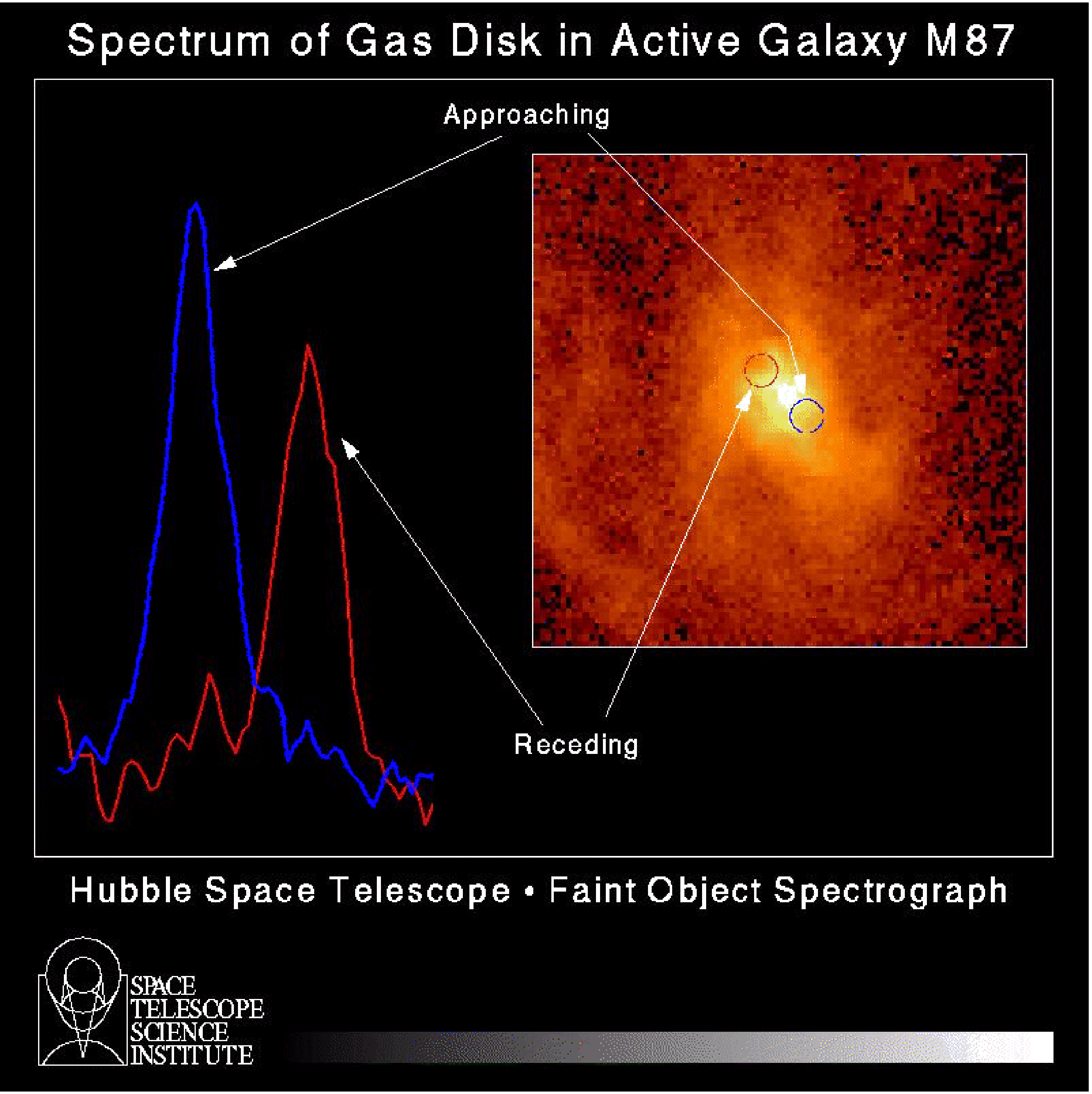
Black Holes & ELT

Wolfram Freudling

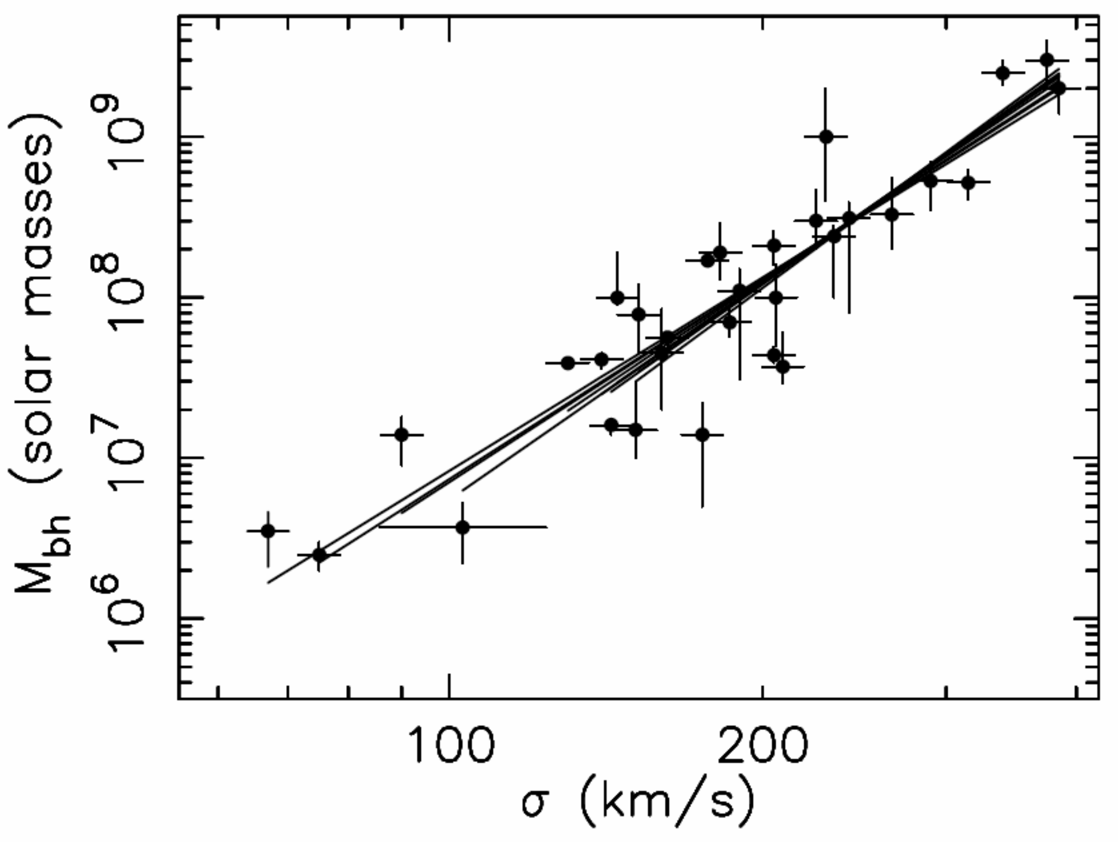
Eric Emsellem



record for direct measured BH mass

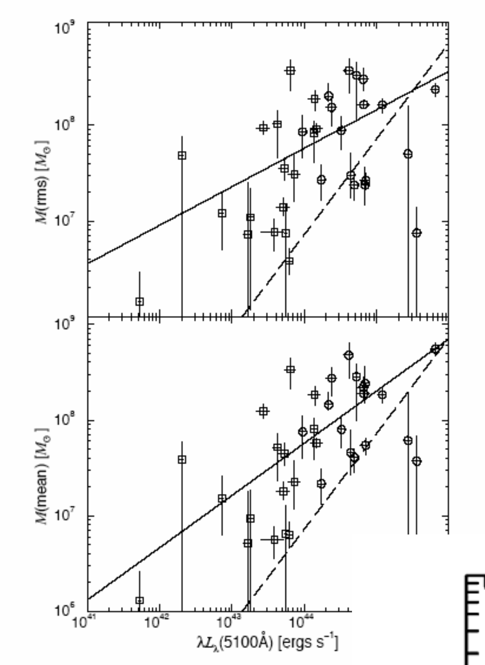
M_{BH}~$3x10^9$

M_{BH}-σ relation

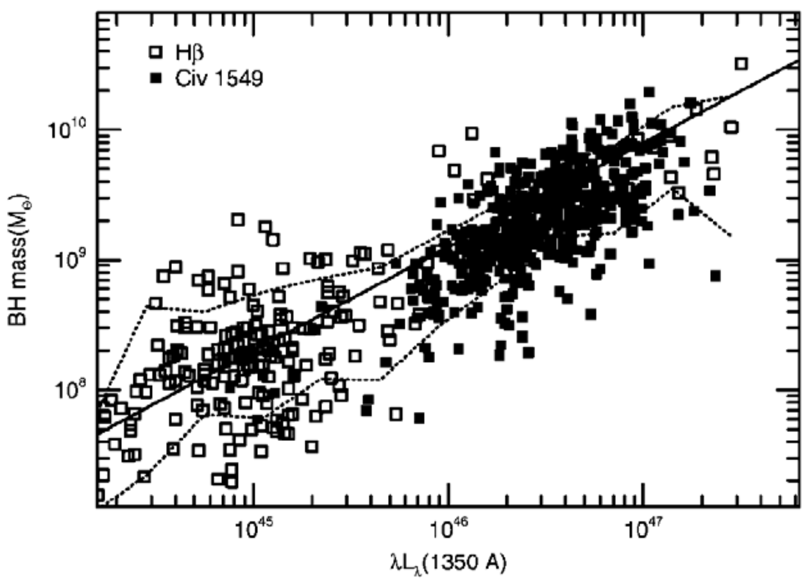


M_{BH} mass vs. bulge velocity dispersion
Tremaine et al. 2002

Evidence for $M \sim 10^{10}$ Black Holes



Kaspi et al.
