Cosmci star formation history revealed with the AKARI space telescope

Tomo GOTO (NTHU),
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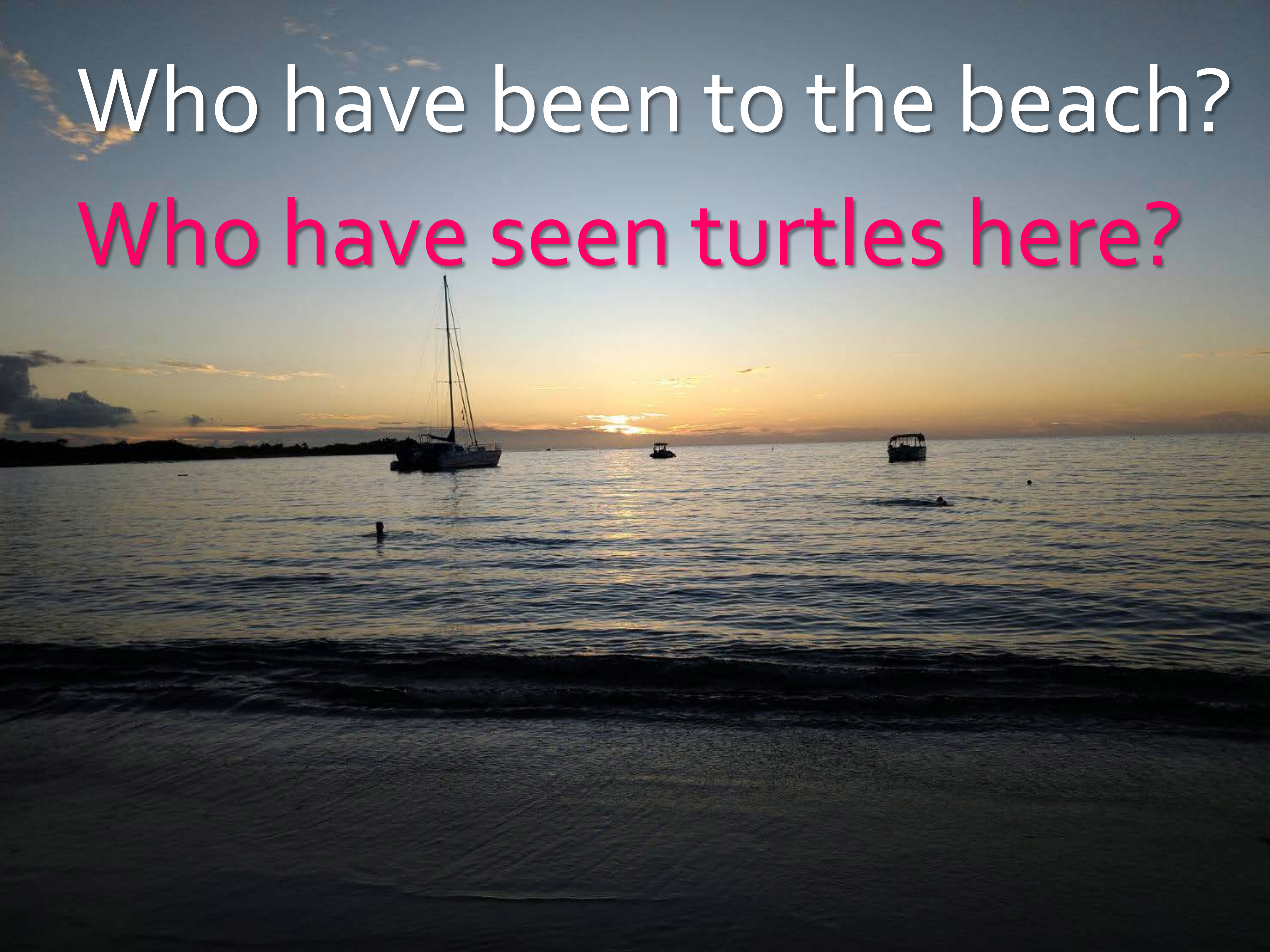
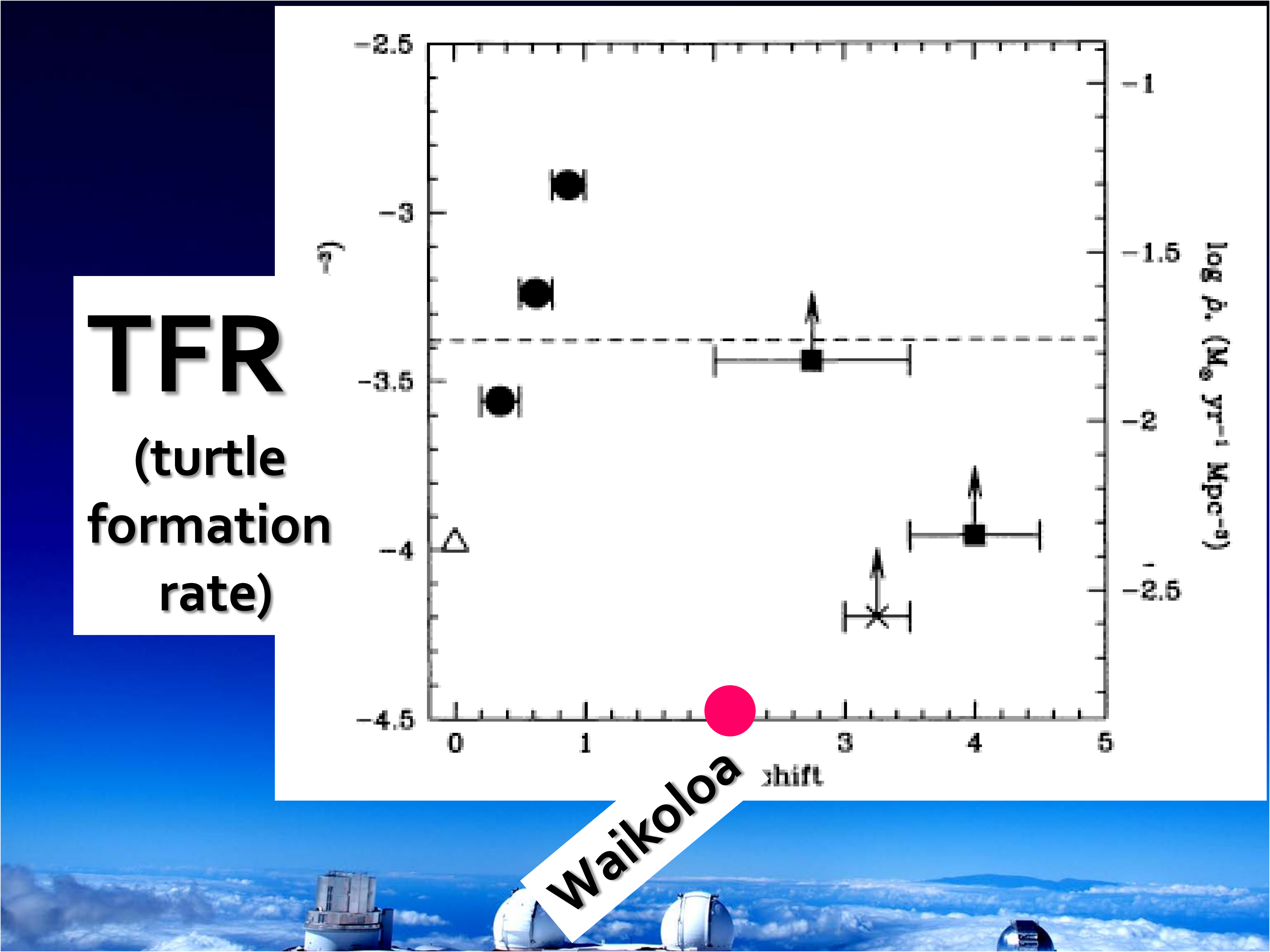
AKARI NEP team, AKARI ASS team, Korean AKARI team…

Astro-F AKA


Who have been to the beach?
Who have seen turtles here?



TFR
(turtle formation rate)
Waikoloa
−2.5
−3
−3.5
−4
−4.5
0
1
3
4
5
hift
−1
−1.5
−2
−2.5
log ρ̇, (M⊙ yr⁻¹ Mpc⁻³)


TFR>0
at z=Waikoloa

Obscured TFR

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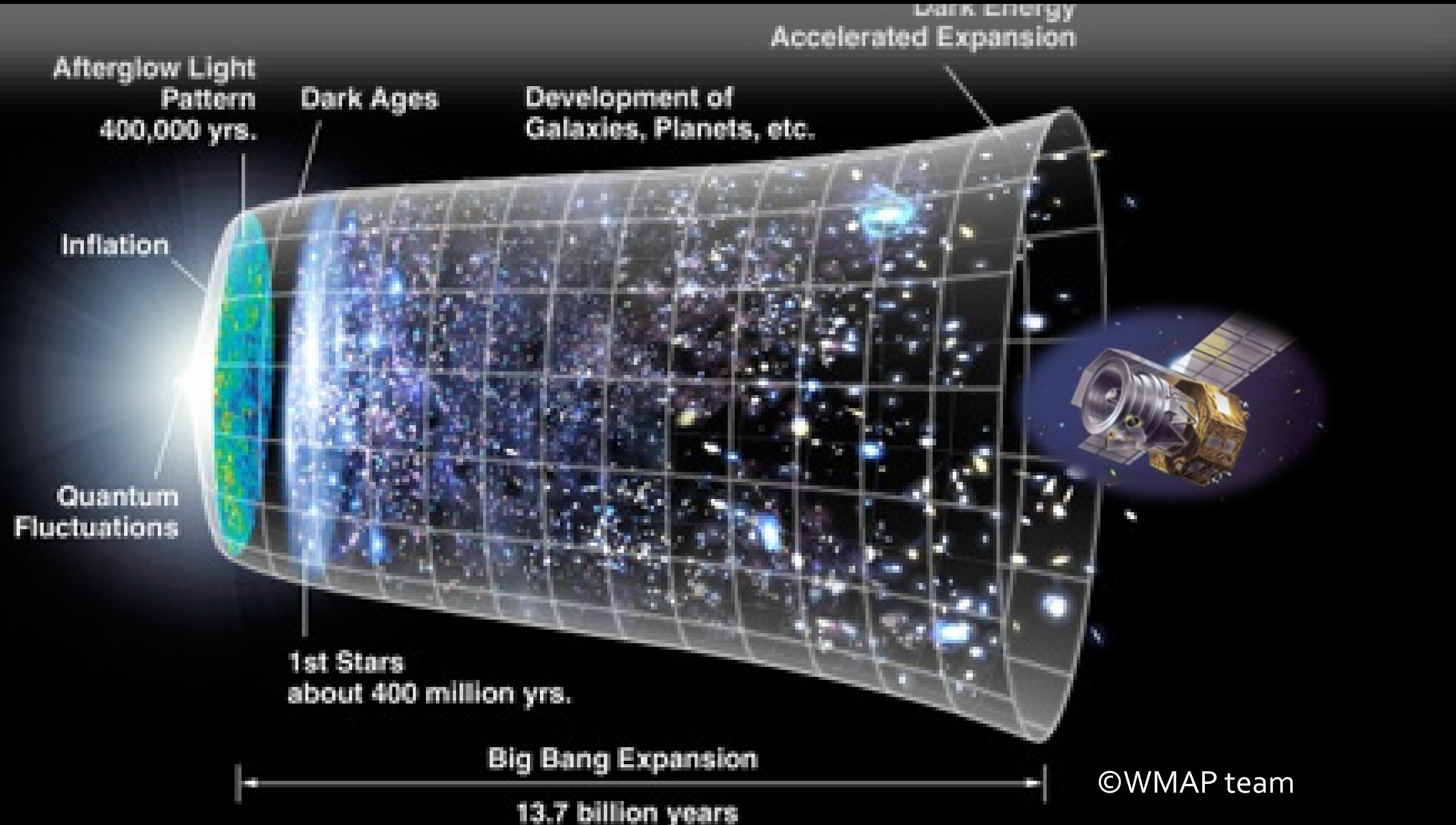
AKARI NEP team, AKARI ASS team, Korean AKARI team…

