Infrared properties of Hickson Compact Groups 56 and 92 based on AKARI/IRC spectroscopy and near- to far-infrared photometric observations

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Introduction (HCGs)

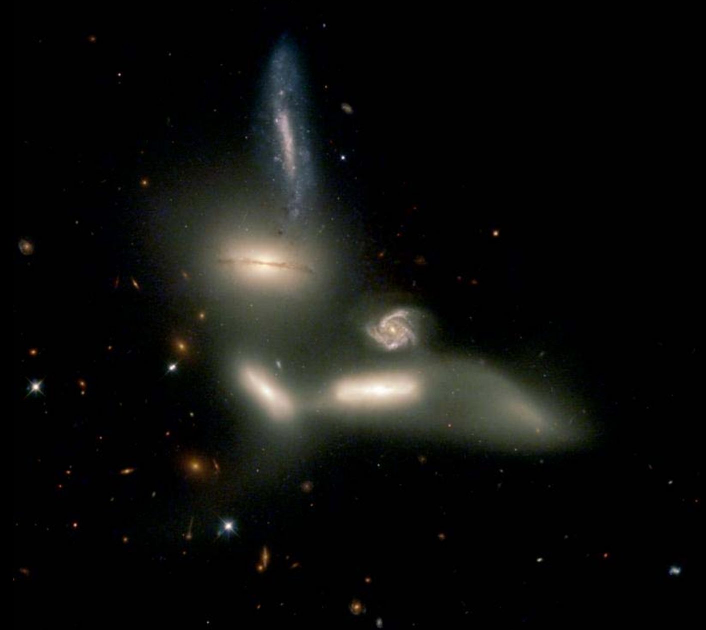
-HCGs (Hickson Compact Groups)

>A catalog of compact groups. Selection is based on galaxy population, isolation and compactness (Hickson 1982).

>Providing an ideal opportunity to investigate the effects of interactions on the galactic environments for the study of galaxy evolution.

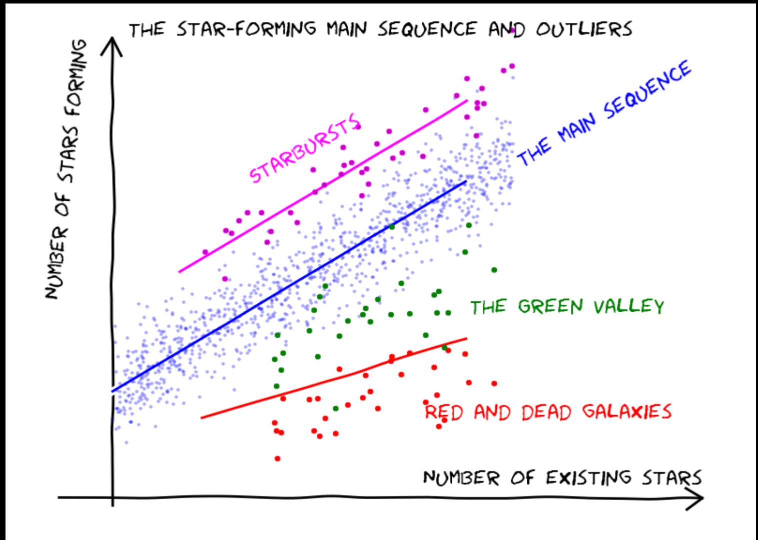
>HCGs contain various kind of galaxies.

(normal star-forming galaxies, ellipticals, starbursts, LINERs, Seyferts, LIRGs, MOHEGs, etc.)

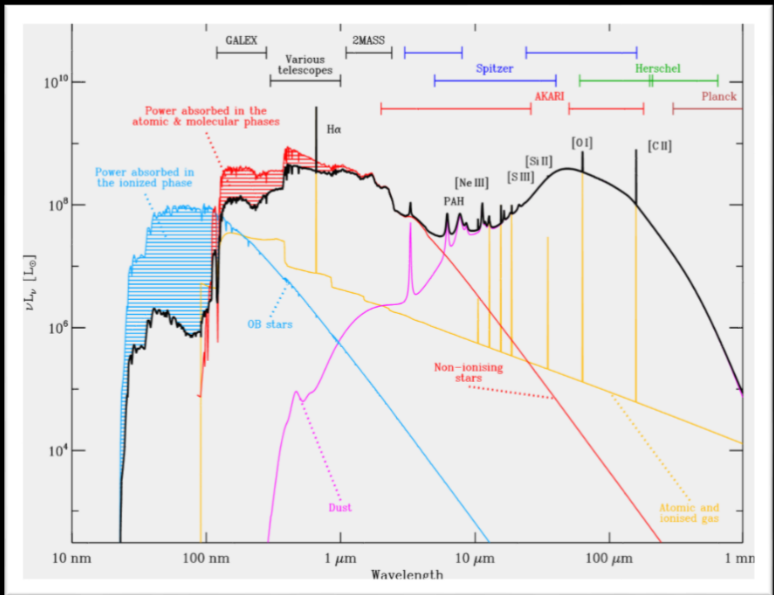


↑HCG 79 (Seyfert's Sextet)
Credit: HST/NASA/ESA

Motivation to investigate



↑Credit: CANDELS Collaboration



↑Credit: Galliano, F.

