miniTAO/ANIR Paα Survey of Local LIRGs

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これは3.にいれるべきでは？

1. Introduction

・Star forming rate (SFR) densities at high redshifts are dominated by infrared bright galaxies (e.g., Goto et al. 2010).

・~~especially~~ Luminous Infrared Galaxies (LIRGs; $L_{IR} = L_{[8\text{-}1000\,um]} = 10^{11\text{-}12}\ L_\odot$) and Ultra Luminous Infrared Galaxies (ULIRGs; $L_{IR} = 10^{12\text{-}13}\ L_\odot$)

In order to know the detailed properties of these galaxies, and understand ~~fully~~ how formed and evolved, ~~spatially resolved information are required.~~
Local U/LIRGs ~~is an~~ ideal laborator~~y~~ for spatially resolved star~~forming~~ processes.

・U/LIRGs are affected by a large amount of dust extinction (~~LIRGs; Av~3mag,~~ Alonso-herrero et al. 2006), produced by their active star formation activities.

・Becase of its relative insensitivity to dust extinction, Paα (1.8751 μm~~; hydrogen emission line~~) represents a nearly unbiassed tracer of the ~~current~~ SFR

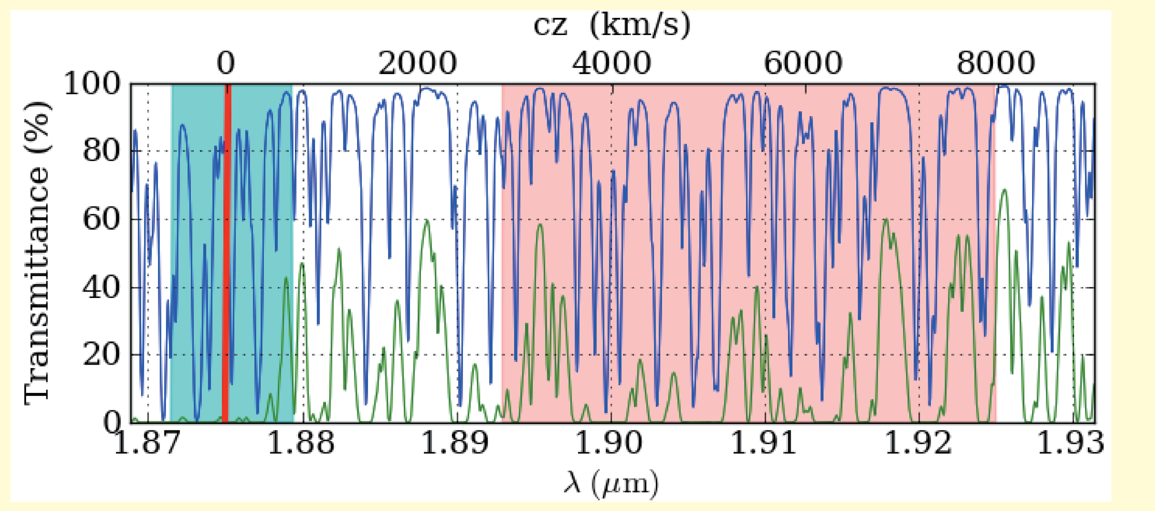
However, ~~for~~ strongly affected by atmospheric absorption, there are few ground-based observations ~~using the line~~ emission.
~~The~~ goal ~~of this paper~~ is to reveal the properies of U/LIRGs, especially SFR and profile of star forming regions using Paα.

