Ionizing Photon Deficit in Ultraluminous Infrared Galaxies Probed with AKARI

Kenichi Yano (Univ. of Tokyo, ISAS/JAXA)
Takao Nakagawa, Naoki Isobe (ISAS/JAXA), Mai Shirahata (NAOJ)

We performed systematic observations of the H I Brα line (4.05 μm) in 51 nearby ($z < 0.3$) ultraluminous infrared galaxies (ULIRGs) to quantitatively estimate star formation rates (SFRs) with AKARI. The Brα line is predicted to be the brightest among the H I recombination lines in ULIRGs with visual extinction higher than 15 mag. We estimated the relative contribution of starburst to the total infrared luminosity (L_{IR}) using the ratio of the Brα line luminosity ($L_{Br\alpha}$) to L_{IR}. The $L_{Br\alpha}/L_{IR}$ ratio in LINERs or Seyferts is significantly lower (~ 50%) than that in H II galaxies. This result indicates that active galactic nuclei contribute significantly (~ 50%) to L_{IR} in LINERs as well as Seyferts. We also estimate the absolute contribution of starburst using the ratio of star formation rates (SFRs) derived from $L_{Br\alpha}$ ($SFR_{Br\alpha}$) and those needed to explain L_{IR} (SFR_{IR}). The mean $SFR_{Br\alpha}/SFR_{IR}$ ratio is only 0.33 even in H II galaxies. We attribute this apparently low $SFR_{Br\alpha}/SFR_{IR}$ ratio to the absorption of ionizing photons by dust within H II regions. The WFIRST/AFTA grism will enable us to investigate this problem in a very large number of galaxies.

1. Introduction

UltraLuminous InfraRed Galaxies (ULIRGs)

ULIRGs radiate most (≥ 90%) of their extremely large, quasar-like luminosities as infrared dust emission.

⇒ precursors of quasars? ($L_{IR} \geq 10^{12} L_\odot$)

Energy sources are hidden behind dust.

- Active Galactic Nuclei (AGN) and/or starburst?

Distinguishing energy sources of ULIRGs has been an important topic on galaxy evolution.

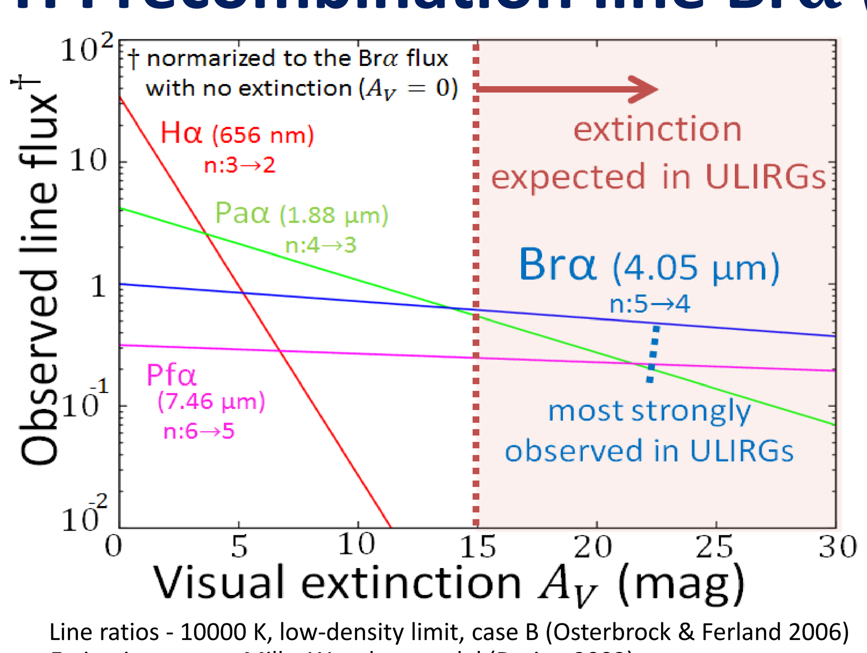
We focus on the H I Brα line to estimate the contribution of starburst to L_{IR}.

$$L_{IR}^{(ULIRG)} = L_{IR}^{(AGN)} + L_{IR}^{(SF)}$$

total infrared luminosity; AGN contribution; star formation contribution; Brα line luminosity $L_{Br\alpha}$

2. Method

H I recombination line Brα (n:5→4, 4.05 μm)



- less affected by dust extinction
  ⇒ brightest among H I lines in ULIRGs ($A_V \geq 15$ mag)
- direct measure of ionizing photons, tracing OB stars

⇒ Its luminosity ($L_{Br\alpha}$) reflects the strength of starburst, i.e. SFR*.