2000



Netzer et al. 2002:
BH masses in AGNs:

$R_{BLR} \sim L_{line}^{a}$

$M_{BH} \sim L_{line}^{a} FWHM^{2}$

calibrated by reverberation mapping

Evidence for M~10^{10} Black Holes

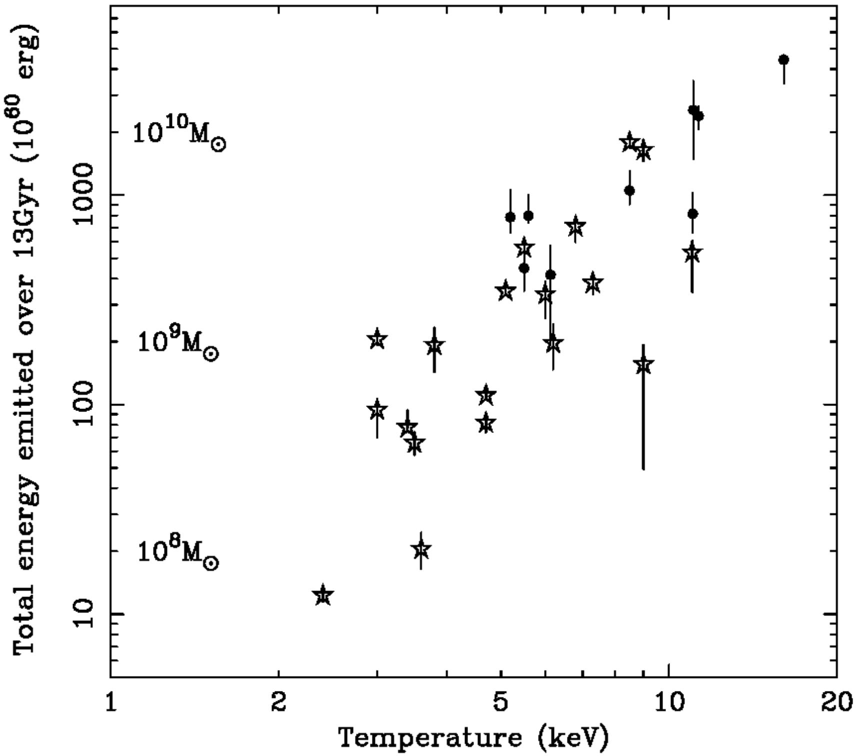


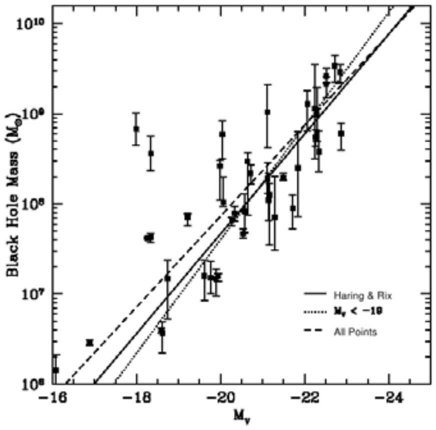
Figure 3. Total energy required to stem cooling flows. The equivalent ac-

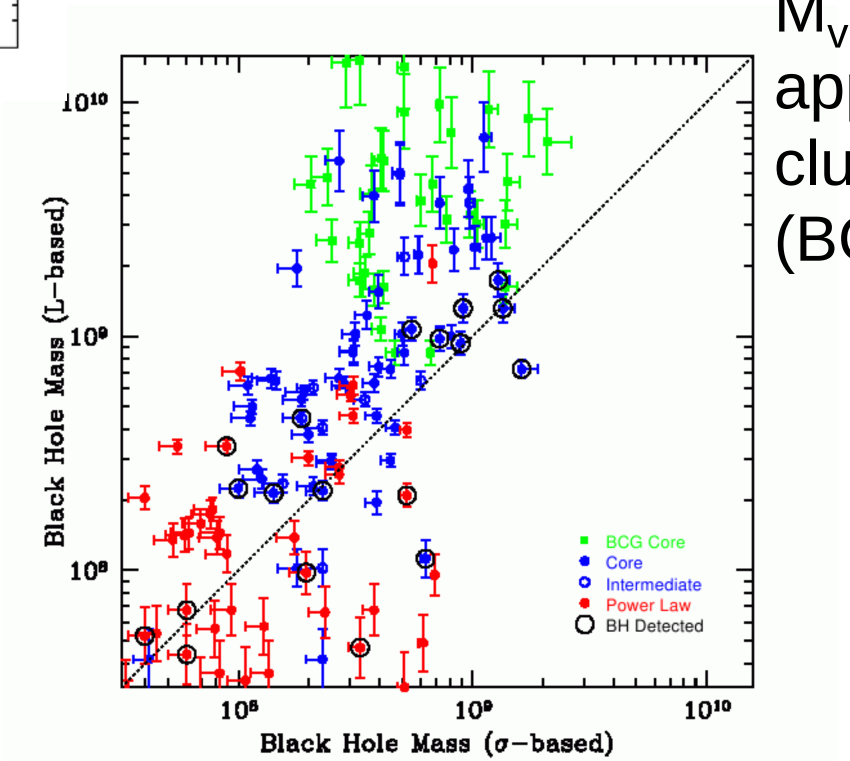
Fabian et al. 2002:

X-ray data of cores of clusters: radiative cooling losses must be balanced by heat source.

accretion on BHs, assume efficiency of 0.1 of rest mass

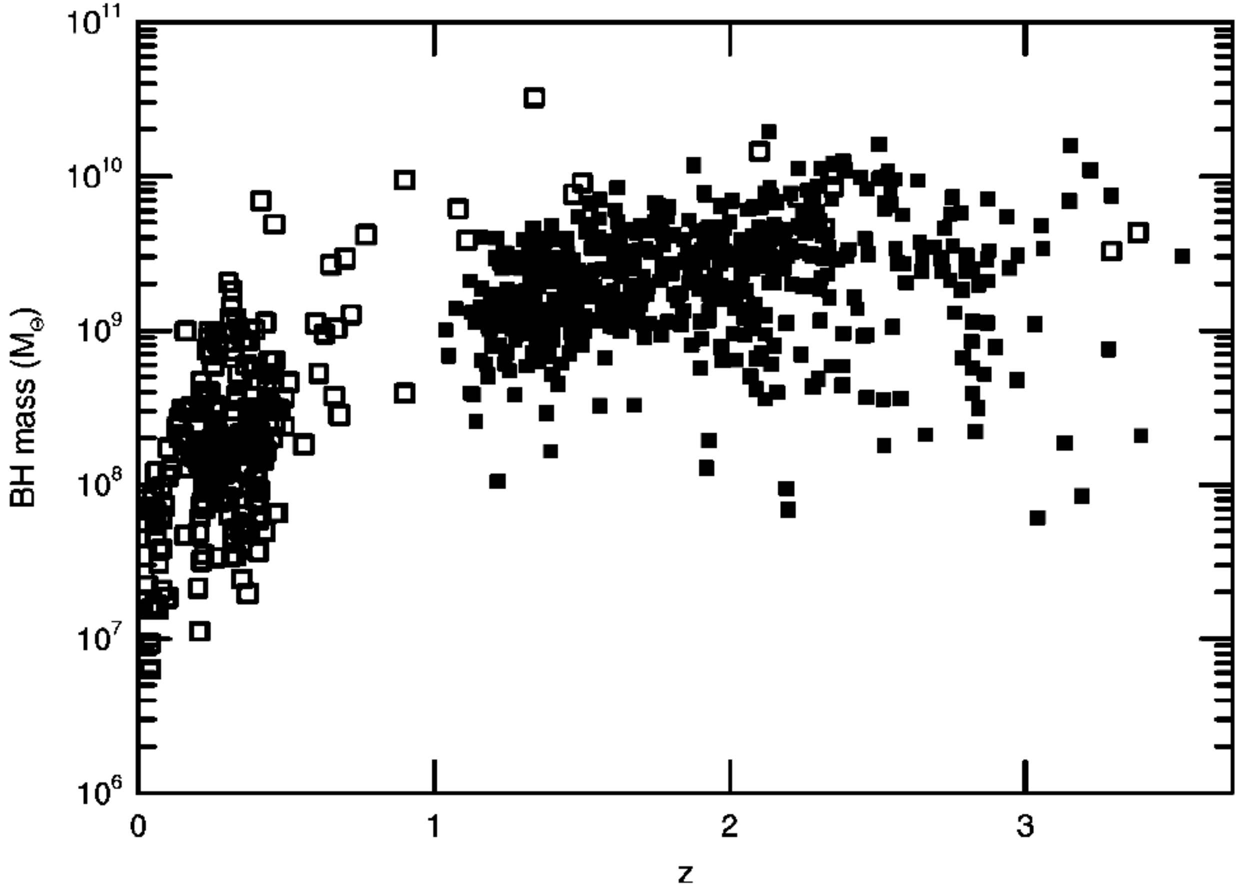
Evidence for M~10^{10} Black Holes





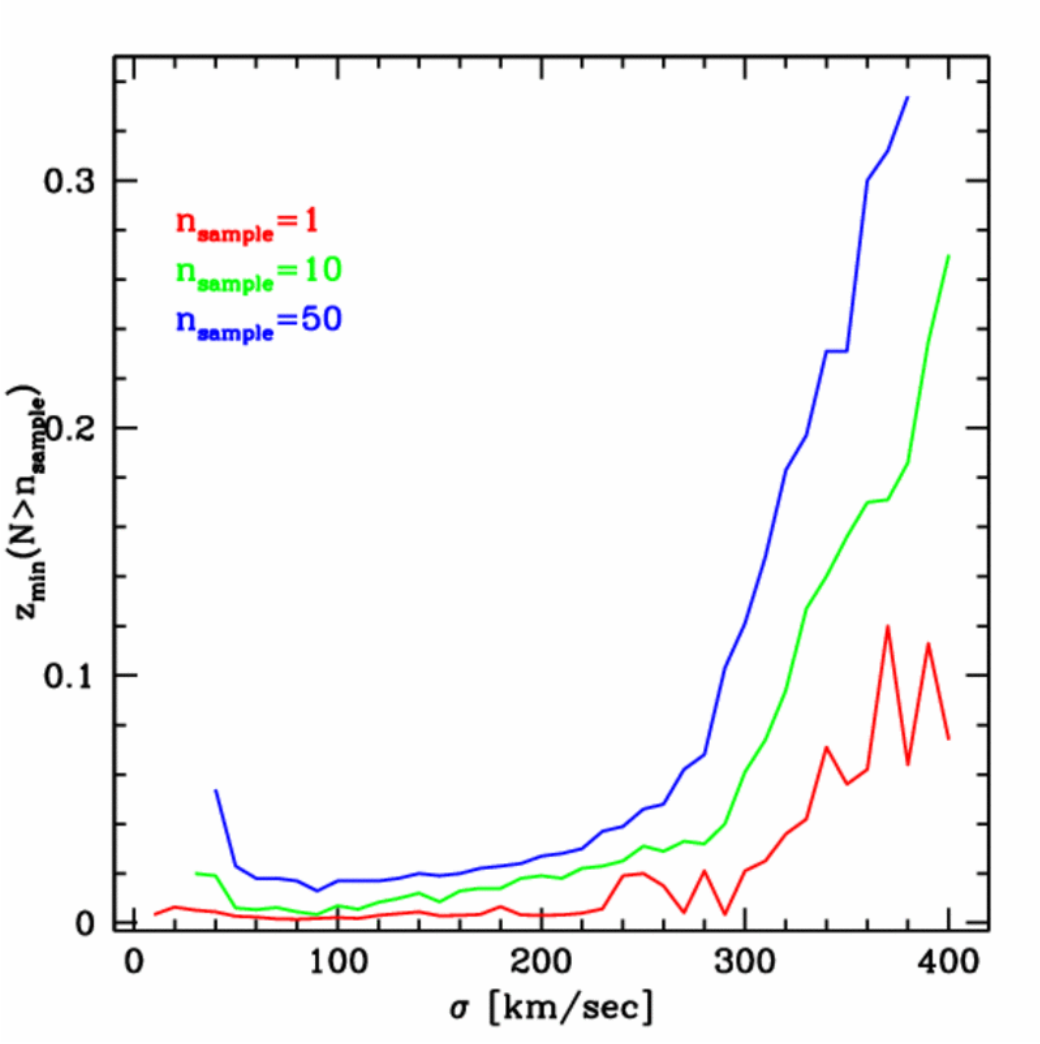
Lauer et al. 2006:

