Star Formation and Dust Extinction Properties of Local Galaxies Seen from AKARI

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INTRODUCTION

An accurate estimation of the star formation-related properties of galaxies is crucial for the understanding the evolution of galaxies. In this study, we investigated

1) Star formation rate
2) Dust extinction

of local galaxies.

<u>Star formation rate (SFR)</u>

The SFR stands for the total mass of newly formed stars in a galaxy per year [$M_{\odot} yr^{-1}$].

<u>Dust extinction</u>

The dust extinction is the amount of light of a galaxy absorbed and/or scattered by dust.

INITIAL MASS FUNCTION

Stellar mass

Newly formed stars have a wide range of mass. This makes difficult to estimate the total mass of newly formed stars.

Initial mass function (IMF)

The IMF represents the number of newly formed stars per mass.

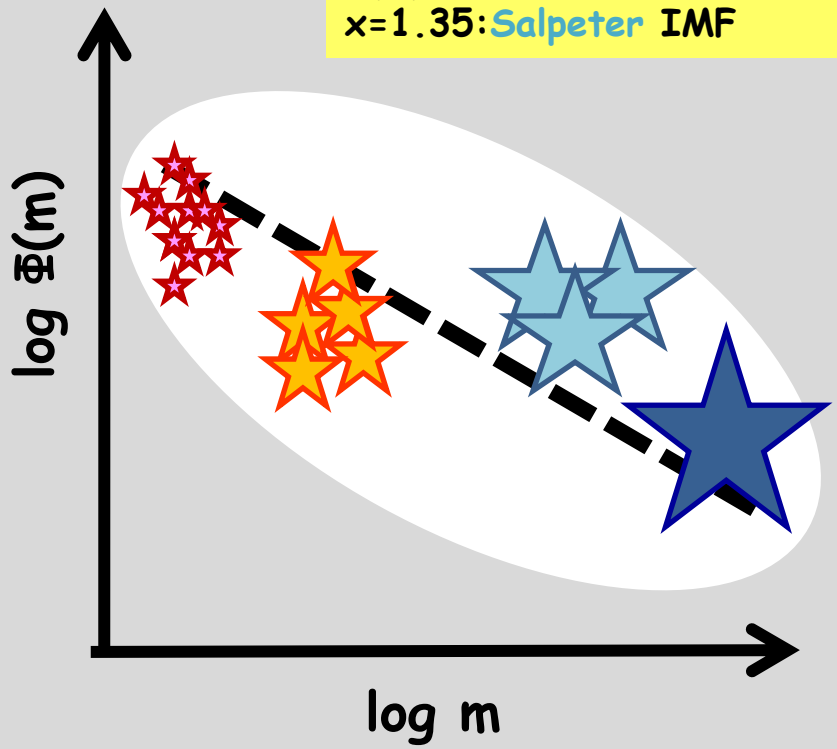
We assumed the Salpeter IMF (Salpeter 1955).

By assuming an IMF, we can obtain the total number of newly formed stars only from the number of massive stars.

$\Phi(m)$ means the number of newly formed stars whose mass is between m and m+dm.

