First Results from the SRG/eROSITA All-Sky Survey:
From Stars to Cosmology
16 September, 2024

✨Hyper-luminous AGN candidates in eFEDS viewed with SCUBA-2 on JCMT and KOOLS-IFU on Seimei Telescope

Toba et al. 2024b, PASJ, in press.
Toba et al., 2024c, ApJ, in prep.

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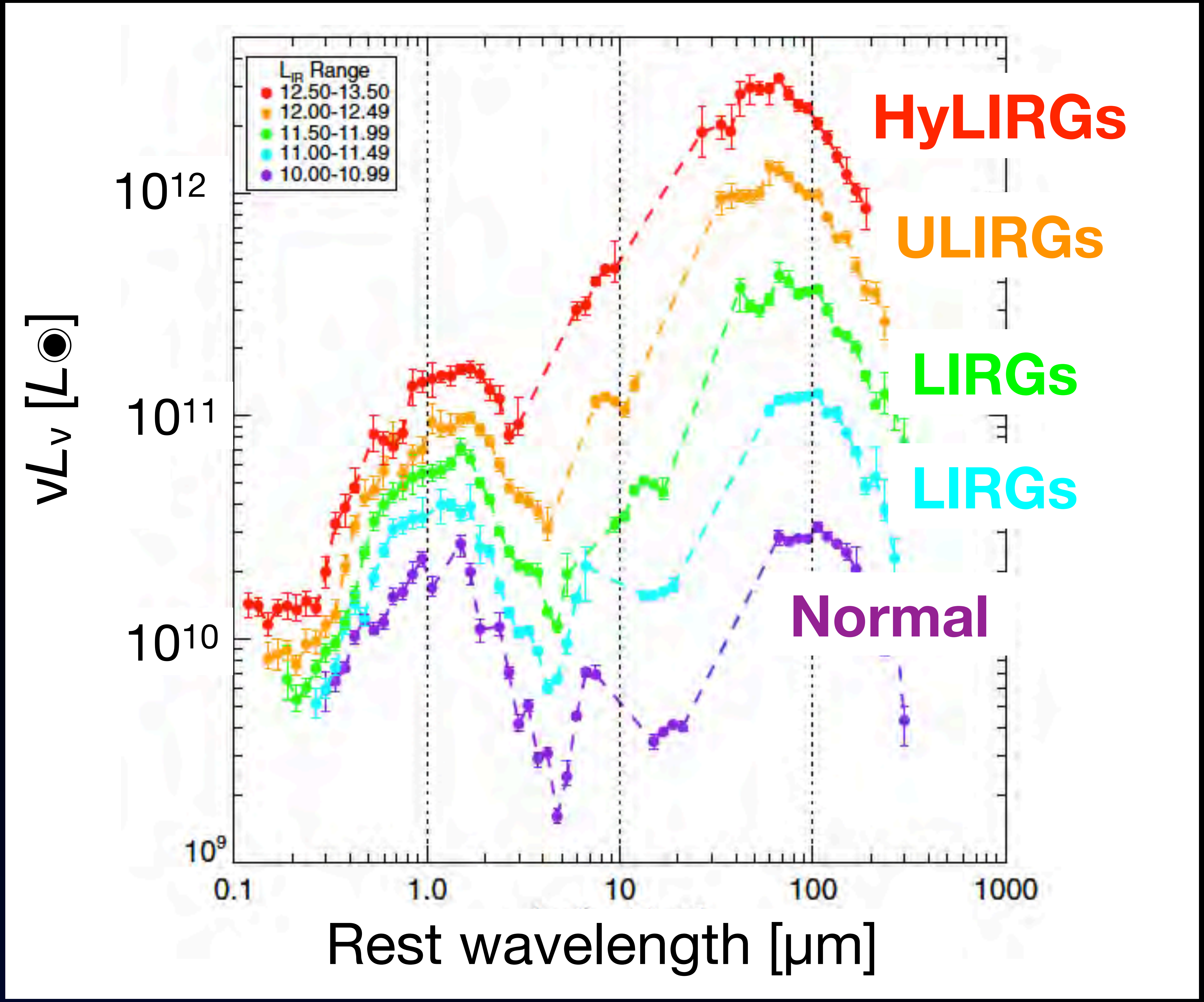
Introduction

- Galaxy classification based on IR luminosity
- Co-evolution of galaxies and SMBH
- Importence of HyLIRGs

Galaxy classification based on IR luminosity

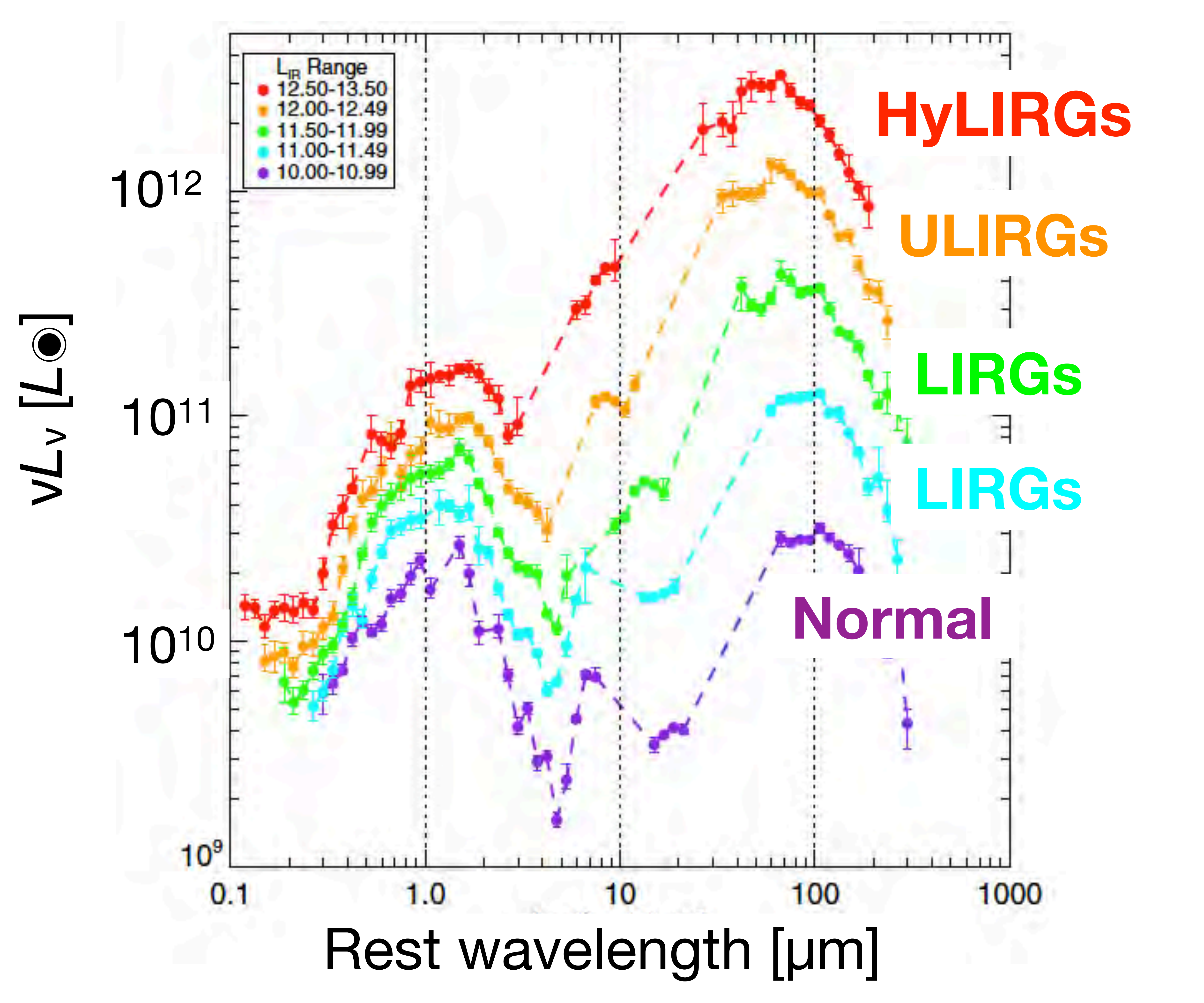
name	log ($L_{IR}/L_\odot$)
Normal	< 11
LIRGs	11 - 12
ULIRGs	12 -13
HyLIRGs	>13



Lee et al. (2013)

Ultra Luminous InfRared Galaxies (ULIRGs)

name	log ($L_{IR}/L_{\odot}$)
Normal	< 11
LIRGs	11 - 12
ULIRGs	12 -13
HyLIRGs	>13



Lee et al. (2013)

Hyper Luminous InfRared Galaxies (HyLIRGs)

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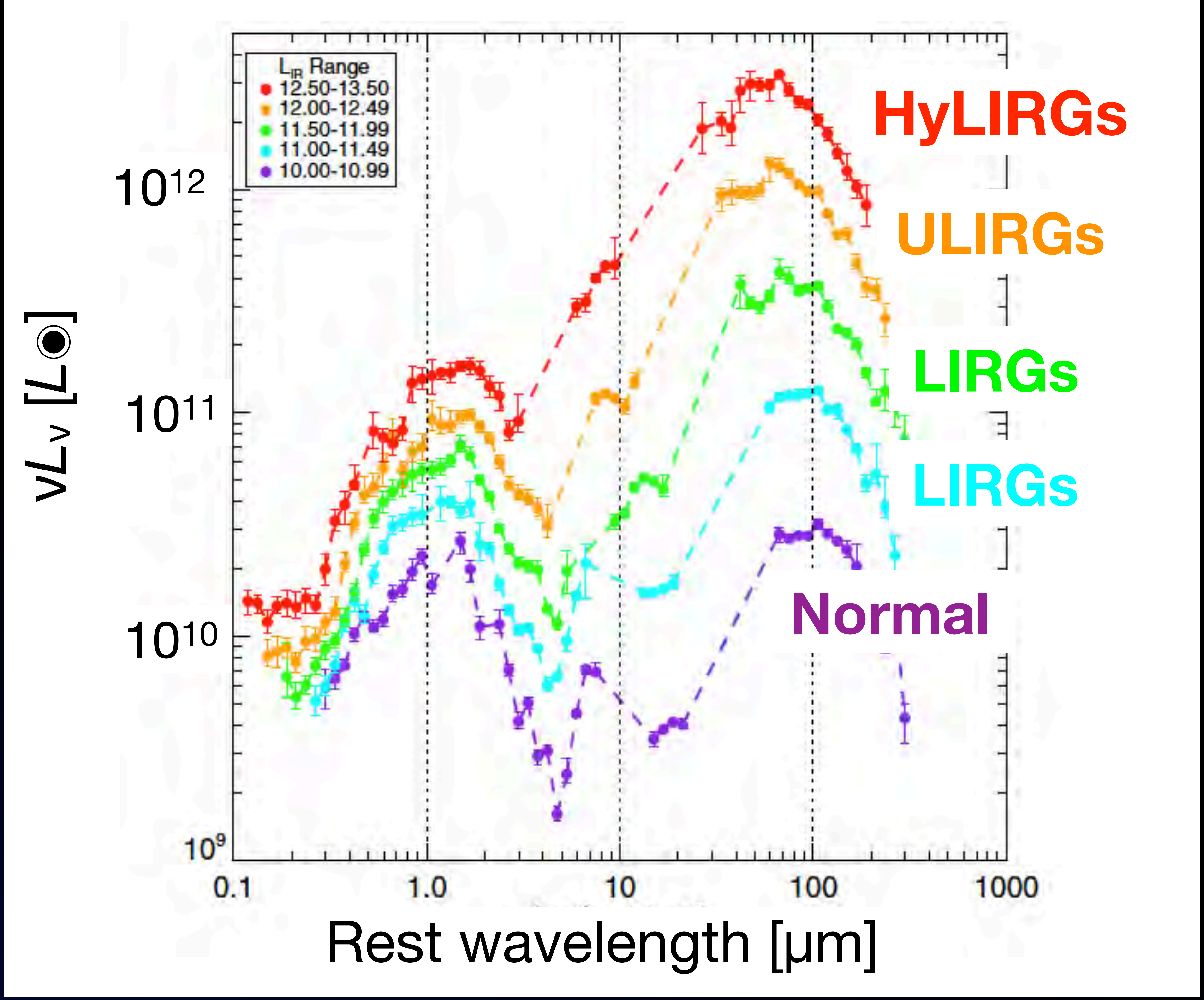

Lee et al. (2013)

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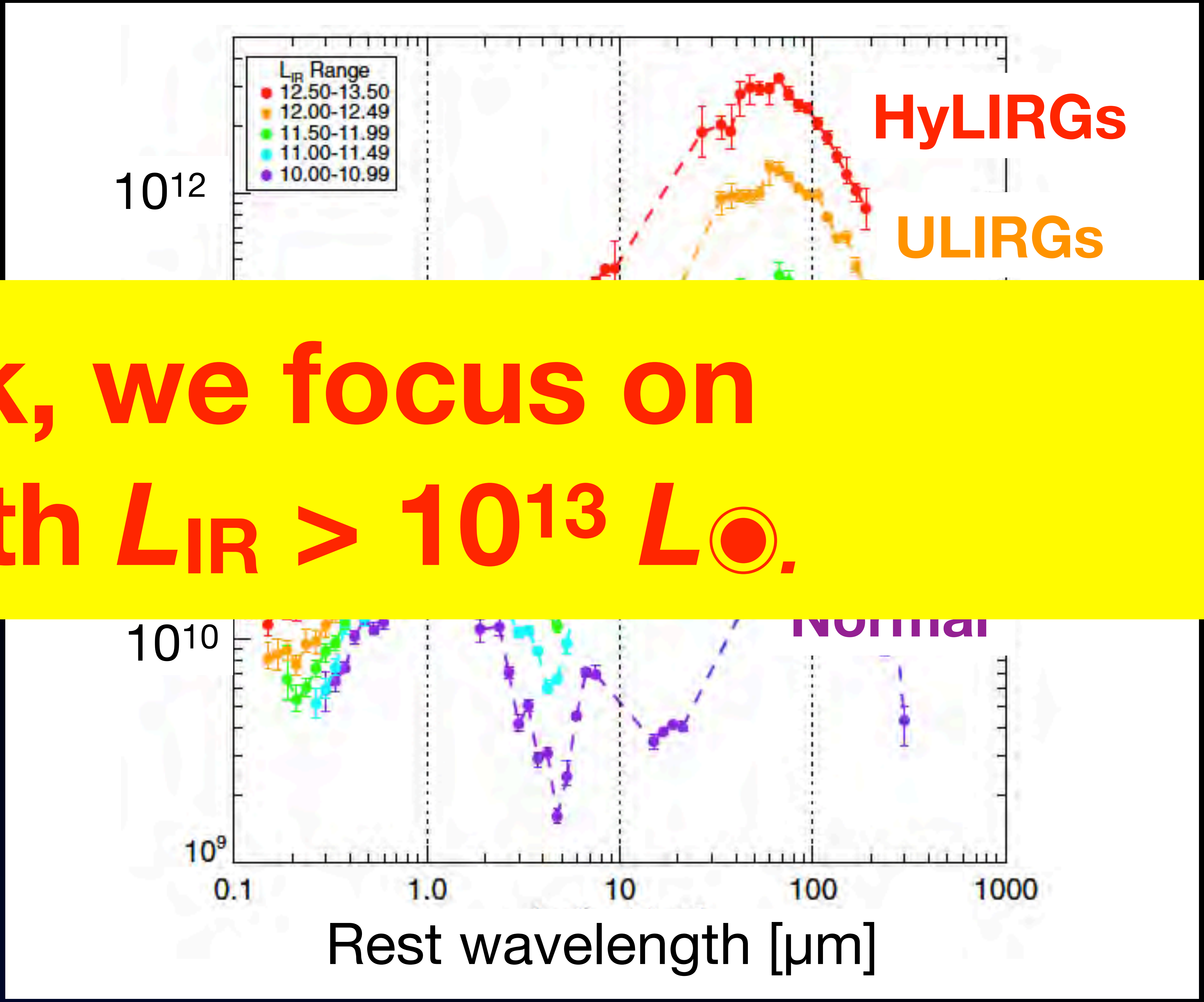

Lee et al. (2013)

In this work, we focus on HyLIRGs with $L_{IR} > 10^{13}$ $L_{\odot}$.