M_V-M_{BH} relation applied to brightest cluster galaxies (BCG)



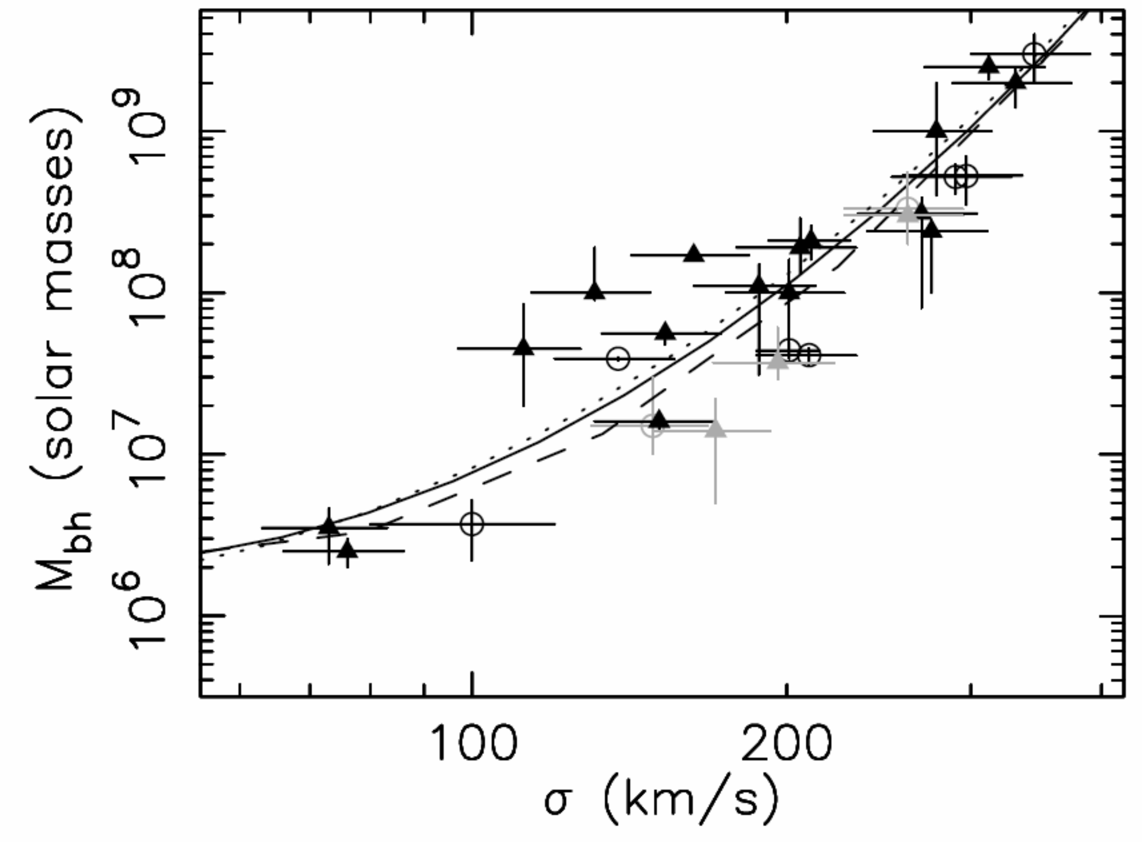
Netzer et al. 2002

number counts vs redshift

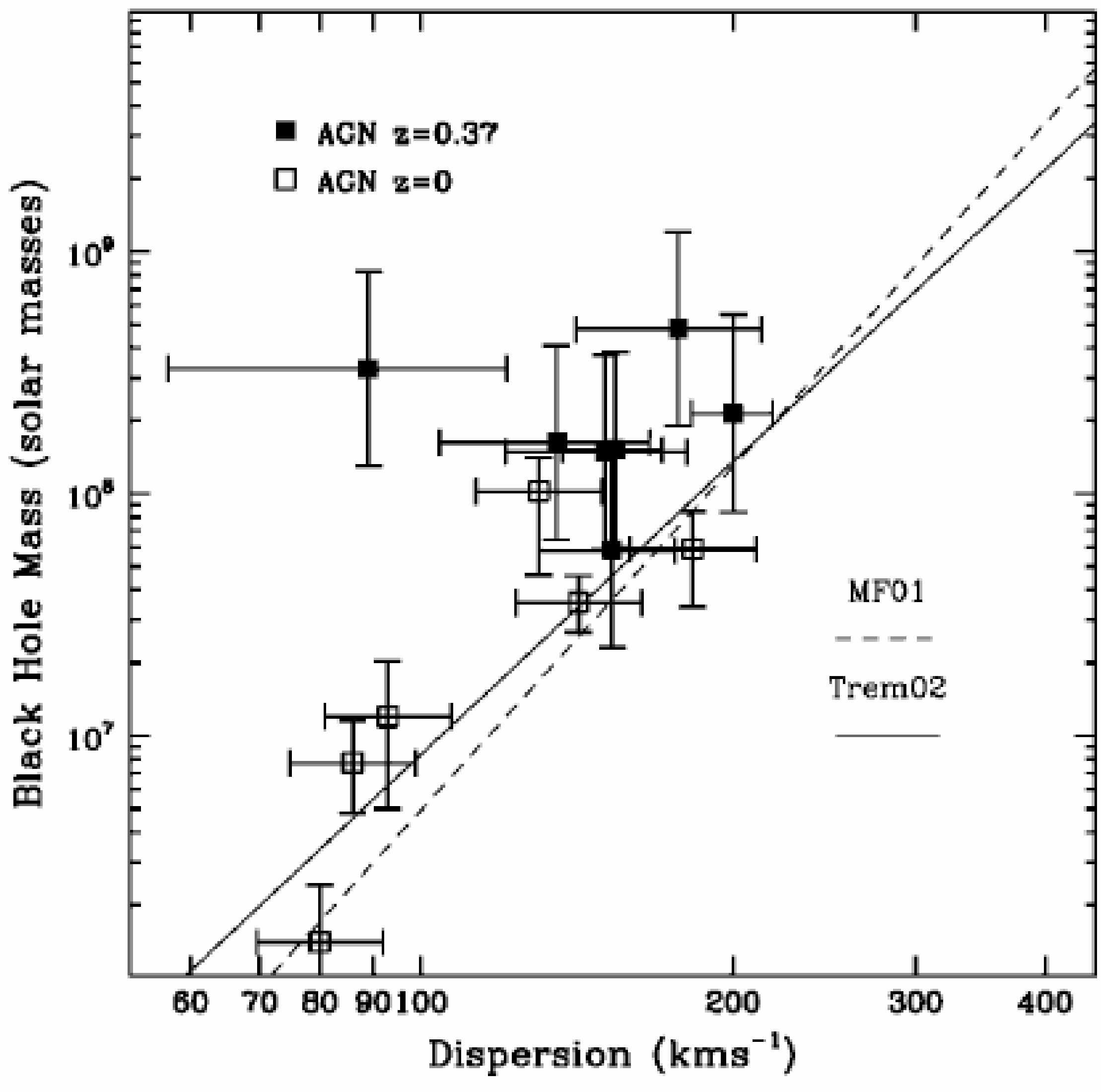


velDisp from SDSS

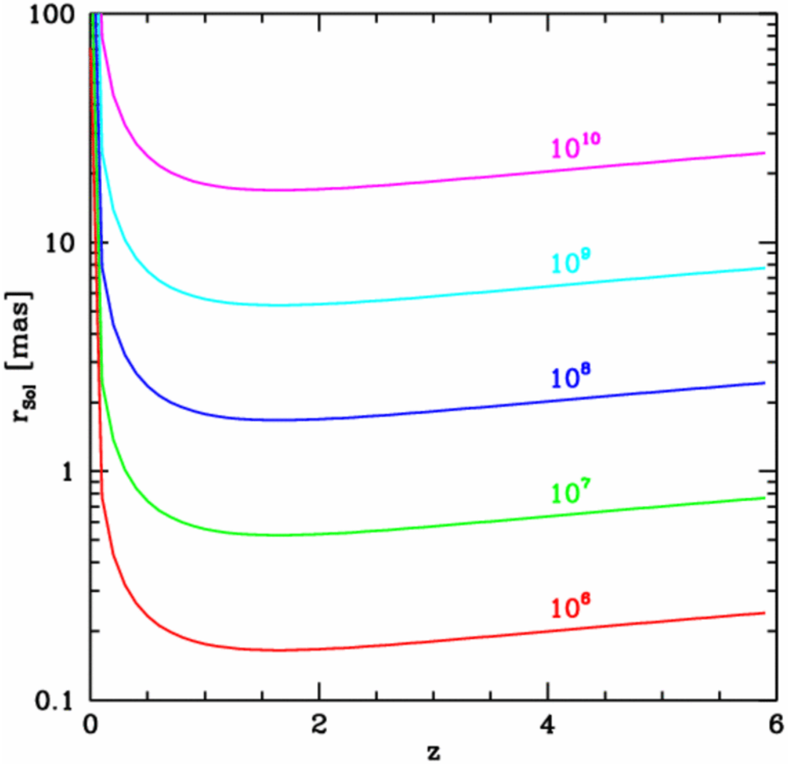
Flattening of M_{BH}-σ relation for small M_{BH}?