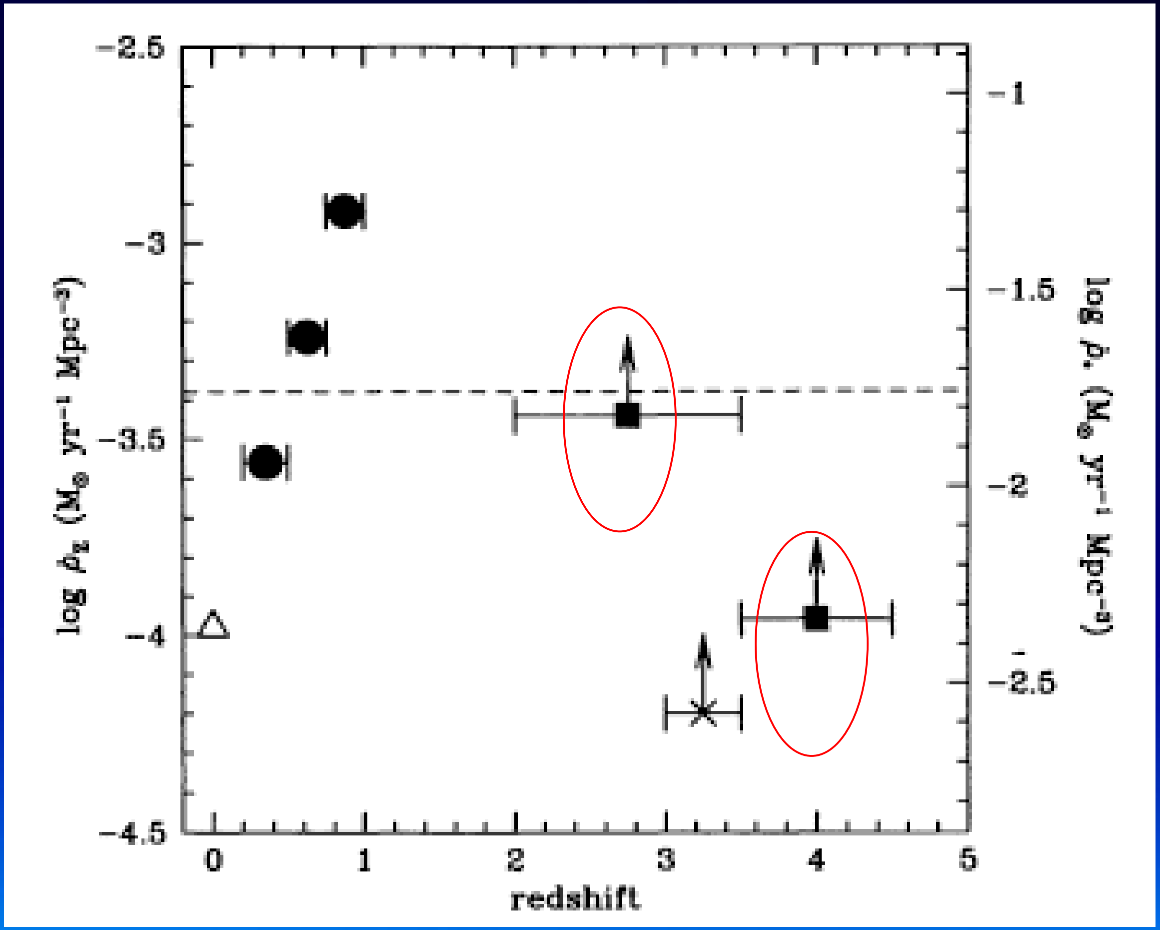
When and where stars/AGN were born?



©WMAP team

We want to reveal cosmic star formation history.

Understanding star formation history of the Universe is one of the major goals, however…



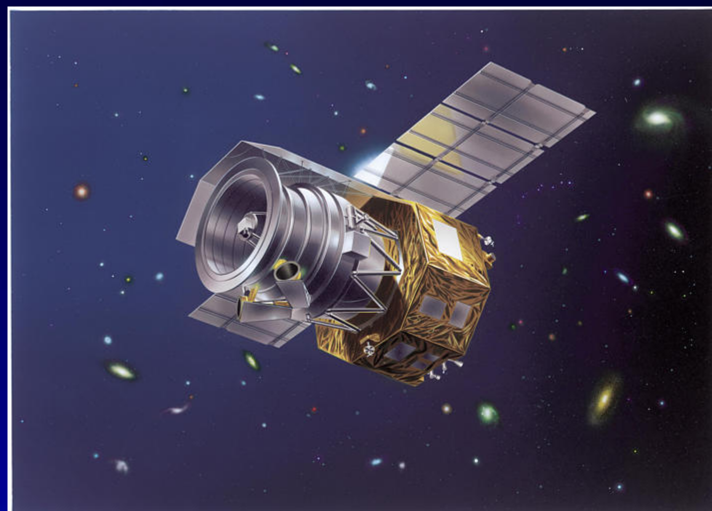
Madau et al. (1996)
Lilly et al. (1996)

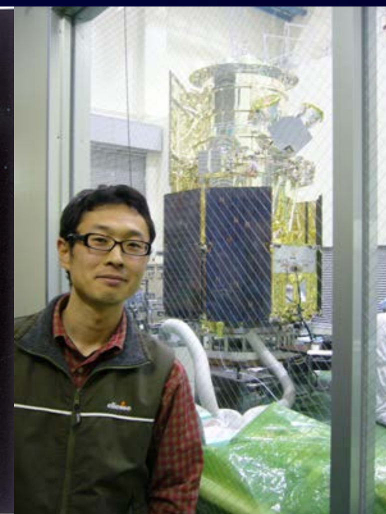
UV estimates are lower limits.

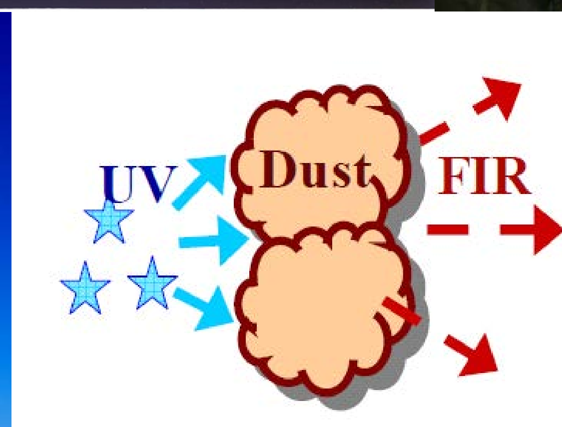
At z～1, 80% of SF is obscured by dust. (Takeuchi+2007)

