# Synergetic studies with Subaru and SPICA

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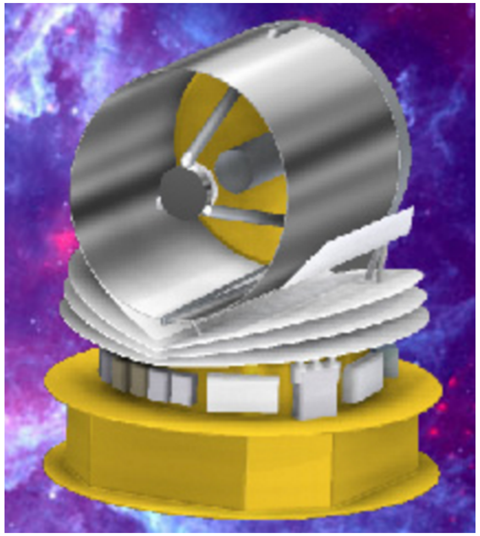

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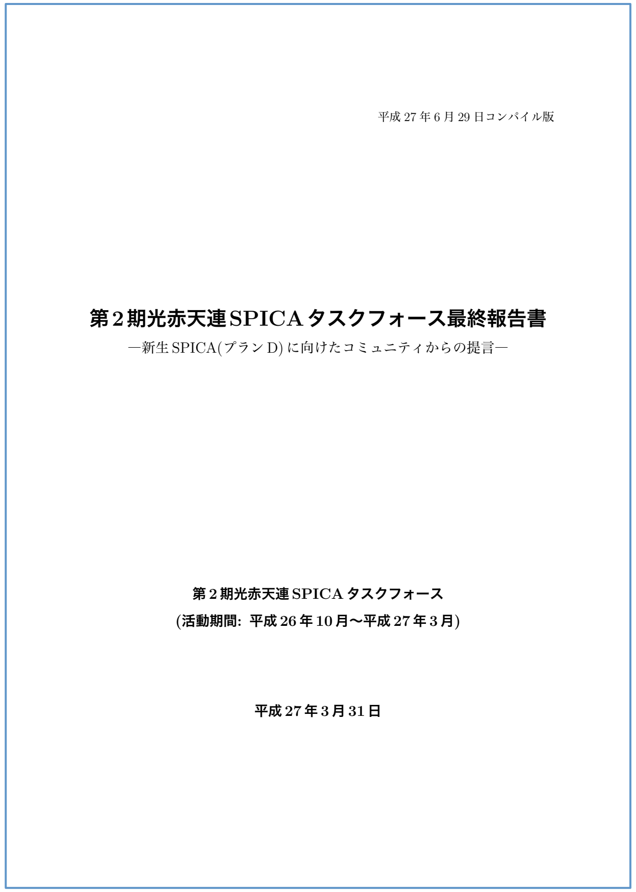
# GOPIRA SPICA Task Force (STF)

GOPIRA: Group of OPtical and InfraRed Astronomers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第２期光赤天連SPICAタスクフォース最終報告書

―新生 SPICA(プラン D) に向けたコミュニティからの提言―

第２期光赤天連SPICAタスクフォース

(活動期間: 平成 26 年 10 月～平成 27 年 3 月)

平成 27 年 3 月 31 日

## GOPIRA-STF (Oct.2014 – Mar.2015):

M. Honda, Y. Koyama, Y. Matsuda, T. Matsuo, T. Miyata, T. Nagao (chair), H. Nomura, and T. Takeuchi

## Purposes:

- ~ Reviewing the proposed SPICA sciences, and judging whether they are still feasible and scientifically valuable even after the change from Plan A/B to Plan D SPICA
- ~ Identifying new scientific ideas that newly become feasible thanks to the change to Plan D SPICA
- ~ Making a report summarizing the above items

※ The report was released in Jul. 2015, and now available at http://gopira.jp/stf/GopiraSTF_report.pdf

# From Plan A/B to Plan D

Aperture size (~3m → 2.5m) & Temperature (6K → 8K)
- ~ Reduced spatial resolution due to smaller aperture size
- ~ Higher temperature is not a problem at $\lambda$ < 230 μm
- ~ Wider field-of-view (now 10 x 10 arcmin$^2$ for SMI)

SAFARI (34-210 μm): Fourier spectrograph → Grating
- ~ Now no blank-field FIR spectroscopic surveys
- ~ A higher sensitivity for targeted spectroscopy

