

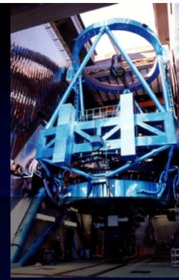

Dusty Galaxies: PFS key-sciences with Herschel-ATLAS galaxies

PFS Science Workshop

9-10 December, 2010 @ NAOJ

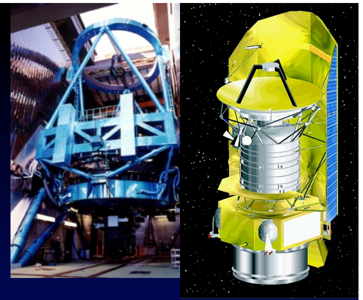
Hideo Matsuhara (ISAS, JAXA)
Tomotsugu Goto (NAOJ/IfA), Toshi Takagi, (ISAS)
Steve Serjeant (Open Univ.),
Matt Malkan (UCLA)

List of my talk

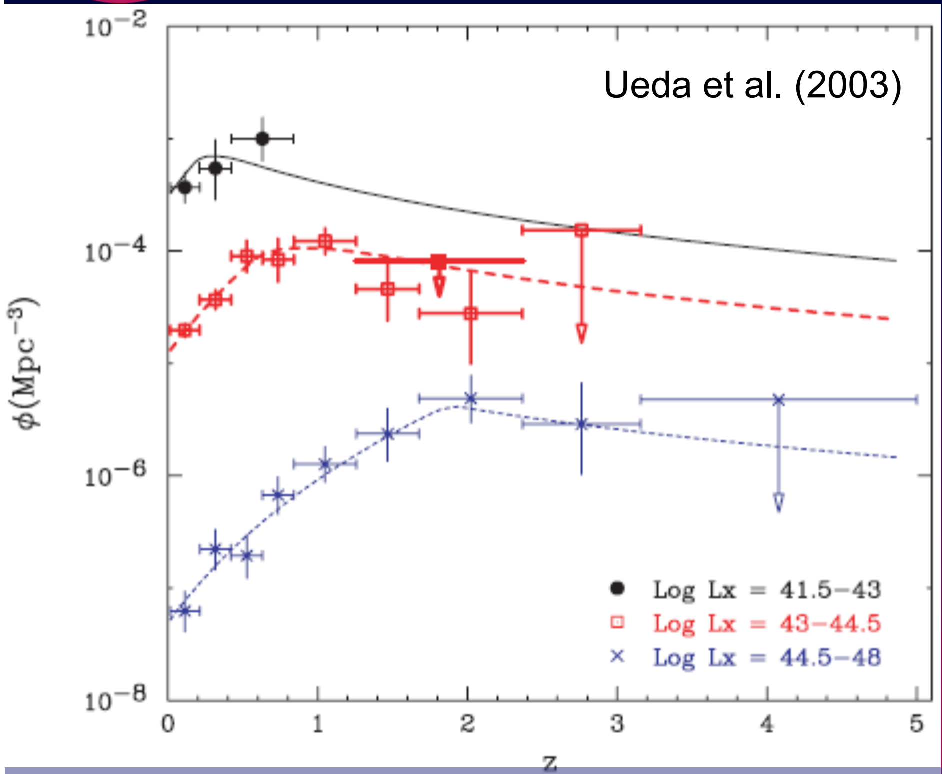


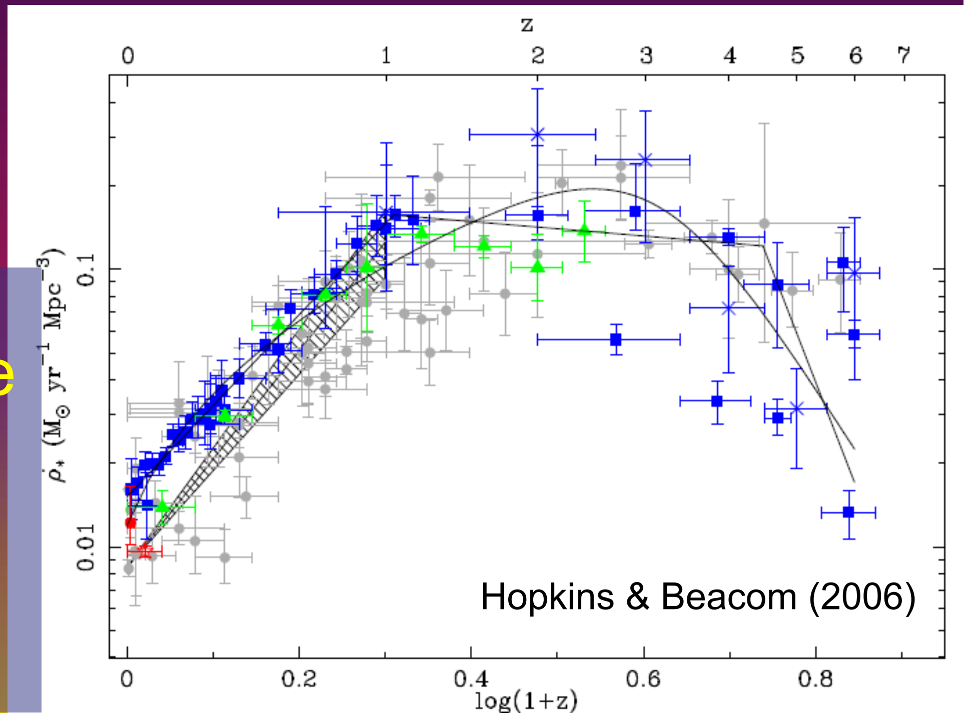
- Background
  - Violent Epoch of the Universe
  - Importance of Far-IR
- Overview of Herschel ATLAS
- Key sciences
  - The obscured cosmic star-formation history (CSFH) and its environment-dependence
  - The link between black hole accretion and stellar mass assembly
  - Discovery of Overwhelmingly Luminous IR Galaxies
  - Redshift determination of a large sample of strong gravitational lenses
- Proposed Survey & requirements
  - Survey Plan
  - Instrument Requirements
- Synergy with SPICA

The `Violent Epoch'

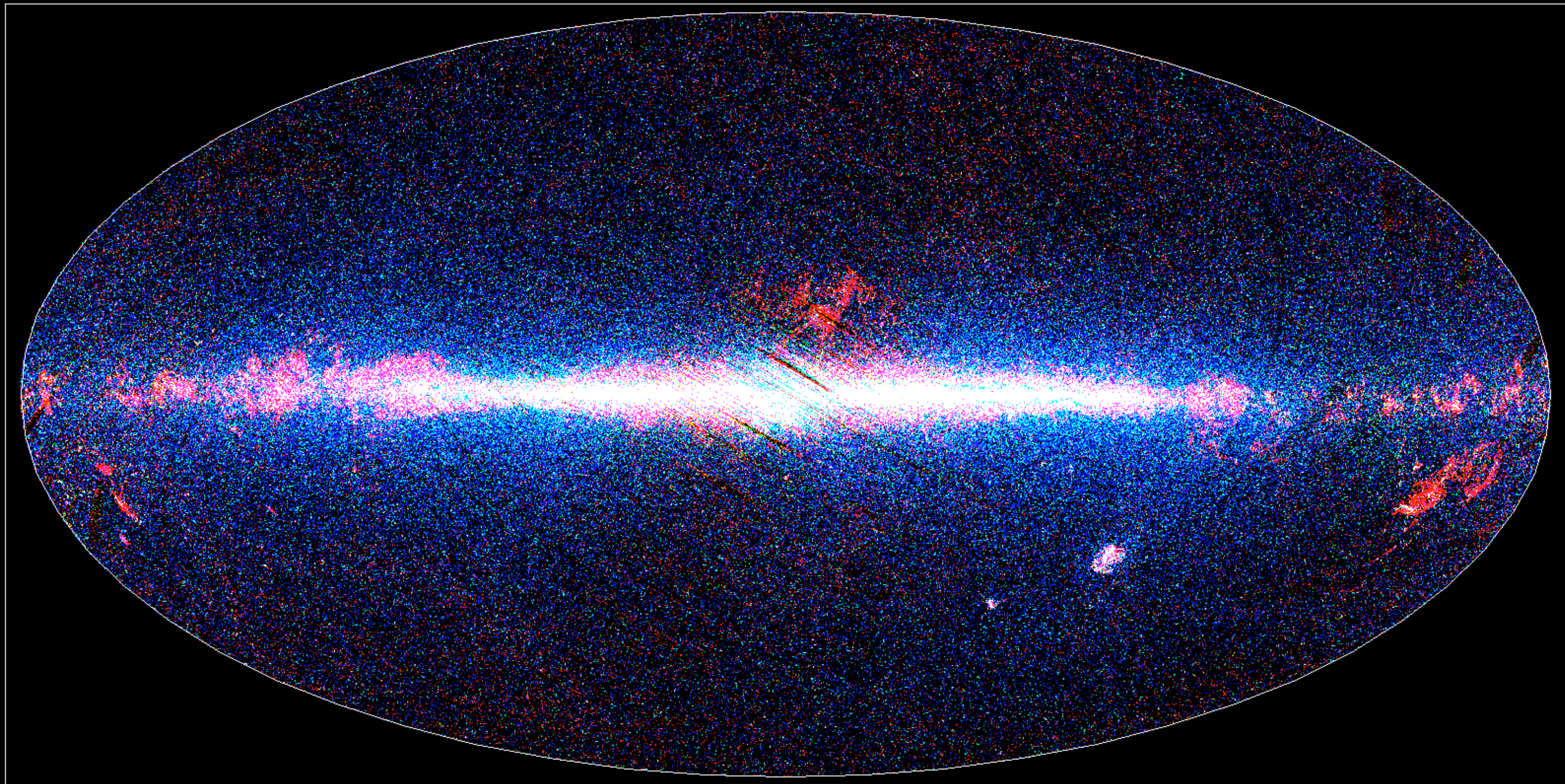


- Universe at z=1~2: evolution of both galaxies and AGN peaks
- decelerating expansion to accelerating expansion due to the dark energy





