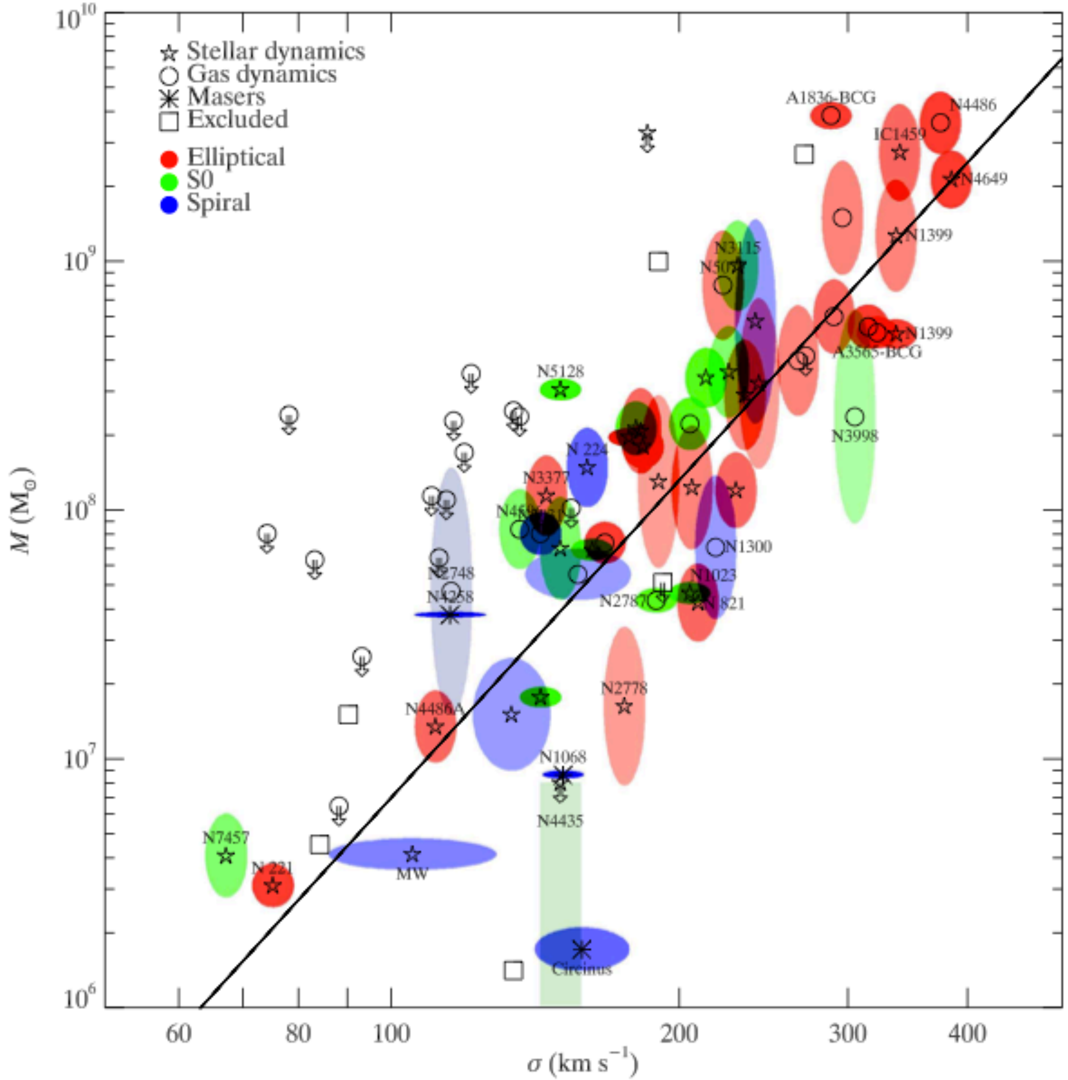
DUNLAP INSTITUTE
for ASTRONOMY & ASTROPHYSICS

PROSPECTS FOR MEASURING SUPERMASSIVE BLACK HOLE MASSES WITH IRIS/TMT

Tuan Do
Dunlap Fellow

From Do T., Wright S. A., Barth A. J., Barton E. J., Simard L., Larkin J. E., Moore A. M., Wang L., Ellerbroek B., 2014, AJ, 143

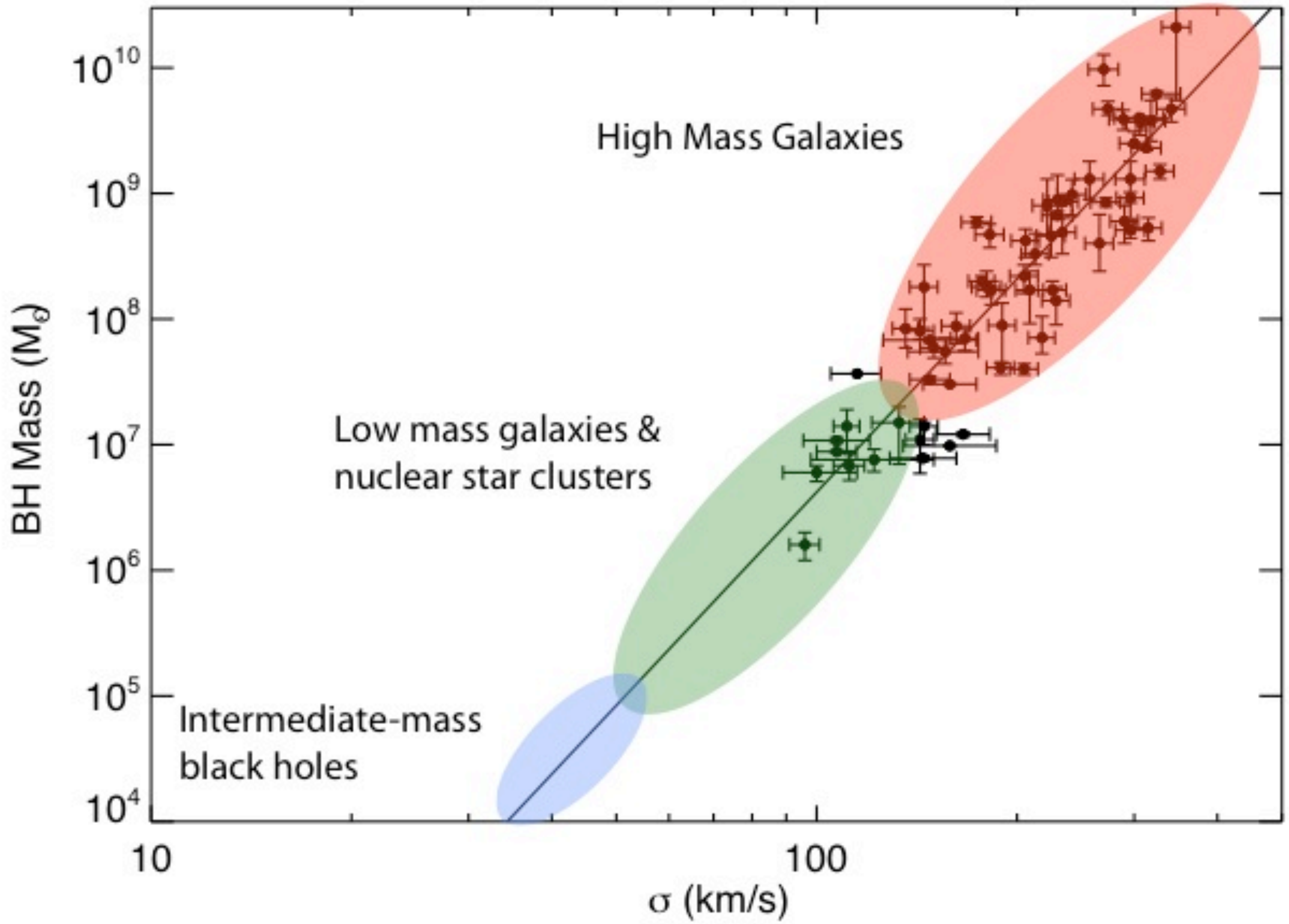
Current measurements of black hole masses are predominantly in the range of 10^7-10^8 $M_\odot$



M_{BH}-σ and M_{BH}-L relationships shows the evolution of the central black hole and galaxies as a whole are connected.