2. Sample selection

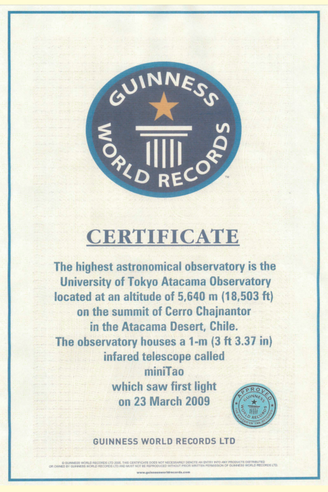
・Sample catalog of IR-galaxies is ~~AKARI/FIS-PSC~~
・Jun 2009 - Oct. 2011 (5 ~~times~~ observation ~~run~~)
・Narrow-band (NB) filter imaging
 - Filters: N191(~~NB filter imaging~~ for redshifted Paα),
  H,Ks (~~broad-band imaging~~ for continuum)
 - Exposure time : about 1h per one set (N191,H,Ks)
 - 9 points dithering ~~observation~~
・38 objects ~~are observed~~ (LIRGs:33, non-LIRGs:5)
 - 2800 km/s ～ 8100 km/s
  (Limited wavelength range of N191 NB filter)
 - $4.5\times10^{10} \leq L_{IR}(8\text{-}1000\mu m)\ [L_\odot] \leq 6.5\times10^{11}$

3. miniTAO / Atacama Near InfraRed Camera

↑FIG.1 ANIR mounted on the Cassegrain focus of miniTAO telescope



↑FIG.3 The transmittance simulation (ATRAN) at 1.9 um (Paα line wavelength region). Blue line is TAO site (5640m; ~~averaged~~ PWV~0.5 mm), and green line is VLT site (2600m; ~~averaged~~ PWV~6mm). Blue area represents the N1875 NB filter, and red ~~area represents~~ the N191 NB filter.



←FIG.2 miniTAO located at an altitude of 5640m (18503 ft) ~~is~~ the highest astronomical obseravtory in the world.The first light obsevation was carried out in July 2009, and Paα images have been suceessfully obtained using N1875 and N191.

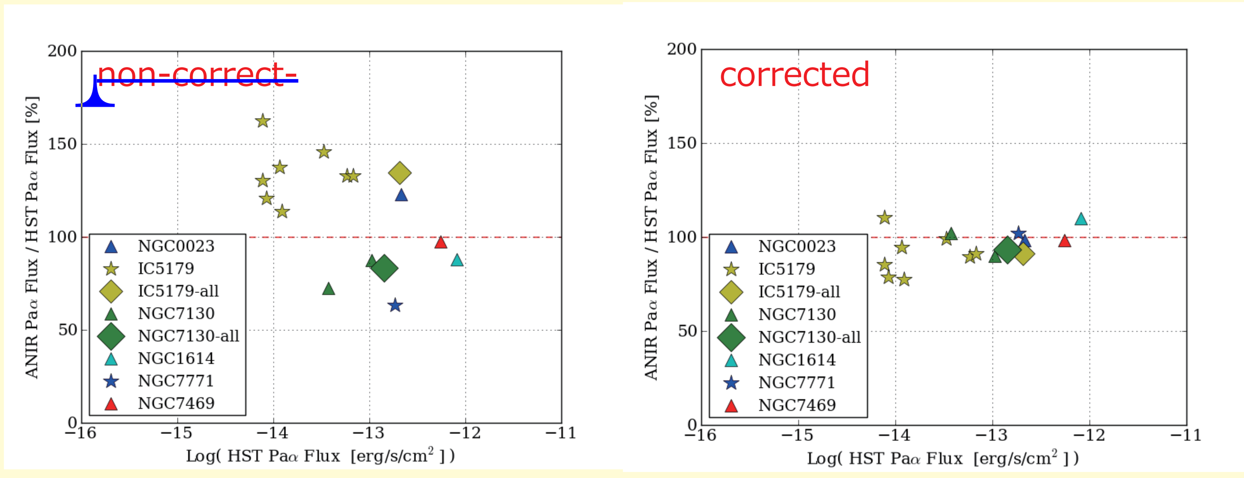
ANIR (Atacama Near InfraRed camera)

A near infrared camera for the University of Tokyo Atacama 1.0m telescope (miniTAO), installed at the summit of Co. Chajnantor (5640m altitude) in northern Chile.