A mysterious relation between galaxies and SMBHs

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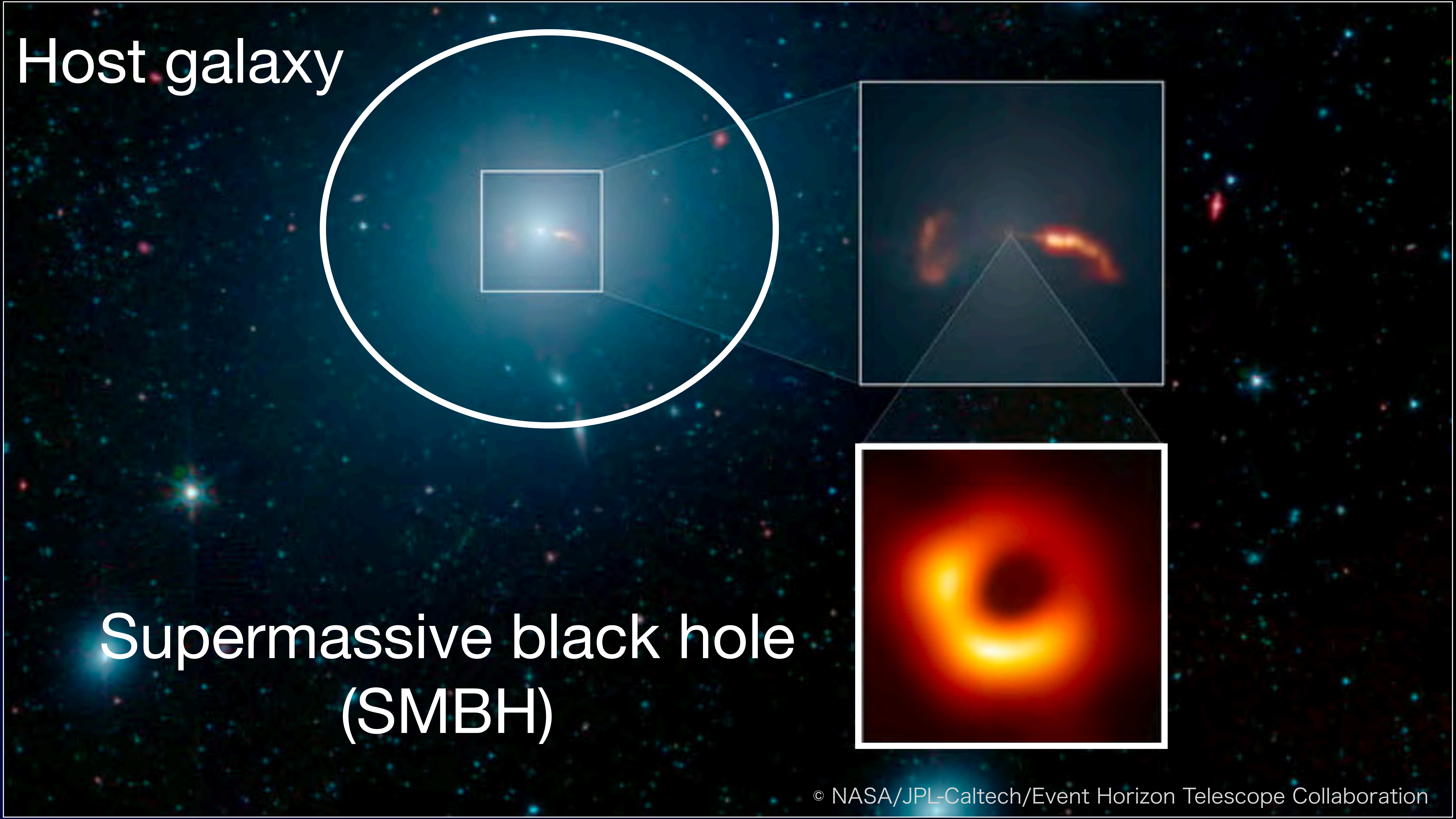
What is interesting about finding HyLIRGs?

A mysterious relation between galaxies and SMBHs



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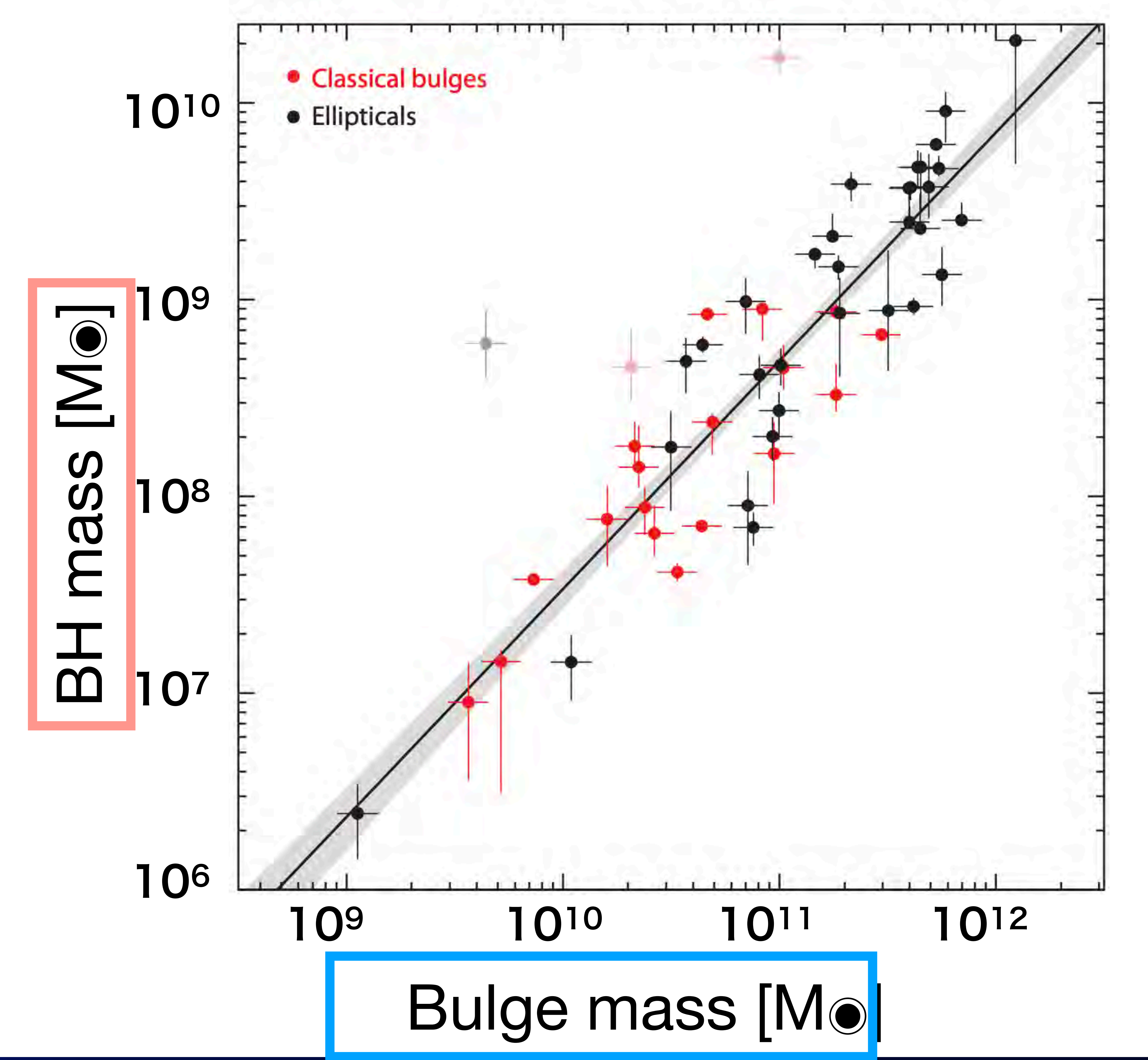
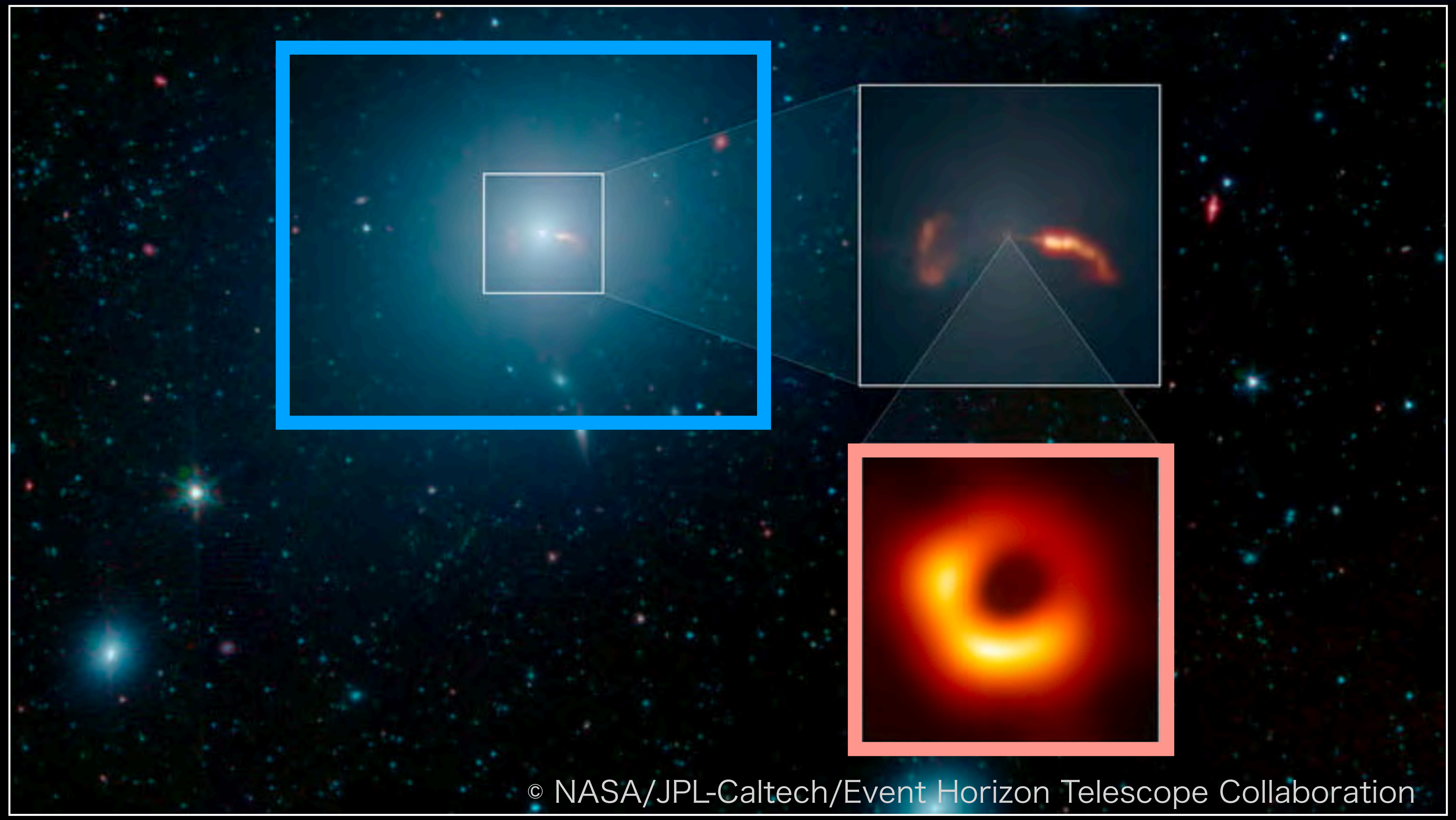
A mysterious relation between galaxies and SMBHs