How do we measure obscured star formation？

AKARI infrared telescope can probe dusty star formation

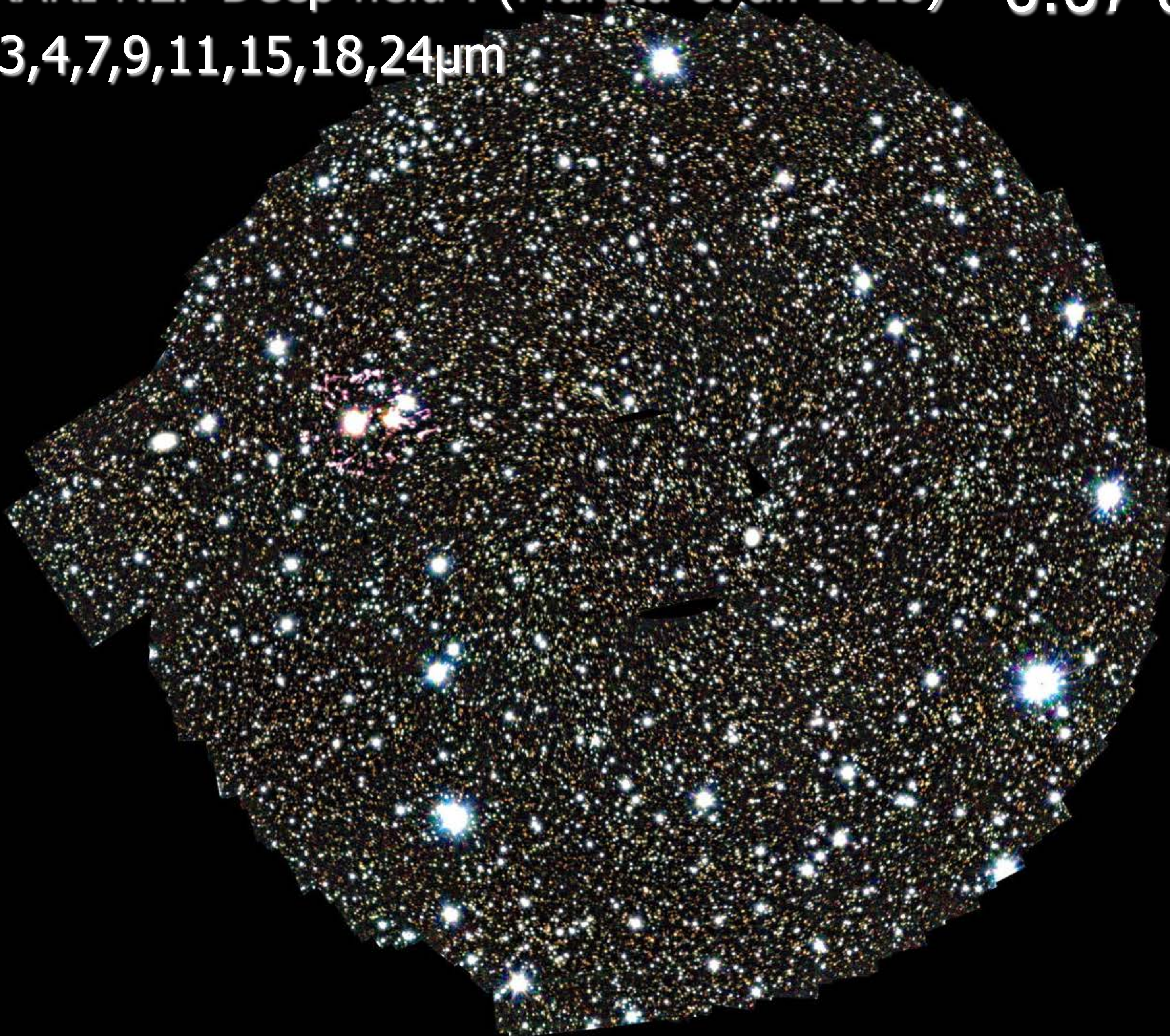




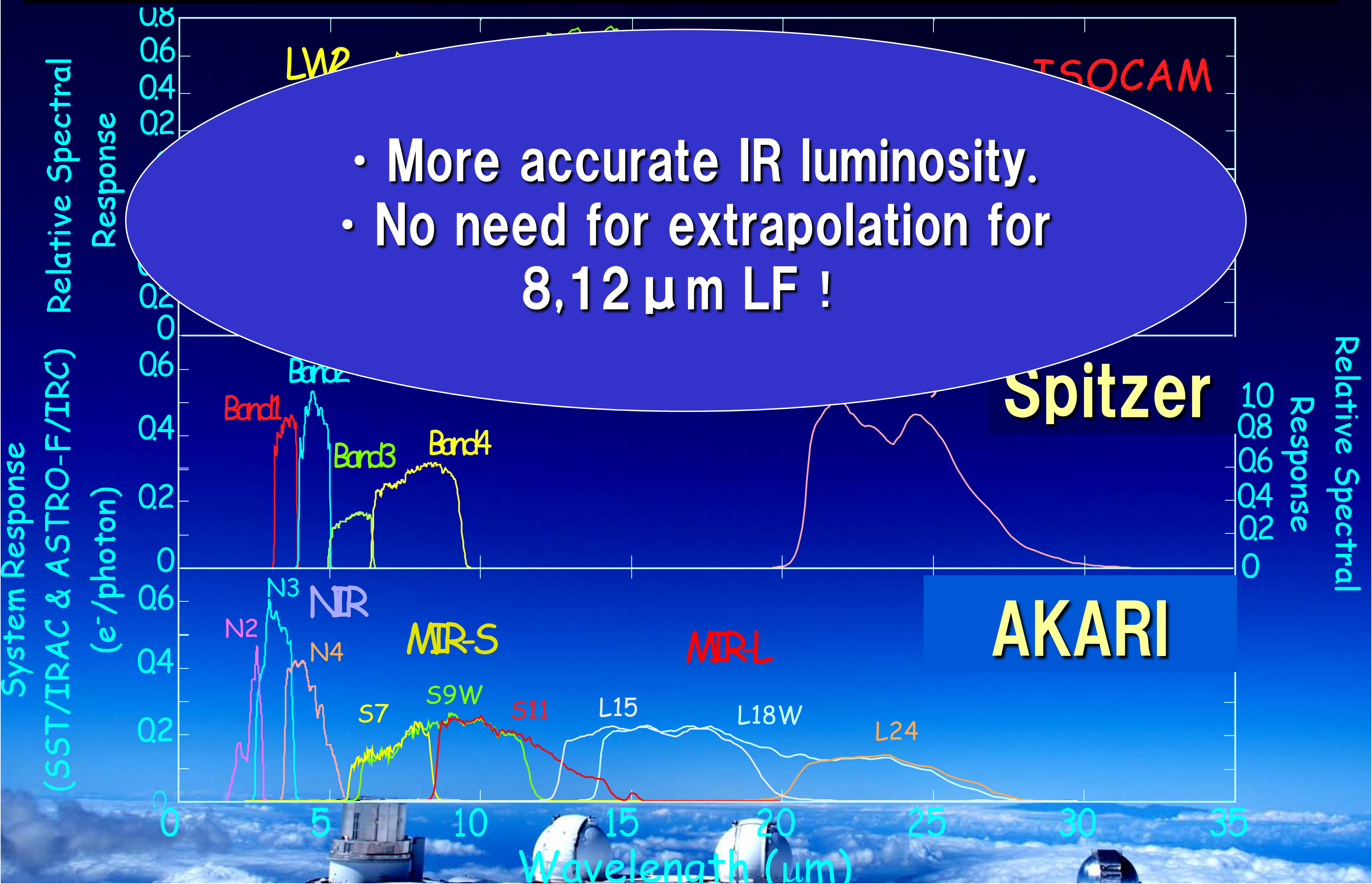


AKARI NEP Deep field : (Murata et al. 2013) 0.67 deg^2

2,3,4,7,9,11,15,18,24μm



AKARI has continuous filters in mid-IR, c.f.Spitzer has a gap between IRAC and MIPS.



- More accurate IR luminosity.
- No need for extrapolation for 8,12μm LF！

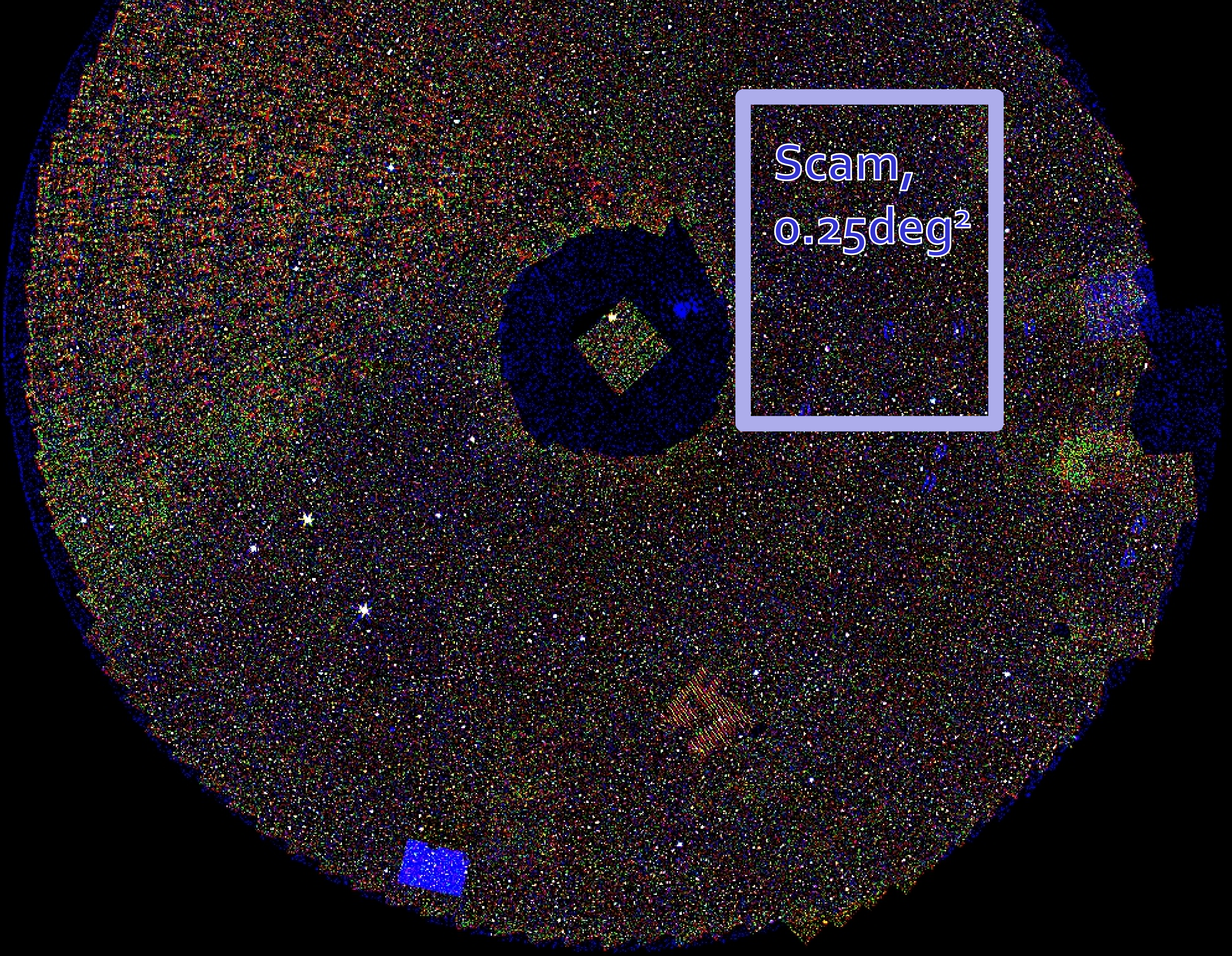
However,

Not all AKARI data were used!

- Limited by smaller optical/near-IR coverage
- Photo-z needed for L_{IR}

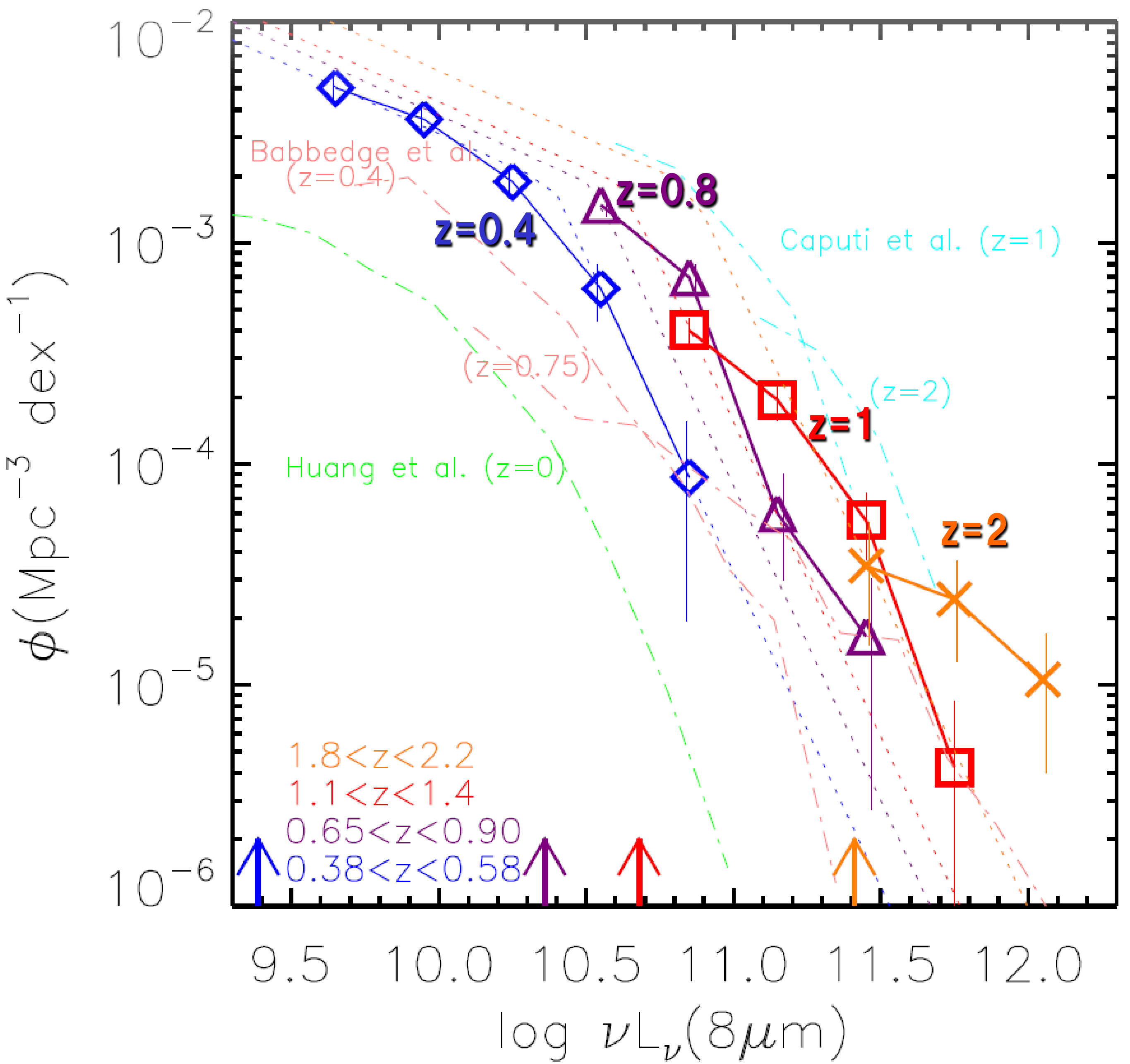
AKARI NEP WIDE (5.4 deg^2)

(Thanks to Seong-Jin, Hynmok, and Korean team)



