AGN Sciences: from Subaru to TMT

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Based on discussion with:
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22-23 July 2013, Waikoloa, Hawaii
Thirty Meter Telescope Science Forum

KYOTO UNIVERSITY KYOTO JAPAN FOUNDED 1897

Hakubi
Kyoto Univ.

~400 pages, issued in Feb. 2011

TMT Science White Paper
made by Japanese astronomers
(led by NAOJ)

~ coordinator: T. Kodama

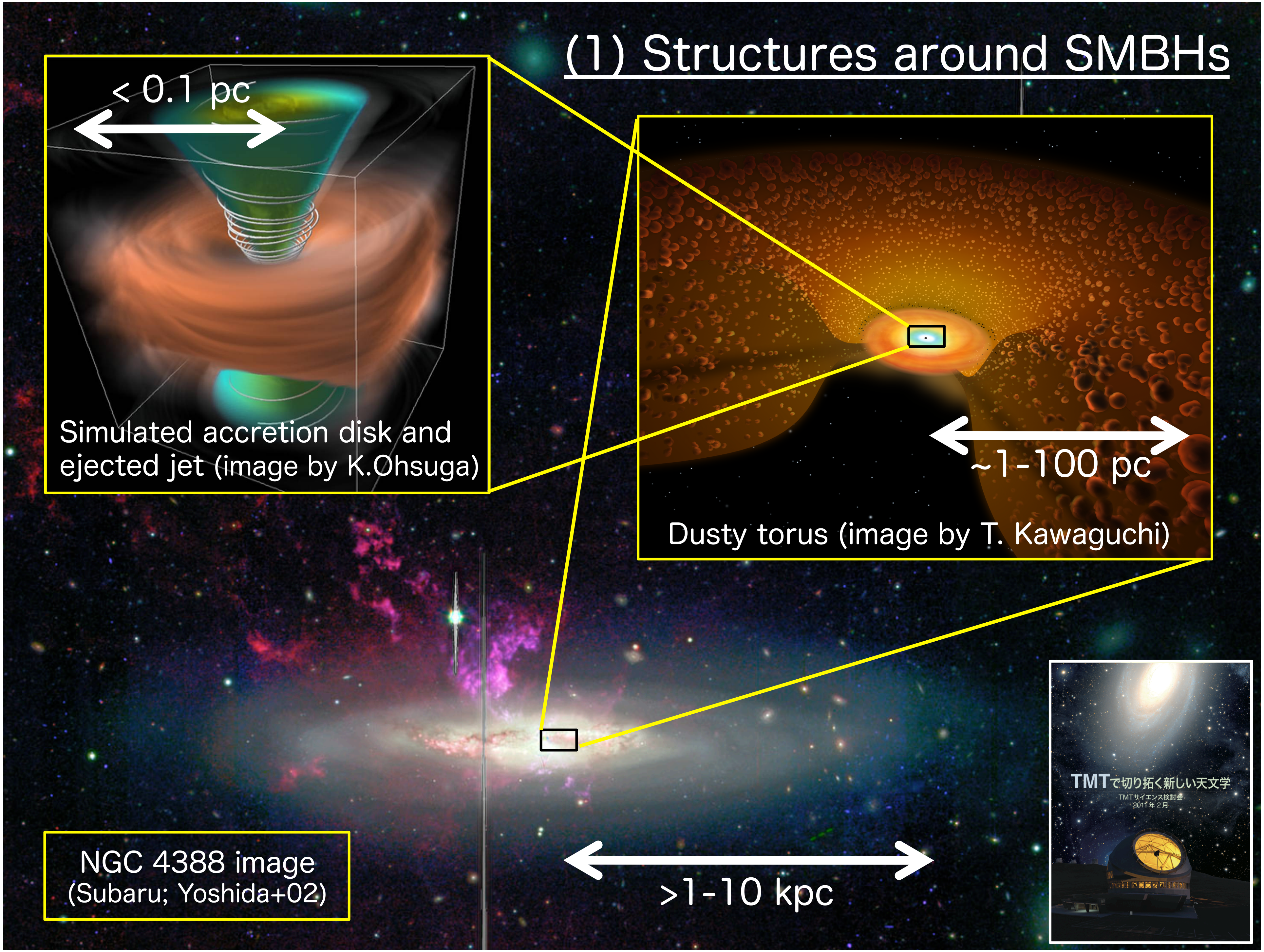
~ cosmology: N. Yoshida et al.
~ galaxies: K. Motohara et al.
~ AGN/SMBH: T. Nagao et al.
~ stars/MW: W. Aoki et al.
~ planets: N. Narita et al.

AGN/SMBH: Big Problems

(1) Structures around SMBHs

(2) Gas inflow/outflow (or “feeding”/“feedback”)

(3) Cosmological evolution of SMBHs and AGNs


(1) Structures around SMBHs
< 0.1 pc
Simulated accretion disk and ejected jet (image by K.Ohsuga)
~1-100 pc
Dusty torus (image by T. Kawaguchi)
NGC 4388 image (Subaru; Yoshida+02)
>1-10 kpc
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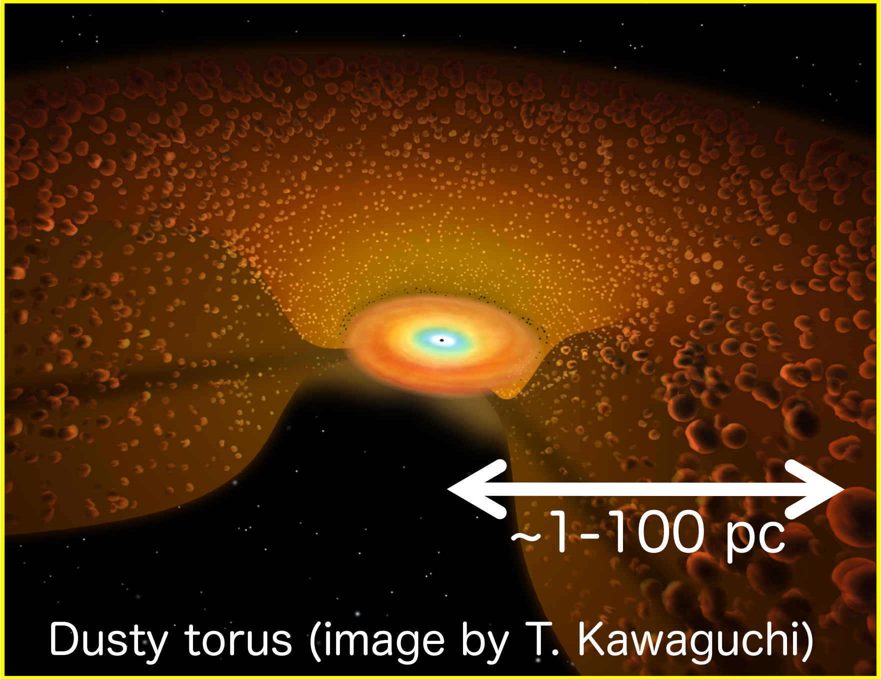
2011年2月