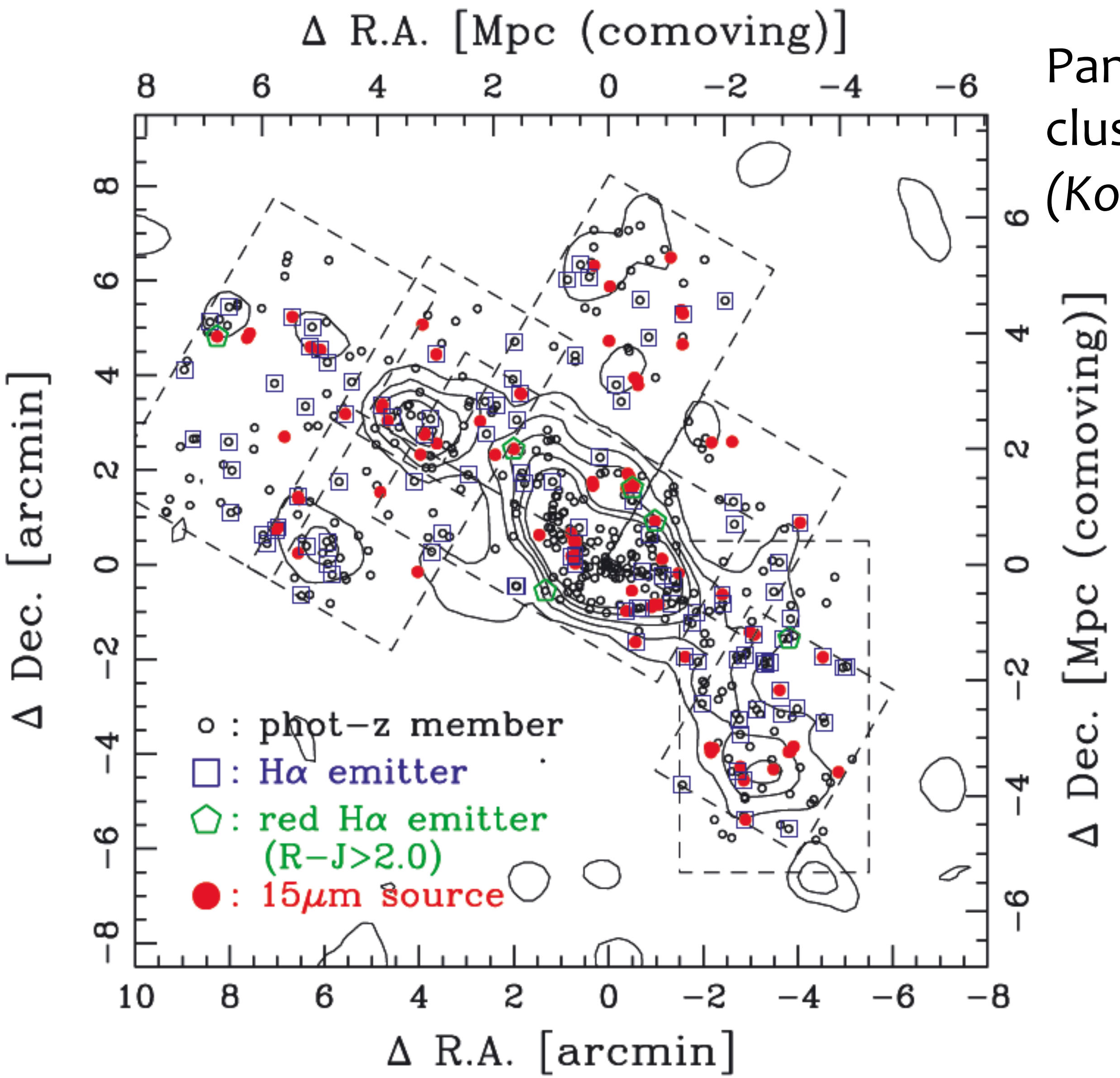
SMI (18-36 μm): New "low-R IFU" & "imaging" modes
- ~ *R*=50 @ 17–36 μm ← former *R*~20 "PAH mapper"
- ~ A new "slit-viewer" imaging capability at 34 μm

New high-dispersion mode on SMI
- ~ *R* = 20,000 – 30,000 @ 12–18 μm

# Wide and deep imaging with Subaru+SPICA

*Input from Koyama san*

# Subaru × AKARI wide-field synergy




Panoramic mapping of z=0.8 cluster with Subaru & AKARI (*Koyama+2010*)

