Super***M***assive ***B***lack ***H***oles…

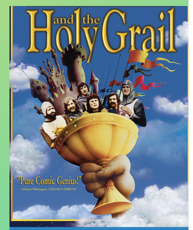
The Big Questions
TMT Should Answer

(according to the *SMBH* ISDT, and
some friendly visitors)

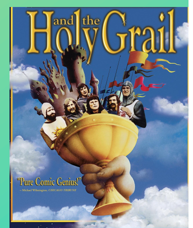
The Galactic Center black hole: our unique laboratory for up-close study of a SMBH

Holy Grails:

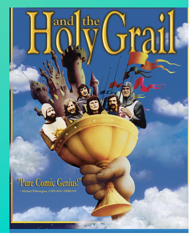
GR precession of periapse in individual stellar orbits;

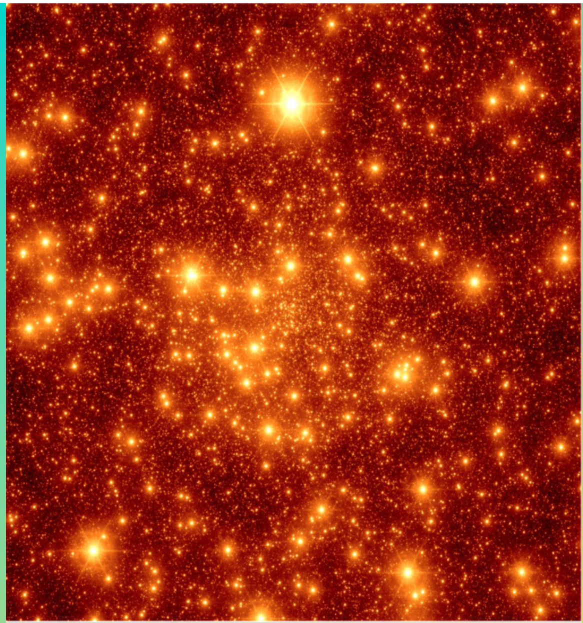


Gravitational Redshift at perigalacticon



Infer BH spin vector from difference of prograde/retrograde orbits





Measuring stars is entirely Confusion-Limited

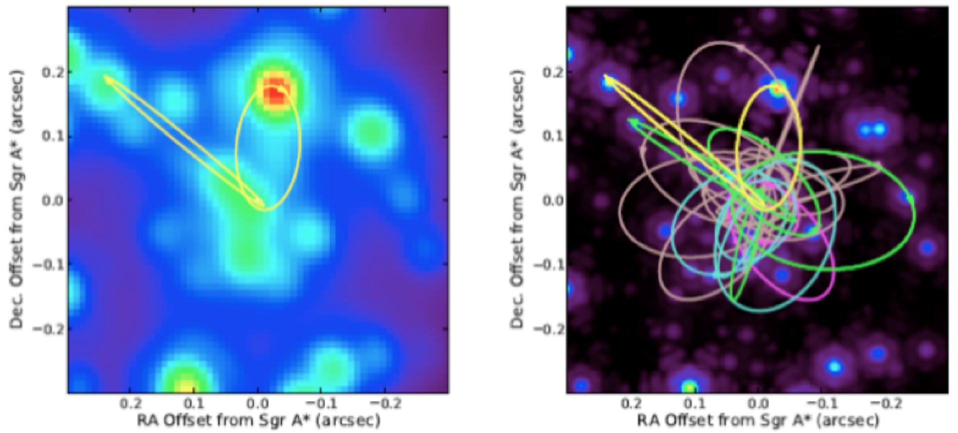


Figure 1, top: Simulated TMT/IRIS near infrared image (t_{int} = 20 s) of the central 17″ × 17″ of the Galaxy, centered on the supermassive black hole, Sgr A*. The image contains ~2×10^5 stars down to K = 24 mag, which includes ~2500 known stars and a theorized population based on the observed GC radial profile and the K-band luminosity function of the Galactic bulge. The image include photon, background, and read noise. *Bottom:* Implications for short-period star orbits (note that a different scale and a different point in time has been chosen, meaning the stars are at different positions). Overlaid are all known orbits and examples of expected orbits with periods less than 23 years that are detectable both astrometrically and spectroscopically (14<K<16, yellow; K<17, green; K<18, cyan; K<19, magenta; K<20, tan). TMT/IRIS will not only increase the number of measurable short period orbits by an order of magnitude, but should also find systems that orbit the SMBH much deeper in the central potential, with orbital periods that are a factor of 5 smaller. These systems are particularly helpful for measurements of post-Newtonian effects (GR and extended mass distribution).

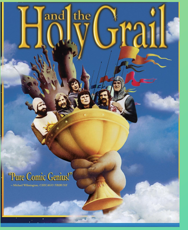
Simulated observations of faint stars near SgrA*:

100 times more (and fainter) stars, including ~a dozen with P~3 years

1.2. Proper Motions around SMBHs in the Nearest Galaxies

M31 Black Hole is ~75 times more distant, but ~40 times more massive.

