Approaching the origin of the super-massive black holes with TMT

review of the science cases from TMT-AGN science WG in Japan

Masayuki Akiyama (Tohoku U.)
Chair: Tohru Nagao (Ehime)
K.Aoki (NAOJ), M.Imanishi (NAOJ), S.Ozaki (NAOJ), N.Kawakatsu (Tsukuba), T.Kawaguchi (Tsukuba), H.Sugai (Kyoto), A.Tanikawa (Tsukuba), Y.Terashima (Ehime), T.Misawa (Shinsyu), T.Minezaki (Tokyo)

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“Origin of the super-massive black hole (SMBHs)”

What do we want to know in general ?

1. Seeds of the SMBHs

Intermediate ? Massive ?

2. Growth history of the SMBHs

Accretion ? Merging ?

Accretion: Eddington-limited ? Super-Eddington ?

Accretion: Obscured ? Non-obscured ?

3. Interplay between growth of SMBHs and galaxies

Feedback processes ?

Feeding processes ?

Three major areas with TMT

A. *SMBHs in the local universe* with nearby galaxies.

= statistical constraints on the seeds of the SMBHs

B. *Central 100pc around SMBHs* with nearby AGNs.

= understanding on the feeding and feedback processes

= obscuration in AGNs

C. *Cosmological evolution of SMBHs* with AGNs at distant universe.

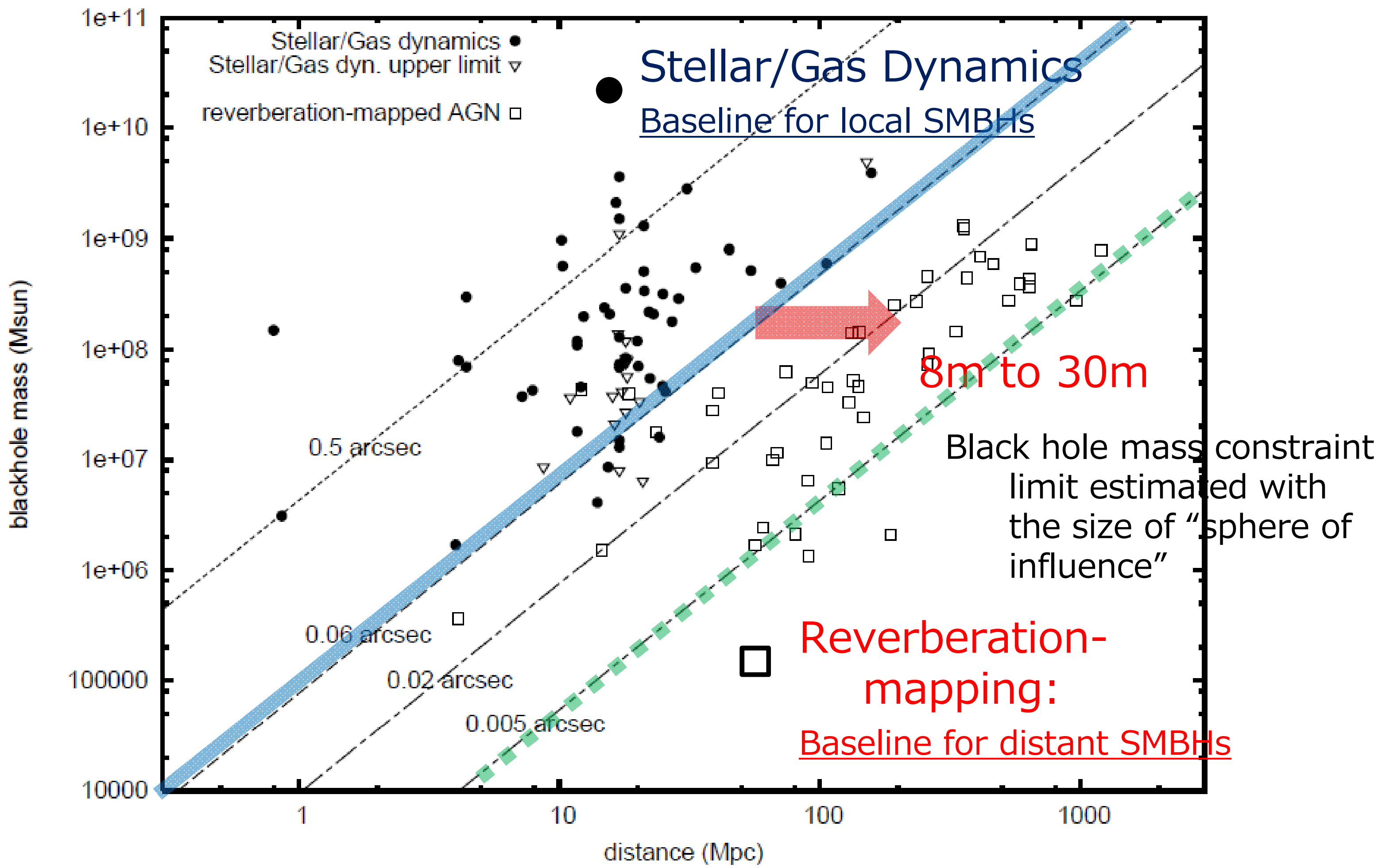
= quantitative understanding on the growth history of SMBHs

= “co-evolution” of SMBHs and galaxies

= feeding and feedback in the “violent” epoch, during the era of significant growth