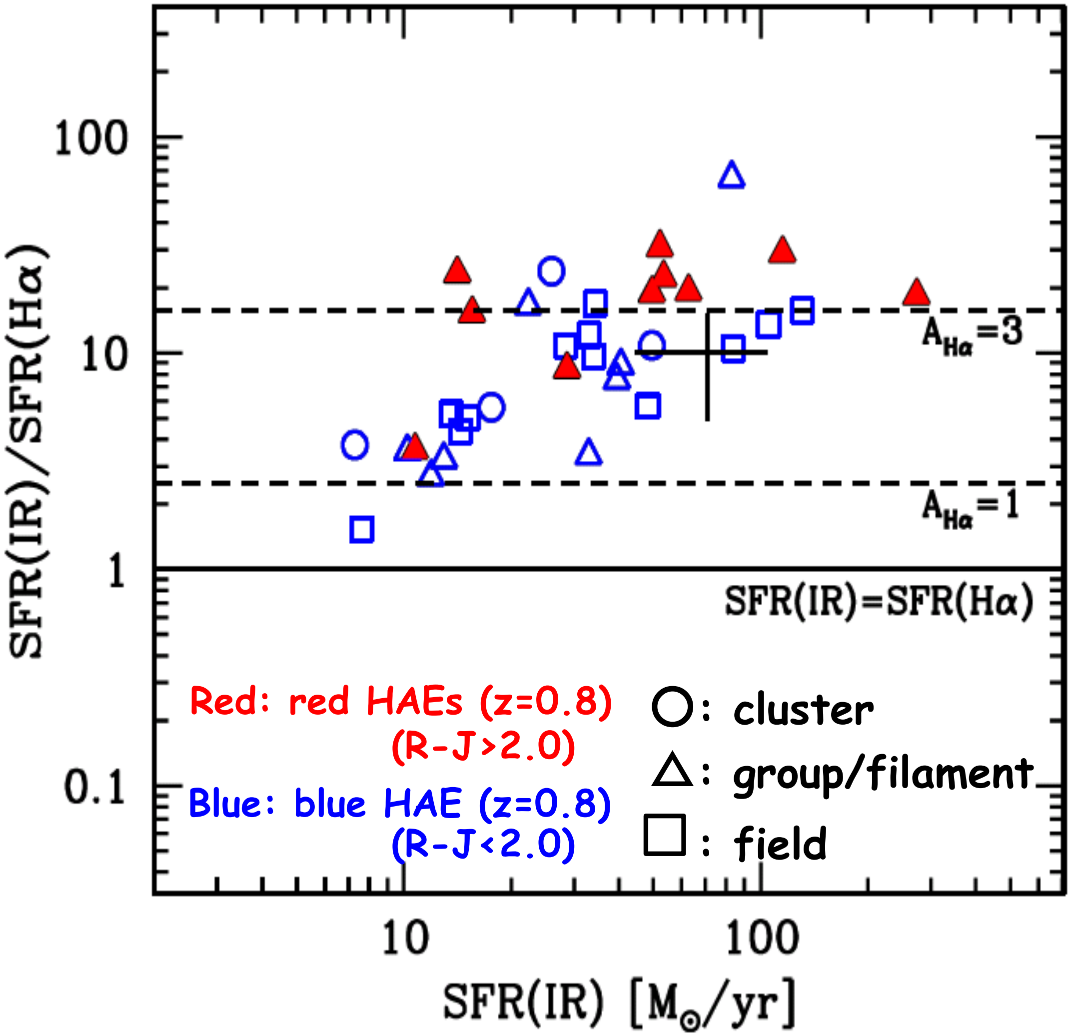
**S-Cam for mapping large-scale structure**