-Interaction effects to star formation activity of member galaxies of HCGs

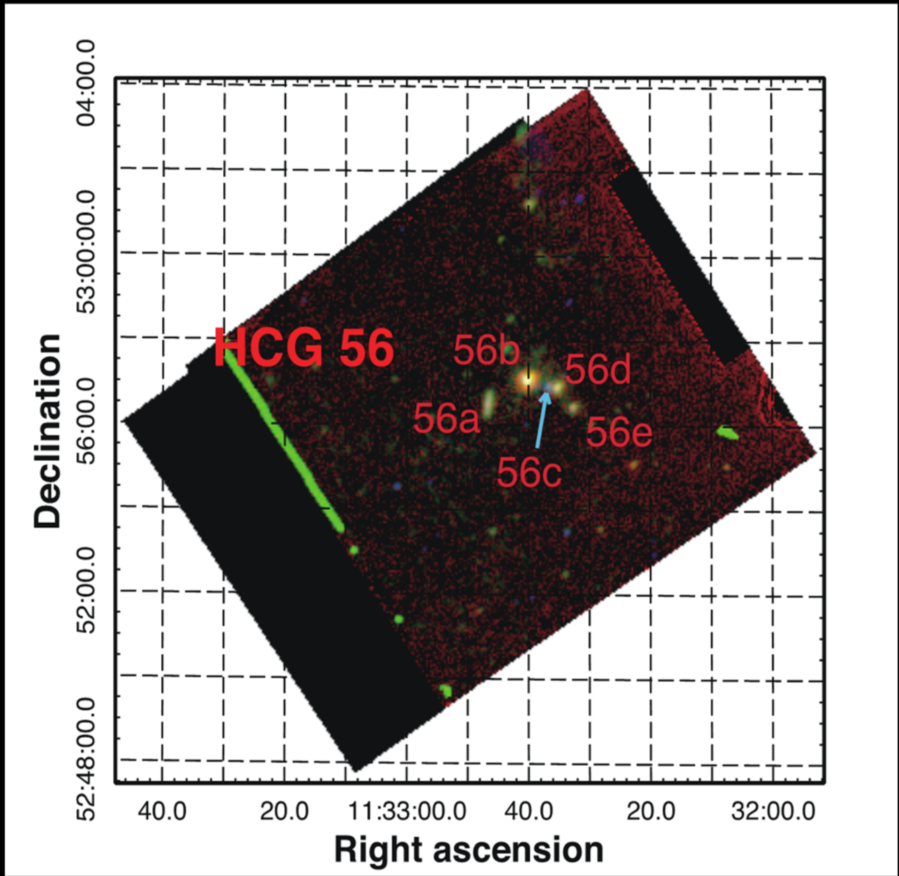
->induced/suppressed

->The nature of the “green valley” object

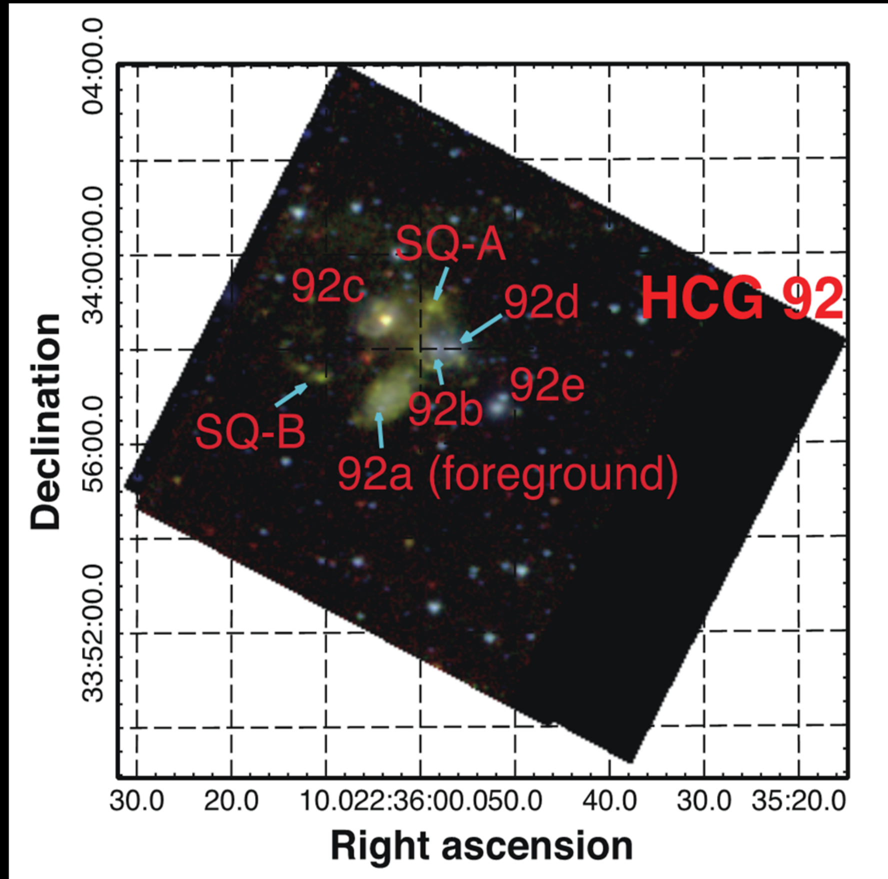
-Interstellar dust traced by infrared observations

->PAH fraction, dust mass, IR luminosity, etc.

Our targets (HCG 56 and 92)