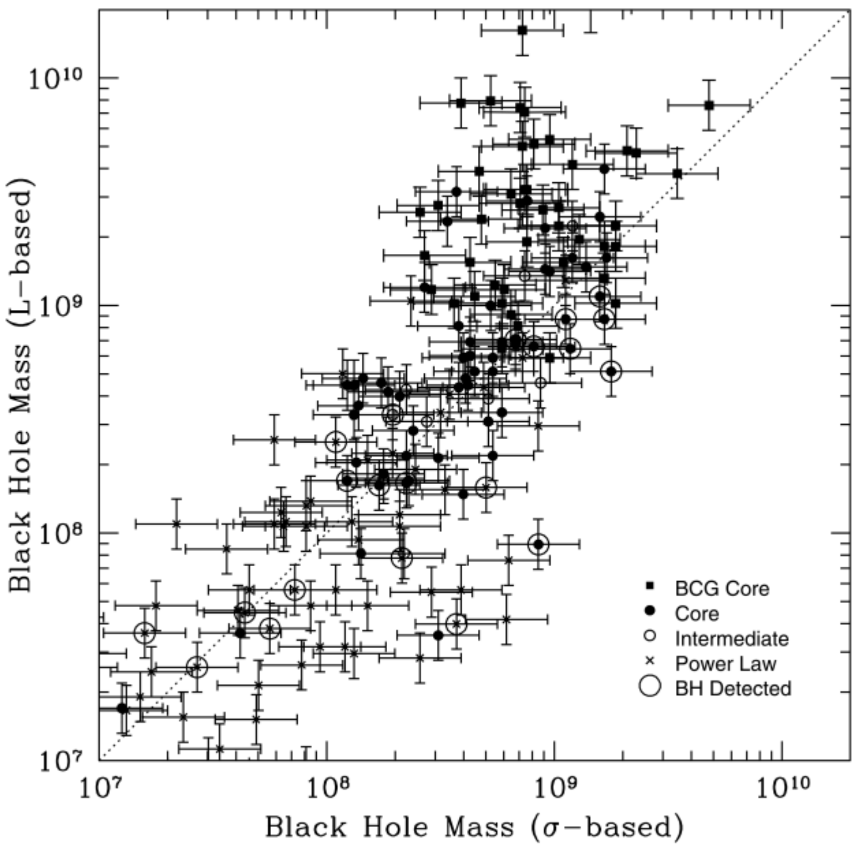
From Gulteken et al. 2009

Large parts of the parameter space in galaxy scaling relationships are unexplored

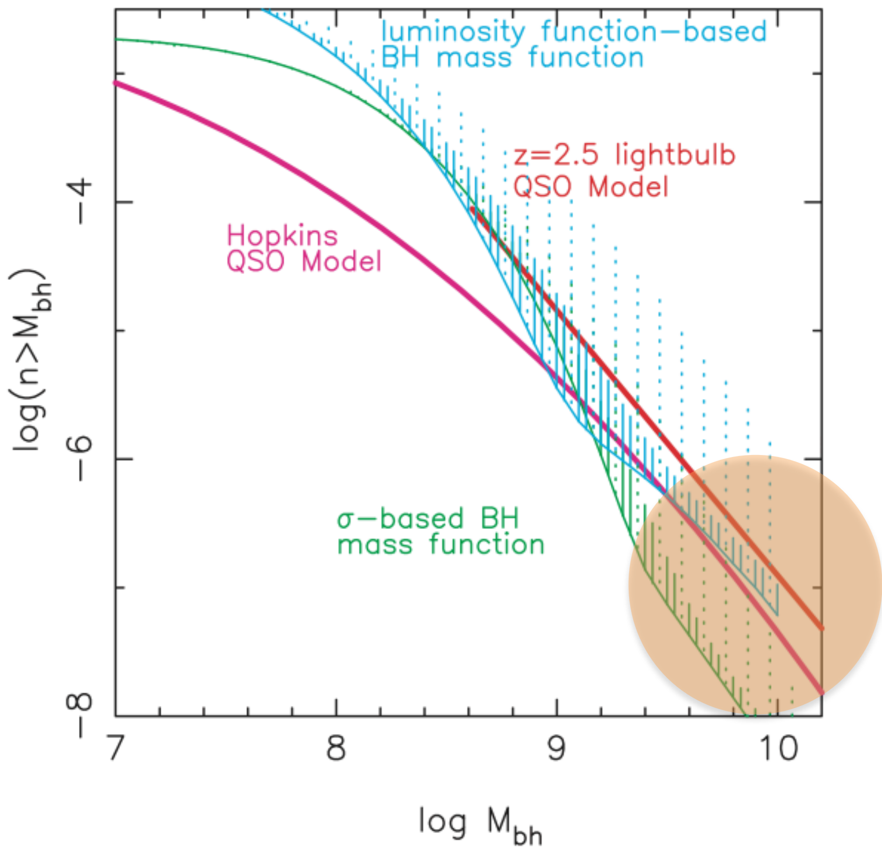


Current compilation black hole masses measured dynamically from McConnell and Ma (2013)

There is a disagreement in the black hole mass scaling relationships at high masses



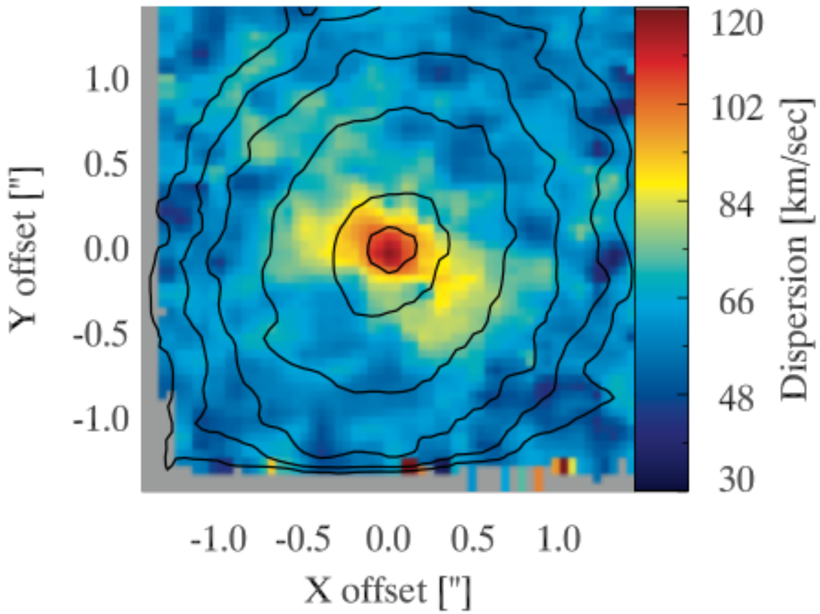
M-sigma relationship predict different black hole masses than M-L



