

Discovery of a **Fading AGN** in a **ULIRG** with **Kpc-scale Fast Wind**

(Chen et al. 2020, ApJL, 905, L2)

[#o29-chen@slack](#)

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Subaru Users Meeting FY2020, March 3-5, 2021

Merger-induced evolutionary scenario of massive galaxies

(c) Interaction/“Merger”



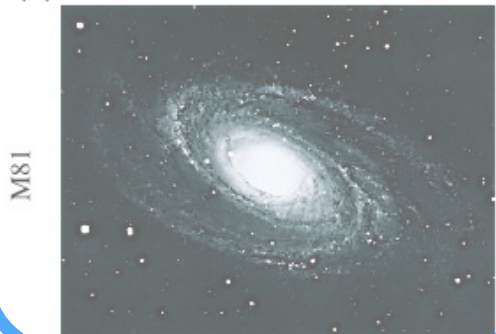
- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

(b) “Small Group”



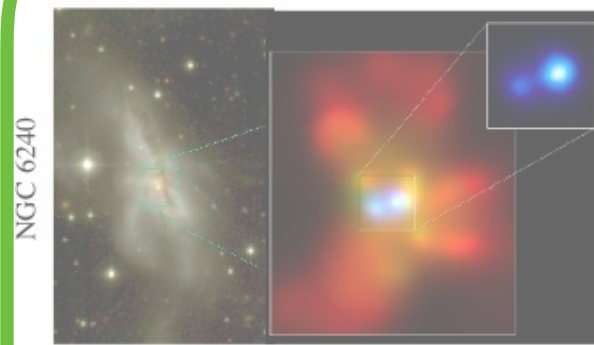
- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently

(a) Isolated Disk



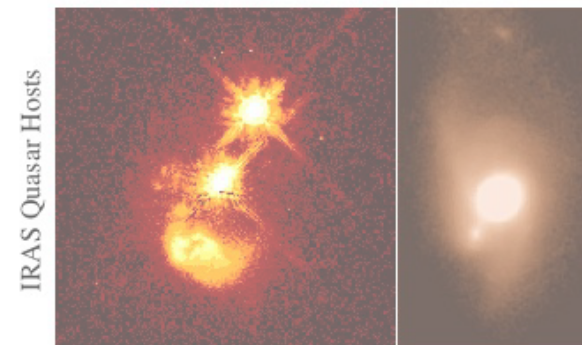
- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- “Seyfert” fueling (AGN with $M_B > -23$)
- cannot redden to the red sequence

(d) Coalescence/(U)LIRG



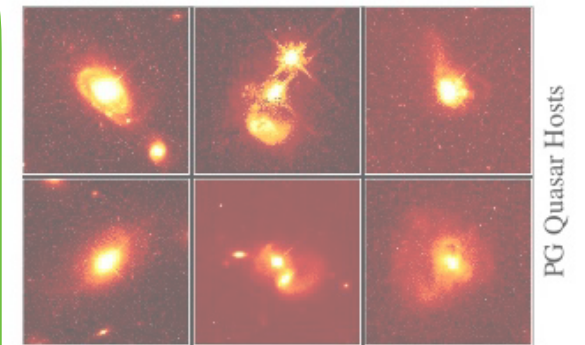
- galaxies coalesce: violent relaxation in core
- gas inflows to starburst
- starburst dominates but, total stellar mass formed is small

(e) “Blowout”



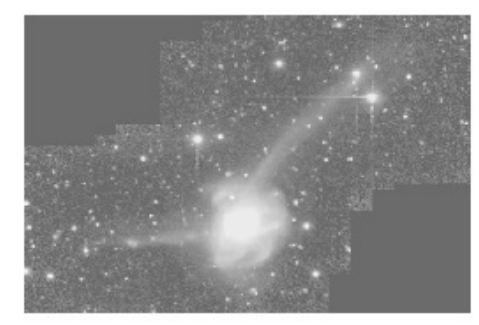
- get reddened (but not Type II) QSO: recent/ongoing SF in host
- high Eddington ratios
- merger signatures still visible

(f) Quasar



- dust removed: now a “traditional” QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(g) Decay/K+A

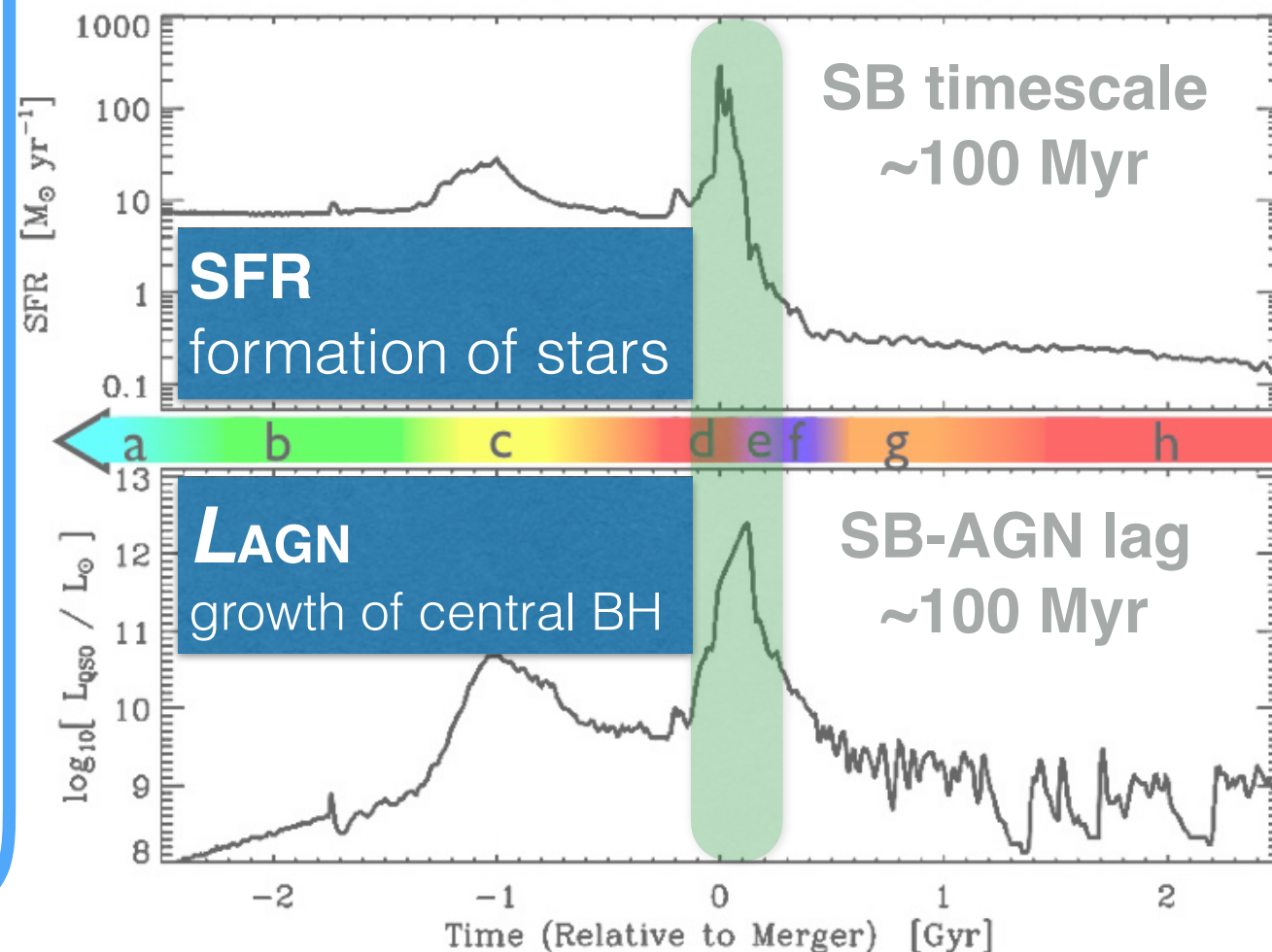


- QSO luminosity fades rapidly
- tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- “hot halo” from feedback
- sets up quasi-static cooling

(h) “Dead” Elliptical



- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to “large group” scales: mergers become inefficient
- growth by “dry” mergers



Hopkins+08

Quenched Galaxy

Normal SF Galaxy

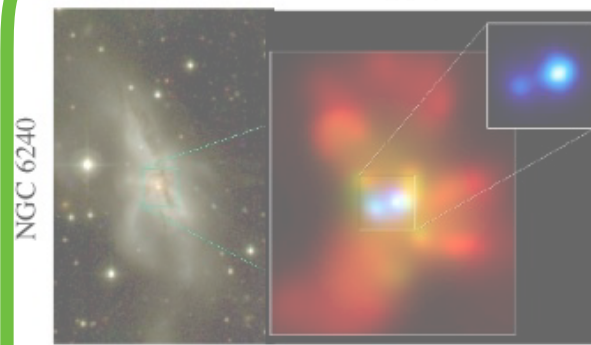
Merger-induced evolutionary scenario of massive galaxies

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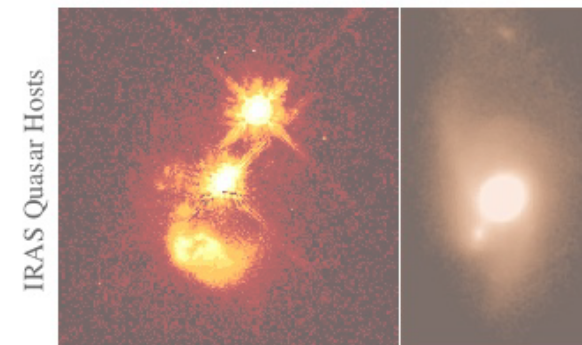
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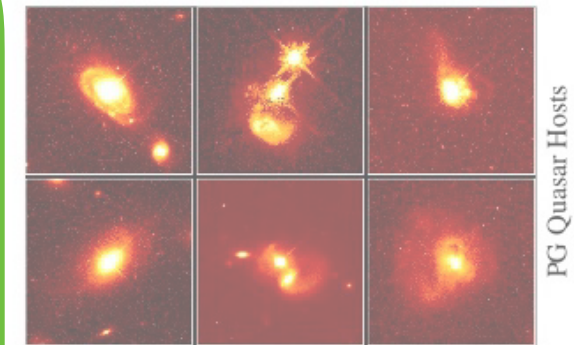
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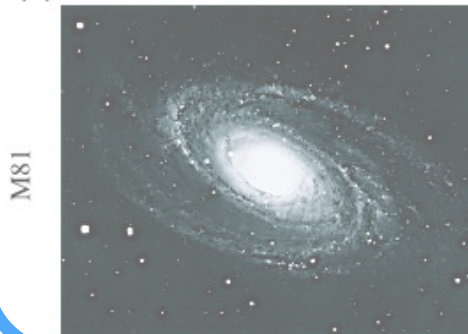
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(b) "Small Group"



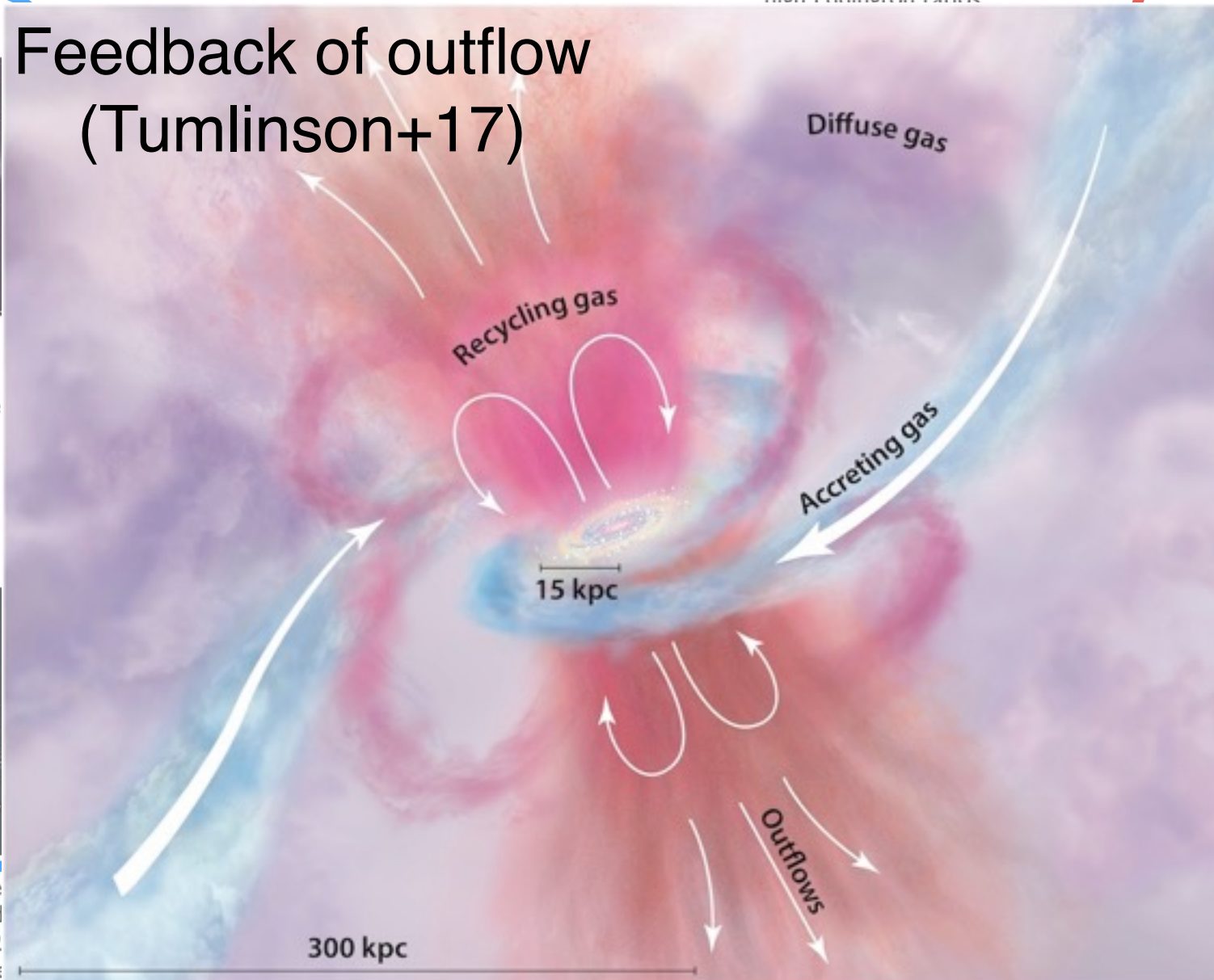
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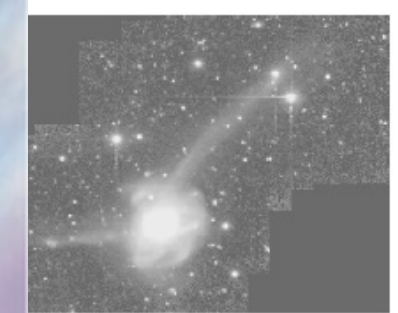