$\Phi(m) \propto m^{-(1+x)}$

x=1.35:Salpeter IMF



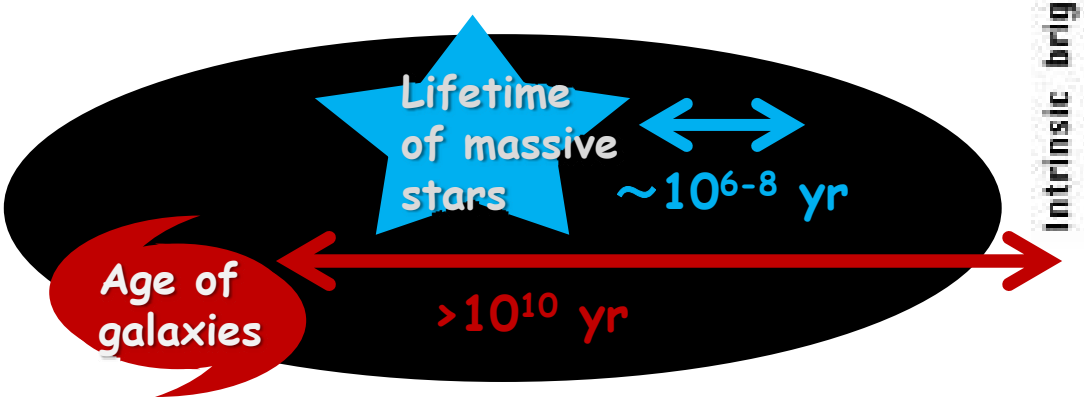
IMF diagram

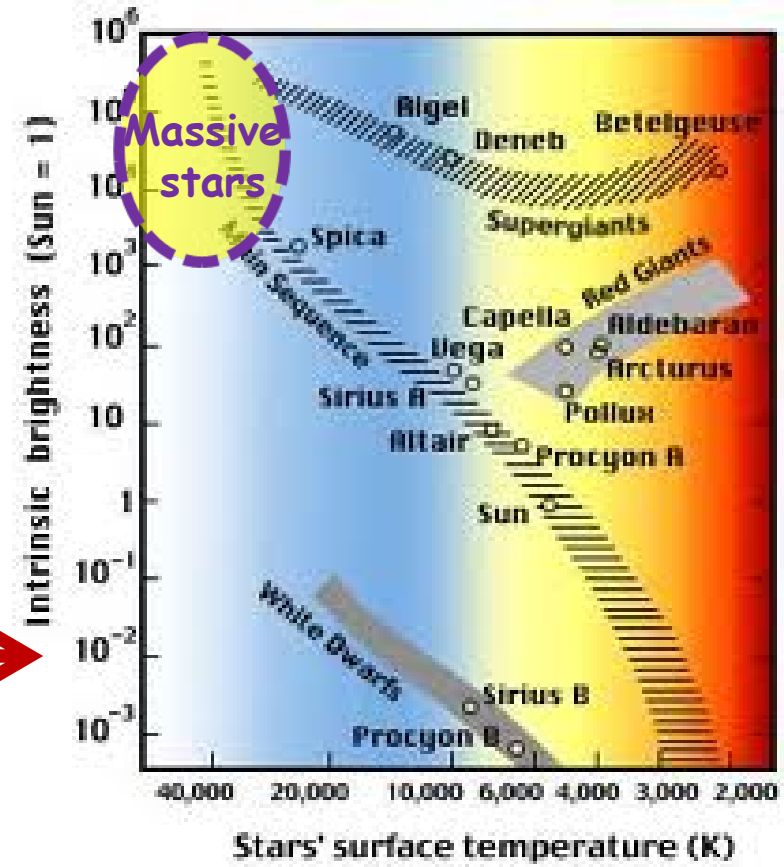
DIRECTLY VISIBLE STAR FORMATION

Directly visible star formation

We can estimate the SF activity directly from massive stars, because they have much shorter lifetime than the age of galaxies or the Universe.

In galaxies, massive stars emit ultraviolet (UV) light.

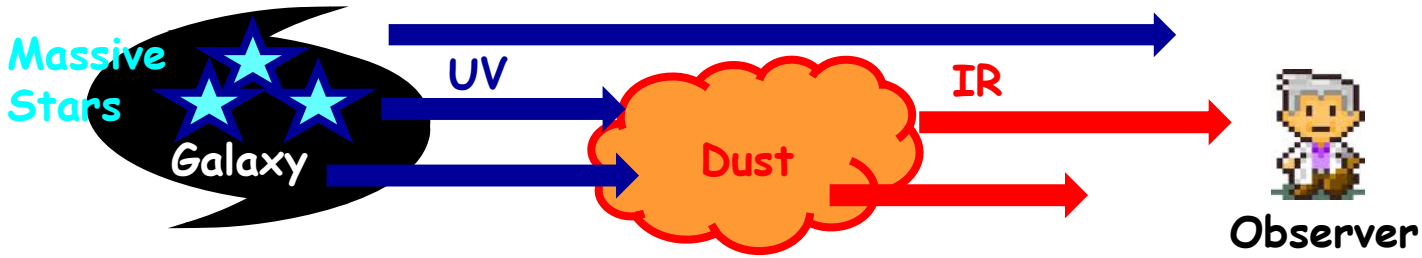




HR diagram

Observationally, the SFR of galaxies is basically measured by their UV luminosity.

