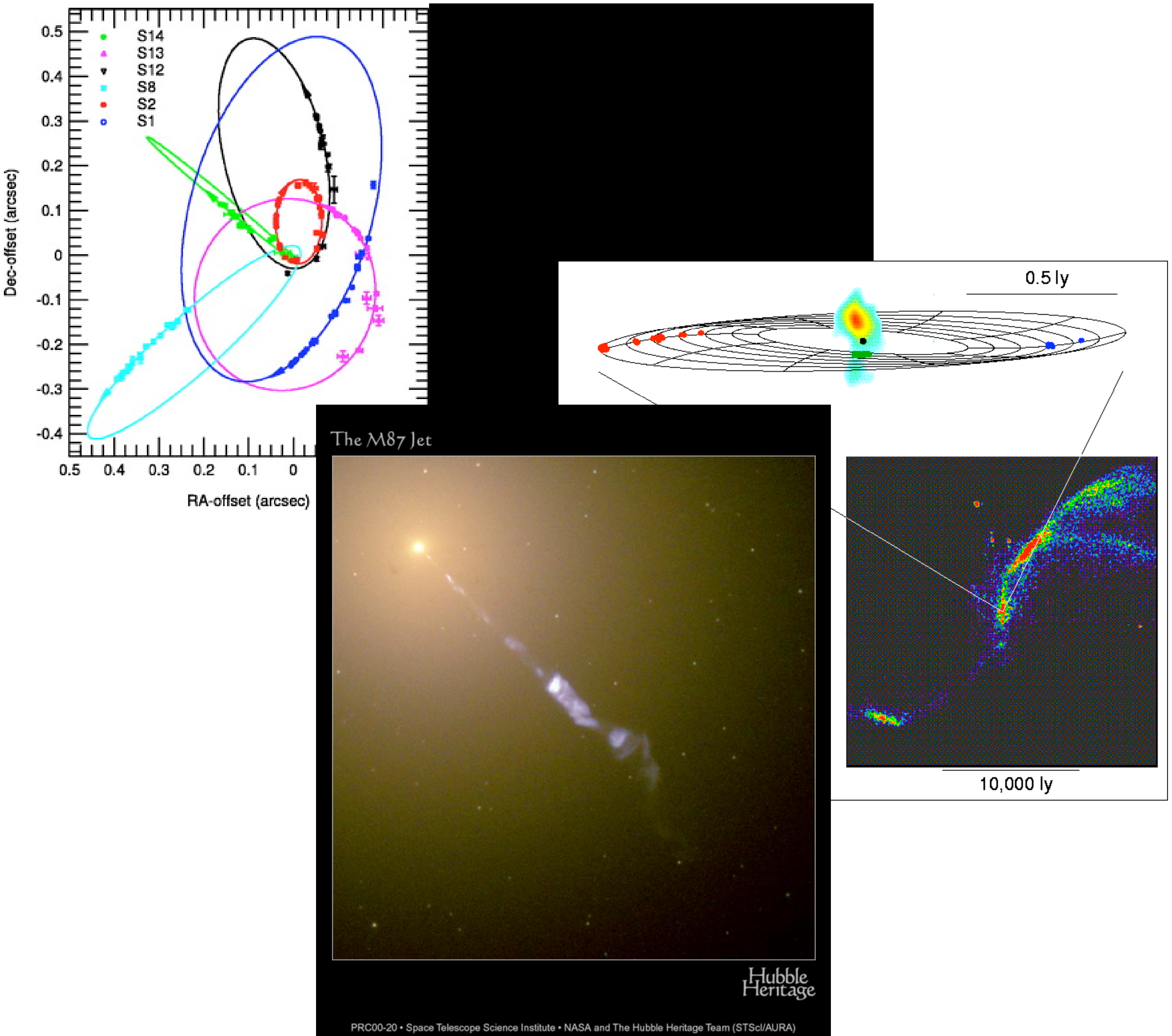
Supermassive Black Holes



- A million to billion solar mass black holes at the center of galaxies
- Almost all galaxies are thought to host a SMBH
- Our galaxy, Milkyway has a $3x10^6$ $M_\odot$ SMBH

GOALS: SMBH Evolution

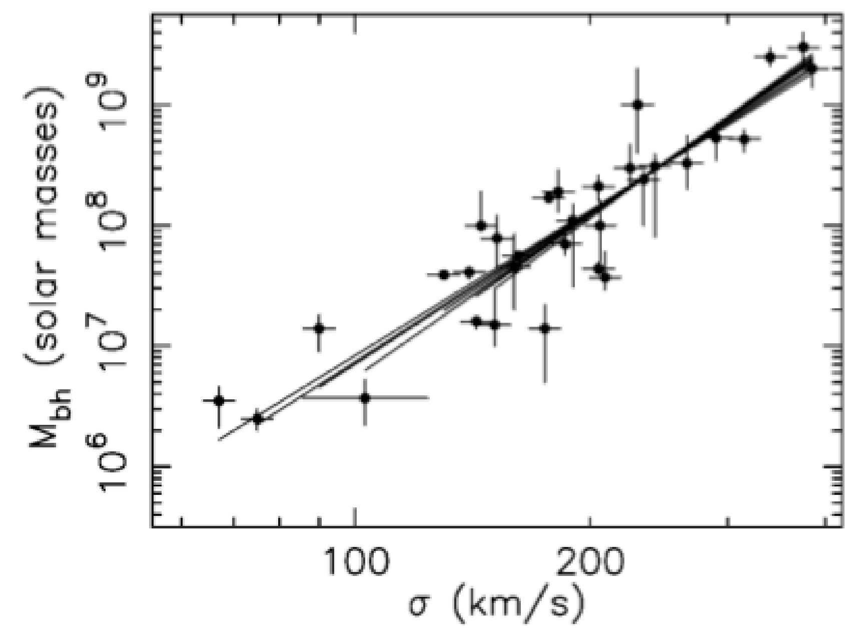
- How do SMBHs grow?
- What is the role of mergers?
- Where are the local counterparts to the z>6 SMBHs?

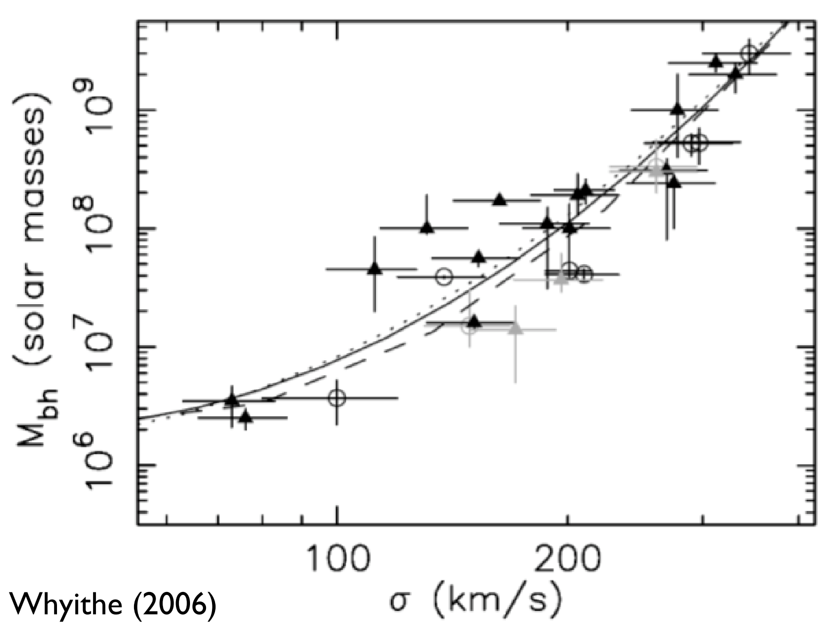
We need to probe:

- Small and large SMBHs
- Dwarf and bright galaxies
- Cluster and field galaxies

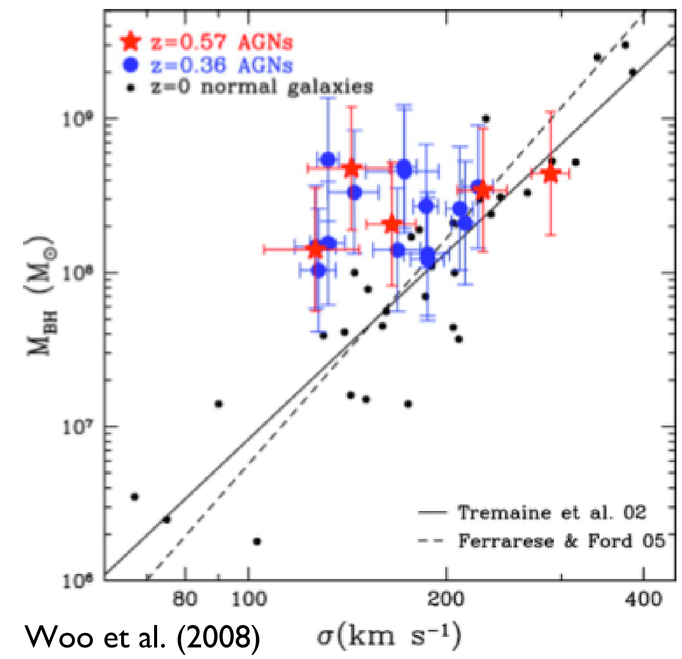
M_{BH}-σ Relation

- Exact slope
- Validity at high-z and for different environments (i.e. cluster)
- Behaviour at low and high velocity dispersion



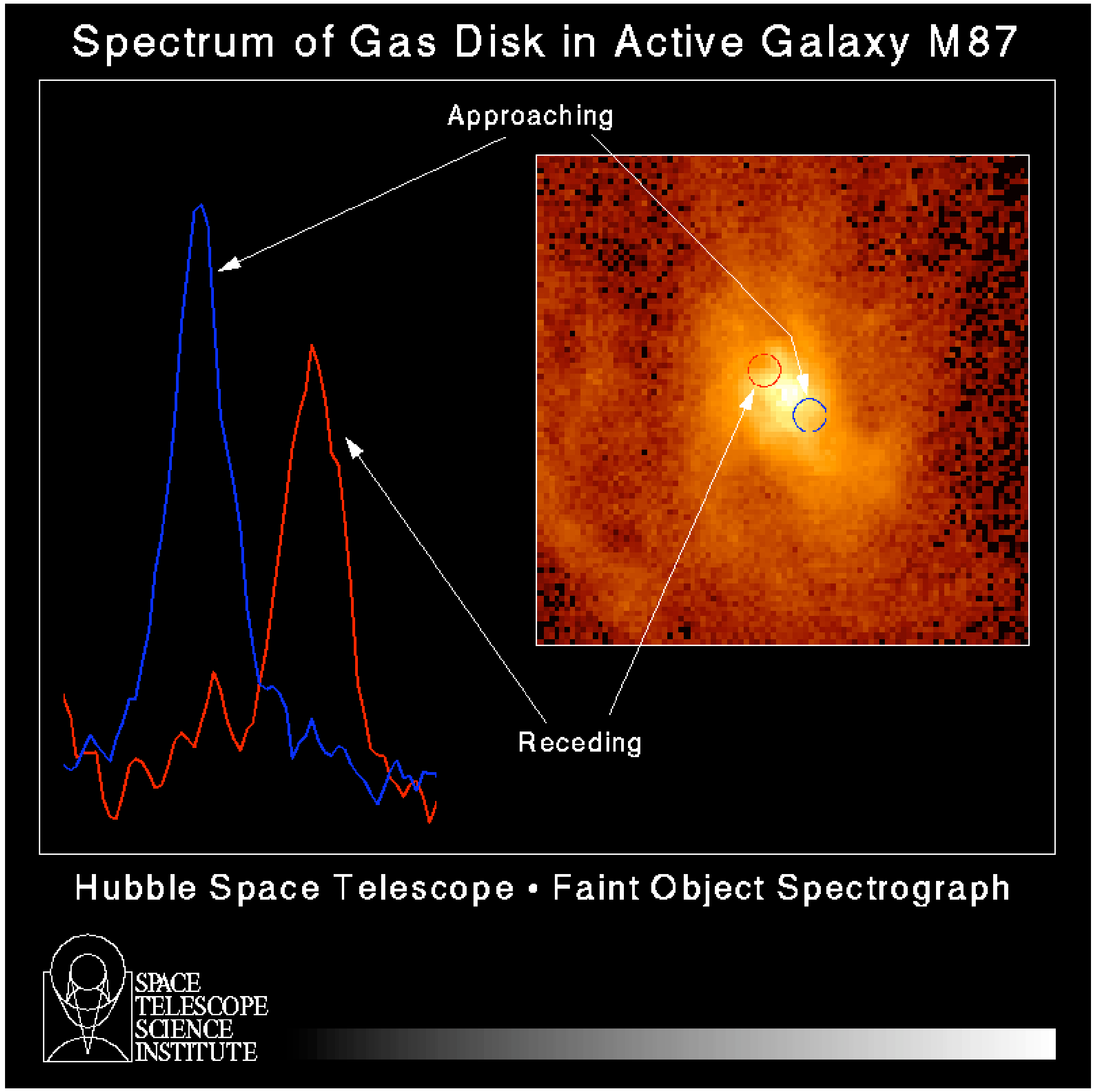


Whyithe (2006)



Woo et al. (2008)

Measuring SMBH Mass



- Gas and stellar dynamics
- Rotating gas disk at galactic center
- Measured rotation implied a central object of 3 billion solar masses!

How?

- BH in Milky Way (10^6-10^7 $M_\odot$) out to Virgo distance (~16 Mpc, SoI ~ 4 pc, 1 arcsec > 77 pc)