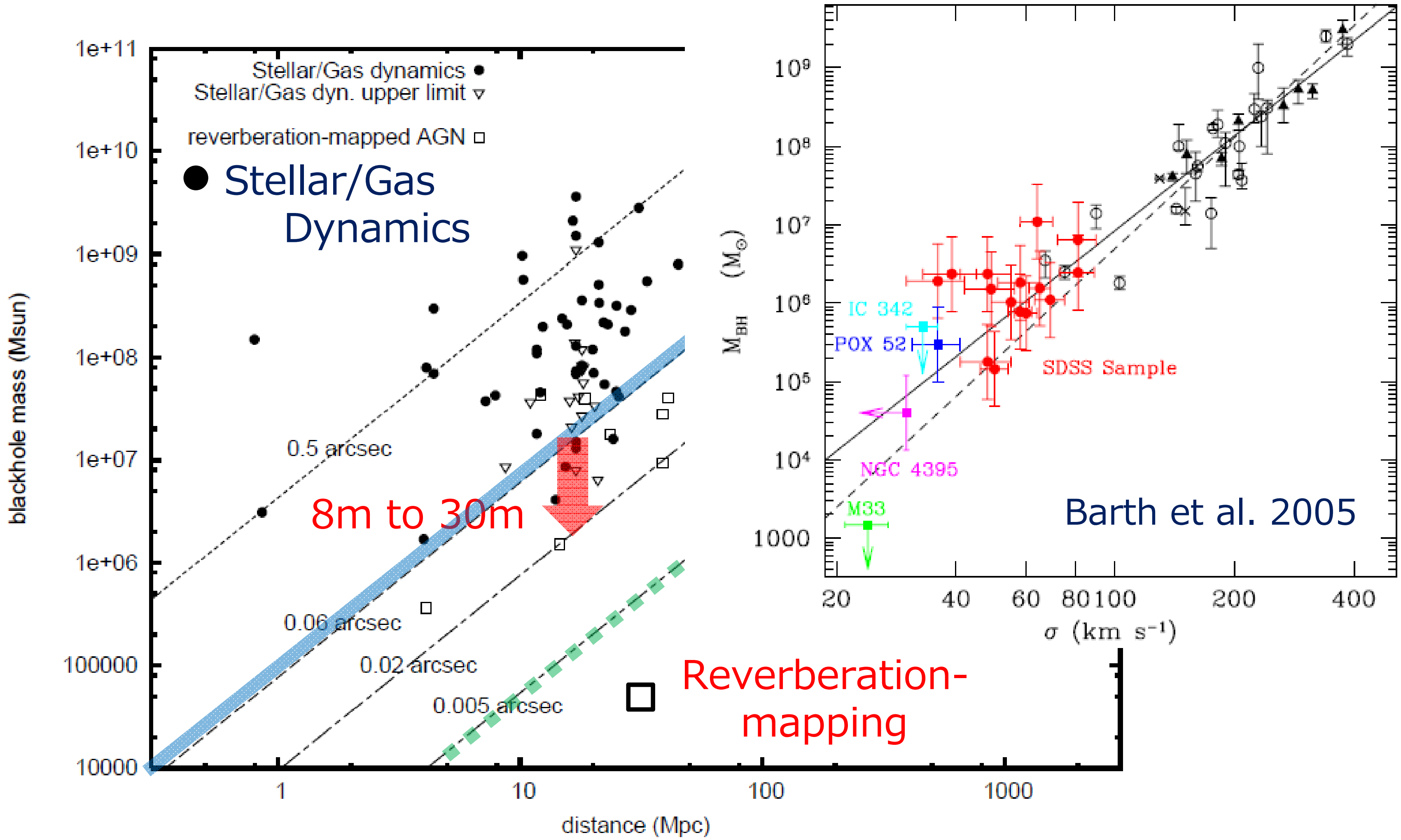
A. SMBHs in the local universe

A-1: Pushing stellar/gas dynamics SMBH mass estimate to more distant galaxies (<1000Mpc), establish connection between stellar/gas dynamics and reverberation mapping studies (currently only 2 cross calibration available).



A. SMBHs in the local universe

A-2: Pushing stellar/gas dynamics SMBH mass estimate to lower black hole mass range with dwarf galaxies to examine the low mass end of the mass function of SMBHs which can constrain the mass of the seed black holes.



A. SMBHs in the local universe

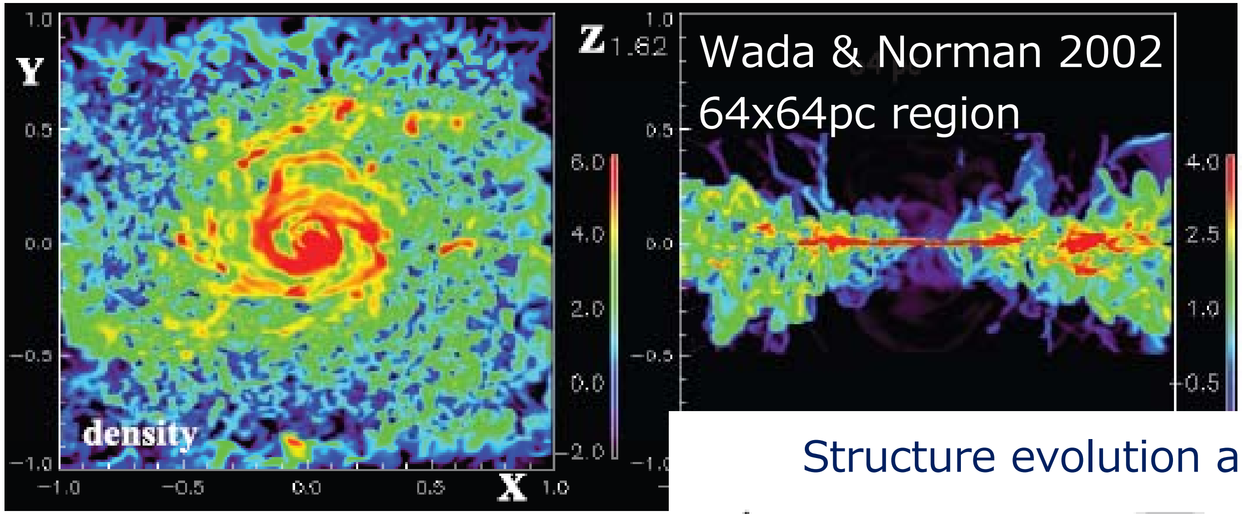
A-3: Intermediate mass black hole can provide us direct constraints on the seed black hole.