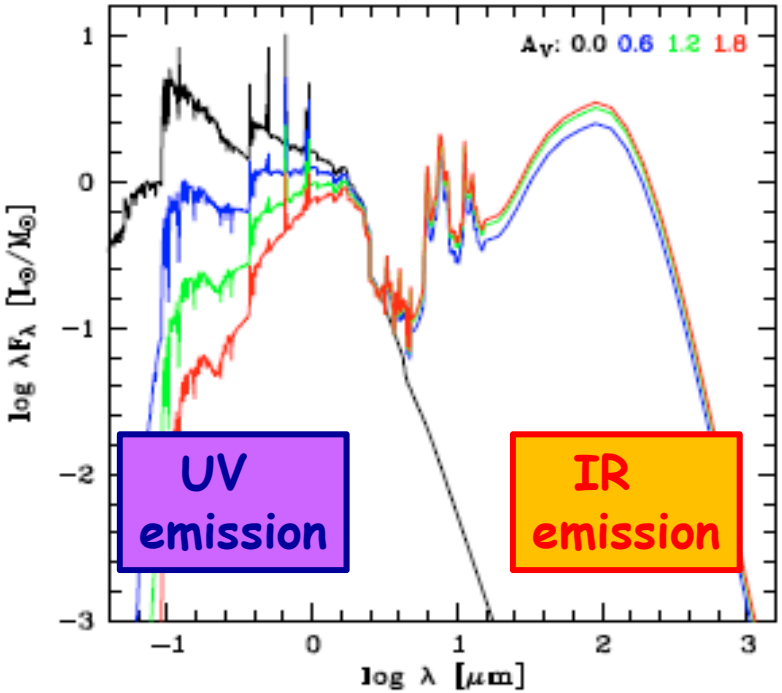
HIDDEN STAR FORMATION



Dust formation

Star formation activity is accompanied by dust formation. The UV photons from massive stars are easily absorbed and scattered by dust grains. Then they are re-emitted as mid and far-infrared photons.

So, we investigated star formation–related properties from UV and IR data.



Spectrum energy distribution of galaxies.
(Noll et al. 2009)

OBSERVATIONAL DATA

IRAS
an infrared satellite

wavebands
- 12μm
- 25μm
- 60μm
- 100μm

We based on the galaxies whose redshifts z have been obtained by the IRAS IIFSCz survey (Wang & Rowan-Robinson, 2009).

AKARI
an infrared satellite

wavebands
4 bands of AKARI FIS
- 65μm(N60)
- 90μm(WIDE-S)
- 140μm(WIDE-L)
- 165μm(N160)

We used AKARI all sky survey 90μm–selected galaxies.

GALEX
an UV satellite

wavebands
- 1530Å(FUV)
- 2310Å(NUV)

GALEX performed an all sky survey with detection limits of 19.9 mag (FUV) and 20.8 mag (NUV). (Morrissey et al. 2007) We measured the FUV and NUV flux densities from GALEX image data.

After the selection and matching, the number of galaxies is 3891.

TOTAL IR LUMINOSITY

We obtained total IR luminosity from 4 bands of AKARI FIS. We adopted following formula, which is fitting function that data of AKARI to the estimation of total IR luminosity from IRAS data. (Sanders & Mirabel)

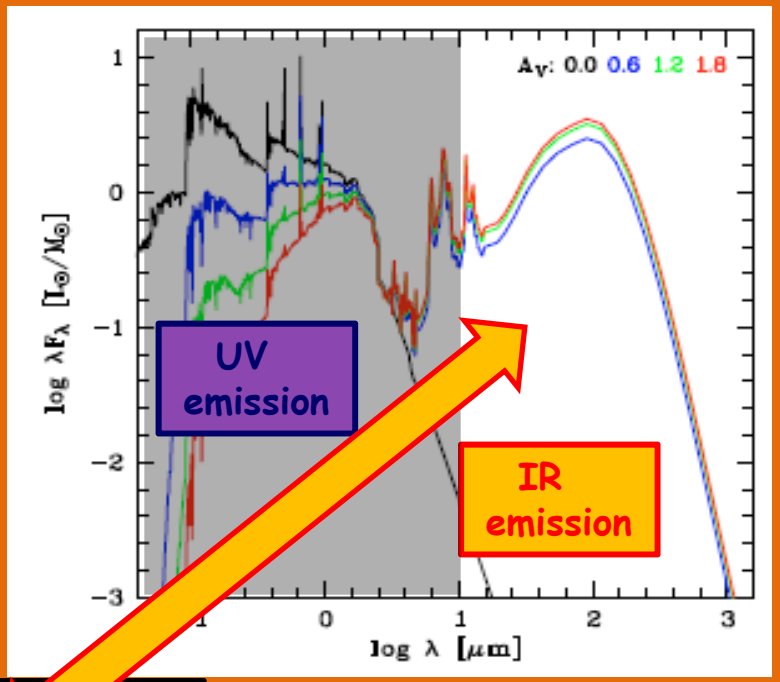
Formula (Hirashita et al. 2008)

$$L_{\rm AKARI}^{\rm 2band} = \Delta\nu(WIDE\text{-}S)\,L_\nu(90\ \mu{\rm m}) + \Delta\nu(WIDE\text{-}L)\,L_\nu(140\ \mu{\rm m})$$