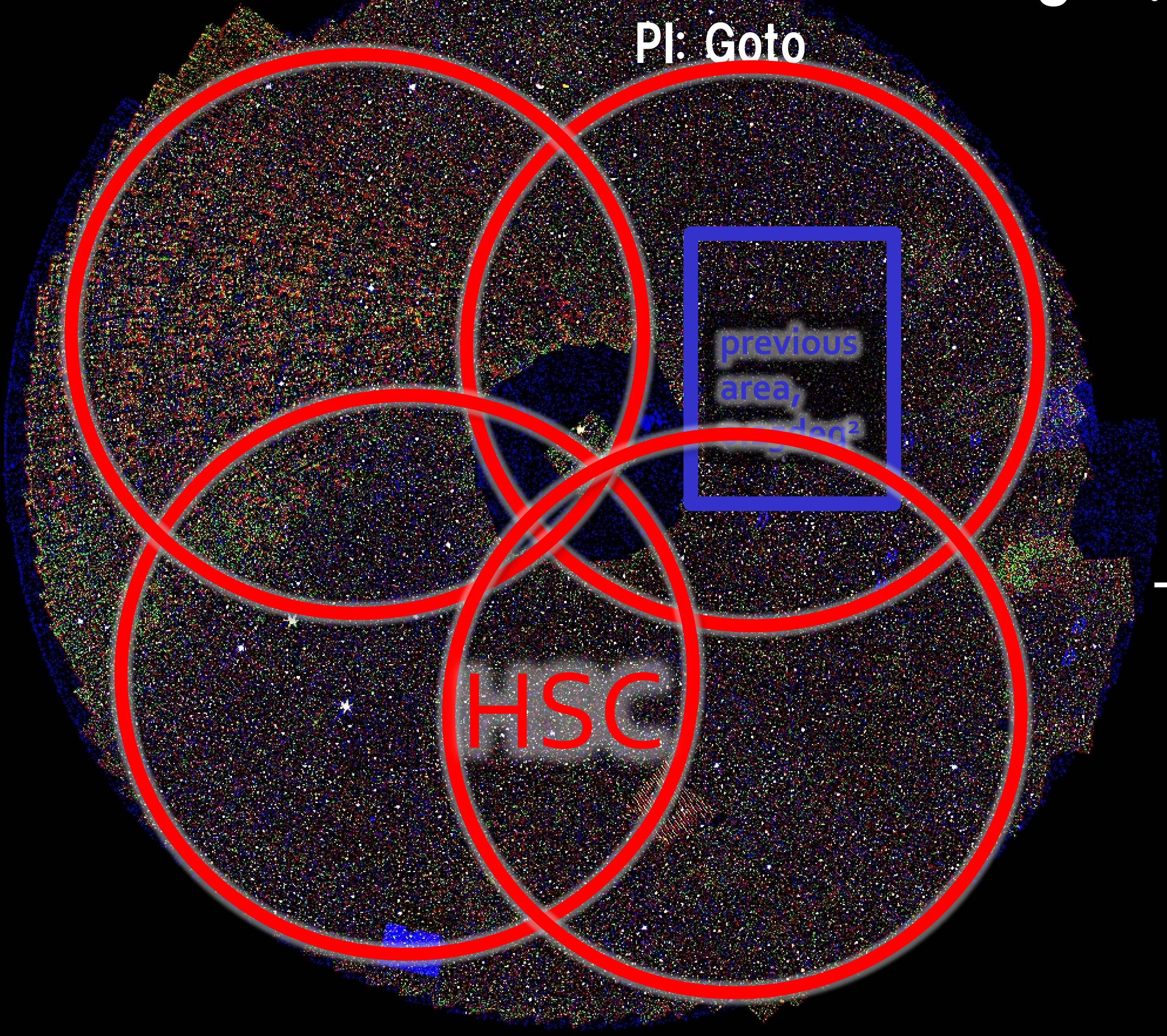
Seong-Jin at NTHU

Cosmic variance



New HSC observation covering 5.4deg^2,

PI: Goto

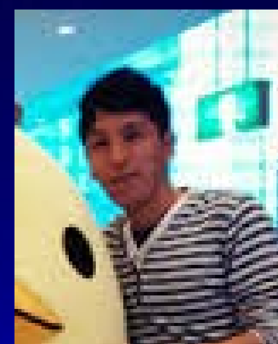


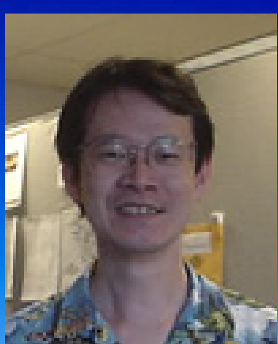
x20
larger
area

Thank you
HSC!

Observation by Nagisa, Rieko, Yoshiki, Yosuke, Youichi, Hiryoyuki!








HSC grizy data over 5.4deg^2

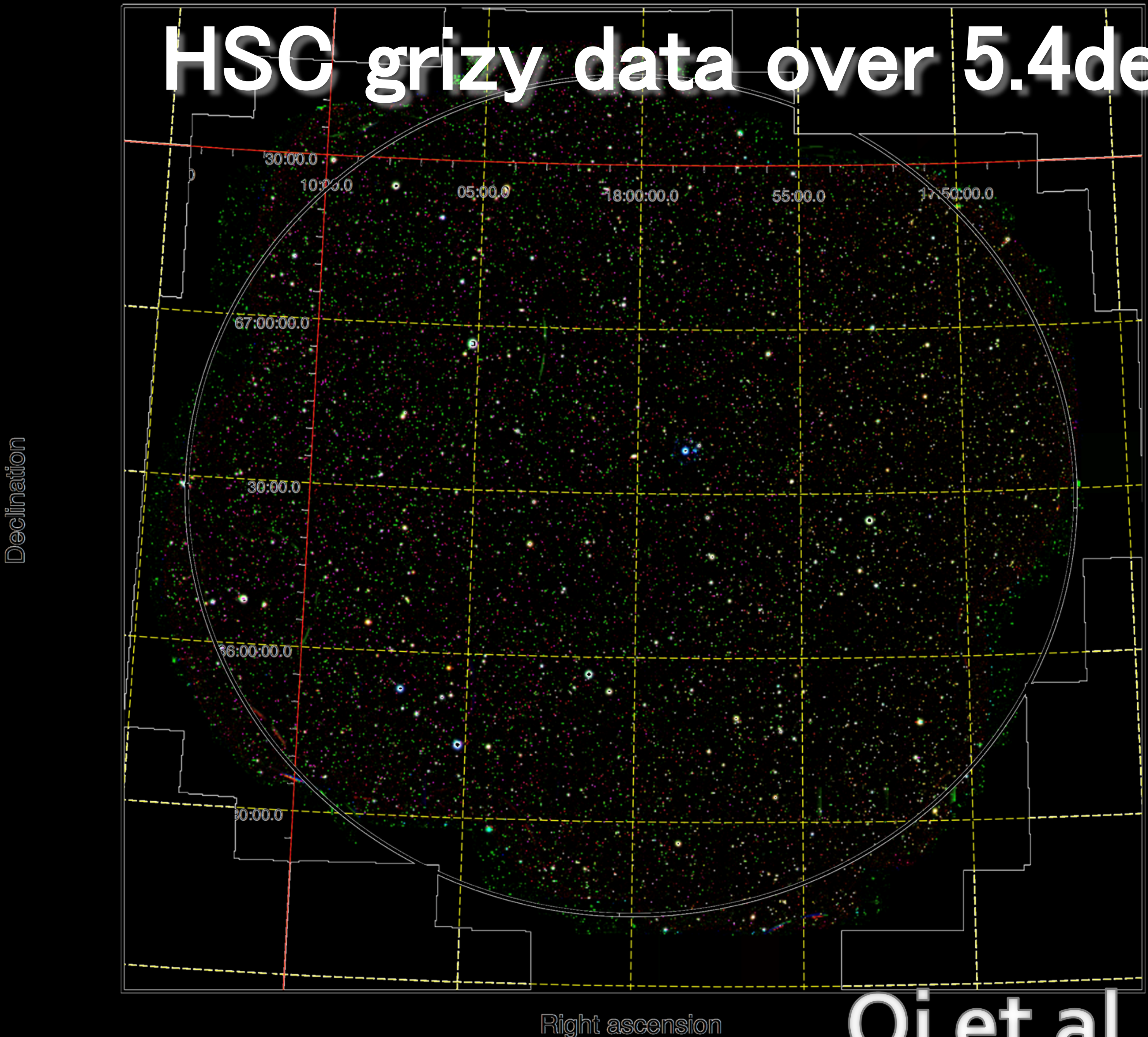


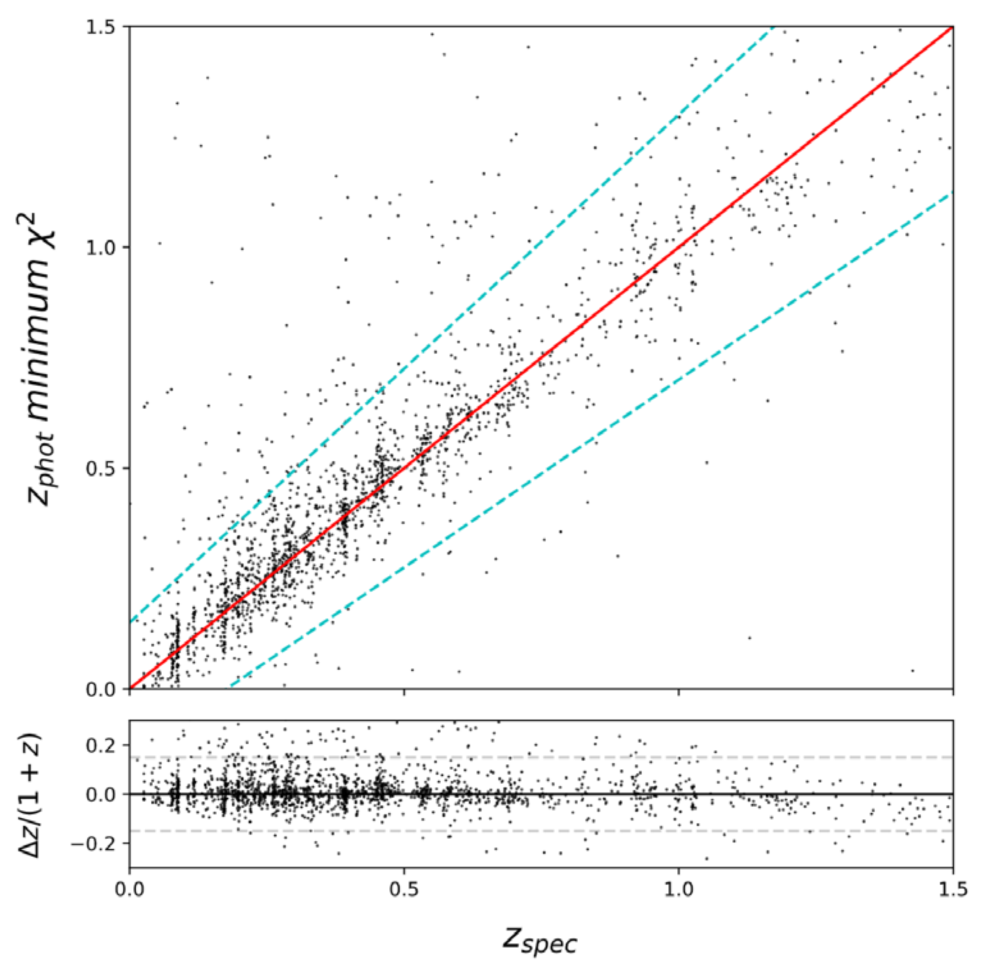
Fig. 1. HSC three color (g, r, i) composite image of the NEP wide field (5.4 deg^2). The AKARI NEP wide data exist within the white circle.

g' 27.5mag
r 26.5
i' 25.4
z' 24.7
y 24.3

Oi et al. in prep

Photo-z computed for 180,000 AKARI sources in NEP Wide

(Ho et al. in prep.)



With u-band,

Dispersion σ~0.049

Catastrophic rate η~9.2%

Thanks to spec-z from Hynjin, Myunshin (Hydra), Shogaki, Takagi, Matt, Helen (DEIMOS), Nagisa (FMOS)…etc.