- Are intermediate mass black holes associated with globular clusters ?
  - Use change of radial velocity of stars in the central region instead of velocity dispersion etc.
  - Expected velocity change due to Keplarian motion around 3000Msolar black hole is 200-300m/s/yr at 1500AU from the black hole.

- Intermediate mass black holes identified with ultra-luminous X-ray sources ?
  - Detecting optical counterparts of ULXs systematically.
  - Detailed studies on the optical counterparts, i.e. SEDs and line diagnostics.

B. Central 100pc around SMBHs

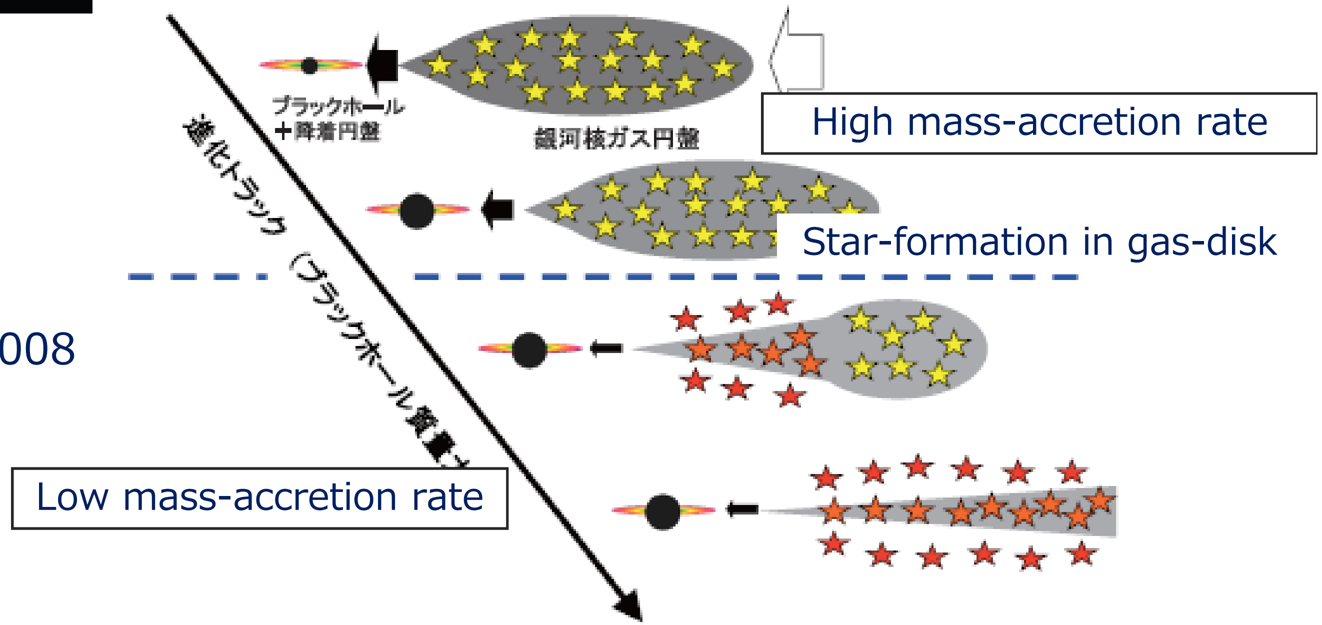
B-1: Mid-IR observation of dusty torus = structure of dusty obscuration and large-scale feeding to the SMBHs



Simulations on the structure of molecular gas torus.

MIR diffraction limited imaging (Q-band 0.12”=20pc@z=0.01) to examine the structure in the lower temperature dust component