$$\Delta\nu(WIDE\text{-}S) = 1.47\times10^{12}\ [{\rm Hz}]$$

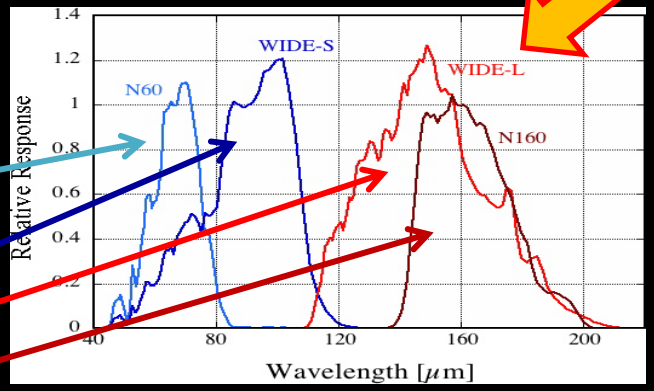
$$\Delta\nu(WIDE\text{-}L) = 0.831\times10^{12}\ [{\rm Hz}]$$

$$\log L_{\rm TIR} = 0.964 + \log L_{\rm AKARI}^{\rm 2band} + 0.814$$



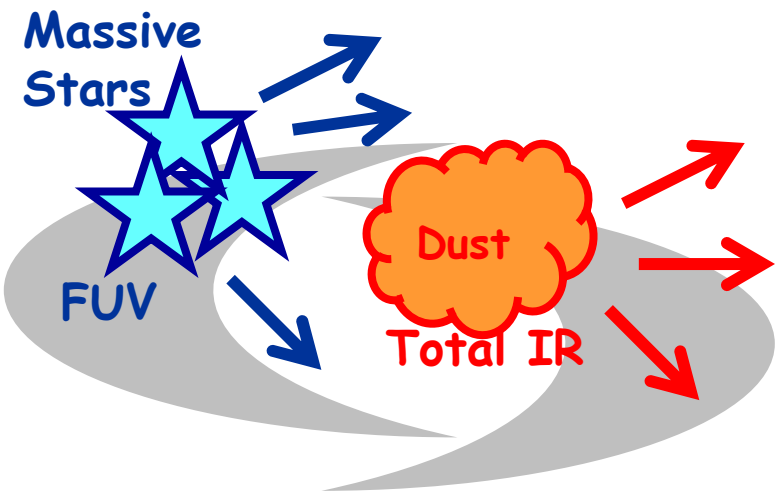
SED of galaxies (Noll et al. 2009)

65μm(N60)
90μm(WIDE-S)
140μm(WIDE-L)
165μm(N160)



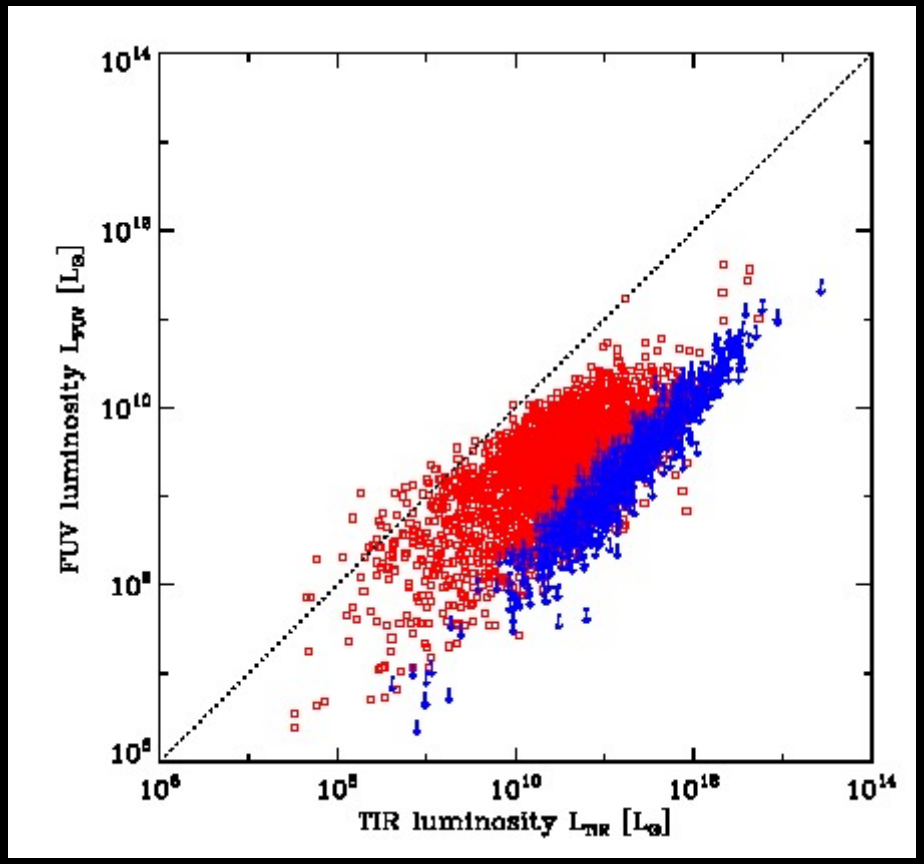
Filter response function of AKARI FIS

RESULT-1



The comparison between L_{FUV} and L_{TIR} shows that a number of galaxies have L_{TIR} significantly larger than L_{FUV}.