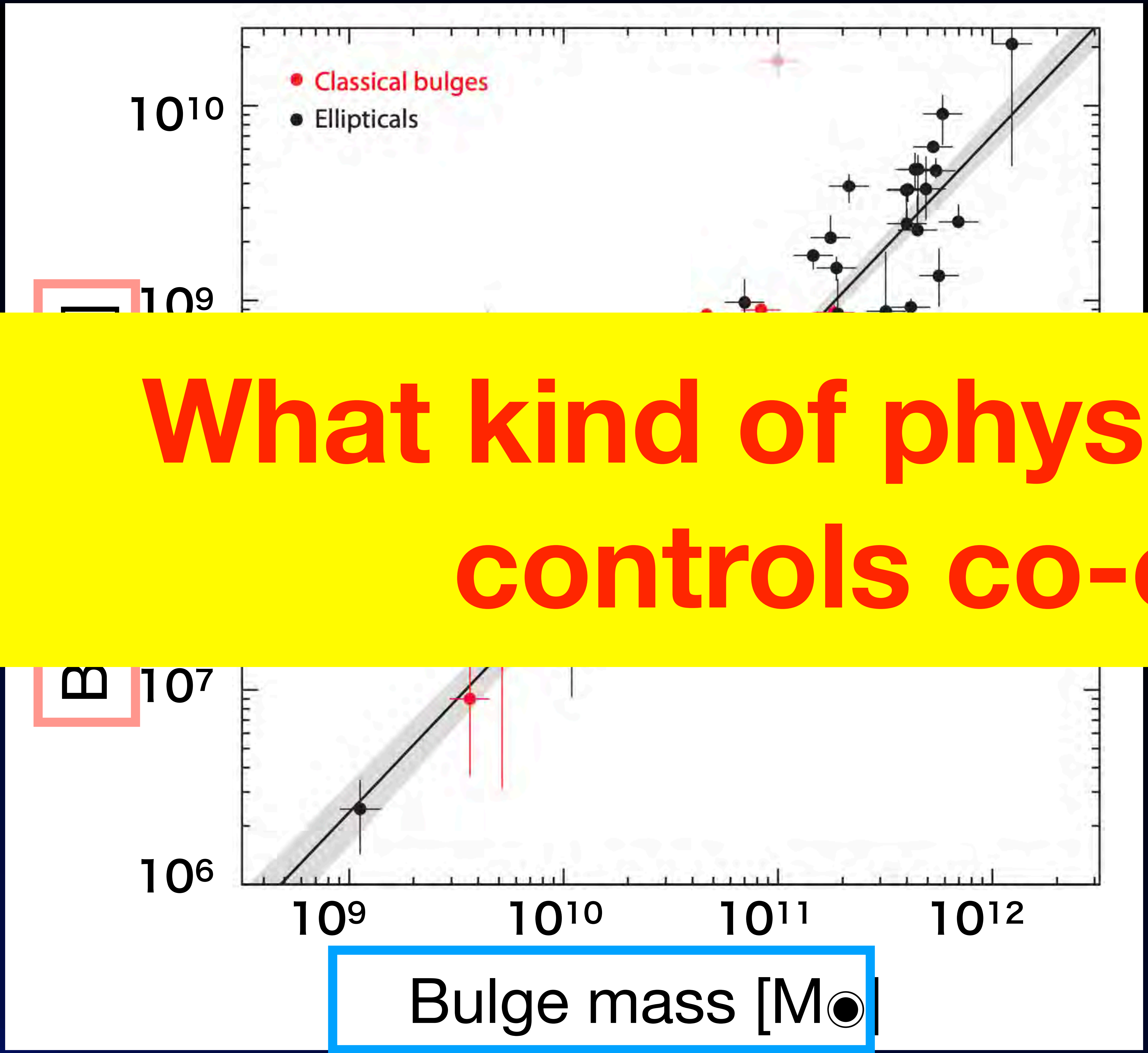


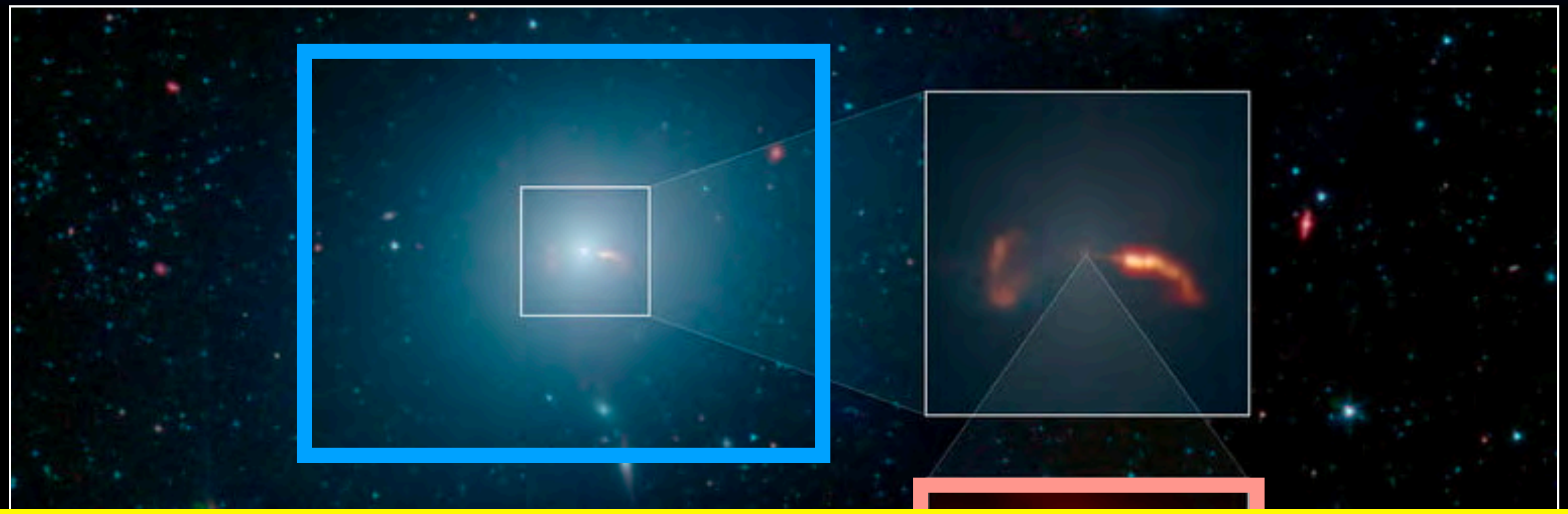
$M_{\mathrm{SMBH}} \sim 1/1000\ M_{\mathrm{bulge}}$

※ The physical scale of the two is different by an order of 8-9!

Kormendy & Ho (2013)

A mysterious relation between galaxies and SMBHs





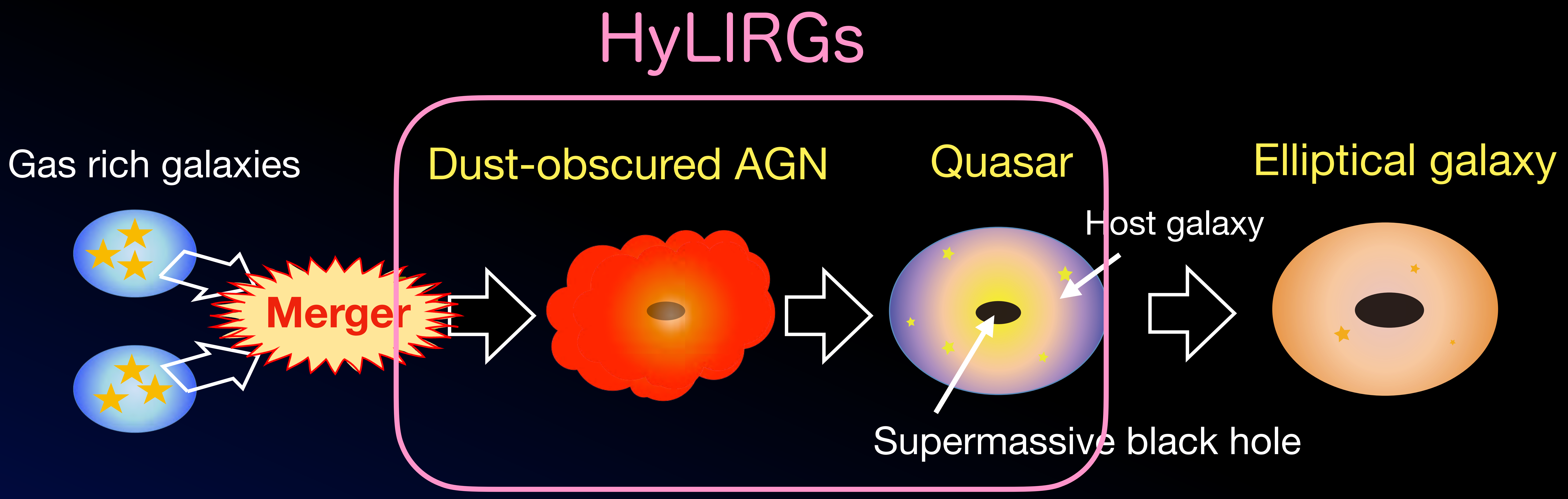
What kind of physical mechanism controls co-evolution?

M_{SMBH} ~ 1/1000 M_{bulge}

※ The physical scale of the two is different by an order of 8-9!

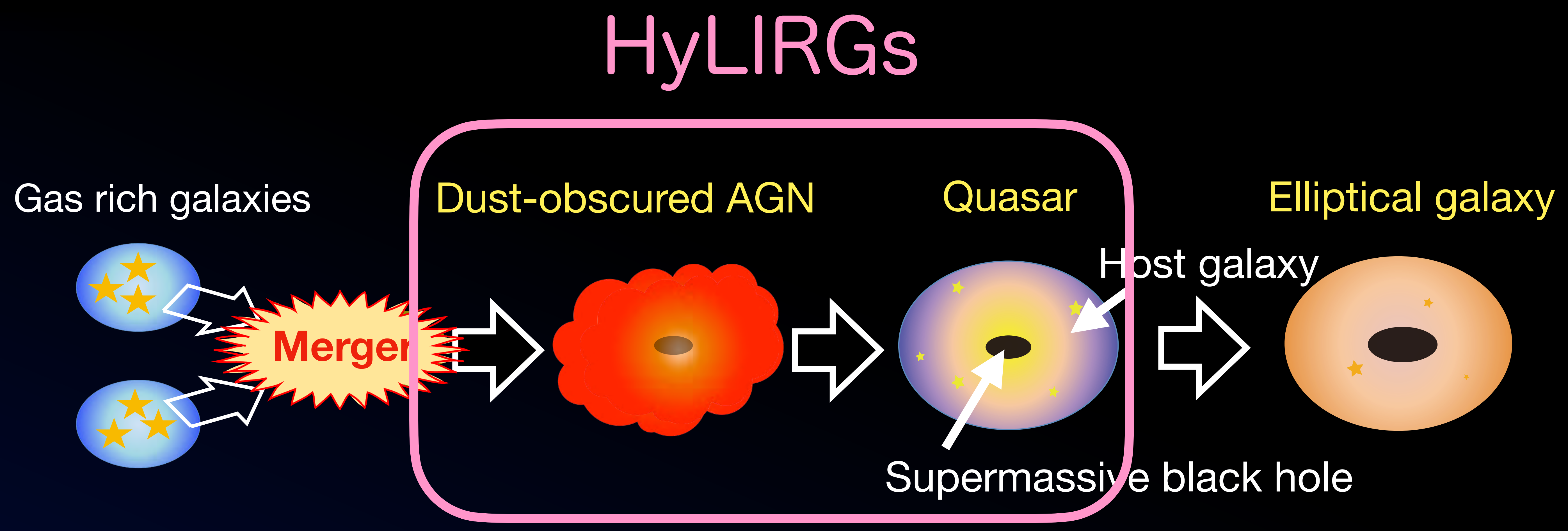
Kormendy & Ho (2013)

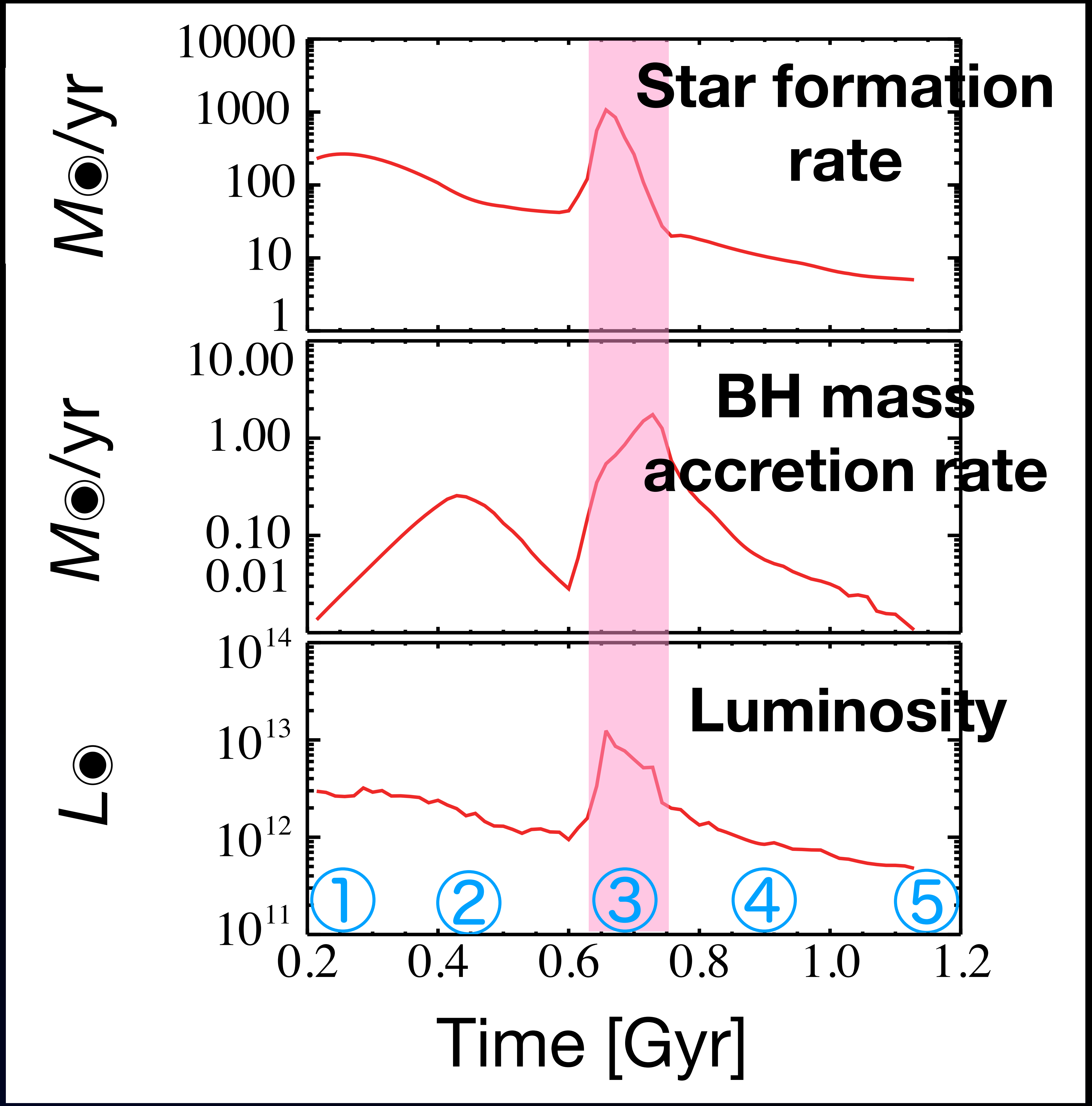
What is the importance of finding HyLIRGs?



See, e.g., Hopkins et al. (2008), Blecha et al. (2018).

What is the importance of finding HyLIRGs?





Narayanan et al. (2010) (see also e.g., Yutani, **Toba** et al. 2022).

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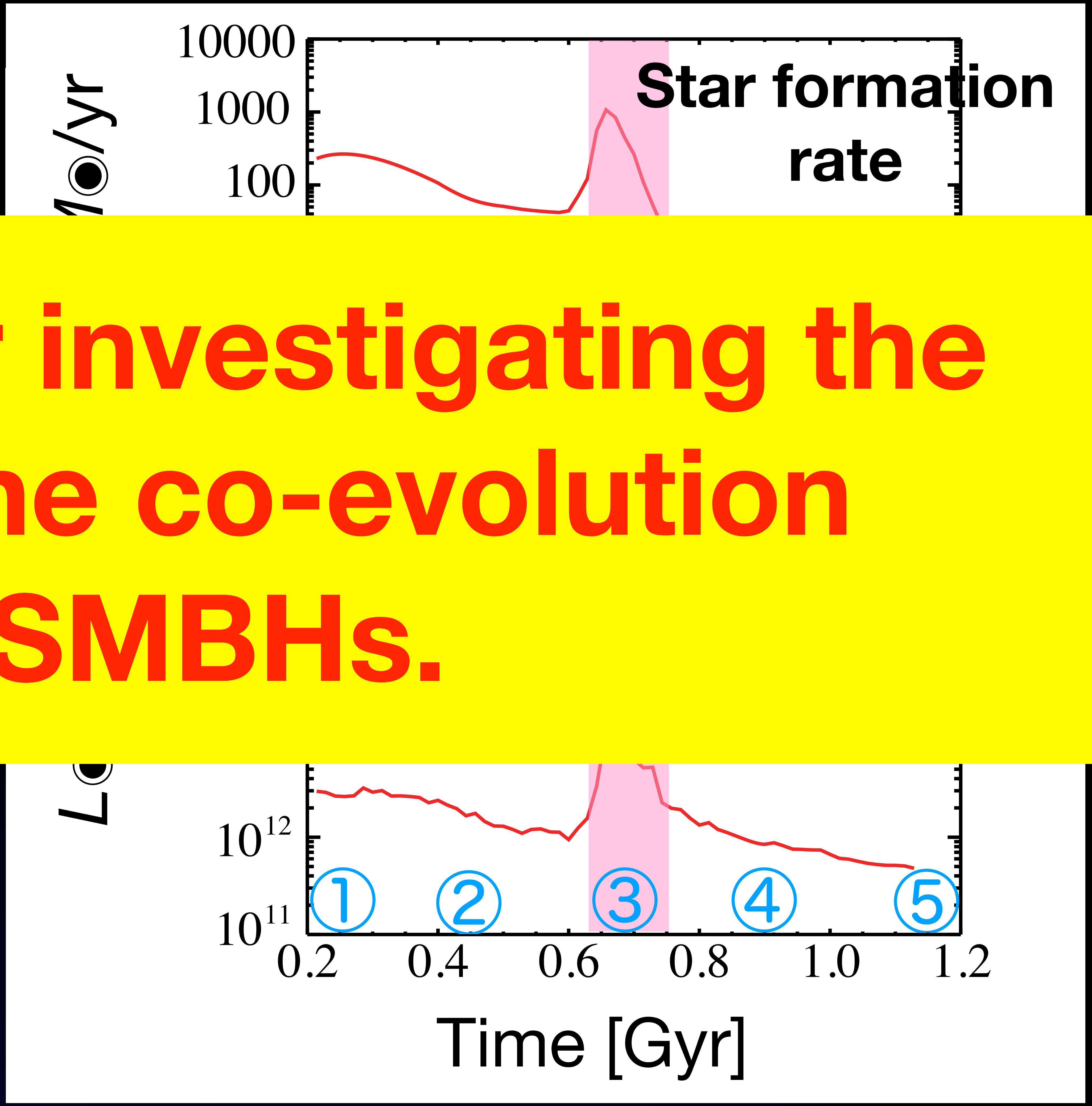


HyLIRGs are essential for investigating the "maximum phase" of the co-evolution of galaxies and SMBHs.