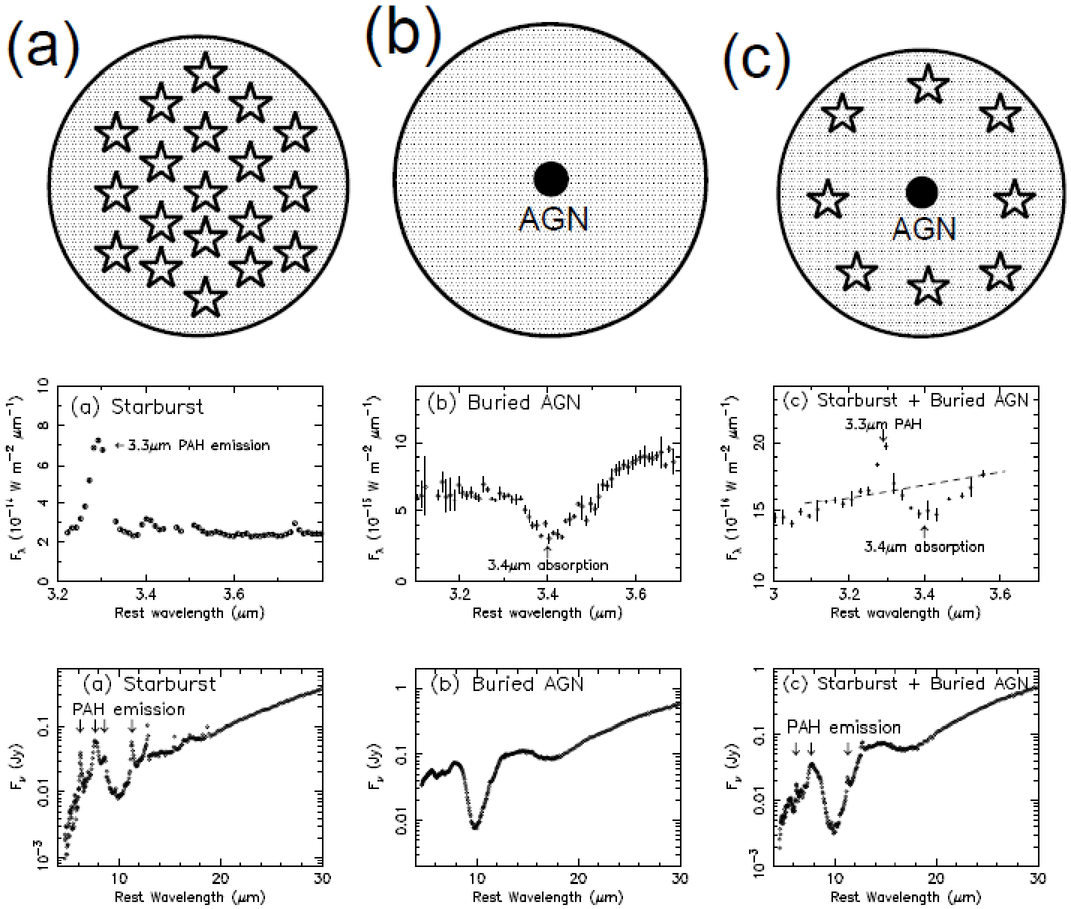
Structure evolution around 100pc region



Kawakatsu & Wada 2008

B. Central 100pc around SMBHs

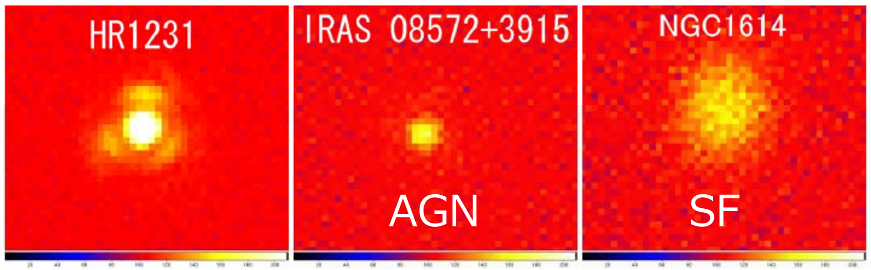
B-2: Energetic in the heavily-obscured AGNs, i.e. ULIRGs



MIR high-spatial-resolution spectroscopy and imaging are necessary to quantitatively evaluate the energetic in the ULIRGs.

MIR imaging can constrain the contribution from SF based on limits on the surface density of SF.