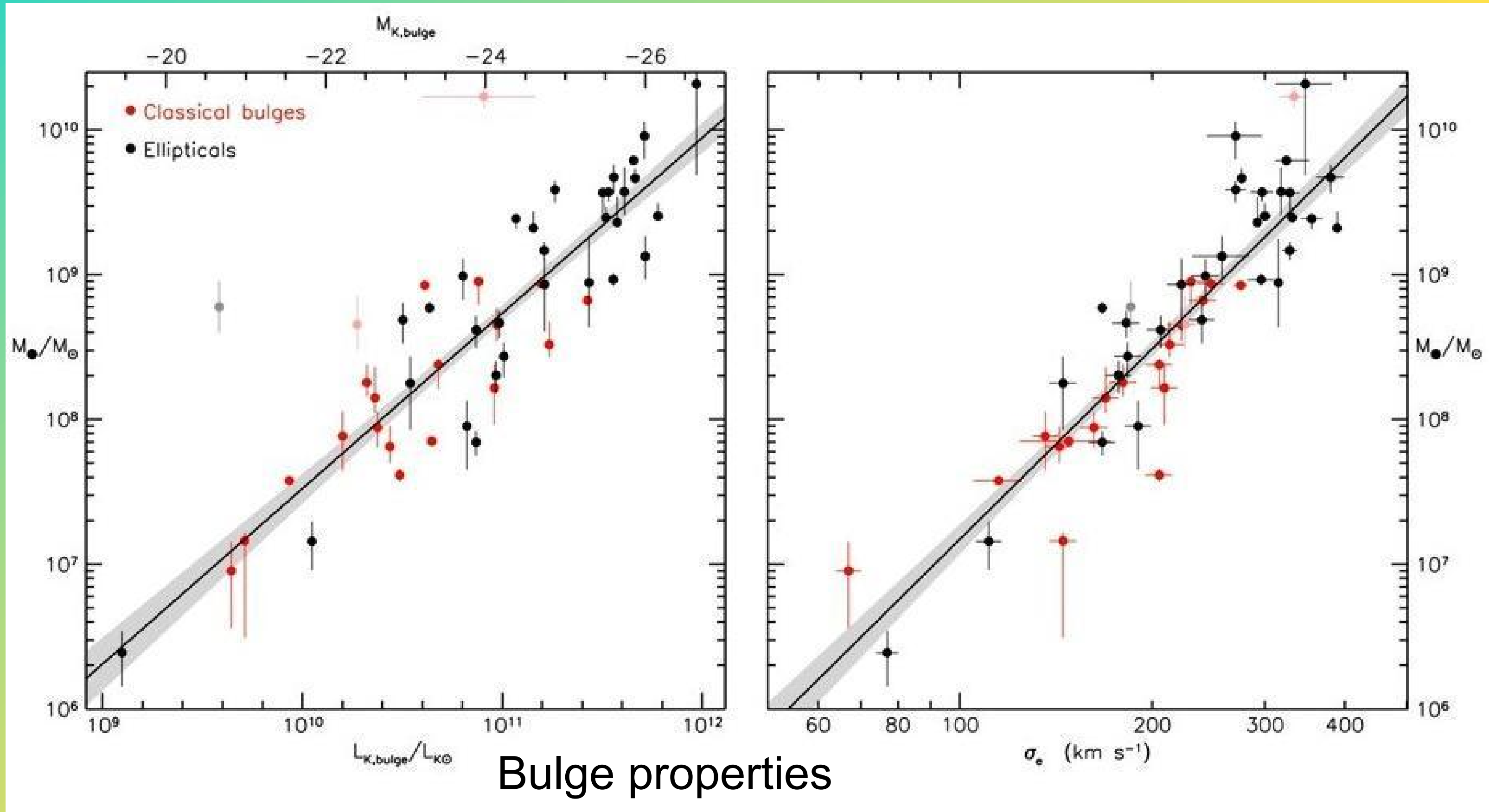
So stellar orbits within its “Sphere of Influence” can be studied, if high resolution can overcome the confusion



--> Second-ever orbital determination of mass of an SMBH

2. Dynamical detections of SMBHs; Demographics

Mbh
Measured
from
Kinematics
of
Stars
or gas



Bulge properties

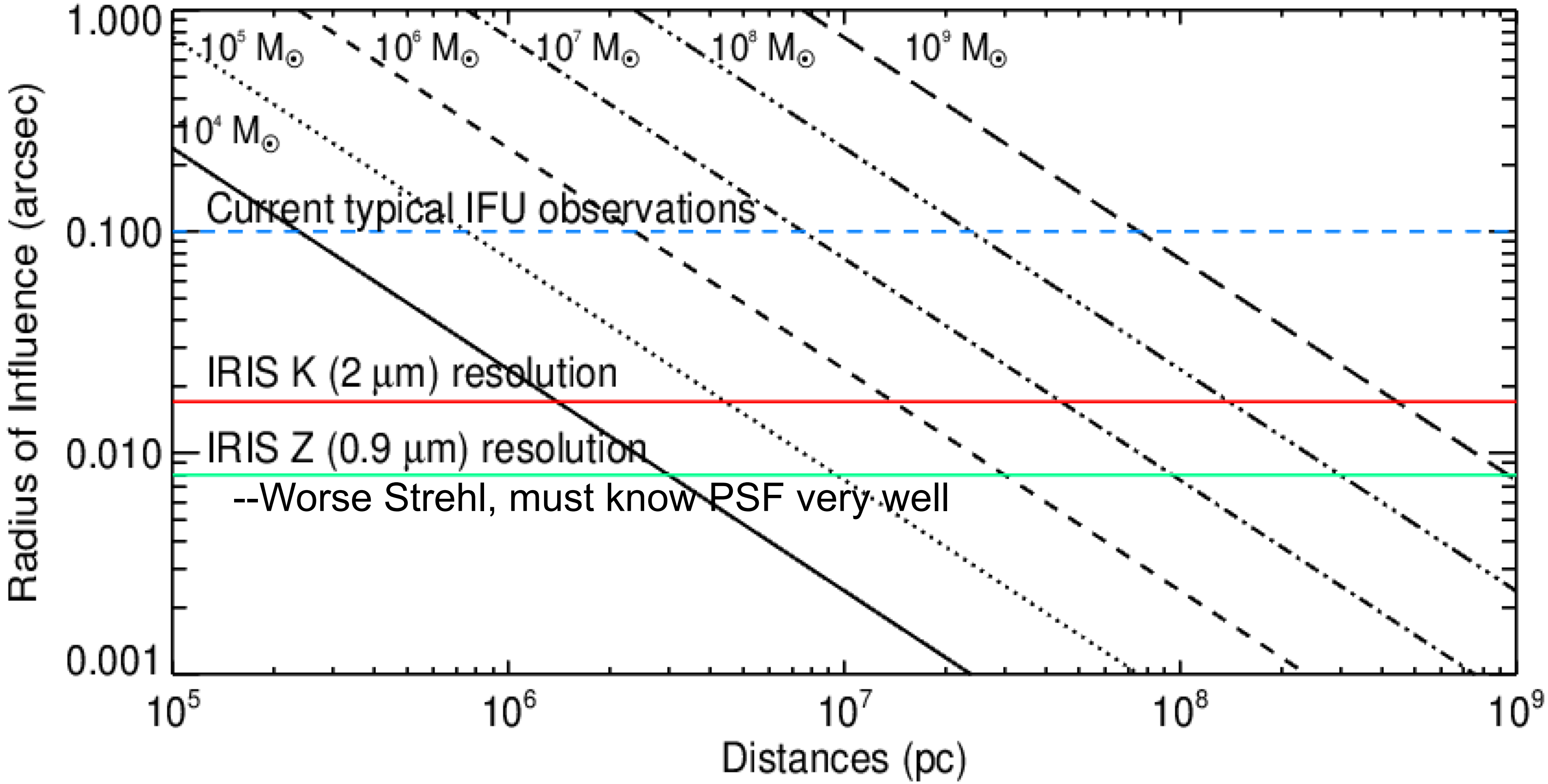
The MBH/Bulge Correlation

(virtually all >>10^7 Suns) will become a

Gateway Relation

Understand its functional form, dependence on other properties,

Distribution over all types of galaxies, “Naked Black Holes”?