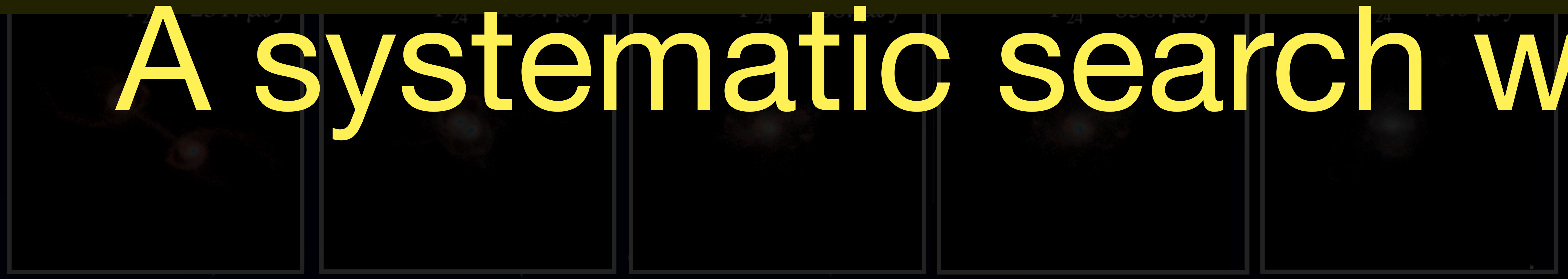
Narayanan et al. (2010) (see also e.g., Yutani, **Toba** et al. 2022).

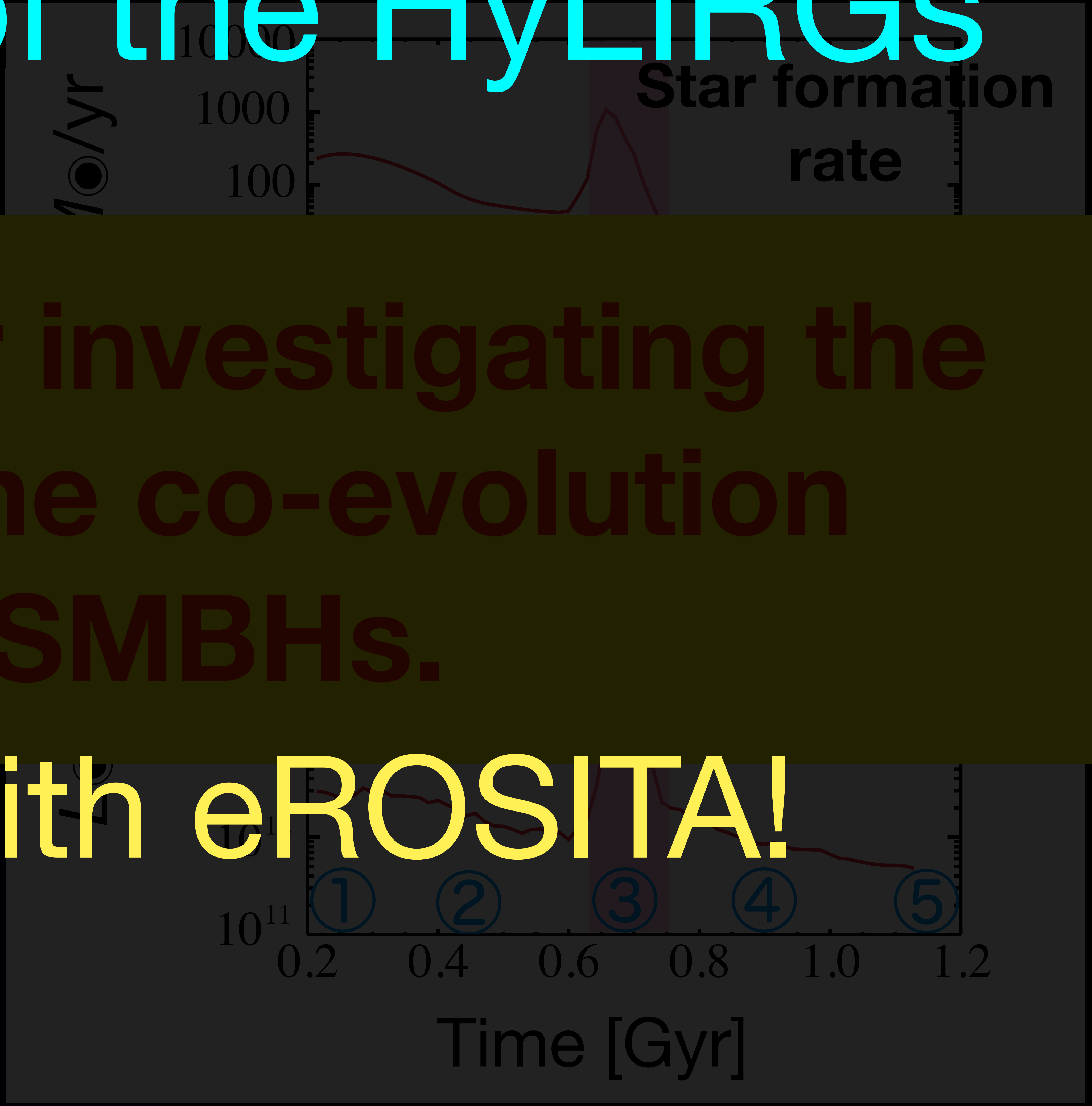
What is the importance of finding HyLIRGs?

The volume density of the HyLIRGs is extremely low..😢

HyLIRGs are essential for investigating the "maximum phase" of the co-evolution of galaxies and SMBHs.

A systematic search with eROSITA!





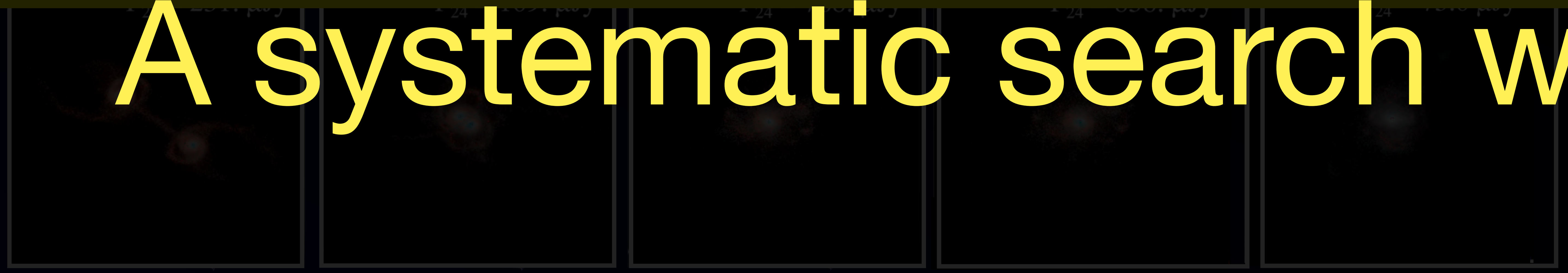
Narayanan et al. (2010) (see also e.g., Yutani, **Toba** et al. 2022).

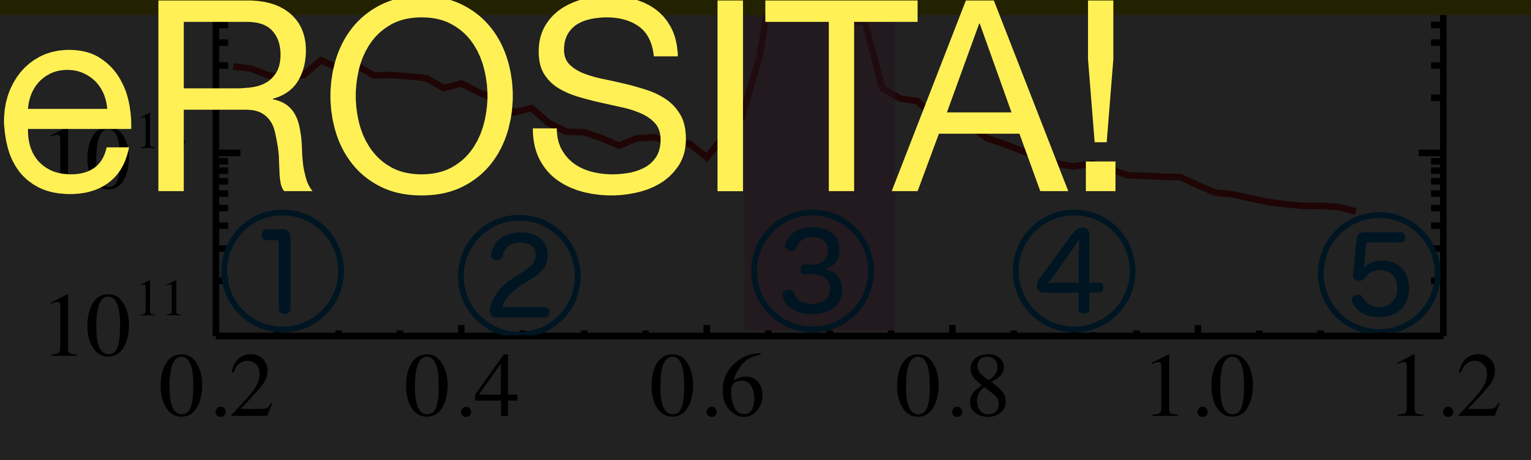
What is the importance of finding HyLIRGs?

The volume density of the HyLIRGs

To find HyLIRGs and investigate their physical properties.

A systematic search with eROSITA!





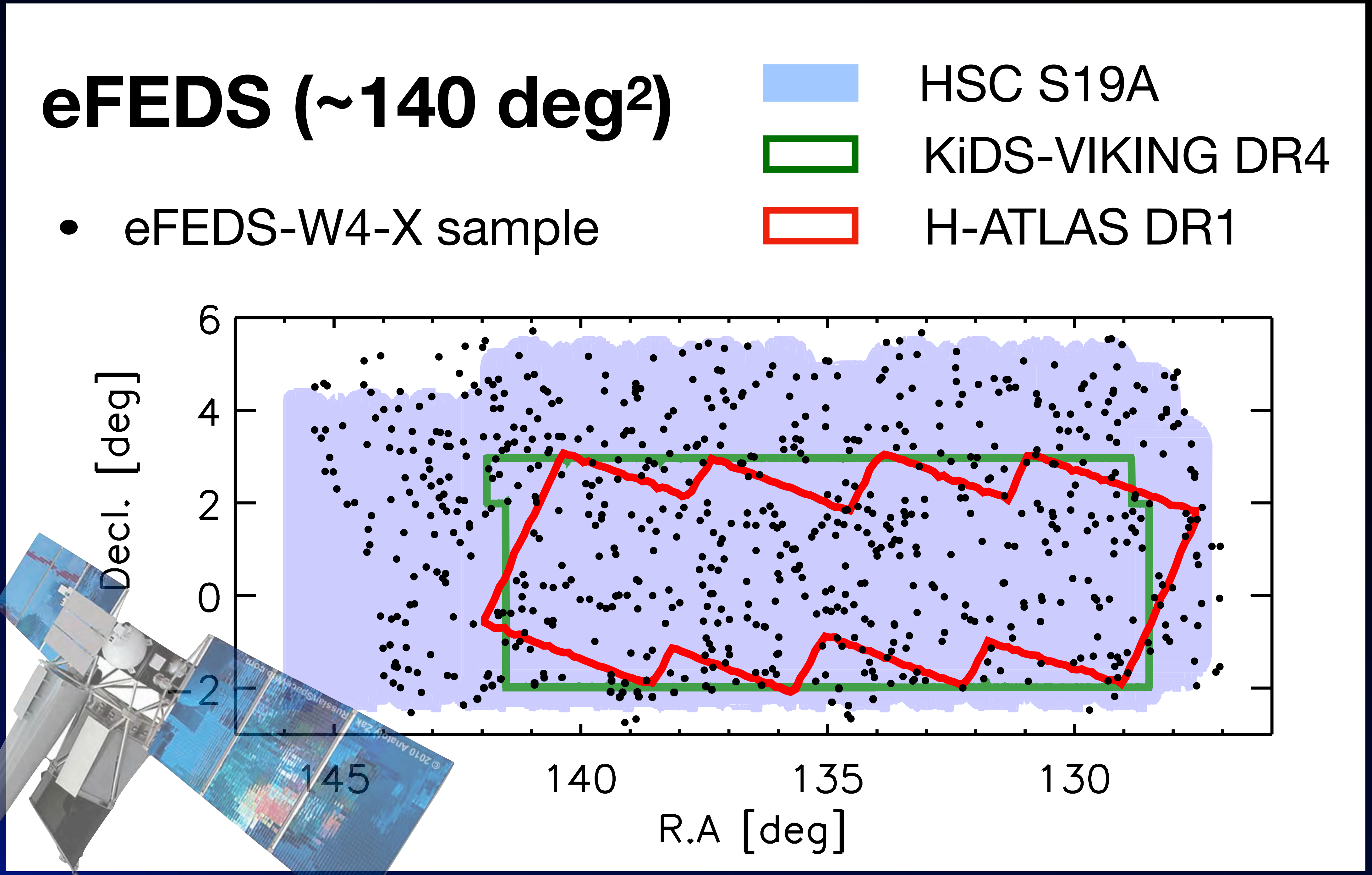
Narayanan et al. (2010) (see also e.g., Yutani, **Toba** et al. 2022).