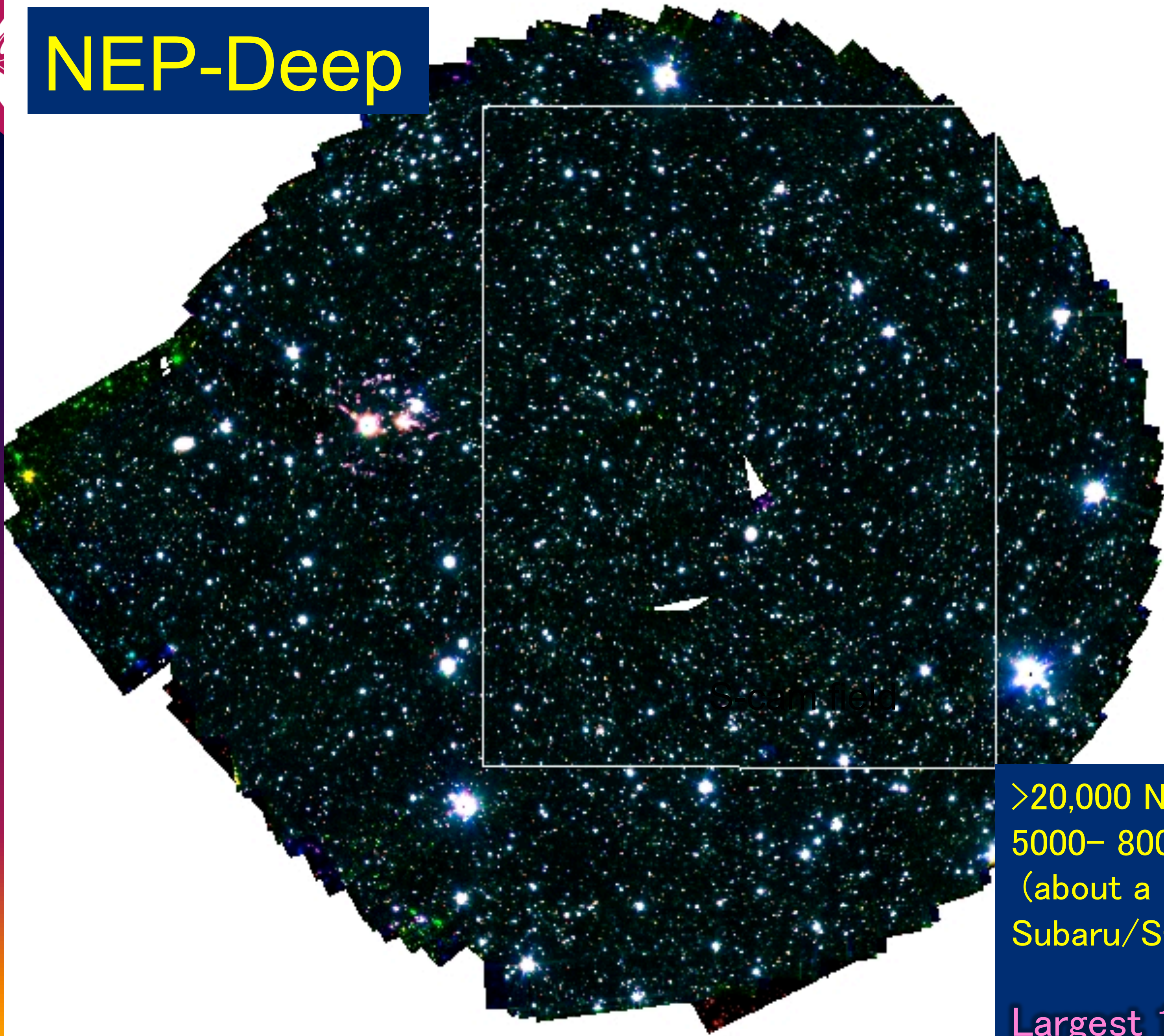
- More Intense Starburst, the more deeply embedded in the dust
- AGN are heaviliy obscured at their youngest, Compton thick age

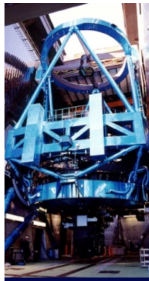


catalog now released

- Pointing Deep Survey
  - NEP deep Field
  - ADF-S

NEP-Deep

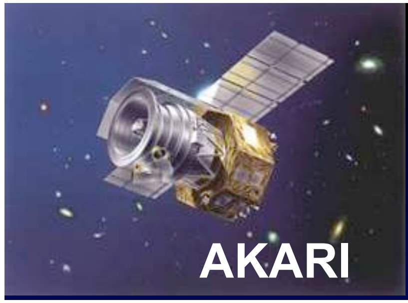




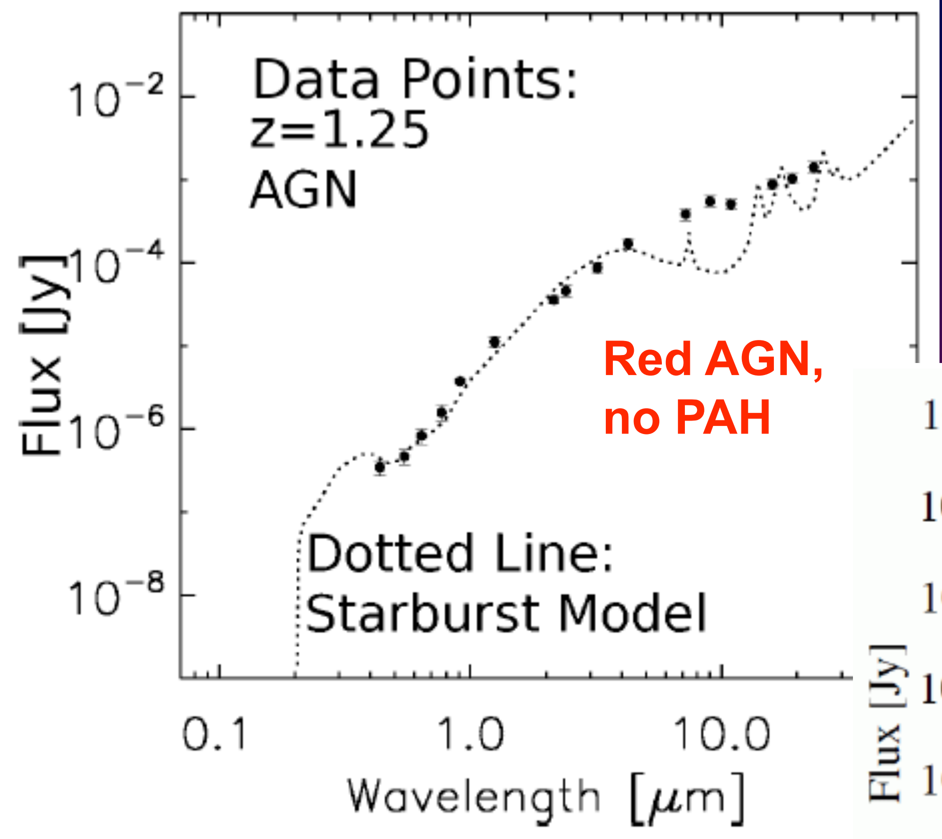
>20,000 NIR sources
5000– 8000 MIR sources
(about a half is inside the Subaru/S-cam deep image)

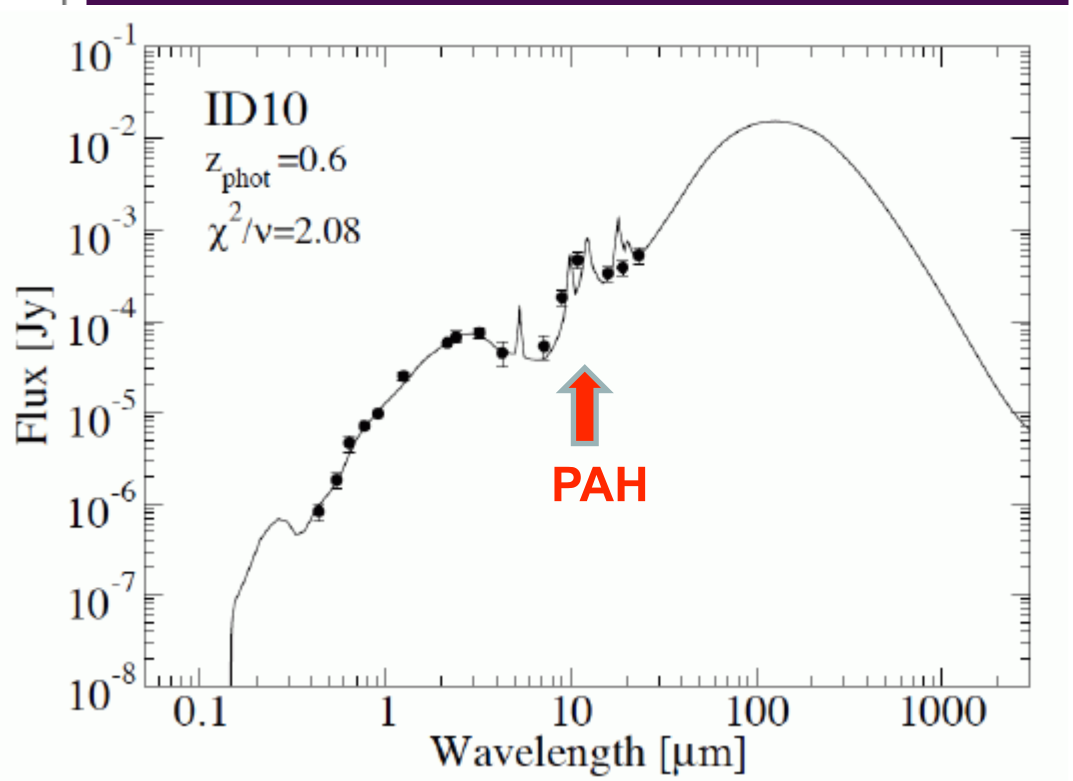
Largest 15 & 18 μm selected galaxy sample

AKARI/IRC 2,3,4μm colour image



SED diagnostics of AGN/ Starburst

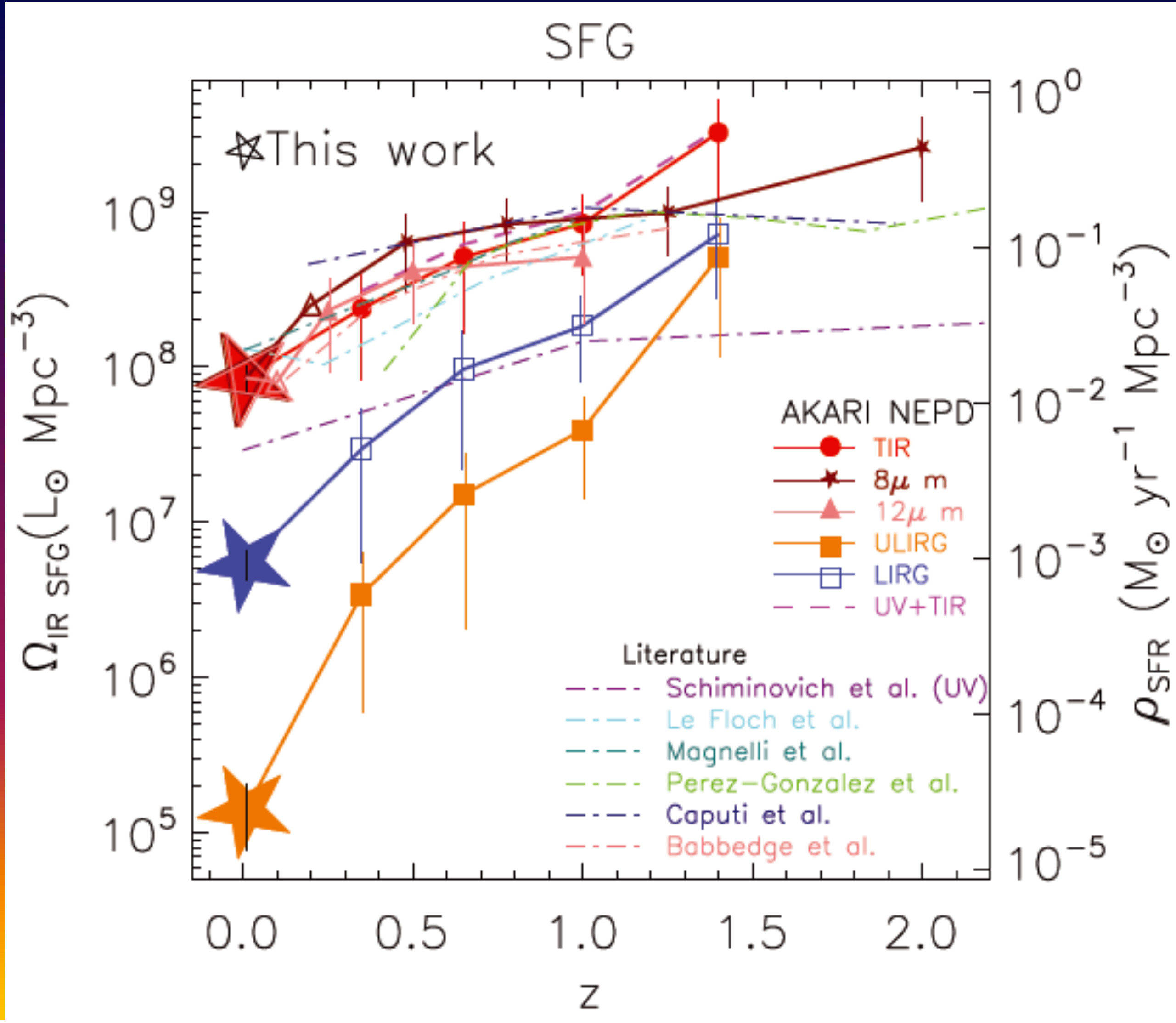




Broad, Continuous wavelength coverage is essential!