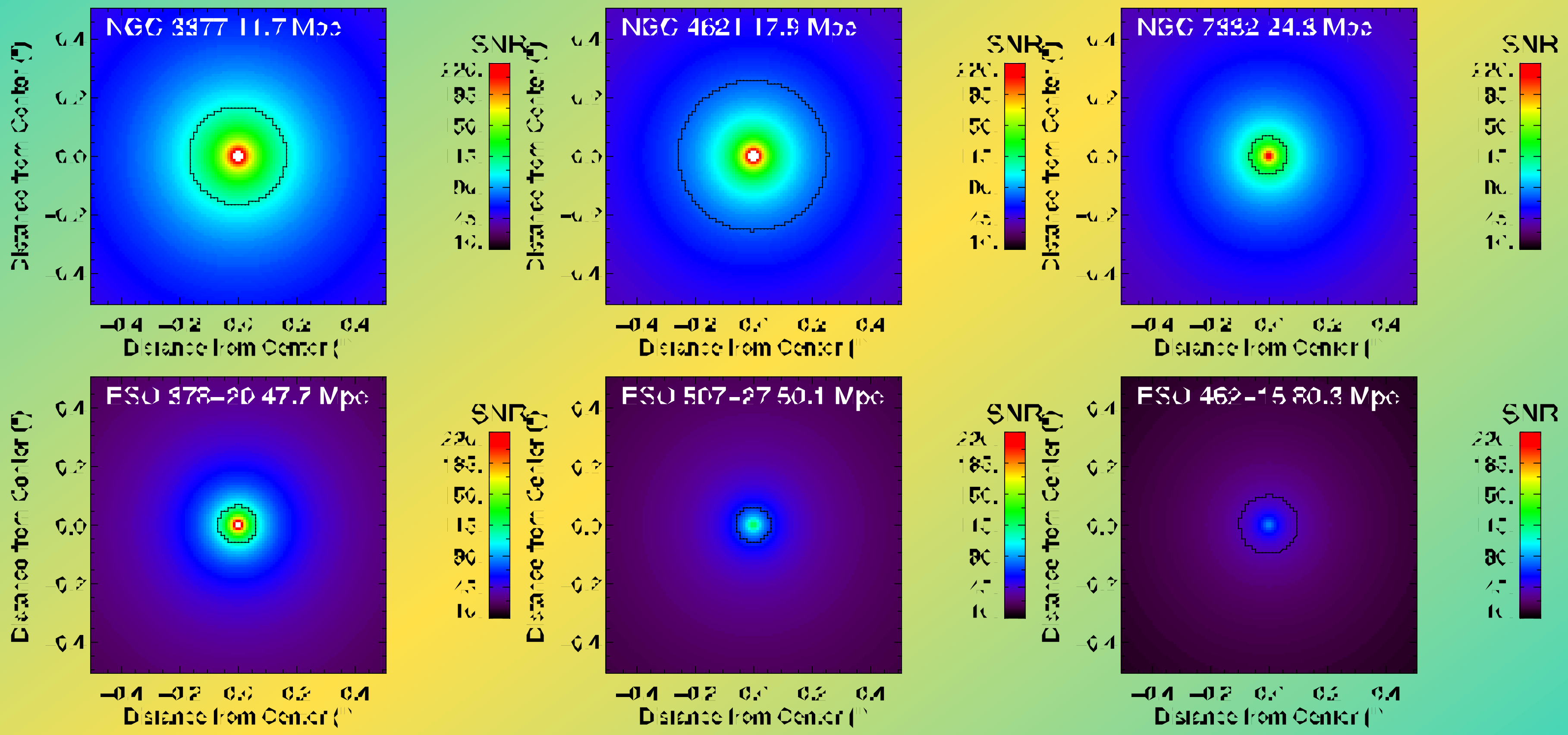
MBH "Sphere of Influence" Resolved by IRIS:

--For typical MBH out to large distances (including >10^5 Sloan galaxies)

--For big MBH out to 'any' distance

--For the nearest IMBHs

IRIS simulations (T.Do, publd)



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.

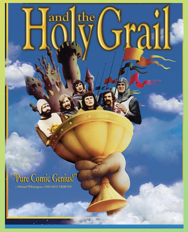
SNR~40/pixel is widely accepted as good enough, to measure LOSVD, h3, h4 and sharp rotation velocity gradient…Huge Leap in Capability

2.2. The most massive black holes

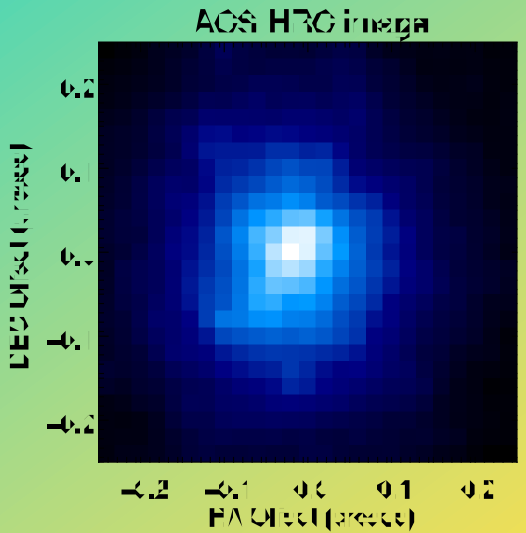
in brightest cluster galaxies…at any redshift