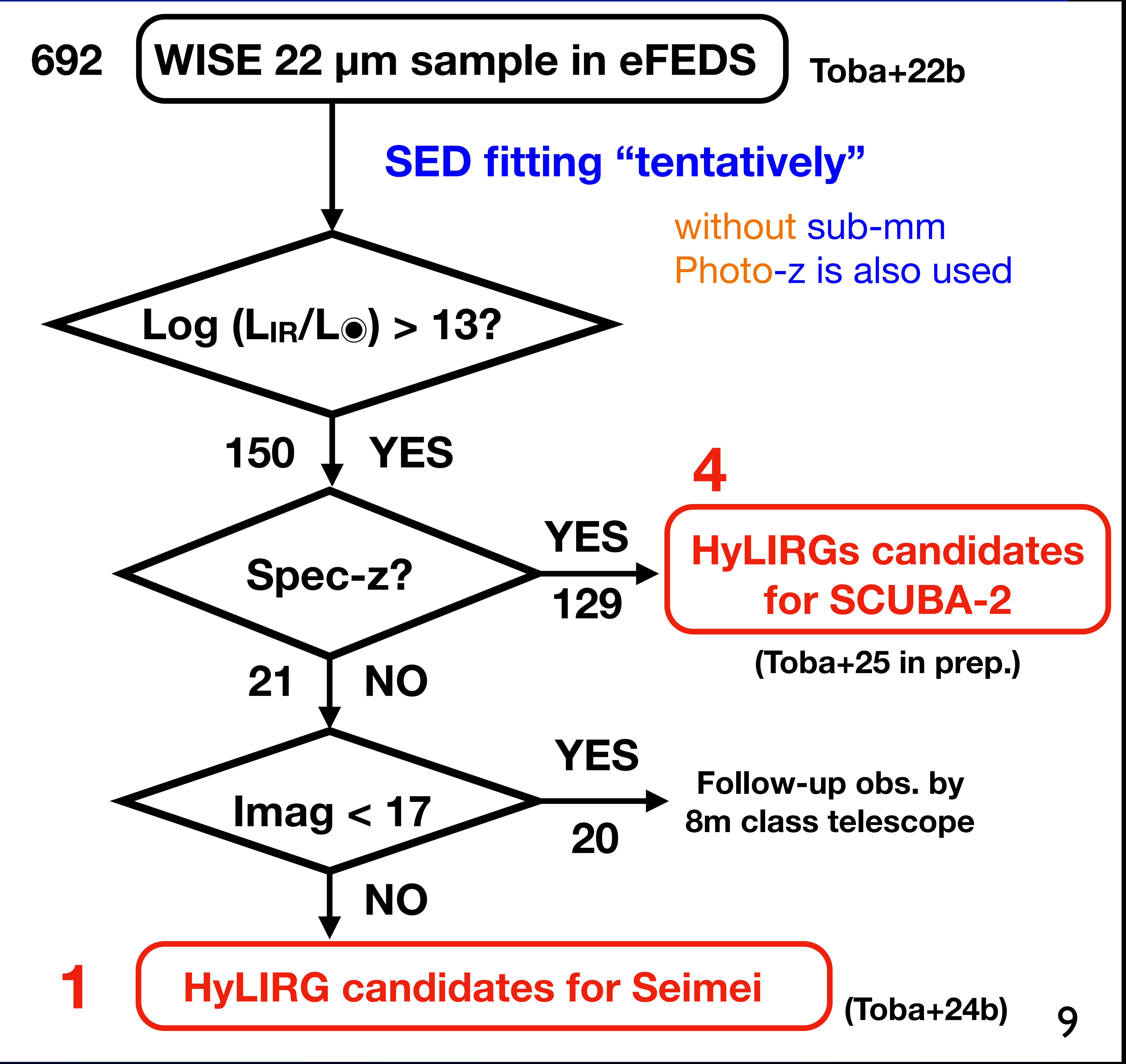
Data and analysis

- Candidates selection
- Data set
- Spectral fitting method
- SED fitting method

Sample selection

- From 27,369 X-ray sources, 692 WISE 22 μm sources were studied in Toba+22.
- **One object with z_{phot} was targeted for KOOLS-IFU, while four objects with z_{spec} were targeted for SCUBA-2 obs.**

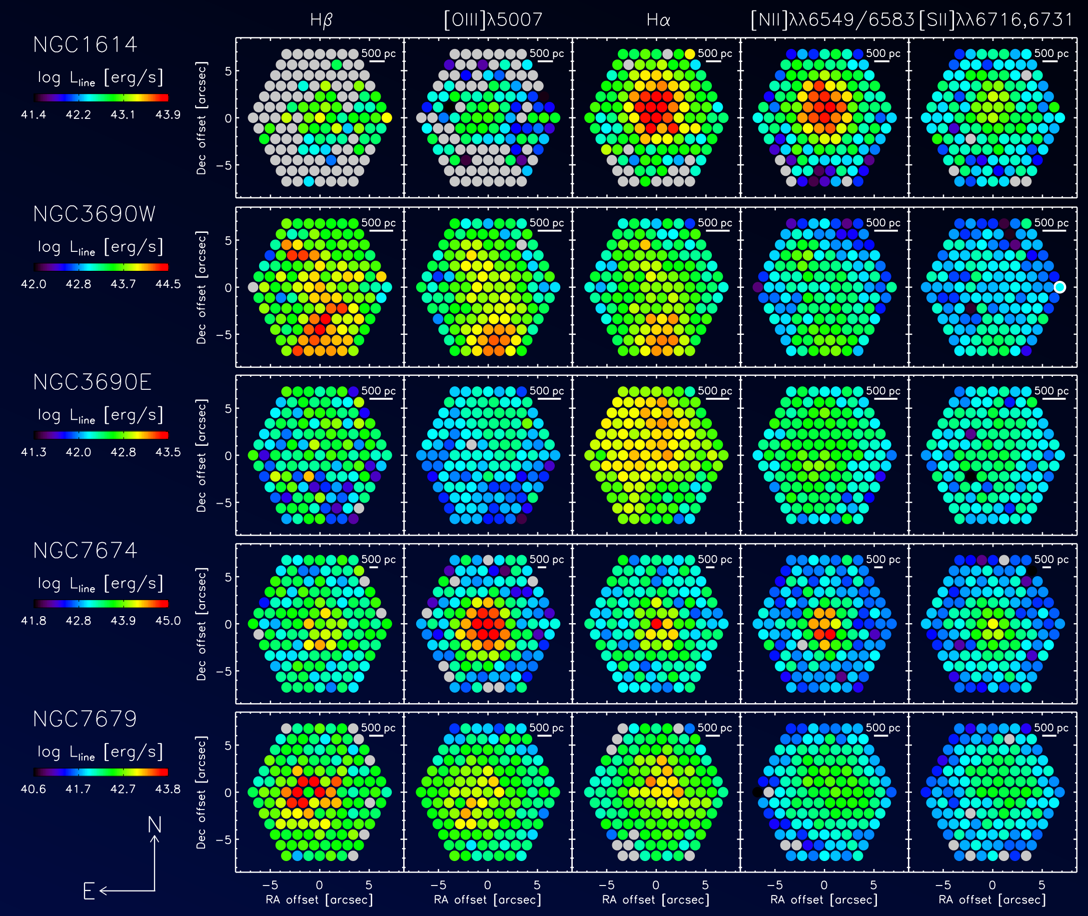




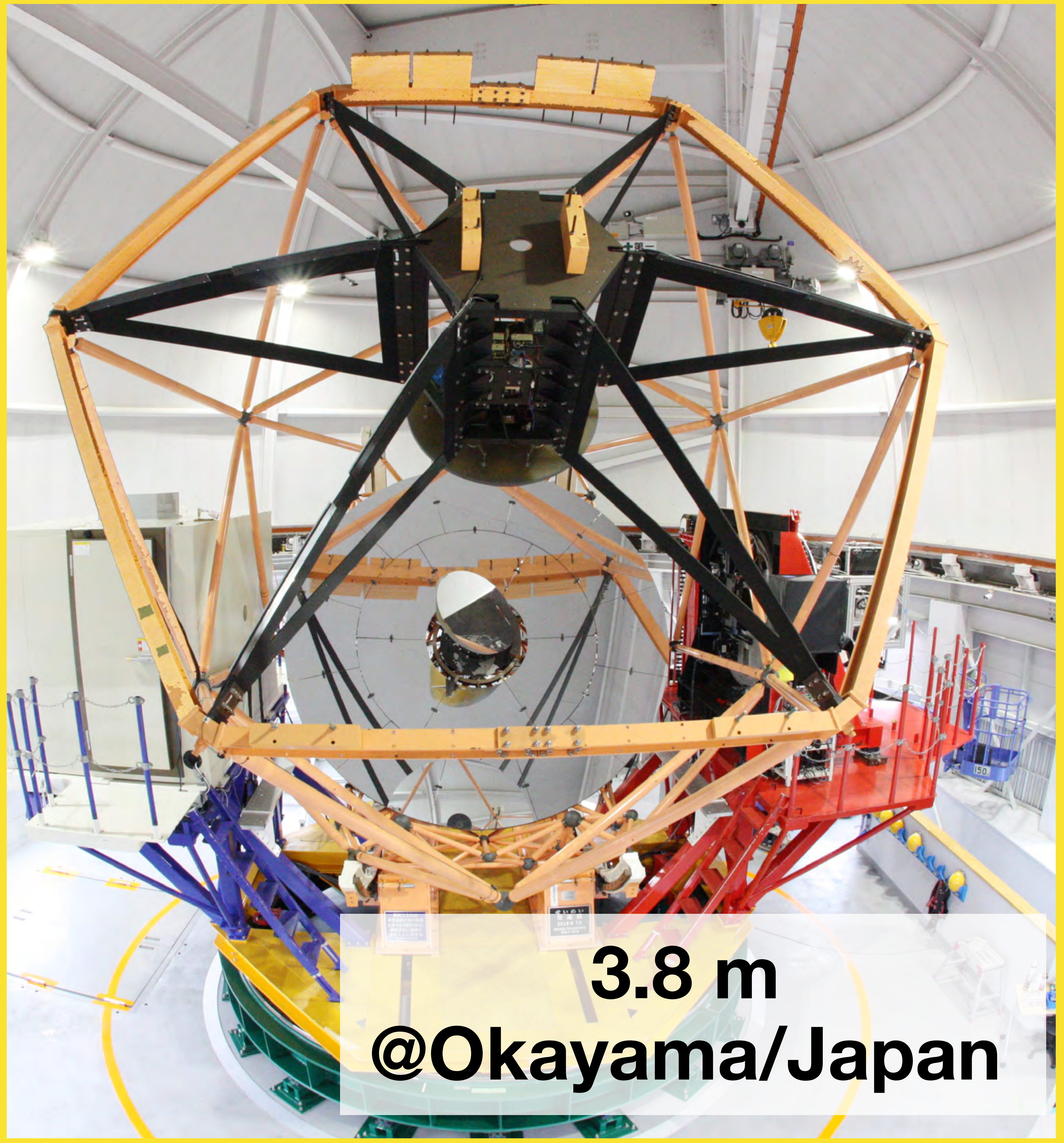
KOOLS-IFU on Seimei Telescope

Kyoto **O**kayama **O**ptical **L**ow-dispersion **S**pectrograph with optical-fiber **I**ntegral **F**ield **U**nit

Number of fibers	117 (= 110 for objects and 7 for sky)
FoV of a fiber	regular hexagon of 0.42 arcsec inradius
Fiber pitch	0.84 ± 0.07 arcsec
Total FoV	8.4 x 8.0 arcsec for object and 2.5 x 2.4 arcsec for sky FoV for aladin (vot file). Please see like here for usage.
Fiber core filling factor	~100%



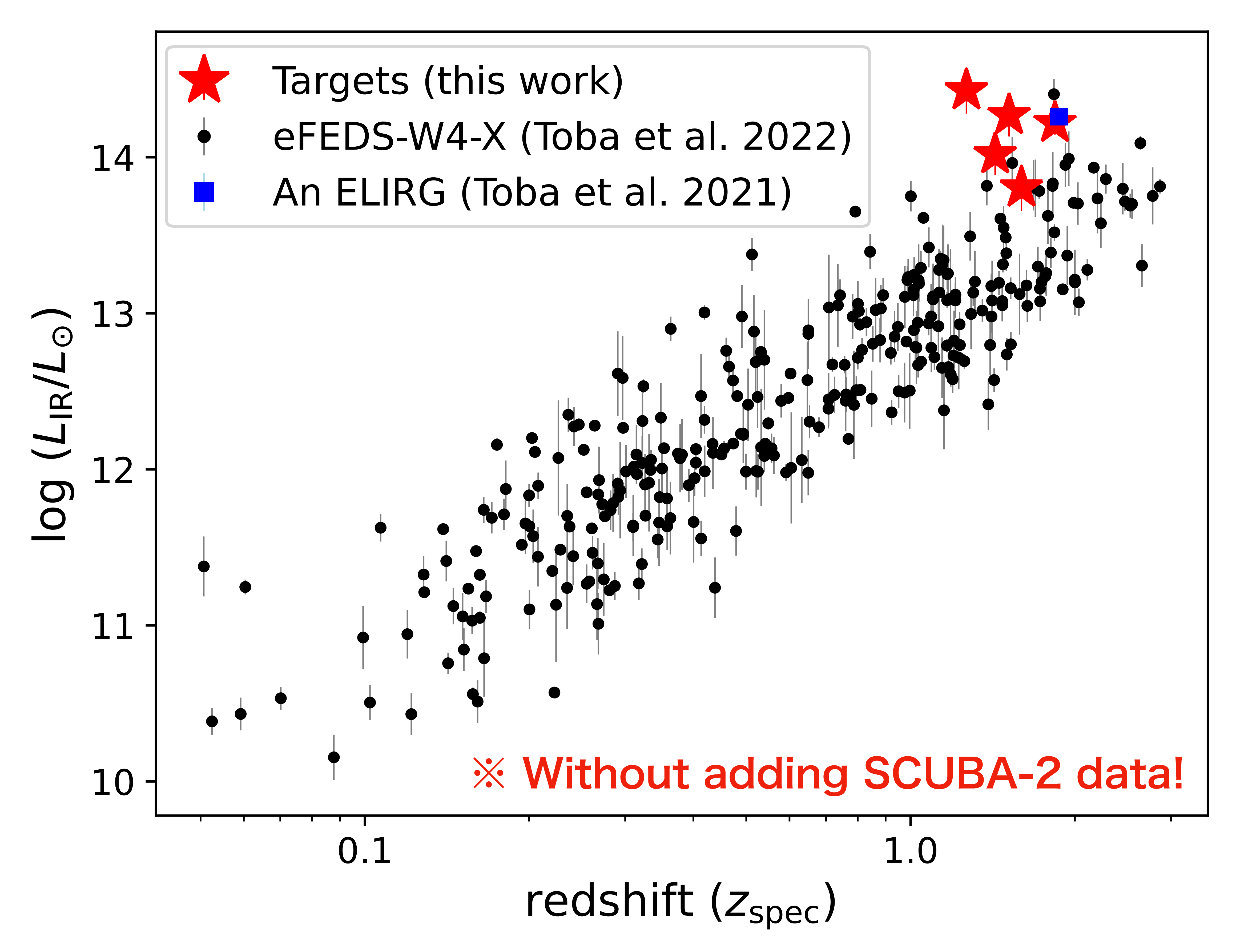
Examples of the KOOL-IFU observations for nearby U/LIRGs (Toba et al. 2020)



3.8 m
@Okayama/Japan

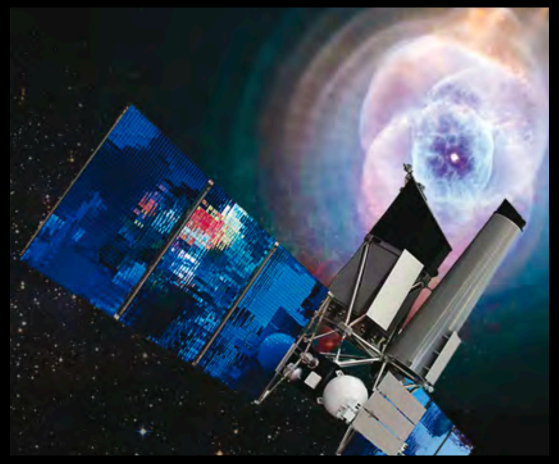
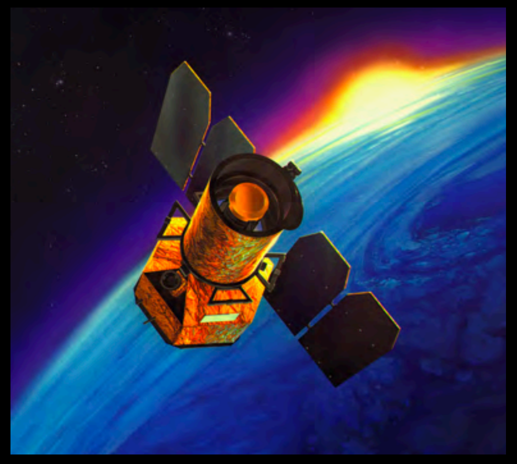
Target list for KOOLS-IFU and SCUBA-2