HSC grizy + CFHT u-band data over 5.4deg^2

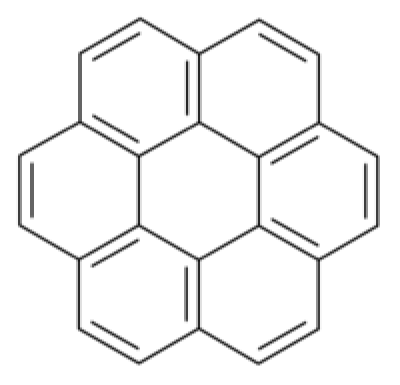
- Cross-match
- Photo-z
- Vmax

→LF

Result1:

8μm LF with HSC

At 8 μm, PAH emissions are important for SF



C-H, C-C bending/stretching modes

Transiently heated by UV photons from young stars, then emit mid-IR band emissions

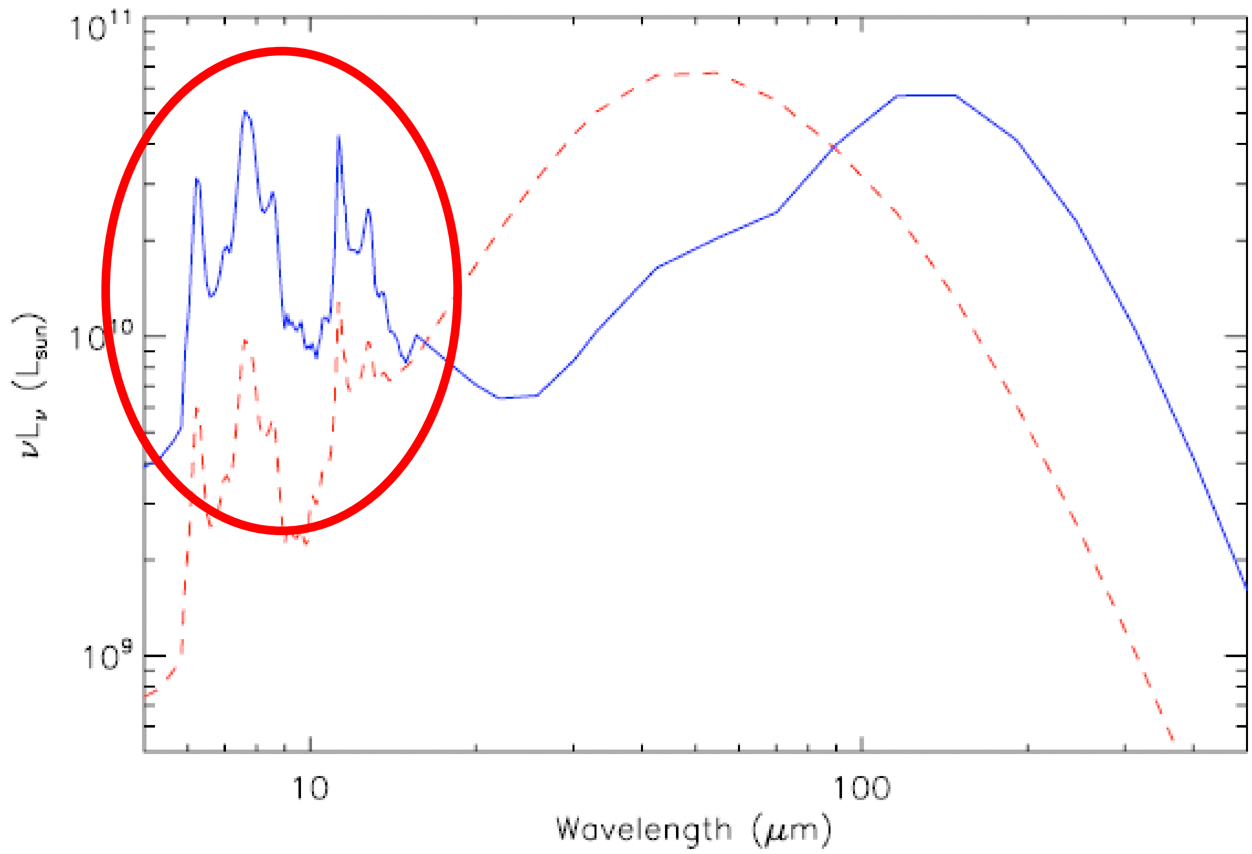
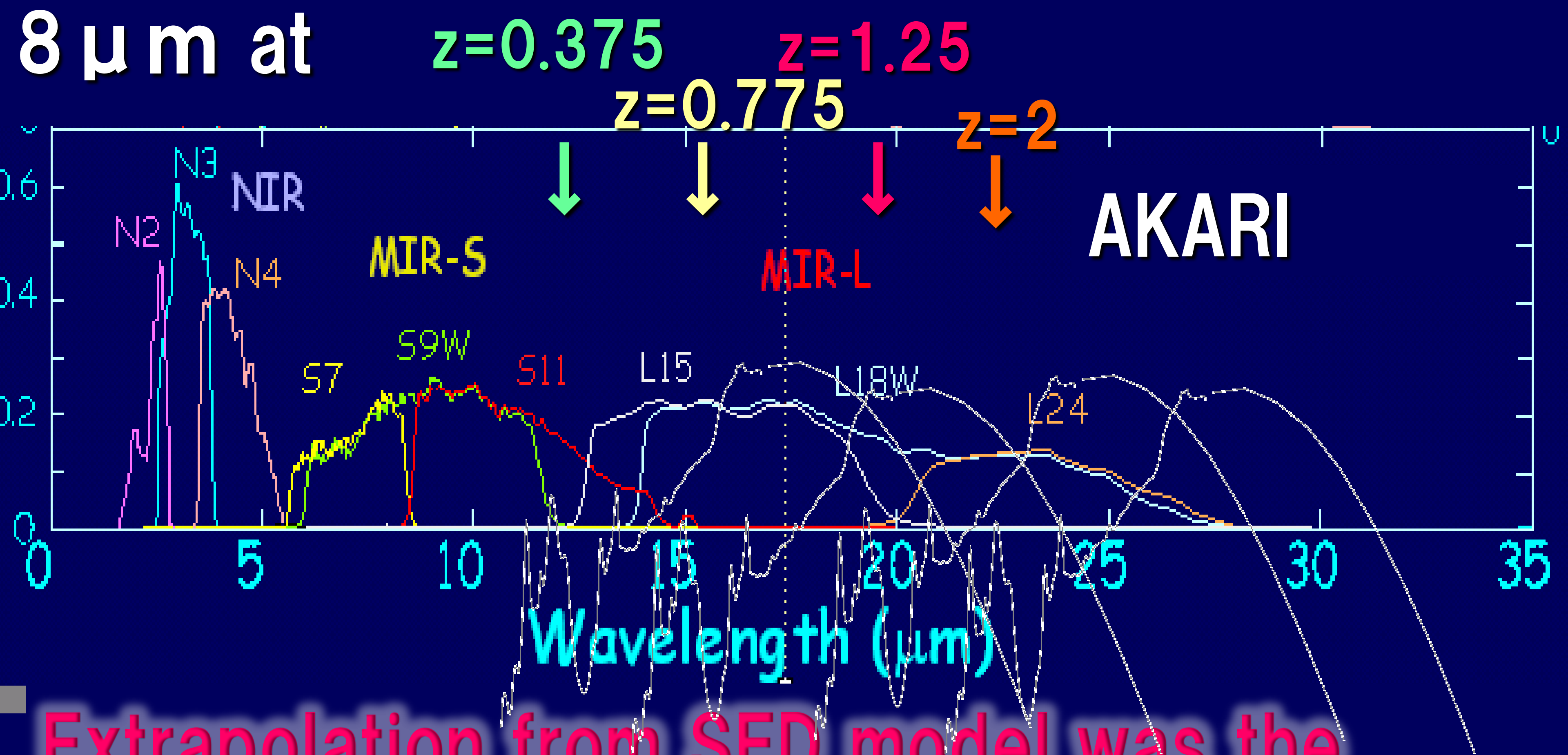


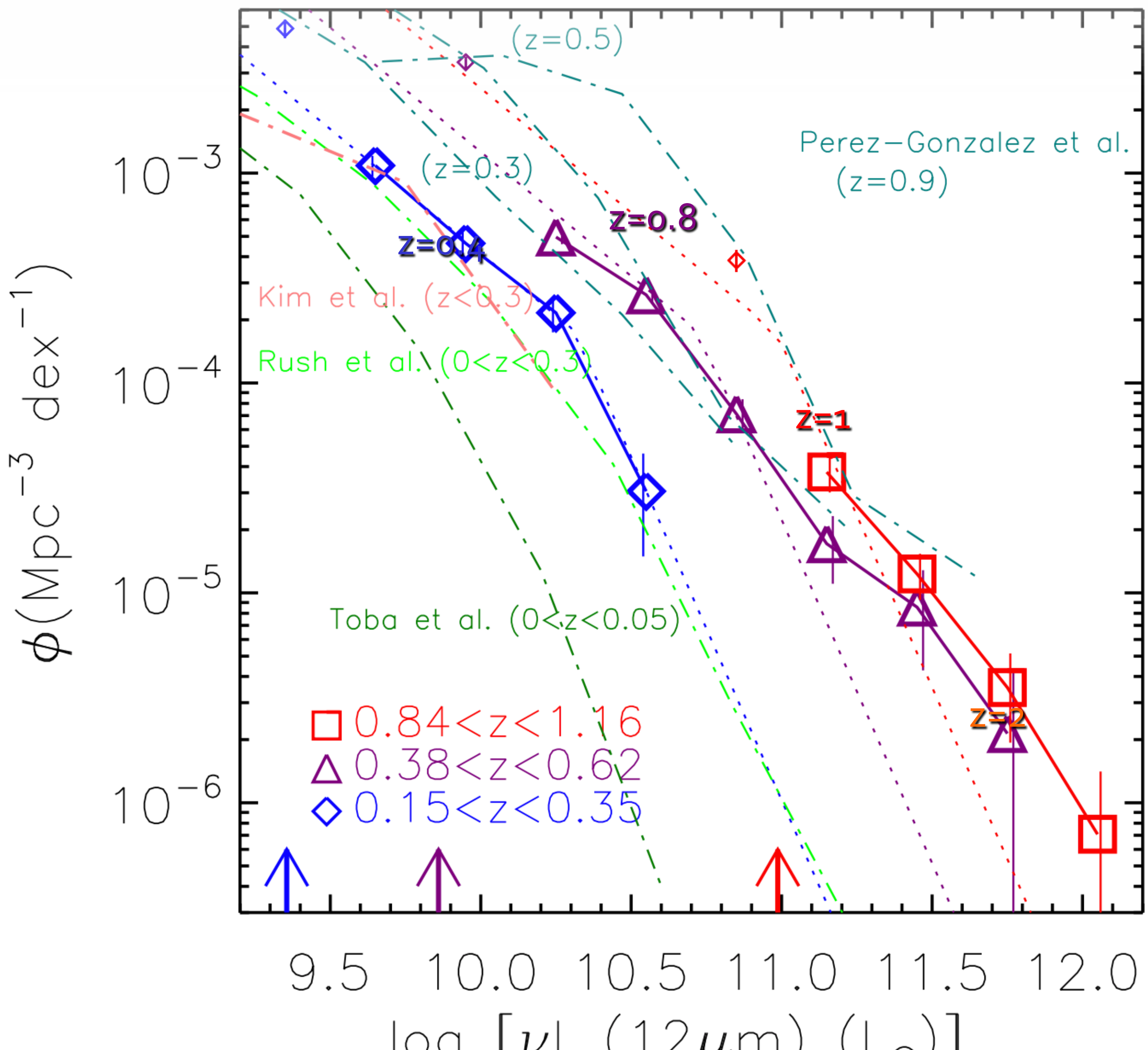
Fig. B.1. Spectral energy distribution of the two templates from the Dale & Helou (2002) library used in the simulation. The solid blue line corresponds to $\alpha = 3.5$ (the cold template) and the dashed red line corresponds to $\alpha = 1.3$ (the warm template). Both templates are normalized to the same total infrared luminosity ($L_{IR} = 10^{11}\ L_\odot$).