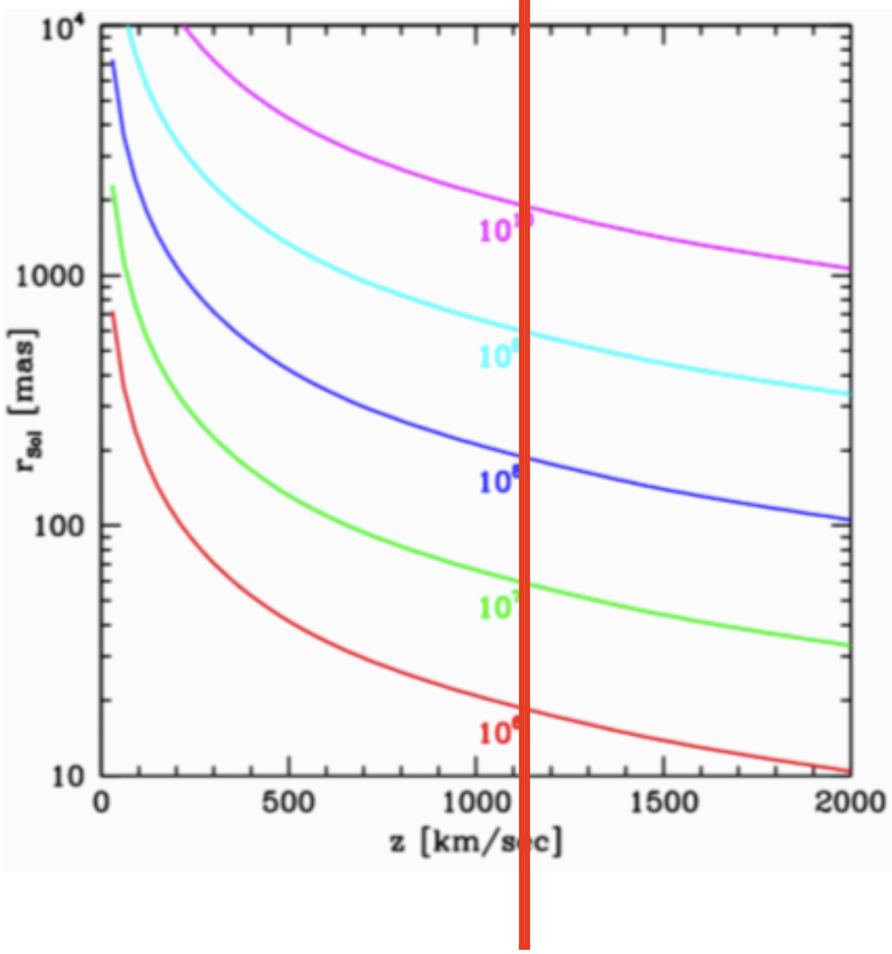
- resolve Sphere of influence

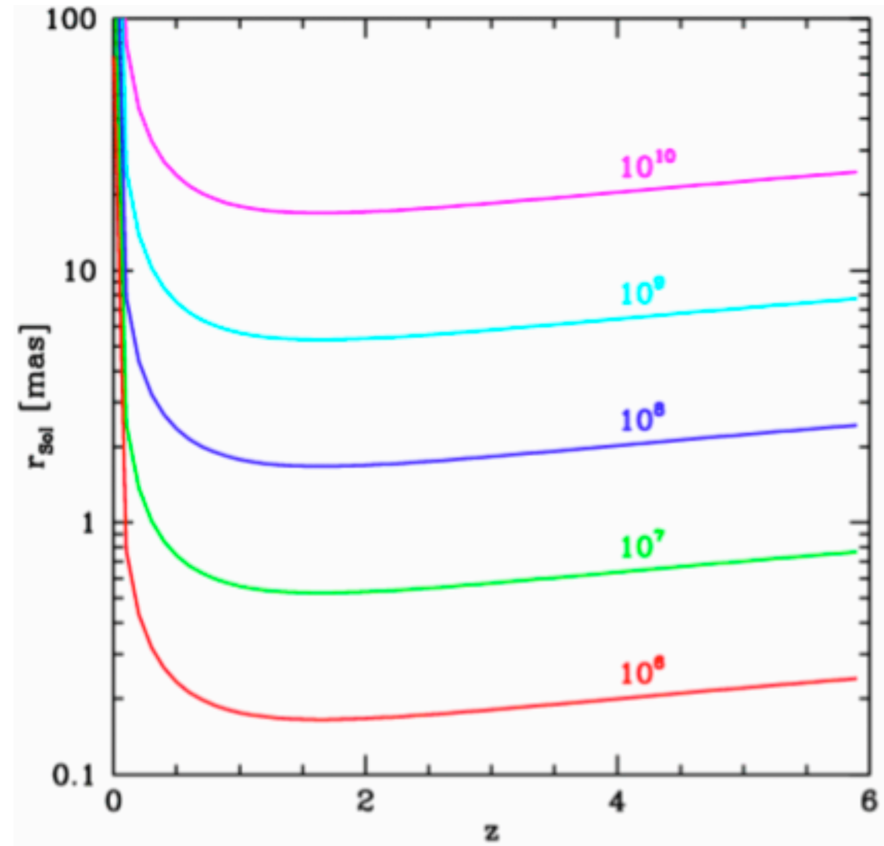
$$r_i = GM_{BH}/\sigma^2 = 4.3pc(M_{BH}/10^7 M_\odot)/(\sigma/100km/s)^2$$

for M~10^9 $M_\odot$ out to z ~ 0.2

- search for extremely massive BHs M > 10^{10} $M_\odot$ out to z ~ 0.3

Sphere of Influence





Requirements

- spectral resolution: 1000 - 10000
- spatial resolution: 5 mas
- spatial coverage: Integral Field Unit (IFU)
- wavelength: red - NIR

➡ European Extremely Large Telescope (E-ELT)

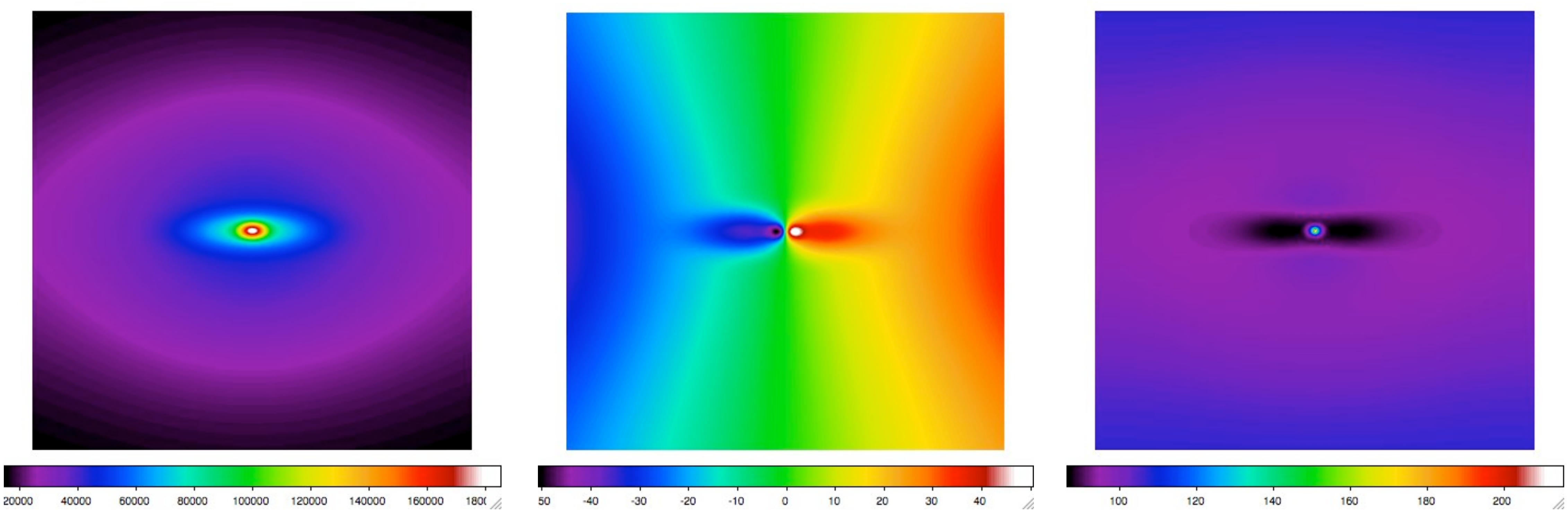
✤DRM Science Case G9: A Survey of Black Holes in Different Environments (PI: W. Freudling, ESO)

Simulations: Input Kinetmatics

- 3-d models: Jeans Anisotropic multi-Gaussian expansion dynamical models of stellar kinematics of galaxies (Emsellem et al. 94, Cappellari 2002, Cappellari 2008)

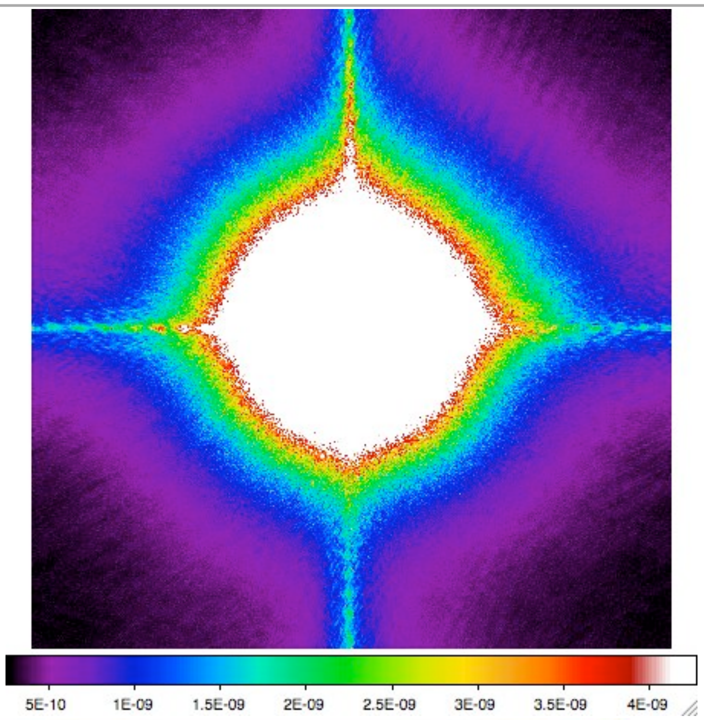
- fit for M87 (giant elliptical), NGC 5308 (S0) and NGC 4486a (dwarf elliptical)

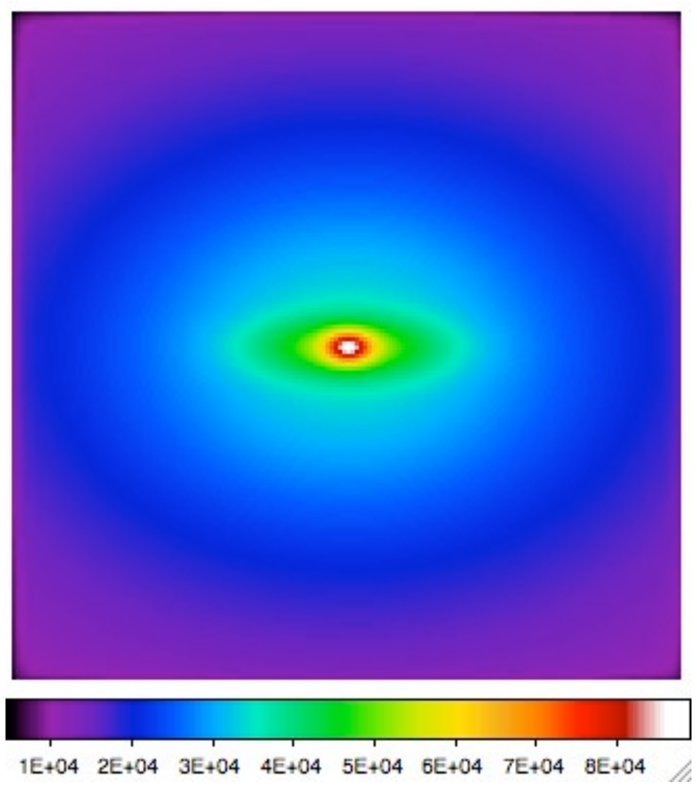
- inclination 90 degrees(edge-on), constant M/L, different values for the BH mass and redshift