2.3 Intermediate-mass black holes:

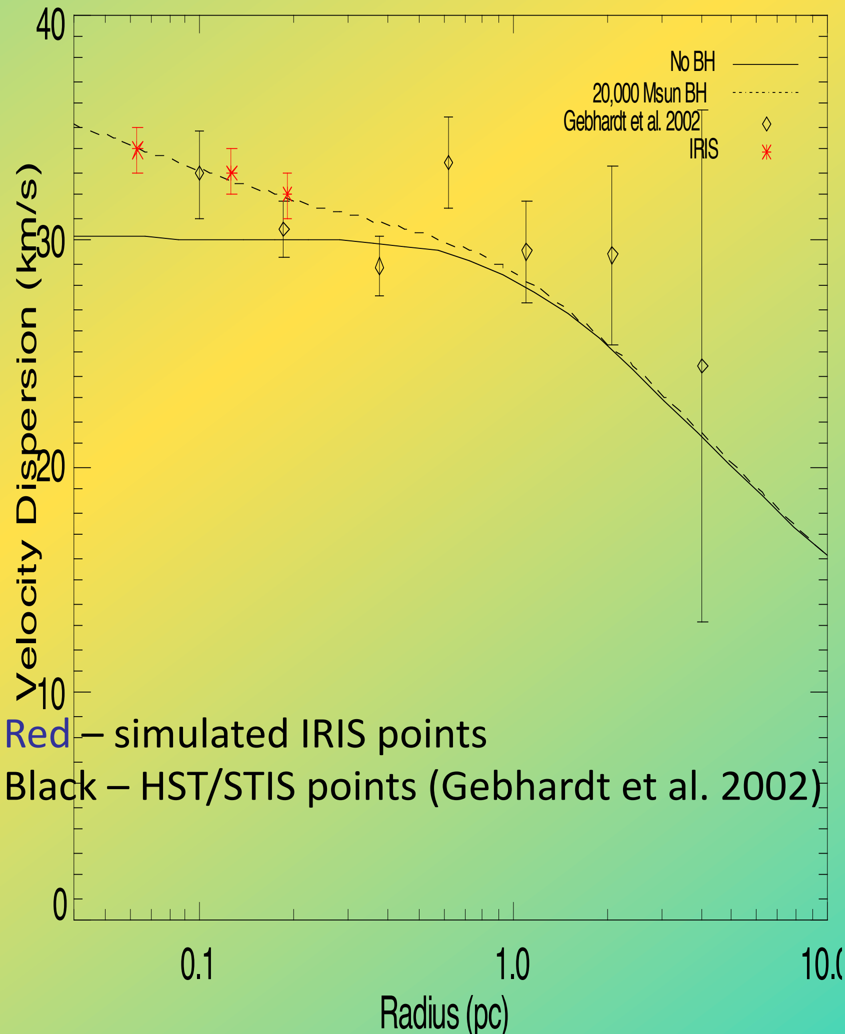
Do they exist? (BH formation)



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



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



Red – simulated IRIS points

Black – HST/STIS points (Gebhardt et al. 2002)

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

2.4. Calibration of the black hole mass scale in active galactic nuclei

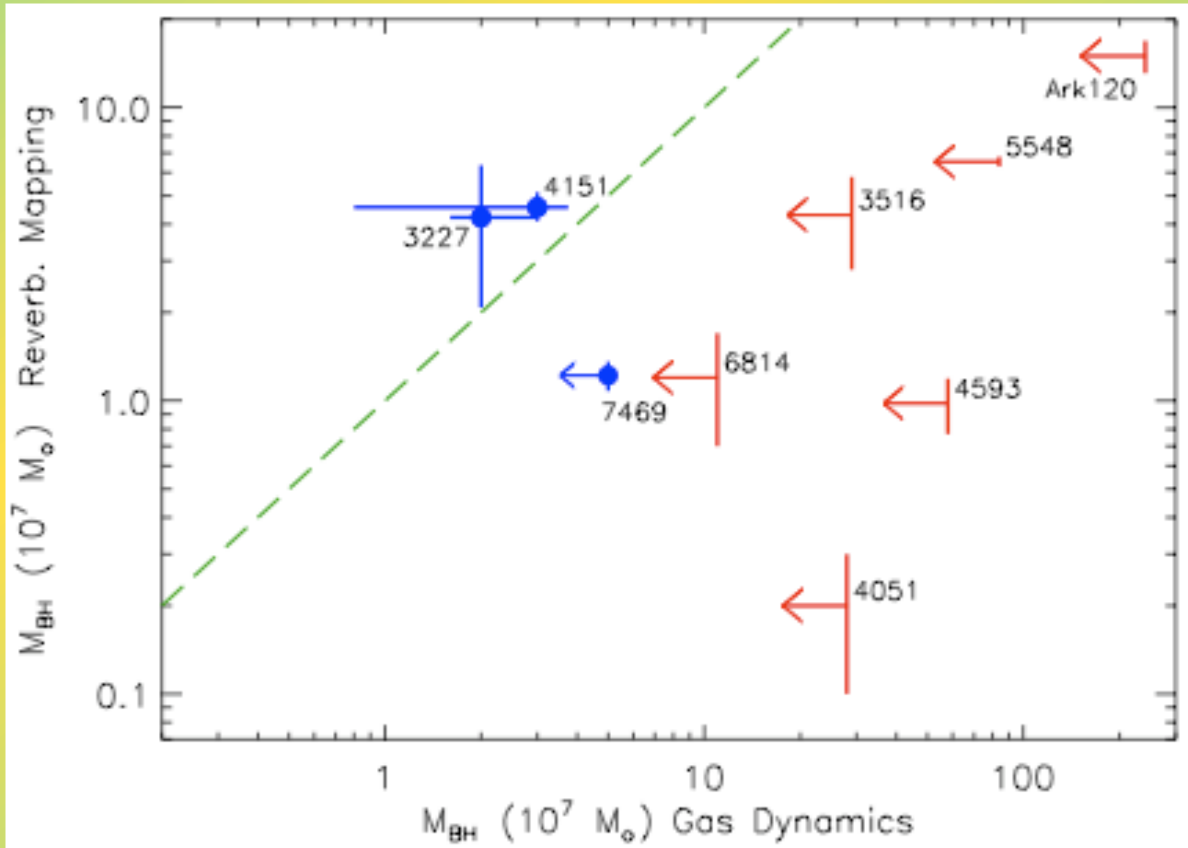
(with Reverberation Mapping:

are motions in BLR primarily orbital?)