IR Luminosity Density Evolution with AKARI

- Strong evolution seen esp. in ULIRGs



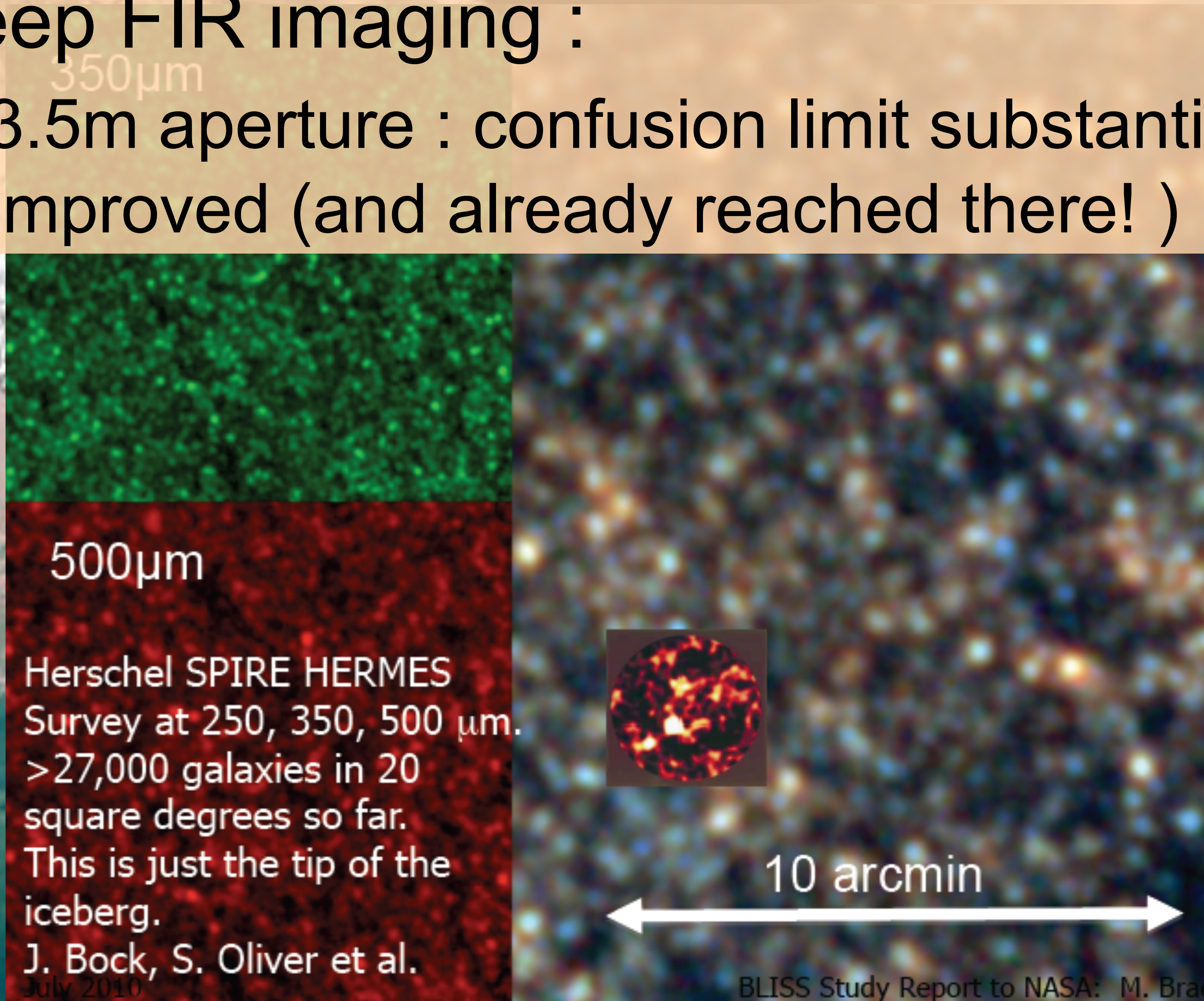
CSFH obscured by Dust: Weakness of Spitzer & AKARI

- Extrapolate the MIR luminosity to the total IR (bolometric) luminosity
  - Relatively hot dust seen at MIR – so dusty AGN can contribute
  - Self-absorption by dust is not negligible in MIR, hence spatial structure affects the SED
- Far-IR & Submm wavelengths
  - trace relatively cold dust, good Star-formation indicator
  - BUT, at far-IR, <1m telescope cannot go beyond z~1

Herschel launched !!!

14 May 2009

- Deep FIR imaging :
  - 3.5m aperture : confusion limit substantially improved (and already reached there!)