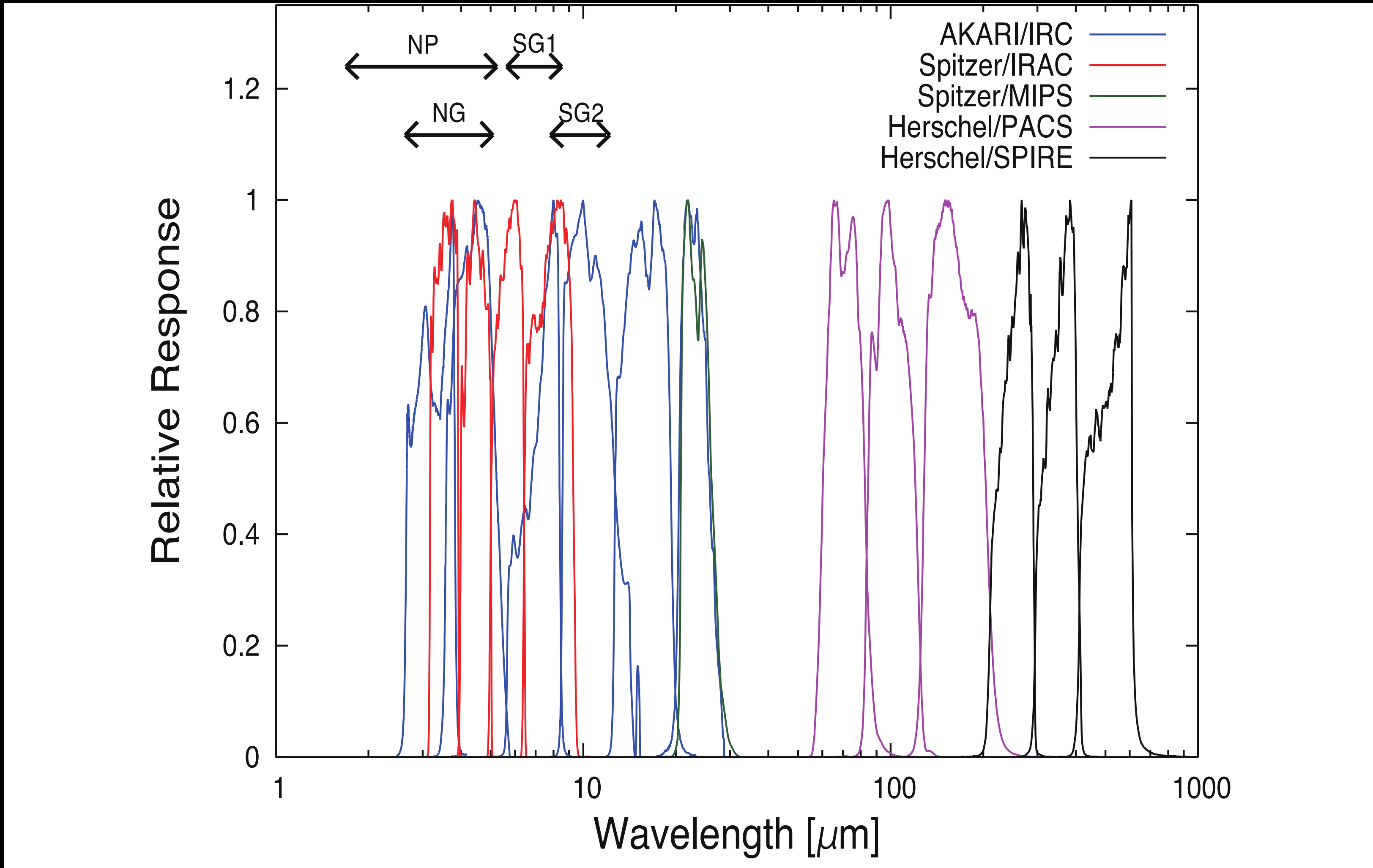


↑Blue 3.2 μm; Green 11 μm; Red 24 μm
z~0.027 (~120 Mpc)
Morphology; Sc (56a), SB0 (56b), S0 (56c), S0 (56d), S0 (56e)
HCG 56b is a Seyfert 1 galaxy.
Bridge structure exists between 56b and 56c in optical wavelengths.



↑Blue 3.2 μm; Green 7 μm; Red 11 μm
Alias; Stephan's Quintet (SQ)
z~0.0225 (60-80 Mpc) w/o HCG 92a.
HCG 92c is a Seyfert 2 galaxy.
SQ-A and SQ-B are tidal debris (dwarf galaxy candidate) found by ISO/ISOCAM.

Our datasets

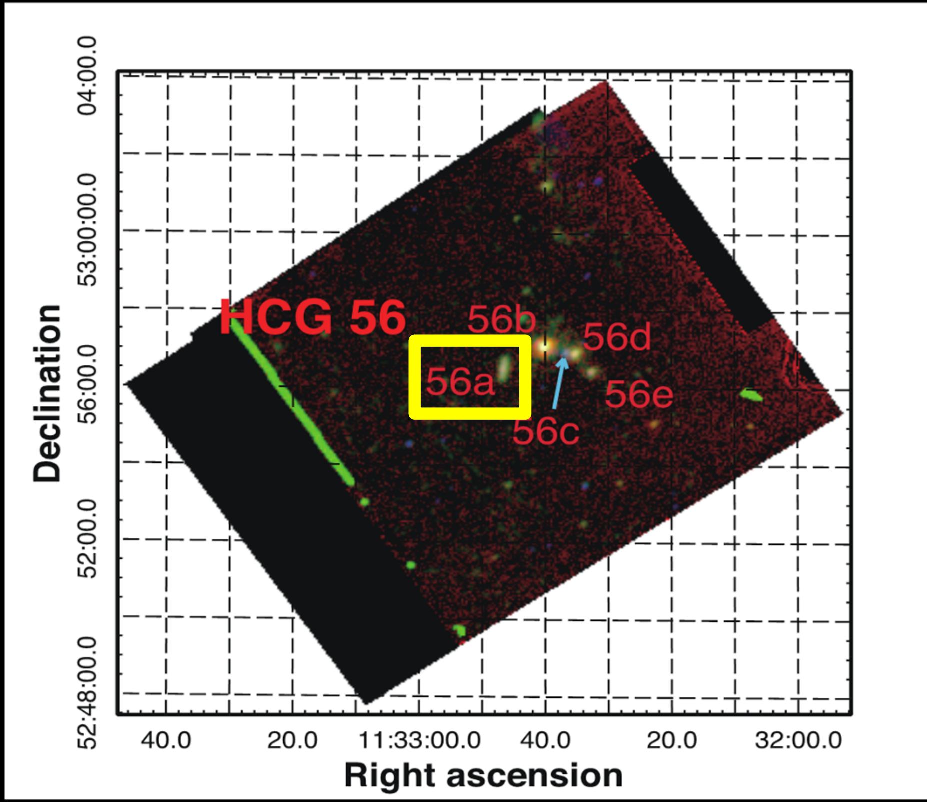


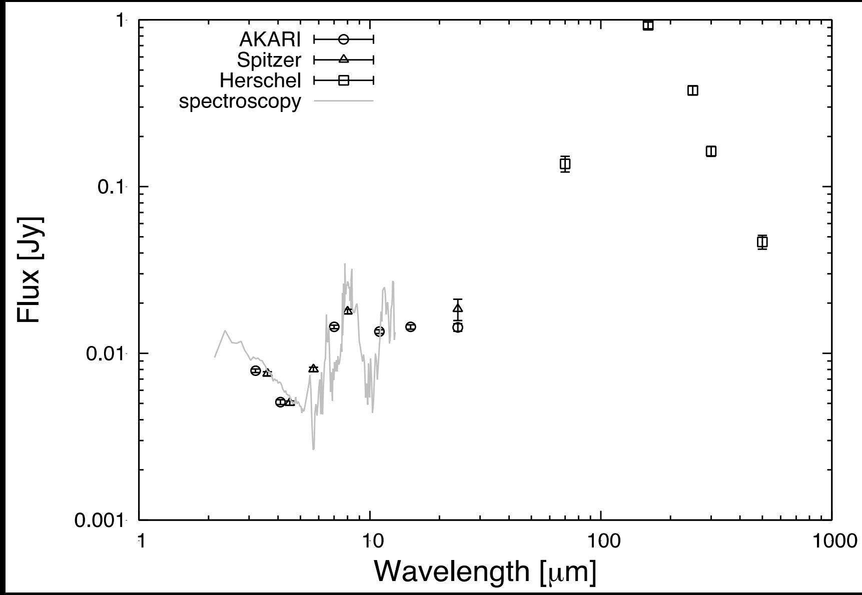
-Spectra of a whole galaxy extracted from AKARI/IRC slit-less spectroscopy + SED constructed from wide range photometry in infrared