Dusty Torus around SMBH



Dusty torus (image by T. Kawaguchi)

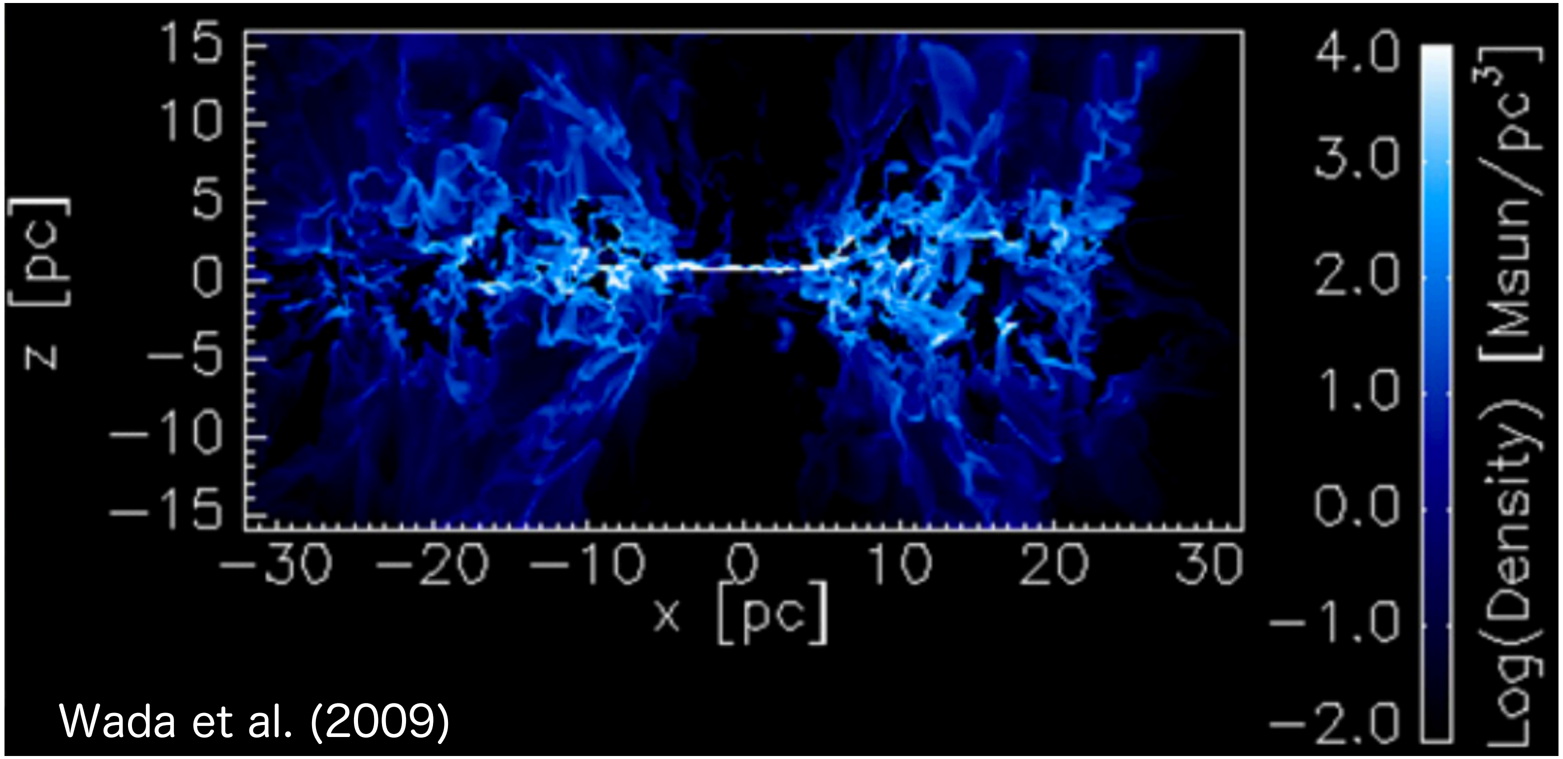
Important, because...

~ determining the AGN type
~ dominating the IR SED of AGNs
~ could be massive gas reservers
~ possible sites for star formation

However, currently...

~ various models proposed so far
~ but not yet discriminated
~ since the torus has not spatially unresolved observationally
~ thus its true spatial structure is unknown
~ relation with the star-formation activity also unknown

Dusty Torus around SMBH



An example of numerical simulations for dusty tori

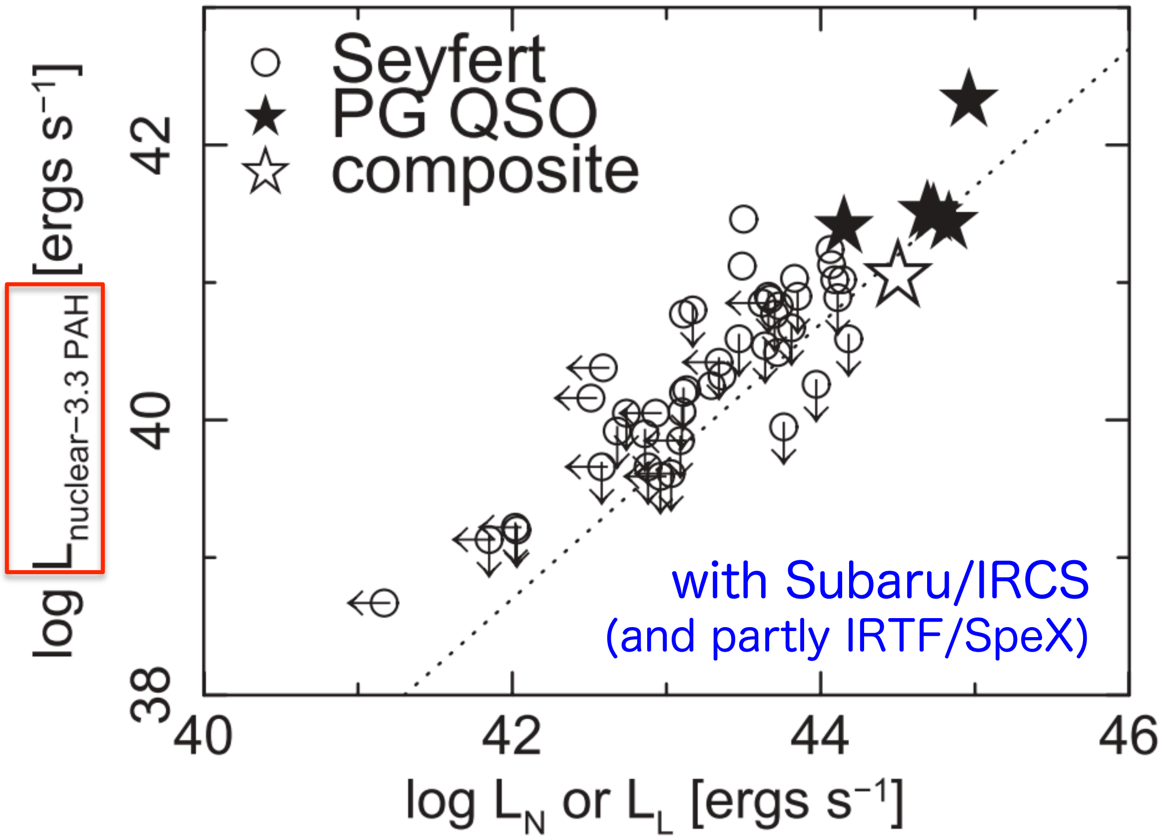
- ~ (in this case) a few tens pc, distributed around 1.3×10^7 M_{sun} SMBH
- ~ circumnuclear starformation (SNe) makes the vertical structure
- ~ is the circumnuclear starformation required for tori and AGNs?