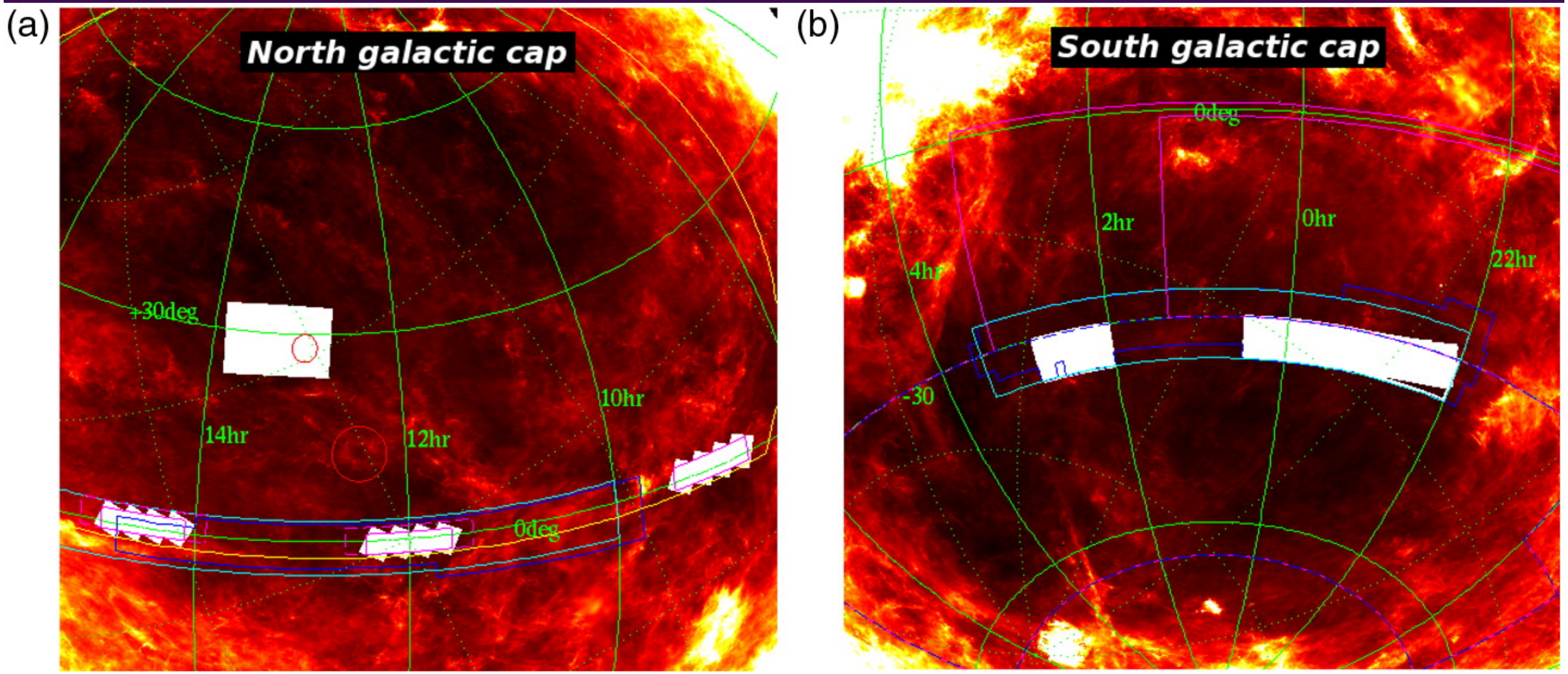
Credit: ESA

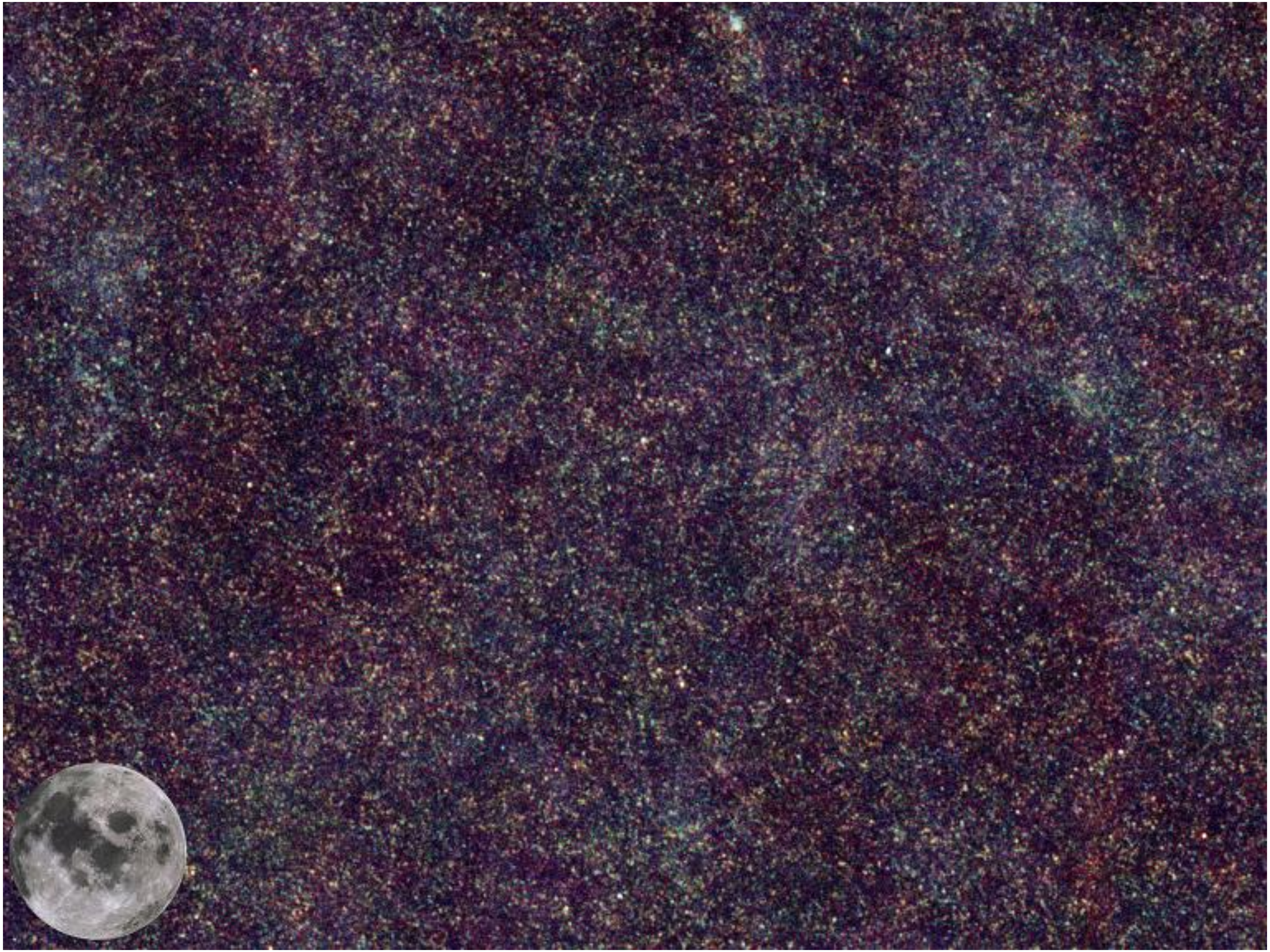
Herschel - ATLAS key project

Astrophysical Terahertz Large Area Survey

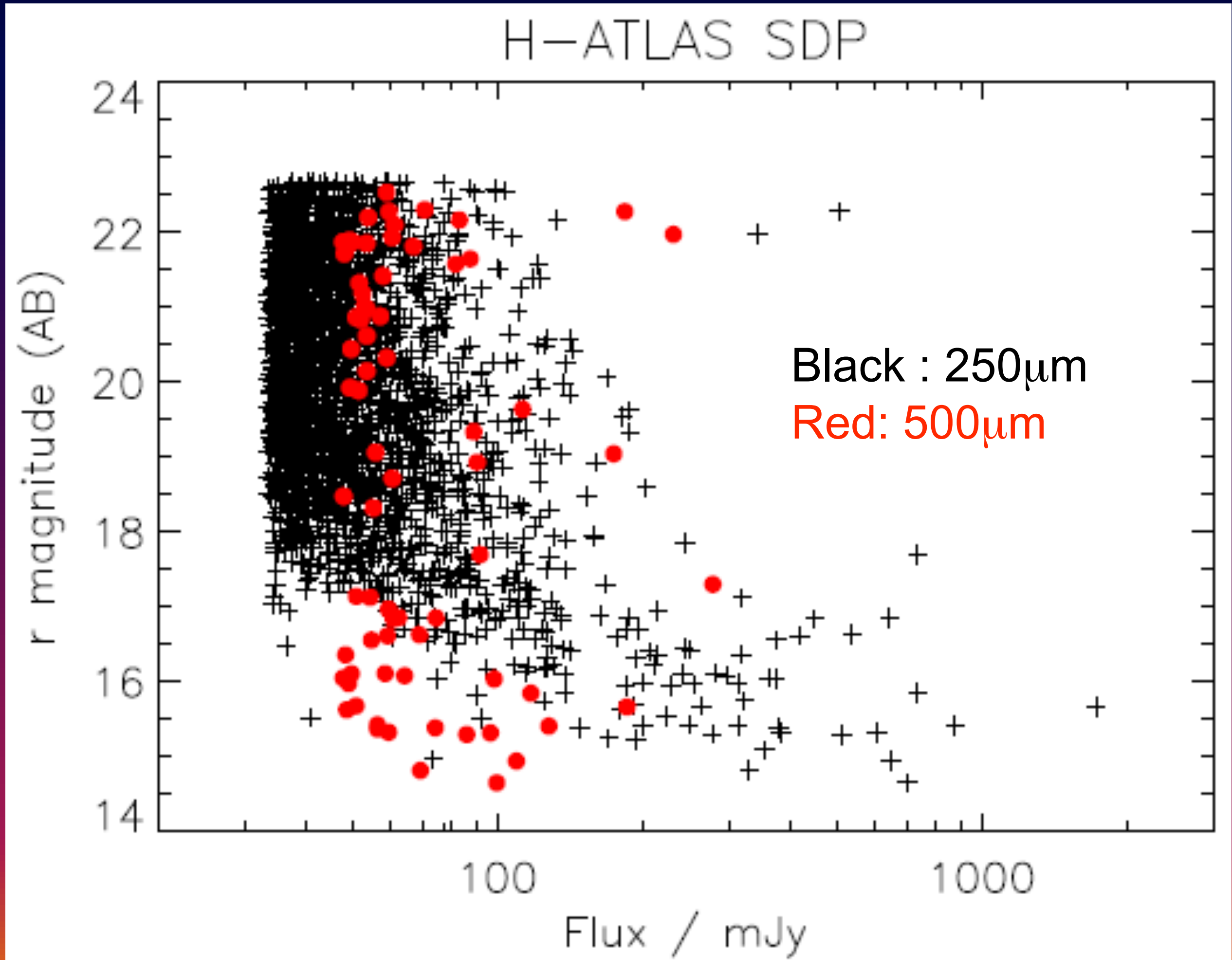
Eales et al. (2010)

- Total 550 deg^2 OTKP on Herschel
  - 110, 170μm (PACS) 250, 350, 500μm (SPIRE)
  - 18” resolution @ 250 μm





SDSS Optical Identifications



- Only 36% (23%) at 250(500) μm sample are identified by SDSS

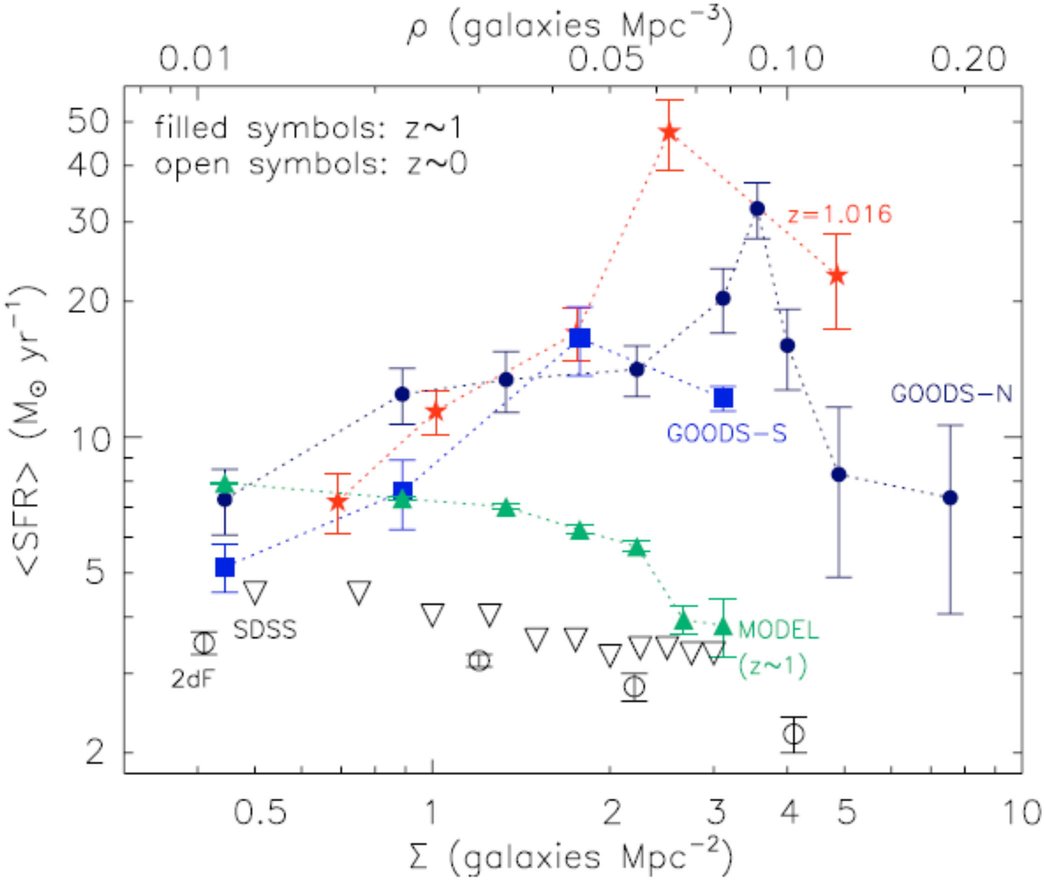
KEY SCIENCES

The Obscured CSFH & its environmental dependence (1)

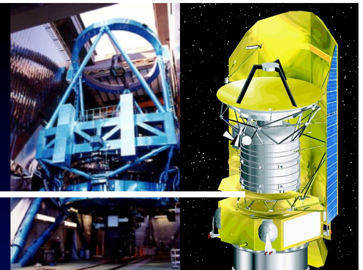
- CSFH z<1 from H-ATLAS galaxies with PFS follow-up
  - Thorough wavelength coverage for the cold dust emission → accurate total IR luminosity
  - Best possible direct measurement of dust-shrouded star-formation rates by tracing the reprocessed emission from young massive stars.
- Extremely Large area survey (~100deg^2) at z=0.5-1 is sufficient to be free from the Cosmic Variance

The Obscured CSFH & its environmental dependence (2)