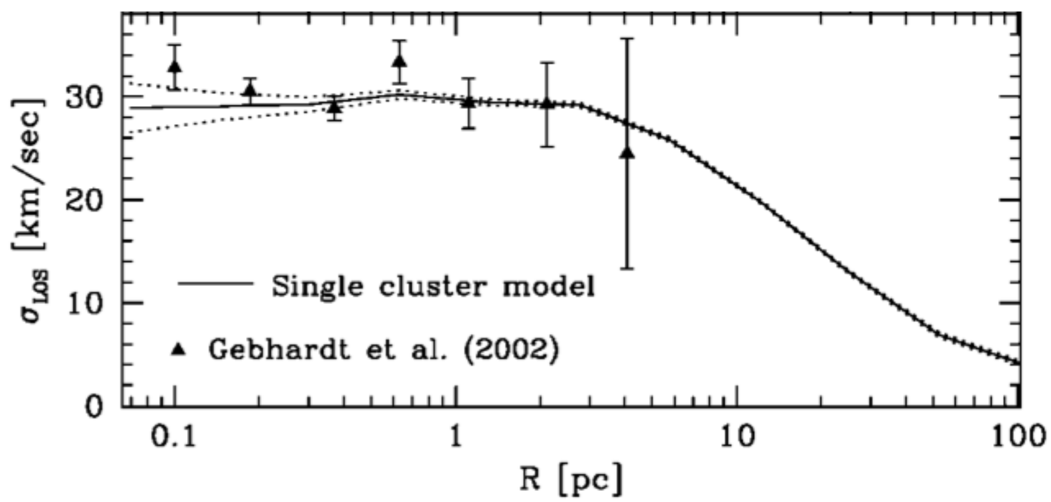
The two relationships predict very different space densities for the highest mass black holes

From Lauer et al. 2007

There are currently very few confirmed black hole masses < 10^6 $M_\odot$



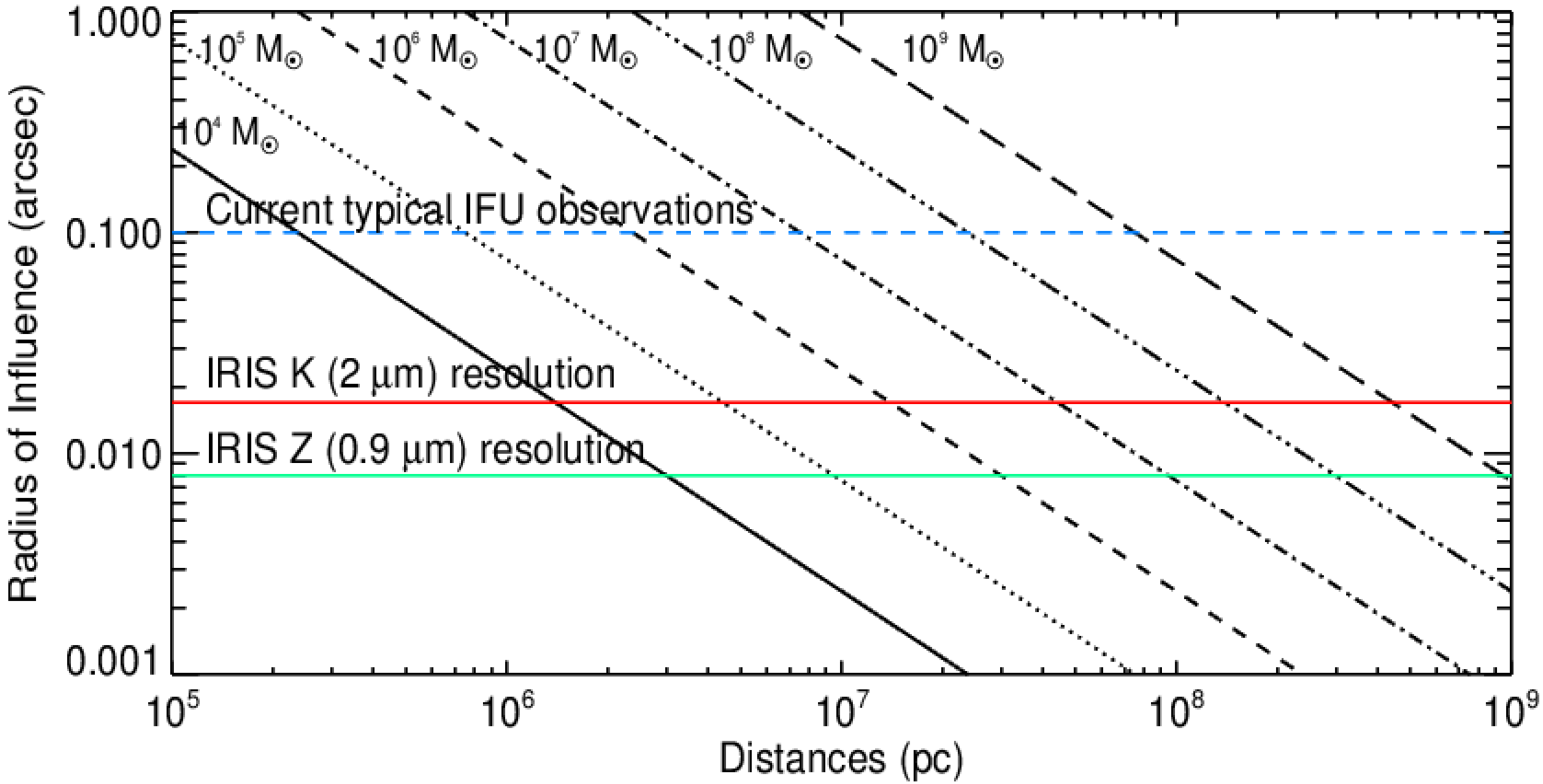
Current best measurement of the kinematics of the nucleus of M32 with a 2×10^6 $M_\odot$ BH (Seth 2010)



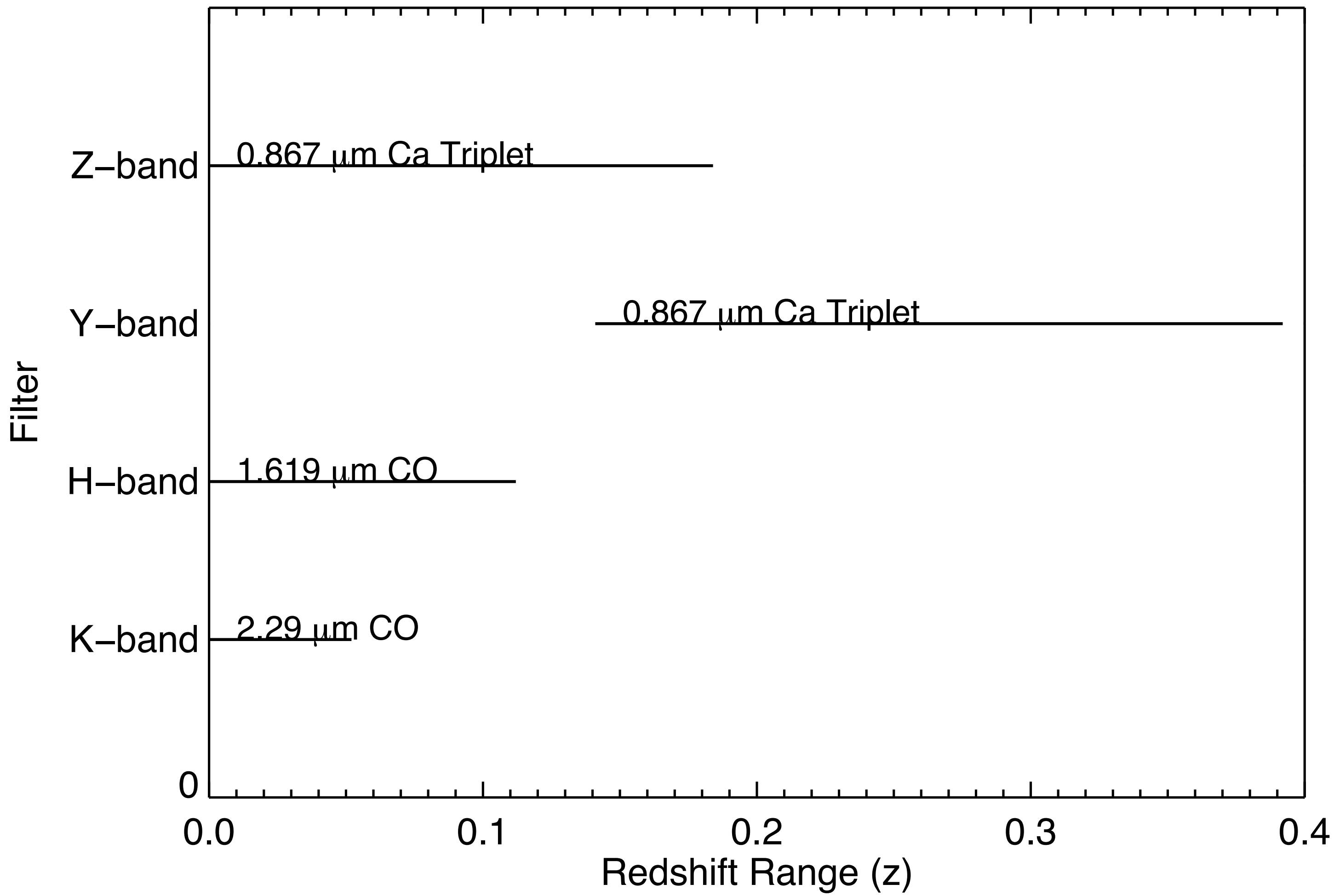
Stellar velocity dispersion measurements for the globular cluster G1 may indicate a $10^4 M_\odot$ BH, but may be consistent with only a stellar cluster. (Gebhardt et al 2002, Baumgardt et al. 2003)