The blue symbols have a distribution shifted from those with detections in the figure.



The comparison between L_{FUV} and L_{TIR}

Red : Detection

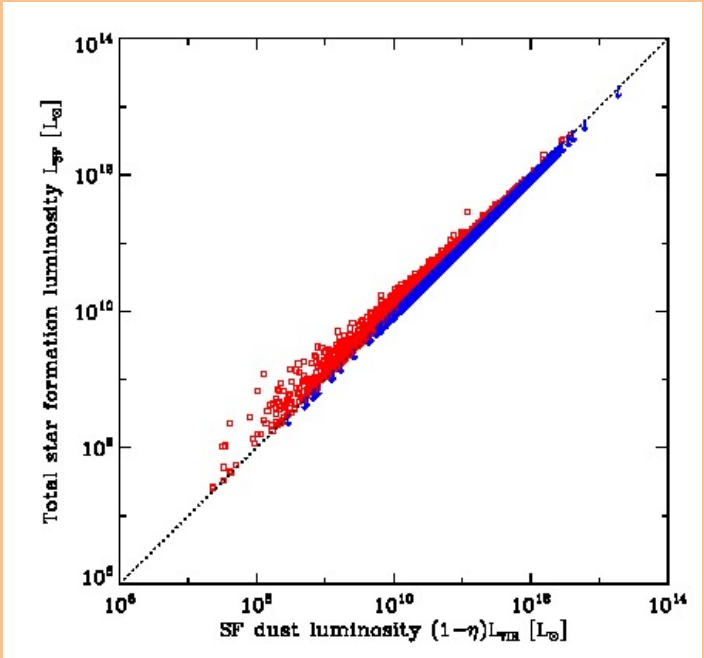
Blue : Detection limit

RESULT-2

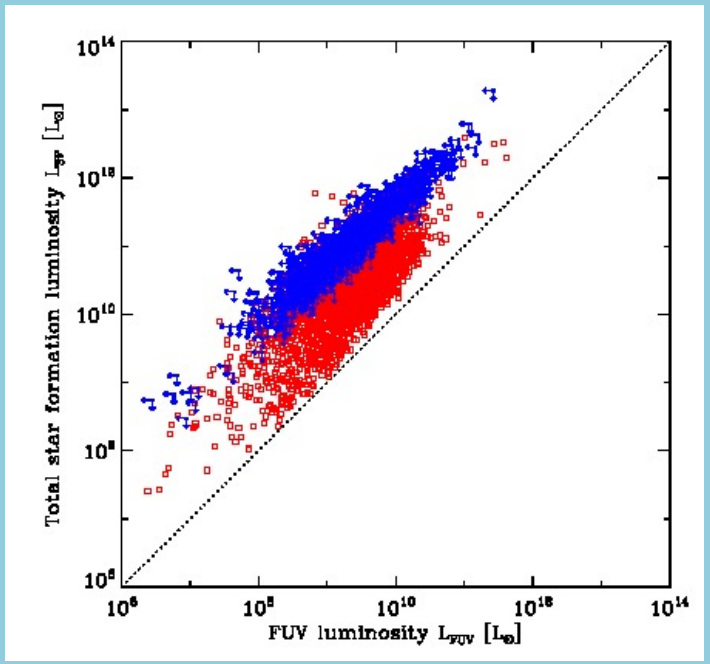
Total star formation luminosity L_{SF}

$$L_{\rm SF} \equiv L_{\rm FUV} + (1-\eta) L_{\rm TIR}$$

The parameter η is the fraction of the IR emission produced by dust heated by old stars which are not related to the current star formation. We adopted a value of 30% for this fraction. (e.g., Hirashita et al. 2003)