AKARI MIR filters can trace $L_{8\mu m}$ evolution without using extrapolation from SED models



Extrapolation from SED model was the largest uncertainty in previous work.

8μm LF (via Vmax, completeness correction)



- x20 larger area
- Smaller errors

Results2:

12μm LF with HSC

Result 3

Total IR LF with HSC

L_{TIR} with Lephare SED fit

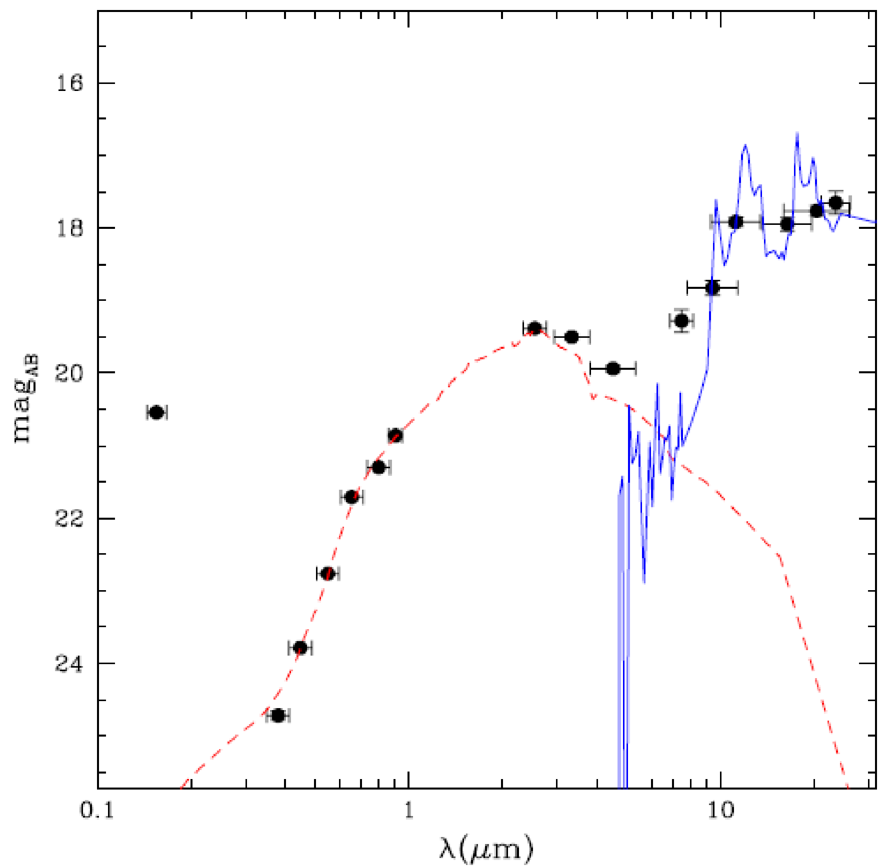
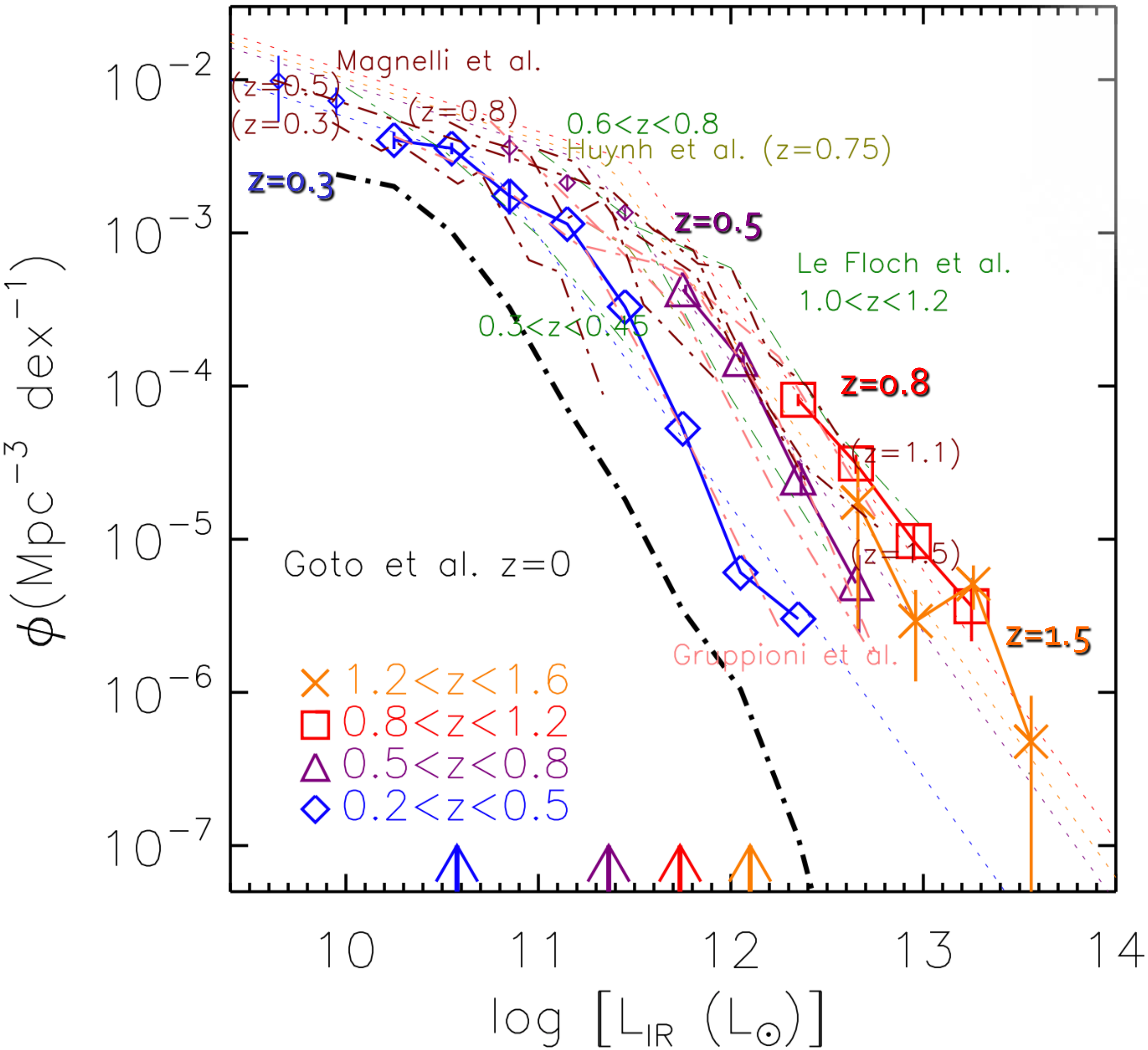


Fig. 11. An example of the SED fit. The red dashed line shows the best-fit SED for the UV-optical-NIR SED, mainly to estimate photometric redshift. The blue solid line shows the best-fit model for the IR SED at $\lambda > 6\mu m$, to estimate L_{TIR}.

9 mid-IR bands still help.

Total IR LF

- x20 larger sample
- Smaller errorbar

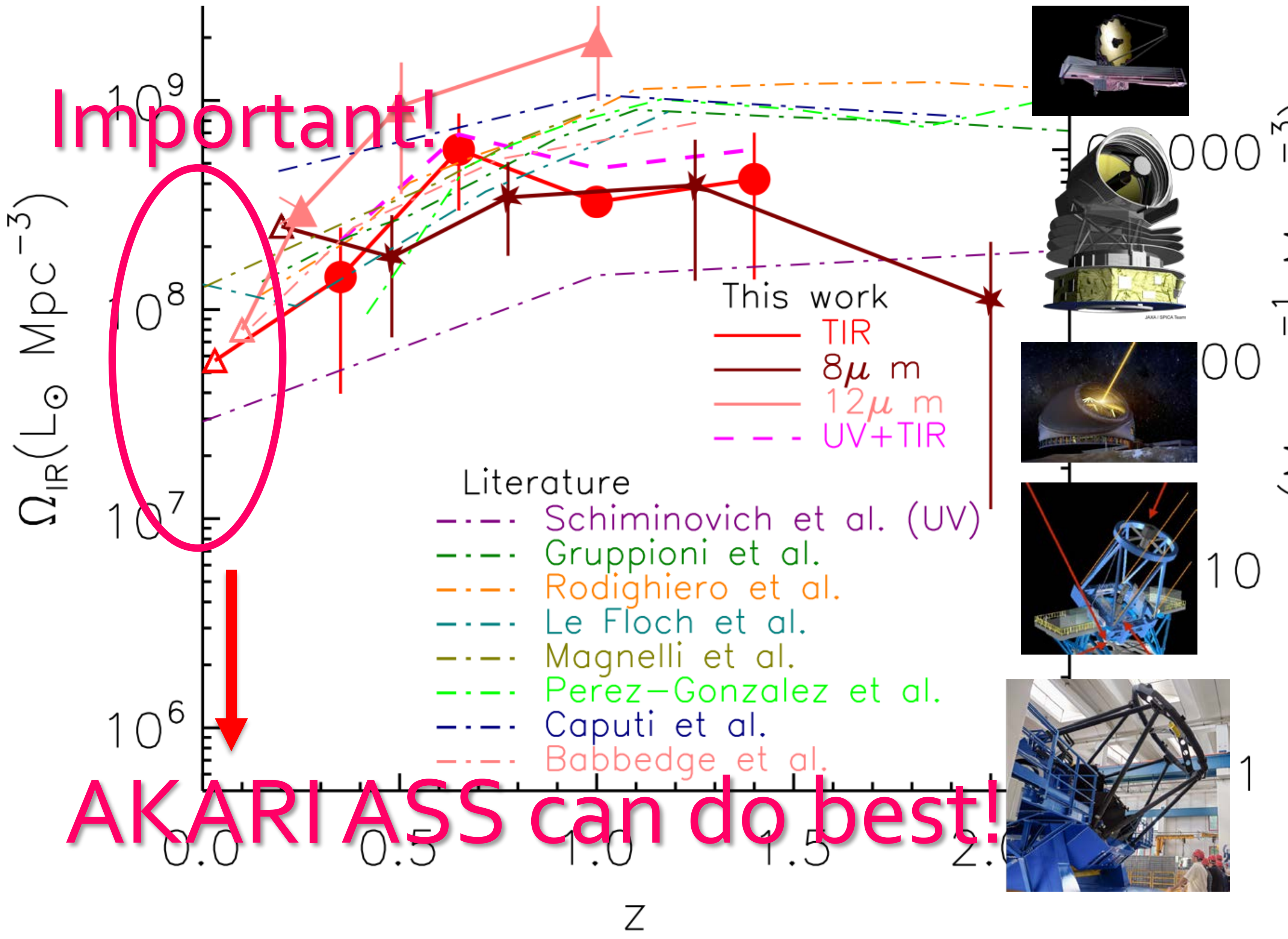


AKARI can do more…

JWST, SPICA, TMT, Euclid, WFIRST…
They all need local benchmark to study evolution

→AKARI ASS can do best!