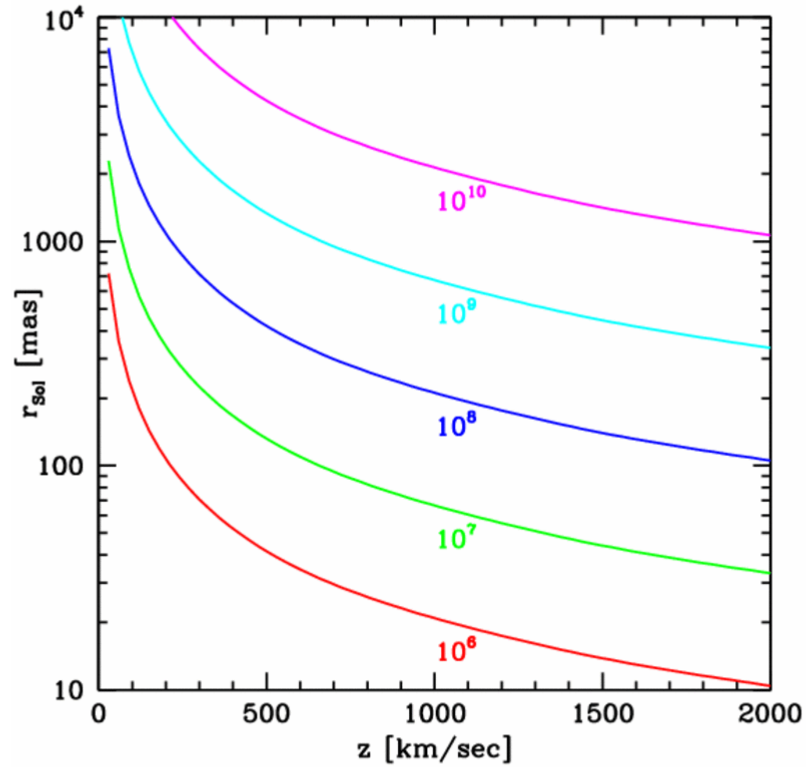
Wyithe 2006



Treu et al 2004

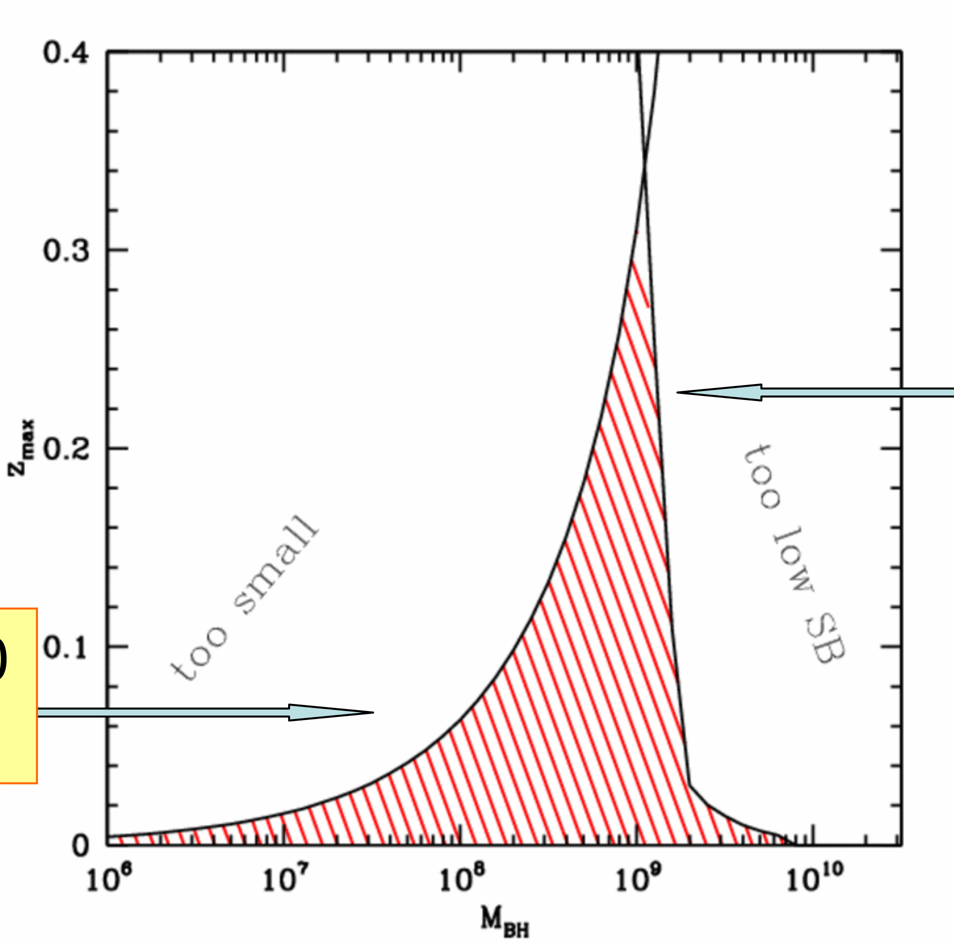


100
10
1
0.1
0
2
4
6
z
r_{Sol} [mas]
10^{10}
10^9
10^8
10^7
10^6



10^4
1000
100
10
0
500
1000
1500
2000
z [km/sec]
r_{Sol} [mas]
10^{10}
10^9
10^8
10^7
10^6

To what distance can BHs be detected?



Lauer et al. 2006:

cusp brightness μ fainter with higher BH mass

SoI > 10 mas

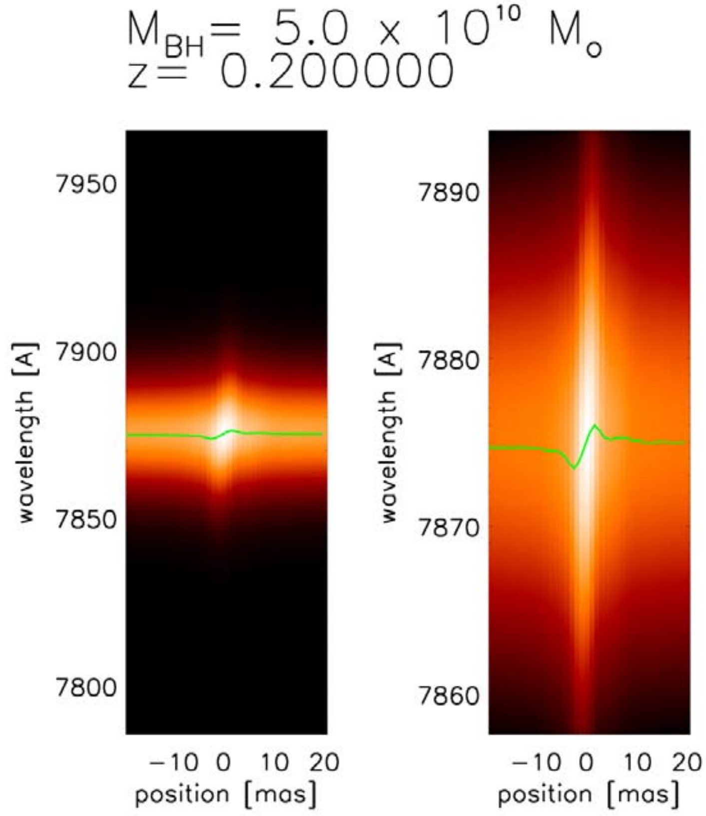
Goals

- BH in Milky Way out to Virgo distance
- Resolve Sphere of Influence (SoI) for $M \sim 10^9$ out to $z \sim 0.2$
- Search for extremely massive BHs $M > 10^{10}$ out to $z \sim 0.3$
- Resolve bright stars in circumnuclear region to measure age, metallicity, and velocity - only known in MW