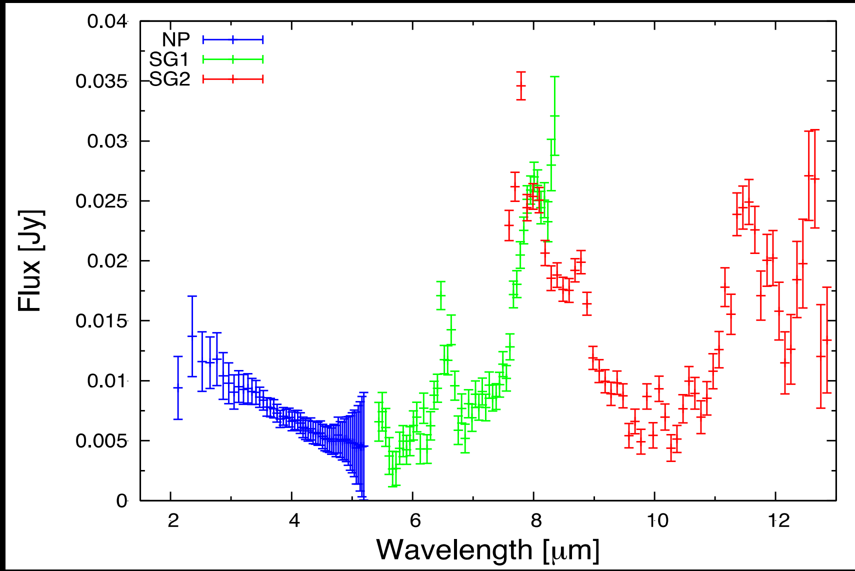
>Galaxy-scale dust properties with precision (q_{PAH}, M_{dust}, <U>, etc.)

->Understanding the ongoing interaction

Results of photometry and spectroscopy (HCG 56a)