- halo & disk grow, most stars formed
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Feedback of outflow (Tumlinson+17)



Decay/K+A



- luminosity fades rapidly
- tidal features visible only with very deep observations
- dust reddens rapidly (E+A/K+A)
- "halo" from feedback
- sets up quasi-static cooling

"Dead" Elliptical

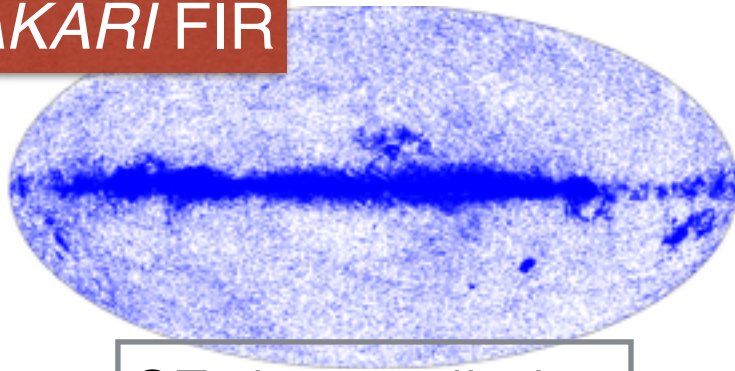


- formation terminated
- BH/spheroid - efficient feedback
- grows to "large group" scales: mergers become inefficient
- with by "dry" mergers