Wavelength	0.85-2.5 μm
Detector	PACE-HAWAII2
Pixel format	1024 x 1024
Pixel pitch	18.5 μm
Readout noise	< 15 e⁻ r.m.s. (CDS)
Field of view	5′ .25 x 5′ .25
Pixel scale	0″ .308 pixel⁻¹
Broad-band Filters	Y,J,H,Ks (MKO filter set)
Narrow -band Filters	N128(Paβ), N131(Paβ-off), N1875(Paα), N191(Paα-off), N207(CIV)

The high altitude and extremely low precipitable water vapor (PWV=0.5mm) of the site enable us to perform observation of Paα (1.8751 μm).

4. Data reduction & Flux Calibration

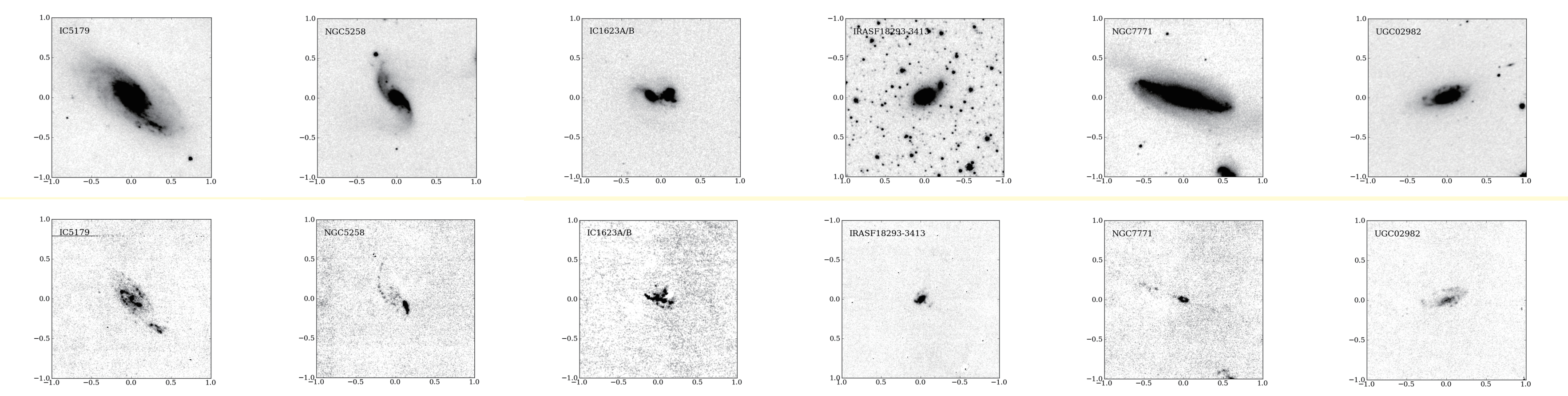


←FIG.4 ~~X-axis is~~ Paα flux obtained by HST/NICMOS, ~~and y-axis is~~ the ratio of the flux obtained by HST/NICMOS to miniTAO/ANIR. Atmospheric absorption ~~non-corrected Paα flux of miniTAO/ANIR is left figure, and right figure is atmospheric absorption corrected flux.~~

It is difficult to calibrate the emission line flux accurately, as there are many atmospheric absorption features within the wavelength range of the narrow-band filters ~~(see~~ FIG.3 ~~please~~)
and they vary temporally due to change of PWV.