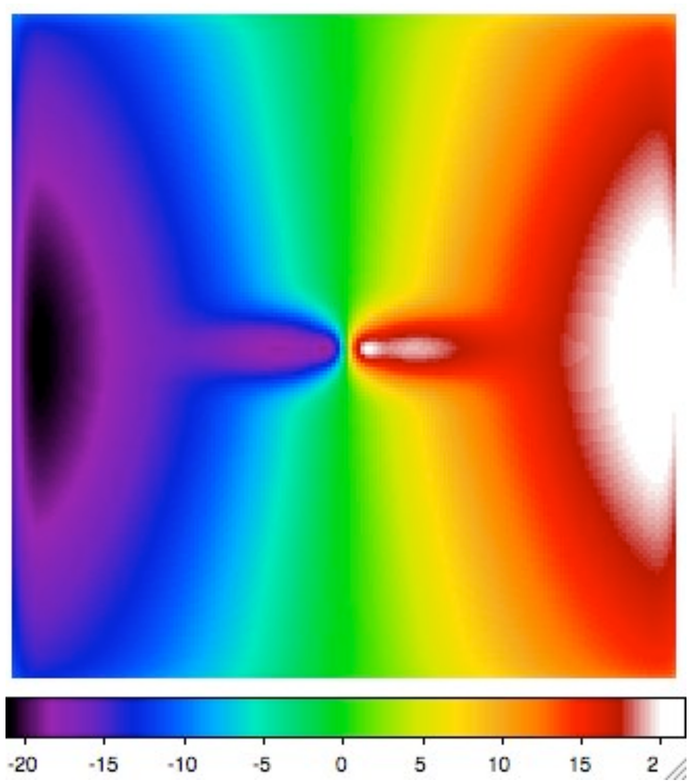


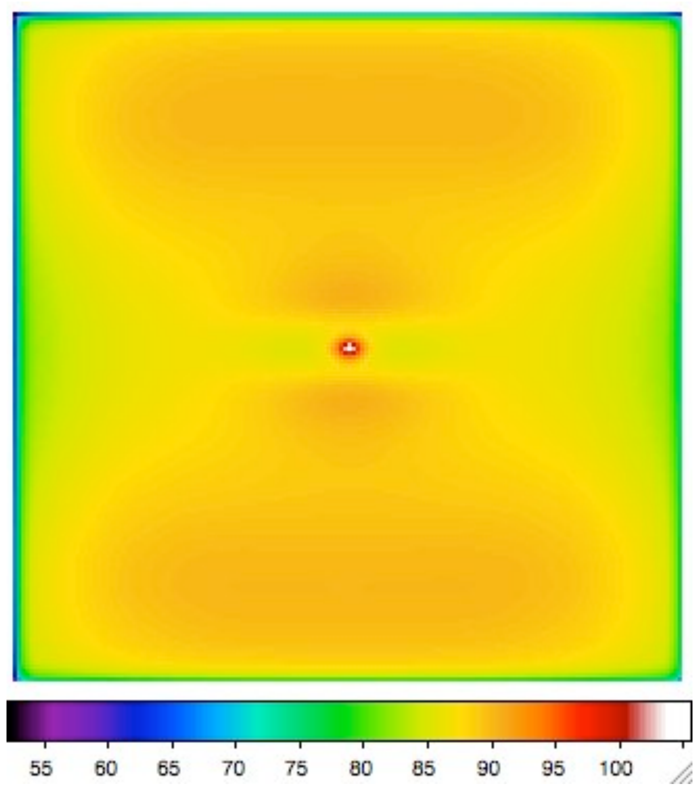
Simulations: Input PSF

- Degrade to IFU resolution (5 mas/spaxel)
- Luminosity weighted convolution with E-ELT LTAO PSF (from E-ELT technical database)







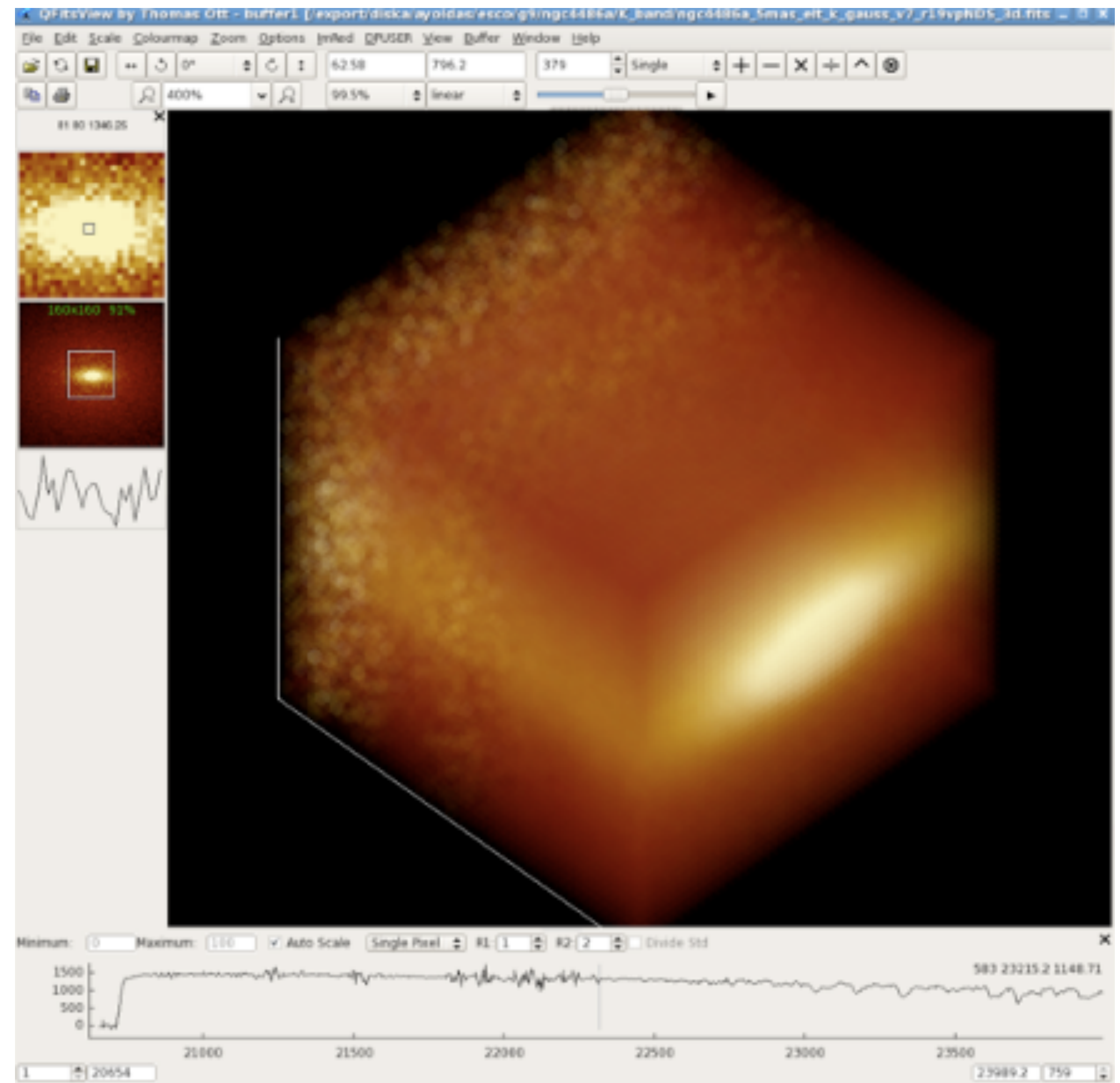


Simulations: Output Datacube

For each spaxel:

- Template stellar spectra is redshifted (velocity(from the maps), z)
- Gaussian convolved (σ_V from the maps)
- background (atmosphere lines+absorption +scattering+continuum) + telescope (emissivity) × telescope (throughput) × detector (QE)
- read-out noise, dark current, Poisson noise
- Sky subtracted