*star formation rate

We utilize the $L_{Br\alpha}/L_{IR}$ ratio as an indicator of the contribution of starburst to L_{IR}

It is difficult to observe the Brα line from the ground.

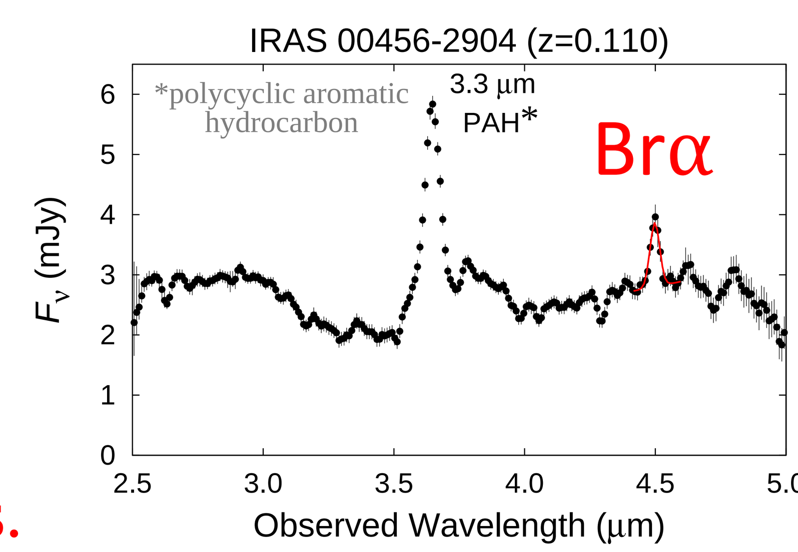
⇒ We used unique data (2.5-5.0 μm) of AKARI.

3. Observation & Result

AKARI/IRC NIR spectroscopy

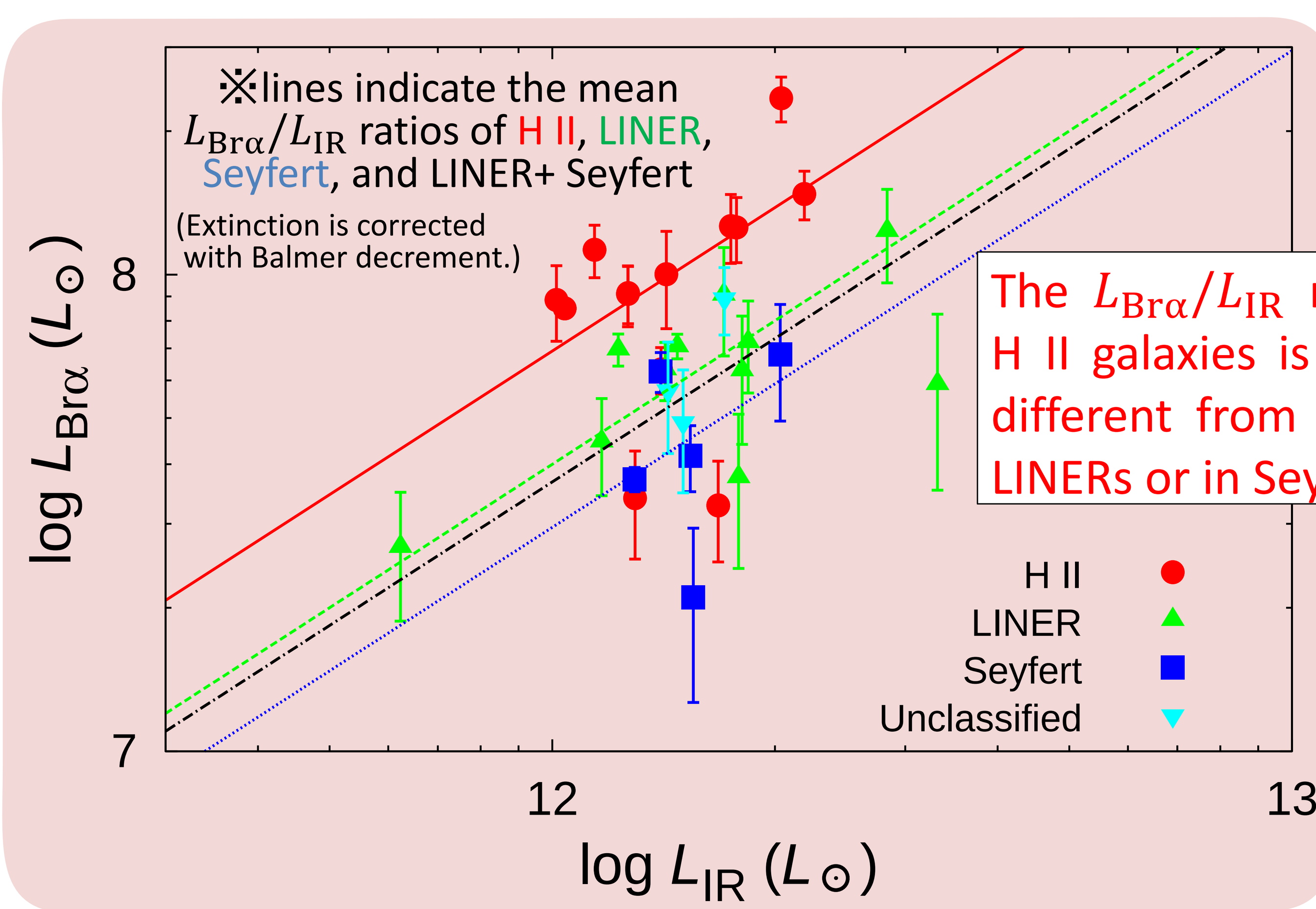
- AKARI: Japanese infrared astronomical satellite
- 2.5-5.0 μm, R~120
  - wavelength coverage unique to AKARI