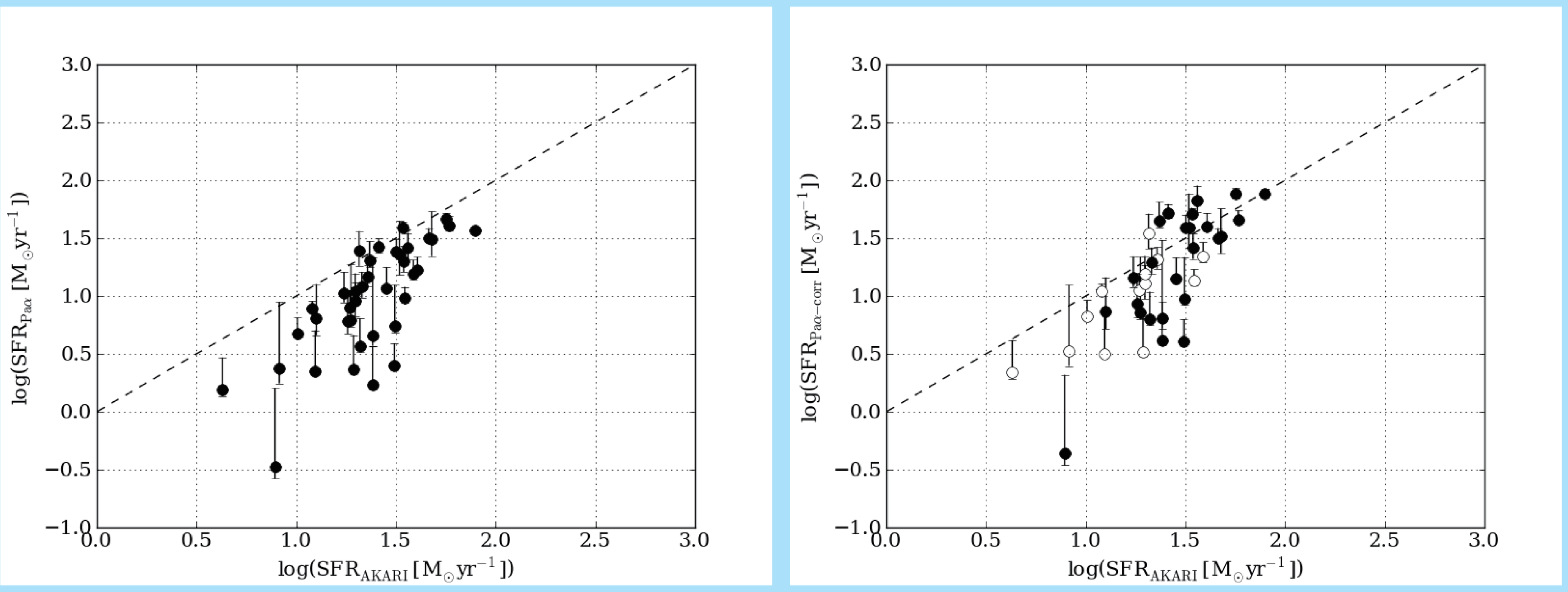
~~In this paper,~~ We have developed a new method to restore Paα flux from ground-based observations ~~with a NB filter~~ using model atmosphere by ATRAN (Lord,S.D., 1992)

we ~~were successful in estimating~~ the line emission strength ~~about~~ 10% accuracy ~~relative to other observations from space telescope (HST/NICMOS) (Tateuchi et al. in prep.).~~



↑FIG.5 Upper ~~images~~: 1.9μm continuum images, Lower ~~images~~ : Paα-line images

5. Star Forming Rate derived using Paα



↑FIG.6 Comparison of the SFRs derived using the infrared obtained by AKAIR and Paα. The SFRs ~~of~~ dust extinction ~~non-corrected Paα is left figure and~~ right ~~figure is SFRs of~~ dust extinction ~~corrected Paα~~ (~~Cardelli et al. (1989) dust extinction model~~ is used). White circles in right figure represent ~~that the~~ amounts of dust extinction is ~~assuming~~ E(B-V)=0.83 ~~uniform.~~ (median amount of dust extinction of IR-galaxies using optical slit spectroscopy (Kim et al. 1995)).