Star Formation around SMBH

PAH emission:
good tracer of
the star formation

MIR (L-band in this case):
observations from
Mauna Kea are very
powerful and efficient

Imanishi et al. (2011,12)



Active star formation is actually seen in active AGNs

~ is this starformation occurring at the torus region?

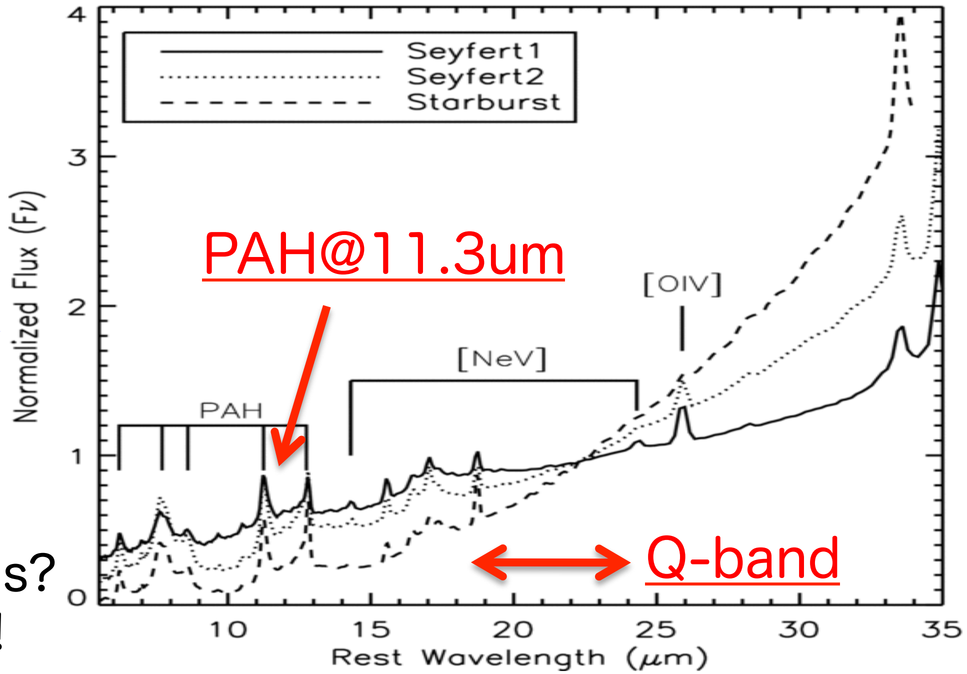
~ spatial info of the torus and star-forming regions necessary

Mid-IR Observations with TMT

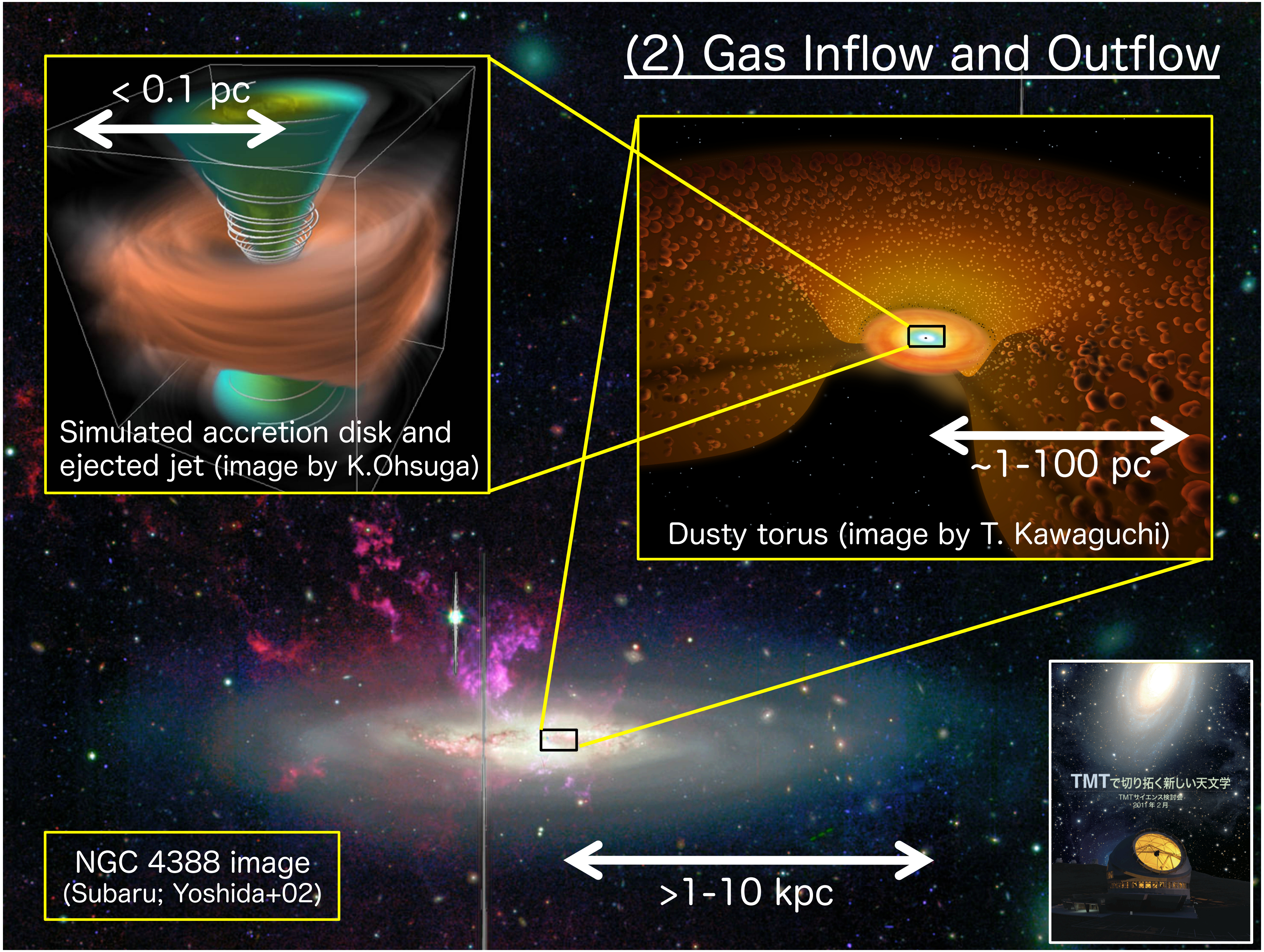
Q-band (20um) imaging
- ~ 0.12” resolution with MIR-AO
- ~ corresponds to ~20pc @z=0.01
- ~ for resolving the dusty torus