Quenched Galaxy

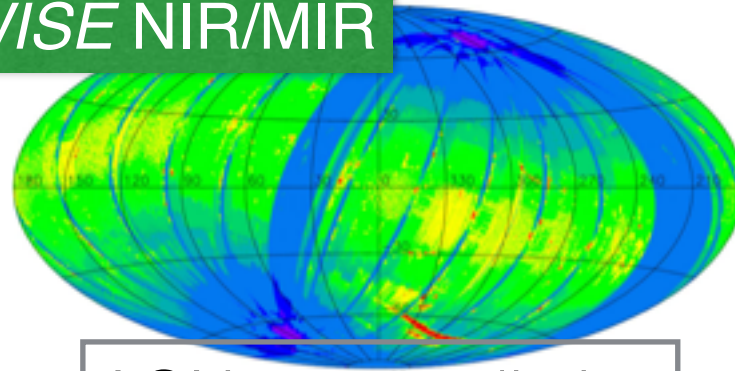
Normal SF Galaxy

AKARI FIR



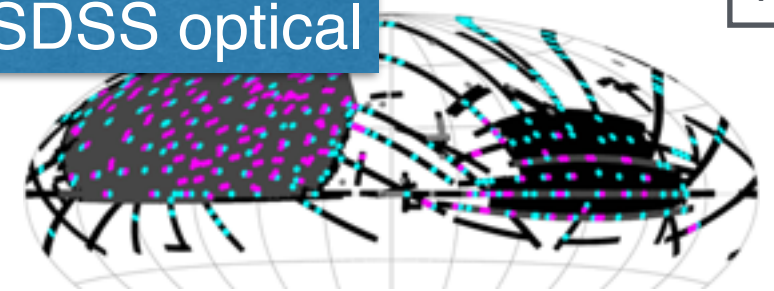
SF dust radiation

WISE NIR/MIR



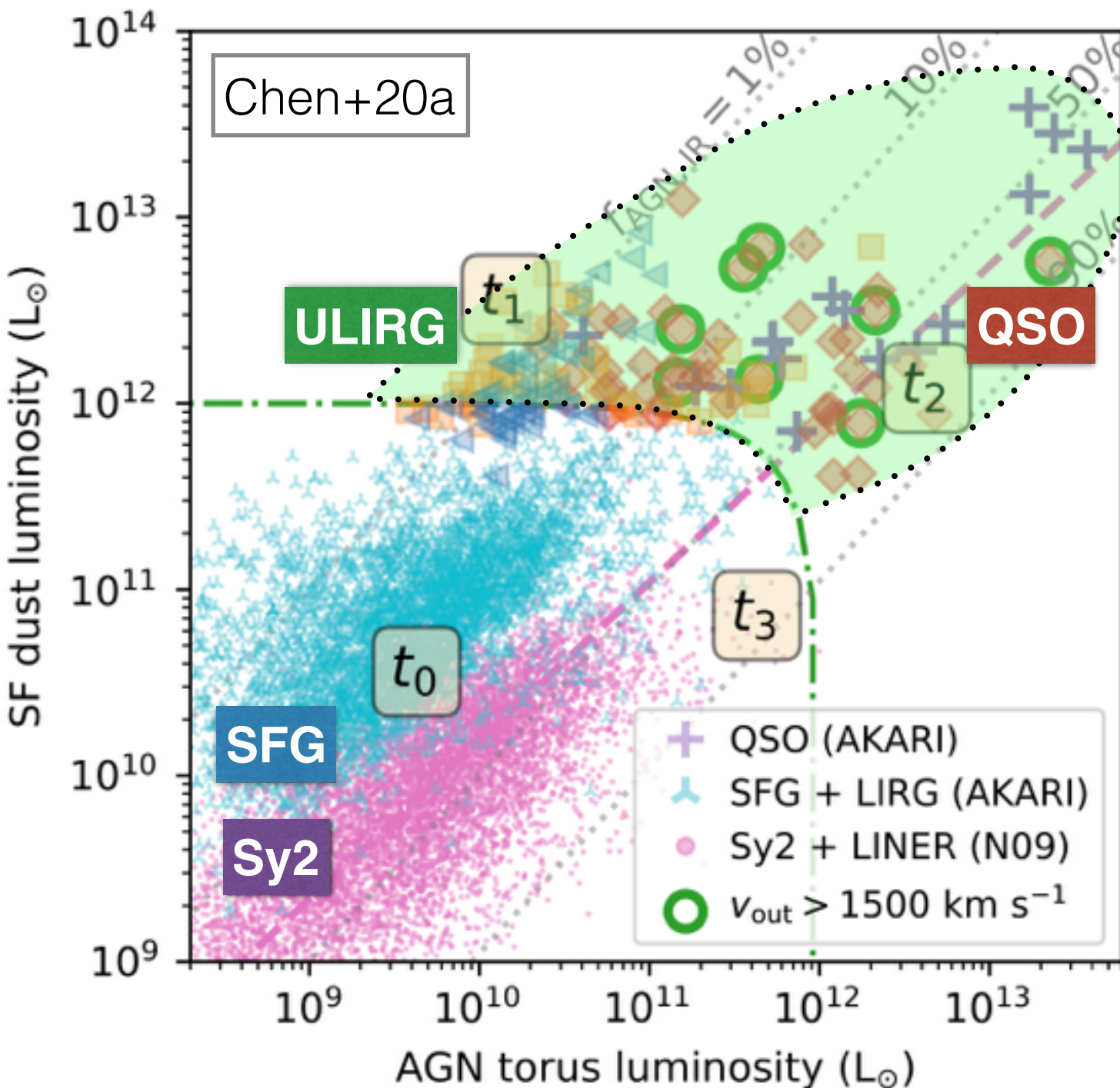
AGN torus radiation

SDSS optical



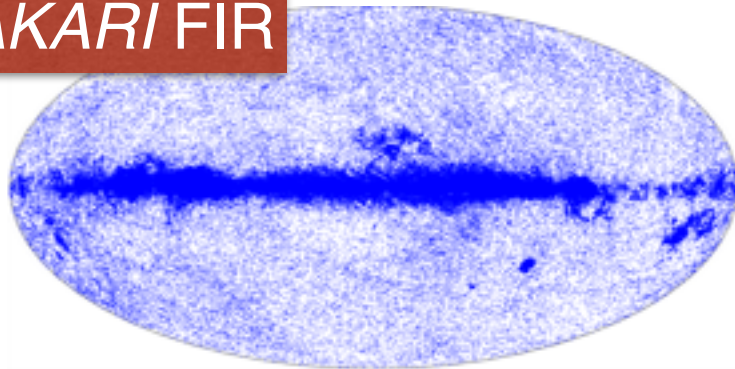
stellar radiation, outflow

4

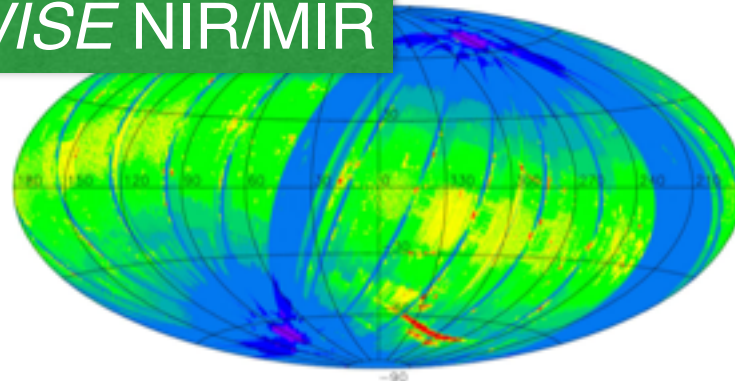


1077 ULIRGs selected with
AKARI+WISE+SDSS:
202 with SDSS or FOCAS spectra

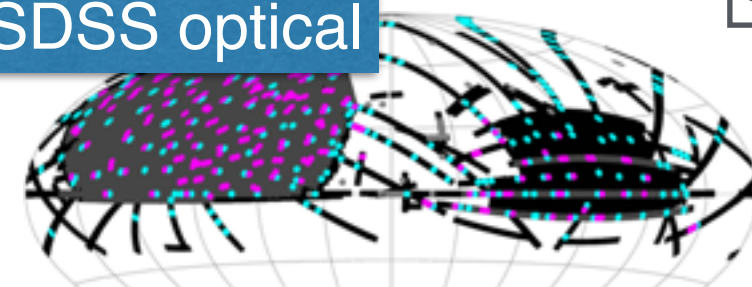
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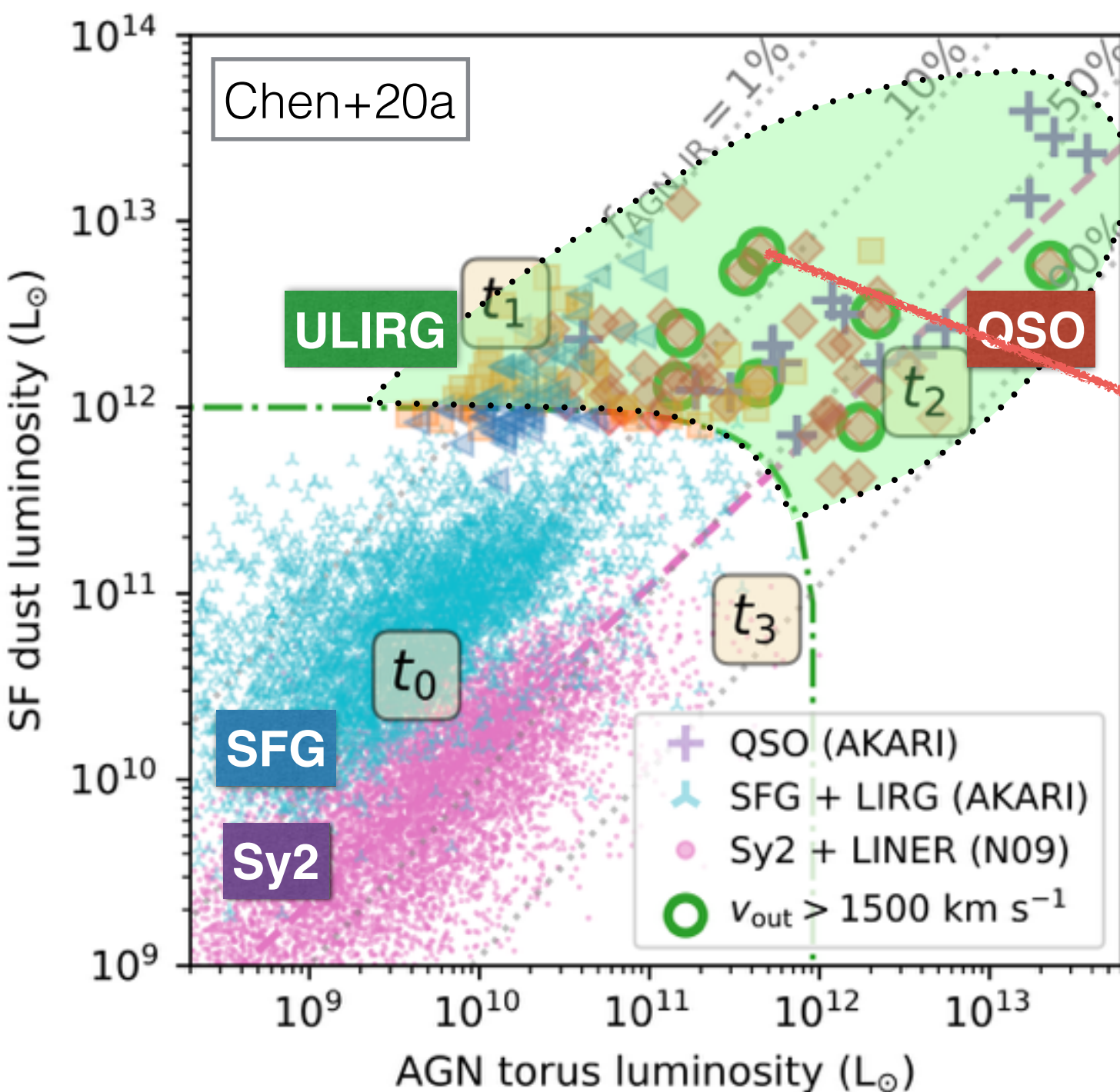
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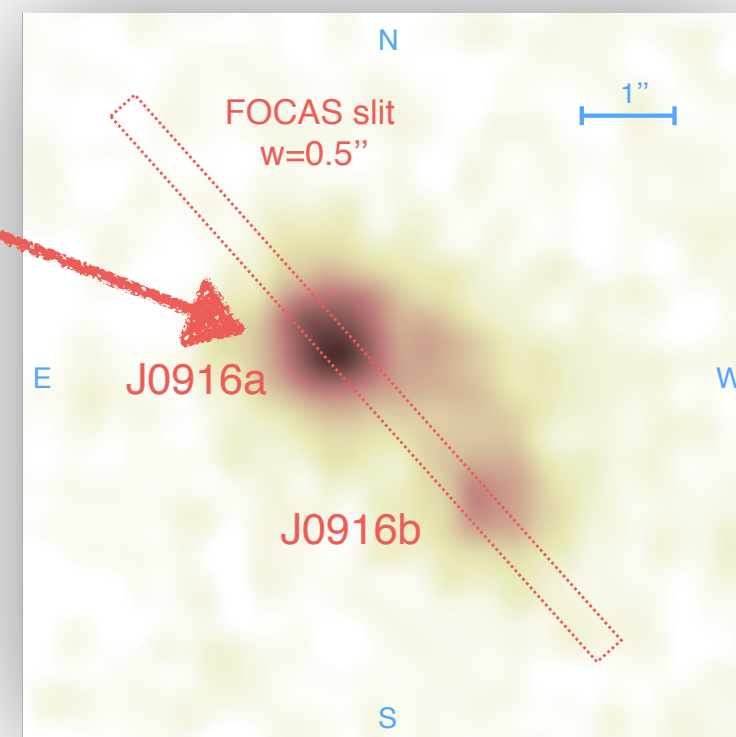
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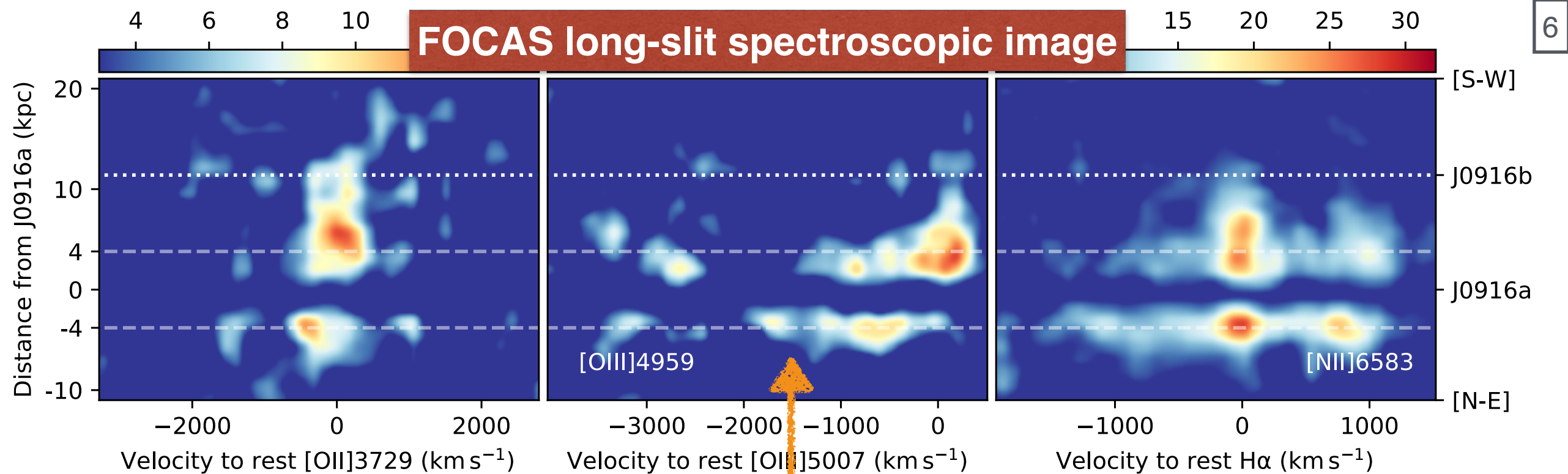
5



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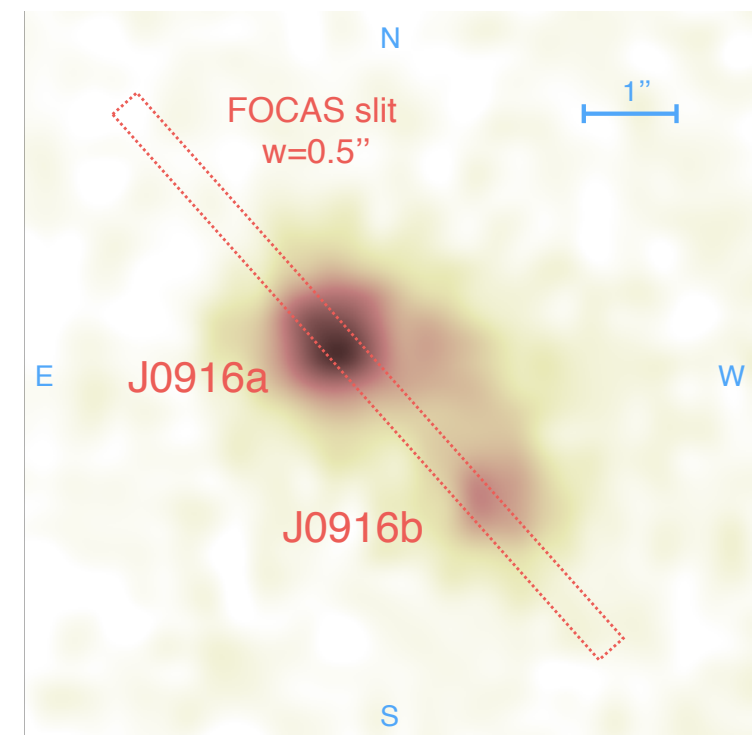
Subaru/FOCAS
 (PI:Akiyama, S17A)



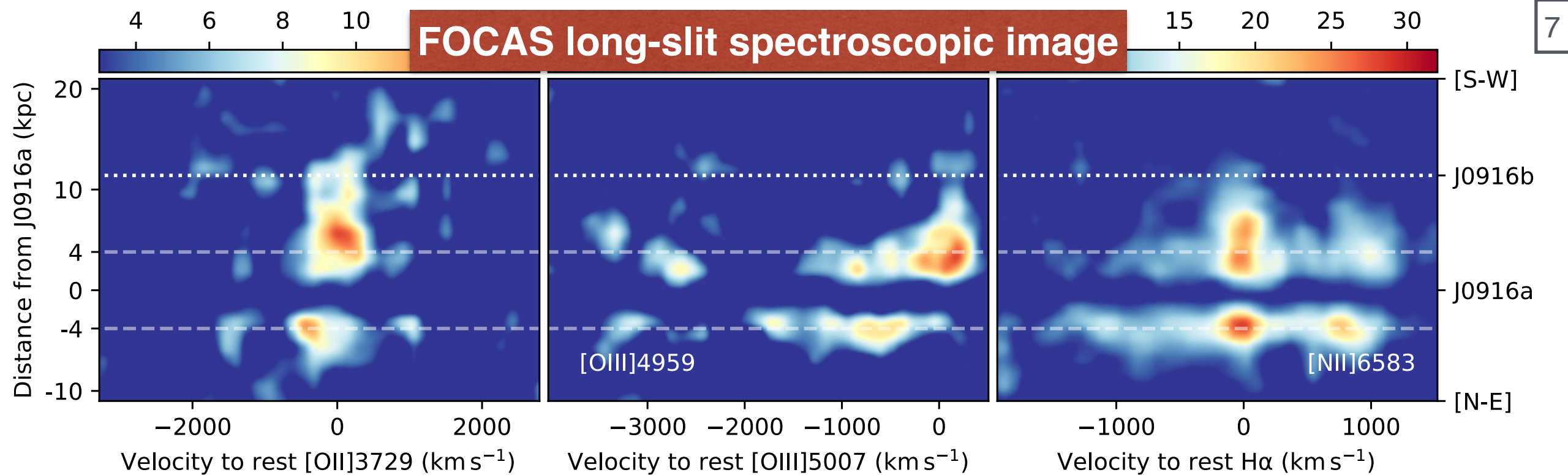
Chen+19

J0916a, an *AKARI*-ULIRGs at $z=0.49$

1) **[OIII] outflow** up to 2000 km/s
extends to 4 kpc scale;