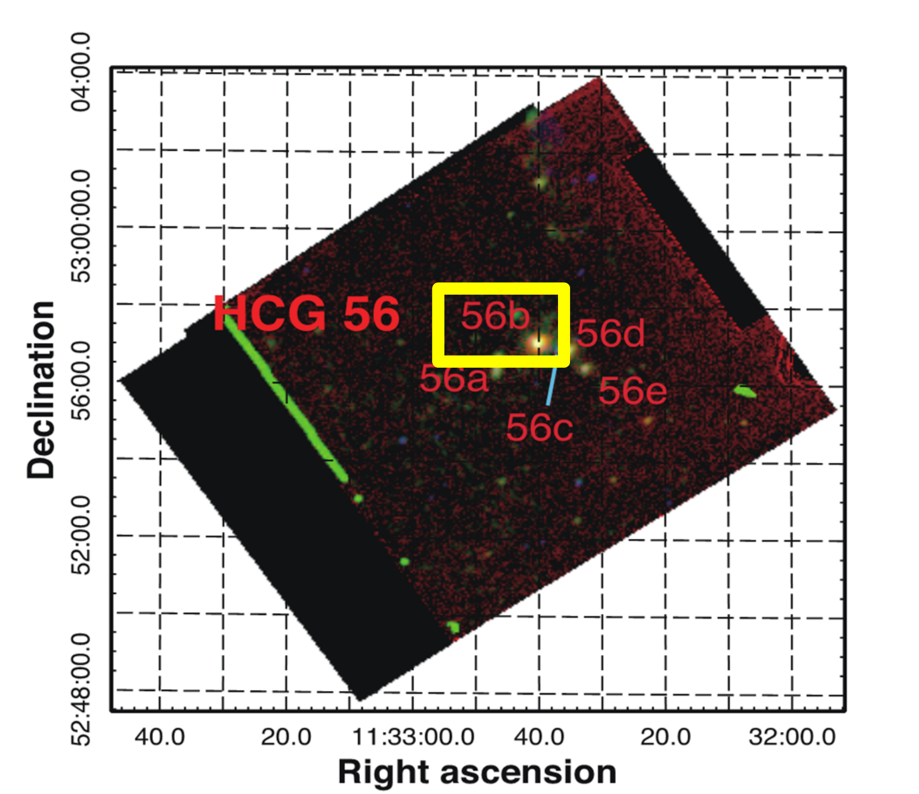


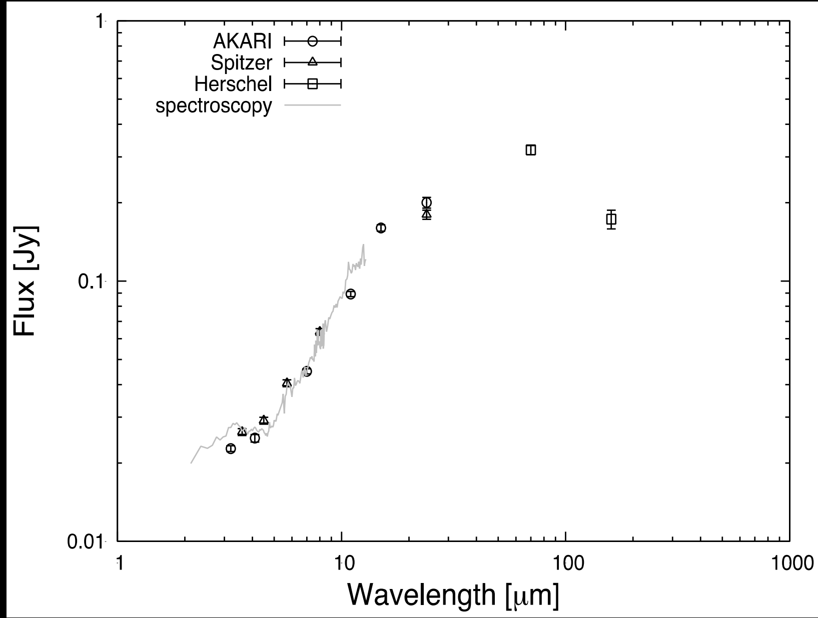


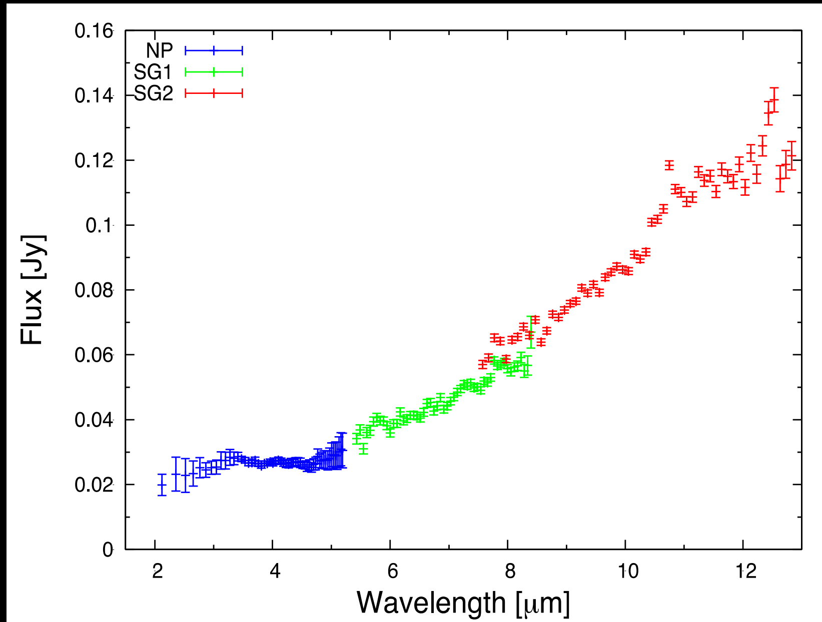
-Presence of UIR bands features at 6.2, 7.7, 8.6 and 11.3 μm.

-This galaxy looks like a normal star-forming galaxy.

Results of photometry and spectroscopy (HCG 56b)







-Red continuum with no clear presence of UIR band features

>Typical features of AGN host galaxies

-Red continuum with a lack of silicate absorption at 9.7μm

>Consistent with the classification of Seyfert 1 (face on)

SED fitting technique (Non-uniformly illuminated dust mixture)

$dM_{dust} \propto U^{-\alpha} dU$ between Umin and Umax (Dale et al., 2001)

-Assuming that the dust is exposed to the above distribution of starlight intensities (non-uniformly illuminated dust mixture).

->This compensates our ignorance of the actual topology of the ISM and the distribution of stars.

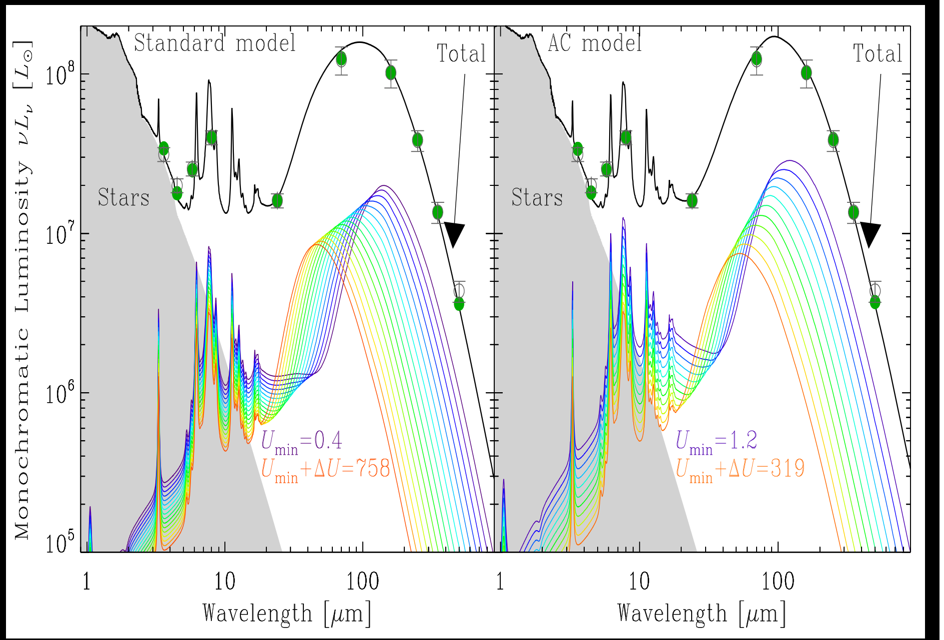
-We fitted the SEDs using two different models (Galliano et al. 2011 & Jones et al. 2013).

->We confirmed the robustness against what grain properties we assume.

-The search for best parameters is done by minimizing the χ^2, using the Levenberg-Marquardt method (Markwardt 2009). We perform Monte-Carlo propagation of the uncertainties for all the parameters.

-An old stellar population template (PEGASE; Fioc & Rocca- Volmerange 1997) is added to SED in order to model the near-IR emission.

-For HCG 56b and 92c, we added AGN templates of Siebenmorgen et al. (2015) because these galaxies are AGN host galaxies.



↑The idea of non-uniformly illuminated dust mixture quoted from Galliano et al. (2011).