The Gateway Relation for AGN

$M_{bh} = f \Delta v^2 R_{reverb} / G$

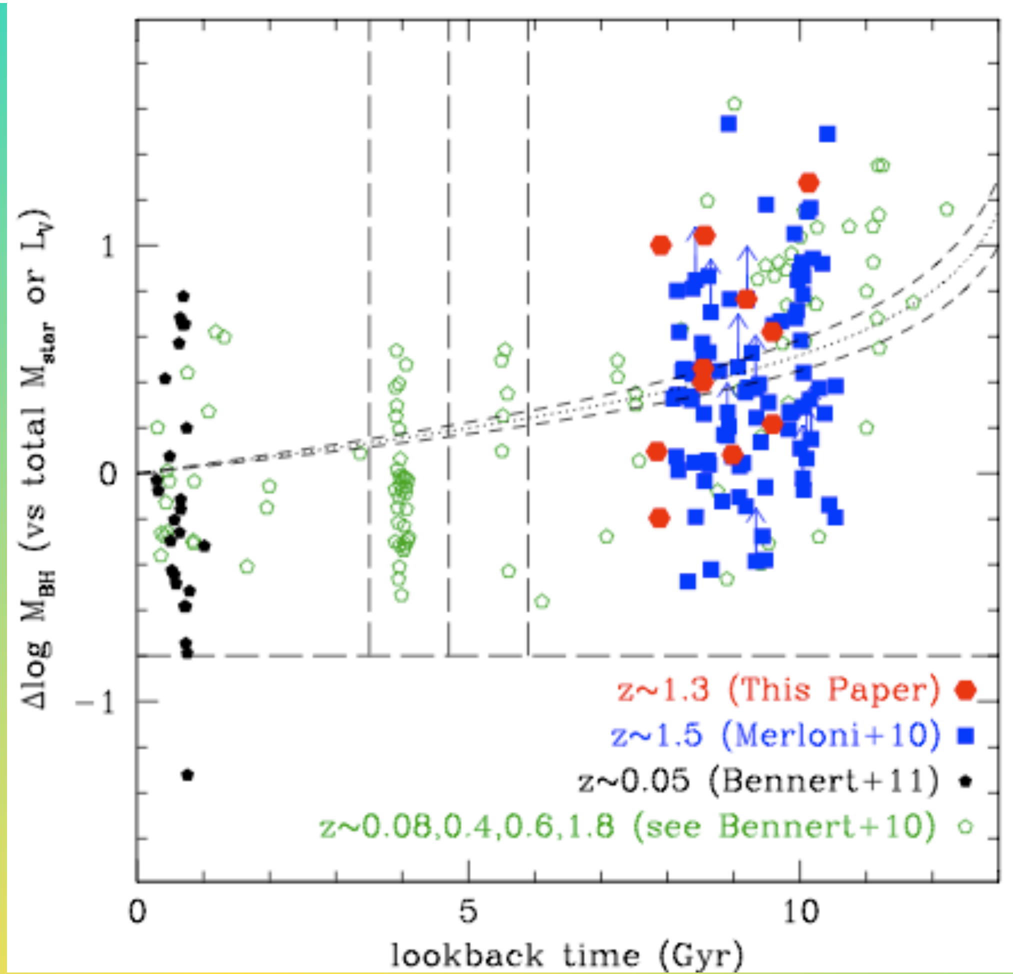
Where fudge factor f is guestimated by assuming Sefyert hosts follow same Mbh/sigma correlation as normal galaxies



3. Coevolution of supermassive black holes and galaxies; AGN Fueling and Feedback.

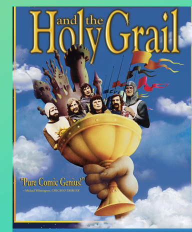
Measure If, When and How the SMBH/Host Galaxy Relations have evolved (together?)

Key ingredient in understanding *Galaxy Evolution*



SMBHs at high z appear to be 'too massive' for their host galaxies.

Did the egg come before the chicken?



The true *evolution of the Mbh/Bulge relations* is still not established after many years of effort.

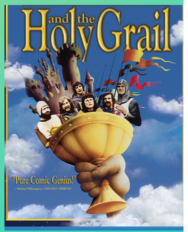
3.3 Quasar Host Galaxies.

Detailed spectroscopic comparison with ‘normal’ galaxies
At same redshifts:

What is it about the host galaxy which nurtured
the birth and feeding of the SMBH?
How did the SMBH in turn effect the galaxy’s evolution?

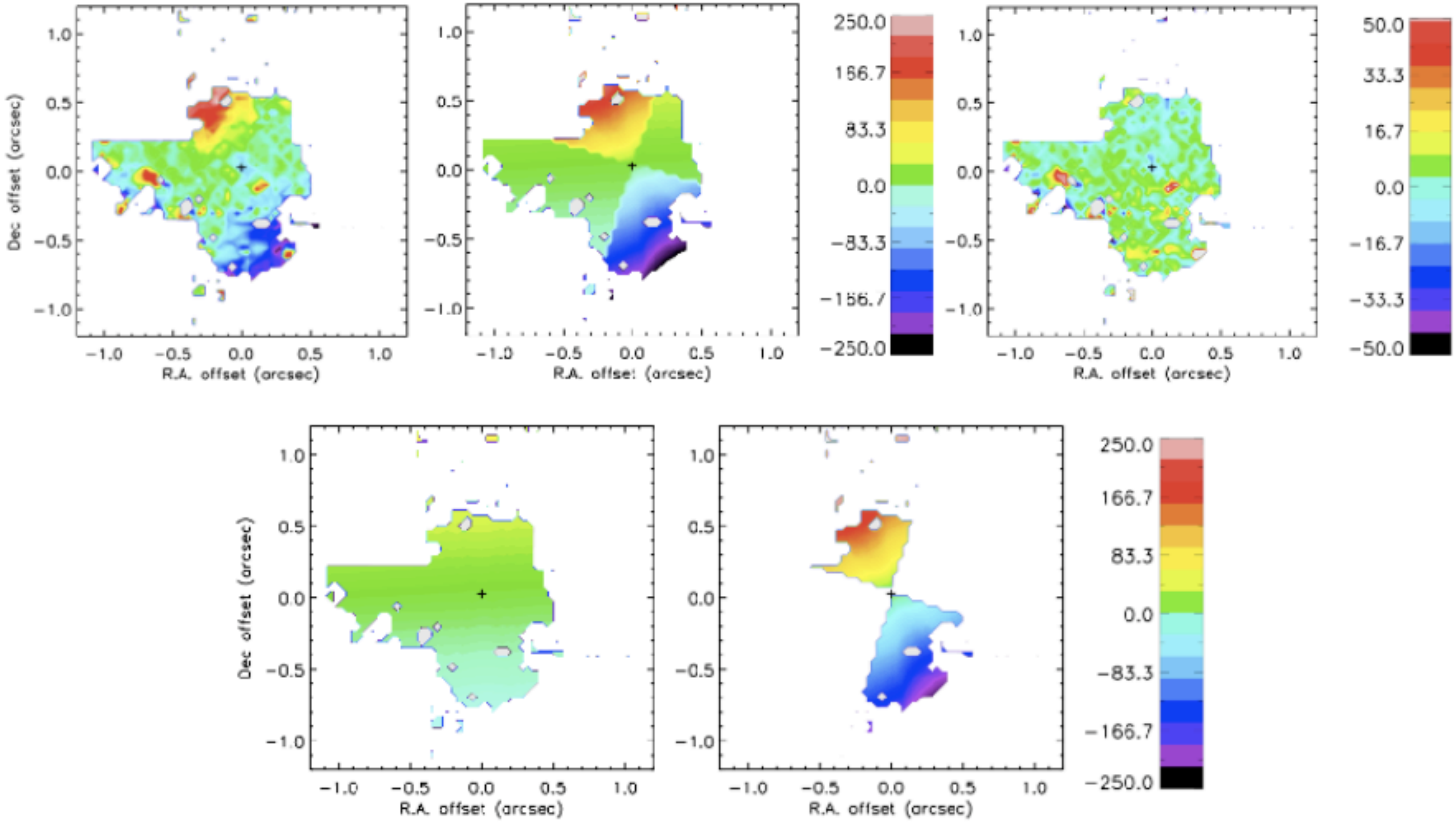
3.4 Tracing the Infall of Gas to the Central SMBH; the ‘last parsec’ problem