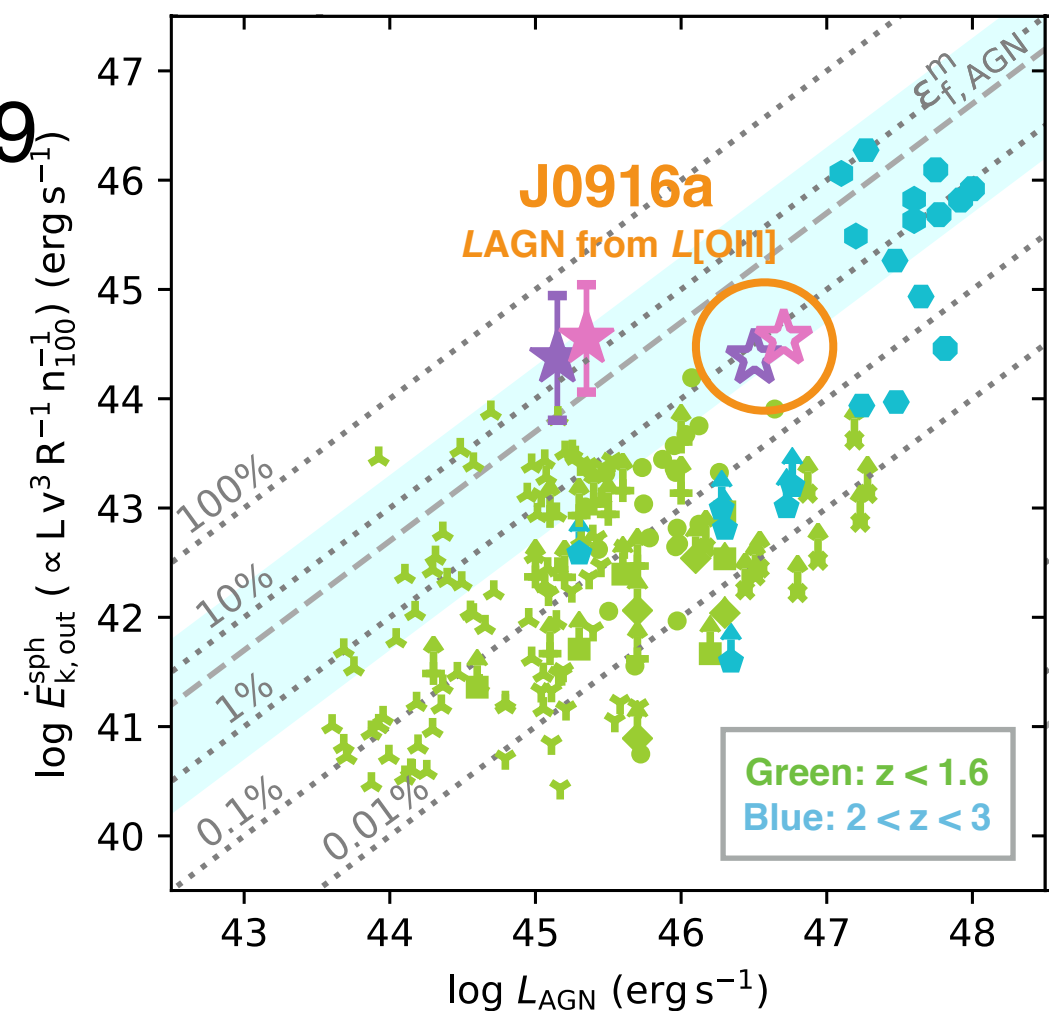
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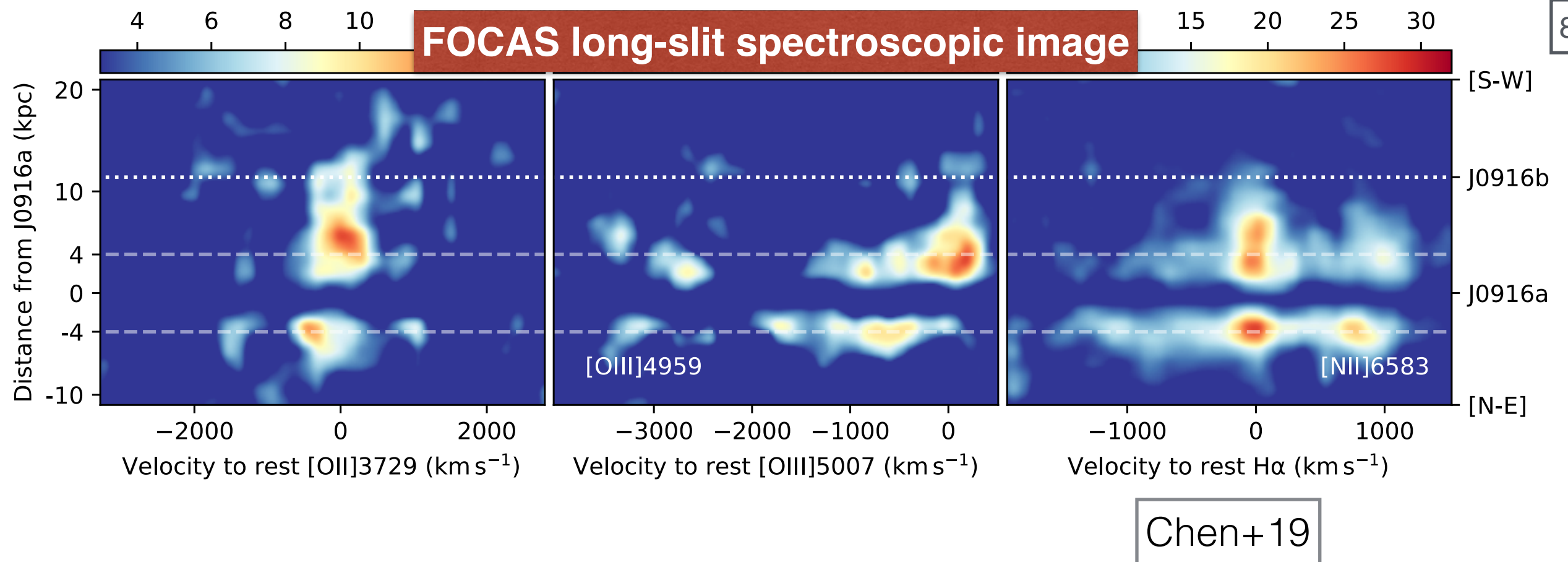


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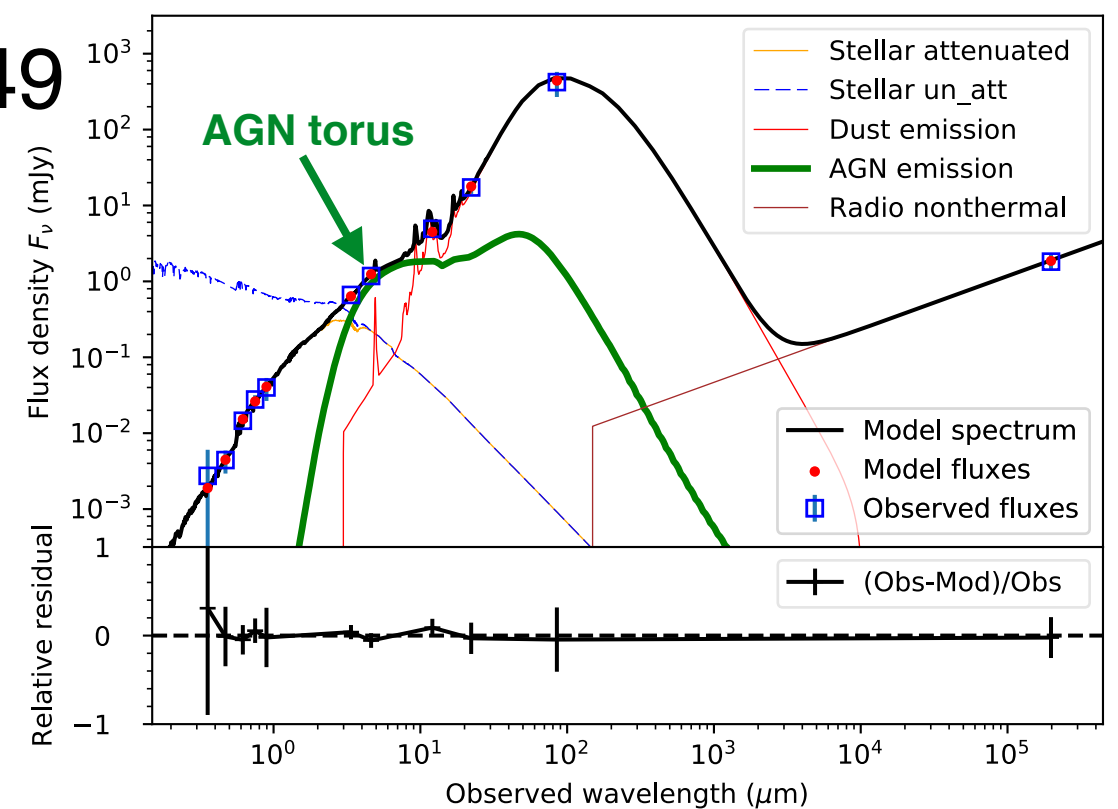
- 1) **[OIII] outflow** up to 2000 km/s extends to 4 kpc scale;
- 2) **highest kinetic-energy ejection rate** at ULIRGs/AGNs at $z < 1.6$;

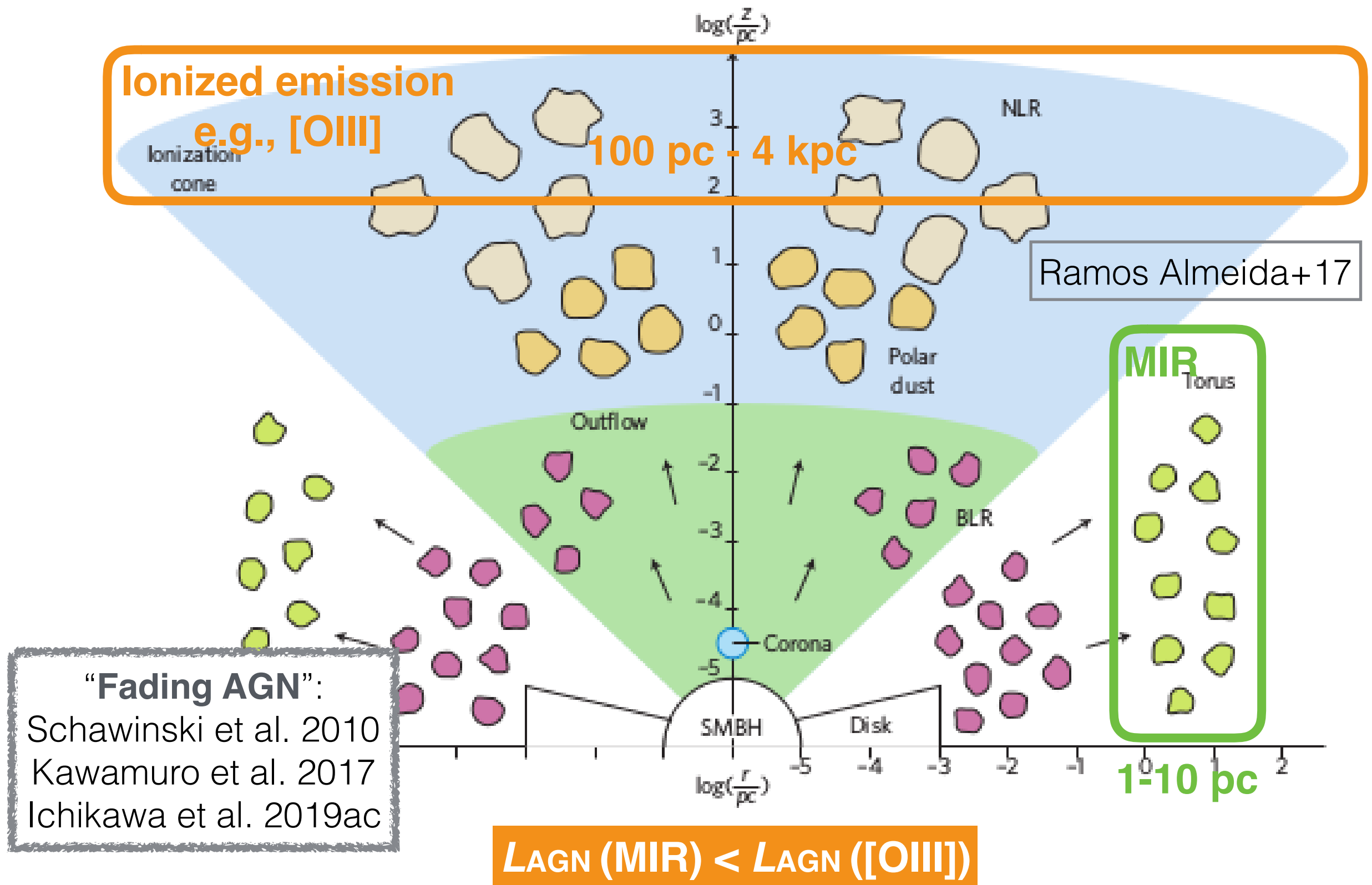




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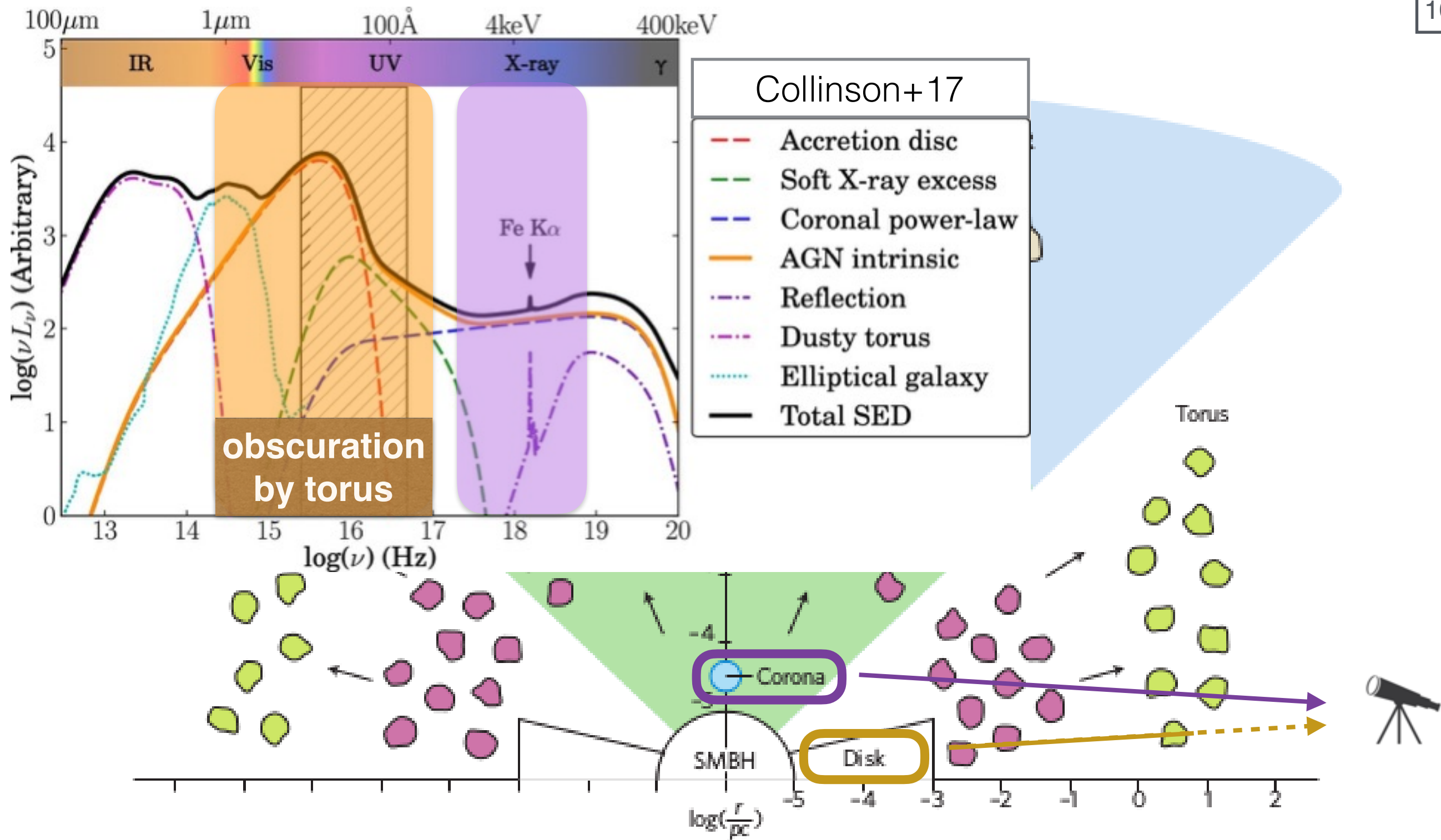
- 1) **[OIII] outflow** up to 2000 km/s extends to 4 kpc scale;
- 2) **highest kinetic-energy ejection rate** at ULIRGs/AGNs at $z < 1.6$;
- 3) **L_{AGN} (MIR) is fainter** (30%) than the L_{AGN} estimated from **[OIII]**.