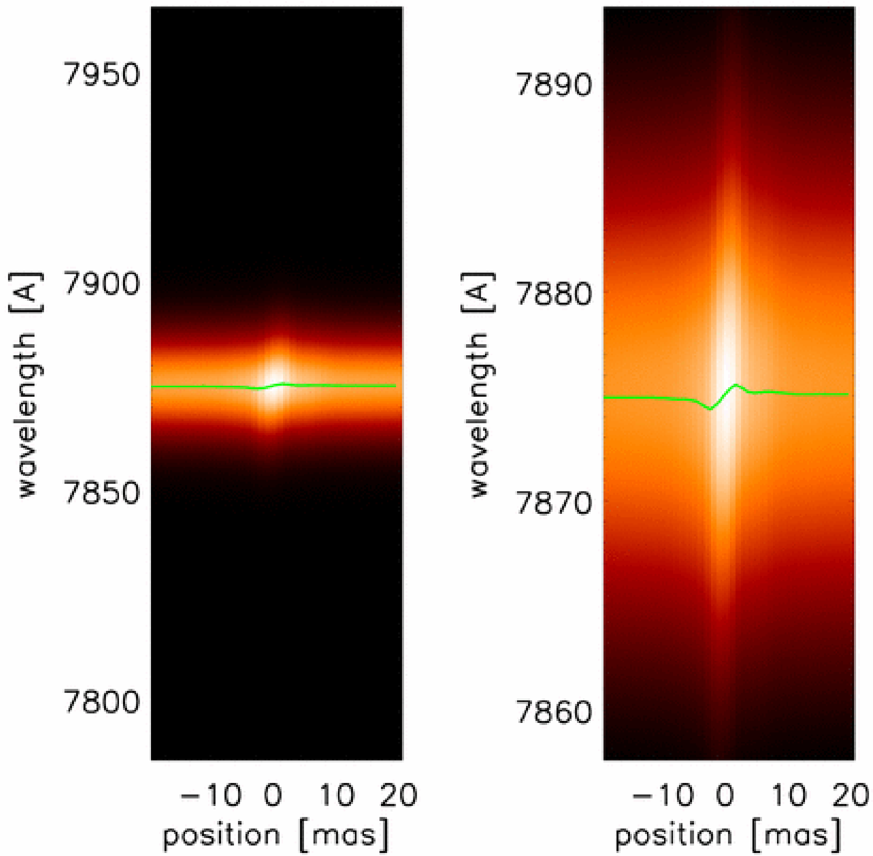
BH Simulations

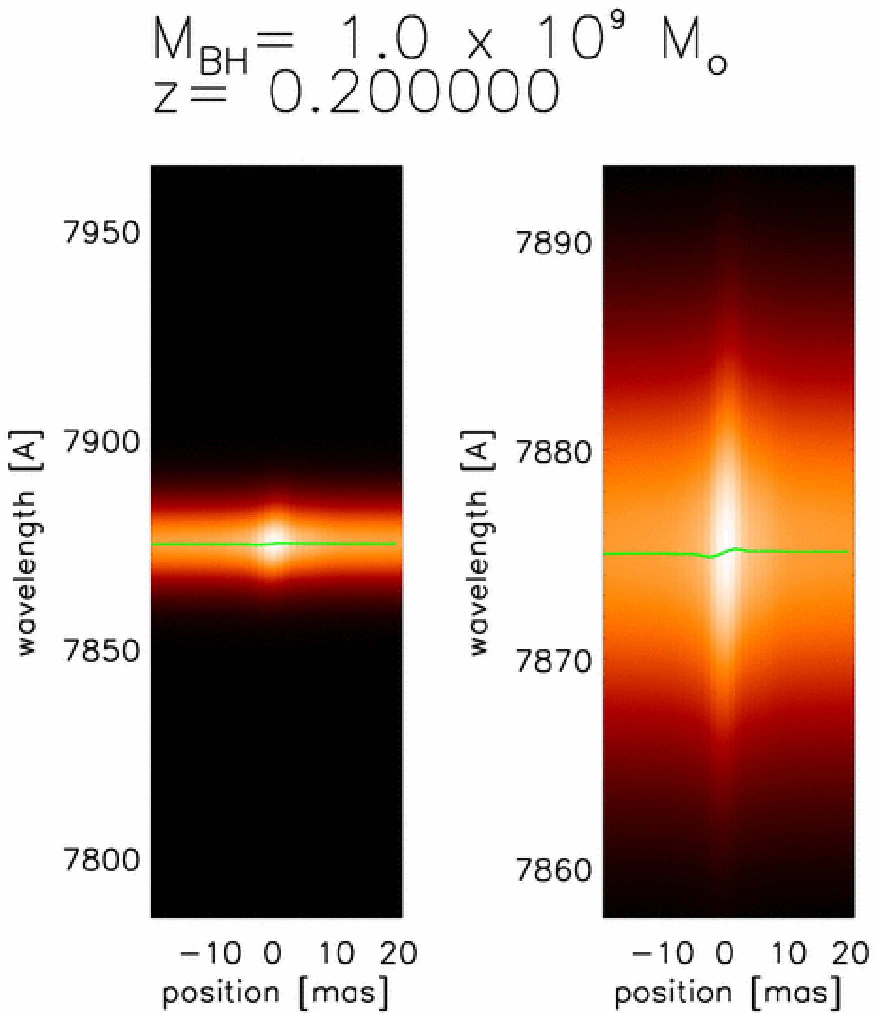
- 3-d models: multi-Gaussian expansion density distribution (Emsellem et al. 94, Cappellari 2002)
- fit to NGC 3377 (lenticular) and M87 (giant elliptical)
- inclination 90 degrees (edge-on), constant M/L, different values for the BH mass
- V and σ_v for grid of points on sky
- convolve with I-band LTAO PSF
- convolve with spectrum (for now 1 line)
- for now noiseless