In a few nearest AGN, OSIRIS on edge of detecting
small infall velocities of H2,
Possibly driven by inner (<10pc) bar



3.5. Binary and Merging SMBH in the Nearby Universe

Find binary SMBH’s near ‘Stalling Radius’,
~0.03” in nearby galaxies



Coronal Emission Lines [SiVI]1.96um shows different kinematics from stars or other gas. Unlike their rotation, [SiVI] is primarily an outflow, best fitted by a bicone.

Are these outflows sufficient to make <u>"AGN feedback"</u> viable?

4. Structure and Physics of the Central Engine.

4.1. Nature of Dust and Absorption inside AGN

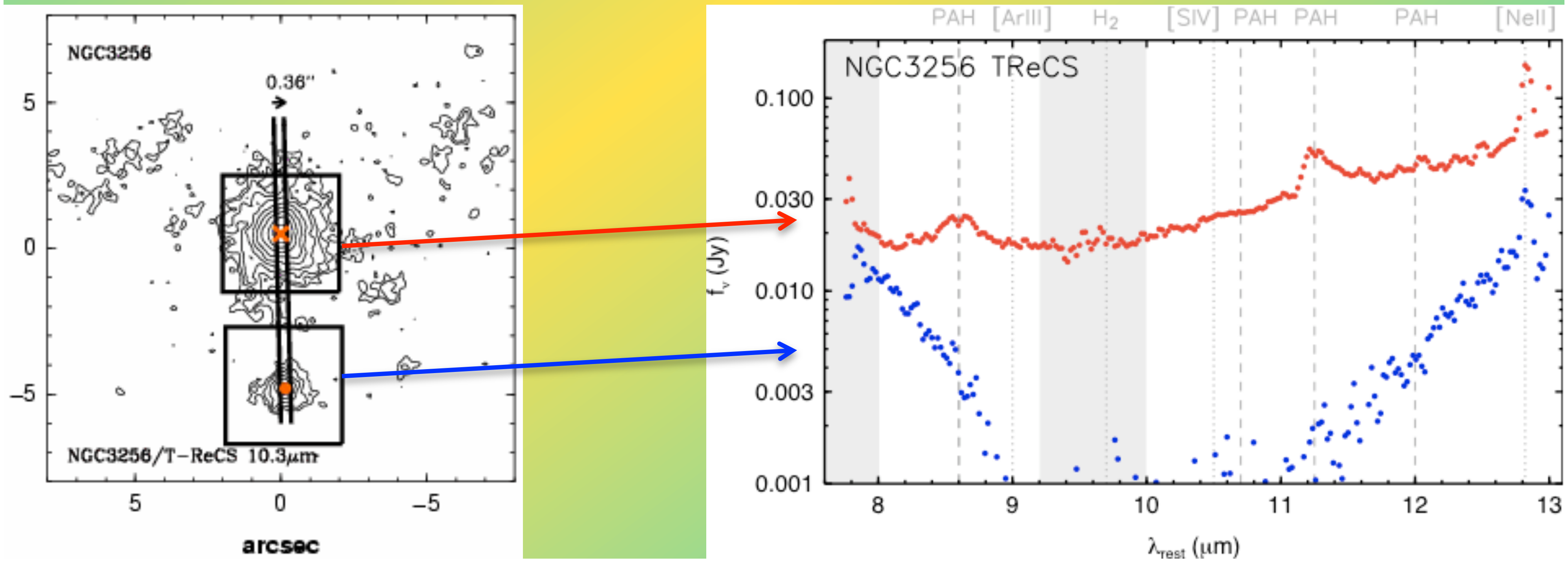
Most of the Black Hole Accretion in the Universe is Invisible

Because of: host galaxy dilution, and/or

Heavy Dust Reddening

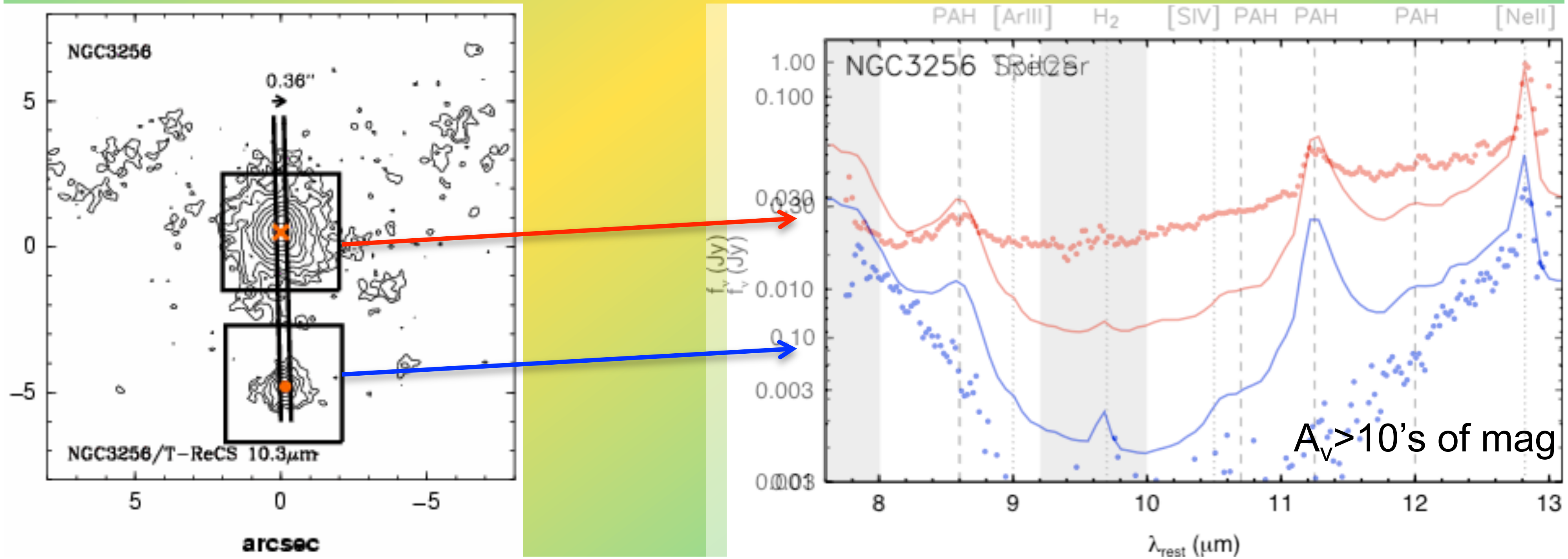
Need MIR Spectra with highest spatial resolution