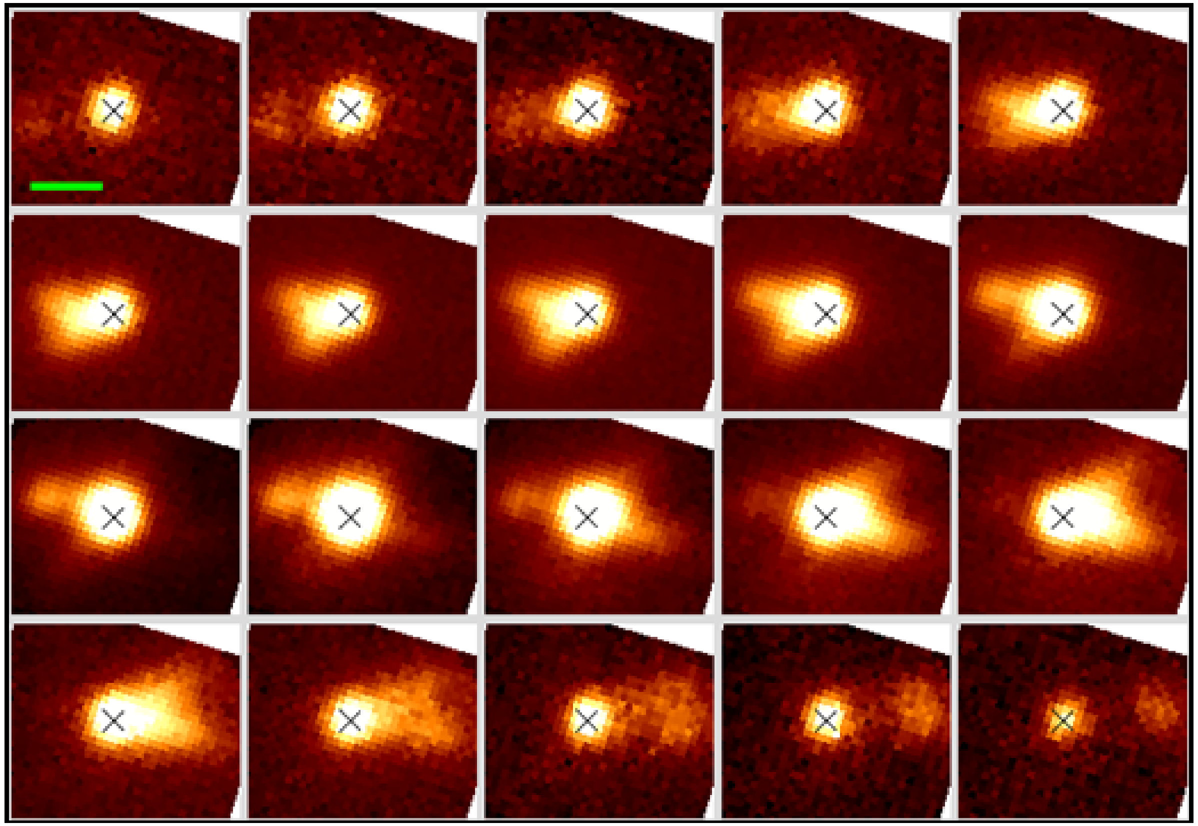
Imanishi et al 2006, 2007



Imanishi et al 2010

B. Central 100pc around SMBHs

B-3: Feedback processes examined with NLR structure (associated narrow-absorption lines of QSOs and NLRs of distant AGNs at high-redshifts)



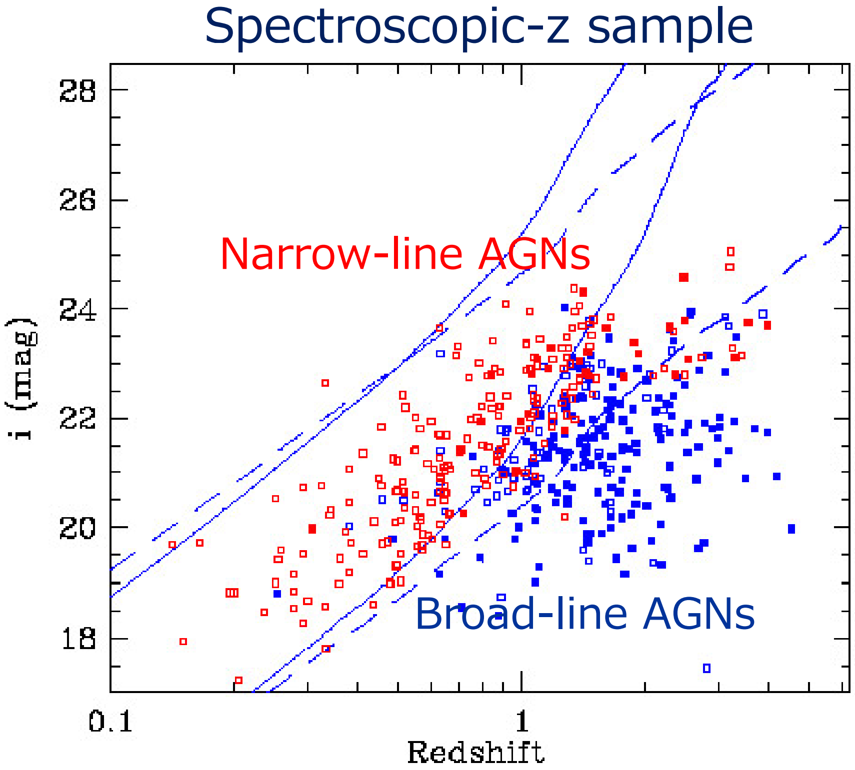
Dynamical structure of narrow-line region can provide us information on feedback processes.

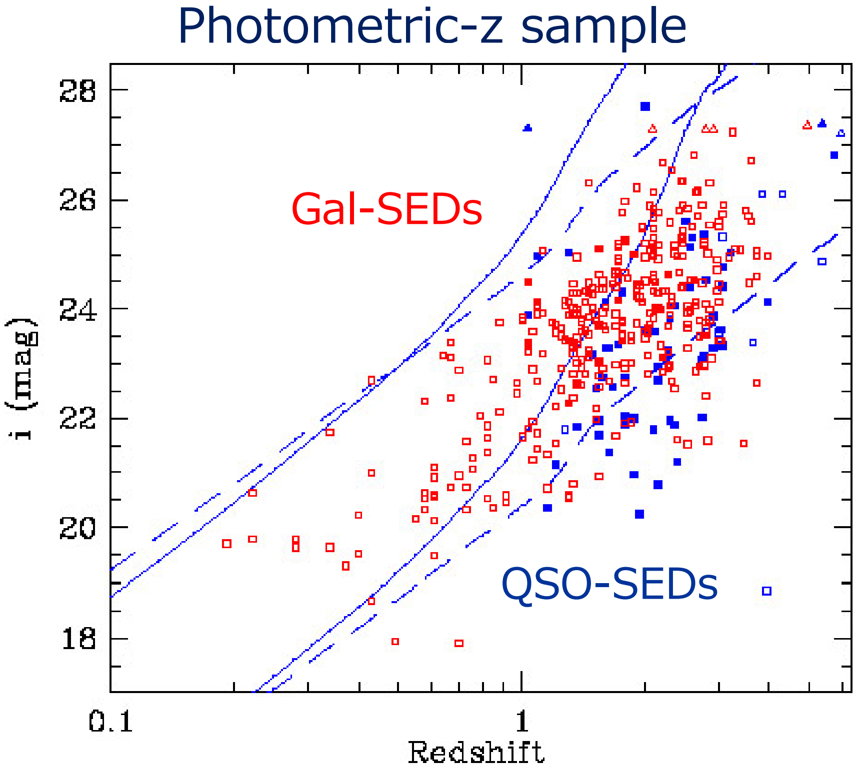
Feedback processes can be evaluated with associated narrow-absorption lines of QSOs and NLR dynamics of AGNs at high-redshifts