**MOIRCS to derive SFR(Hα) & M★**

**AKARI/IRC 15um for rest-8um mapping dust-obscured SFR**

*Input from Koyama san*

# Subaru × AKARI wide-field synergy



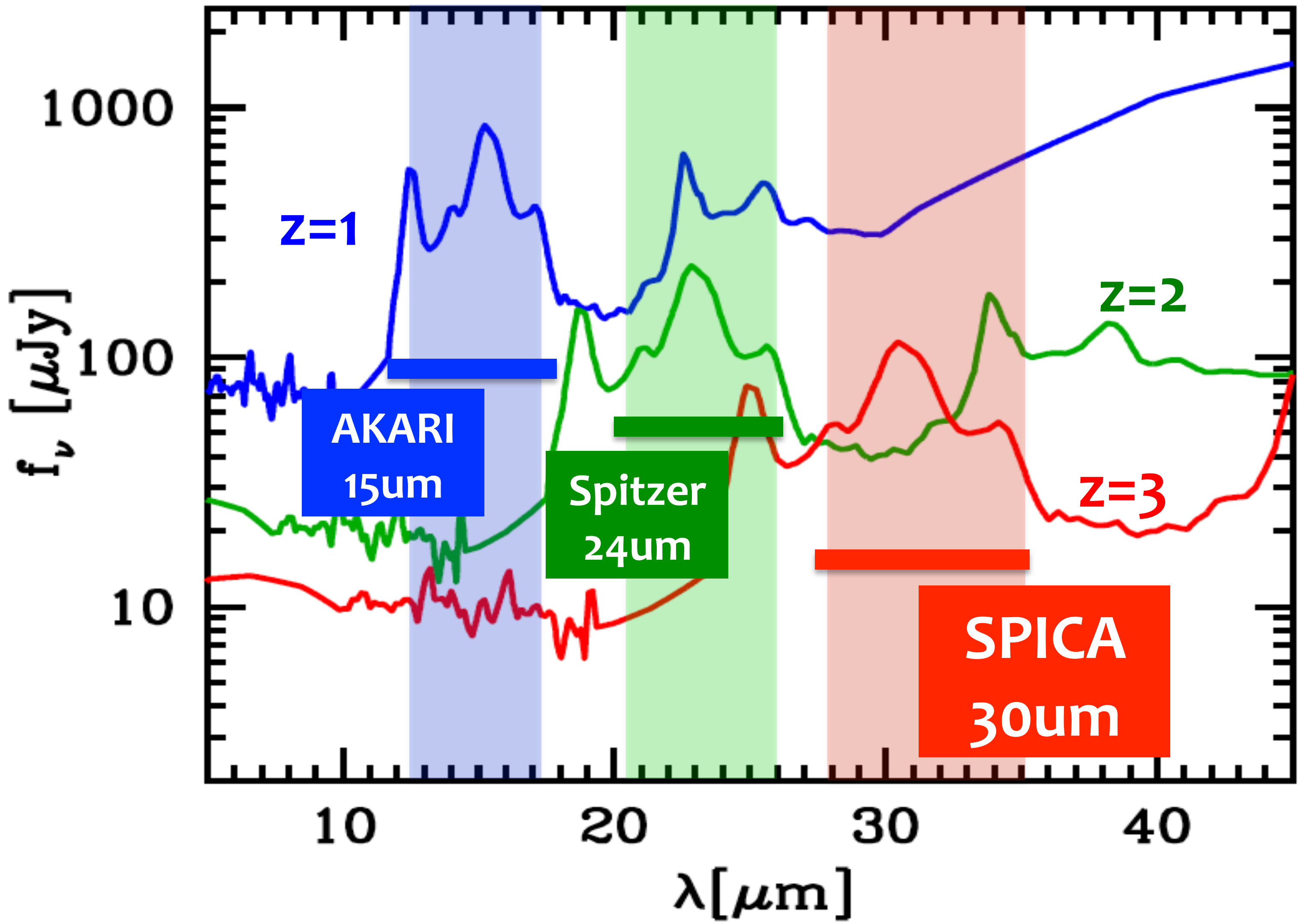

Panoramic Ha & MIR mapping of z=0.8 cluster revealed that extremely dusty galaxies (with AHa > 3 mag) are preferentially located in group-scale environments.

*(Koyama et al. 2010)*

*Input from Koyama san*

# SPICA can go deeper (w/ rest-8um)

ULIRG SEDs with typical flux limits for AKARI / Spitzer / SPICA



*Input from Masayuki Tanaka san,*
*on behalf of the galaxy evolution WG in the Gopira future-planning discussion*

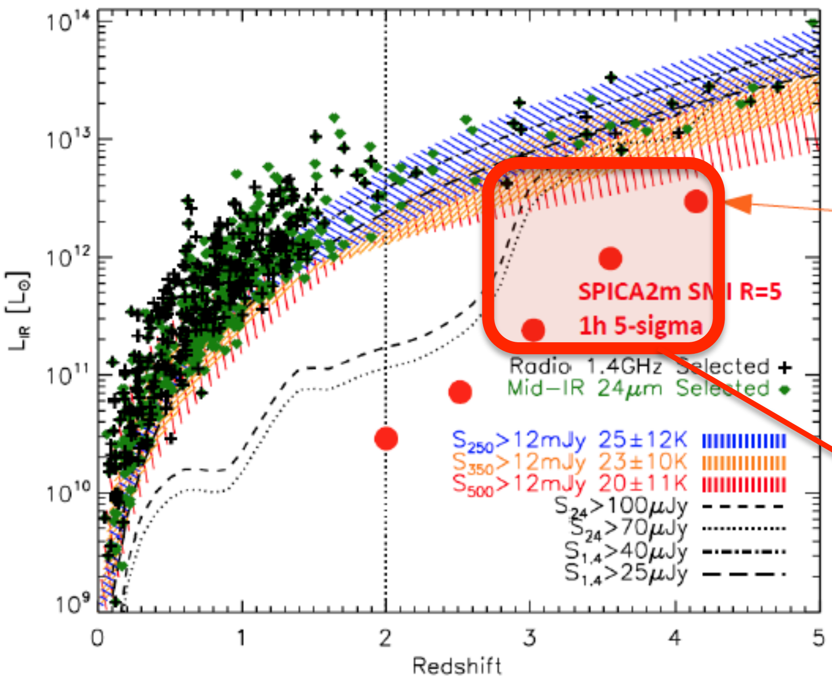
# Synergy between Subaru and SPICA

- SPICA will hopefully fly in late 2020's.
- An obvious synergy: wide-area optical/nearIR imaging+spectroscopy from Subaru and IR data from SPICA.
- Optical data will be from HSC+PFS. SSP data will be available around the equator. No such wide+deep data set is currently secured around NEP, where the visibility from SPICA is best. Perhaps a dedicated program is needed.
- There are a few options for near-IR data: the best is WFIRST. If WFIRST does not cover the equator or the northern hemisphere at all, then EUCLID is the $2^{nd}$ choice. ULTIME-Subaru may also contribute here with K-band and narrow/medium bands over a wide area.
- Given the SPICA's schedule, the synergy will be like “Subaru paves the road for SPICA with wide-area optical/nearIR data before it flies.”
- From the galaxy evolution point of view, mid-IR survey to extend Spitzer/MIPS to higher redshifts is very interesting and perhaps that is where we can expect a strong synergy with Subaru (see next slide).

*Input from Masayuki Tanaka san,*
*on behalf of the galaxy evolution WG in the Gopira future-planning discussion*

# Synergy between Subaru and SPICA

Mid-IR observations of star forming galaxies over a wide area (~10 sqdeg) will have a lot of synergy with Subaru – some of these IR galaxies may be very dusty and deep optical/nearIR data will be essential to understand the nature of these galaxies, and also follow-up spectroscopy with PFS to measure redshifts, SFRs, and metallicity of the IR sources will be very complementary to the SPICA's science. Far-IR spectroscopy from SPICA will then unveil detailed physics of star formation and chemical enrichment.




Casey et al. 2012

Note 1: JWST/MIRI also has imaging capability, but with a very small FoV:
MIRI: (1.2'x1.9')x($\pi$x6.5m^2) ~ 300
SMI: (10'x10')x($\pi$x2.5m^2) ~ 1960

SPICA is more sensitive than MIPS and reaches higher redshifts. The plot is for 2m (2.5m should be better). A statistical study of star forming galaxies out to z~4 will be very unique Subaru + SPICA science.