Cosmic star formation history



Local IR LF from AKARI all sky survey(9,18,65,90,140,169μm)

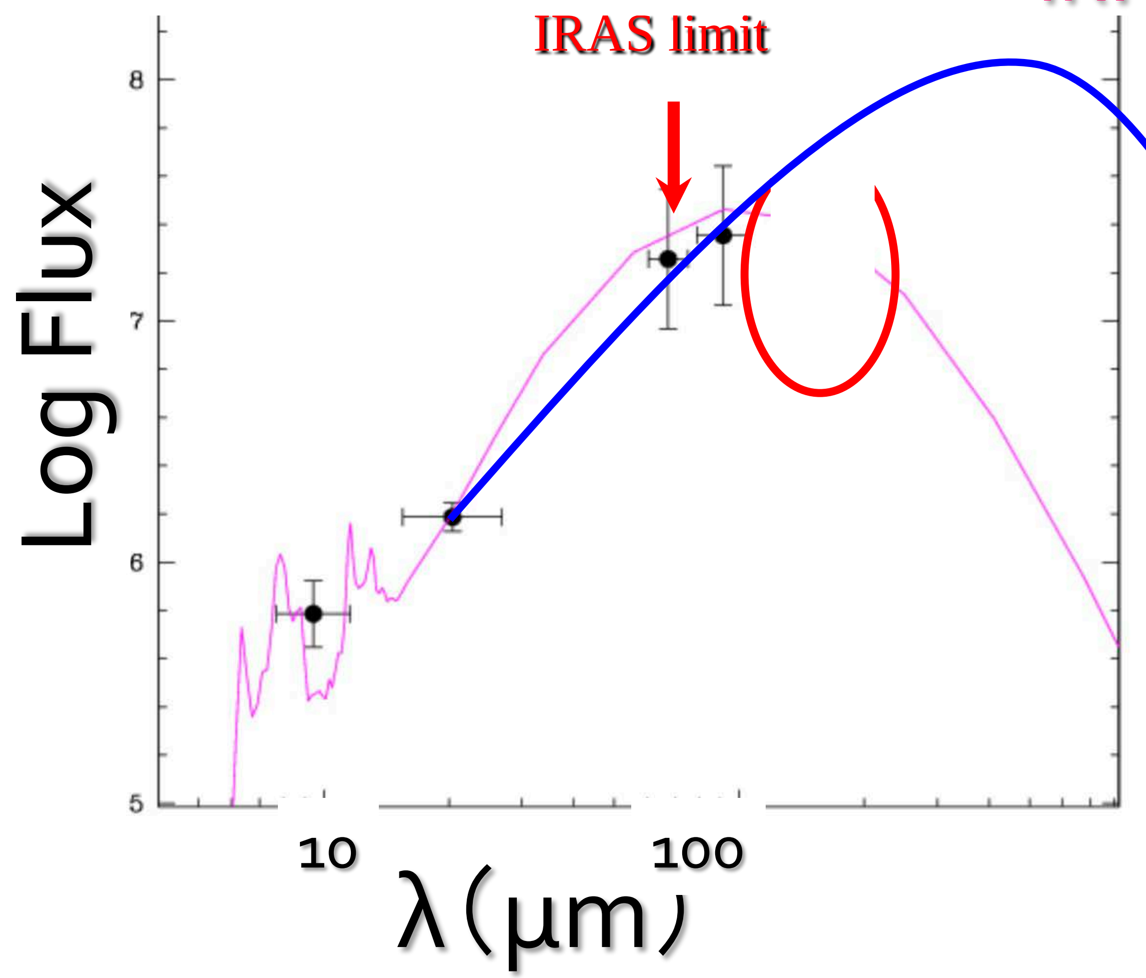
Previous local IR LF (Sanders+03) :
(IRAS data from 20 years ago. Cited 1000 times)

Two key points.

1. AKARI reaches 160μm,
   IRAS was up to 100μm

2. Revised Bright Galaxy Sample(Sanders+03):
   Only 629 galaxies

160μm is critical to accurately measure $L_{IR.}$



160μm is critical!

AKARI is the only satellite to provide 160μm in all sky.

Figure 2. An example of the SED fit. We fit the AKARI 6-band pho
to the SED model of Chary & Elbaz (2001) to estimate L_{TIR}.


629 ⇒15000 galaxie
DSS
Specz from 6dF
AKARI
UK Schmidt Telescope:
Home to 6dF
L. Campbell
Specz from 2MRS
galaxies
e-field Infra
vey Explore
x20

Method

- 15638 IR galaxies
- Spec-z
- SED fit⇒Lir
- V_{max} (completeness correction)

  →Luminosity Functions

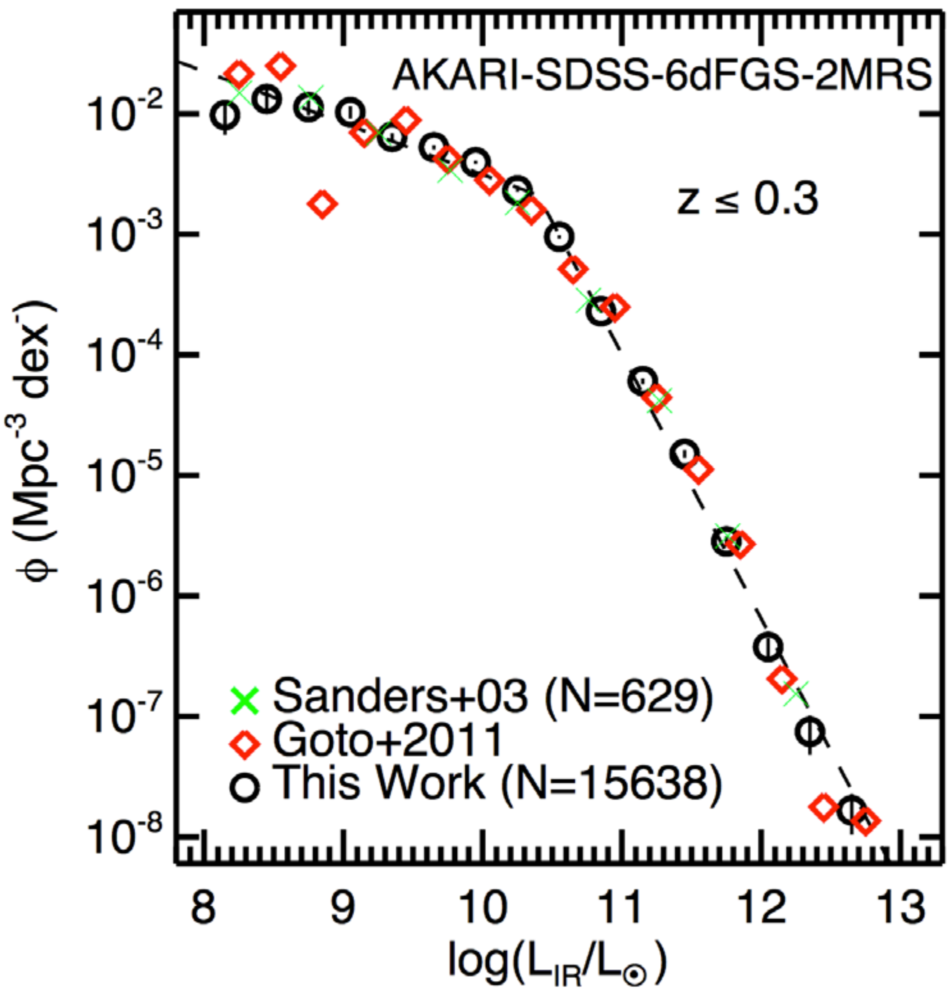


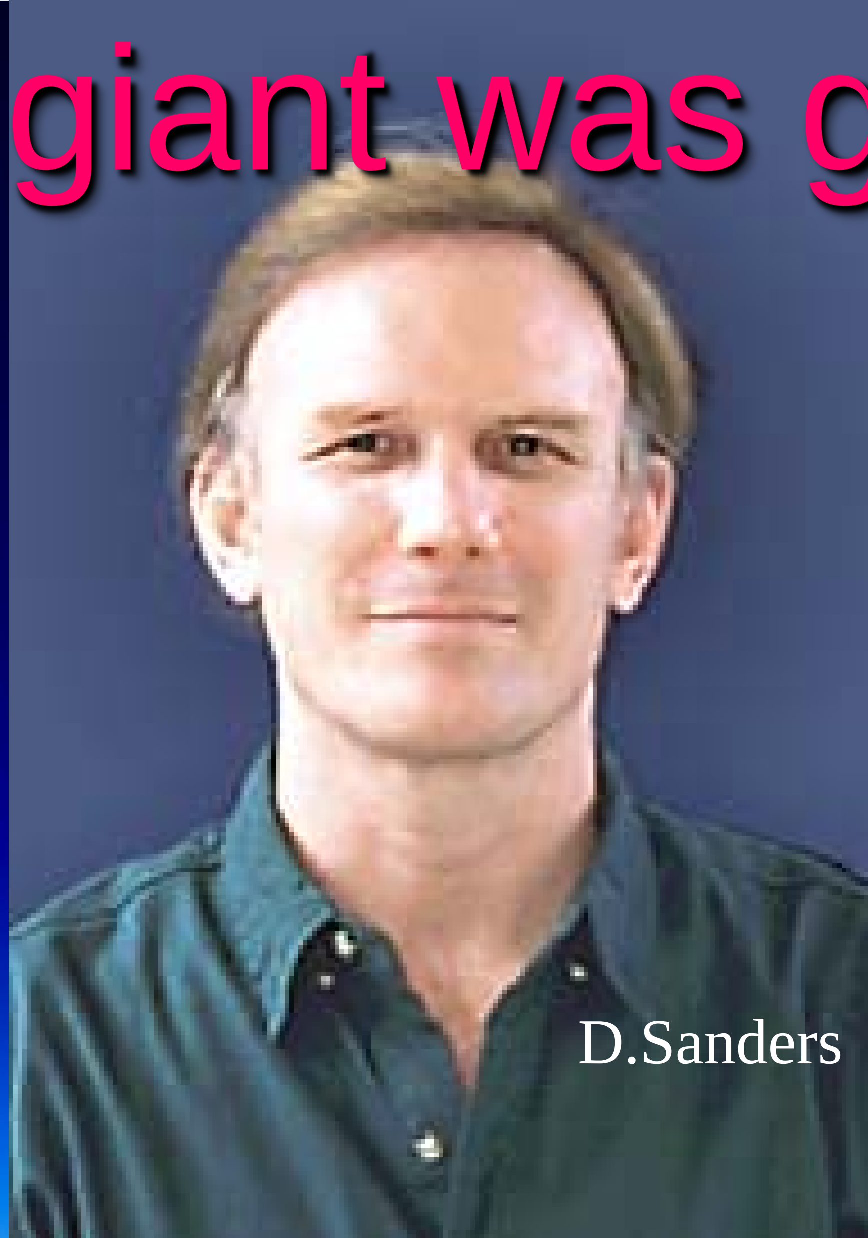
Figure 3. The IR LF of **15638** ***AKARI*–SDSS–6dFGS–2MRS** galaxies (open circles). The best-fitting double power law is shown as dashed line. For comparison the total IR LF derived from the *IRAS* RBGS is shown (crosses Sanders et al. 2003). The red diamonds are the $1/V_{max}$ data points of the RBGS sample adopted from Goto et al. (2011a).

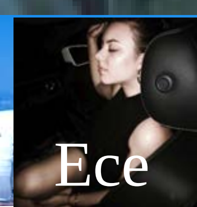
The best local IR LF!

- Ω_{TIR}=6.3±0.3x $10^7 L_{sun}$
- 6.0% by LIRG,
- 0.4% by ULIRG

Kierci Eser et al. 2018

IR giant was giant.

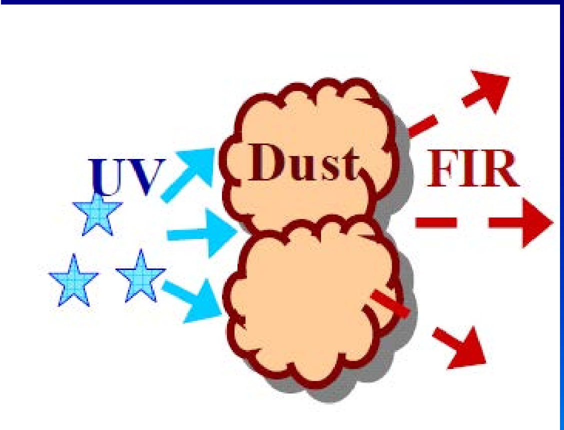




What about SFH?