What will TMT do?

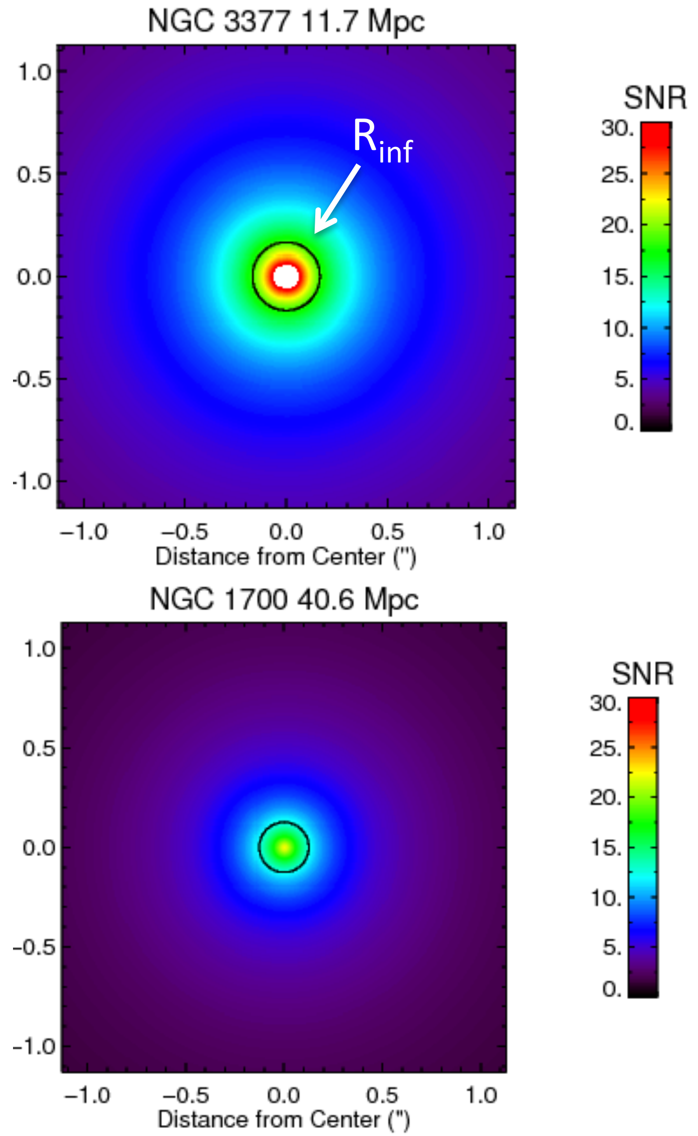
TMT will certainly have the angular resolution



The range of filters are important to sample galaxies at multiple redshifts



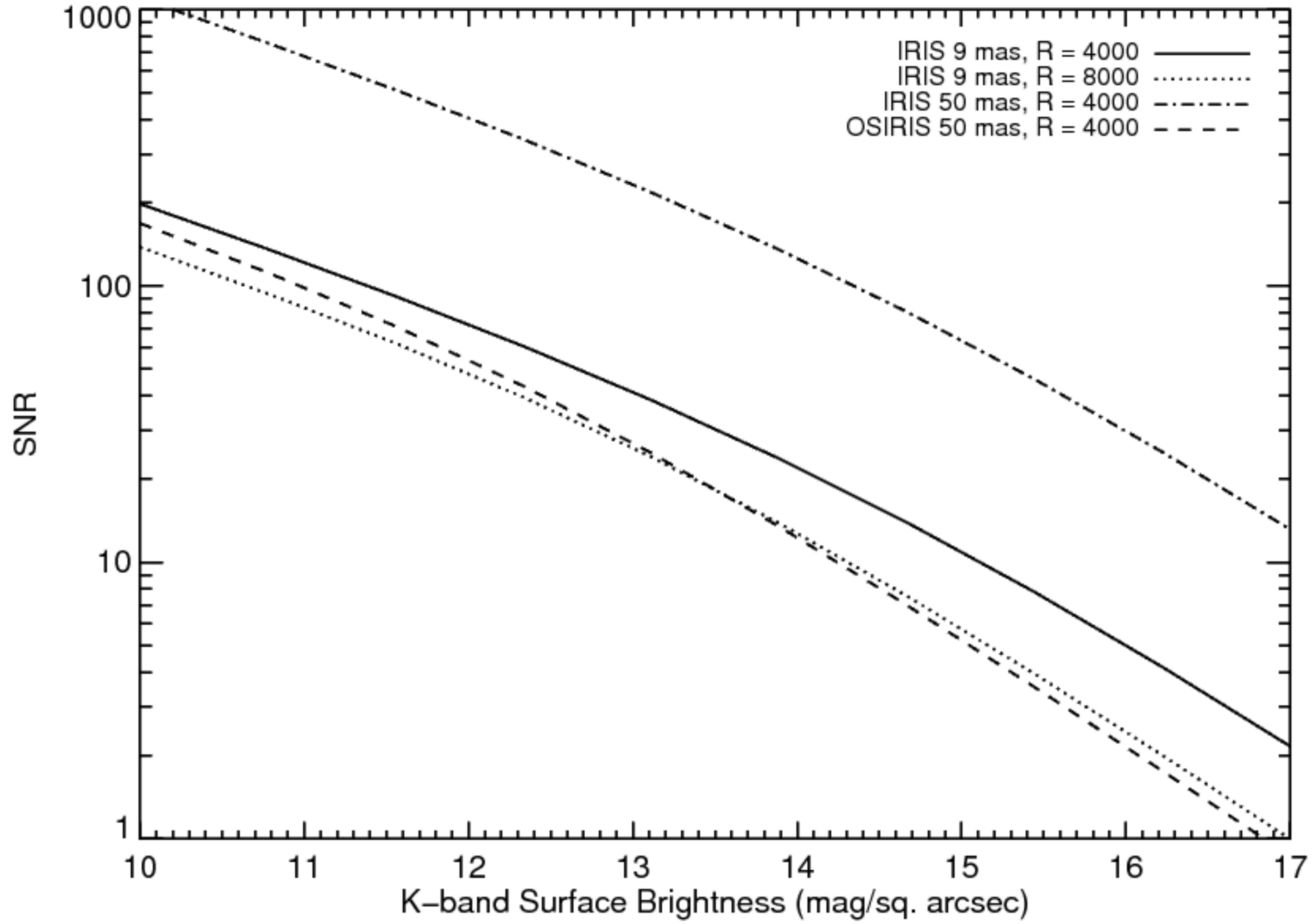
Simulating galactic nuclei



- AO K-band PSFs from NFIRAOS – Strehl ratio ~72% at zenith, at 2 µm
- Detector: 0.002 e-/s dark current, 2 e- read noise.
- K-band sky background: 13.9 mag/ sq. arcsec
- Surface brightness profiles extrapolated from current high angular resolution observations (HST & AO)
- Gravitational radius of influence estimated by using BH mass prediction from M-L relationship