AGN is faint in the central region (in space)

AGN is currently **fading** (in time)



Much nearer
to SMBH

Accretion Disk (UV/Opt.) $\rightarrow$ obscured

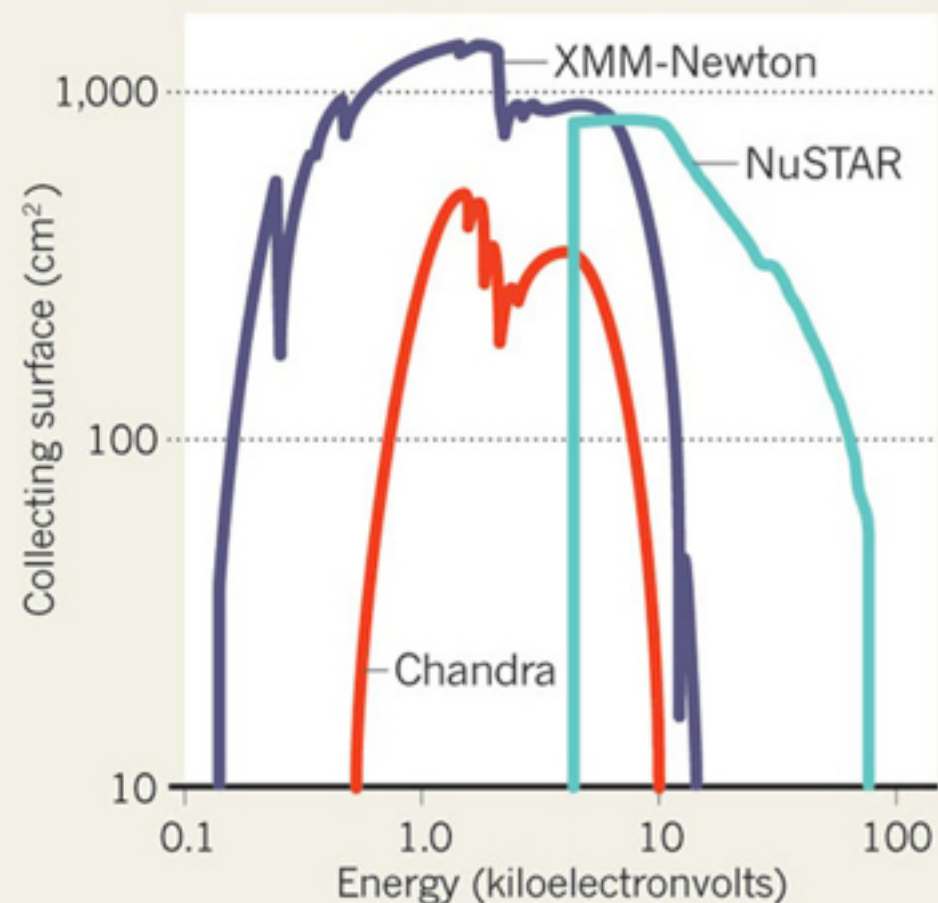
Corona (X-ray) $\rightarrow$ penetrating gas/dust
especially hard X-ray (> 10 keV)



- **NuSTAR** is the best instrument for the **hard X-ray (> 10 keV)** follow-up of J0916a.

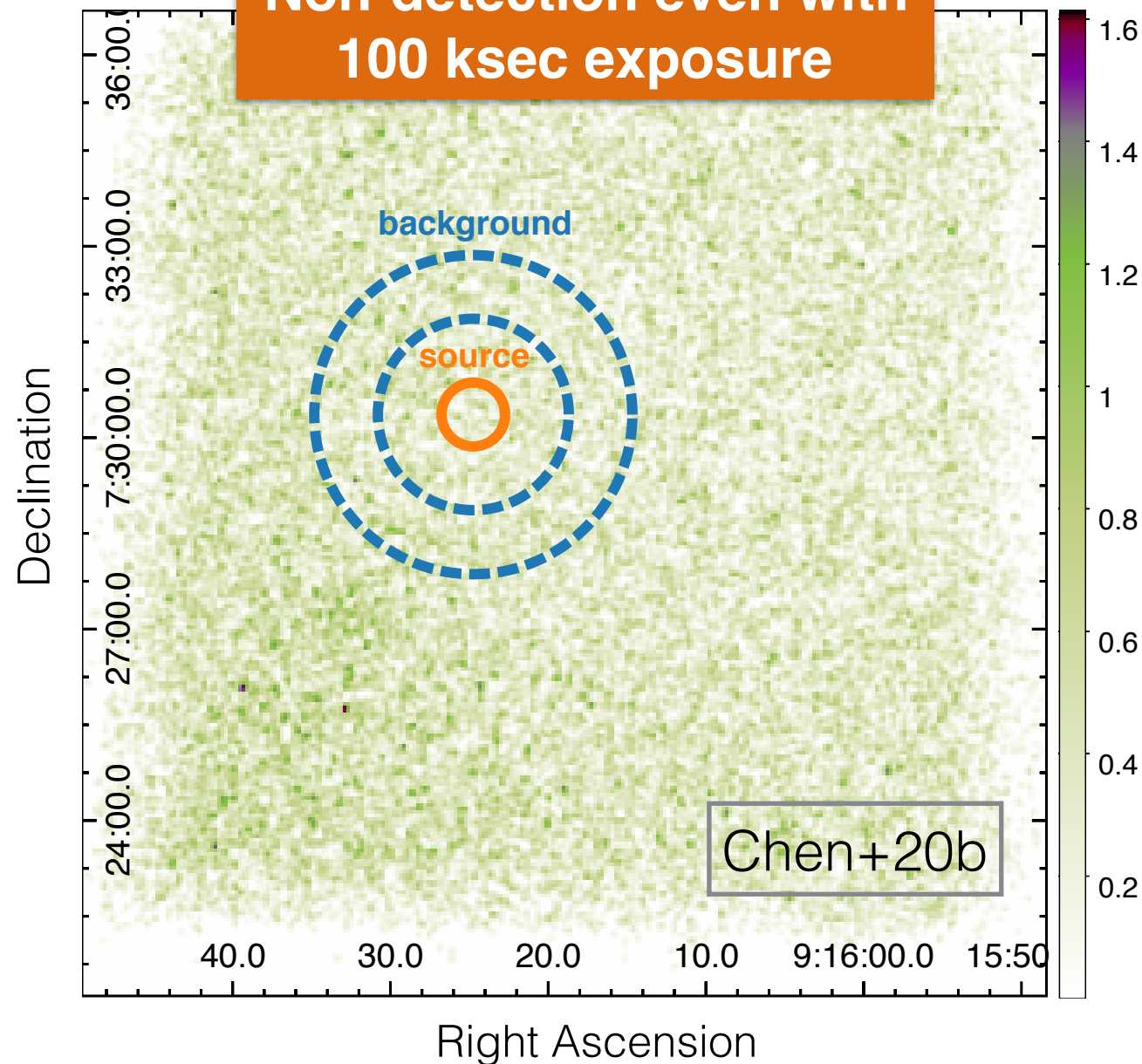
GOING TO EXTREMES

Compared with other X-ray telescopes, NuSTAR has a larger collecting surface at higher energies.



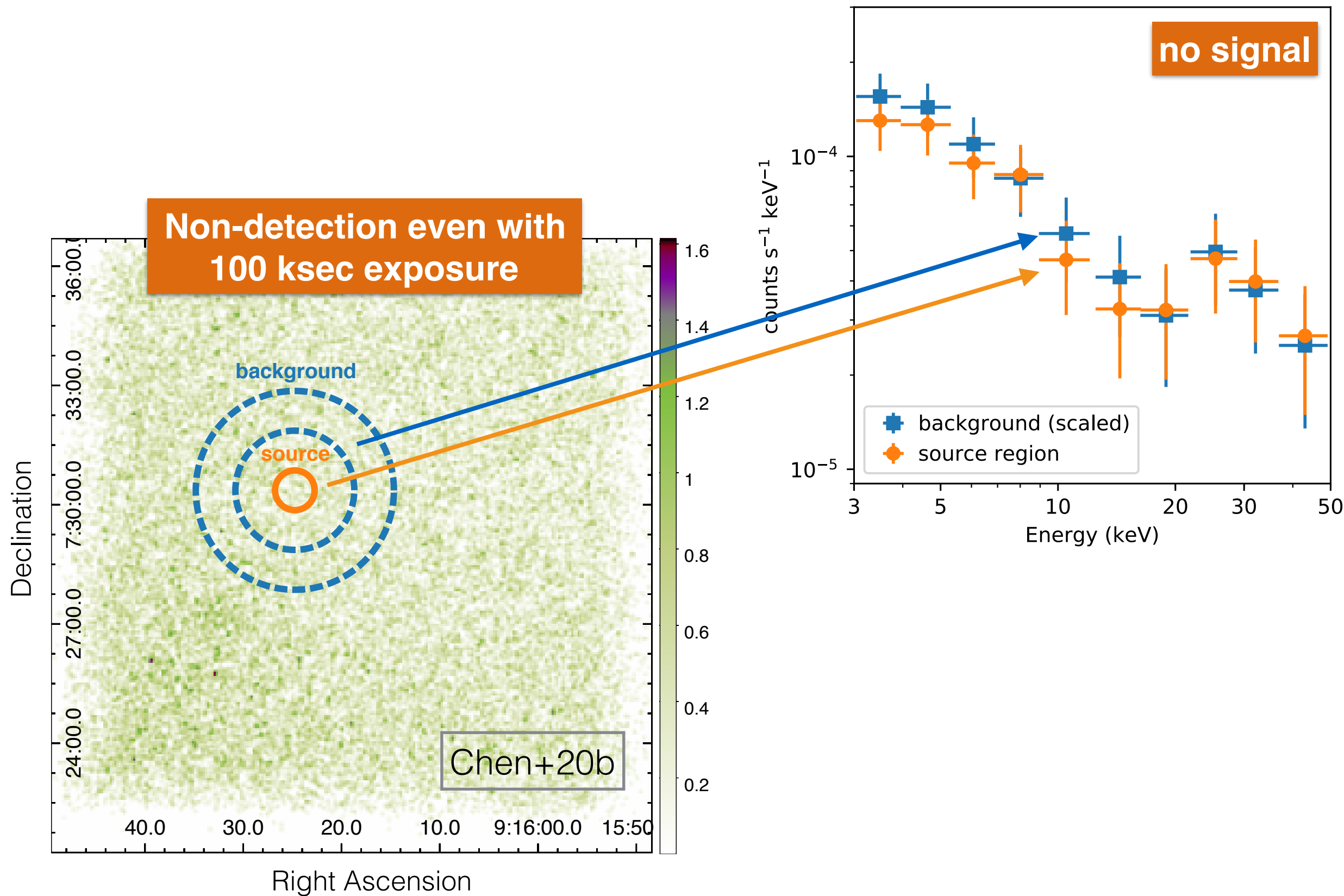
- **100 ksec** observation was awarded in **NuSTAR Cycle 6 (PI: Chen)**.
- The corona radiation could be detected if the AGN is as faint as shown by torus/MIR.