N-band (10um) IFS spectroscopy
- ~ 0.06” resolution with MIR-AO
- ~ corresponds to ~10pc @z=0.01
- ~ for tracing the star formation
- ~ is the SF associated with the torus?
- ~ examining the spatial coincidence!

Wu et al. (2010)



No 1st gen. MIR instruments on TMT, but possibly in 2nd gen.
- ~ “MICHI”; please see posters by Packham-san and Honda-san
- ~ with imaging, high-dispersion spec, and IFS functions
- ~ Mauna Kea has a great advantage at MIR than GMT/E-ELT
- ~ No planned Q-band function on E-ELT
- ~ JWST cannot achieve this spatial resolution at MIR
- ~ Unique science for TMT, in the ELT era!!



(2) Gas Inflow and Outflow
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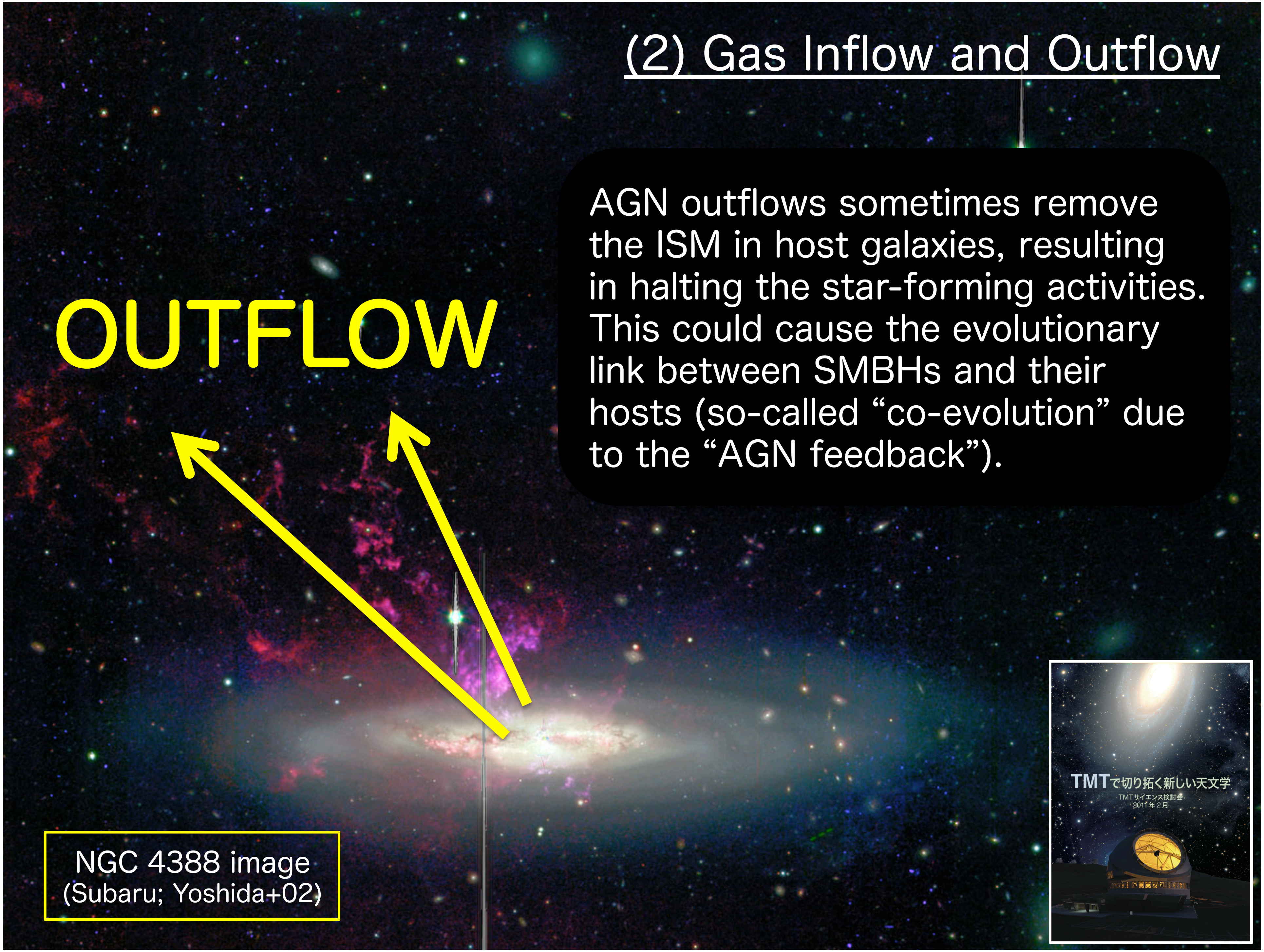
(2) Gas Inflow and Outflow
AGN outflows sometimes remove the ISM in host galaxies, resulting in halting the star-forming activities. This could cause the evolutionary link between SMBHs and their hosts (so-called “co-evolution” due to the “AGN feedback”).
OUTFLOW
NGC 4388 image
(Subaru; Yoshida+02)
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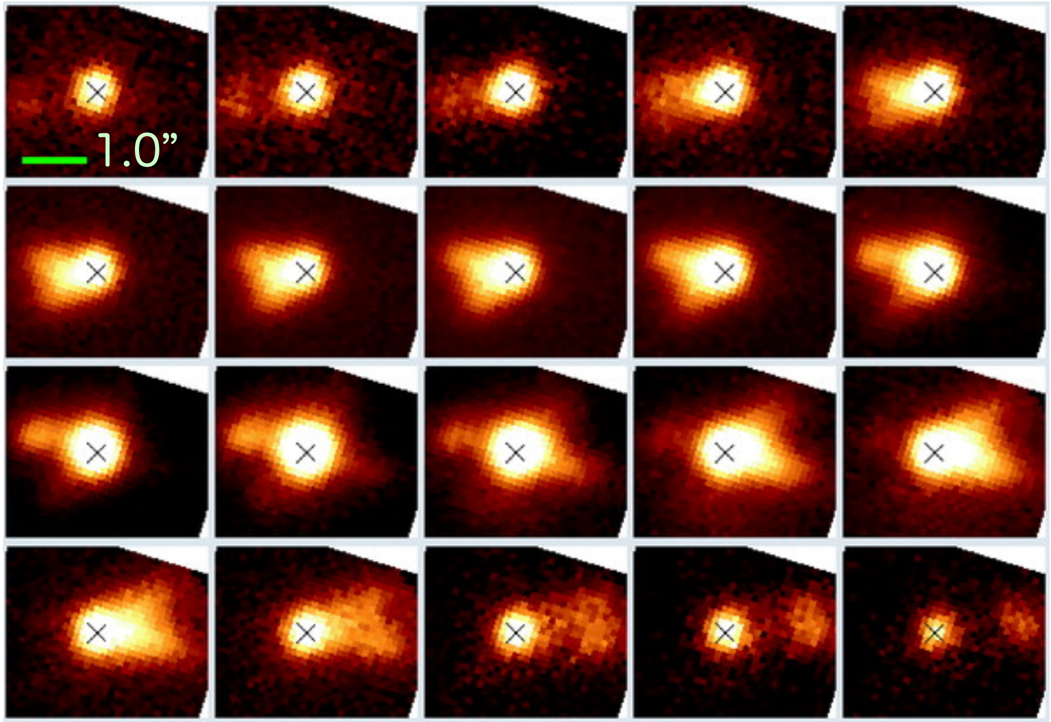
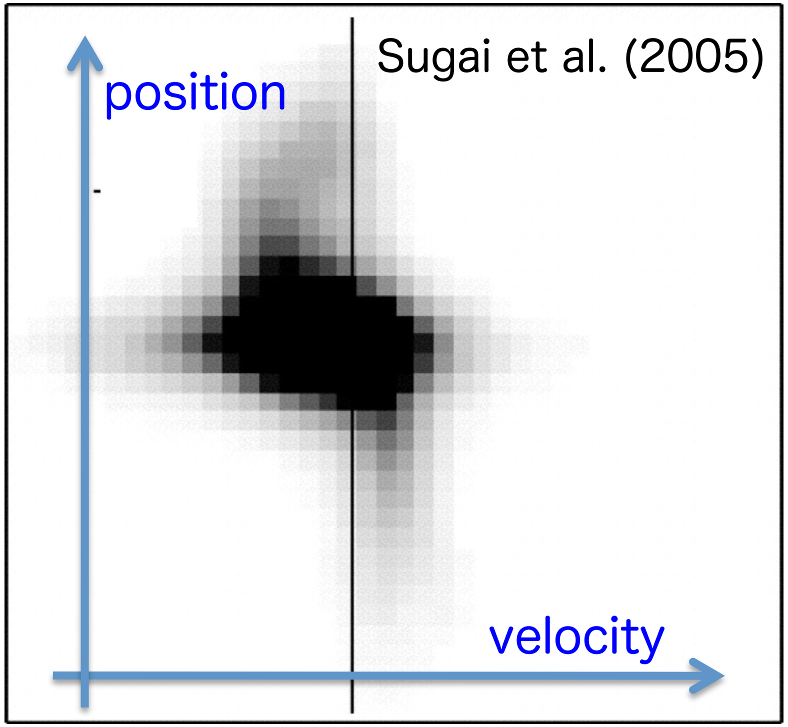
NGC 1052: [OIII]5007 channel map