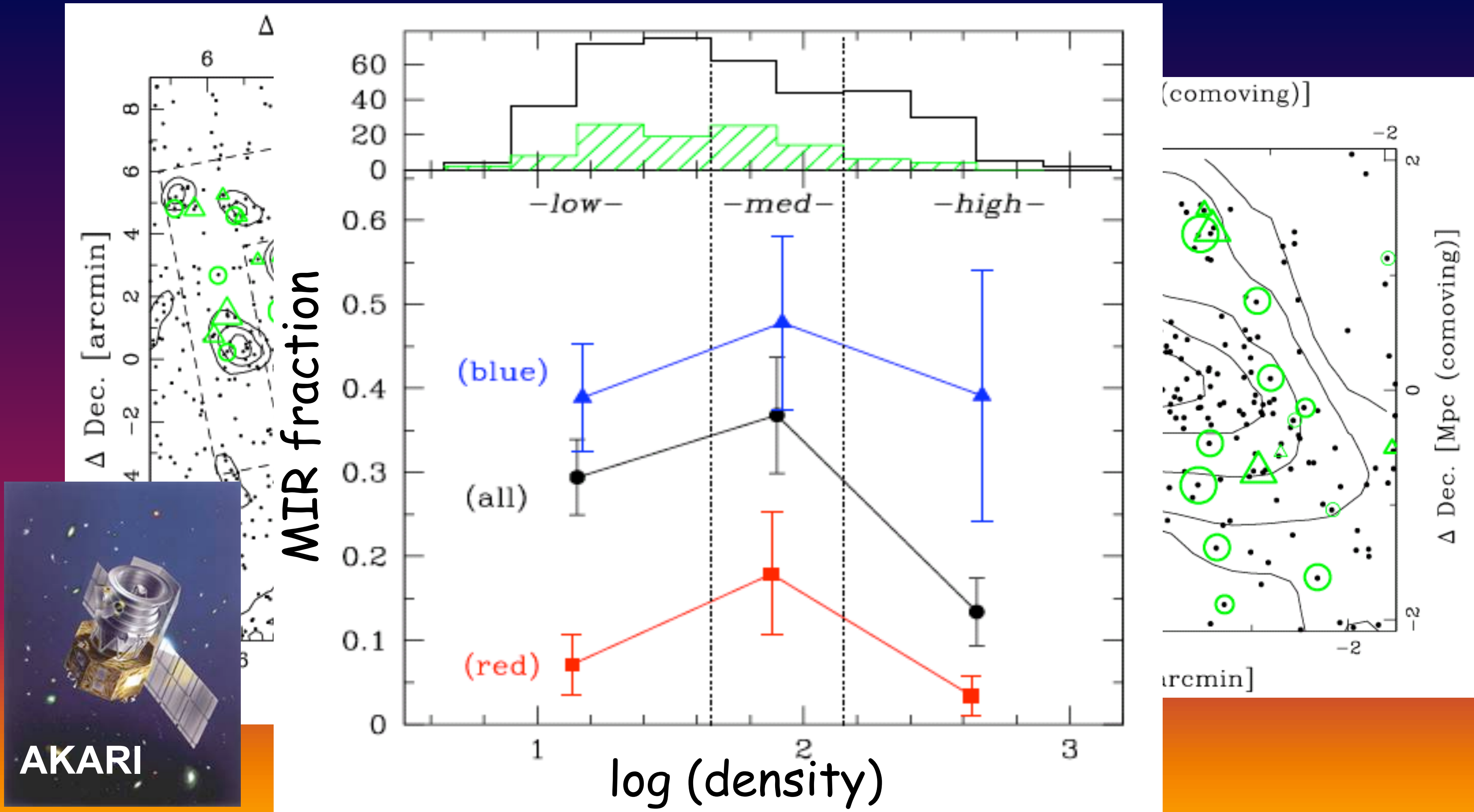
- Environmental dependence
  - Star-forming galaxies avoid richer environments in the local Universe, but this relation is reversed at z~1 (Elbaz et al. 2007)
- ~60 (Abell class 1 or greater) clusters enable to test his relationship at z<1.



AKARI MIR galaxies in the transition region

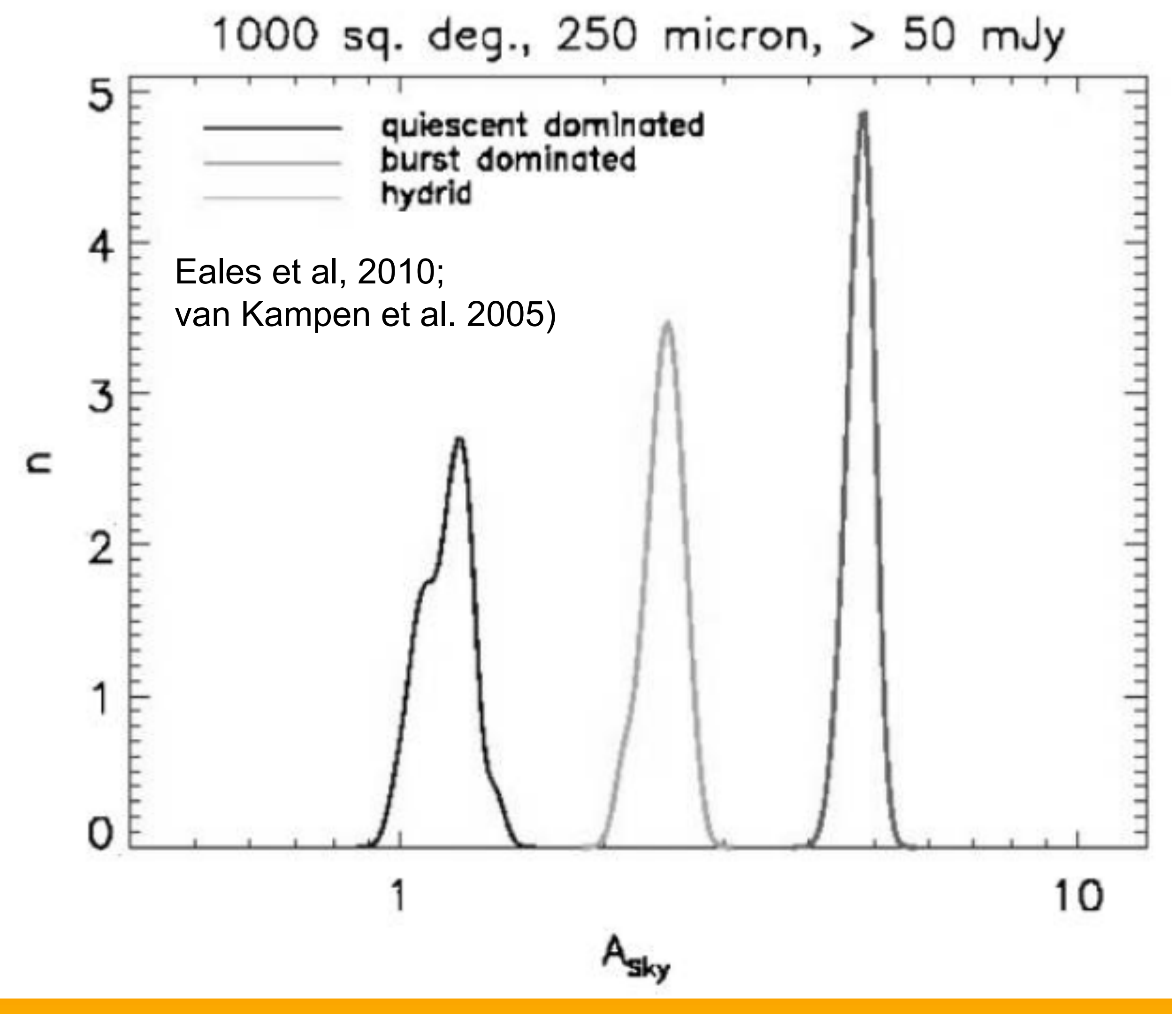


MIR galaxies prefer cluster outskirts, but avoid cluster centre



Angular correlation function on large scales

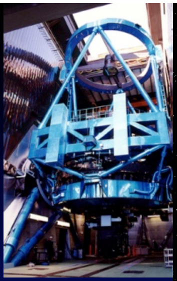
- Large-scale structure of the star-forming galaxies up to ~1000Mpc scale at z~1
- Monte Carlo simulation to predict the angular correlation function

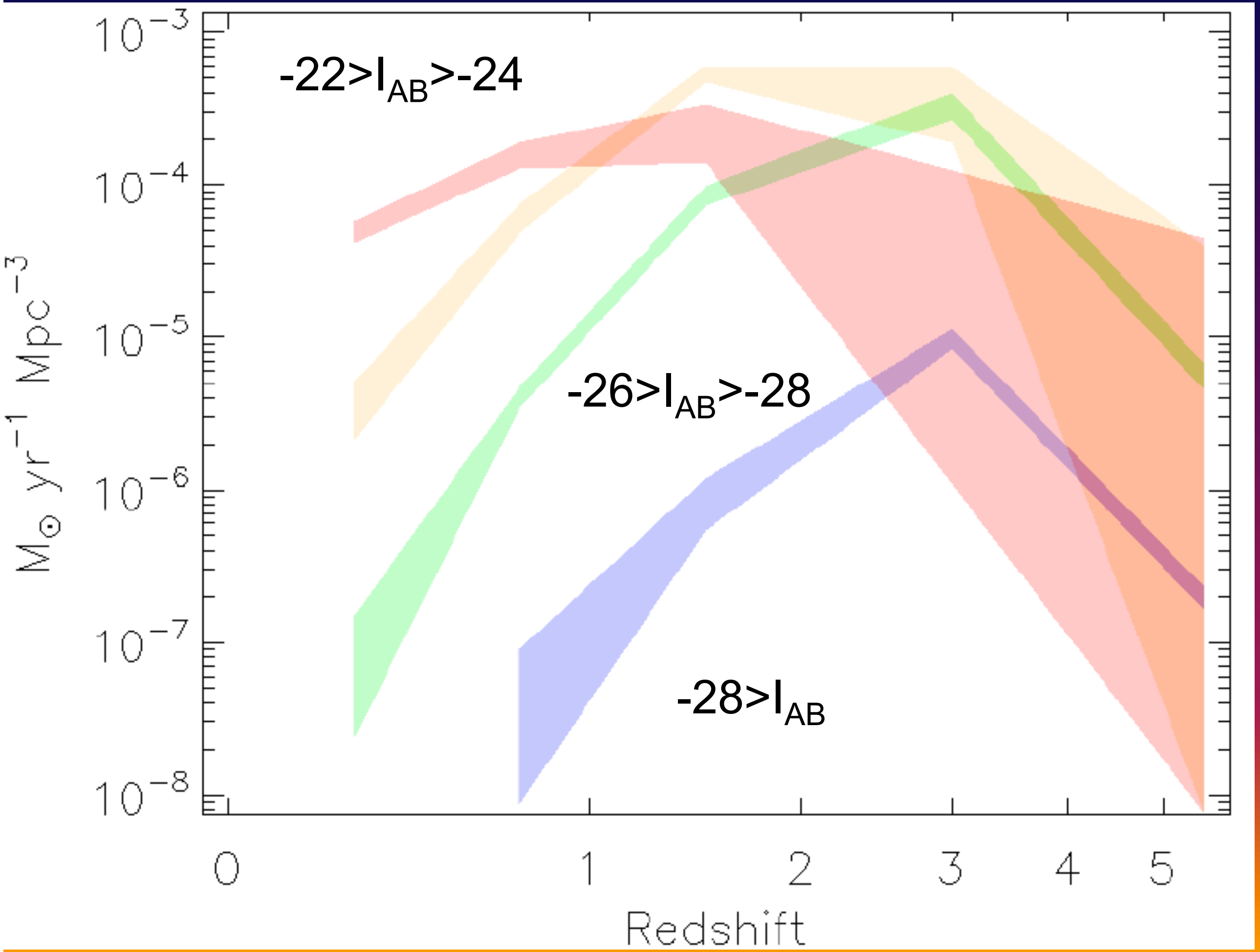


The Link between Black Hole Accretion and Stellar Mass Assembly

- Indication of AGN feedback (energy input) to host galaxies regulating star-formation
  - Close relationship between Black Hole growth and stellar mass assembly
  - AGN contribution to bolometric luminosity increases for higher luminosity starbursts
- Measure star-formation rates in the QSO host galaxies
  - ~60,000 AGN candidates in ATLAS NGP field
  - Pioneering work (Serjeant et al. 2010) by using the stacking analysis of SDP Herschel images