- Surrounding area contamination defeats interpretation
  - 1” resolution of nearby LIRG shows AGN contribution (<)<30%

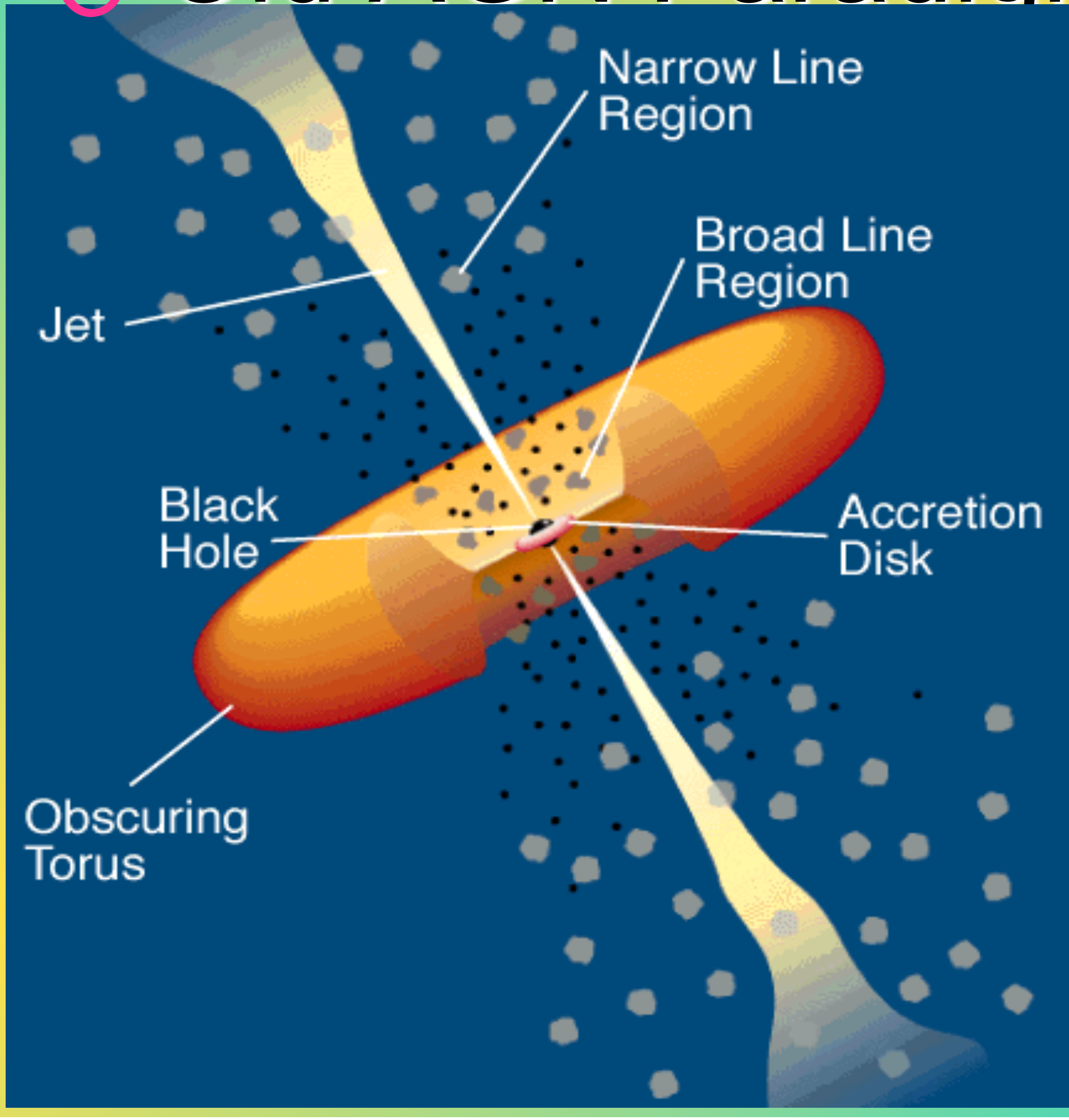


Need MIR Spectra with highest spatial resolution

- Surrounding galaxy contamination defeats interpretation
  - 1” resolution of nearby LIRG shows AGN contribution (<)<30%