Note 2: 4000A-break feature shifts at $\lambda$>1.6$\mu$m for galaxies at z > 3, thus we need deep & wide K-band image
→ UltimateSubaru, not WFIRST/Euclid

# Beyond z=5 with Subaru+SPICA

# Dust in high-z quasars: SDSS+Spitzer view

nature

LETTERS

## Dust-free quasars in the

Linhua Jiang[1], Xiaohui Fan[1,2], W. N. Brandt[3], Chris L.
Gordon T. Richards[7], Yue Shen[8], Michael A. Strauss[9]

**The most distant quasars known, at redshifts $z \approx 6$, generally ha properties indistinguishable from those of lower-redshift quas in the rest-frame ultraviolet/optical and X-ray bands[1–3]. This pu ling result suggests that these distant quasars are evolved obje even though the Universe was only seven per cent of its current a at these redshifts. Recently one $z \approx 6$ quasar was shown not to ha any detectable emission from hot dust[4], but it was unclear wheth that indicated different hot-dust properties at high redshift or i is simply an outlier. Here we report the discovery of a seco quasar without hot-dust emission in a sample of 21 $z \approx 6$ quasa Such apparently hot-dust-free quasars have no counterparts at l redshift. Moreover, we demonstrate that the hot-dust abundan in the 21 quasars builds up in tandem with the growth of t central black hole, whereas at low redshift it is almost independ of the black hole mass. Thus $z \approx 6$ quasars are indeed at an ea evolutionary stage, with rapid mass accretion and dust formati The two hot-dust-free quasars are likely to be first-generati quasars born in dust-free environments and are too young to ha formed a detectable amount of hot dust around them.**

More than 40 quasars have been discovered at redshifts $z \approx 6$ (r 5, 6); at this epoch, the Universe was less than one billion years o They harbour black holes with masses higher than $10^8$ solar mas ($10^8$ $M_\odot$) and emit radiation at about the Eddington limit According to unification models of active galactic nuclei, the bla hole accretion disk is surrounded by a dusty structure[8,9]. A significa fraction of the quasar's ultraviolet and optical radiation is absorb by the dust and is re-emitted at infrared wavelengths. In particul the hottest dust is directly heated by the central engine and produ near-infrared (NIR) emission[10–12]. Radiation from hot dust observed to be a ubiquitous feature among quasars, and is stro evidence for these unification models.

In order to study the properties of hot dust at high redshift, obtained deep infrared photometry of 21 $z \approx 6$ quasars using the