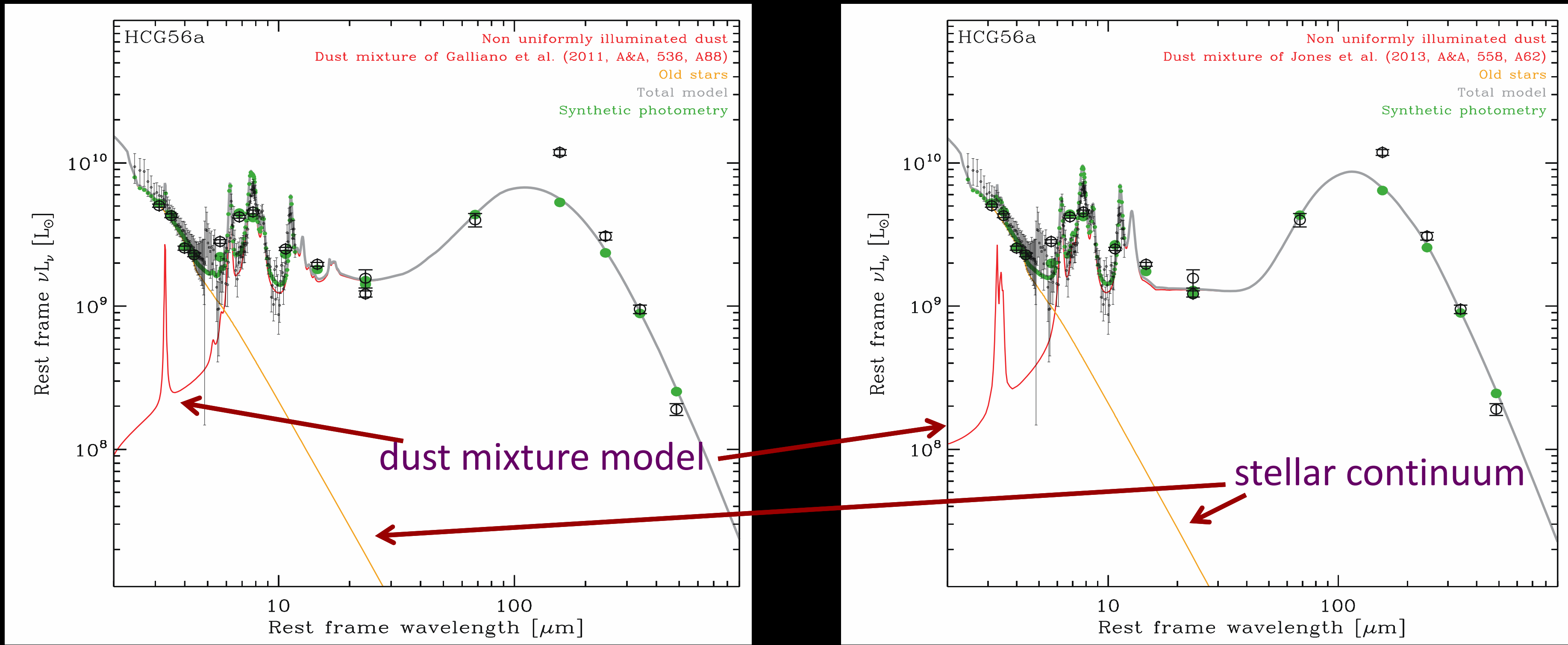
-free parameters

U_{min}, U_{max}, α, q_{PAH}, f_+ and $M_\star$

-derived parameter

<U>

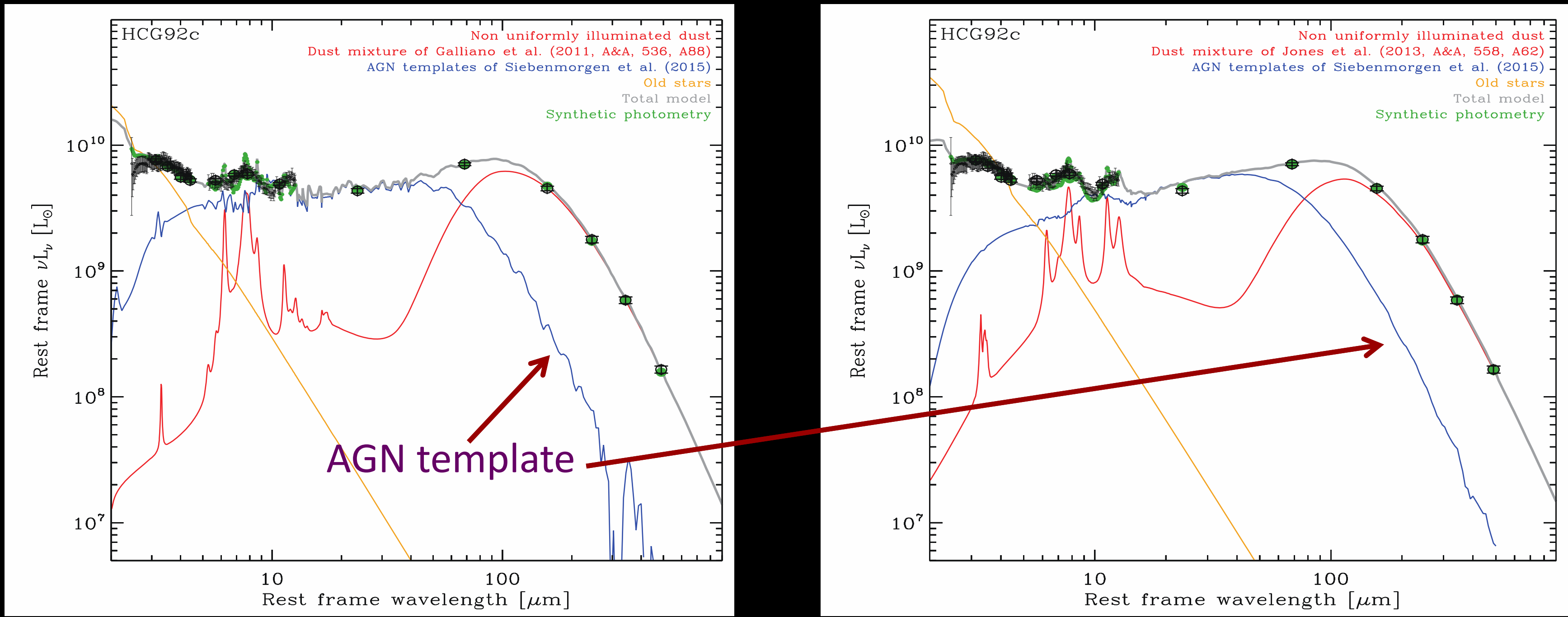
Results of SED fitting (HCG 56a)



-The possibility of data artifact at PACS 160 μm.
-Normal disk galaxy (quite a cold SED with no clear emission in mid- infrared spectrum).
-Its PAH mass fraction (~8.20%) is roughly Galactic (~4.6%).
->Suggesting its metallicity is close to solar.

↑The SED models of HCG 56a.
left: The AC composition (Galliano et al. 2011)
right: The THEMIS composition (Jones et al. 2013)