IR luminosity density (Ω_{IR})
= LF x luminosity integrated.

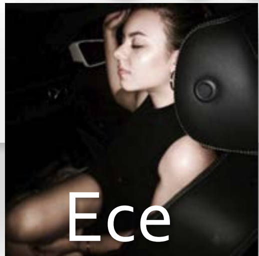
Ω_{IR} = SFR/AGN density

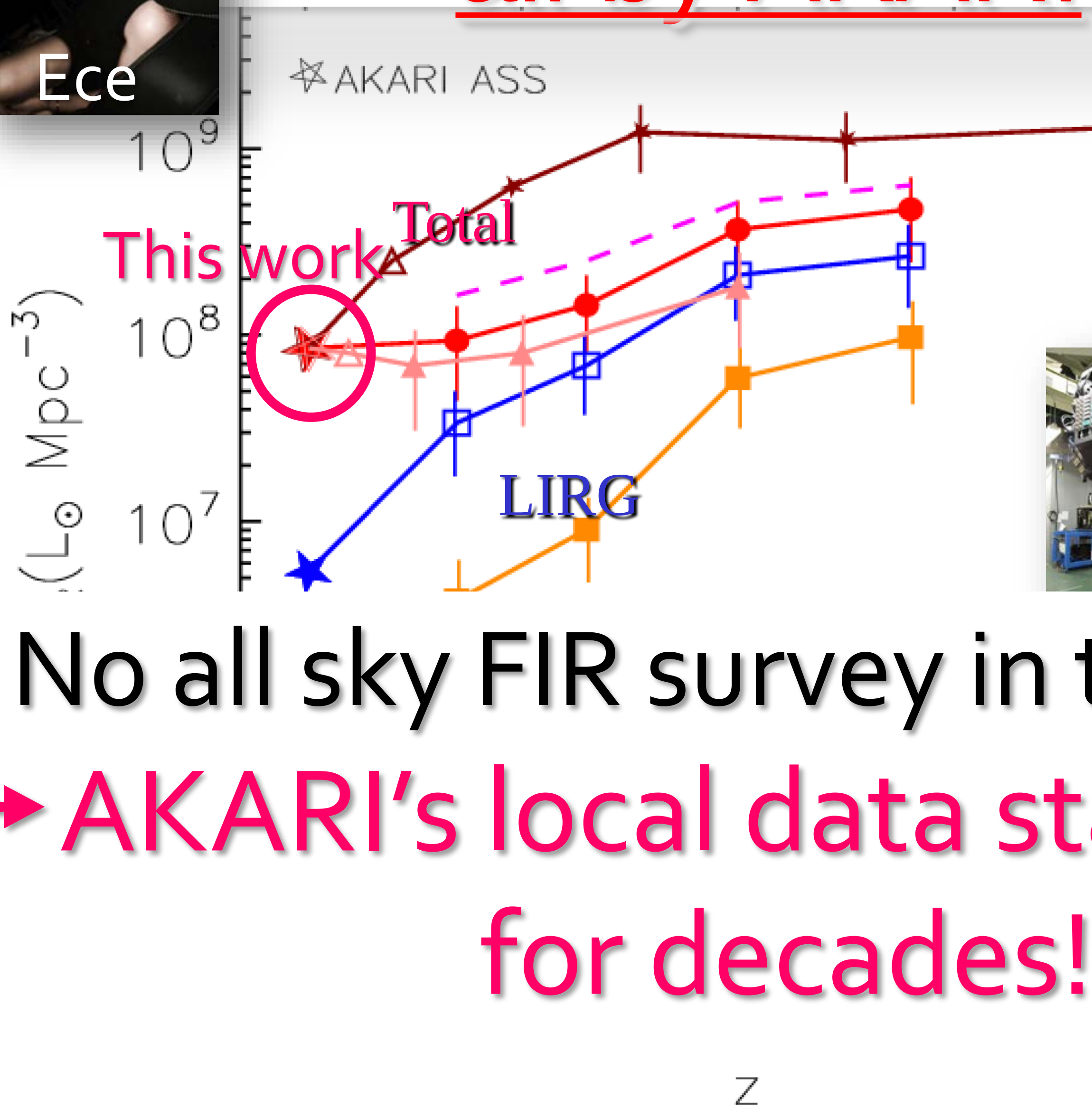


$$SFR(M_\odot\ \mathrm{yr}^{-1}) = 1.72 \times 10^{-10}\ L_{\mathrm{TIR}}(L_\odot)$$

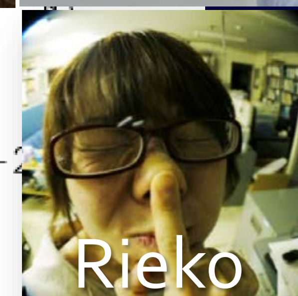
Kennicutt+98

Cosmic star formation history all by AKARI





See also talks by high-z team

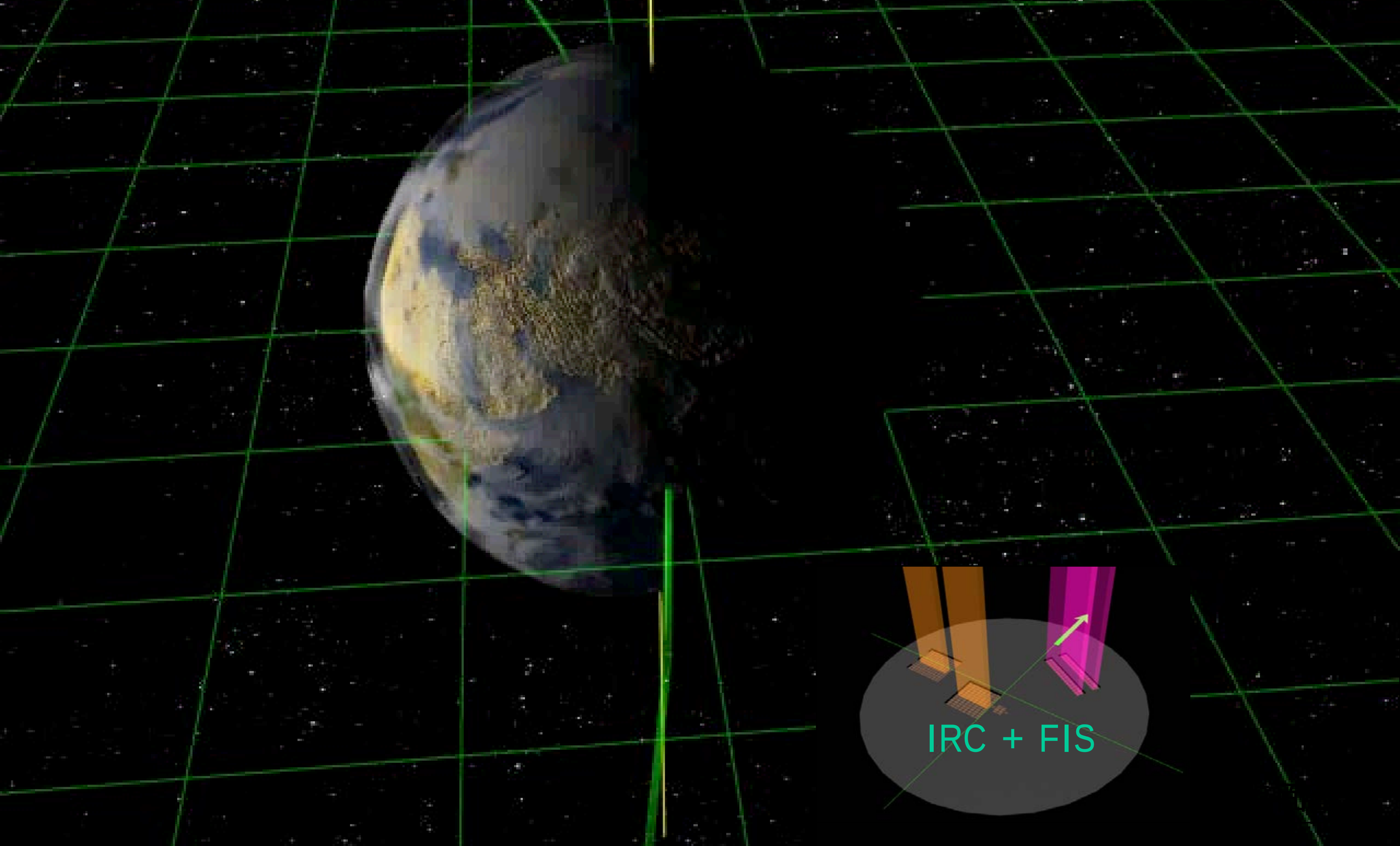


No all sky FIR survey in the future.

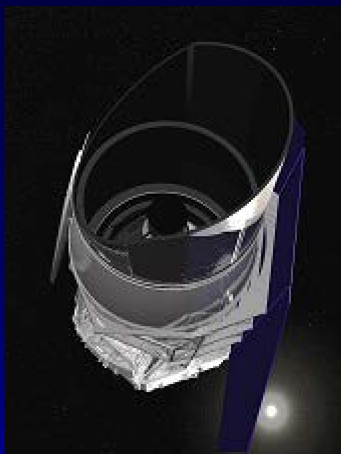
→AKARI's local data stay the best for decades!

Future of the NEP field

AKARI: All sky survey in 9, 18, 60, 90,140 and NEP field: 2,3,4,7,9,11,15,18, and 24 μm



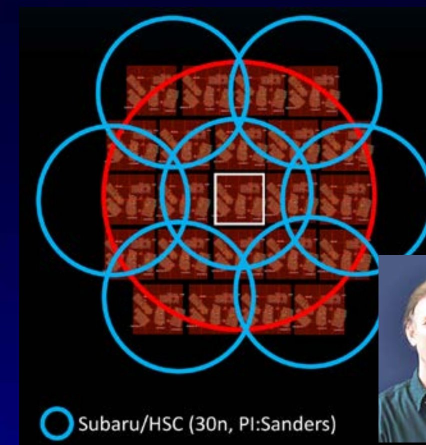
Good visibility for Future telescopes (HSC data + 3000 specz +AKARI+SCUBA2)



WFIRST

EUCLID

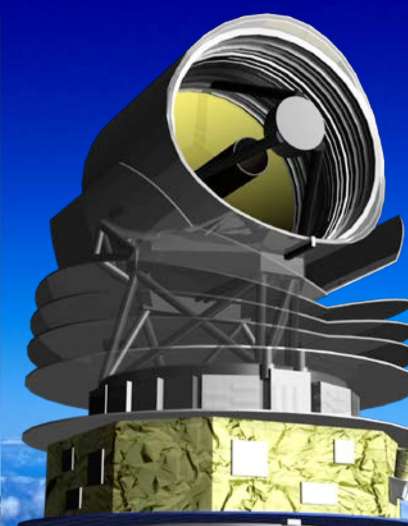
JWST



Subaru/HSC

Spitzer

Toltec 50m



SPICA

Summary

- NEP wide + HSC

(0.25⟶5.4 deg²) area x20

⇛Most accurate mid-IR high-z LFs

(Goto et al, accepted)

- AKARI ASS +SDSS+6dF+2MRS (15,000 gals)

⇛Most accurate local IR LF (needed for future)

- *(Kilerci Eser, & Goto, MNRAS,474,5363)*

- 18 band mid-IR SED fitting for thousands of galaxies (most complete mid-IR SED fit)

⇛Census of obscured AGNs