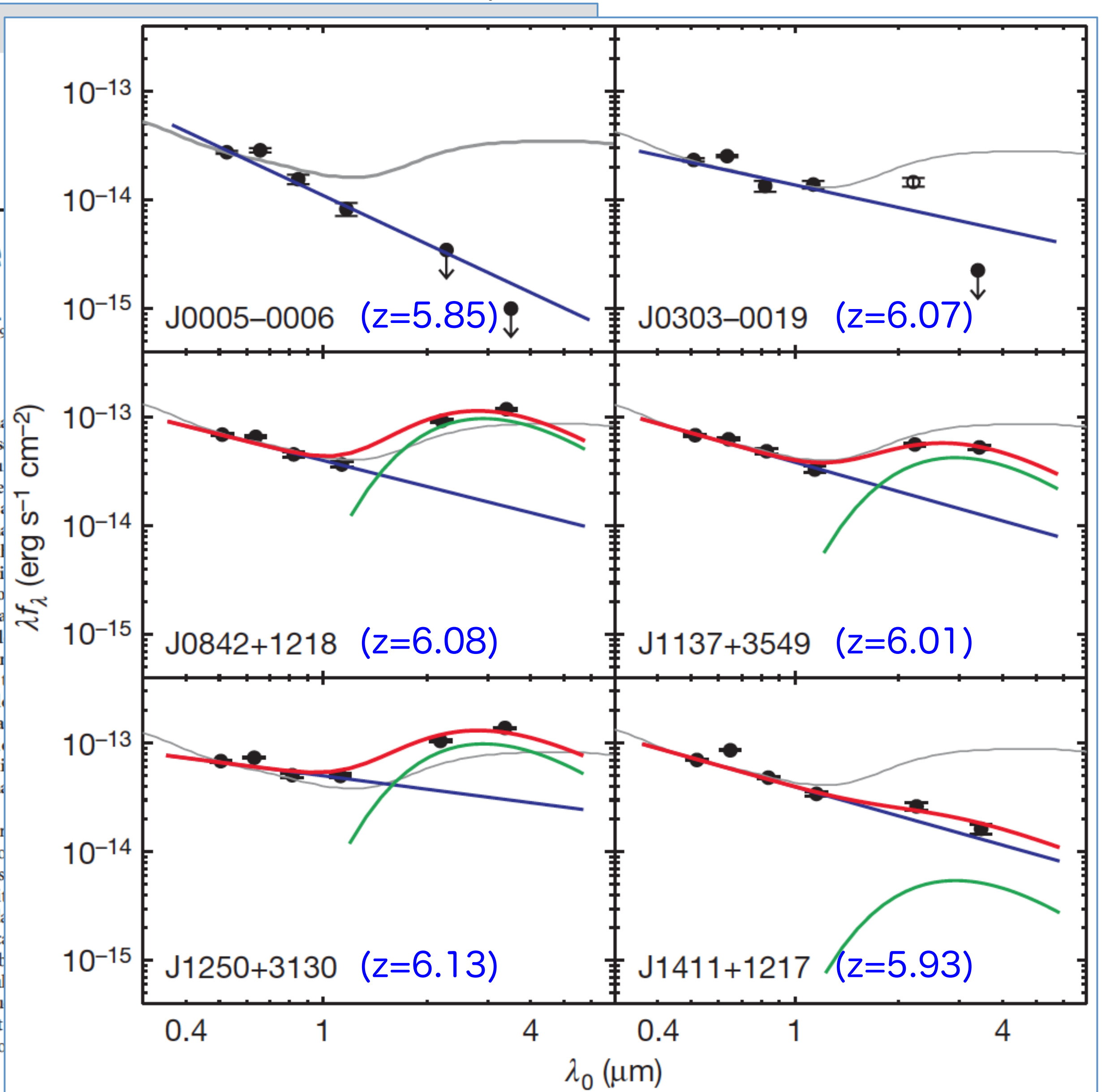



**Figure 1 | Spitzer SEDs of $z \approx 6$ quasars.** Filled circles, rest-frame SEDs of six representative quasars from our sample in the four IRAC channels, the

Jiang+10

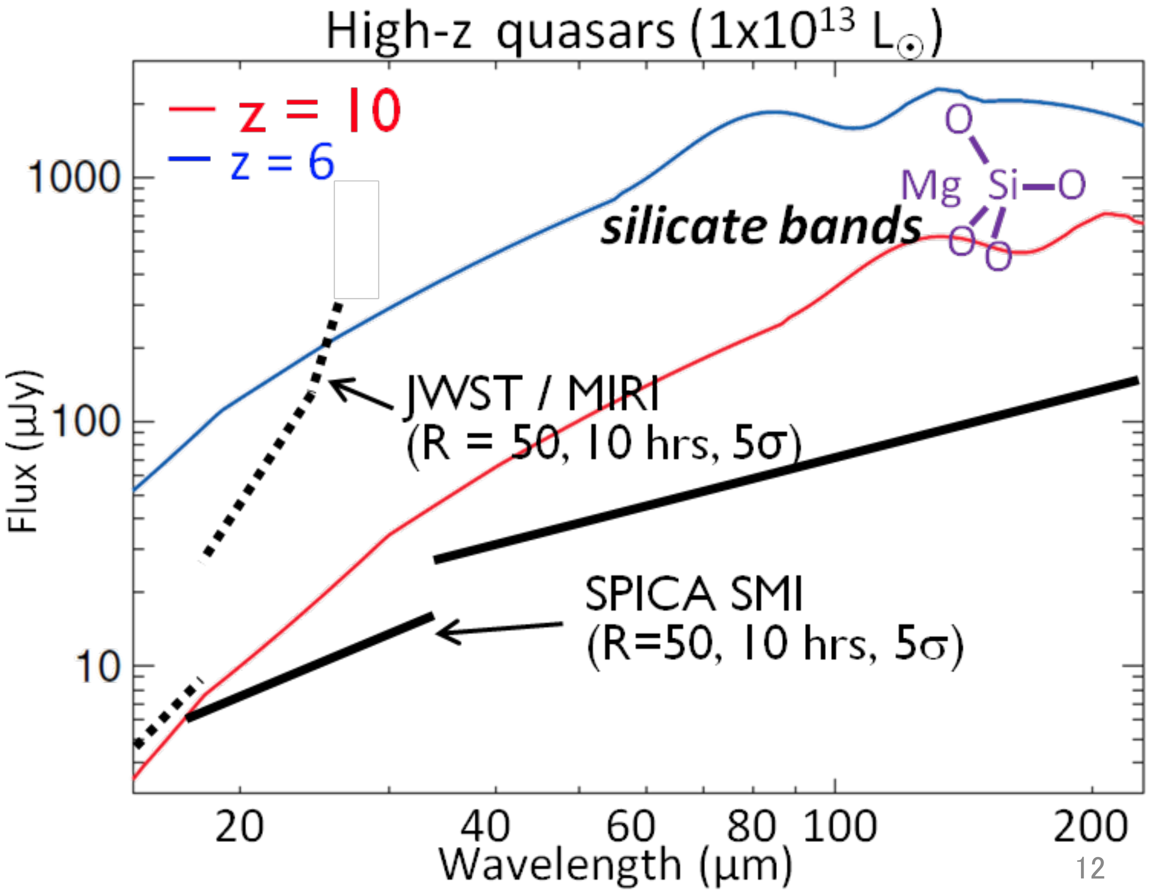
# Dust in high-z quasars: SPICA view

- Really "dust-free"? Lacking only "hot-dust" component?
- How common at z~6 ? How about z > 6 ?

→ SPICA can detect both hot and warm dust, even at z~10
(Note1: JWST-MIRI can detect only hottest dust at z < 7 ...)