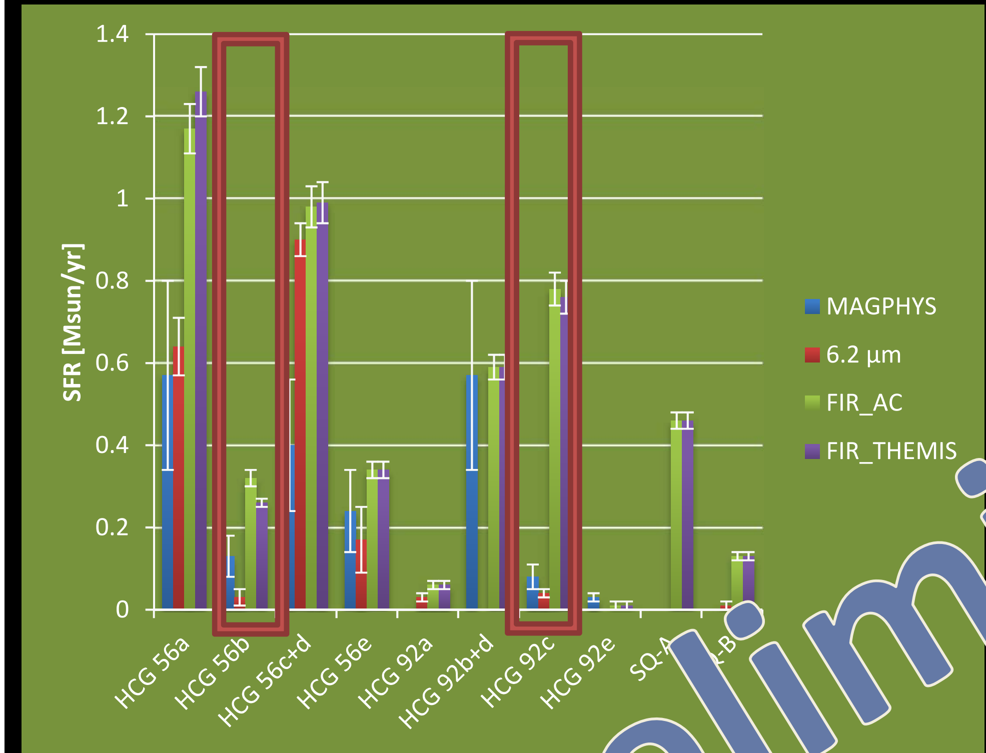
Result of SED fitting (HCG 92c)



-This is a known Seyfert 2 galaxy, and strong continuum in mid- IR also indicates the presence of AGN.
>We added AGN templates of Siebenmorgen et al. (2015) to fit.
->The luminosity fraction of AGN illuminated dust to the total infrared luminosity is ~57.7% (AC model).

↑The SED models of HCG 92c.
left: The AC composition
right: The THEMIS composition

Discussion (SFR)



-Star Formation Rates derived from from different methods.

-$SFR_{MAGPHYS}$ are retrieved from Bitsakis et al. (2014).

-SFR_{FIR} is calculated from following equation;

SFR_{FIR} [$M_{\odot}$ / yr] = $2.54 \times 10^{-44} L_{8-1000\mu m}$ [erg/s]. (1)

-$SFR_{6.2\mu m}$ is calculated from following equation;

$SFR_{6.2\mu m}$ [$M_{\odot}$ / yr] = $10^{-40.06+0.96 \text{ x } \log L\, 6.2\mu m \text{ [erg/s]}}$ (2)

-Eq. (1) and (2) are retrieved from Shipley et al. (accepted for publication in ApJ).

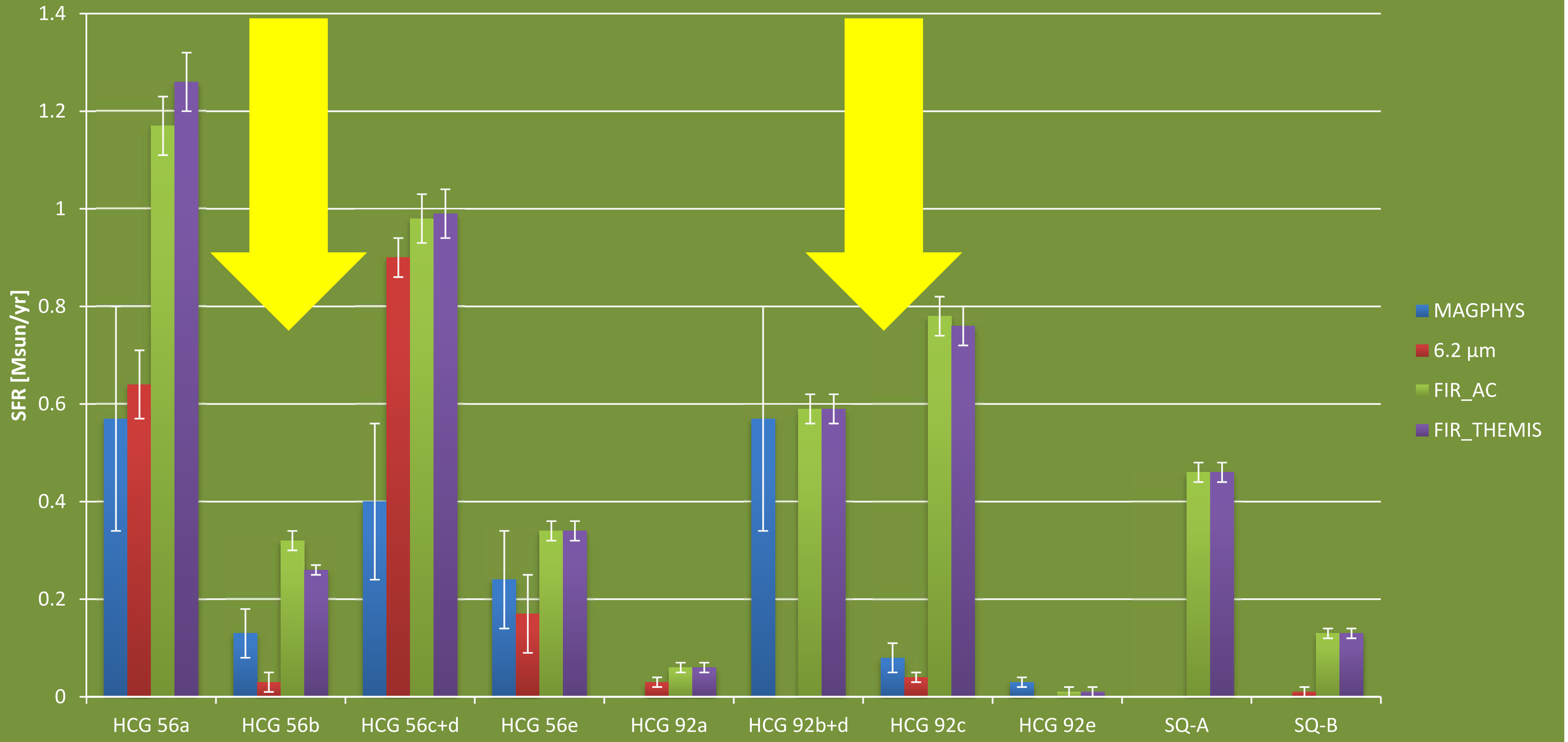
-For HCG 56b and 92e, the far-infrared luminosity associated only with starburst component is used for the calculation of SFR_{FIR}.

>Huge discrepancy (an order of magnitude) between SFR_{FIR} and $SFR_{6.2\mu m}$ at AGN host galaxies.