OUTPUT: Reduced (sky subtracted) datacube



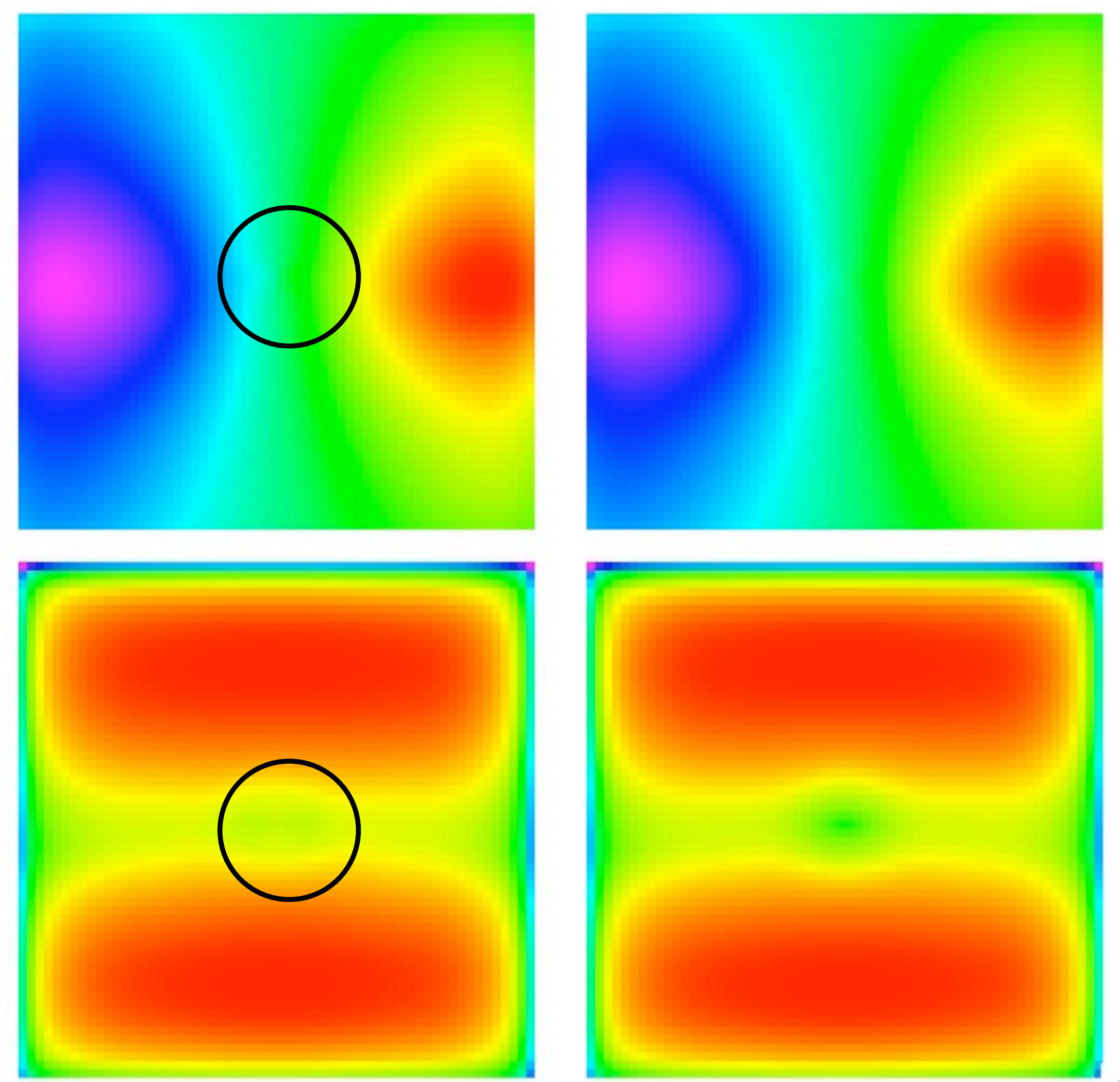
Kinematic Analysis

Panelized PiXel-Fitting (pPXF): An IDL program to extract the stellar kinematics from absorption-line spectra of galaxies (Cappellari & Emsellem 2004)

http://www-astro.physics.ox.ac.uk/~mxc/idl/

- using a maximum penalized likelihood approach
- fitting template spectra convolved with Gauss-Hermit polynomials with a bias of h3,h4 measurements towards zero (Gaussian LOSVD)

Test Case: NGC 4486a

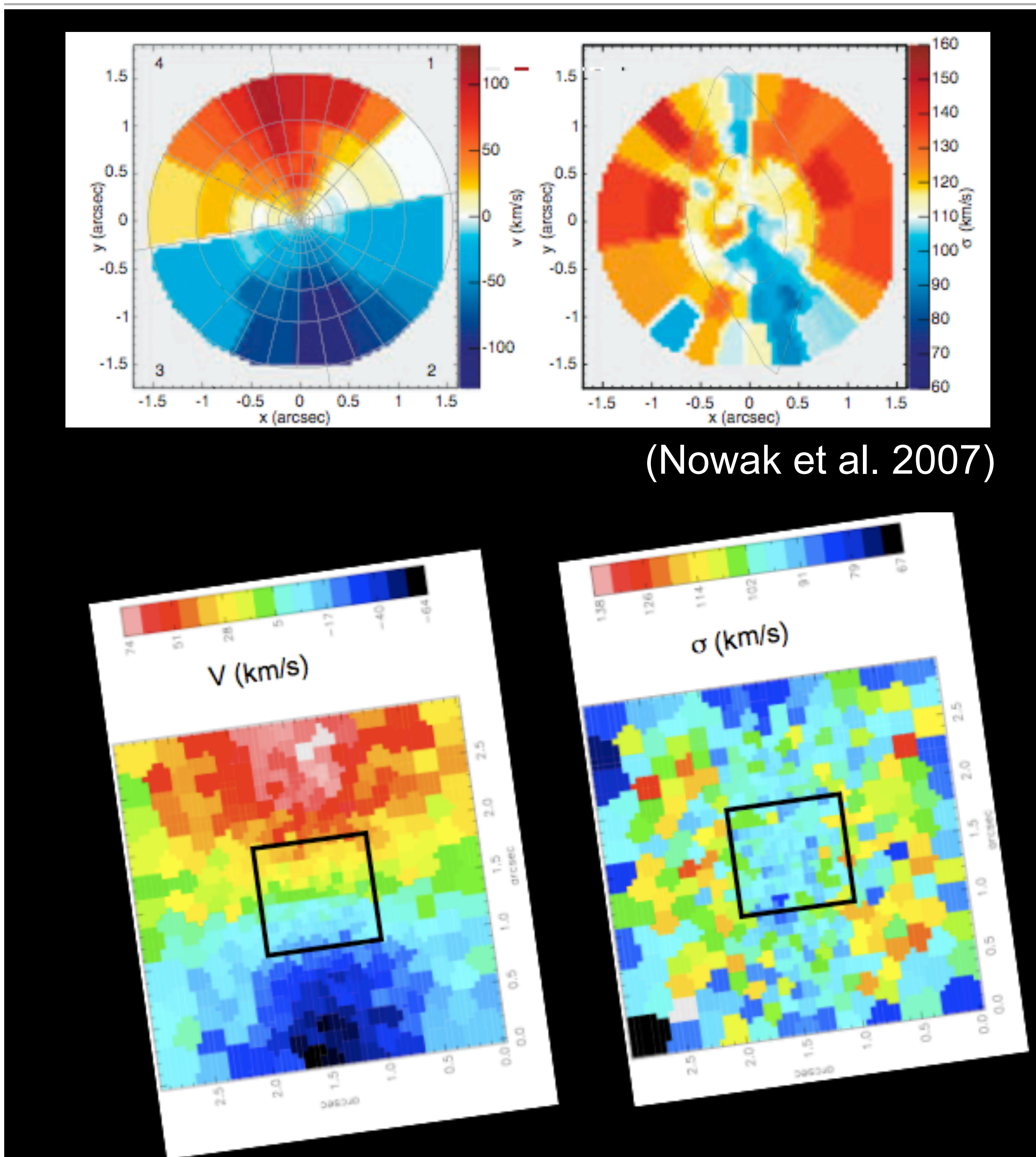


- NGC4486a @ 16 Mpc
- observed with SINFONI K-band
- 50 mas spaxel

Input:

- $M_{BH} = 1.25e7\ M_{\odot}$
- SINFONI PSF (Nowak et al. 2007)

Test Case: NGC 4486a



(Nowak et al. 2007)