① The AKARI FIR luminosity (Takeuchi et al. 2010)

$$L_{AKARI} \equiv \Delta\nu(N60)L_\nu(65\mu m)+\Delta\nu(WIDE\text{-}S)L_\nu(90\mu m)+\Delta(WIDE\text{-}L)L_\nu(140\mu m)$$

$$\log L_{TIR} = 0.940 \log L_{AKARI} + 0.914$$

② The relation between SFR and Luminosity (kennicutt et al. 1998, Rieke et al.2009)

$$SFR\ (M_\odot\ yr^{-1}) \equiv 4.5\times10^{-44}\ L_{IR}[8\text{-}1000\mu m]\ (erg\ s^{-1})$$

$$SFR\ (M_\odot\ yr^{-1}) \equiv 6.2\times10^{-41}\ L(Pa)\ (erg\ s^{-1}).$$

~~Left figure of FIG.6 :~~
~~the relation between SFRs(IR) and SFRs(Paα-non-corrected) is good correlation. The median of SFRs(Paα-non-corrected)/SFRs(IR) is about 0.5, and it shows that it is possible to be good starforming indicator without correctingdust extinction.~~

~~Right figure of FIG.6 :~~
~~In this figure, dust extinction corrected SFR(Paα) are used. The correction method we used is Balmer line ratio Hα/Hβ. This figure shows that the relation between SFRs(IR) and SFRs(Paα-corrected) is better correlation. However, for some galaxies, SFRs(Paα) are lower than SFRs(IR) by an order of magnitude.~~

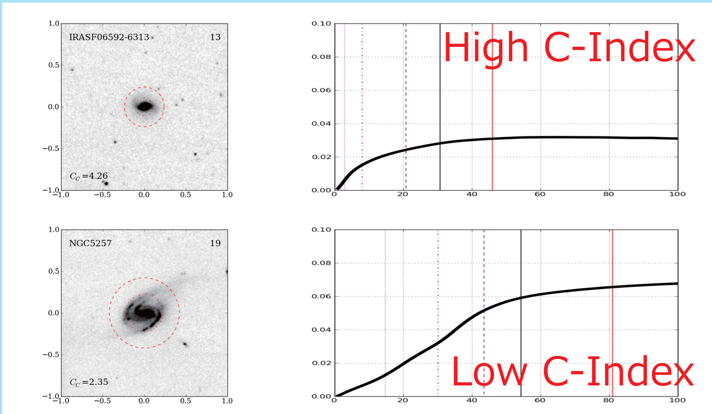
~~This suggests that the~~ correction for dust extinction estimated in optical wavelengths is insufficient due to huge amount of dust in those galaxies.

6. Star forming region ~~profile~~ of local LIRGs

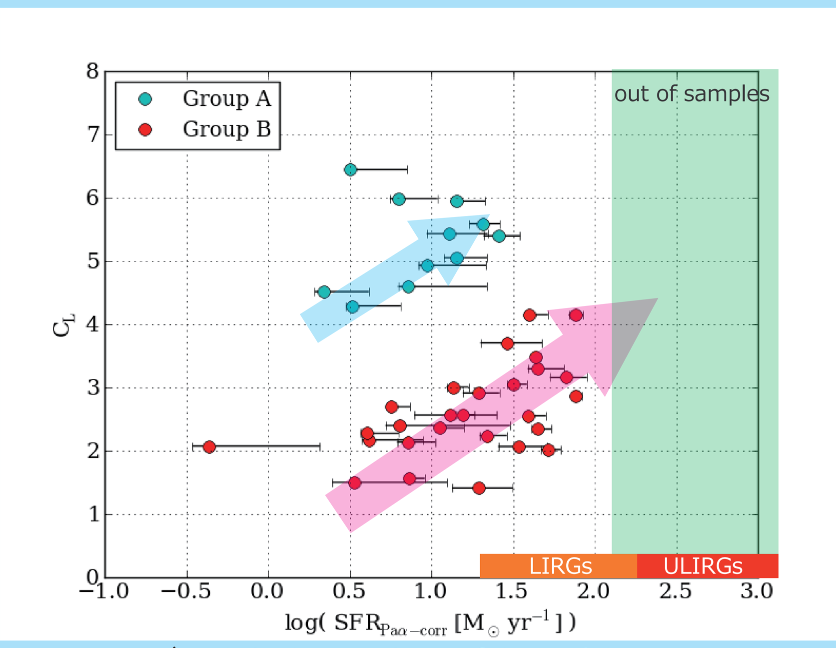
To evaluate ~~quantity~~ of star forming region ~~profile of local LIRGs,~~ concentration index (Conselice et al. 2003) are used.