NGC 1052: PV diagram



(data: Subaru/Kyoto3DII IFU mode, with 0.4” resolution at optical)

AGN outflow can be characterized by IFS observations

~ size, velocity, luminosity → mass-outflow rate, kinematic energy

~ diagnosing whether the star formation can be halted or not

How about at higher redshifts (z>1) ?

~ AGN feedback are “expected” to be more common... Really?

~ diffuse low surface brightness at high-z... TMT needed!!

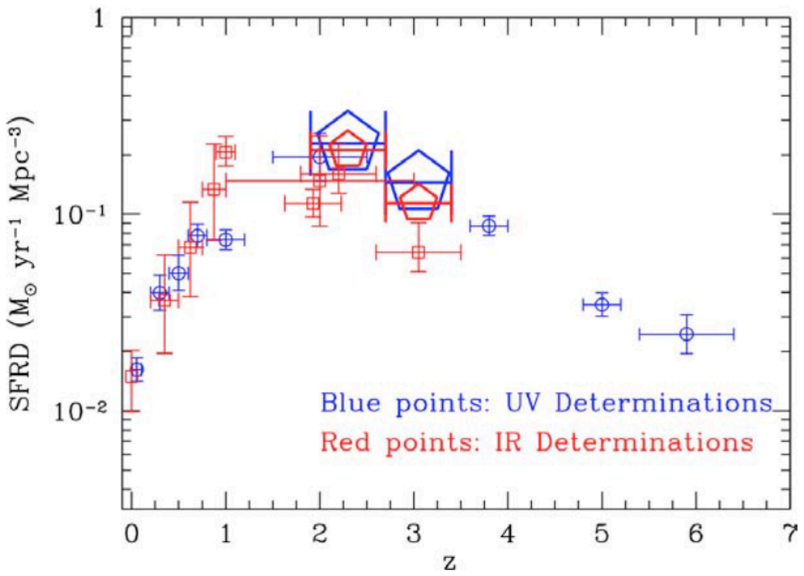
Near-IR IFS Observations with TMT

IRIS (1st gen. instrument) has the near-IR IFS modes

~ diffraction-limited resolution: 15 mas @K-band (with NFIRAOS)
~ FoV of 0.45”x0.64” - 2.25”x4.4” with 4-50 mas/spaxel
~ R=4000-10000, ideal to avoid OH sky lines (cf. X-Shooter)
~ Δv=30-75 km/s, enough for resolving the velocity structure