Maps derived from observations

- Marginal BH detection
- $M_{BH} = (1.25^{+0.75}_{-0.79})e7\ M_\odot$ (90% C.L.) (Nowak et al. 2007)

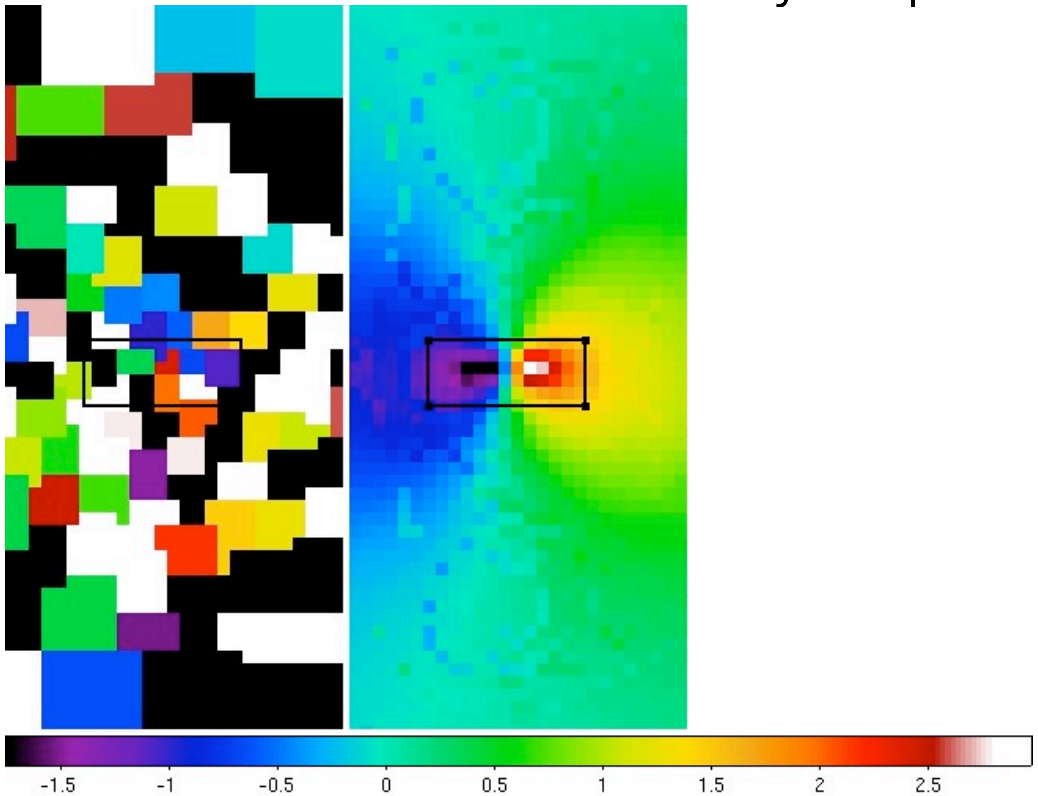
Exposure time: 14 x 600 sec

Maps derived from simulated datacubes

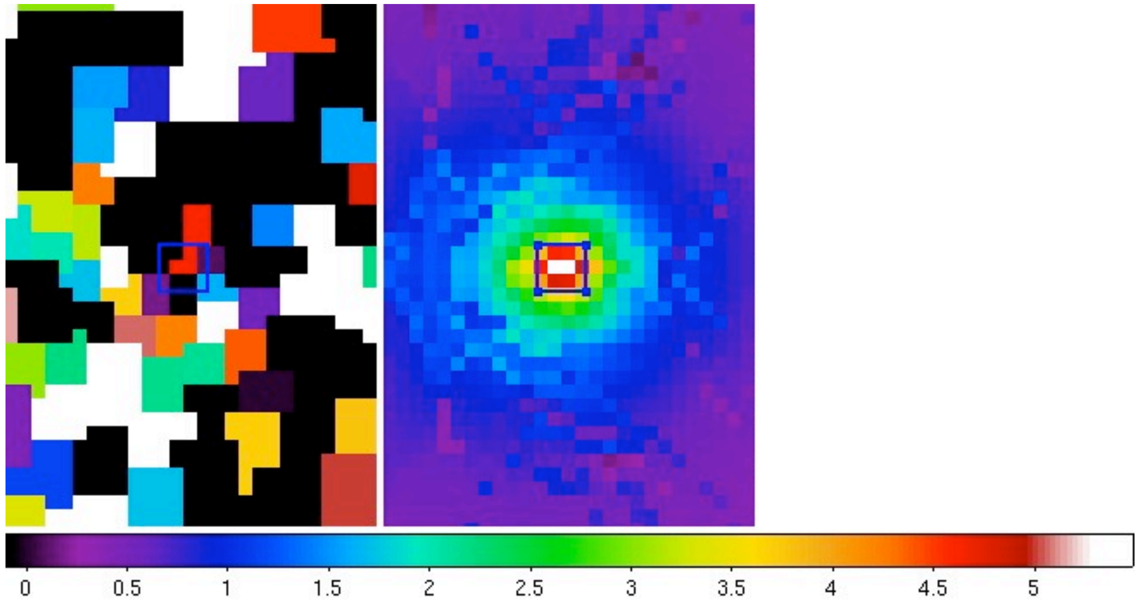
- Voronoi Binned to S/N~20
- Black square marks the 0.8”x0.8” FoV of Single IFU (I.e. HARMONI) on E-ELT

Test Case: NGC 4486a

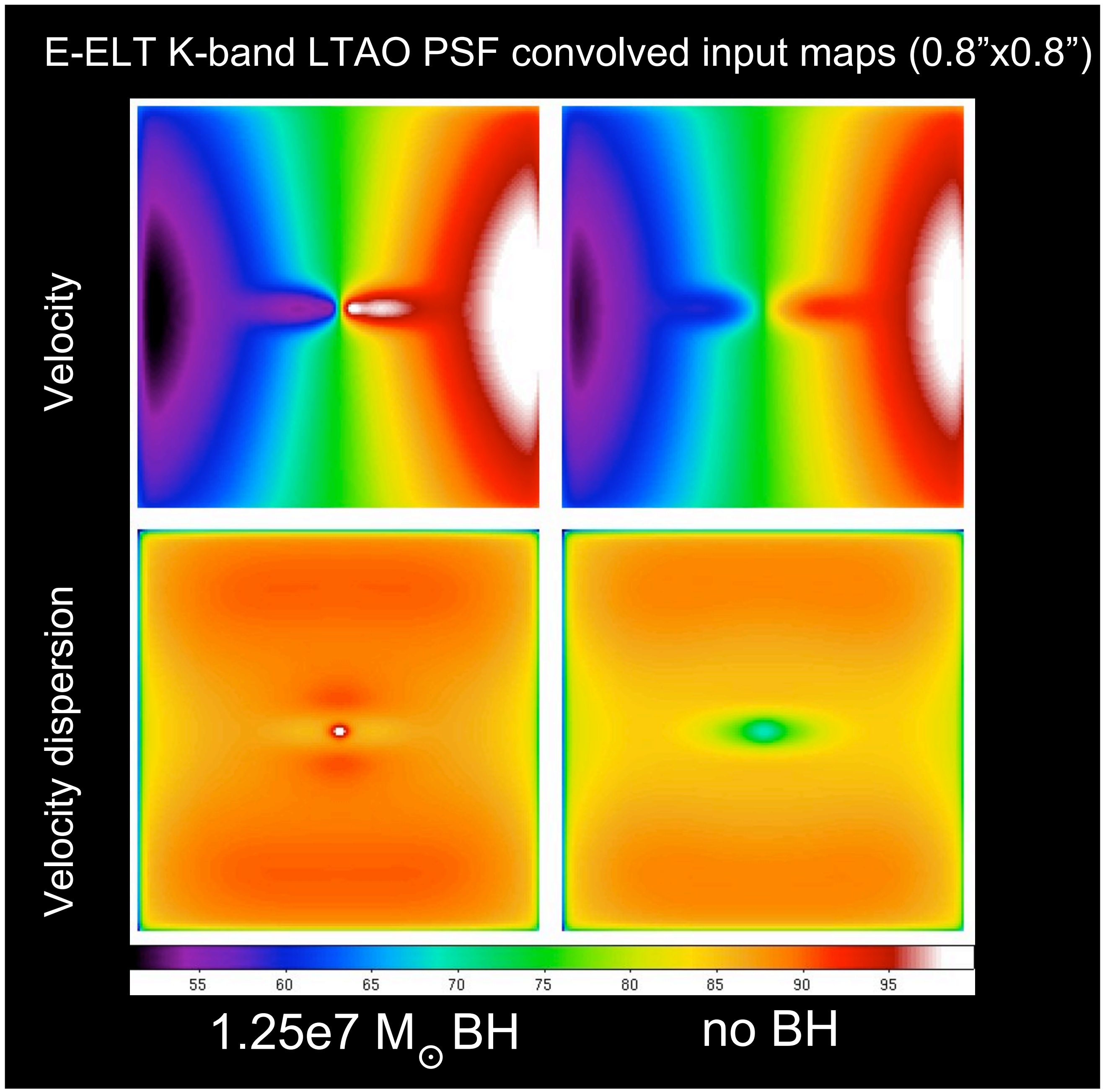
SINFONI Sim. with 1.25e7 BH velocity map - Sim. without BH velocity map