Mean K-band SNR for 9 mas plate scale, R = 8000, 2.5 hr. int. time

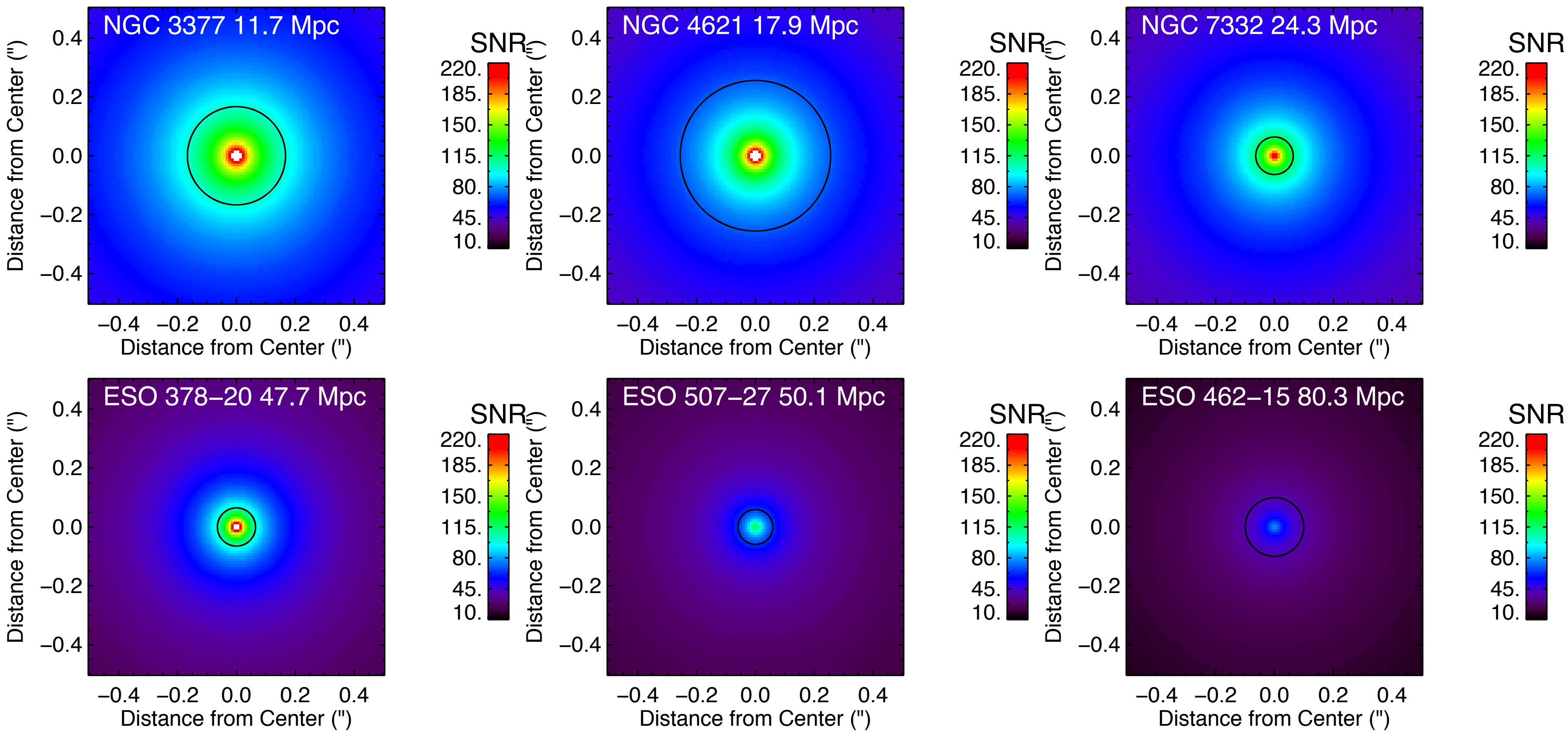
Spectrograph: extended source sensitivity



Ave. SNR over K-band for 5 hours of integration time (20x900 s exposures)

(From Do et al. 2014)

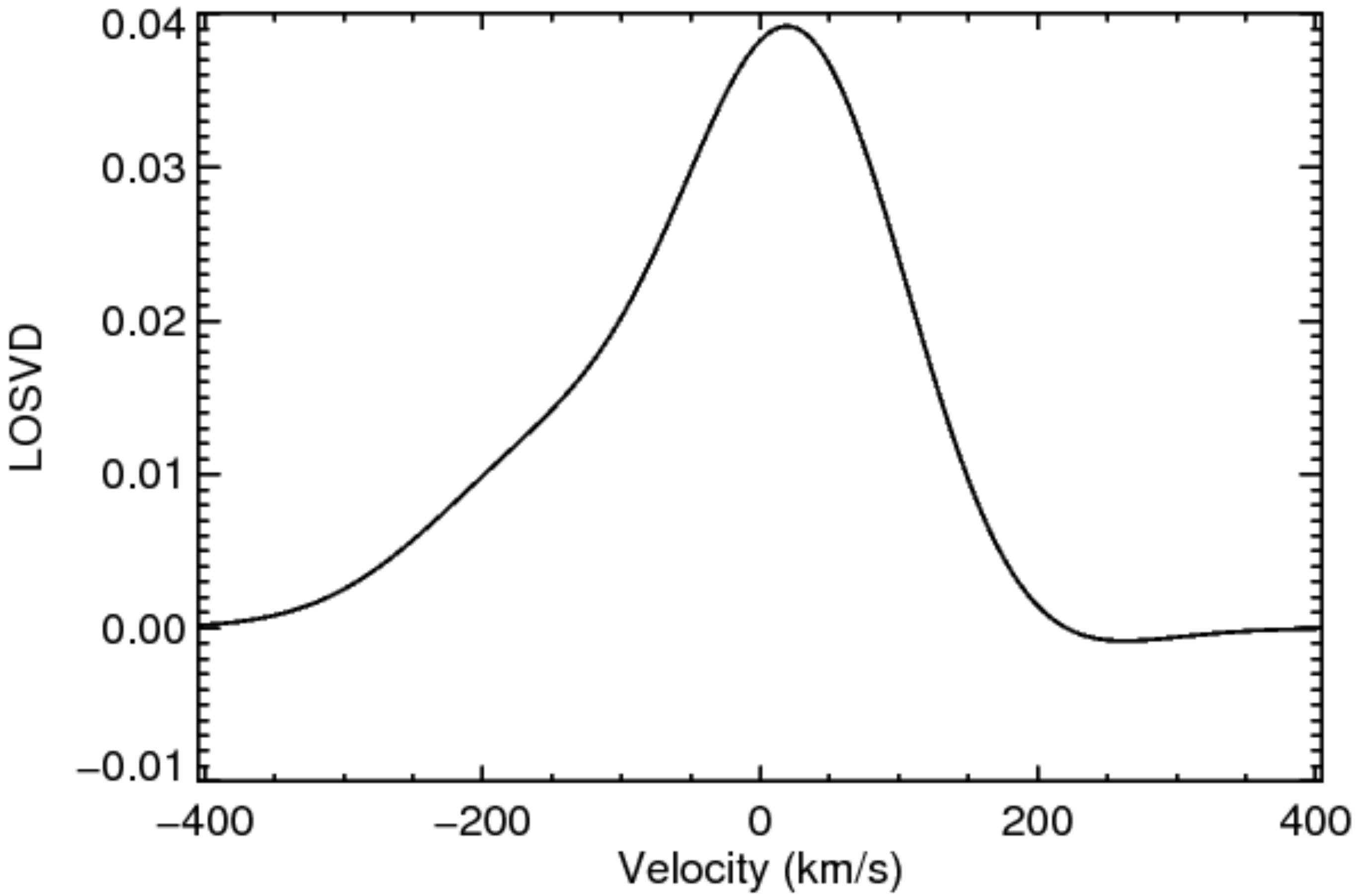
Examples of IRIS simulations



Simulated average S/N per spectral channel at 9 mas plate in *K* band with eight observations of 900 s each (2 hr integration time) at *R* = 4000.