0.4 arcsec-resolution 3D-spectrograph data of NGC1052
102km/s velocity difference
Sugai et al. 2005

C. Cosmological evolution of SMBHs

C-1: Spectroscopic identification of obscured AGNs at high redshifts are crucial for quantitative understanding of SMBHs accretion growth



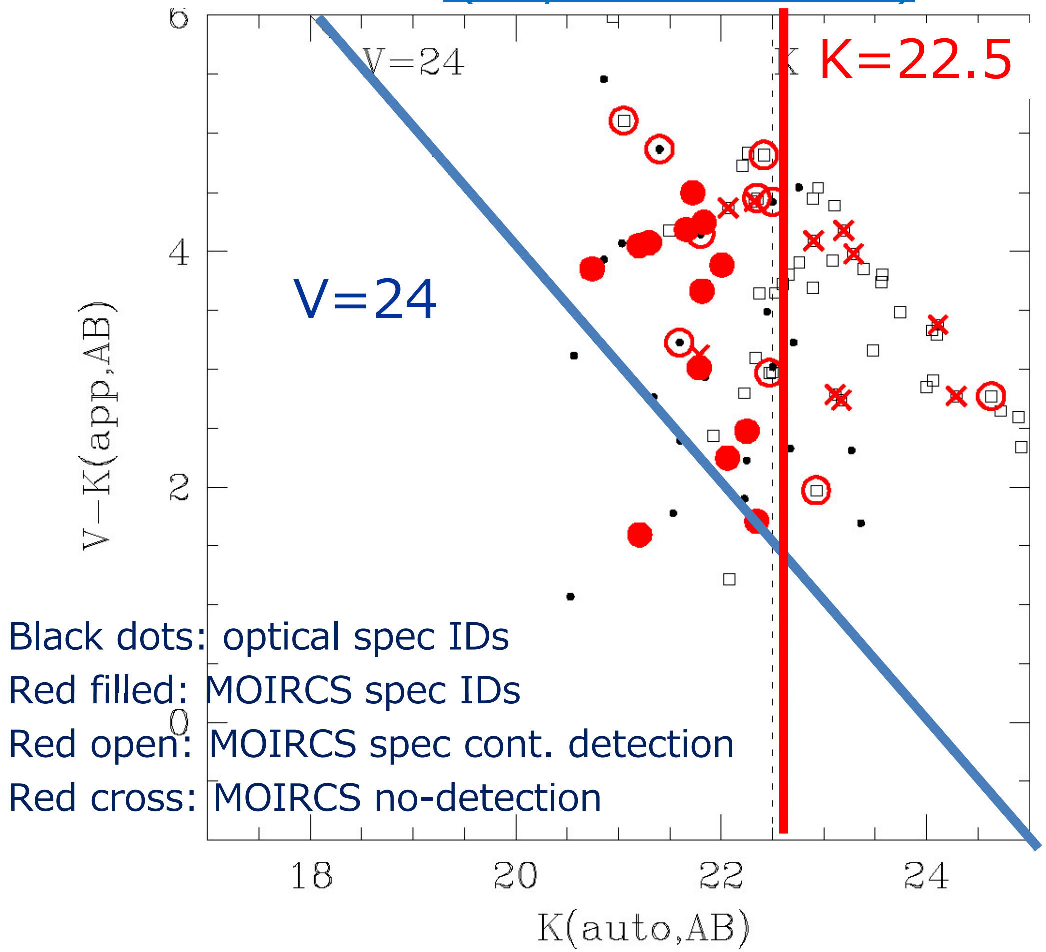


Photometric redshift estimations of X-ray sources found in Subaru XMM-Newton Deep Survey field suggest that there are large number of obscured AGNs at redshift >1 among the sample beyond optical spectroscopy limits of 8-10m class telescope (Akiyama et al. 2011).

C. Cosmological evolution of SMBHs

C-1: Spectroscopic identification of obscured AGNs at high redshifts are crucial for quantitative understanding of SMBHs accretion growth

Z>1.5 X-ray sources (zspec or zphot) in GOODS-North
(Akiyama et al. 2011)