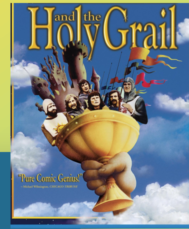
Obsolete Old AGN Paradigm

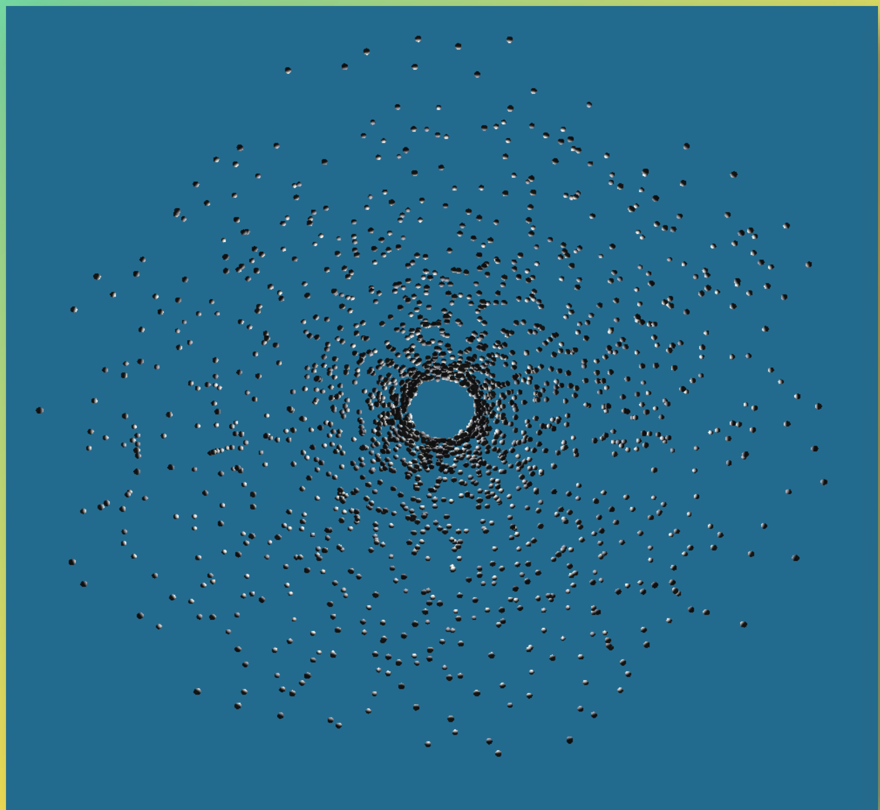


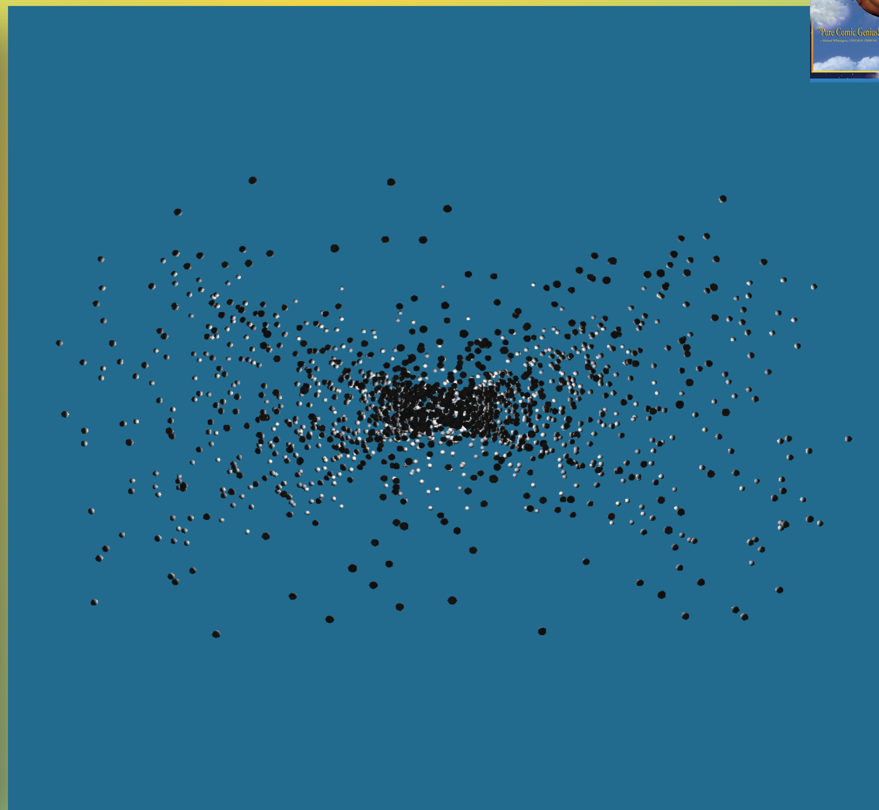
- Line of sight affords radically different views of the AGN central engine
- Obscuration due to the torus is fundamental to AGN theories
  - Detailed knowledge of the torus is crucial

Now Replaced by Clumpy ‘Torus’ (Wind?)

- Clumpy distribution puts cooler dust (on protected side) closer to nucleus than continuous dust distribution
  - Far more compact torus, least luminous ones could be ~3pc (*exceeds TMT DL* in local Universe;forget JWST)
  - May not exist at all in low-L, or in high-L AGN…

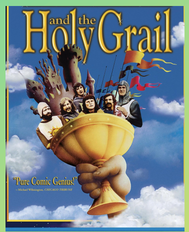



Pole-on

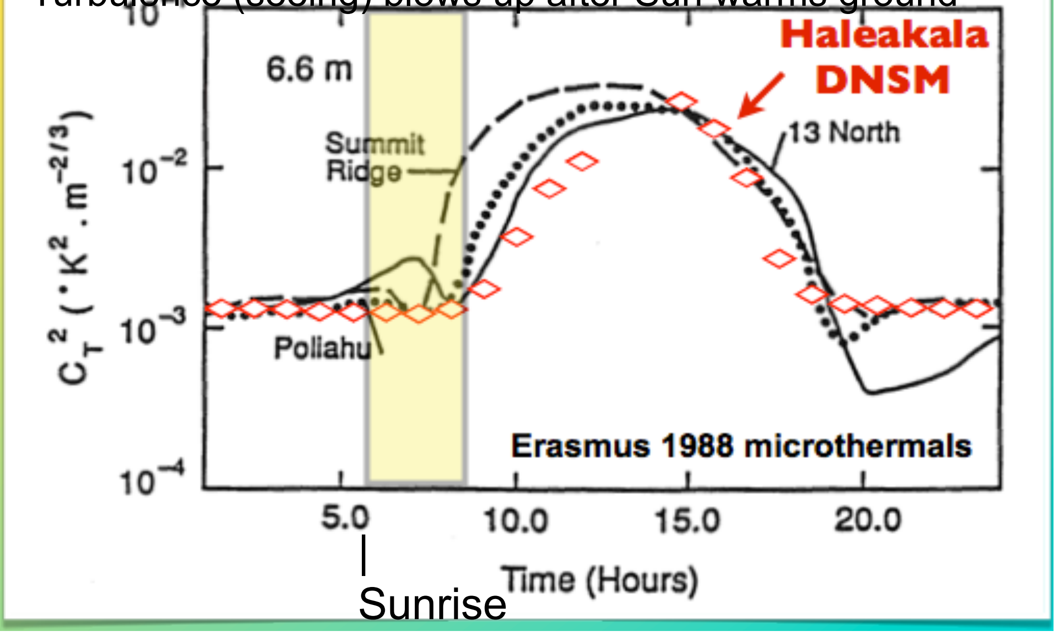

Edge-on

Mid-IR Adaptive Optics

- ***Daytime observing***
  - MIRAO/未知 could exploit excellent seeing conditions in early morning after sunrise:
  - Appears feasible with no loss in performance for many bright objects; affords extra **1-2 hours per night** of TMT observing time
    - Need to understand operational implications
  - R&D efforts
    - New NB filters in hand to be used on Subaru's AO system soon



Turbulence (seeing) blows up after Sun warms ground



4. Structure and Physics of the Central Engine.

Time Domain Studies,

Internal

and External

"All" Accreting Black Holes are VARIABLE

Multiwavelength *variability reveals geometry* (accretion disks, jets, Broad Emission Lines, Broad Absorption Lines)

Microlensing (size estimates, if components resolved)

Tidal Disruption Events