Object name	Spec-z	AGN tyoe	KOOLS-IFU obs?	SCUBA-2 obs?
eFEDSJ0828	?	?	O	O
eFEDSJ0841	1.839	quasar	X	O
eFEDSJ0856	1.515	quasar	X	O
eFEDSJ0908	1.266	quasar	X	O
eFEDSJ0926	1.429	quasar	X	O



Multi-wavelength dataset

	X-ray	UV	optical	near-IR	mid-IR	far-IR / sub-mm	
Instrument	eROSITA	GALEX	SDSS	UKIDSS	WISE	AKARI	SCUBA-2
Band	2-10 keV	FUV NUV	u, g, r, i, z	Y, J, H, K	3.4, 4.6, 12, 22	90	450, 850
tracer	AGN		stellar population		hot dust	warm/cold dust	

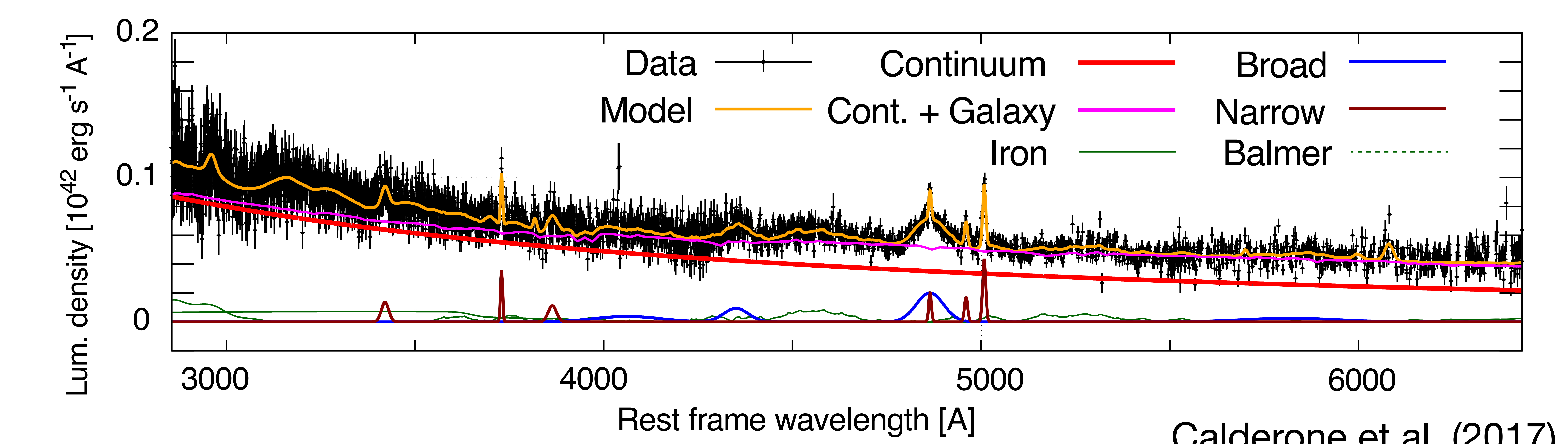






QSFit

Spectral fitting

$$\lambda_{Edd} = \frac{L_{bol}}{L_{Edd}}, \quad L_{Edd} \propto M_{BH}$$



Calderone et al. (2017)

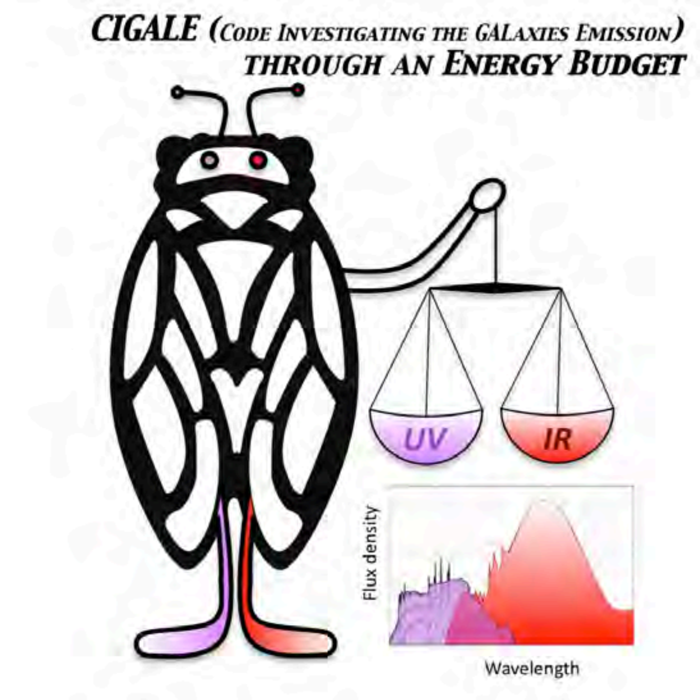
$$M_{\rm BH}\,[M_\odot] = 10^{6.86}\left[\frac{\rm FWHM\,(MgII)}{1000\,{\rm km\,s^{-1}}}\right]^2\left[\frac{\lambda L_\lambda\,(3000\,\text{Å})}{10^{44}\,{\rm erg\,s^{-1}}}\right]^{0.5}$$

Vestergaard & Osmer (2009)

$$L_{\rm bol}^{\rm AGN} = (5.2 \pm 0.2) \times \lambda L_\lambda\,(3000\,\text{Å})$$

Vestergaard & Osmer (2009)

SED fitting



Code **I**nvestigating **GAL**axy **E**mission

Boquien et al. (2019)

- CIGALE performs the SED fitting by considering the energy balance between UV/optical and IR.
- We need to assume, e.g., star-formation history, single stellar population, and AGN dust model.
- CIGALE tells us e.g., stellar mass, SFR, dust extinction of galaxies.

Parameter	Value
Delayed SFH with recent starburst (Ciesla et al. 2017)	
$\tau_{\rm main}$ [Gyr]	1.0, 4.0, 8.0, 12
age [Gyr]	0.5, 1.0, 1.5, 2.0
age of burst [Myr]	10, 50, 100
R_sfr	1, 5, 10
SSP (Bruzual & Charlot 2003)	
IMF	Chabrier 2003
Metallicity	0.02
Nebular emission (Inoue 2011)	
$\log U$	−3.0, −2.0, −1.0
Dust attenuation (Calzetti et al. 2000; Leitherer et al. 2002)	
$E(B-V)_{\rm lines}$	0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 1.0
AGN Emission (Stalevski et al. 2012; Stalevski et al. 2016)	
$\tau_{9.7}$	3, 7, 11
p	0.5, 1.5
q	0.5, 1.5
Δ [°]	40
$R_{\rm max}/R_{\rm min}$	30
θ [°]	0, 10, 20
$f_{\rm AGN}$	0.4, 0.5, 0.6, 0.7, 0.8, 0.9
Dust Emission (Draine et al. 2014)	
$q_{\rm PAH}$	2.50, 5.26, 6.63, 7.32
$U_{\rm min}$	10.0, 50.0
α	1.0, 1.5, 2.0
γ	0.01, 0.1, 1.0
X-ray Emission (Yang et al. 2022)	
AGN photon index (Γ)	2.0
$\alpha_{\rm OX}$	−2.0, −1.9, −1.8, −1.7
$\lvert\Delta\alpha_{\rm OX}\rvert_{\rm max}$	0.5

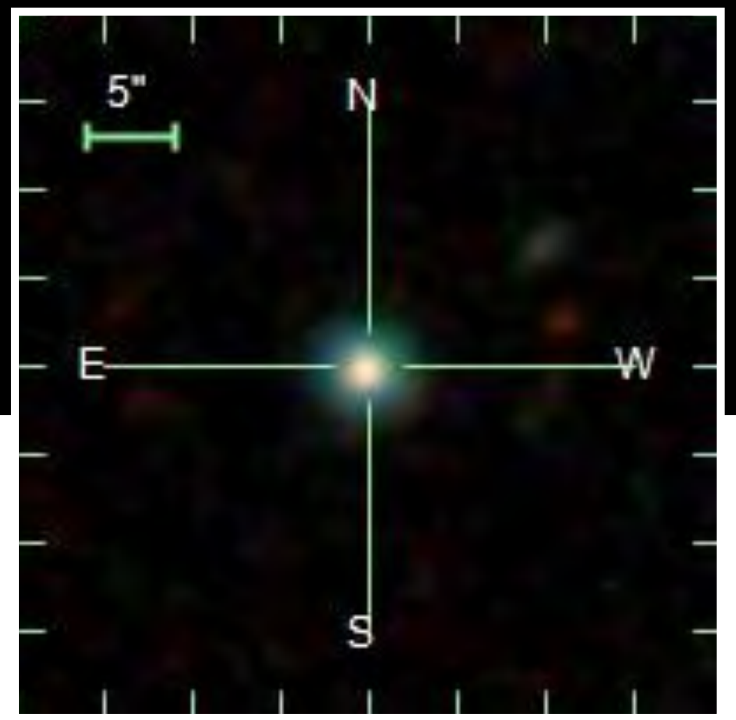
Results and discussion

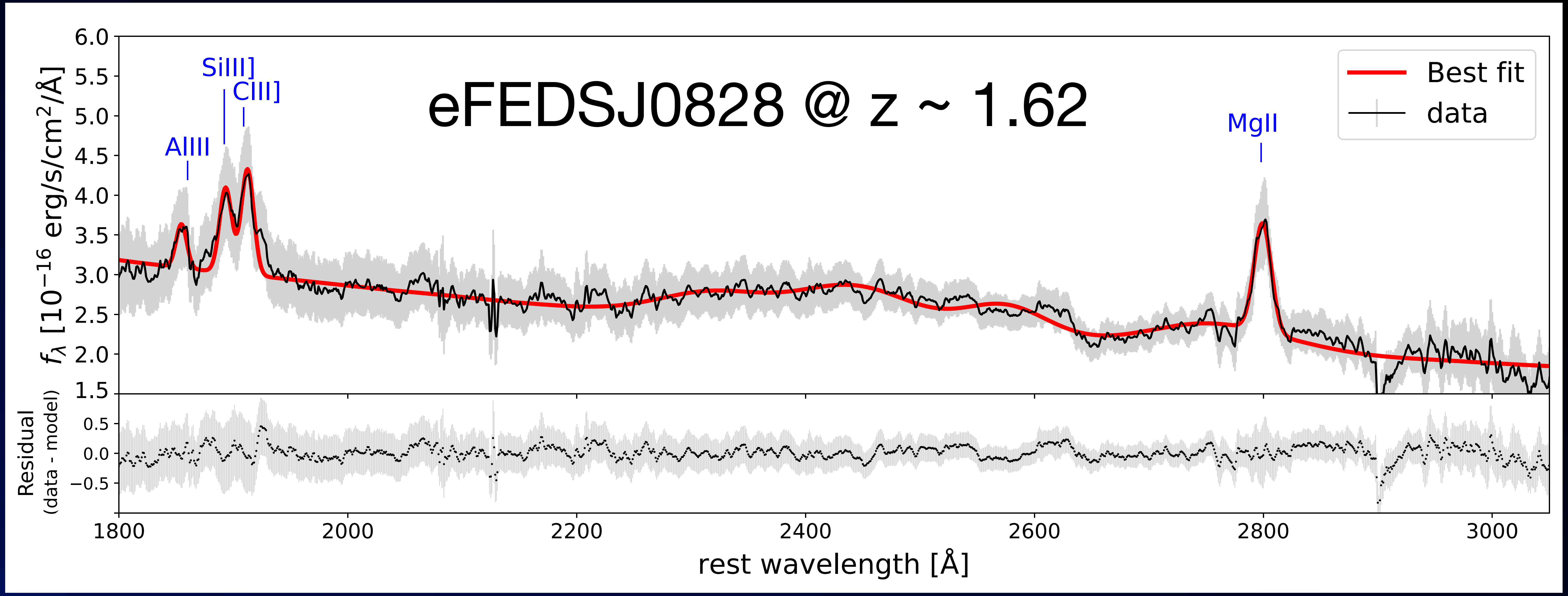
- Results of the spectral fitting
- Results of the SED fitting
- Discovery of new HyLIRGs

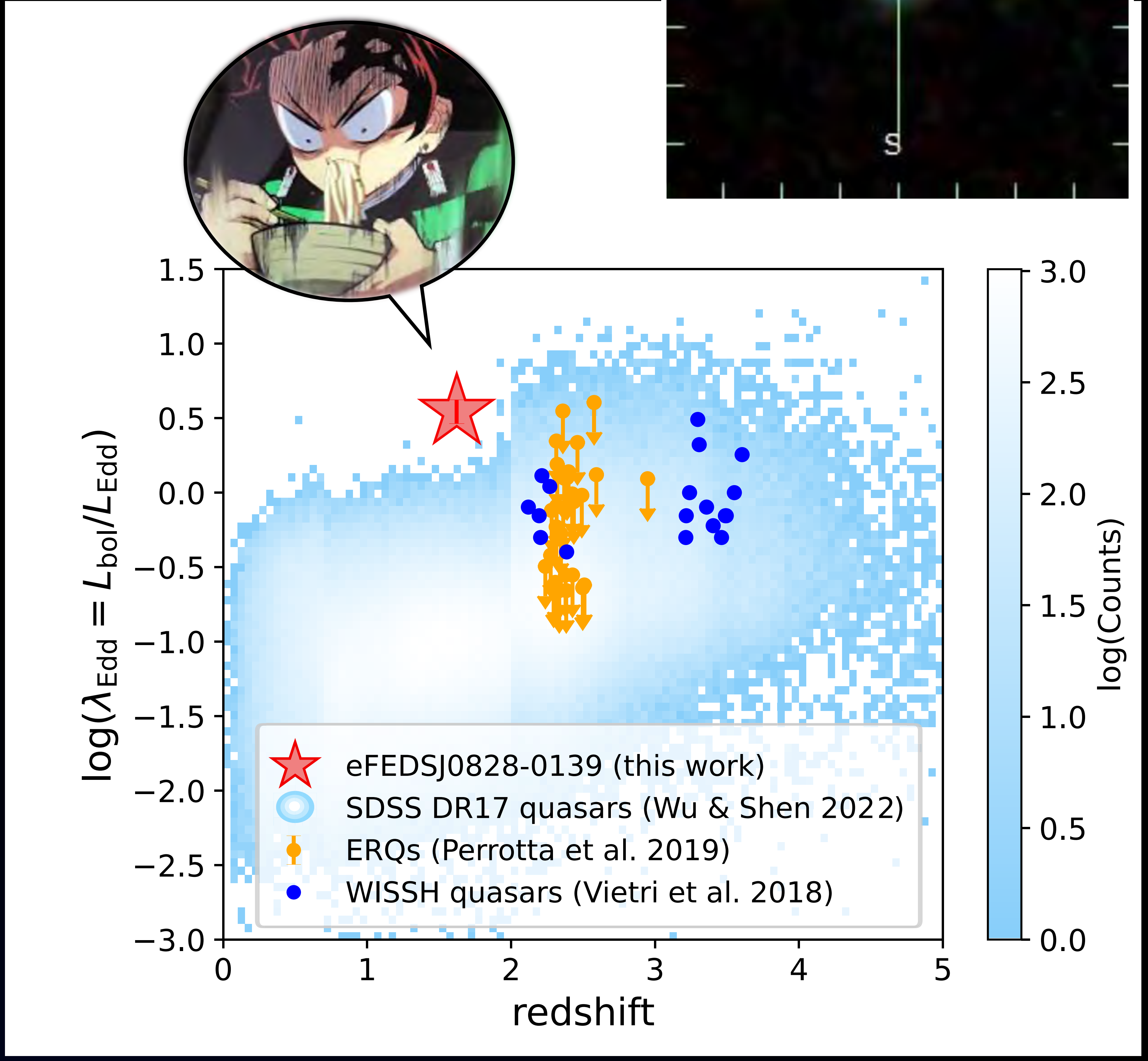
Discovery of the hyperluminous quasar with supper Eddington ratio