Non-detection even with
100 ksec exposure

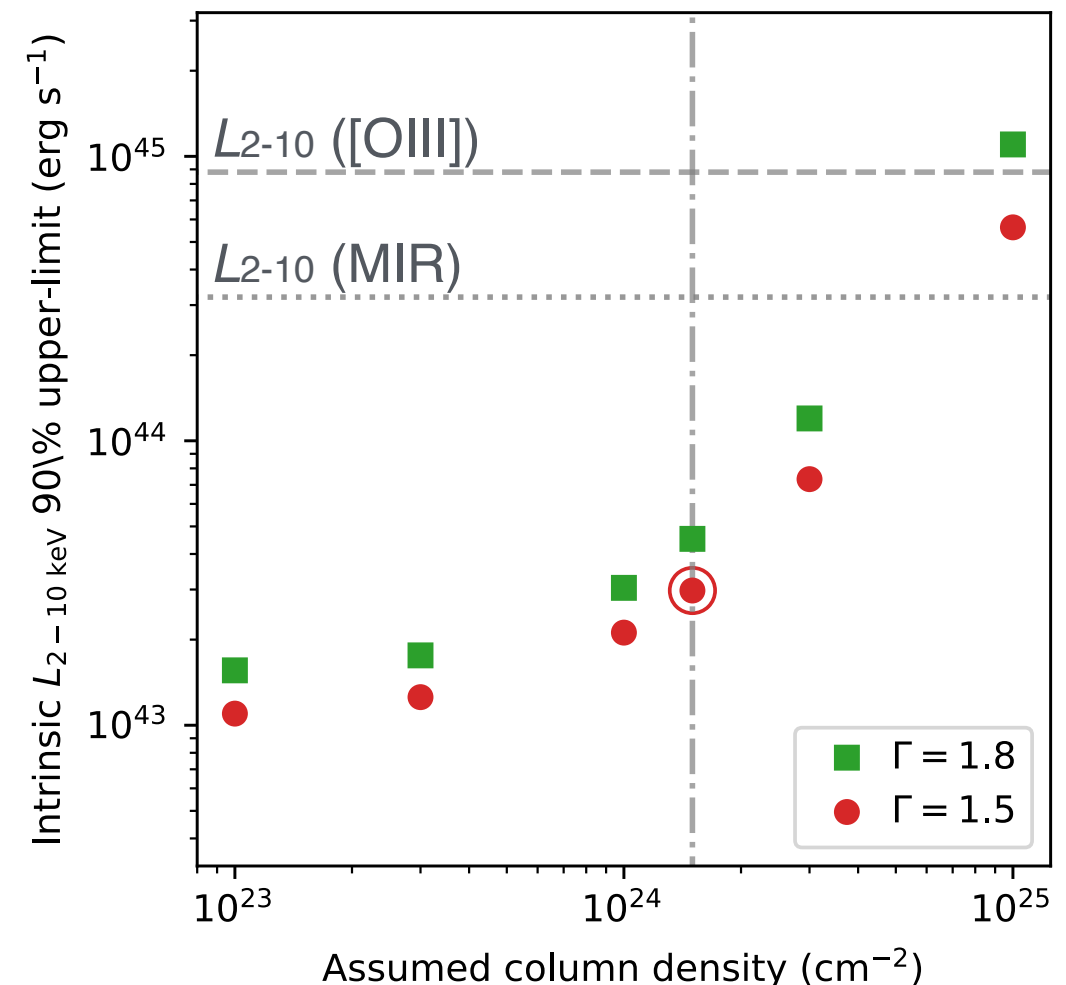
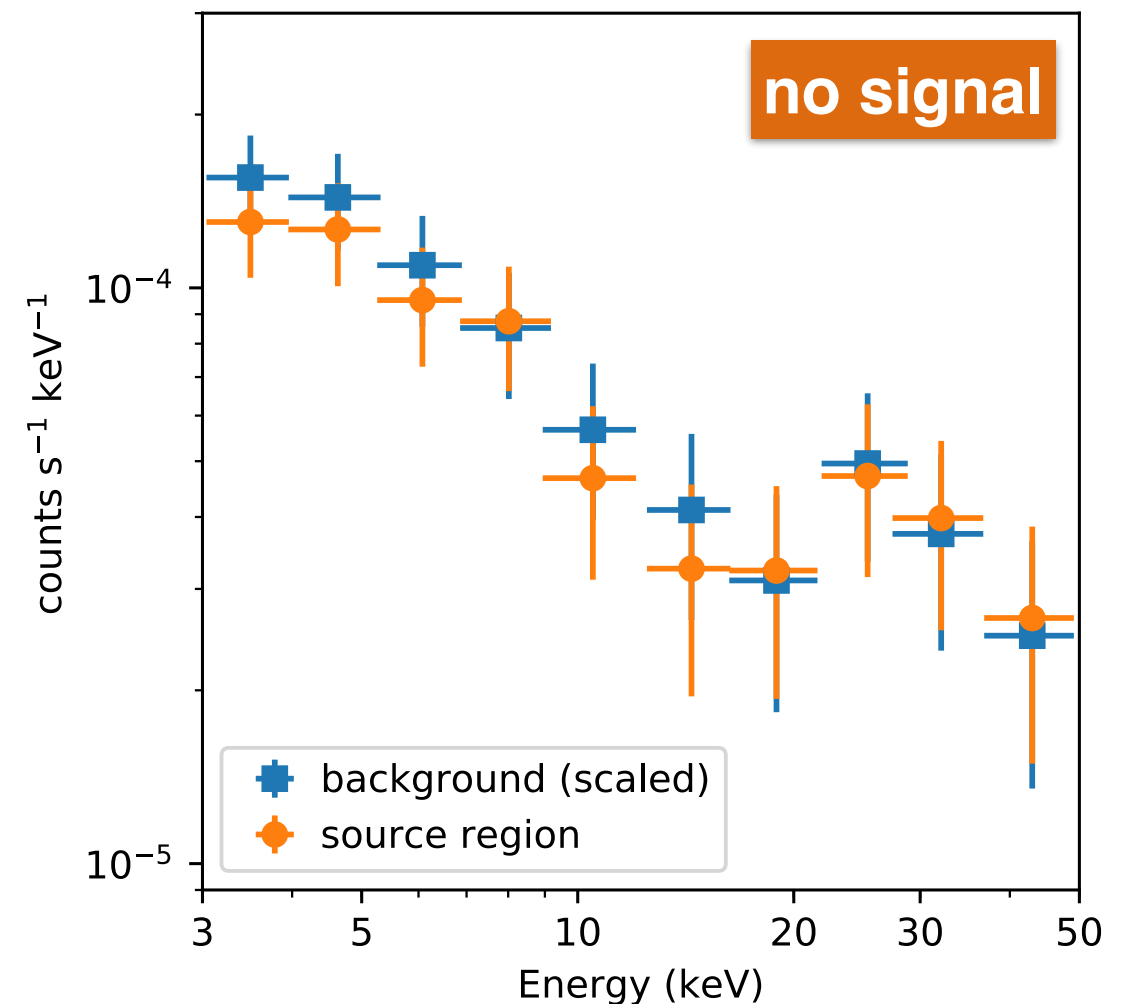


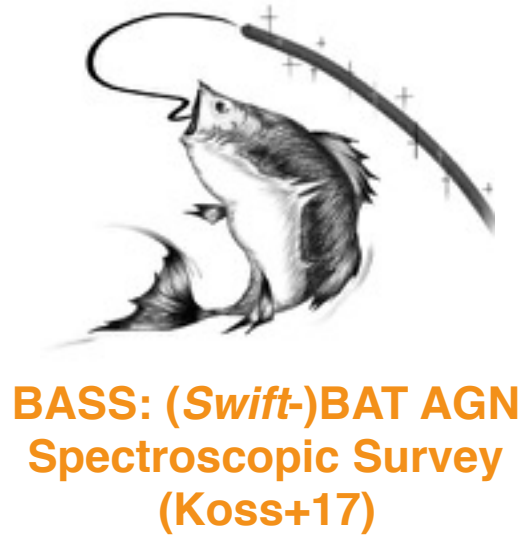
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$$L_{\text{AGN}}(\text{X-ray}) < L_{\text{AGN}}(\text{MIR})$$

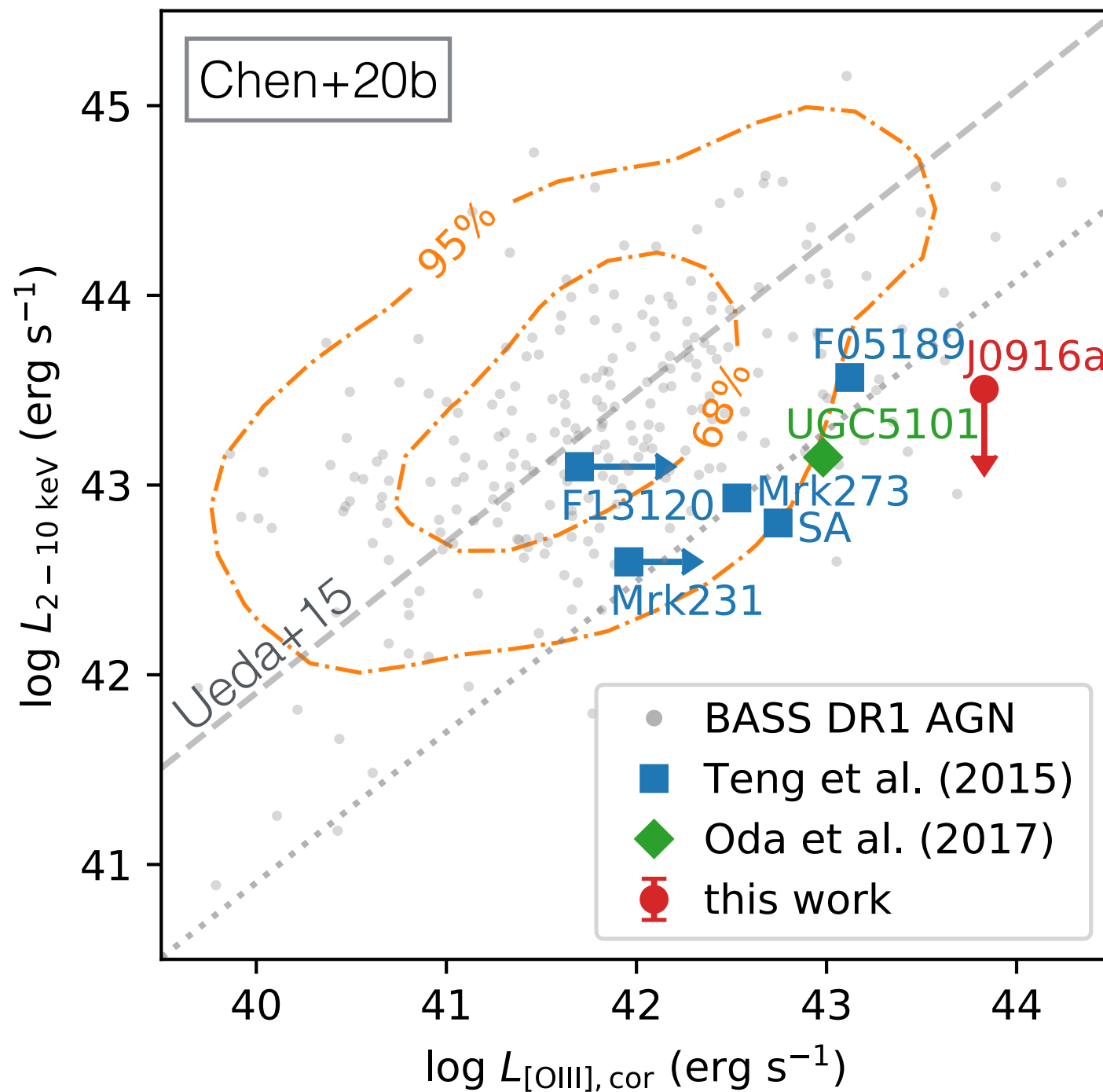


- The estimation of upper-limit of L_{AGN} (X-ray) depends on assumption of gas column density, N_{H} .
- Assuming typical N_{H} of ULIRGs of $1.5 \times 10^{24} \text{ cm}^{-2}$ (e.g., Teng+15), the **90% upper-limit of 2-10 keV luminosity is $3.0 \times 10^{43} \text{ erg/s}$** .