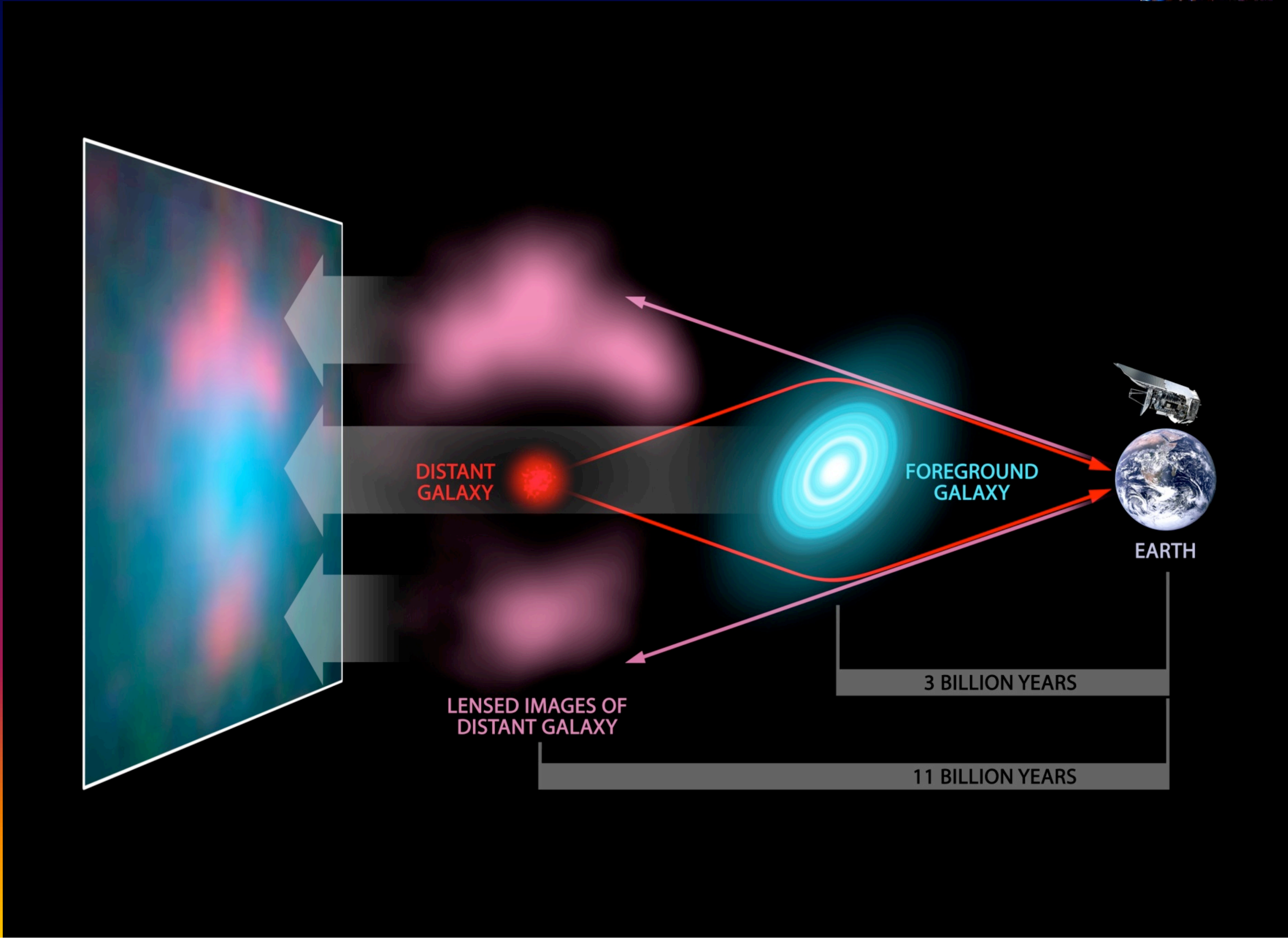
CSFH of Quasar Host Galaxies (Serjeant et al. 2010)

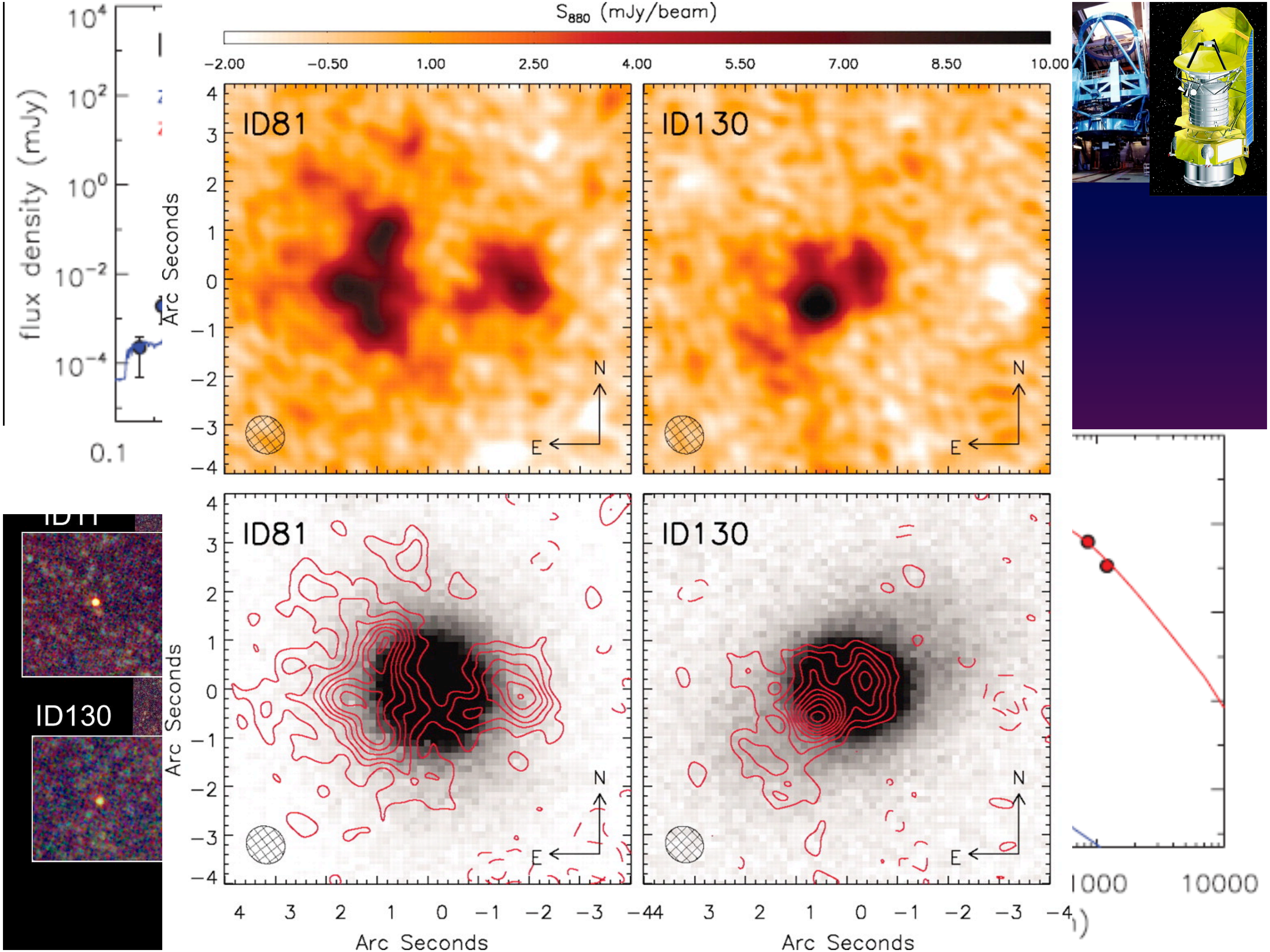


- Very strong evolution rate at high luminosities

Gravitational Lensing

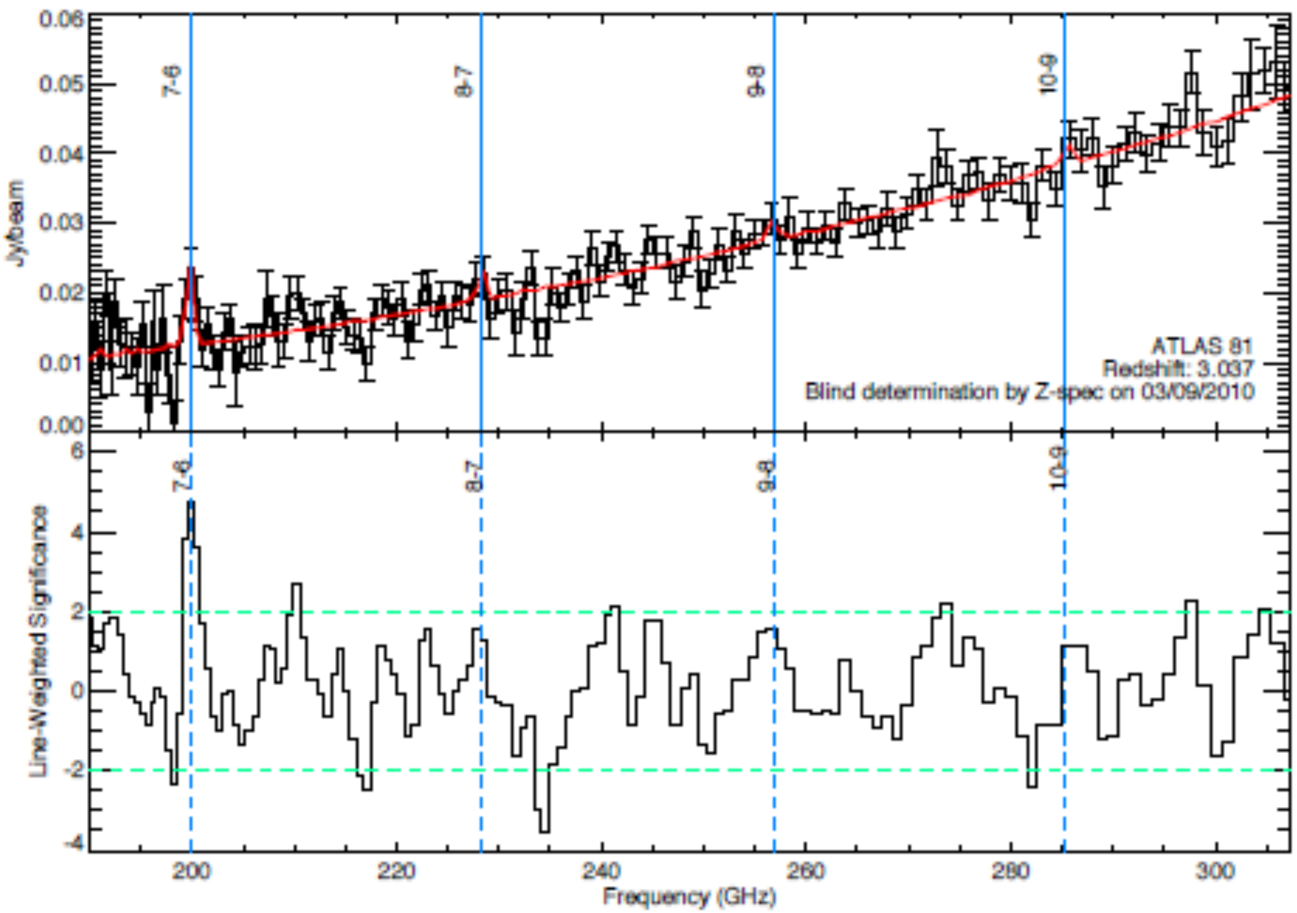



S880 (mJy/beam)
−2.00
−0.50
1.00
2.50
4.00
5.50
7.00
8.50
10.00
ID81
ID130
ID81
ID130
N
E
Arc Seconds
Arc Seconds
Arc Seconds
Arc Seconds
flux density (mJy)
ID130
1000
10000