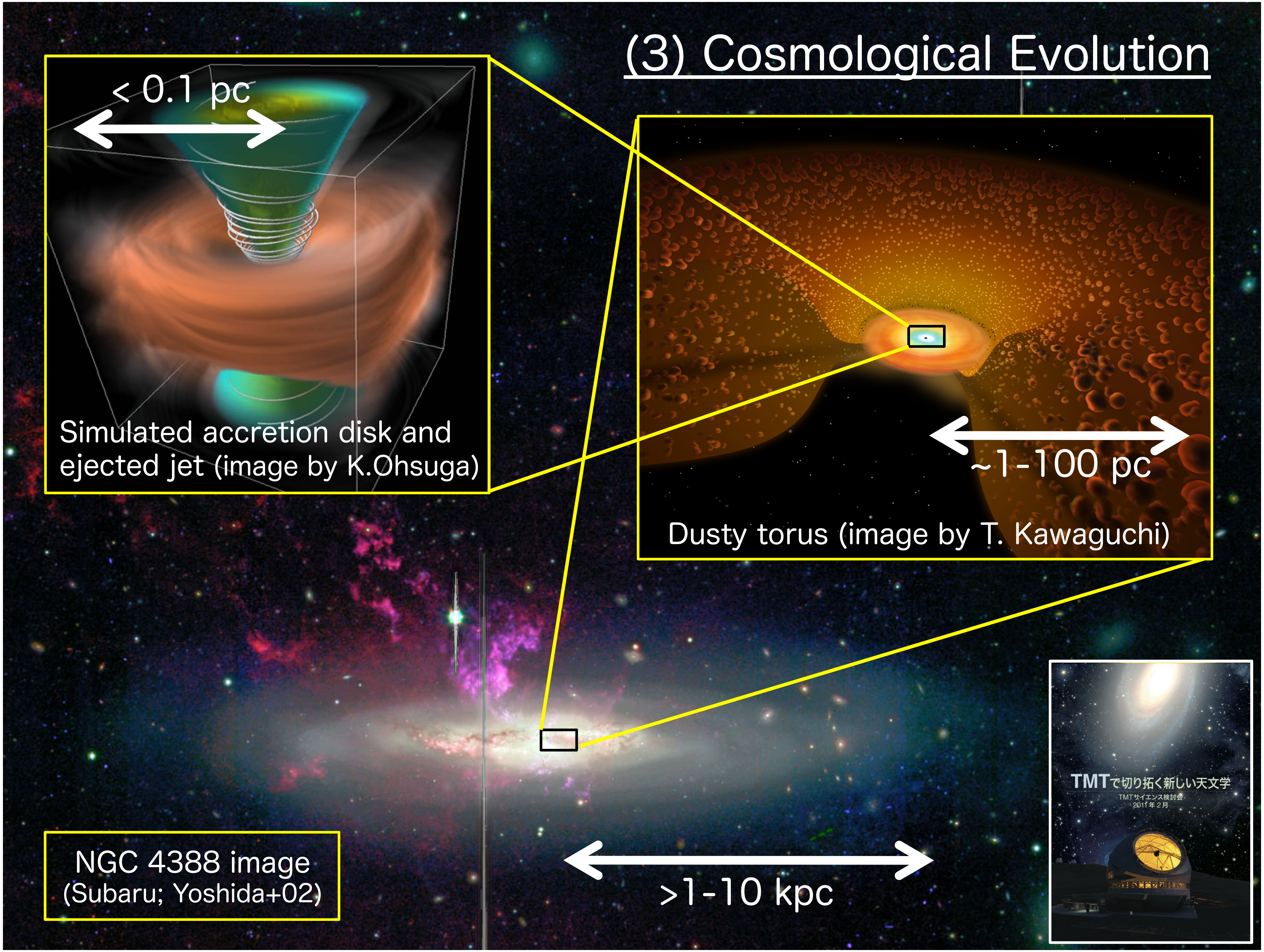
Powerful to explore the velocity structure in galaxies

~ 15 mas corresponds to 100pc @z~0.5, 150pc @z>1
~ matching with the ALMA resolution (most extended config.)
~ combining TMT & ALMA → both atomic & molecular phases



Understanding the quenching mechanism of the star formation is important, specifically at z~1-2 where the global SFRD and the accretion onto SMBHs start to decline.

Reddy et al. (2007)
see also the TMT Detailed Science Case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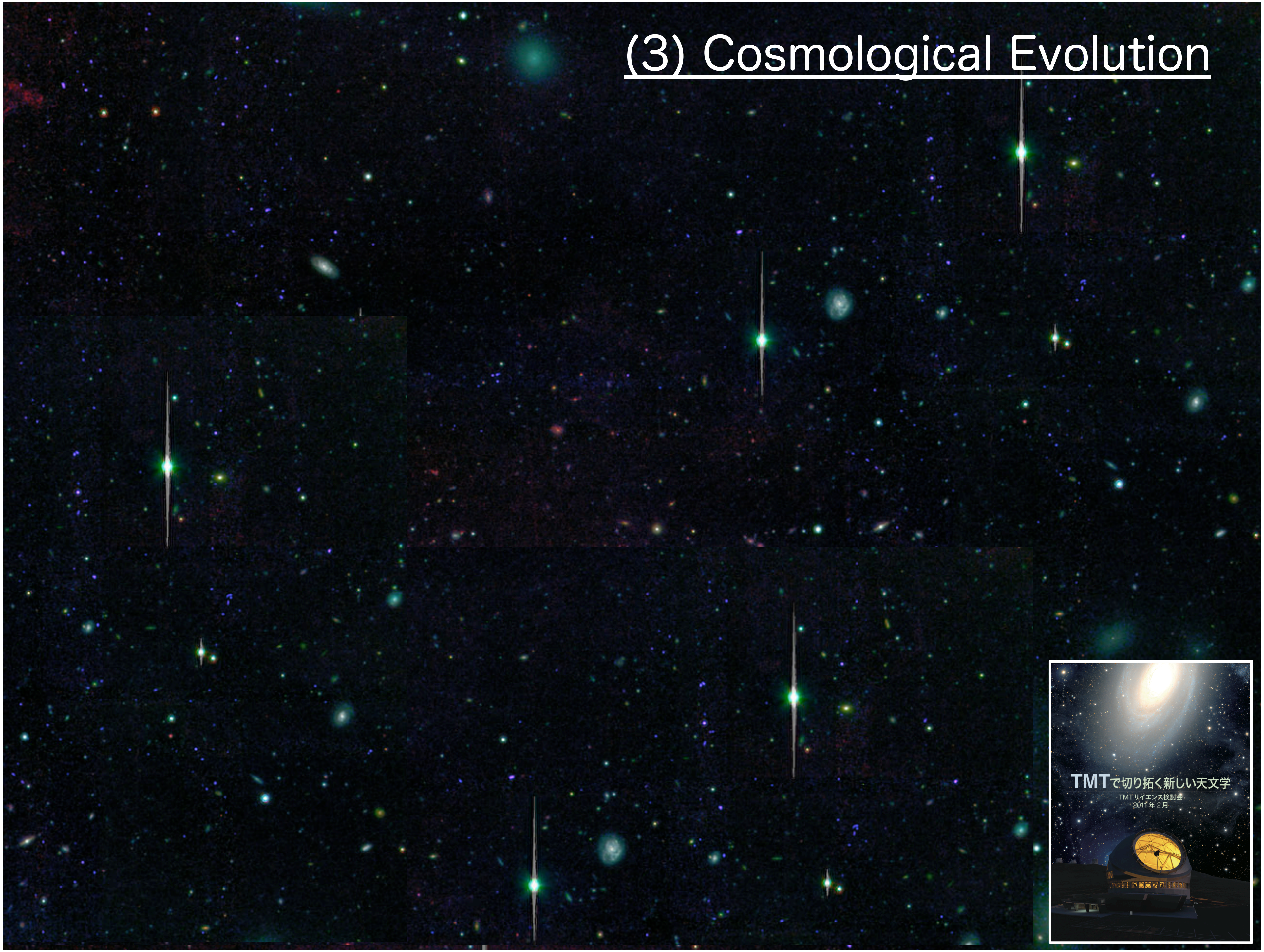
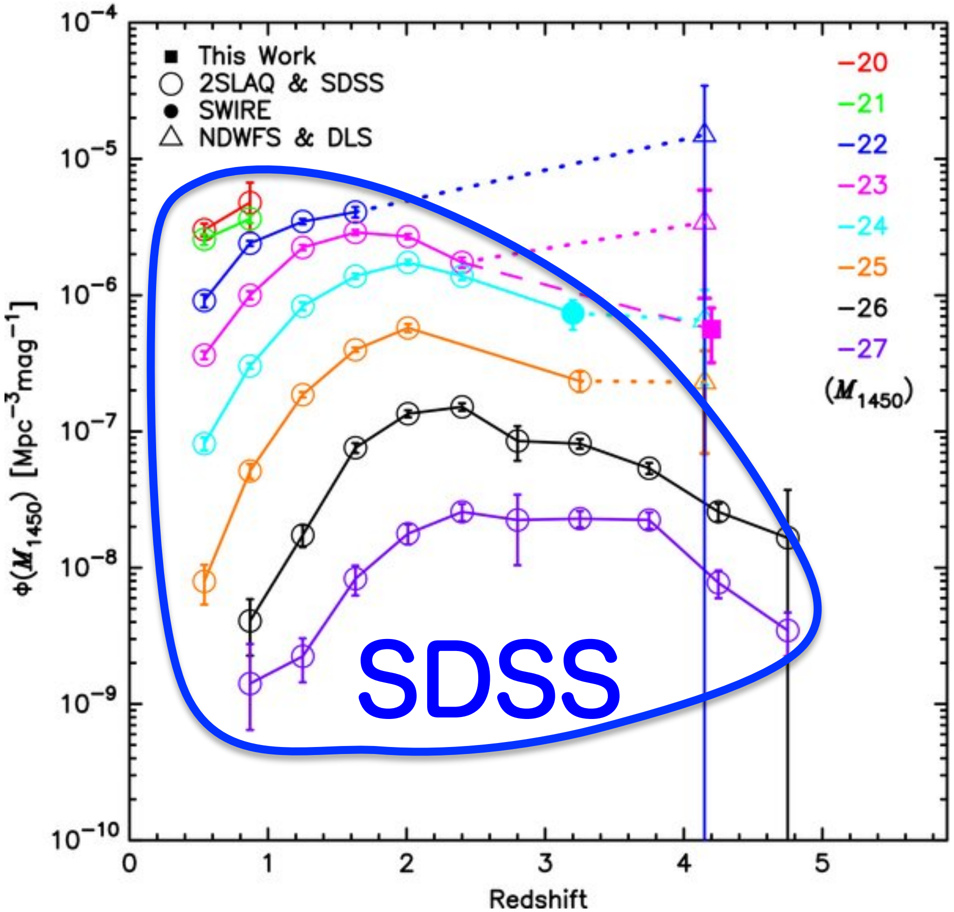
(3) Cosmological Evolution