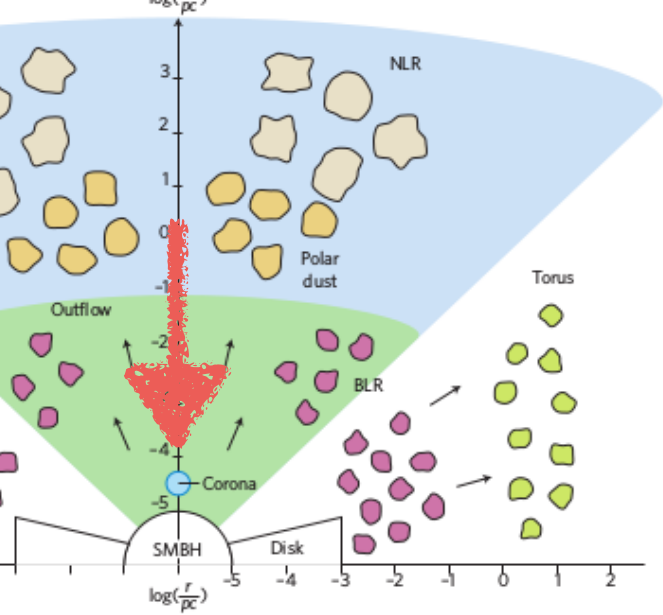


Compared to ULIRGs/AGNs

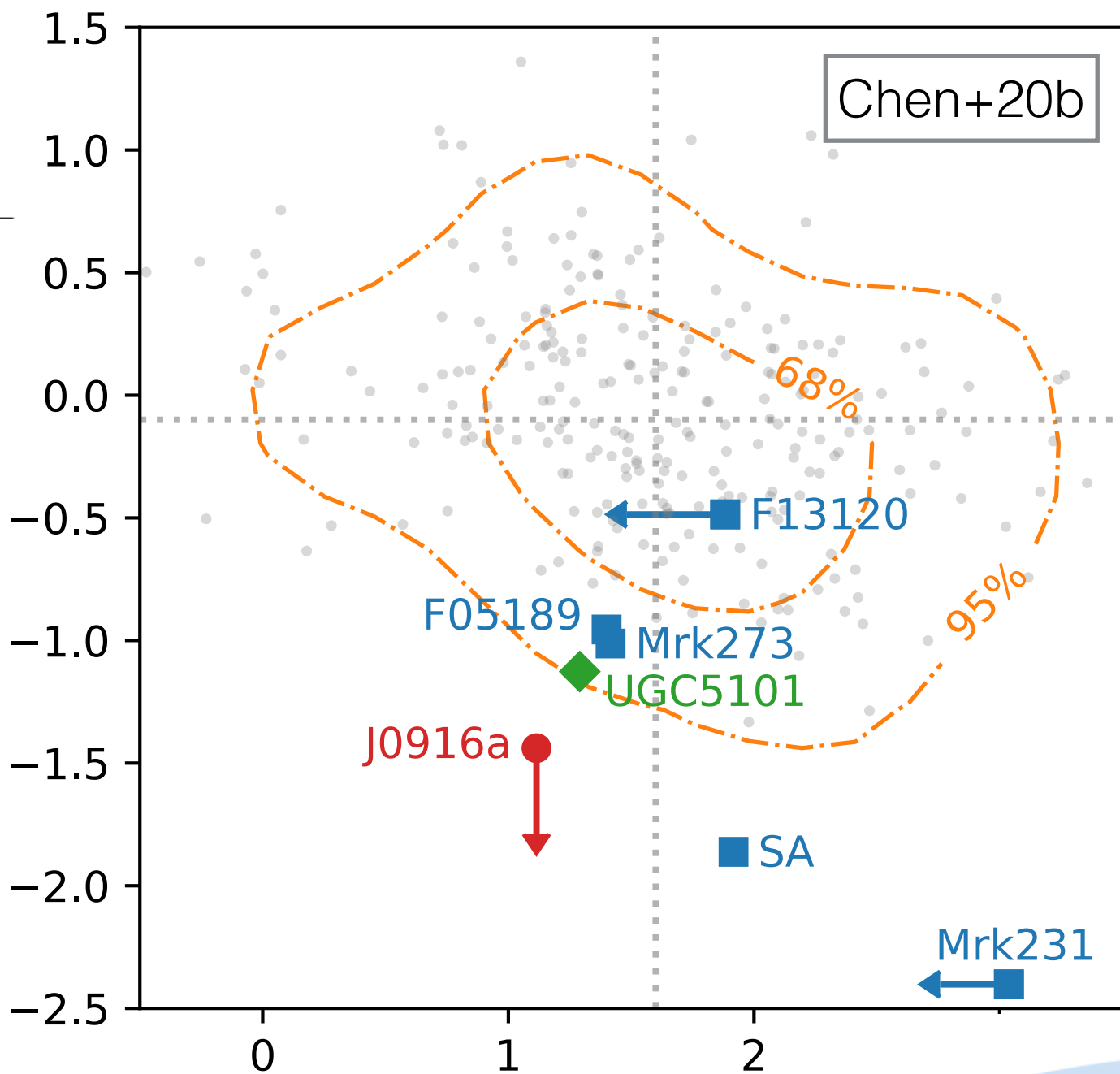


J0916a:
the most extreme
X-ray deficit
($< 3.6\%$).

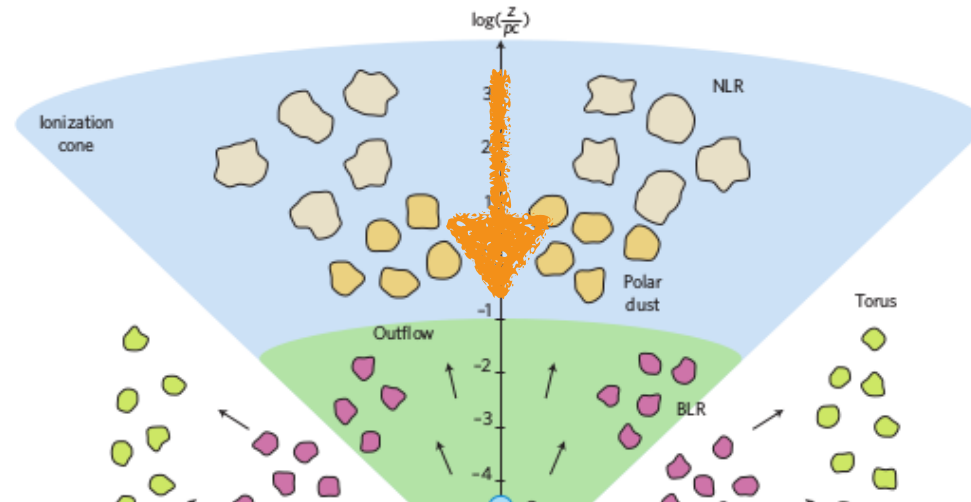
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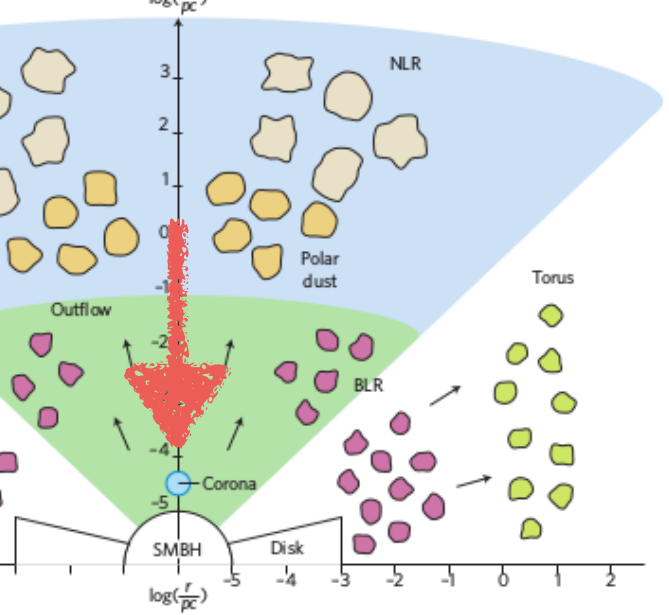
Fading
milli-pc
10pc
 $\log(L_{2-10\text{ keV}} / L_{5-38\text{ }\mu\text{m}})$



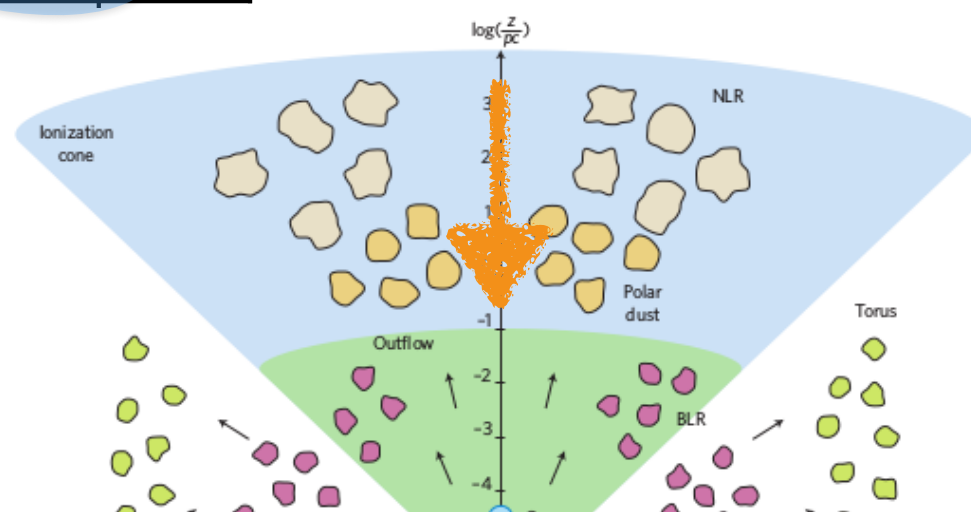
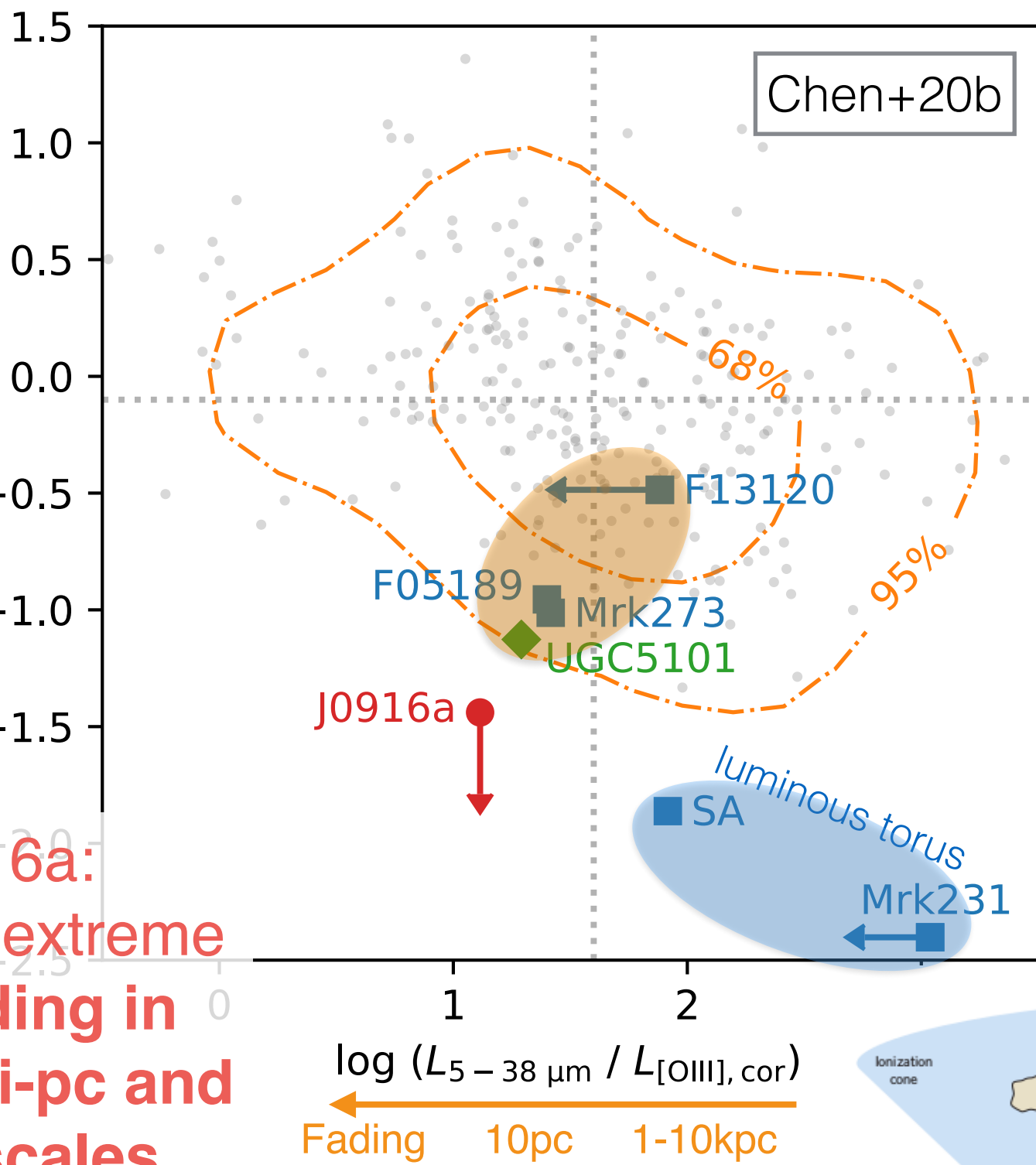
$\log(L_{5-38\text{ }\mu\text{m}} / L_{[\text{OIII}], \text{cor}})$
Fading
10pc
1-10kpc



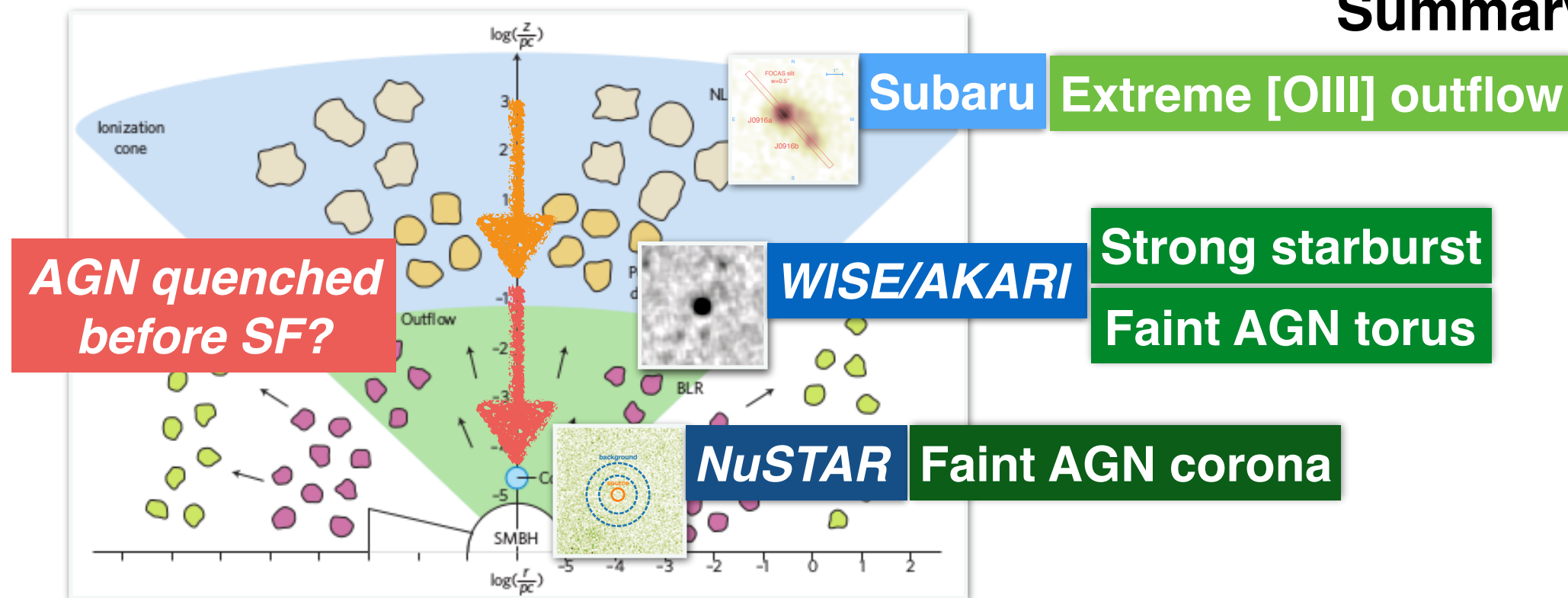
Compared to ULIRGs/AGNs



J0916a:
the most extreme
with fading in
both milli-pc and
10 pc scales.