$$C = 5 \log (r_{80}/r_{20})$$

r_{80} : the radii which contain 80% of the totalflux
r_{20} : the radii which contain 20% of the total flux
~~The total flux : 1.5 times the radius Petorsian~~
C_L : C-Index of starforming regions (Paα line)
C_C : C-Index of stellar population (1.9μm continuum)



↑FIG.7 Two cases of C-Index.

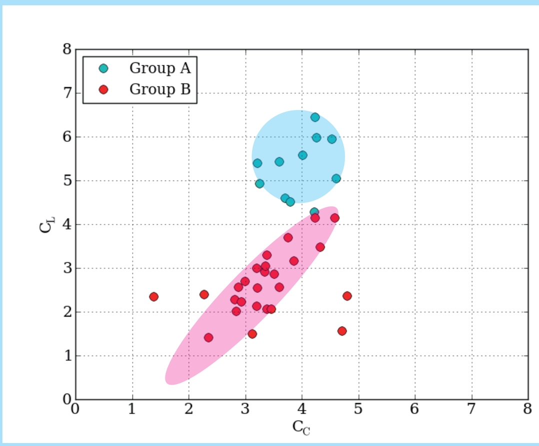


↑FIG.8 Comparison of CL and SFR

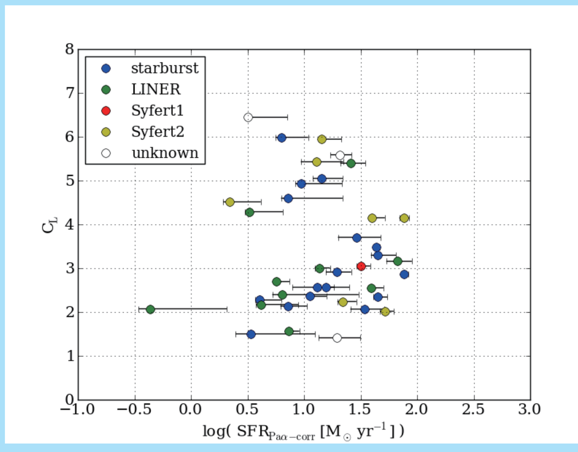
① ~~FIG.9 shows~~ there are two star forming mode
② In ~~these two~~ modes, as ~~the~~ SFR ~~is increased, the value of C_L is increased~~.
③ SFRs of Group-A ≤ 30 $M_\odot$ yr^{-1}

Genellary, LIRGs have ~~diffused~~ star forming reagions (kpc scale), ~~and~~ ULIRGs have compact ~~its~~ (sub-kpc scale) (e.g., Soifer et al. 2000,Kennicutt et al. 2009).

Our results suggests quantitativily that ~~there is a~~ star-forming ~~region profile connection between the LIRGs and ULIRGs~~.



↑FIG.9 comparison of C_L and C_C.



↑FIG.10 ~~type of galactic activites~~

~~FIG.10 is the same as FIG.8, but it is color-coded according to the differences of some types of galactic activities. we can' t find the features about FIG.10.~~

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7. SUMMARY

・38 ~~objects were obtained~~ by miniTAO/ANIR with Paα NB filter ~~imaging~~
・A new method to restore Paα flux from ground-based observations with a NB filter have been developed.
・For some galaxies, SFRs(Paα-corrected) are lower than SFRs(IR) by an order of magnitude. ~~It suggests that the~~ correction for dust extinction estimated in optical wavelengths is insufficient due to huge amount of dust ~~in those galaxies~~.
・We find that ~~LIRGs have two starfoimg mode~~
~~・In these two modes, as the SFR is increased, the value of CL is increased. This trend suggests that there is a star-forming region profile connection between LIRGs and ULIRGs.~~