Stellar dynamical measurement of black hole masses rely on measuring the line-of-sight velocity distribution

V = 0 km/s, σ=200 km/s,
h_3=- 0.144, h_4=0.029



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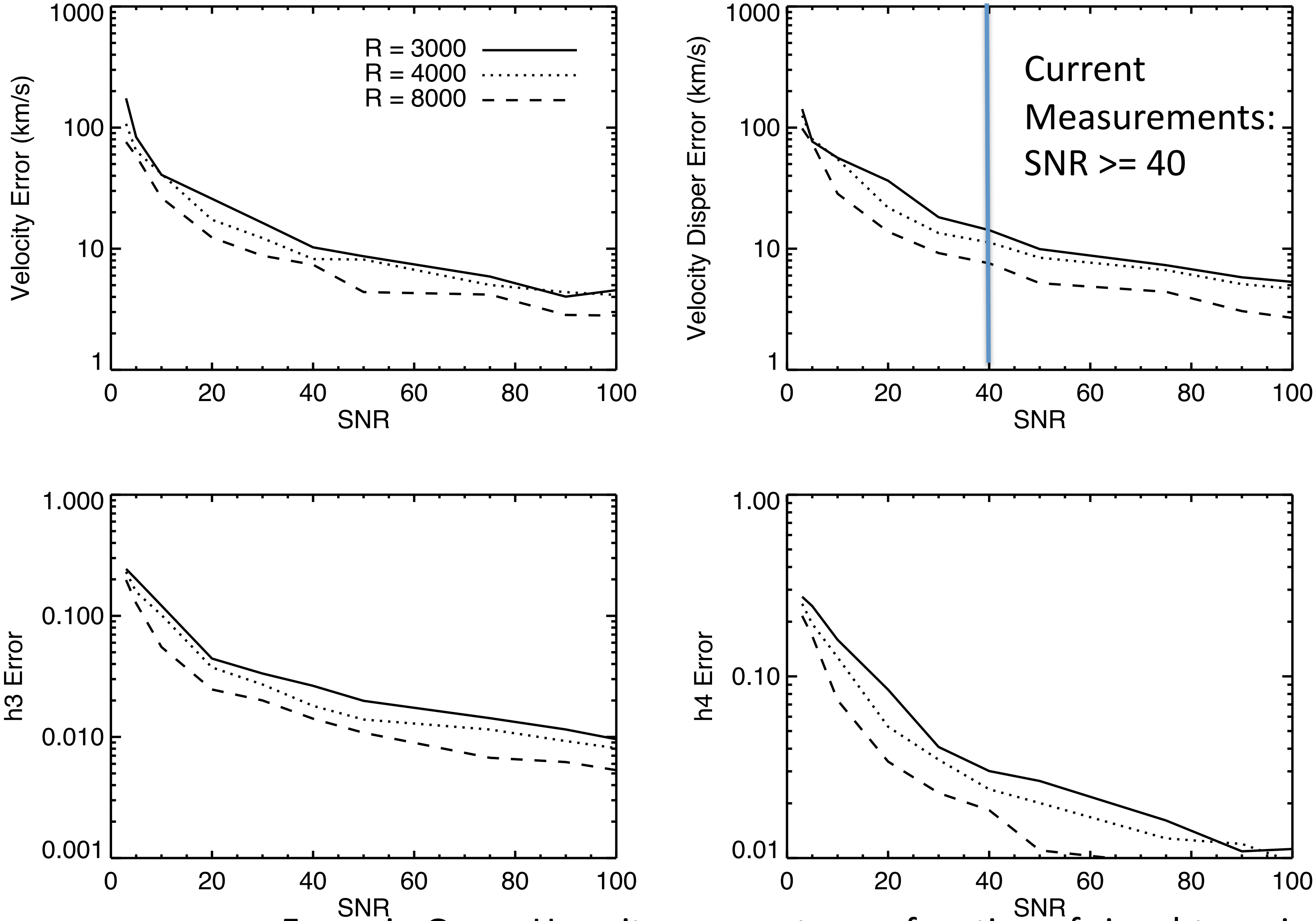
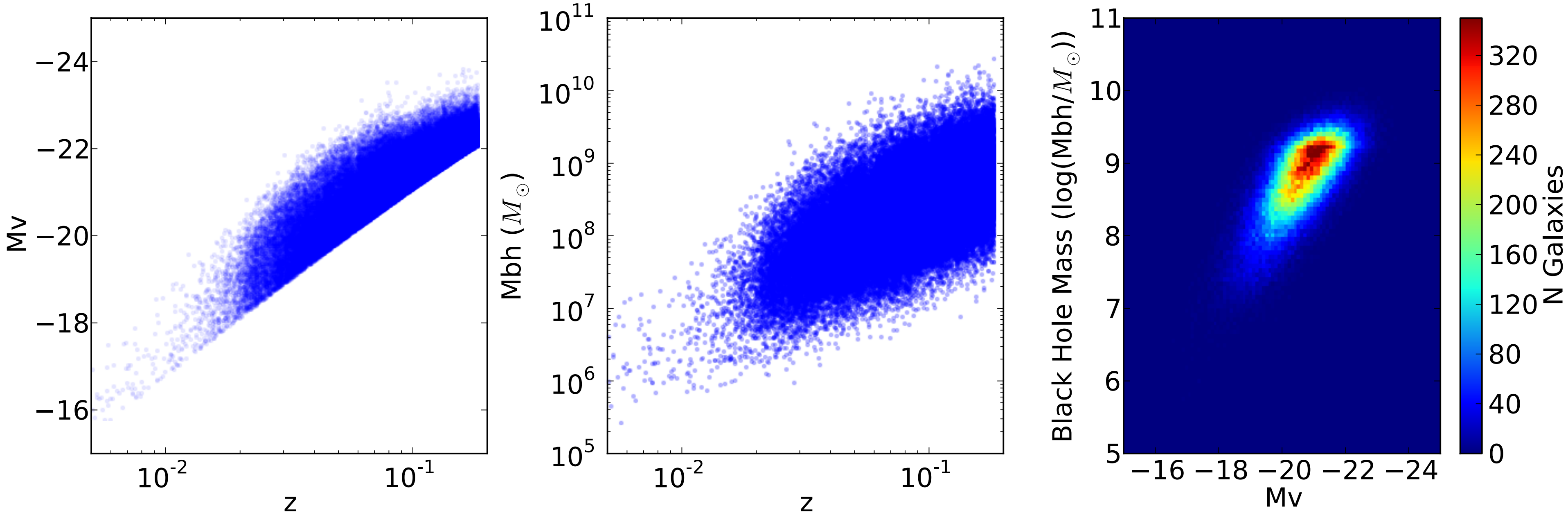