51 nearby ($z < 0.3$) ULIRGs are observed, and the Brα line is detected in 33 ULIRGs.



- The Brα line correlates well with the 3.3 μm PAH emission, so that we assume the Brα line is entirely produced by starburst activity (i.e. not by AGN).

Relative contribution of starburst to L_{IR}



Optical Class	Mean $L_{Br\alpha}/L_{IR}$ (10^{-5})	Relative Contribution of Starburst
H II	6.9	100%
LINERs	4.0	58%
Seyferts	3.0	43%
L + S*	3.7	54%

*LINERs + Seyferts

starburst contribution to L_{IR} in LINERs or Seyferts ⇒ ~ 50% (assuming 100% in H II galaxies)

AGN contribute significantly in LINERs as well as in Seyferts.

4. Ionizing photon deficit

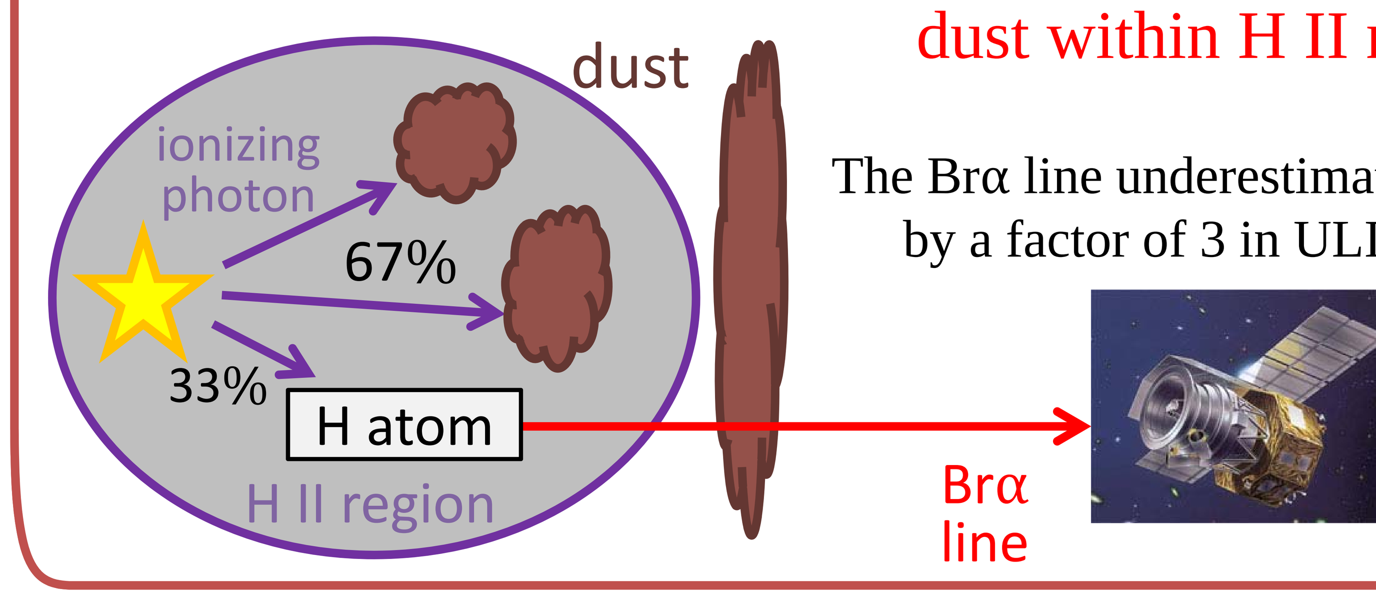
Absolute contribution of starburst to L_{IR}