Note 2: ALMA can also detect dust in high-z quasars, but only for "cool" component

Note 3: SPICA's wide $\lambda$-coverage enables to detect silicate features → constraints on the grain abundance




From SPICA team document

# Targets (z~6-7 quasars) will be provided by HSC


Subaru High-z Exploration of Low-Luminosity Quasars (SHELLQs) led by Matsuoka-san (HSC Project 047)

# Beyond z > 7.5: HSC + Euclid/WFIRST for SPICA

Euclid white paper says:

~ quasars at z~8-9: ~30 obj. for J<22 or 55 obj. for J<22.5 in Wide

~ variability-selected low-L AGNs (1<z<4) in Deep (at NIR: new!)

WFIRST white paper says:

~ quasars at z~8-9: ~100 fainter obj. for J<24 in HLS

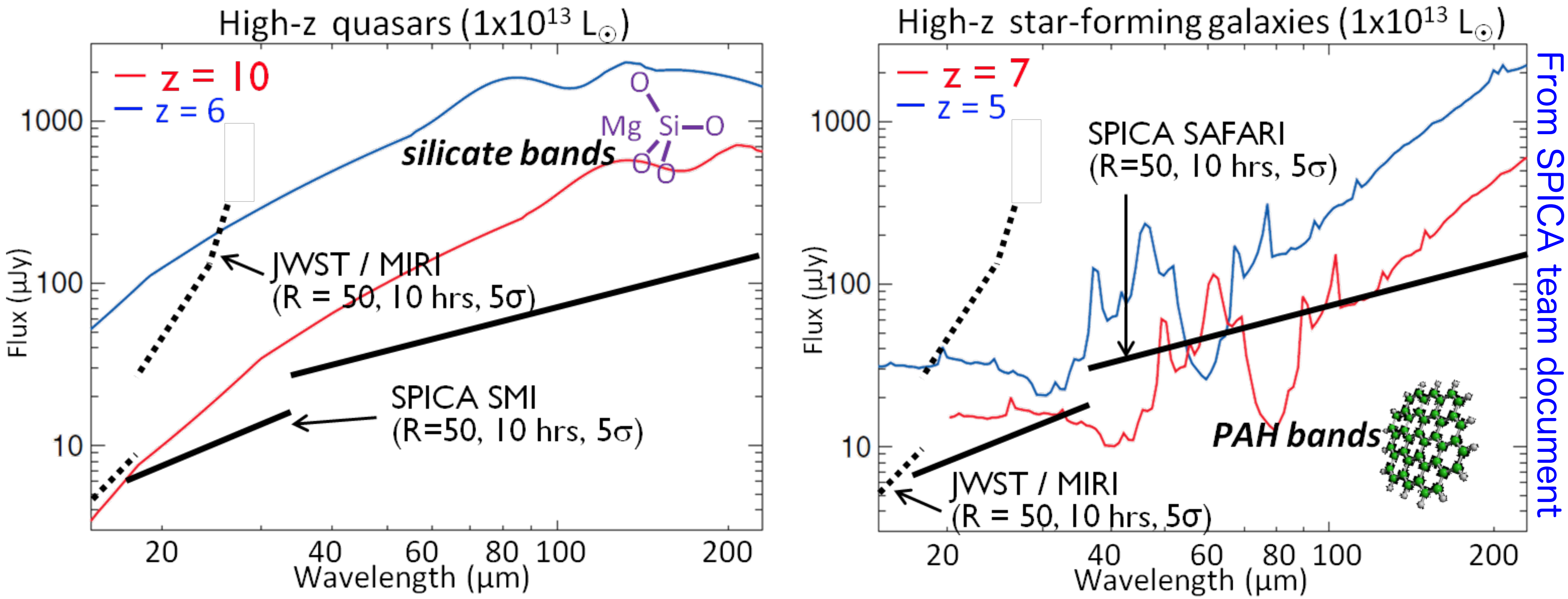
~ variability-selected low-L AGNs (1<z<9) in SN-Wide

How to select photometric candidates of high-z quasars?

→ Wide and moderately deep HSC images for Euclid-Wide regions are extremely powerful