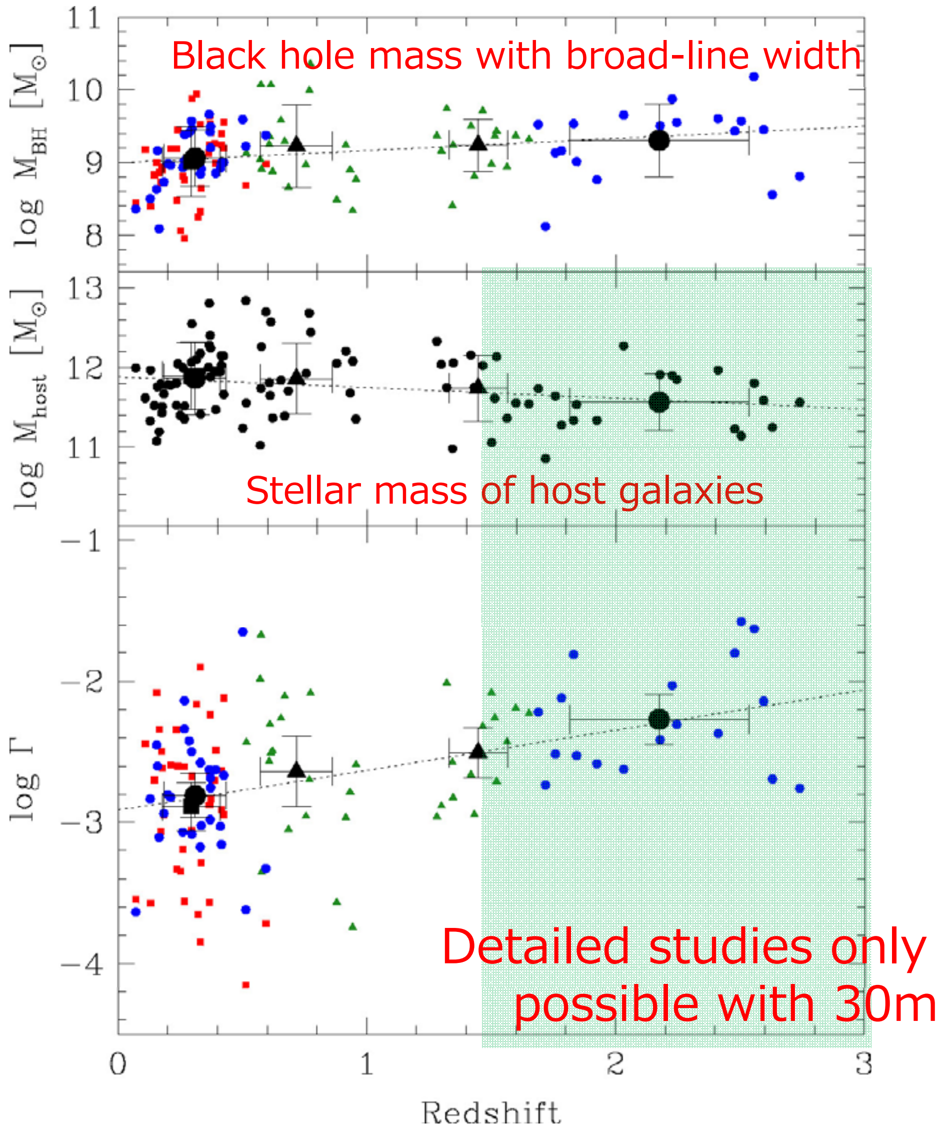


Even with deep (3-5hours) NIR spectroscopic observation cannot identify these objects. There are large number of X-ray sources beyond optical / NIR spectroscopy limit of 8-10m class telescopes.

Considering the X-ray to [OIII] etc line flux ratio, 2-3 hours integration with TMT is necessary to detect rest-frame optical emission lines of X-ray AGNs found in the deepest Chandra fields.

C. Cosmological evolution of SMBHs

C-2: Properties of host galaxies are important to understand co-evolution of SMBHs and galaxies