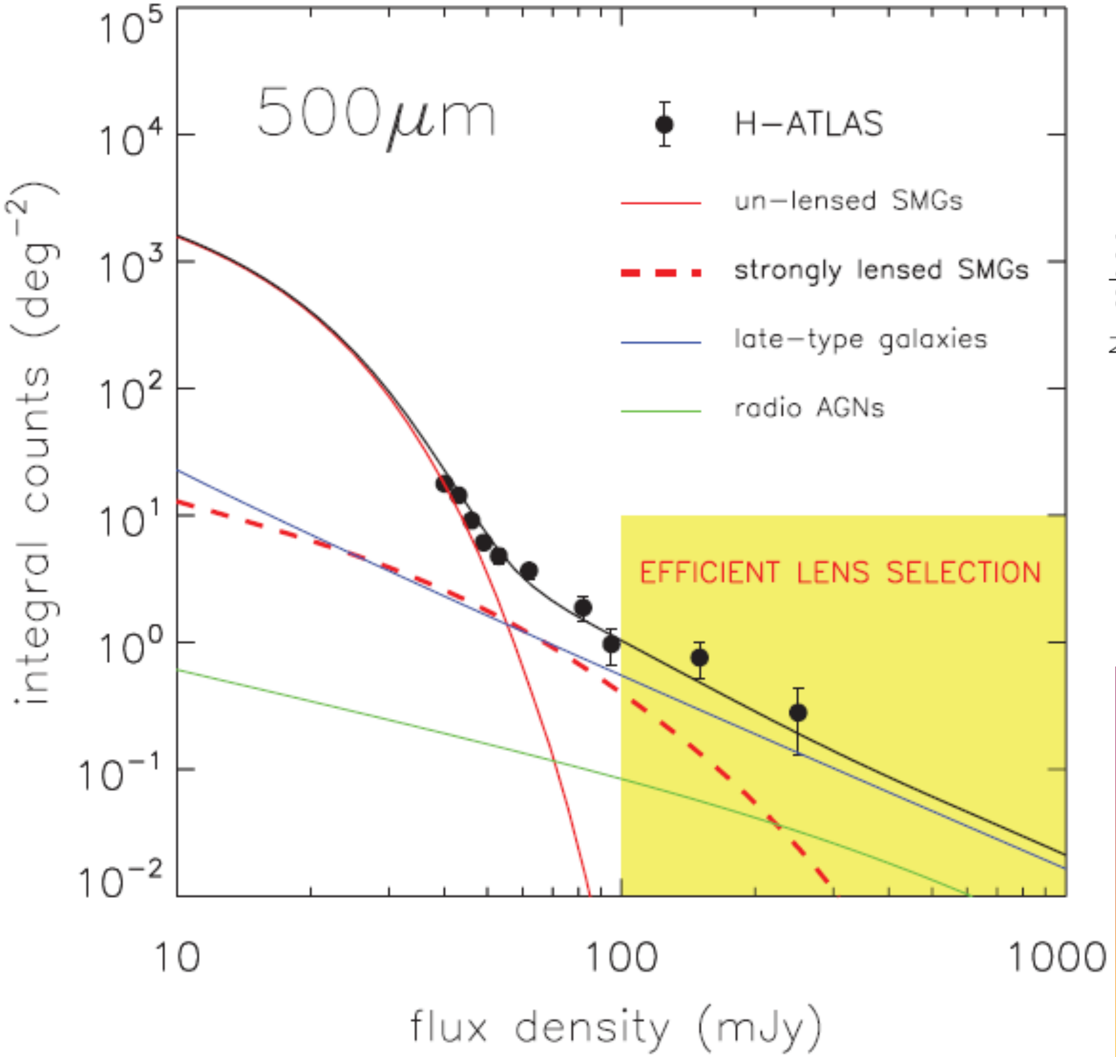
ID 81 blind z=3.04 determination with Z-Spec by using ^{12}CO ladder

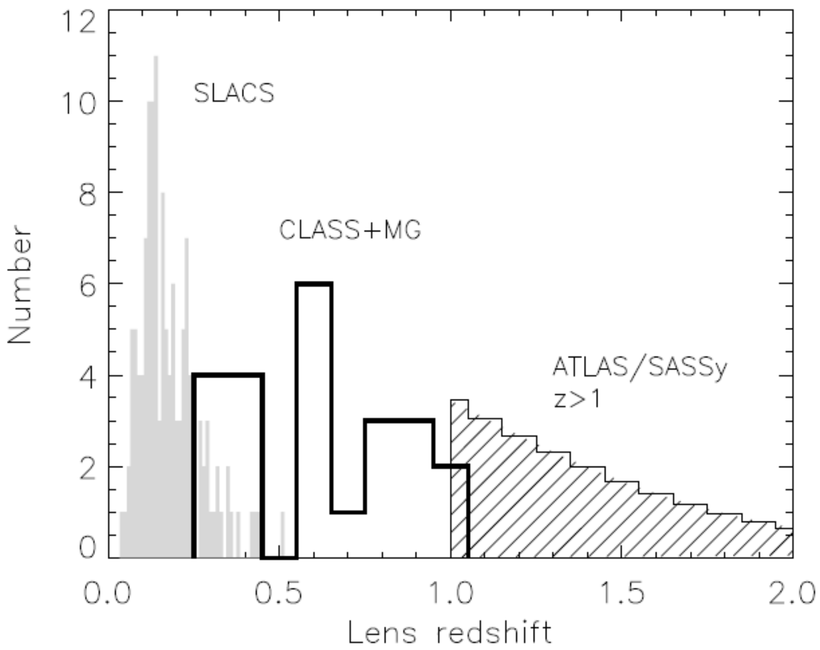
Followed by PdB & GBT

Z-Spec/ CSO, Mauna Kea



Submm Bright source Survey is Quite Efficient Way for Selecting Gravitational Lenses





- Once ATLAS Completed, ~3000 strongly lensed sources are predicted

Subaru/PFS Baseline Survey Plan

- Main sample
  - ATLAS-NGP field (150deg^2, 22,000 galaxies with r_{AB} < 22.4 mag (~1/3 of all Hershel galaxies)
  - z=0.3-0.5? (Dye et al. 2010)
  - ~20 nights assuming 5 FoV (1.5deg^2) can be observed per night
  - So far GAMA survey is r_{AB} < 19.8 mag → GAMA field may be inclluded
- Secondary Sample
  - Fainter sample (r_{AB} < 24 mag) of entire ATLAS (NGP & GAMA) fields
  - z~1? Probably 70,000 galaxies @ ~300deg^2

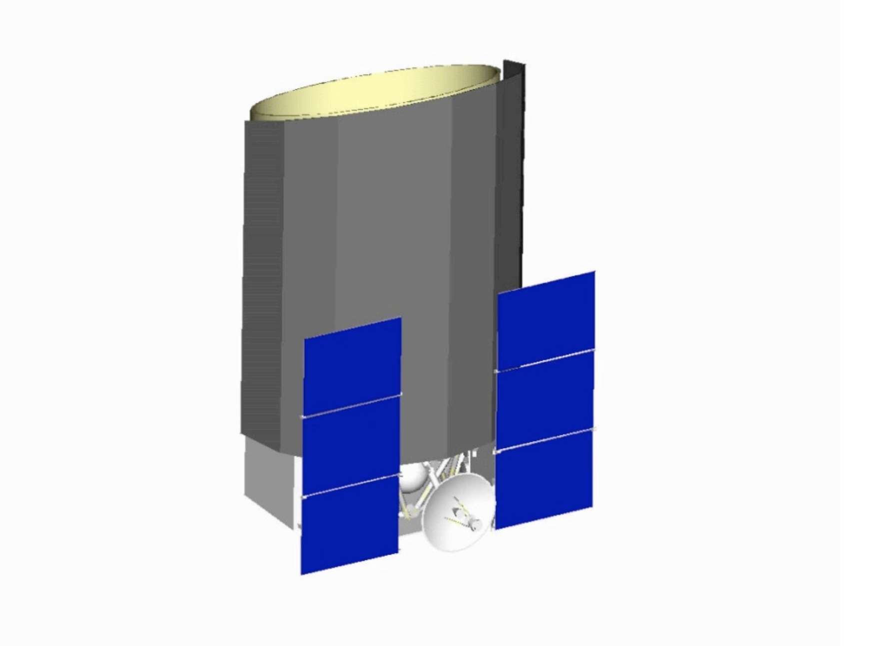
Subaru/PFS Instrument Requirements

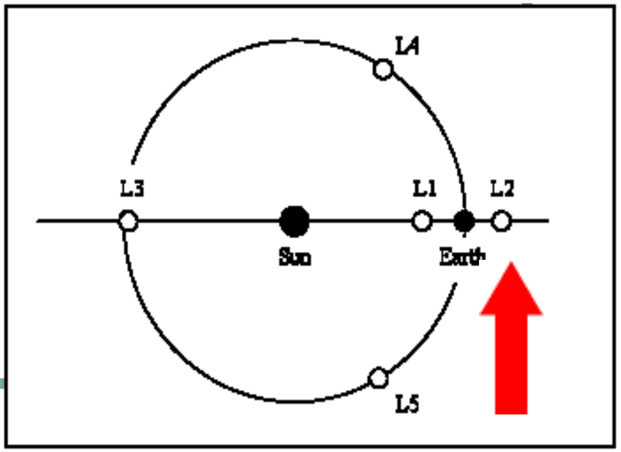
- Field-of-View
  - To survey the entire main sample field in reasonable observing time, 1.5 deg^2 or larger is preferable
- Number of fibers
  - > 500 fibres per deg^2 (surface density of ATLAS sources)
- Throughput
  - the sensitivity is key issue
  - The degraded throughput (10%) of PFS leads to lose the advantage over Keck/DEIMOS (~40%, >200 slits) in the survey speed
- Wavelength coverage
  - Baseline (3900-10800A) is sufficient for z=0.3-0.5 sample
  - Longer extension (upto 1.3 μm) is preferable to observe [O III] @z=1