Quasar Sample: SDSS Era



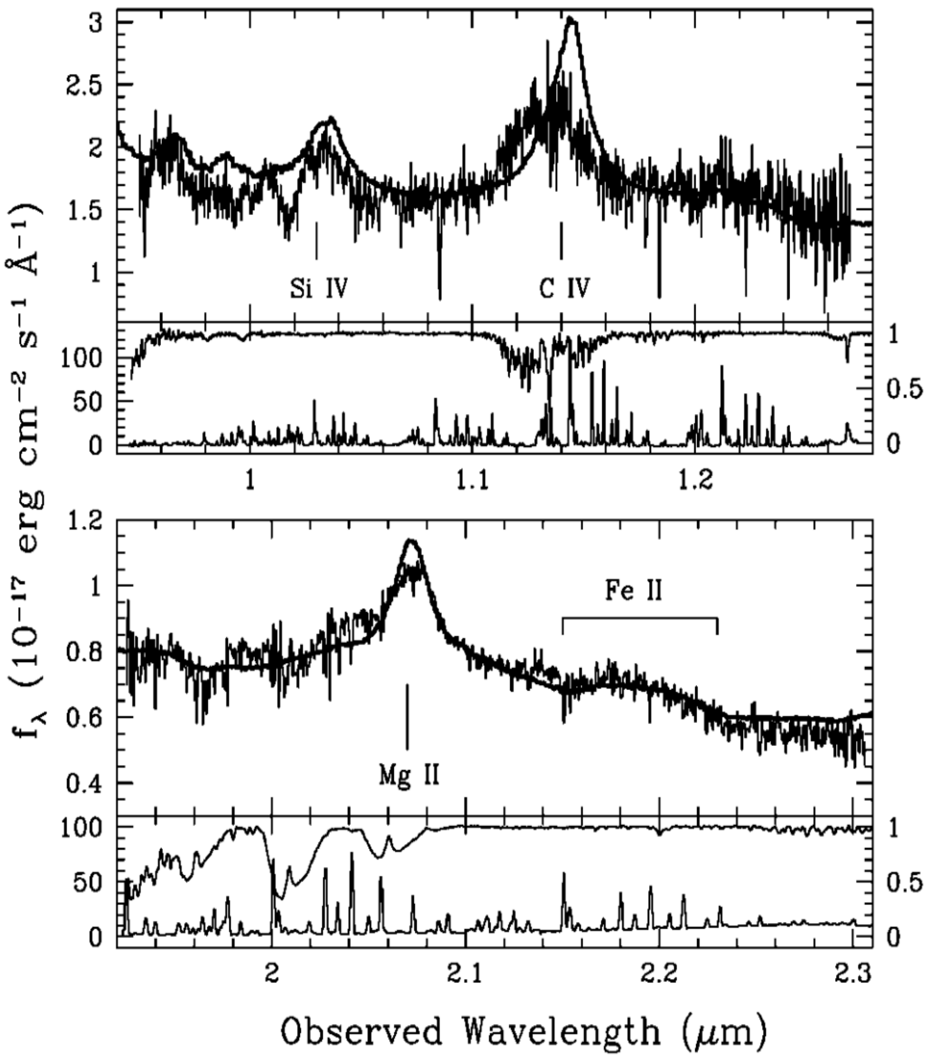
SDSS QSOs (i<21)

Detailed studies do not require TMT in general.