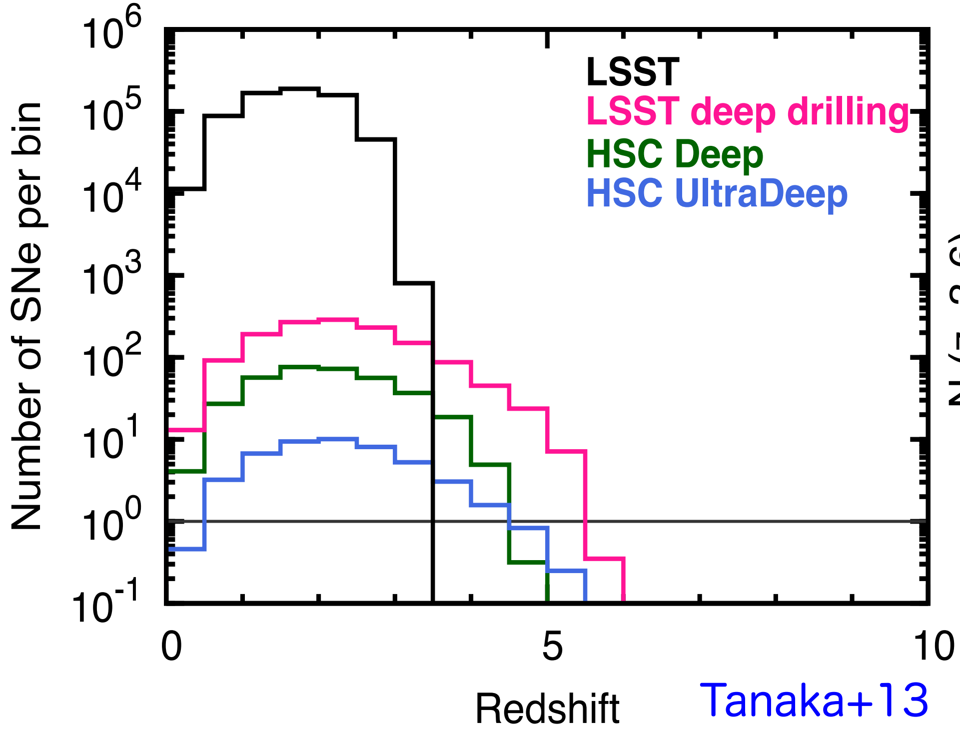
Note: HSC multi-band images for Euclid-Wide regions are extremely powerful not only for high-z quasars, but also for photo-z improvements (→ galaxy evolution studies, cosmology, etc...)

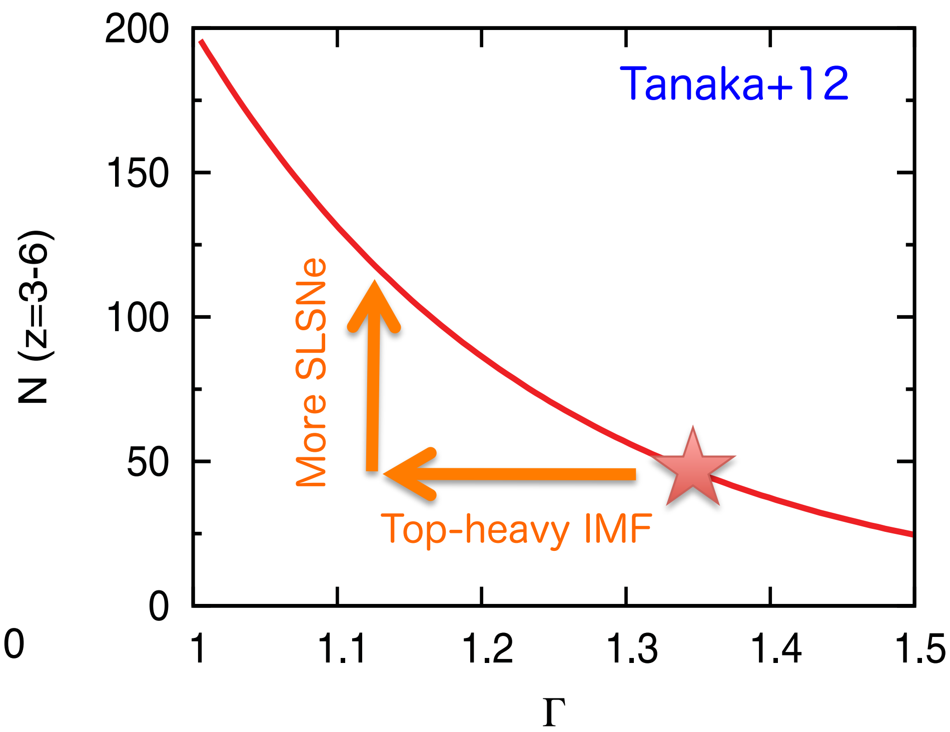
# Also high-z starburst galaxies, not only quasars




- ➢SPICA can detect PAH (and some continuum) emission of z~7 powerful starburst galaxies (but JWST/MIRI cannot)
- ➢Combining MIR spectra of quasars and starbursts at high-z
  - → typical composition of grains (silicate vs carbonaceous)
  - → info on the IMF of high-z stars (or Pop III stars)
    (e.g., Todini+01, Nozawa+03, Schneider+04, Nozawa+14, ...)

# + HSC SLSN searches → further info on IMF




Current HSC survey => SLSN @ z ~ 4-5
Future HSC or LSST => SLSN @ z ~ 7

Number of SLSN: sensitive to the IMF slope (for a given SFR)

Combining SPICA and HSC-SLSN datasets, we will investigate the IMF at very high-z Universe

# Summary

- Extremely powerful MIR imaging survey with SPICA
  - ~ at 34 μm (SMI "slit-viewer" mode)
  - ~ wide-field survey with Subaru+SPICA for full understanding of star-formation at z~3-4
  - ~ UltimateSubaru will be a key for the SED analysis

- SPICA's superb spectroscopic sensitivity at MIR-FIR
  - ~ revealing the dust properties in quasars at $z > 6$
  - ~ silicate features can be detected up to $z \sim 10$
  - ~ targets will be brought from the current HSC-SSP and future Euclid-HSC survey (at $z > 7.5$)
  - ~ PAH in luminous SBGs at z~7 is also detectable
  - ~ combination of SPICA high-z spectroscopy and HSC-SLSN survey will give us info on high-z IMF