SYNERGY WITH SPICA

SPICA Mission Overview

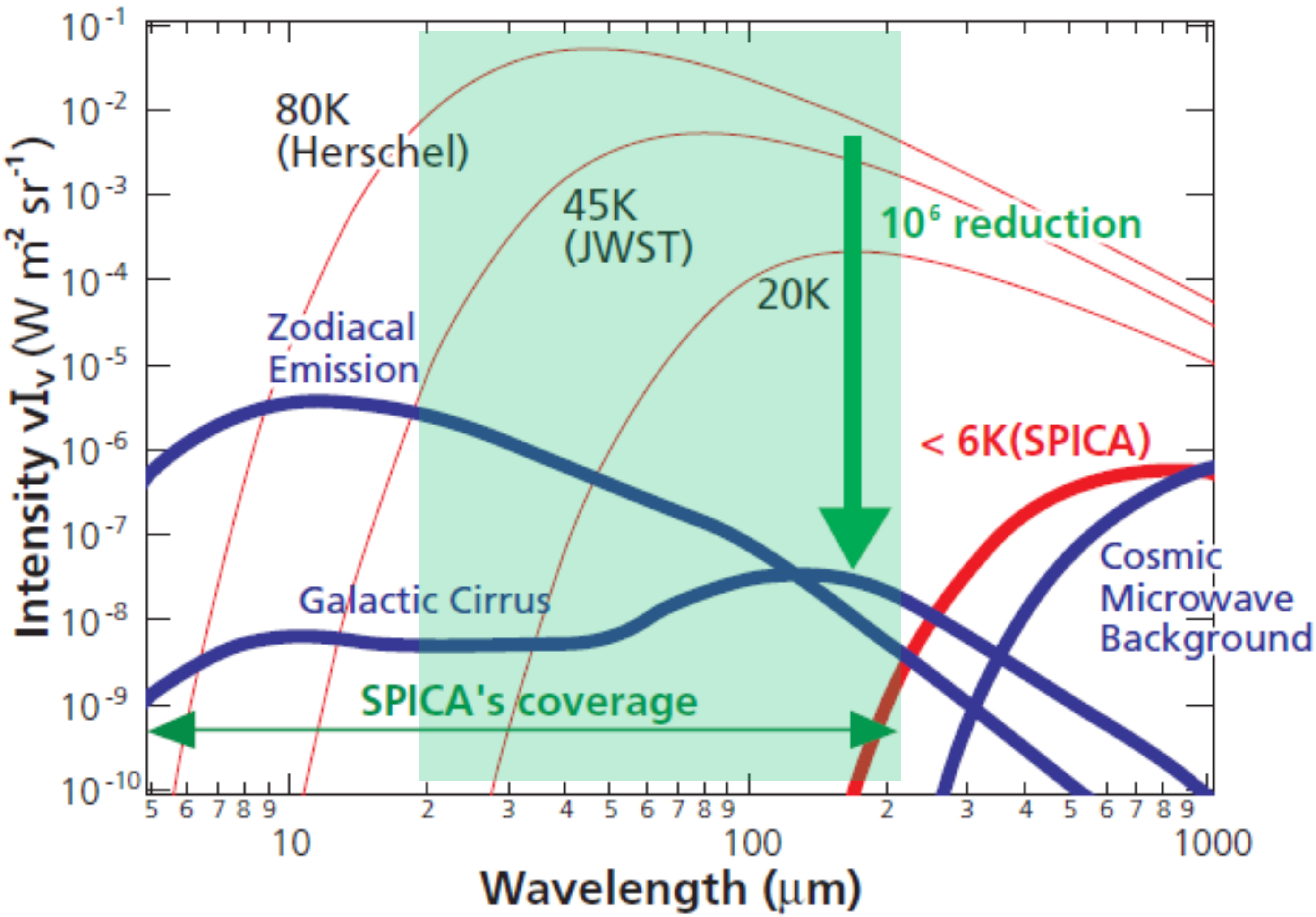
- Specifications
  - Telescope: 3m-class, 6 K
    - Superb spatial resolution with excellent sensitivity
  - Core wavelength: 5-210 μm
  - Orbit: Sun-Earth L2 Halo
  - Mission Life
    - 3 years (nominal)
    - 5 years (goal)
  - Weight: 3.7 t
  - Launch: FY2018 (proposed) with H-IIA-204 (5S fairing)
    - launch schedule under discussion
  - Heritage
    - IRAS, ISO, AKARI, Herschel





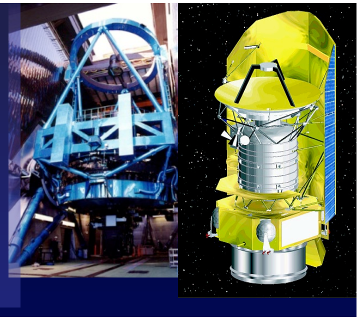
SPICA
Space Infrared Telescope for Cosmology and Astrophysics

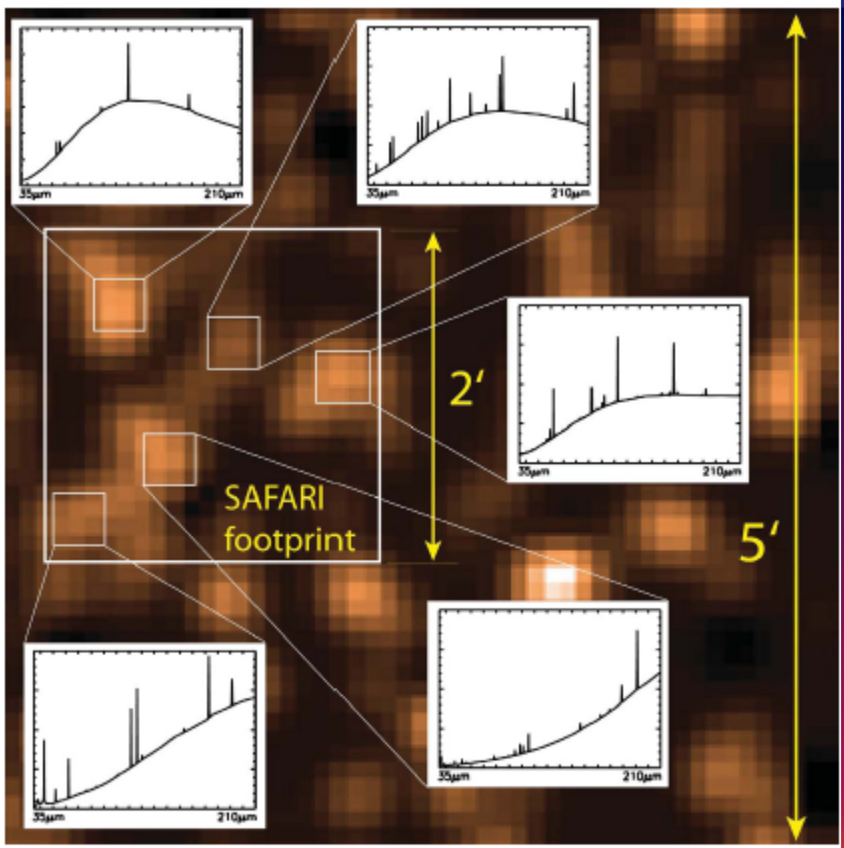
With Cooled telescope Mission !

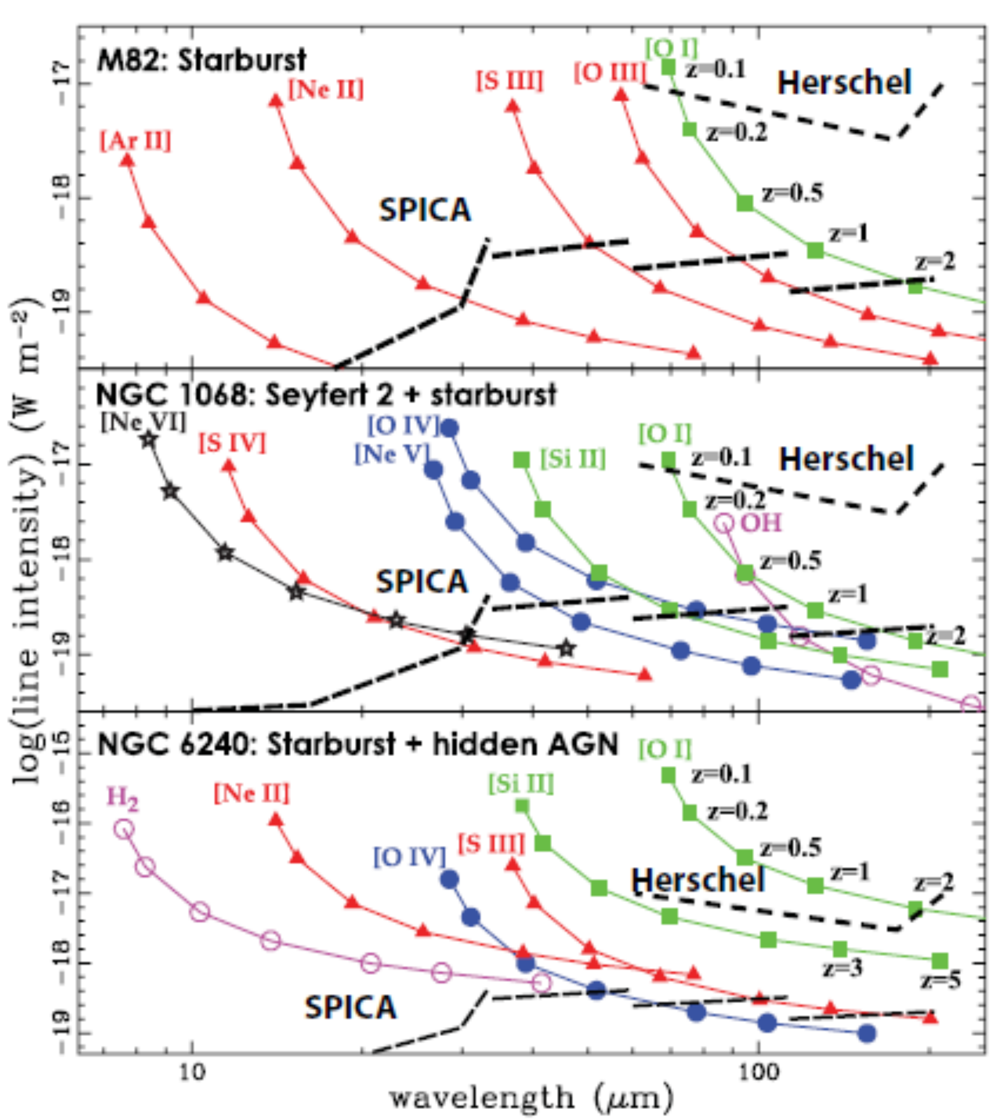


Background will be 1 million times smaller than the warm (passively cooled) telescope !!

Diagnostics of Violent Epoch with much better mid & far-IR spectral-line sensitivity !!







Synergy with SPICA

- Very deep & fast imaging survey at 20-210μm
  - More than $100 deg^2$ @ 100μm is possible
- Very deep mid- far-IR study of dust-obscured galaxies
  - Complementary to optical diagnostics with PFS
- Aimed Launch of SPICA : FY2018
  - Close to the commission of PFS
- SPICA is a Japanese-led Mission
  - Strategic plan with Subaru/HSC & PFS !!

問合せ：spica_ws@ir.isas.jaxa.jp

詳しくはSPICAWebページをご覧下さい。

http://www.ir.isas.jaxa.jp/SPICA/SPICA_HP/index.html

SPiCA

Space Infrared Telescope for Cosmology and Astrophysics

BACKUP SLIDES

The NEP Survey - footprints

- Deep : 0.38 deg^2 (259 pointing)
- Wide : 5.8 deg^2 (446 pointing)