The contribution of $(1-\eta)L_{TIR}$ to L_{SF}



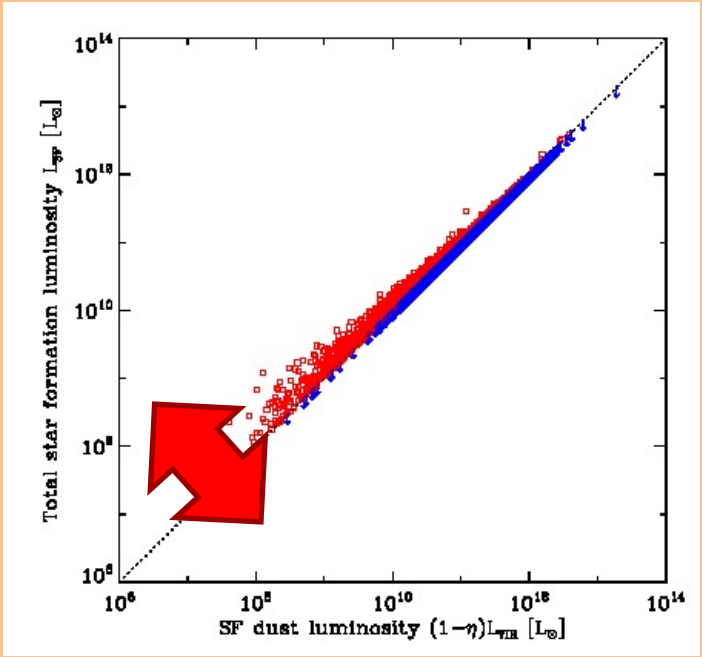
The contribution of L_{FUV} to L_{SF}

Red : Detection
Blue : Detection limit

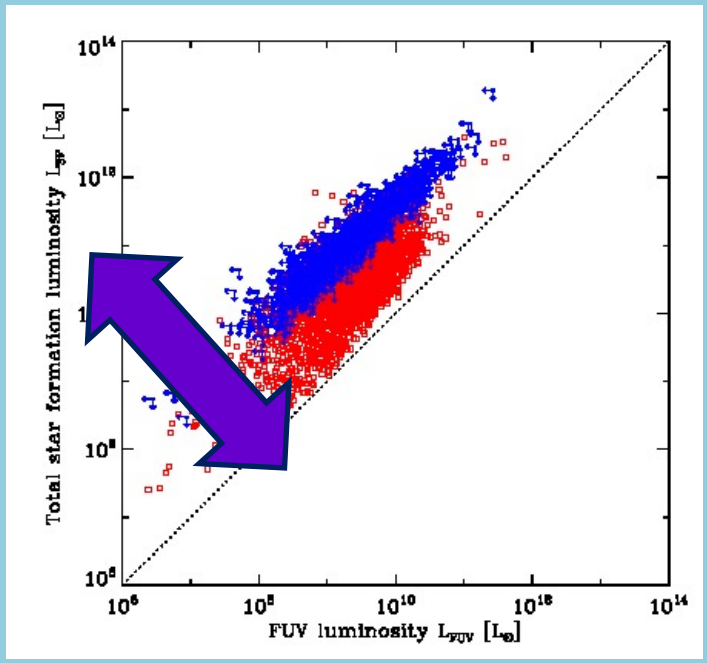
RESULT-2

The contribution of L_{FUV} has a larger scatter than that of L_{TIR} .

(e.g., Hirashita et al. 2003)