Physical properties	Value
L_{bol} [erg/s]	(2.9 ± 0.1) × 10^{47}
M_{BH}	(6.2 ± 1.2) × 10^{8}
λ_{Edd}	**3.6 ± 0.7**

Keito
(NWU)

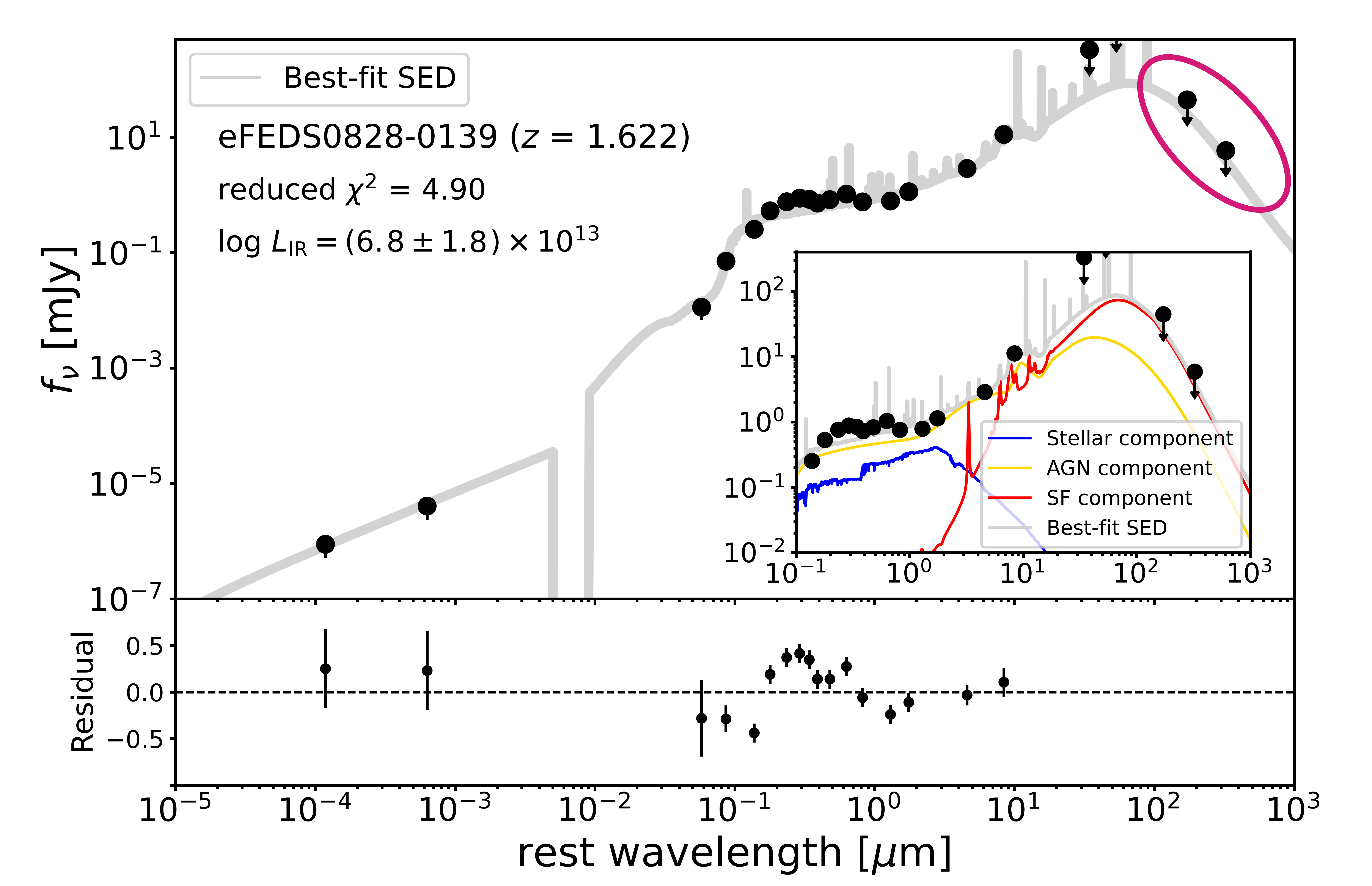


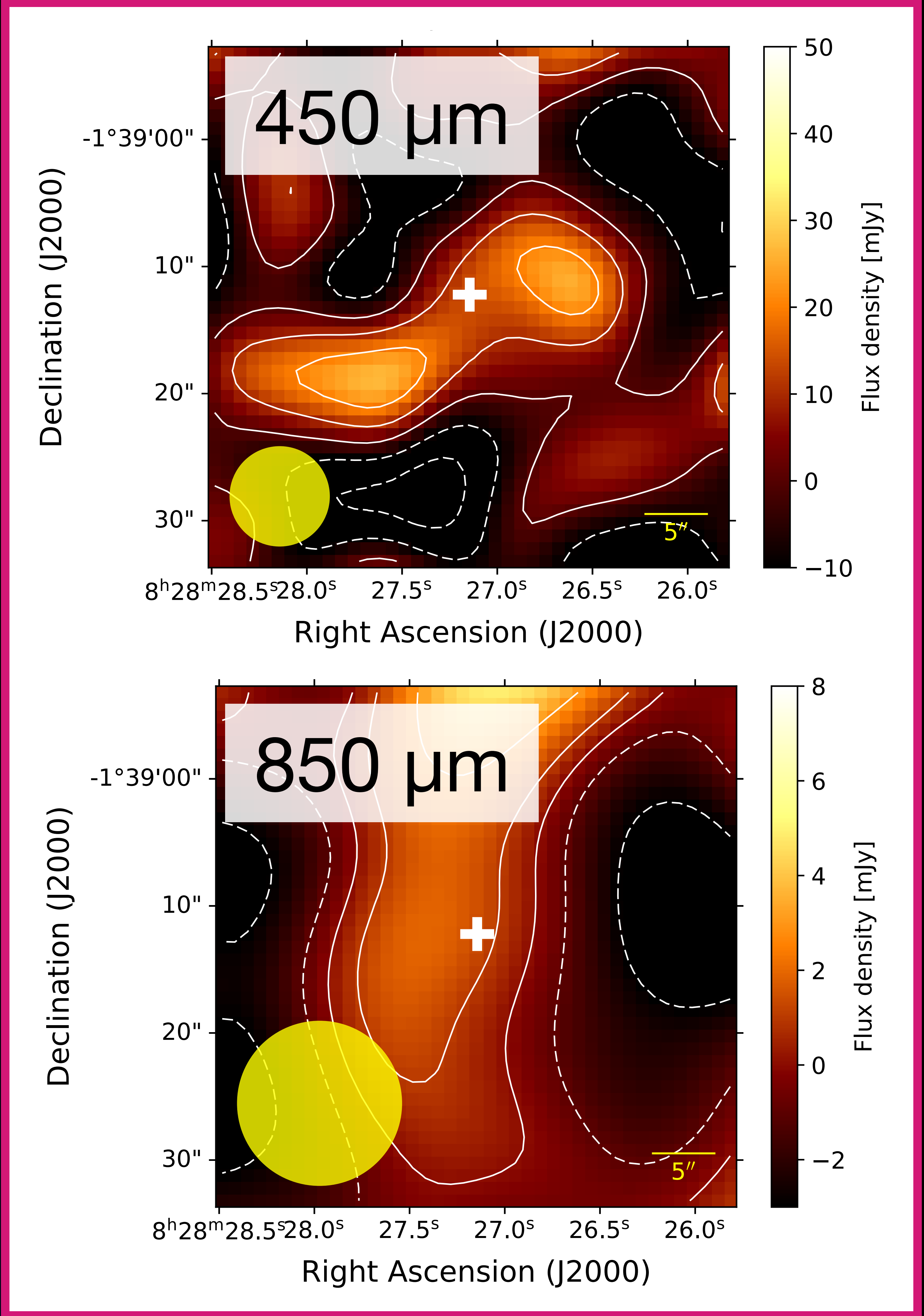




Toba, Masu et al. 2024b, PASJ, in press.

Result of the SED fitting





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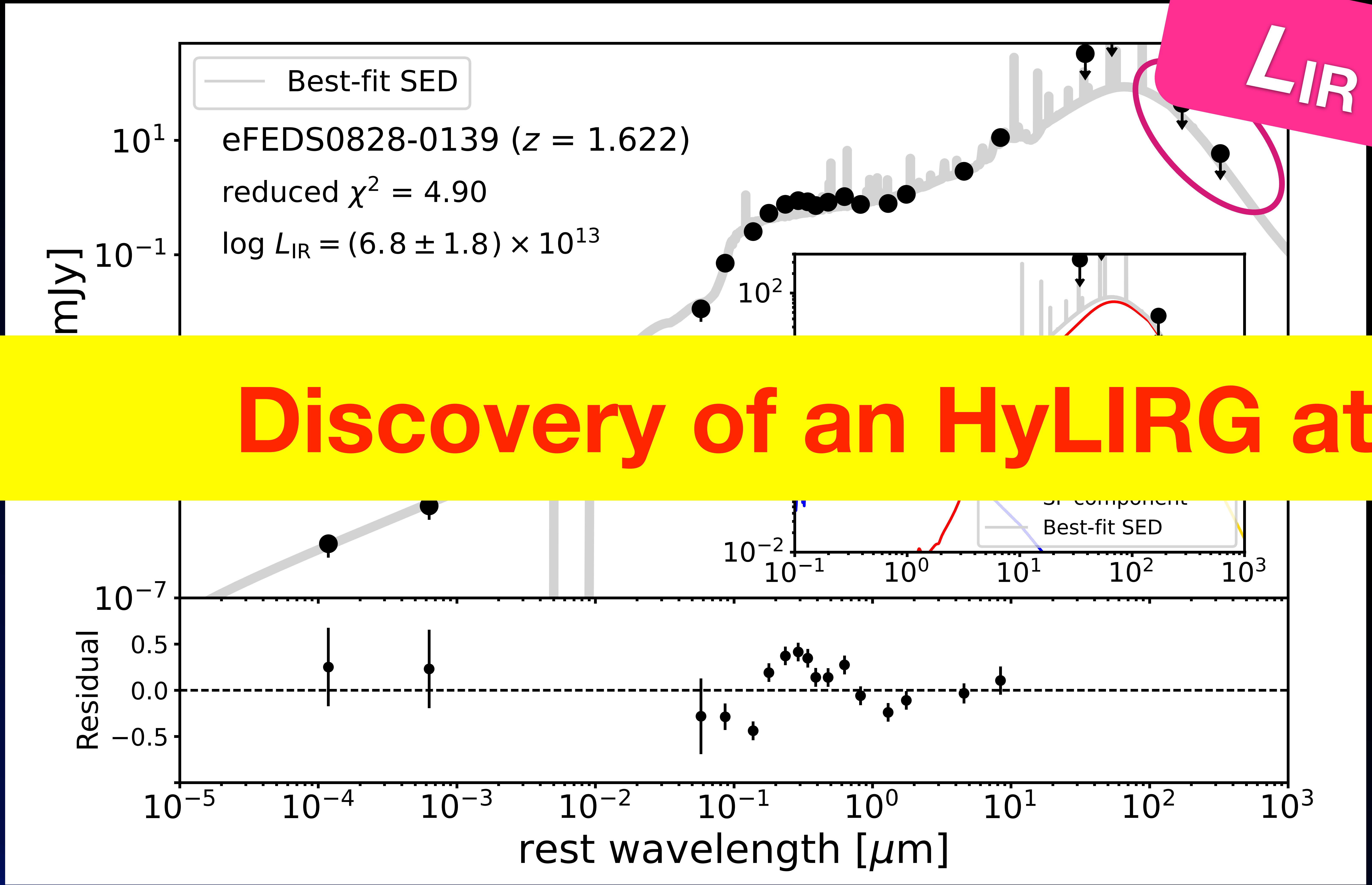
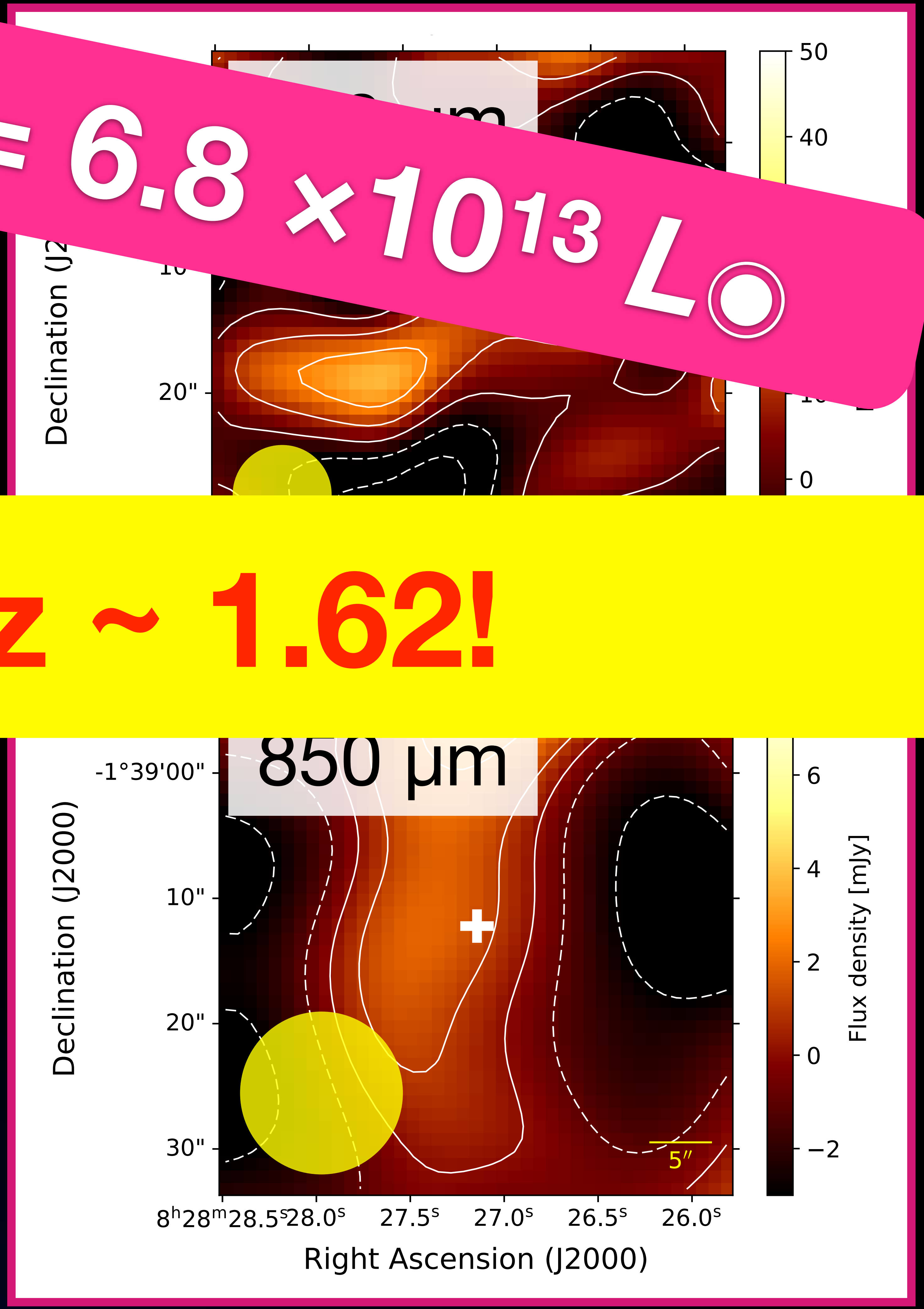