SINFONI Sim. with 1.25e7 BH velocity dispersion map - Sim. without BH velocity dispersion map

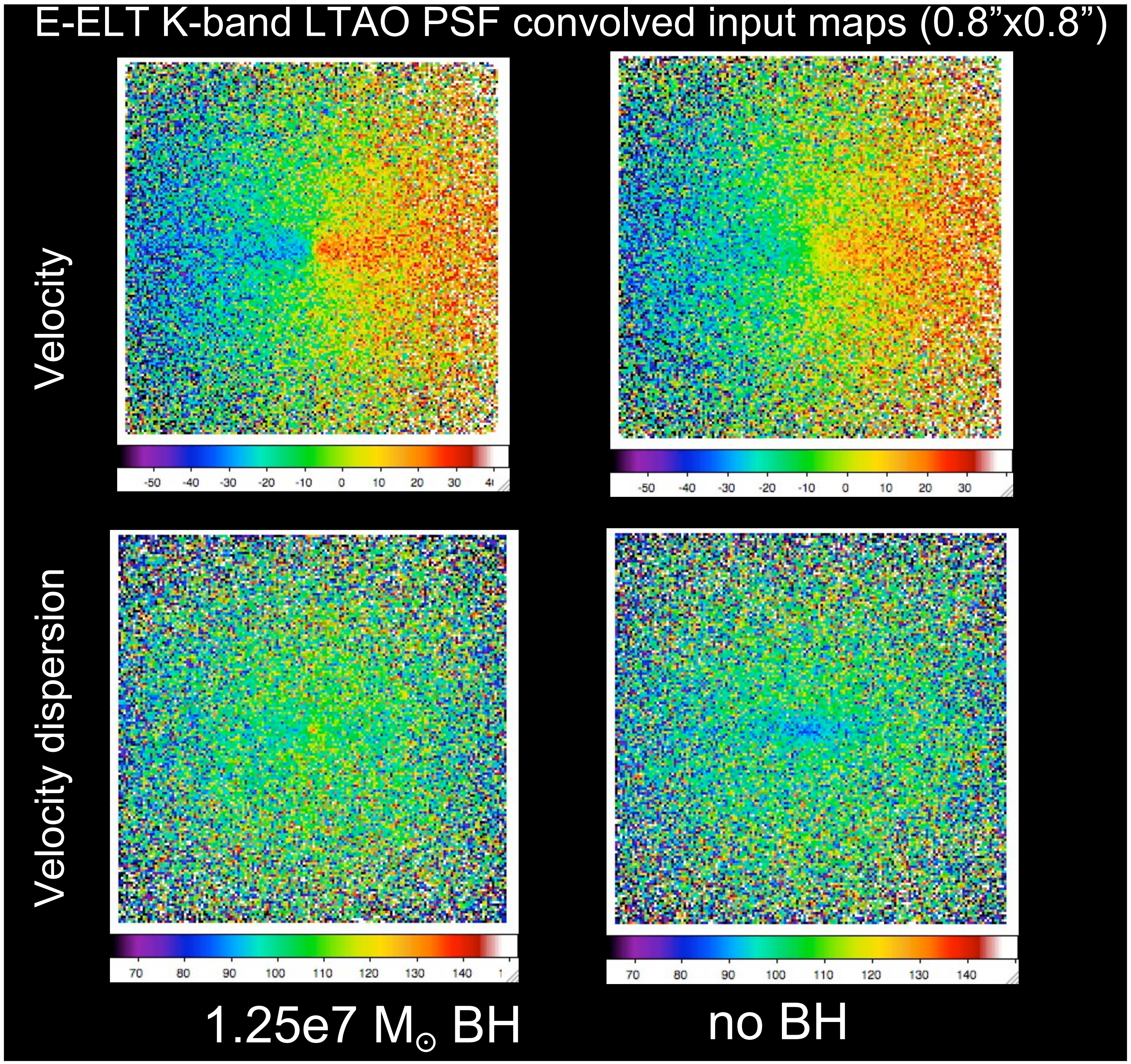


NGC 4486a: E-ELT view



- NGC4486a observed with E-ELT Single IFU K-band
- E-ELT LTAO
- Spaxels: 5 mas
- NGC4486a @ 16 Mpc
- M_{BH} = 1.25e7 $M_{\odot}$

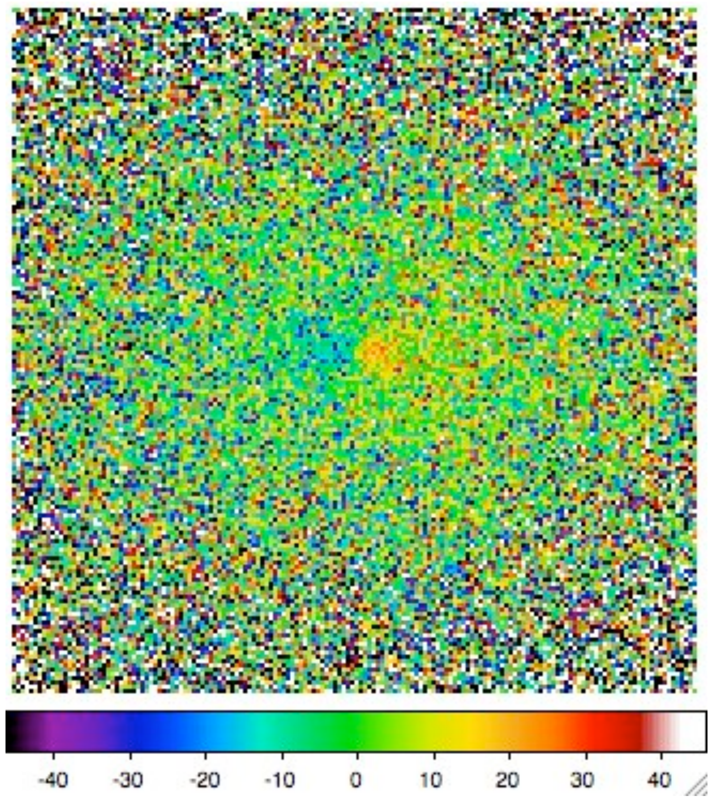
NGC 4486a: E-ELT view

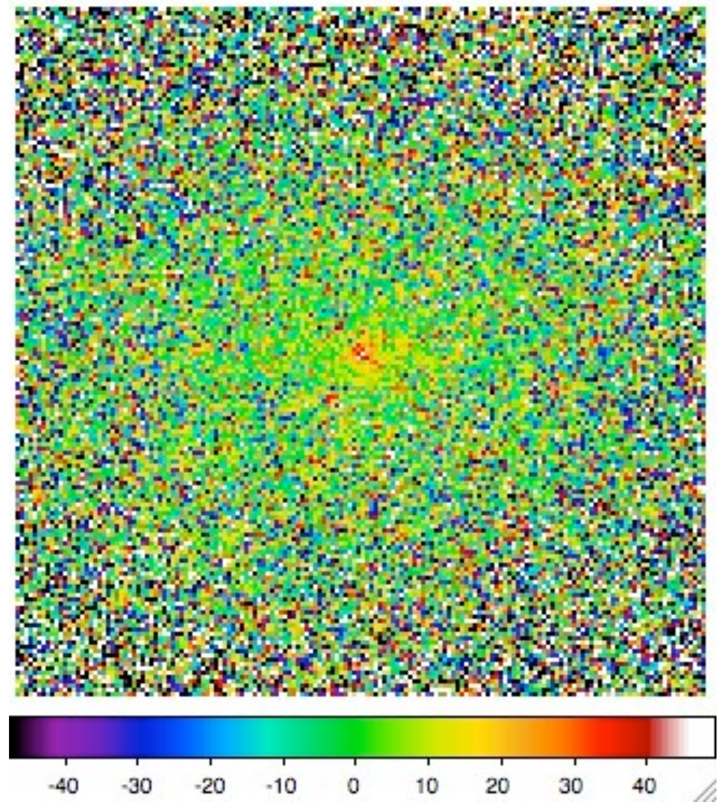


Simulations input:

- Paranal-like site
- Background continuum in K-band
- Telescope throughput for aluminum coating
- Rdnoise = 3.0 e-
- Dark current = 4 e-/h/pix
- QE = 90%
- Poisson noise
- Spaxels: 5 mas
- Exposure time: 12 x 1200 sec

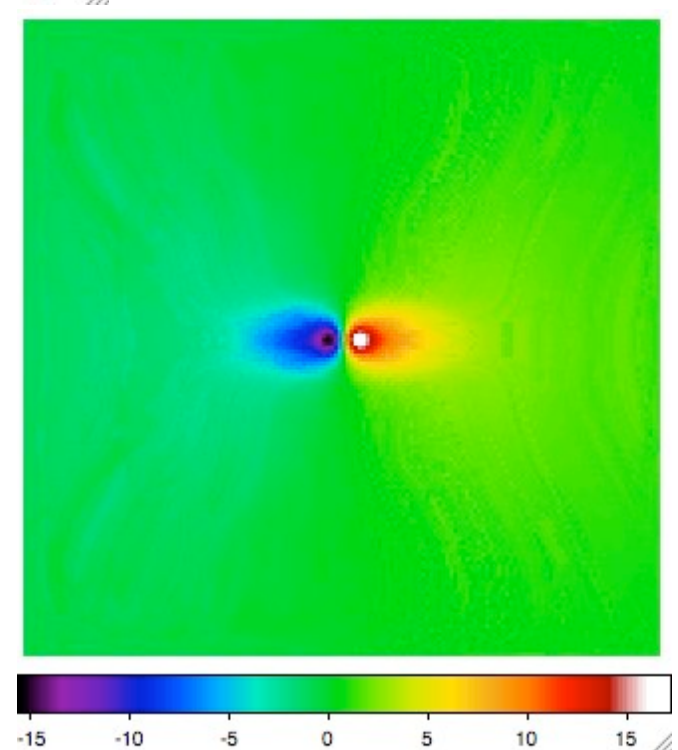
NGC 4486a: E-ELT view

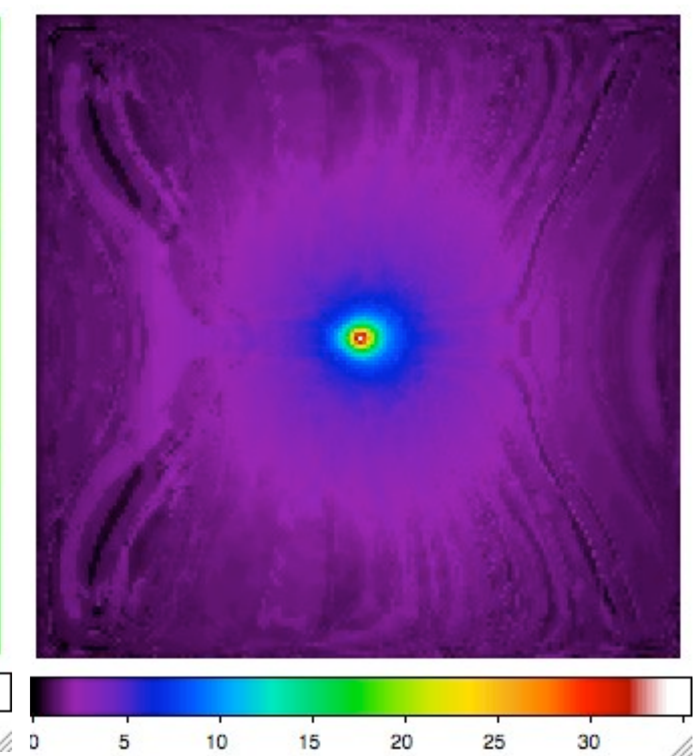




Velocity difference

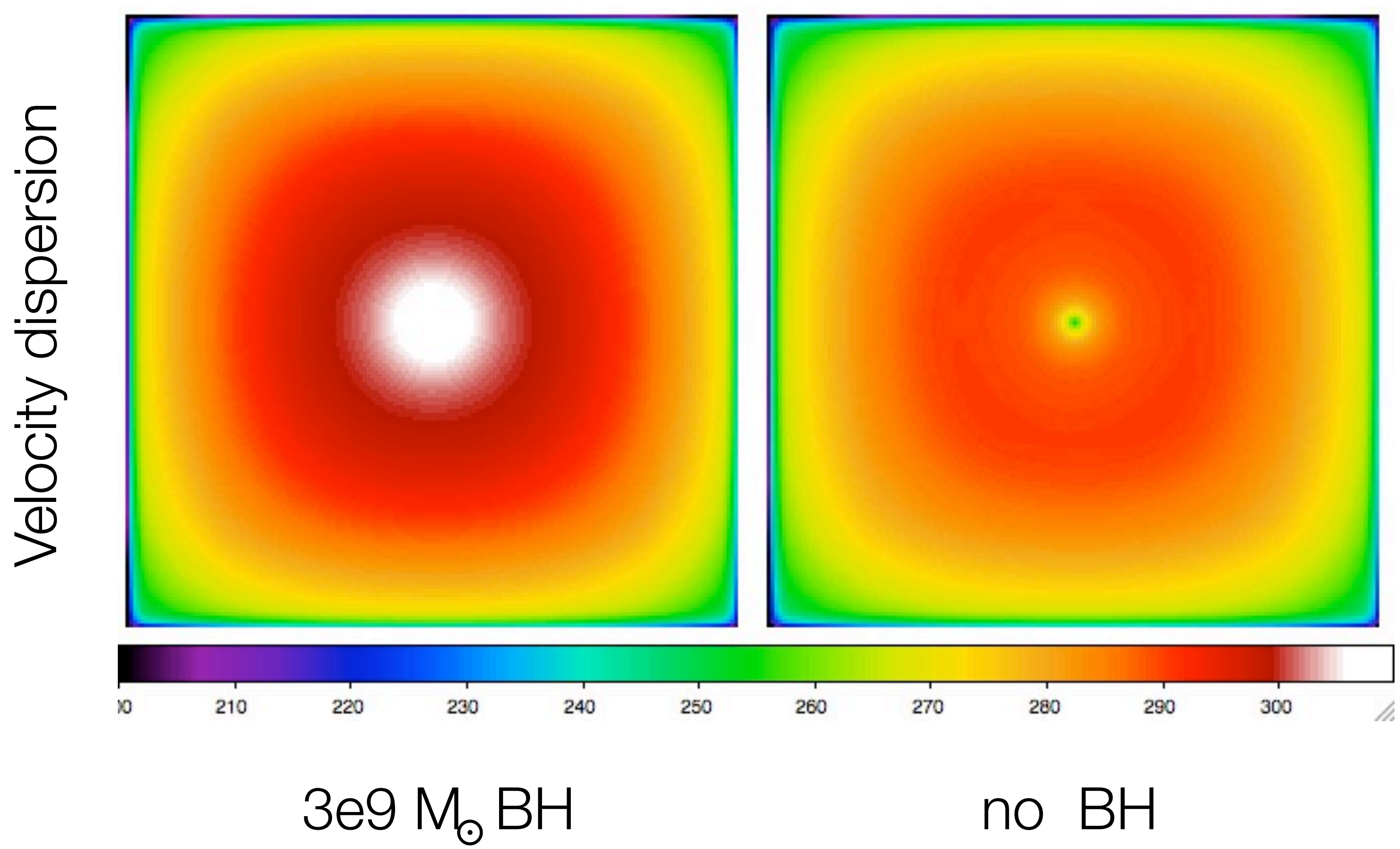
Velocity dispersion difference





Upcoming

E-ELT K-band LTAO PSF convolved input maps (0.8”x0.8”)



- M87 @ z=0.2 observed with E-ELT Single IFU K-band
- E-ELT LTAO
- Spaxels: 5 mas
- M_{BH} = 3e9 $M_\odot$

Conclusions and Outlook

DRM Case G9: A Survey of SMBH in Different Environments

- E-ELT can resolve the sphere of influence of a 10^7 solar mass BH at Virgo distance (~16 Mpc) in a few hours!
- ELT will open new era for SMBH research
- Significant SMBH samples with high S/N dynamical data

OUTLOOK

- M87 and NGC 5308 at redshift z ~ 0.2 - 0.3
- Different sites, mirror coatings
- Different wavelengths
- Different spatial resolutions (Adaptive optics modes)