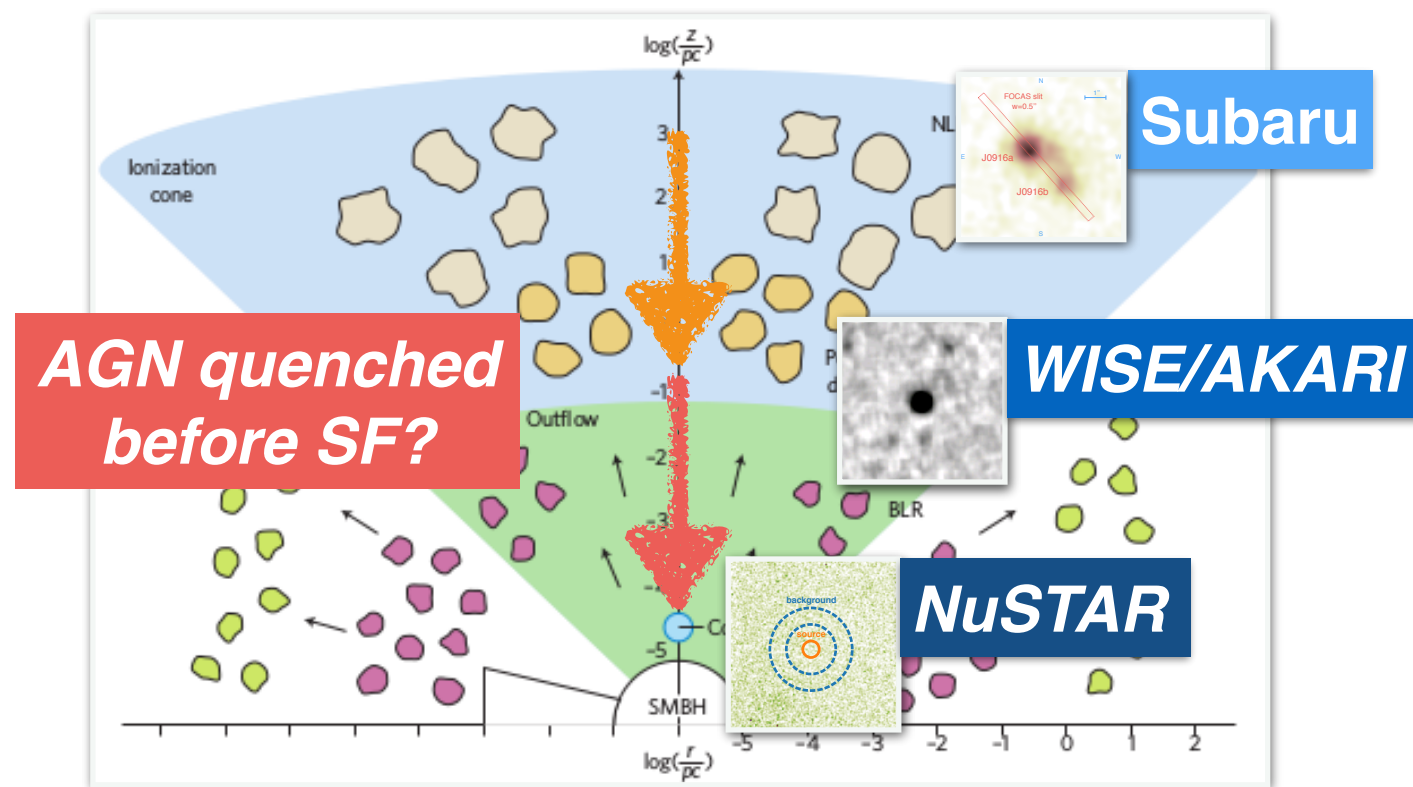
Summary & Discussion



$L_{\text{AGN}} (\text{corona}) < L_{\text{AGN}} (\text{torus}) < L_{\text{AGN}} ([\text{OIII}])$

—> **AGN** in J0916a is **currently fading**.

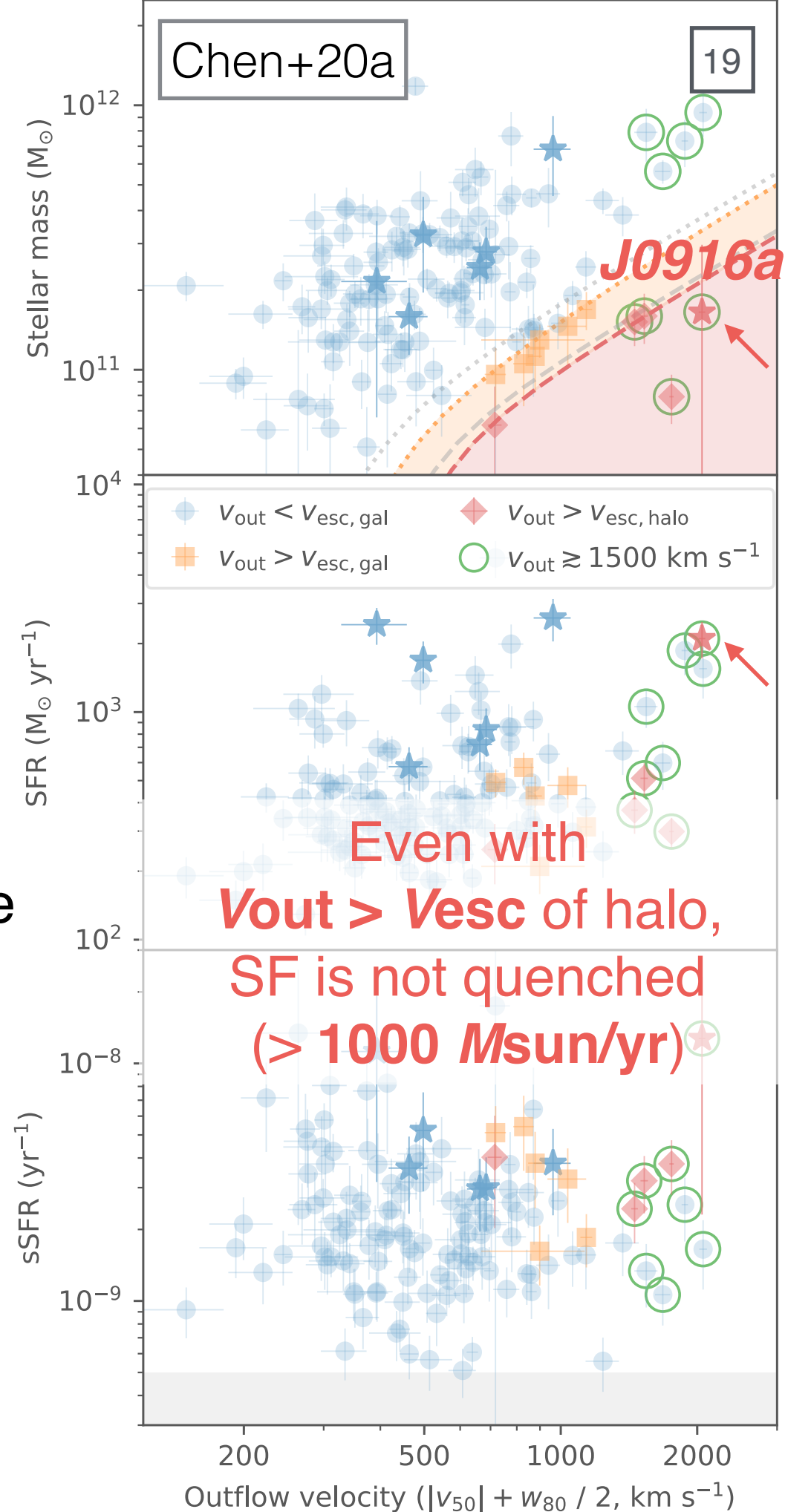
—> the **active epoch** of the AGN is limited by the **fading** timescale, i.e., **< 0.01-1 Myr** (light/outflow traveling), much shorter than the duration of **starbursts**, e.g., **100 Myr** (e.g., Hopkins+08).

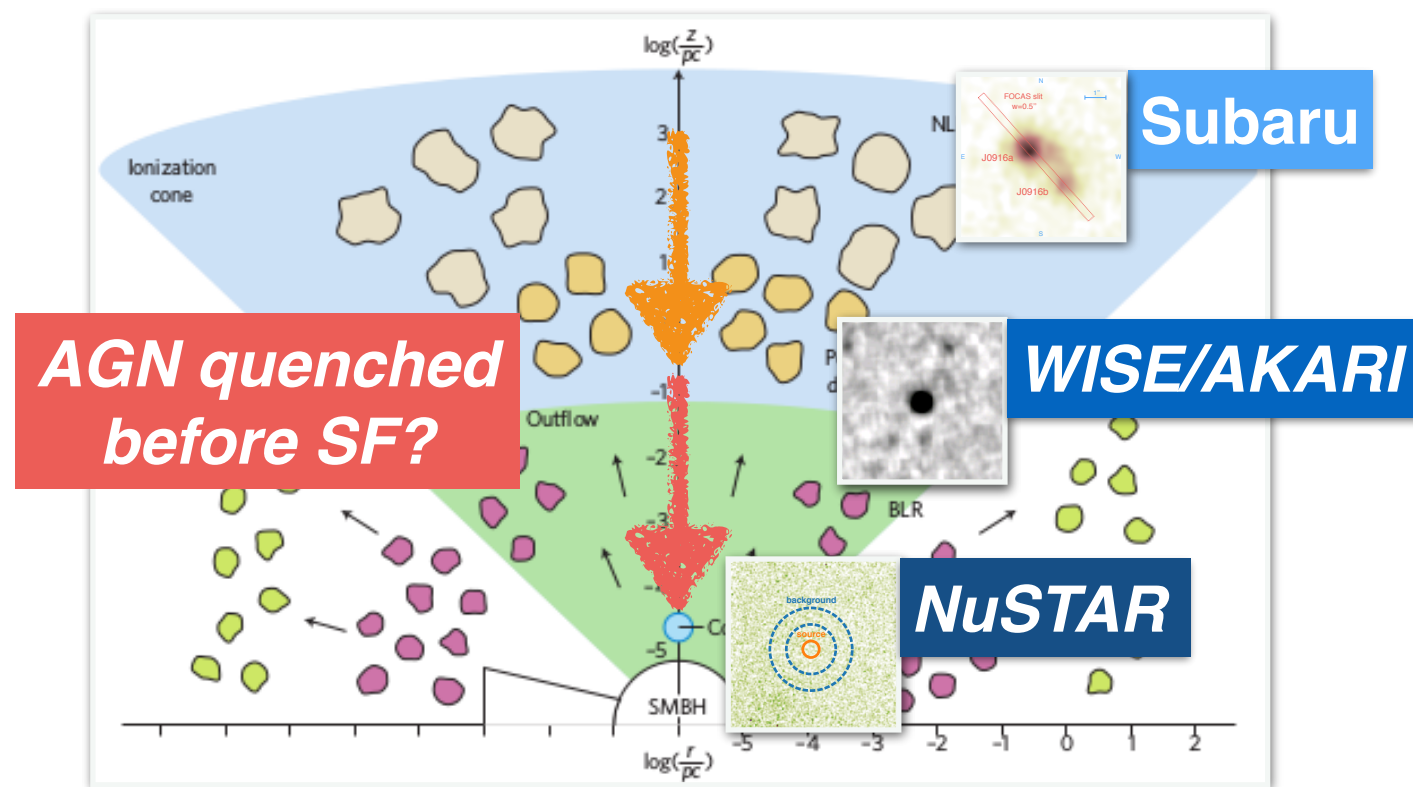


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—> the powerful outflow could not last so long and thus, the **cumulative effect** of the **AGN feedback** on star formation is **limited**.





$L_{\text{AGN}}(\text{corona}) < L_{\text{AGN}}(\text{torus}) < L_{\text{AGN}}([\text{OIII}])$
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—> the powerful outflow
 and thus, the **cumulative**
feedback on star formation

Thanks for your attention.

#o29-chen @slack

(Chen et al. 2020, ApJL, 905, L2)