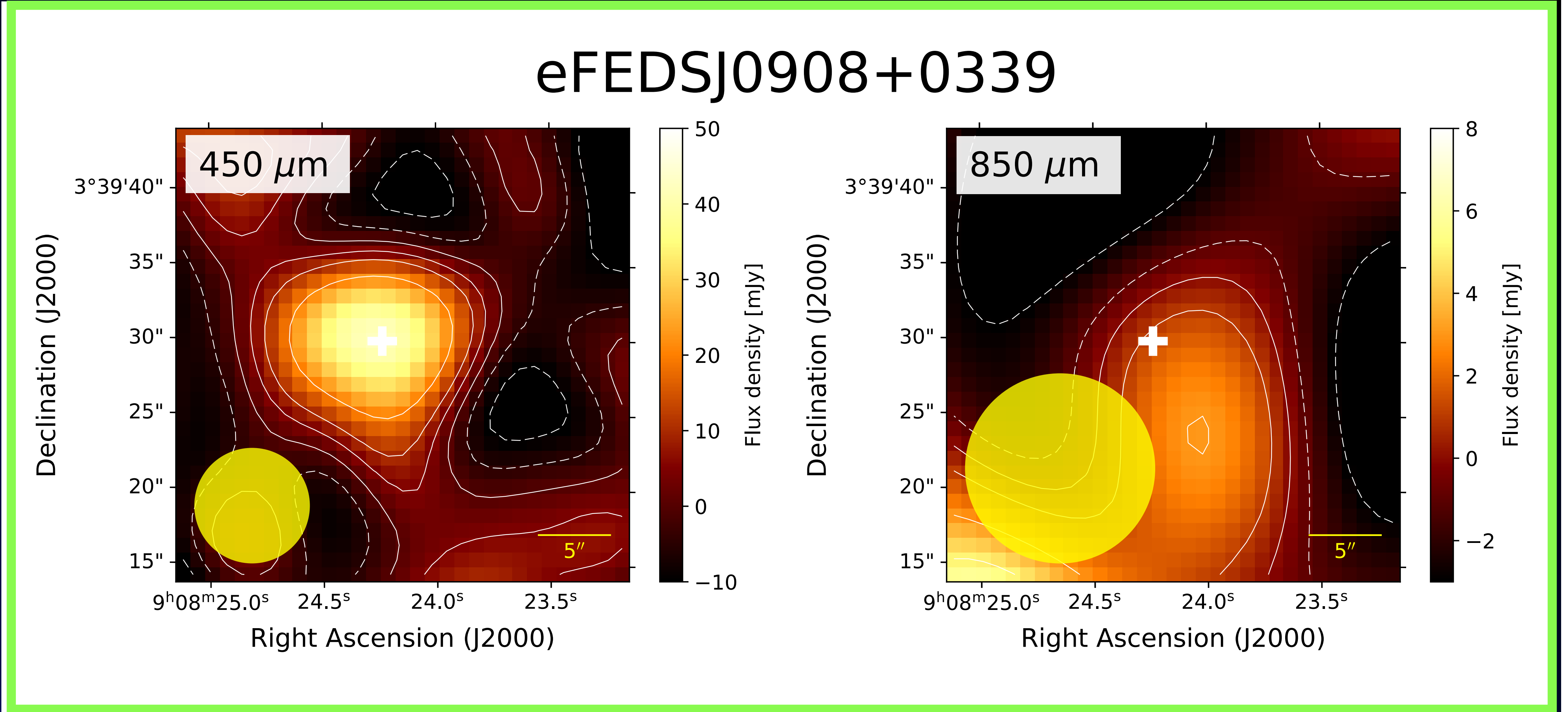
L_{IR} = 6.8 ×10^{13} $L_⊙$

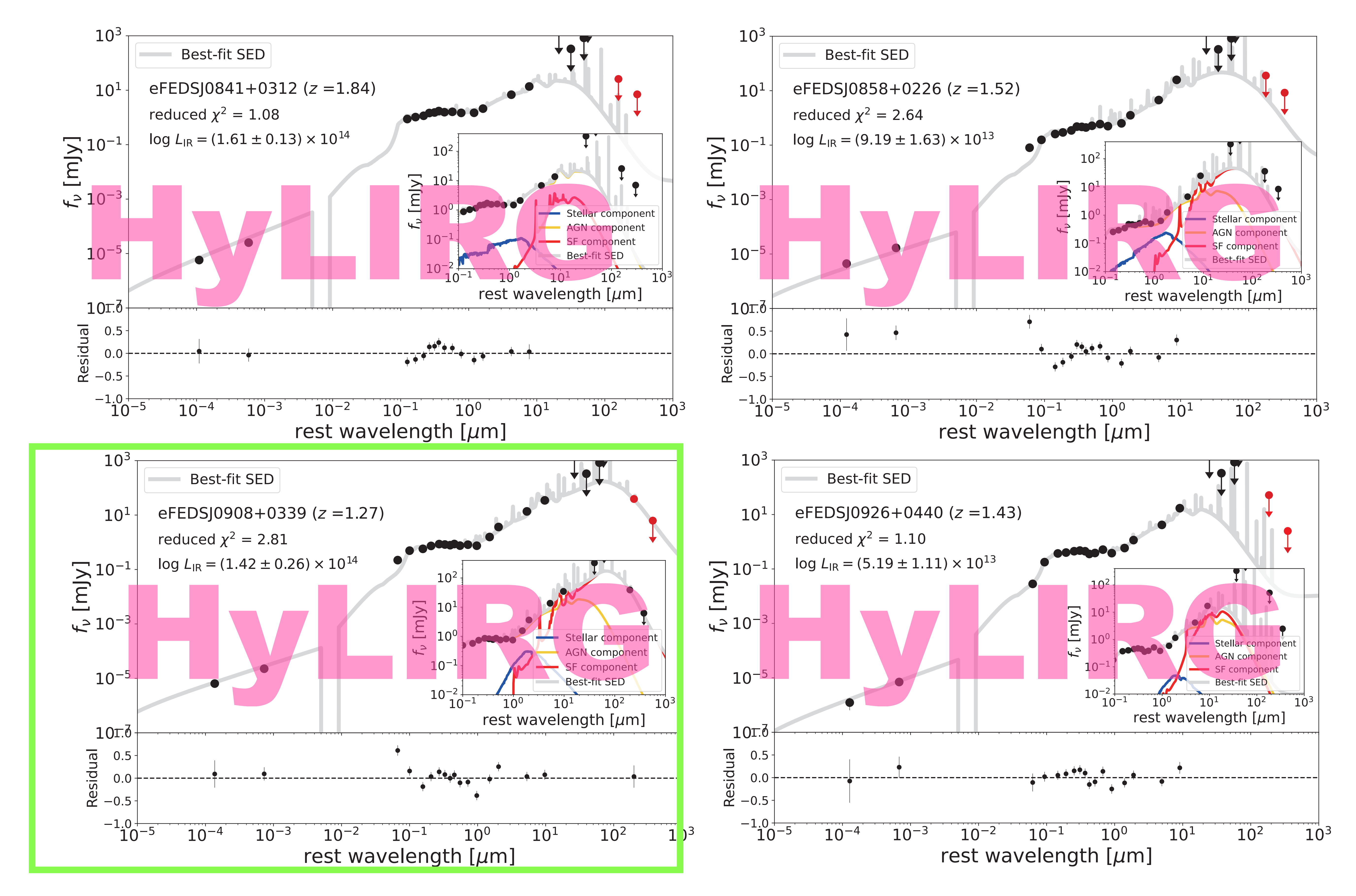
Discovery of an HyLIRG at z ~ 1.62!

Discovery of a few more HyLIRGs!


Zhen-Kai (ASIAA) Wei-Hao (ASIAA)

Objects	Redshift	Log LIR
eFEDS0841	1.84	14.2
eFEDS0858	1.52	14.0
eFEDS0908	1.27	14.2
eFEDS0926	1.43	13.7





Toba, Gao, Wang et al. In prep.

On-going works

Discovery of a few more HyLIRGs!

Zhen-Kai (ASIAA) Wei-Hao (ASIAA)

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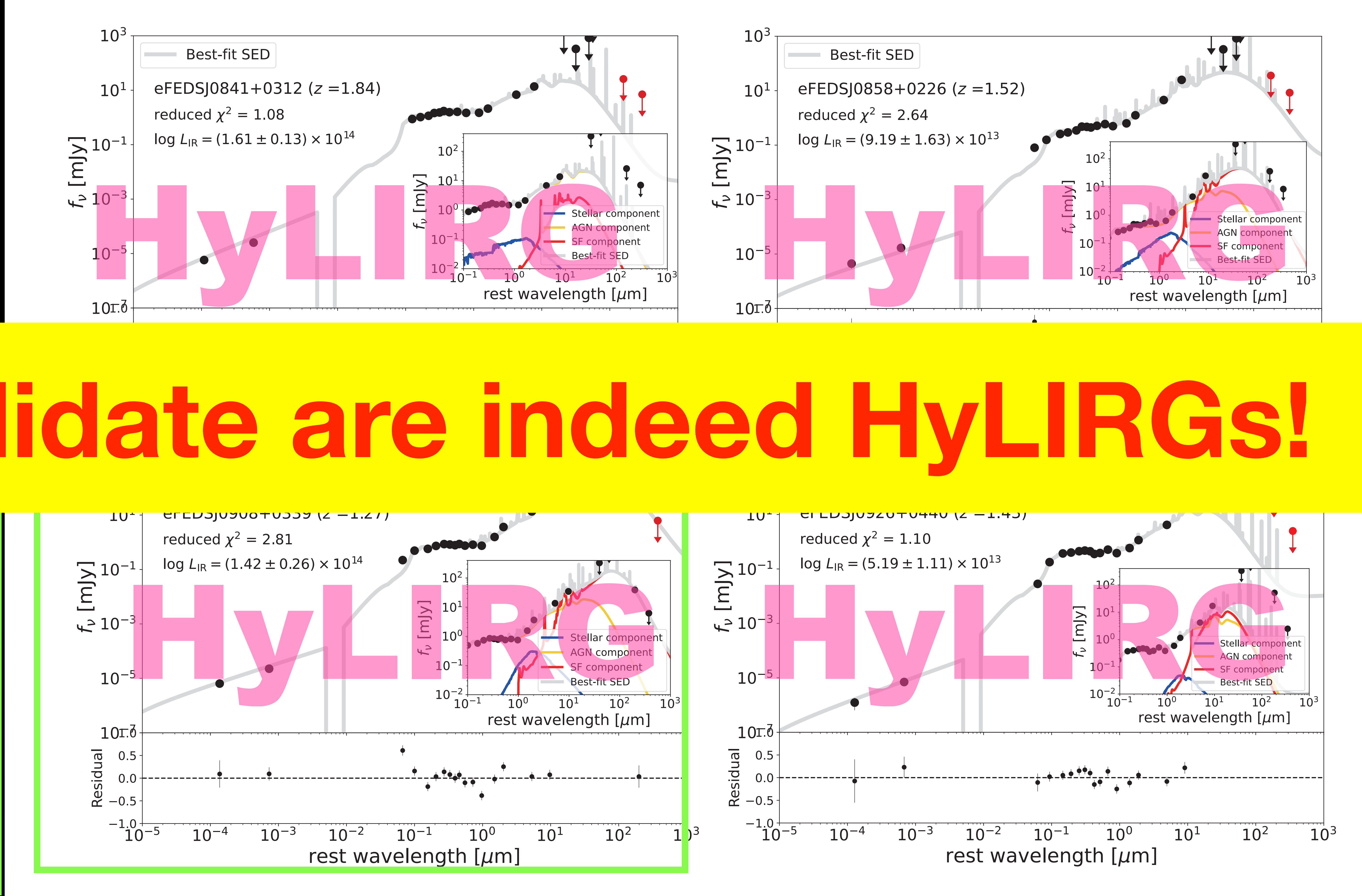
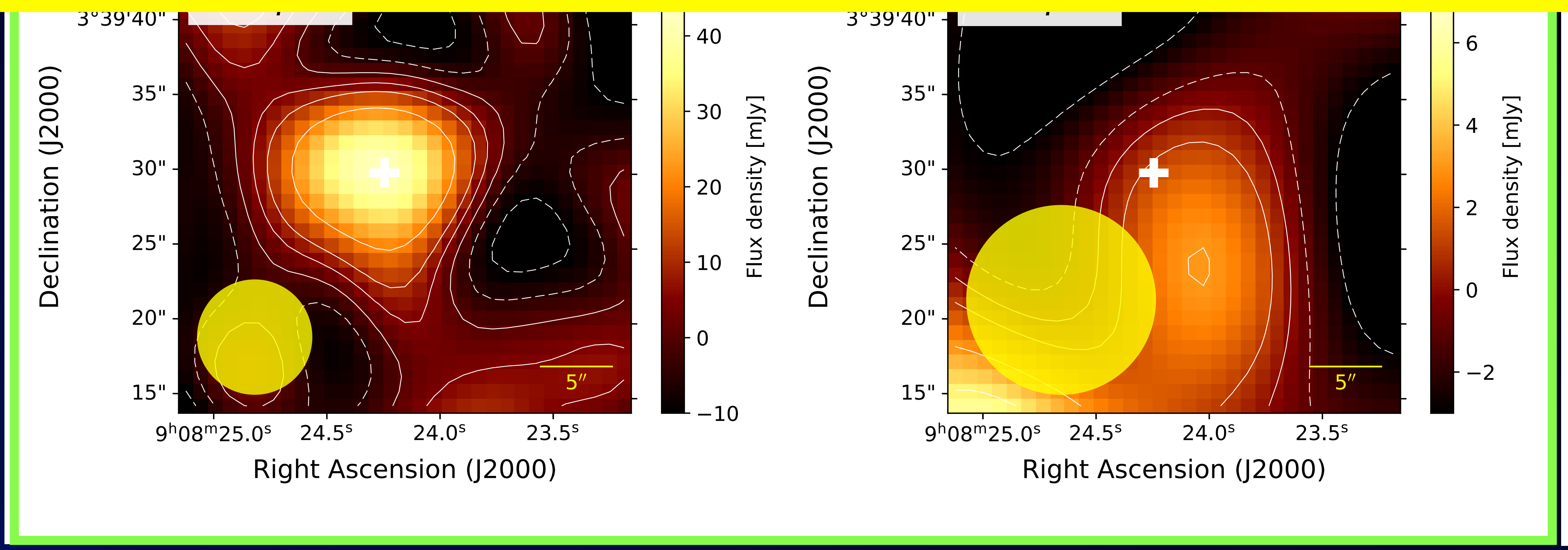


All the HyLIRGs candidate are indeed HyLIRGs!



Toba, Gao, Wang et al. In prep.

Summary

Hyper-luminous infrared galaxies (HyLIRGs)✨

- HyLIRGs are a significant population in understanding the co-evolution of galaxies and SMBHs.
- KOOLS-IFU and SCUBA-2 observed 1 and 5 HyLIRG candidates, respectively.
- **We confirmed all the candidates are HyLIRGs**☺️, and particularly one HyLIRG has an Eddington ratio of ~ 3.6.


END
https://www.pinterest.fr/pin/home--1116048351380059341/