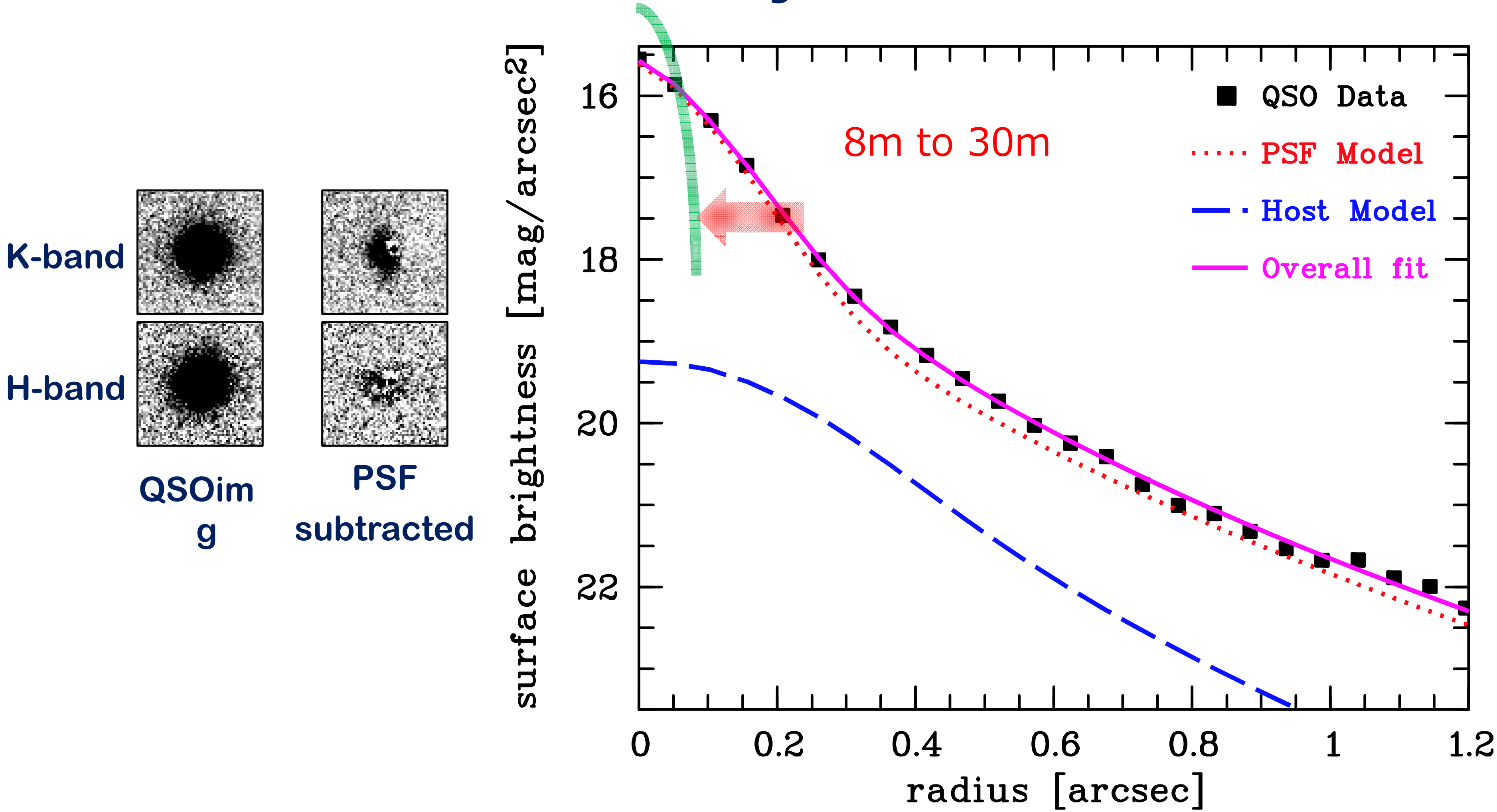


Ratio between black hole mass and stellar mass of host galaxies is examined with ground-based AO-imaging up to redshift ~3 so far (ex. Falomo et al. 2008).

However, the uncertainty with the current dataset is large (see next slide), and 30m diffraction limited studies are necessary to obtain solid constraints on the redshift dependence of the ratio.

C. Cosmological evolution of SMBHs

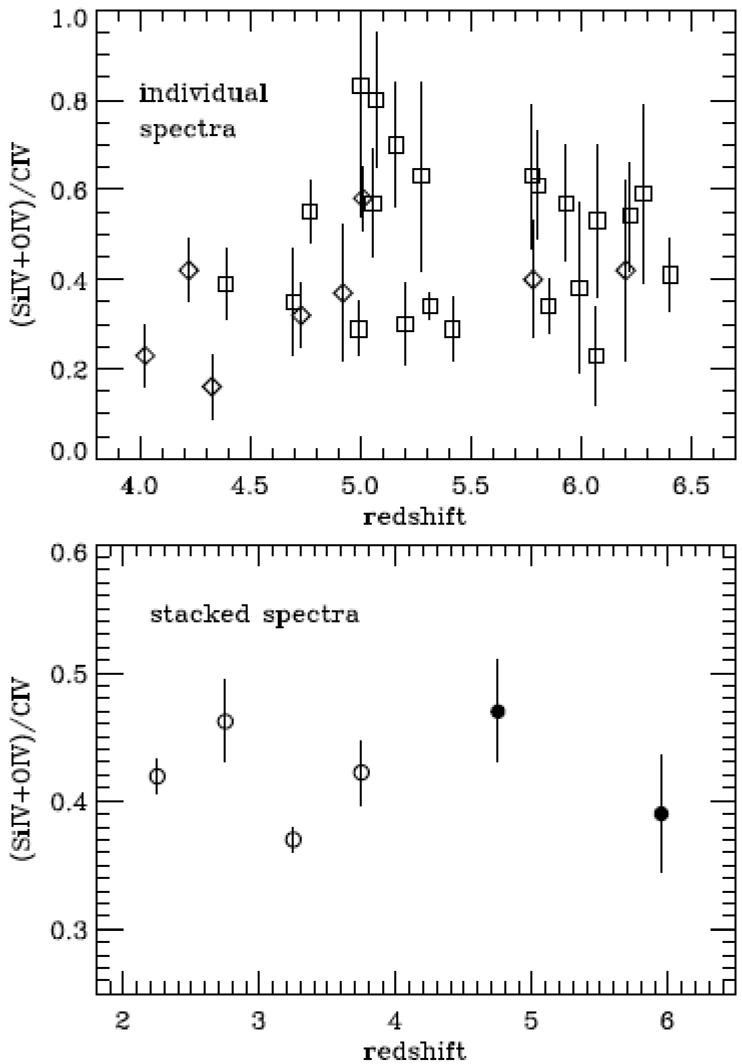
C-2: Properties of host galaxies are important to understand co-evolution of SMBHs and galaxies



Suabru AO188+IRCS imaging of z~3 QSOs (Schramn et al. 2011). Diffraction limited imaging with 30m telescope is critical to detect faint host galaxies around QSOs.

C. Cosmological evolution of SMBHs

C-3: Metalicities of high-redshift QSOs can provide the information on the chemical evolution of the central regions of galaxies



Juarez et al. 2009
including Nagao et al. 2006

Summary and instruments required

A. *SMBHs in the local universe*

A-1: more distant SMBHs = IRIS+NFIRAOS

A-2: lower mass SMBHs = IRIS+NFIRAOS, high-dispersion NIR spectrograph+NFIRAOS

A-3: intermediate mass black holes = IRIS+NFIRAOS, high-dispersion NIR spectrograph+NFIRAOS

B. *Central 100pc around SMBHs*

B-1: dusty torus, feeding = IRIS+NFIRAOS, MIR-imager+MIRAO, high-dispersion NIR spectrograph+NFIRAOS

B-2: energetic in ULIRGs = MIR-imager+MIRAO

B-3: feedback processes = IRIS+NFIRAOS, WFOS+3D, high-dispersion Opt/NIR spectrographs

C. *Cosmological evolution of SMBHs*

C-1: AGN surveys = WFOS, IRMS, wider-field IRMS

C-2: host galaxies = IRIS+NFIRAOS

C-3: metalicity evolution = IRIS, WFOS