Errors in Gauss-Hermite moments as a function of signal-to-noise ratio

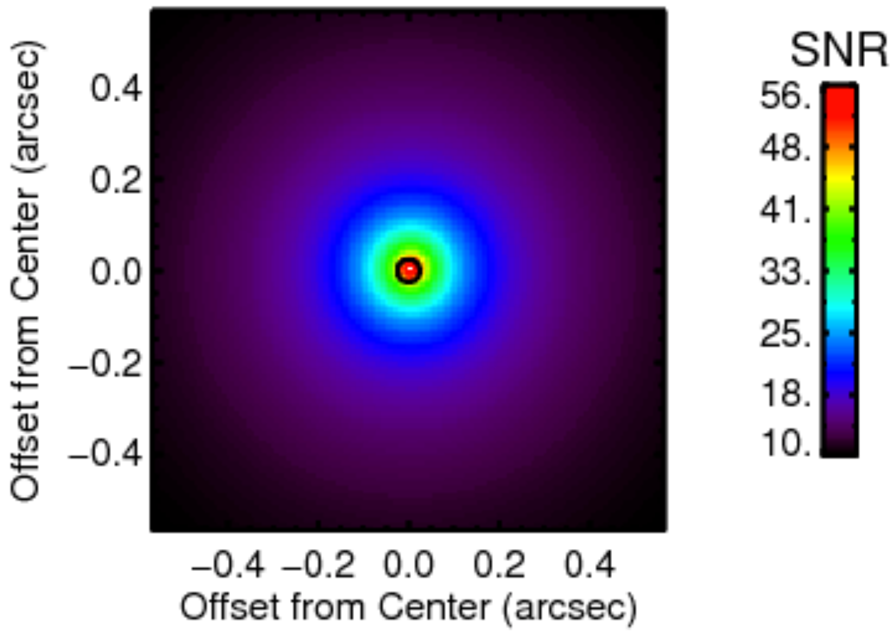
The number of dynamical mass measurements of 10^7-10^9 will increase dramatically



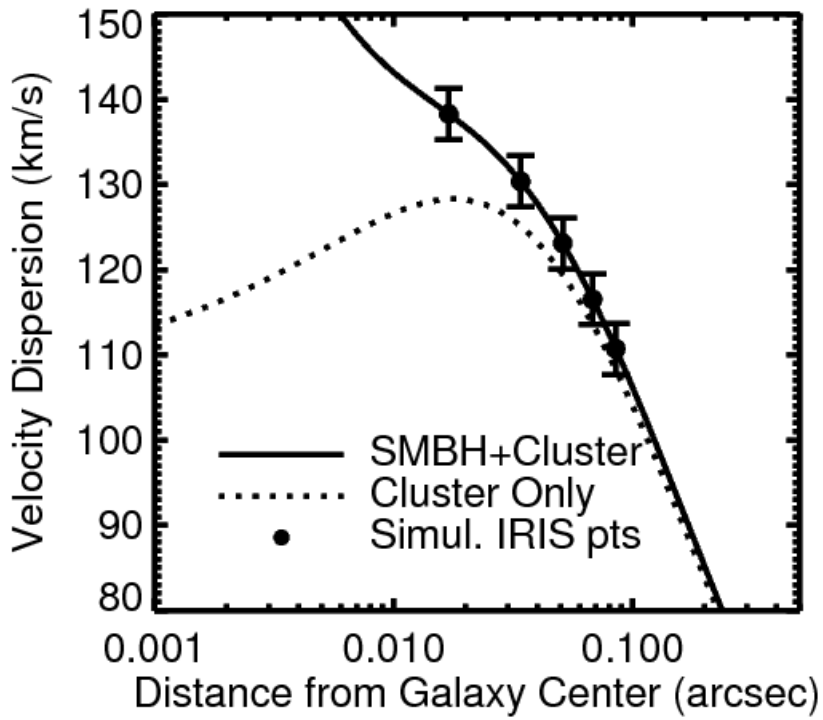
Simulations of SDSS galaxies show that over 10^5 SMBHs will be measurable with IRIS out to z = 0.2

Do et al. (2014)

IRIS will be able to detect Milky Way mass black holes out to the Virgo Cluster



The Milky Way nuclear star cluster without foreground dust extinction, as seen at 16 Mpc (5 hours integration time at K-band).

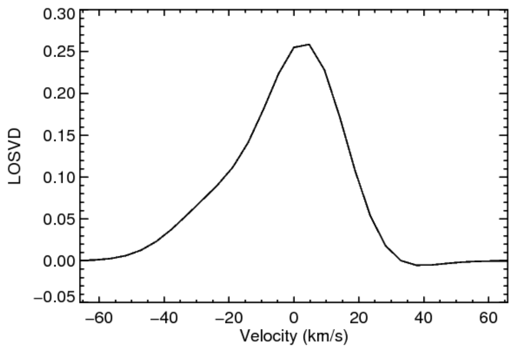


Velocity dispersion for the MW nuculear star cluster cluster with a $4x10^6$ $M_{\odot}$ black hole

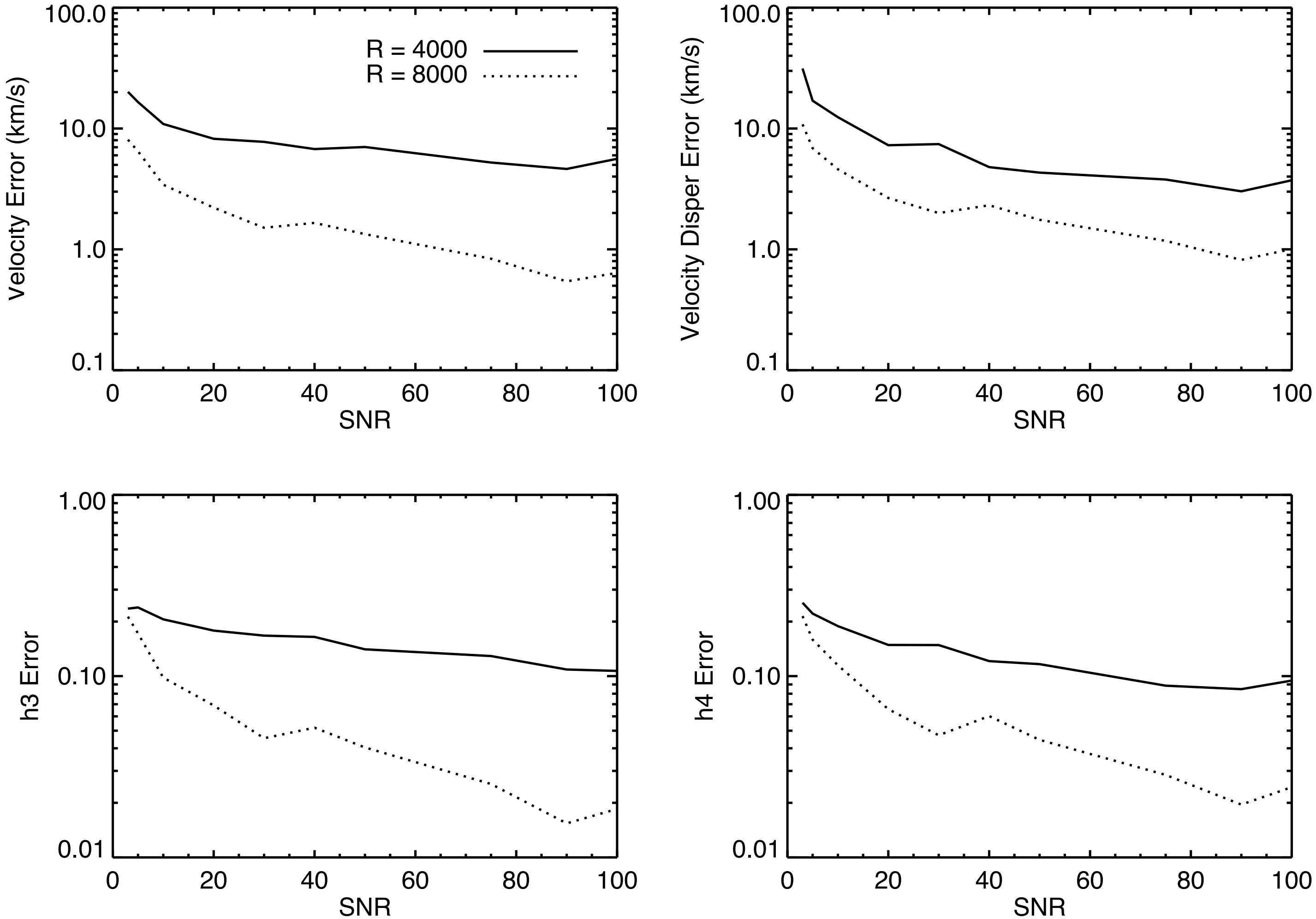
(From Do et al. in prep)