Comparison of SFRs derived from $L_{Br\alpha}$ ($SFR_{Br\alpha}$) with those needed to explain L_{IR} (SFR_{IR})

$L_{Br\alpha}/L_{IR} = 6.9 \times 10^{-5}$ (mean ratio in H II galaxies) ⇒ $SFR_{Br\alpha}/SFR_{IR} = 0.33$

$SFR_{IR}(M_\odot yr^{-1}) \sim 1.5 \times 10^{-11} L_{IR}(L_\odot)$
$SFR_{Br\alpha}(M_\odot yr^{-1}) \sim 7.1 \times 10^{-7} L_{Br\alpha}(L_\odot)$ (Kennicutt & Evans 2012)

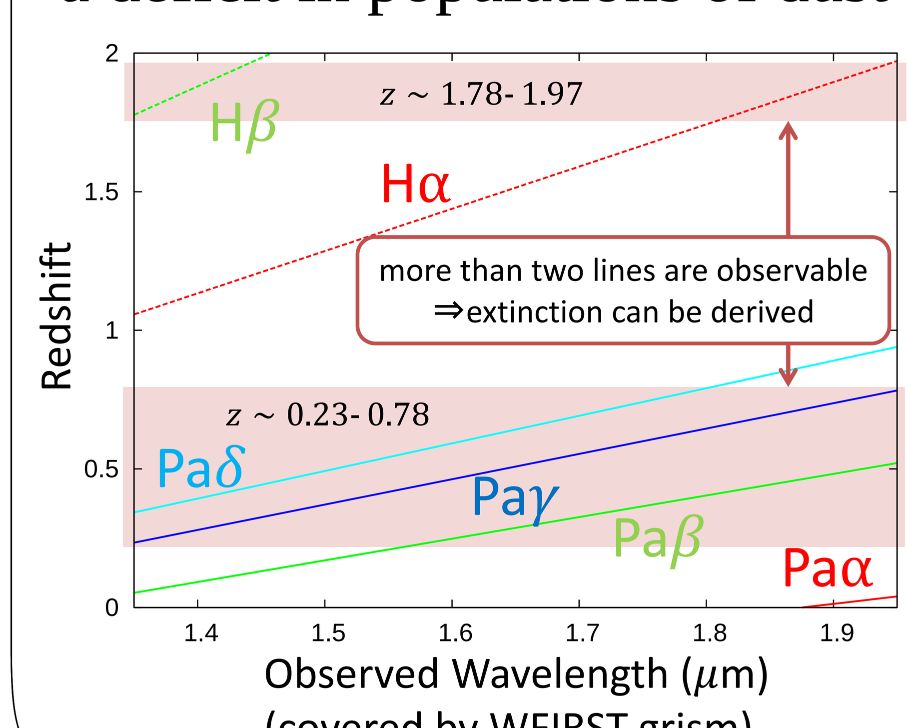
Starburst explains only 1/3 of L_{IR} even in H II galaxies (!?) ⇒ We attribute the low SFR ratio to absorption of ionizing photons by dust within H II regions.



The Brα line underestimates SFRs by a factor of 3 in ULIRGs.

5. WFIRST grism observation

Our result indicates that other lines tracing ionizing photons (e.g. other H I recombination lines) also show a deficit in populations of dust-rich galaxies.



Although careful consideration of dust extinction is required, WFIRST will enable us to investigate this problem in a very large number of distant galaxies.