>>(1) the difference in dust populations/ properties, (2) UIR 6.2μm band weakness in AGN hosts and (3) the limitation of current dust models.

-Our results are roughly consistent with the SFR deriving from MAGPHYS (Bitsakis et al. 2014).

Discussion (SFR)



-Star Formation Rates derived from different methods.

-Our results are roughly consistent with the SFR deriving from MAGPHYS (Bitsakis et al. 2014) except for AGN hosts.

-Discrepancy (an order of magnitude) between SFR_{FIR} and $SFR_{6.2\mu m}$ at AGN hosts.

->the difference in dust populations / properties, the possible destruction of PAHs << the limitation of current dust models.

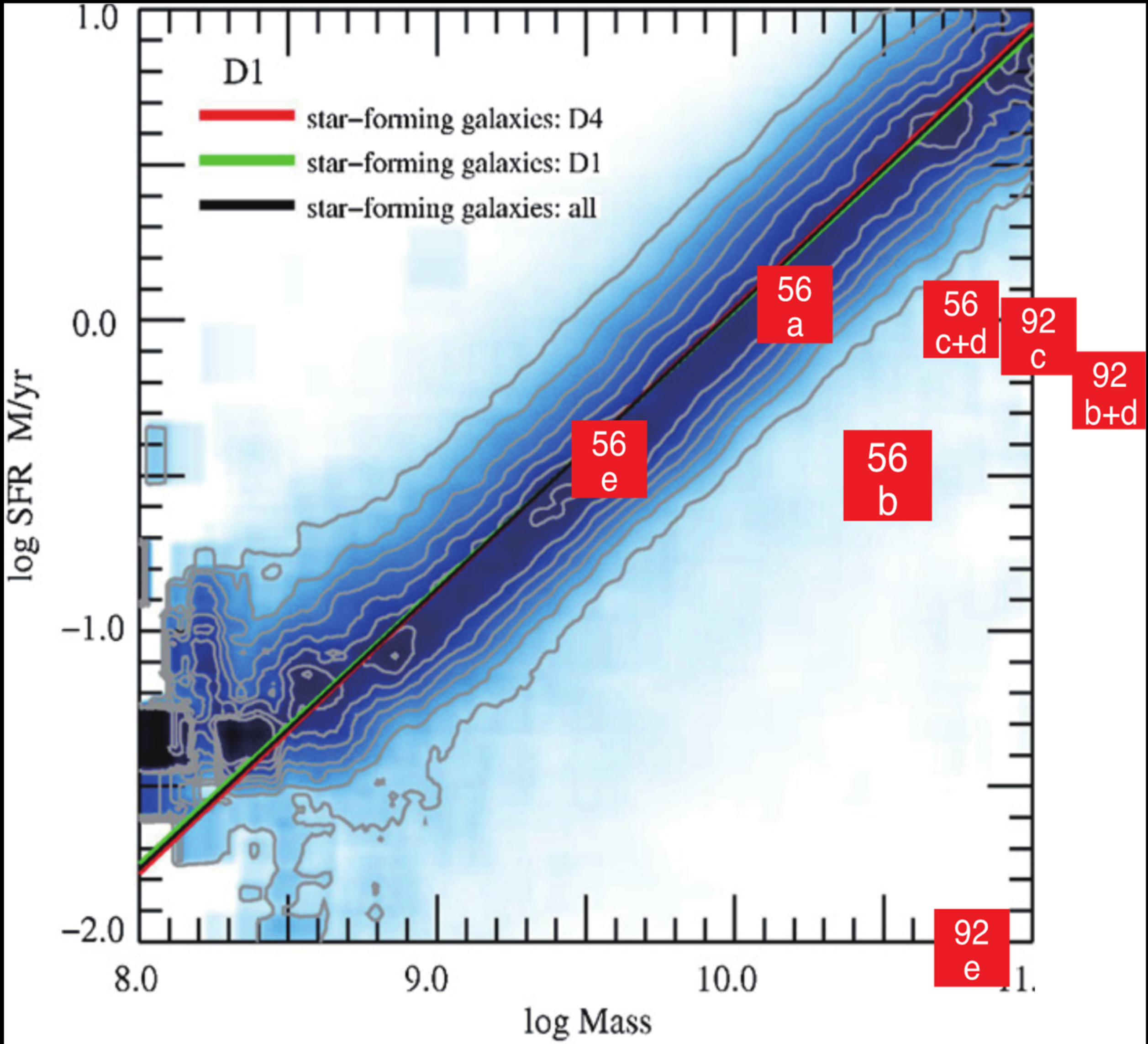
Discussion (SFR)

-The SFRs obtained for the members of HCG 56 and HCG 92 show not significantly higher than the Galactic SFR (0.68–1.45 $M_\odot$/yr ,Robitaille et al. 2010)

-We found that our samples are distributed below the SFR vs. $M_\star$ relation obtained by Peng et al. (2010) and, therefore, less active star formation activities are found in our HCG galaxy samples.

>SFR_{FIR}^{AC} is the largest SFR in many cases of our analyses.

>>The signs of induced star formation due to the galaxy interactions were NOT recognized in the cases of HCG 56 and HCG 92.



↑The SFR-$M_\star$ relationship for star-forming SDSS galaxies (z~0.2) (Peng et al. 2010) over-plotted with our samples. We adopted $M_\star$ of MAGPHYS (Bitsakis et al. 2014) and SFR_{FIR}^{AC} to draw this diagram.

Conclusion

We analyzed AKARI slit-less spectroscopic datasets and AKARI, Spitzer and Herschel photometric datasets of HCG 56 and 92.

We found that the star-formation rate (SFR) of each member galaxy of HCG 56 and 92 are distributed below the low-z star formation main sequence.

Therefore, we have concluded that the induced star-formation activities due to the galaxy interaction have not been recognized and the star formation seems to be suppressed in the case of HCG 56 and 92.

Conclusion

-We found that the star-formation rate (SFR) of each member galaxy of HCG 56 and 92 distribute below the low-z star formation main sequence. Therefore, we have concluded that the induced star-formation activities due to the galaxy interaction have not been recognized from our analyses.

-We analyzed AKARI slit-less spectroscopy datasets of HCG 56 and 92. Consequently, we provided the new mid-infrared spectra of HCG 56a, 92a, 92c and SQ-B.

-We made accurate SED models by collecting photometric datasets in a wide range and by taking account of the latest dust compositions and the AGN presence.

-These SEDs have enabled us to carry out more accurate estimate of star formation rate and to investigate the AGN activities of member galaxies.

Thank you for listening!!