R=8000 spectral-resolution will allow observations of intermediate mass black holes

Line of sight velocity distribution

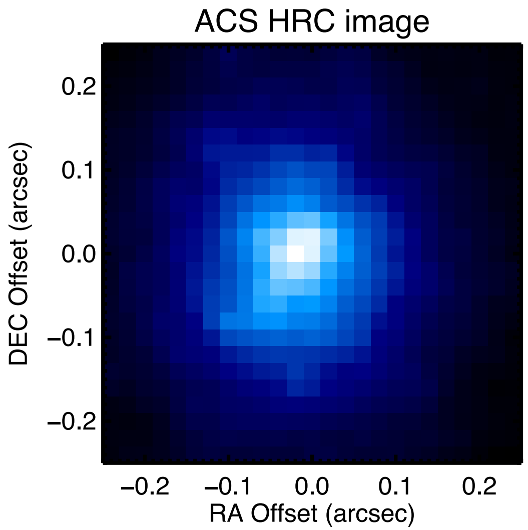


V = 0 km/s, σ=30 km/s,
h_3=- 0.144, h_4=0.029

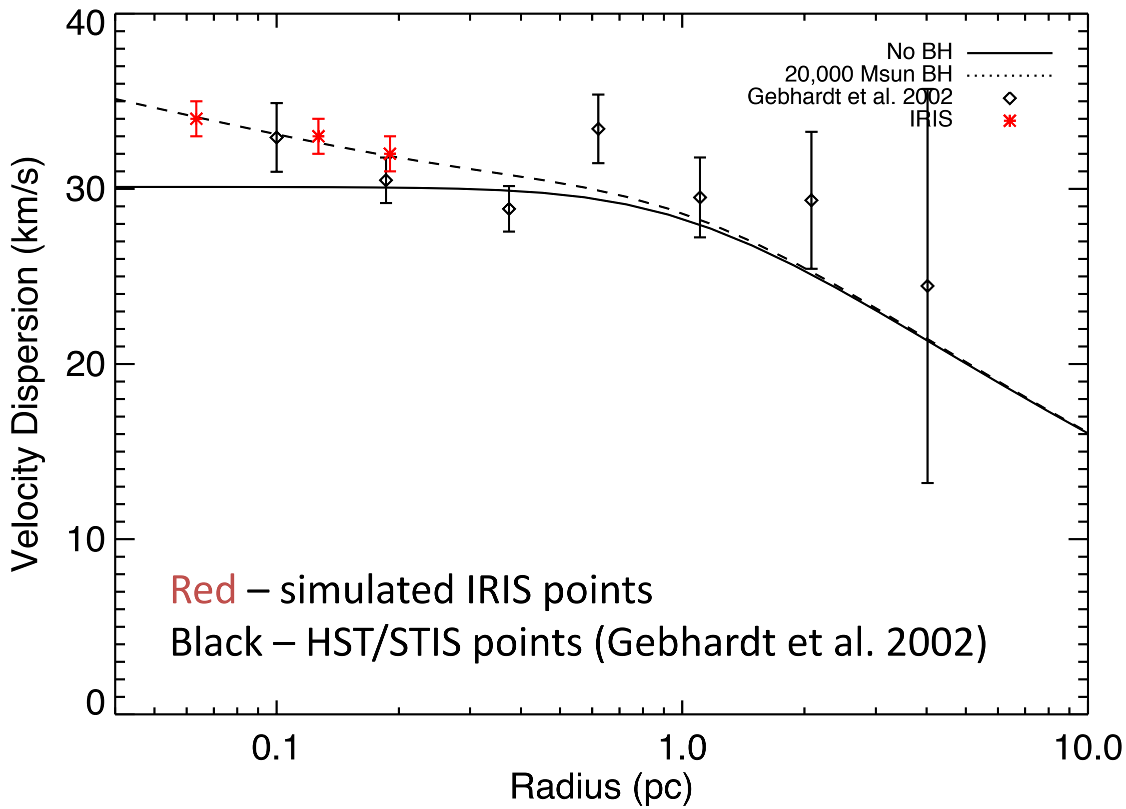


Observations at R = 4000 will be incapable of determining higher-order moments

R=8000 spectral-resolution will allow observations of intermediate mass black holes

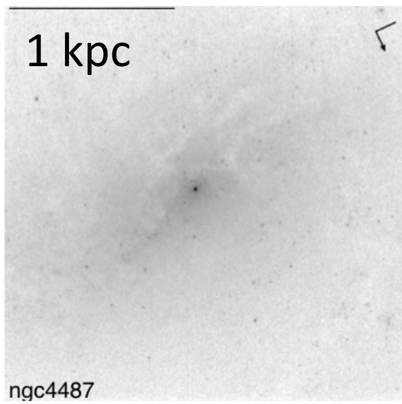


Requires both angular resolution and relatively high (R~8000) spectral resolution

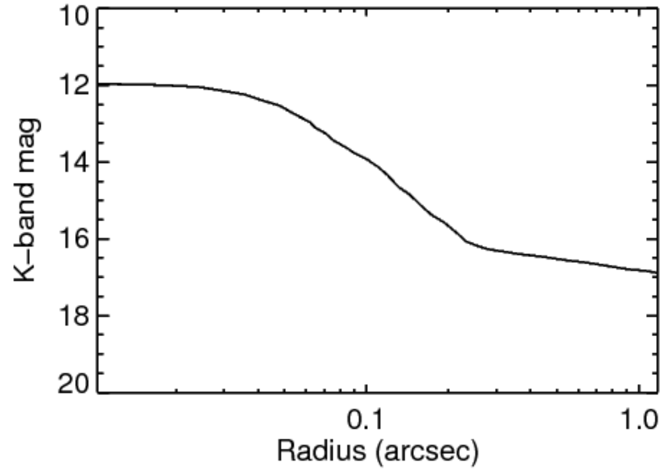


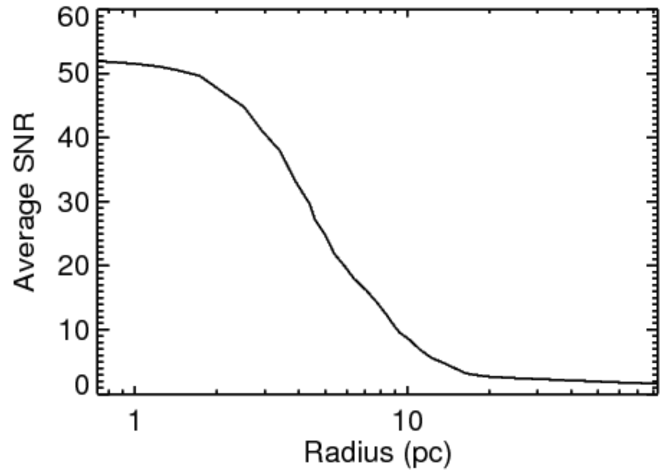
Comparison of the velocity dispersion profile of the globular cluster G1 in M31, with and without a 2×10^4 M_{sun} black hole

Black hole mass measurements in nuclear star clusters will also provide demography of lower mass black holes



WFPC2 F814W from Boker et al. 2002





Simulated sensitivity at R = 8000, with 5 hrs of integration time