The contribution of $(1-\eta)L_{TIR}$ to L_{SF}



The contribution of L_{FUV} to L_{SF}

Red : Detection
Blue : Detection limit

RESULT-3

Formulae of star formation rate

Star formation rate of FUV : SFR_{FUV}

$$\log SFR_{FUV} = \log L_{FUV} - 9.51$$

Star formation rate of IR : SFR_{dust}

$$\log SFR_{dust} = \log L_{TIR} - 9.75 + \log(1 - \eta)$$

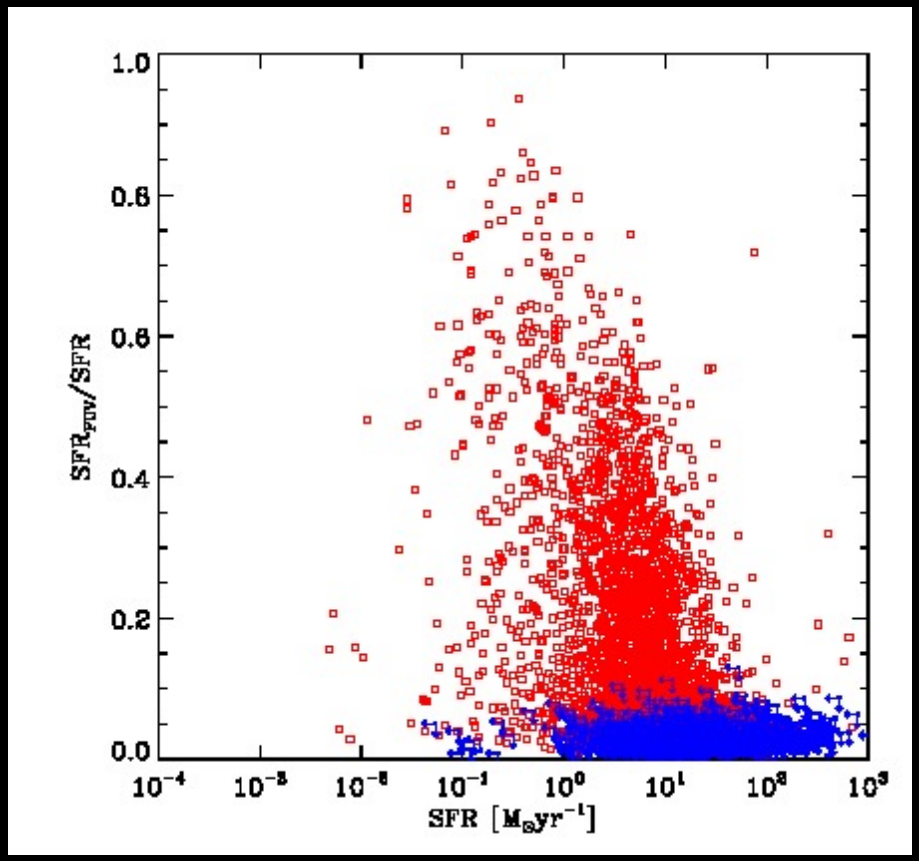
Total star formation rate : SFR

$$SFR = SFR_{FUV} + SFR_{dust}$$

The contribution of the SFR_{FUV}/SFR is shown as a function of the total SFR.

The scatter of the SFR_{FUV}/SFR is very large at SFR < 20 $M_{\odot}yr^{-1}$.

However, we find a sudden drop at SFR ~ 20 $M_{\odot}yr^{-1}$.



The relation between SFR and SFR_{FUV}/SFR.

Red : Detection Blue : Detection limit

RESULT-3

<u>Formulae of star formation rate</u>

Star formation rate of FUV : SFR_{FUV}

$$\log SFR_{FUV} = \log L_{FUV} - 9.51$$

Star formation rate of IR : SFR_{dust}

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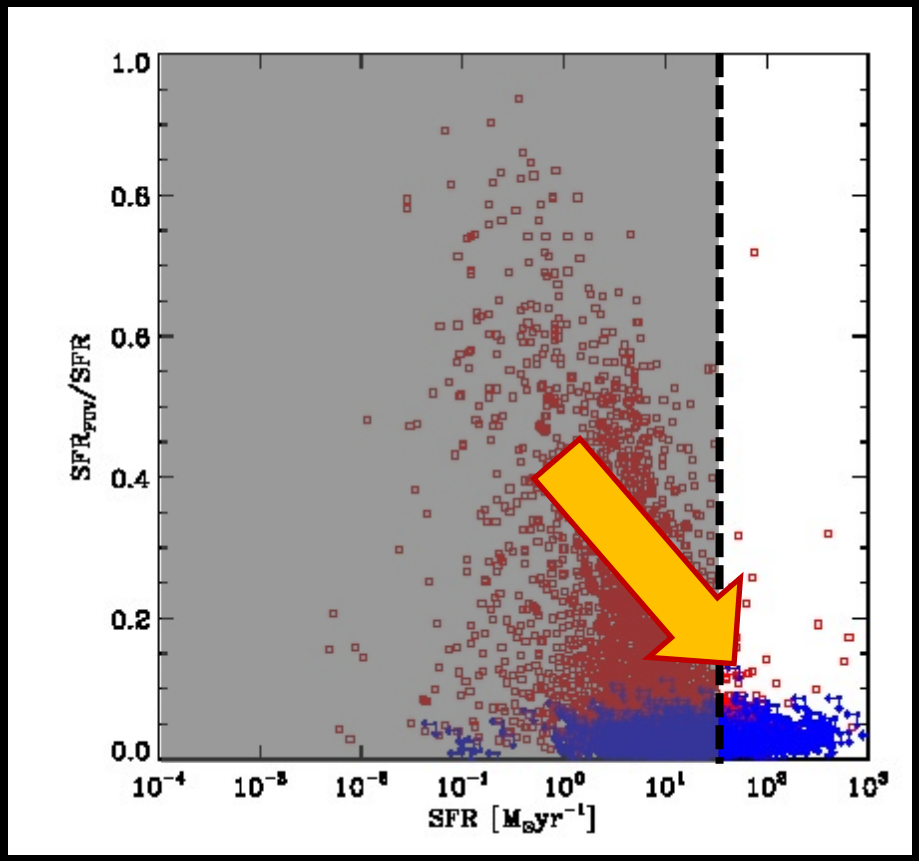


The relation between SFR and SFR_{FUV}/SFR.