Simulation 1: Mass

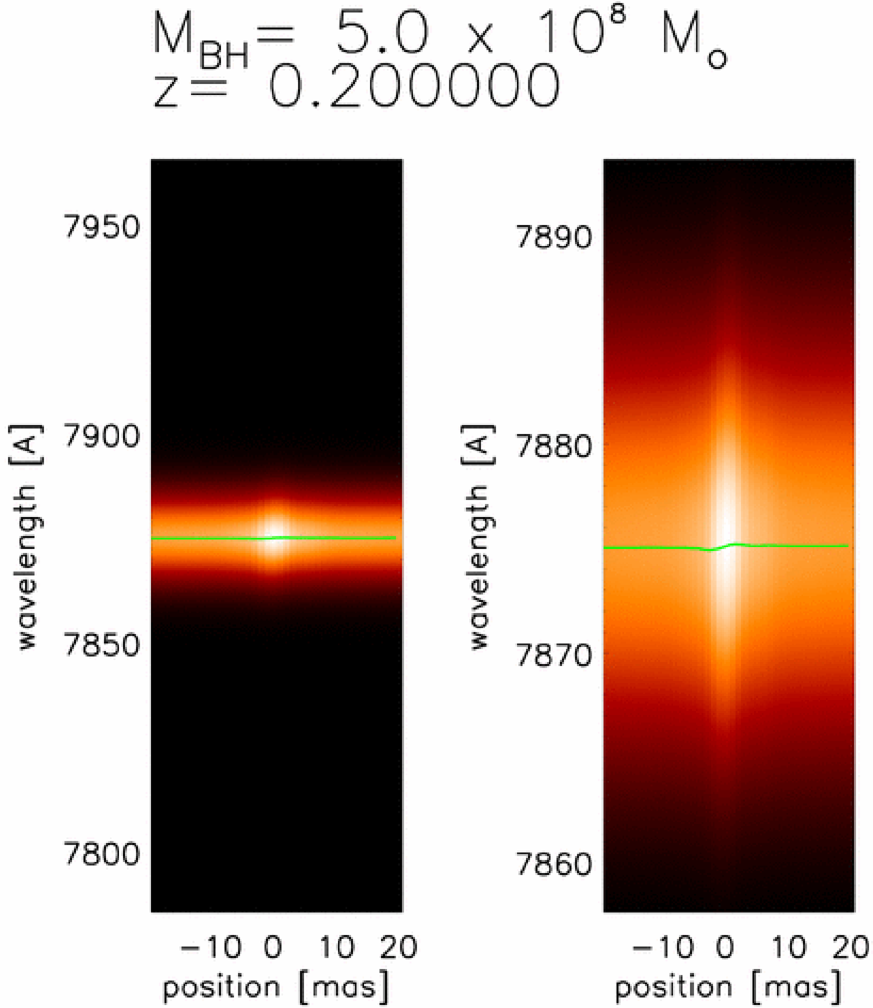


$M_{BH} = 1.0 \times 10^{10}\ M_{o}$
$z = 0.200000$

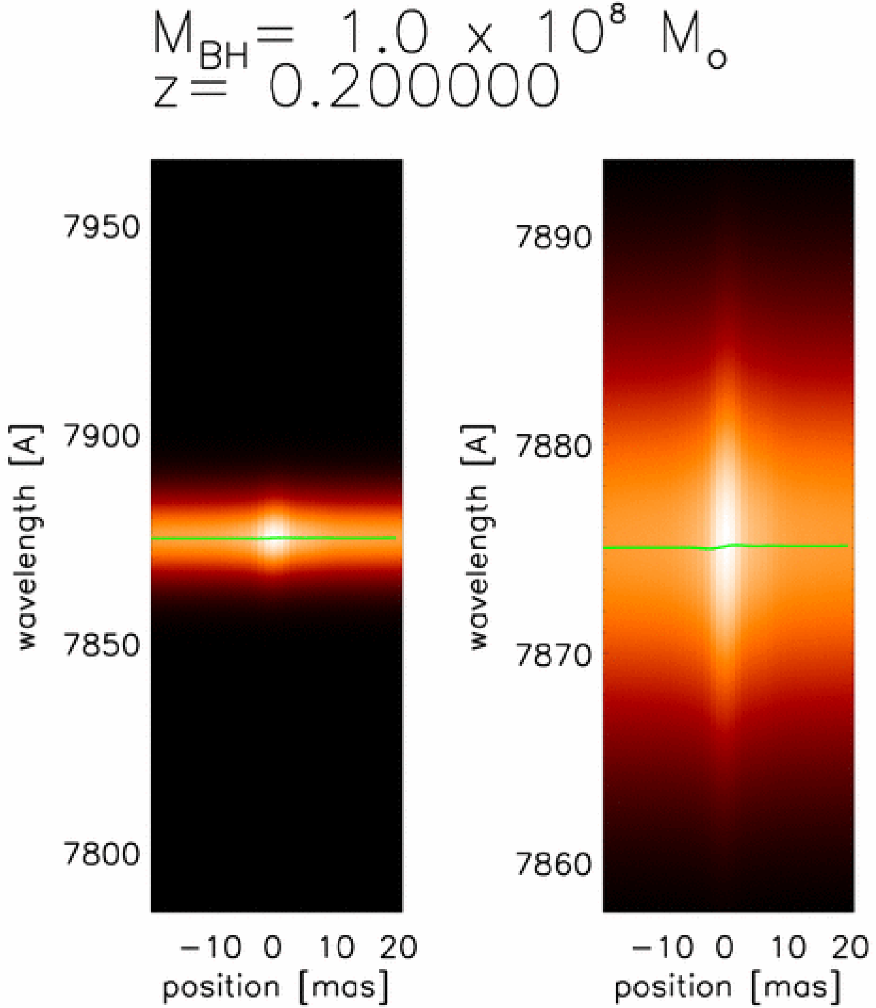




M_BH= 1.0 x 10^9 M_o
z= 0.200000
7950
7900
7850
7800
wavelength [A]
−10 0 10 20
position [mas]
7890
7880
7870
7860
wavelength [A]
−10 0 10 20
position [mas]

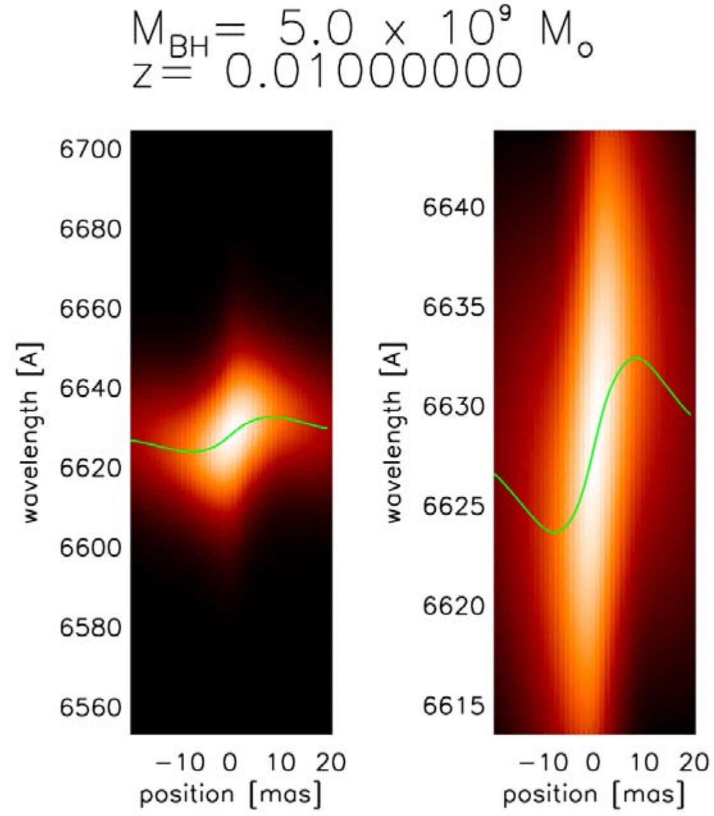


M_{BH} = 5.0 x 10^8 M_o
z = 0.200000
7950
7900
7850
7800
wavelength [A]
−10 0 10 20
position [mas]
7890
7880
7870
7860
wavelength [A]
−10 0 10 20
position [mas]

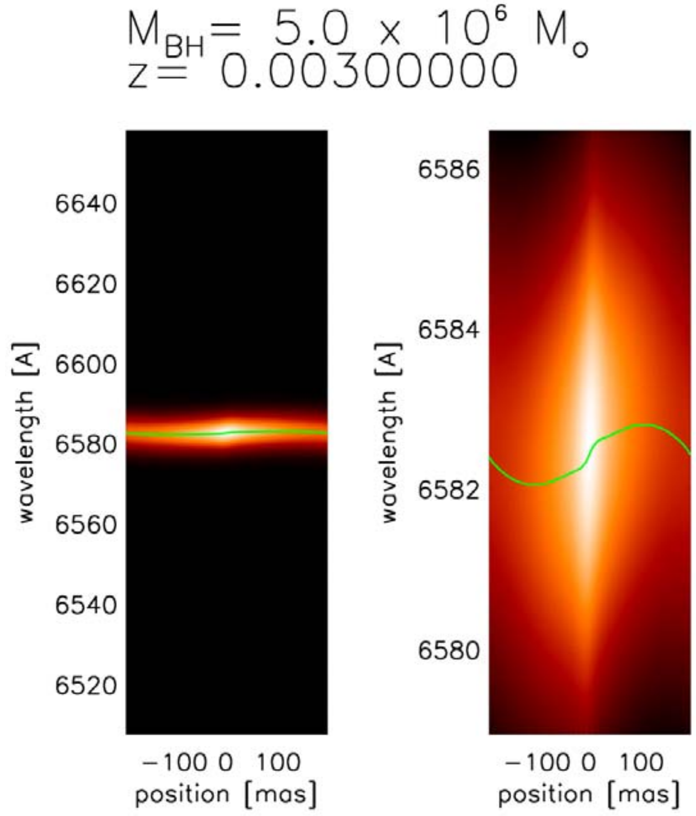


M_{BH}= 1.0 x 10^8 M_o
z= 0.200000
7950
7900
7850
7800
wavelength [A]
−10 0 10 20
position [mas]
7890
7880
7870
7860
wavelength [A]
−10 0 10 20
position [mas]

Simulation 2: Redshift



Simulation 3: $M=5\cdot10^6$ at Virgo



More Realistic Simulations

- different PSFs
- realistic spectrum
- add noise
- scale host galaxy properties with M_{BH}
- recover density/velocity field

Requirements

- spectral resolution ~ 5000-10000
- angular resolution <5 mas

  optical spectrograph with fully sampled PSF
- integration times based on ETC, S/N=30 per 5 mas pixel:
  - ~10 minutes for low-mass BH at Virgo
  - 5 to 10 hours for supermassive BHs at z~0.2