Ikeda, Nagao, et al. (2011,12)
high-z faint sample (COSMOS):
spectroscopically identified with Subaru/FOCAS

Quasar Sample: SDSS Era

SDSS J1148+5251 at z=6.4



Barth et al. (2003)

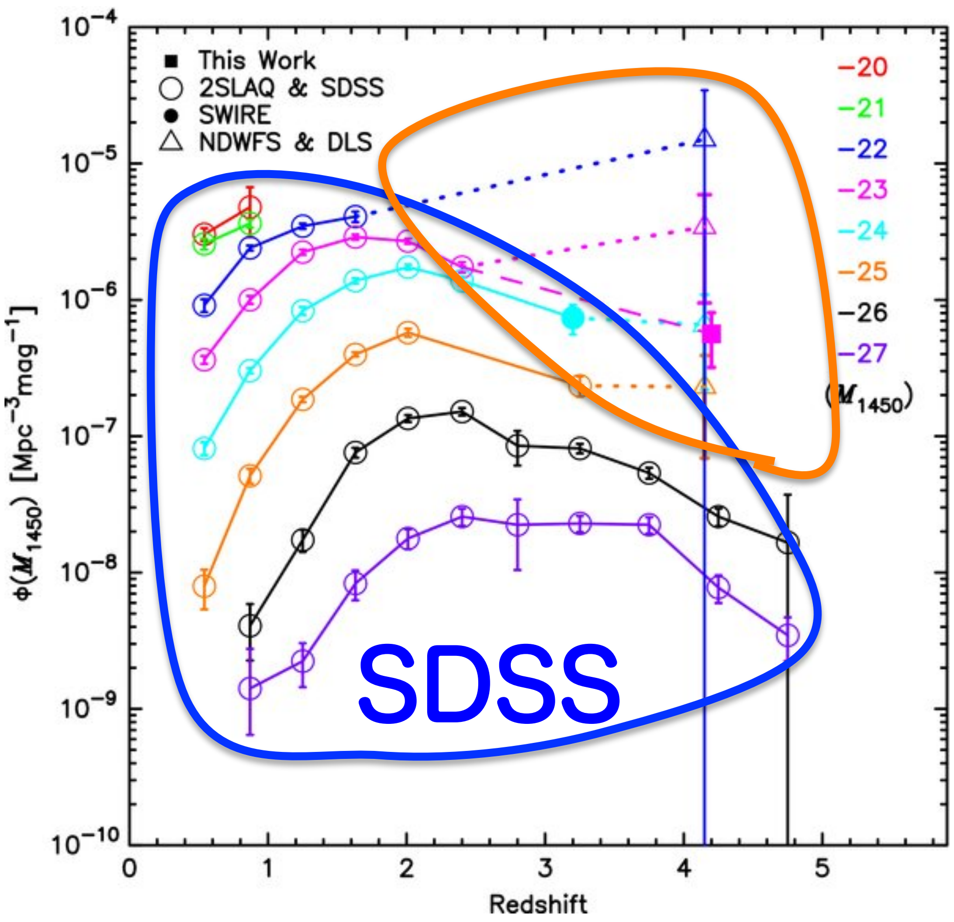
SDSS QSOs (i<21)

Detailed studies do not require TMT in general.

J & K spectra of a SDSS QSO at z=6.4 (z-band mag = 20.0), with Keck/NIRSPEC (2-3 hours for each)

→ M_{BH}, L/L_{Edd}, metallicity, absorption-line system, ...

Quasar Sample: Beyond SDSS



SDSS QSOs (i<21)

Detailed studies do not require TMT in general.

High-z Low-L QSOs (i>22)

Not yet been explored in detail... (especially at z>6)

Number density and its evolution are still controversial.
New systematic surveys for low-luminosity high-z quasars are needed, before detailed TMT observations (we need targets!).

Ikeda, Nagao, et al. (2011,12)
high-z faint sample (COSMOS):
spectroscopically identified with Subaru/FOCAS

Quasar Sample: Subaru/HSC → TMT

Hyper Suprime-Cam on Subaru

Subaru next-gen. wide-field camera
(FoV: 1.5 deg in diameter)
FL has been already done
Legacy survey will start soon
(>1000 deg^2, grizy 5 bands)

High-z Low-L QSOs

Detailed spectra needed for...

~ redshifts
~ M_{BH}, L_{AGN}/L_{Edd}
~ emission-line fluxes → metallicity
~ absorption line systems
~ IGM physical and chemical properties

TMT can measure these quantities, that will result in...

~ identifying very young proto-quasars
~ understanding the origin and evolution of SMBHs

Summary

(1) Structures around SMBHs

~ Resolving dusty tori and nuclear star formation
~ by possible 2nd-gen. MIR instrument with MIR-AO

(2) Gas inflow/outflow (or “feeding”/“feedback”)

~ AGN feedback at z>1 should be examined
~ by diffraction-limited IFS obs. with TMT/IRIS

(3) Cosmological evolution of SMBHs and AGNs

~ High-z low-luminosity quasars should be examined
~ Subaru/HSC will provide good targets to TMT
~ Detailed spectra will bring break-through results

※ Exposure Time Calculator for TMT (developed at TMT-J office) available at:
http://tmt.mtk.nao.ac.jp/ETC-e.html

ETC for TMT on the TMT-J server:
http://tmt.mtk.nao.ac.jp/ETC-e.html

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Home > TMT imaging ETC

TMT Imaging ETC (under construction)

For details of the calculation, please see TMT ETC Readme page.

Basic parameters of TMT first generation instruments (imaging mode)

	IRIS	MOBIE	IRMS
Wavelength coverage (μm)	0.8 – 2.4	0.31 - 1.1	0.95 - 2.45
Field of view	17".2 x 17".2	9'.6 x 4'.2	2' x 2'
Detector	Hawaii-4RG (4K x 4K pix)	Unreleased	Hawaii-2RG (2K x 2K pix)
Pixel scale (mas/pix)	4	50	60
Typical FWHM of PSF (mas)	8 with AO 600 w/o AO	800	8 with AO 600 w/o AO
Read out noise (electrons/pixel in rms)	12	3	15
Dark current (electrons/sec/pixel)	0.01	0.0003	0.01?
Total throughput (%)	~44-52 with AO	~27	~30-40 with AO

Source Geometry:

◉ Point Source	Aperture radius to calculate S/N = FWHM x 2.0
○ Extended Source	Extract square region of size = 1.5 x 1.5 arcsecond^2

Target Brightness:

K (2.1μm)

= 25.0 mag for point source

= 26.0 mag/arcsecond^2 for extended source

○ Vega ◉ AB

System Configuration:

Observatory Site: Hawaii Mt. Maunakea

Telescope Diameter: 30 (Ground) m

Airmass: 1.0

Pixel scale: 50 mas/pixel

FWHM of PSF: 600 mas

Read out noise: 10 electrons/pixel in rms

Dark current: 0.1 electrons/sec/pixel