Red : Detection Blue : Detection limit

RESULT-4

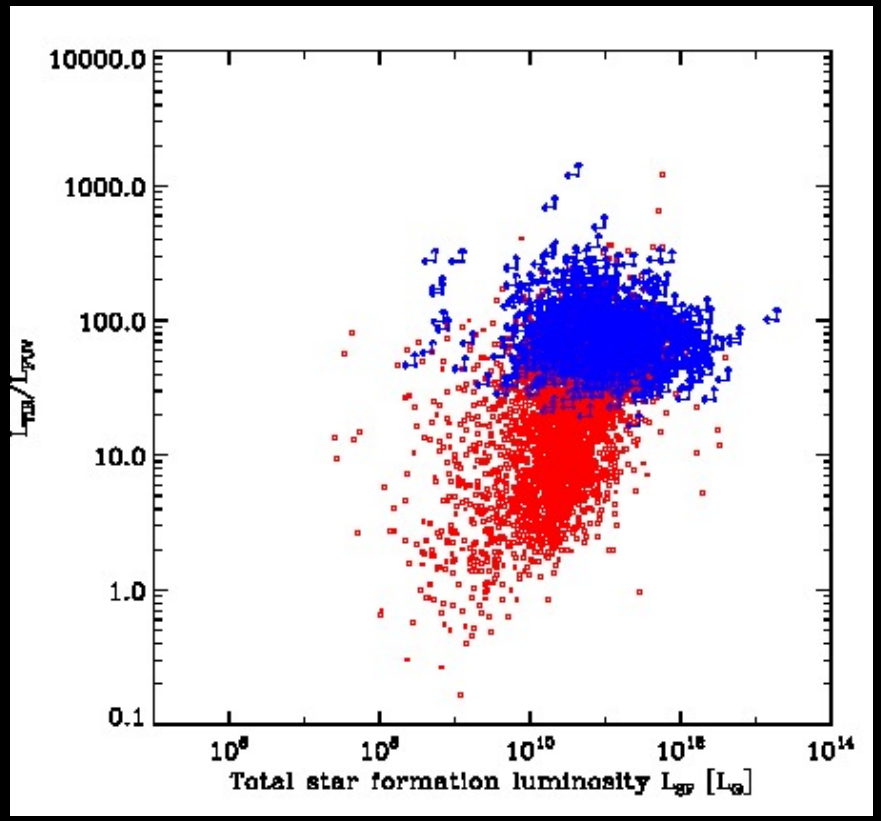
Dust extinction : L_{TIR}/L_{FUV}

Essentially, dust extinction@FUV, A_{FUV}, is expressed by a monotonically increasing function of L_{TIR}/L_{FUV}. So, we can treat L_{TIR}/L_{FUV} as a direct indicator of dust extinction.

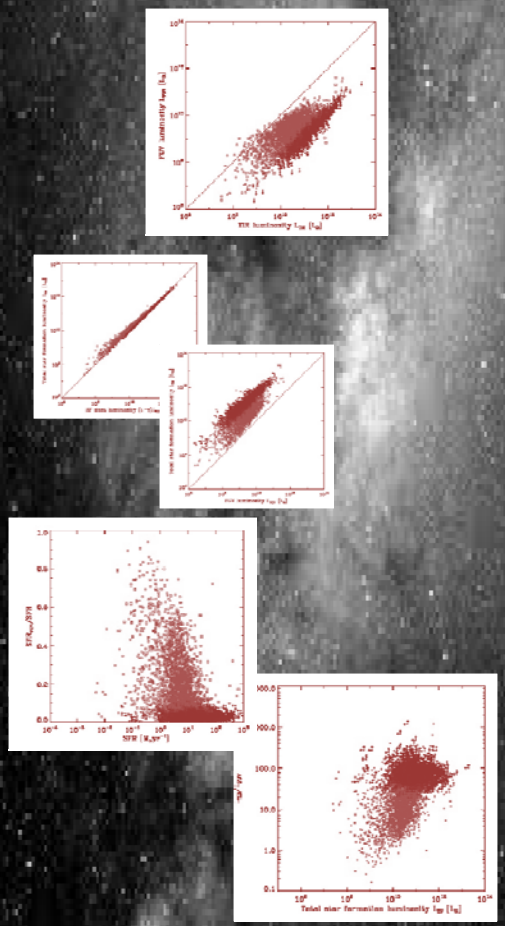
The relation between L_{SF} and L_{TIR}/L_{FUV} has a large scatter.

There is the increasing tendency in the relation.

The range of data values is wider than that of the previous studies because of the larger sample size and better data reduction.



The relation between L_{SF}(x) and L_{TIR}/L_{FUV}(y).
Red : Detection
Blue : Detection limit



SUMMARY

We analyzed star formation–related properties of local galaxies by using AKARI and GALEX data.

- The star formation luminosity, L_{SF}, is dominated by the total infrared luminosity from dust, L_{TIR}.
- The contribution of the ultraviolet luminosity, L_{FUV}, has a larger scatter than that of the contribution of L_{TIR}.
- It is difficult to estimate the star formation activity only from the relation between L_{SF} and L_{FUV}.
- Galaxies with higher SF activity (SFR>20$M_{\odot}yr^{-1}$) have a higher fraction of SF hidden by dust.
- The galaxies which have larger L_{SF} have larger extinction, L_{TIR}/L_{FUV} .

<u>We stress that we confirmed the conclusion of previous studies using large sample.</u>