

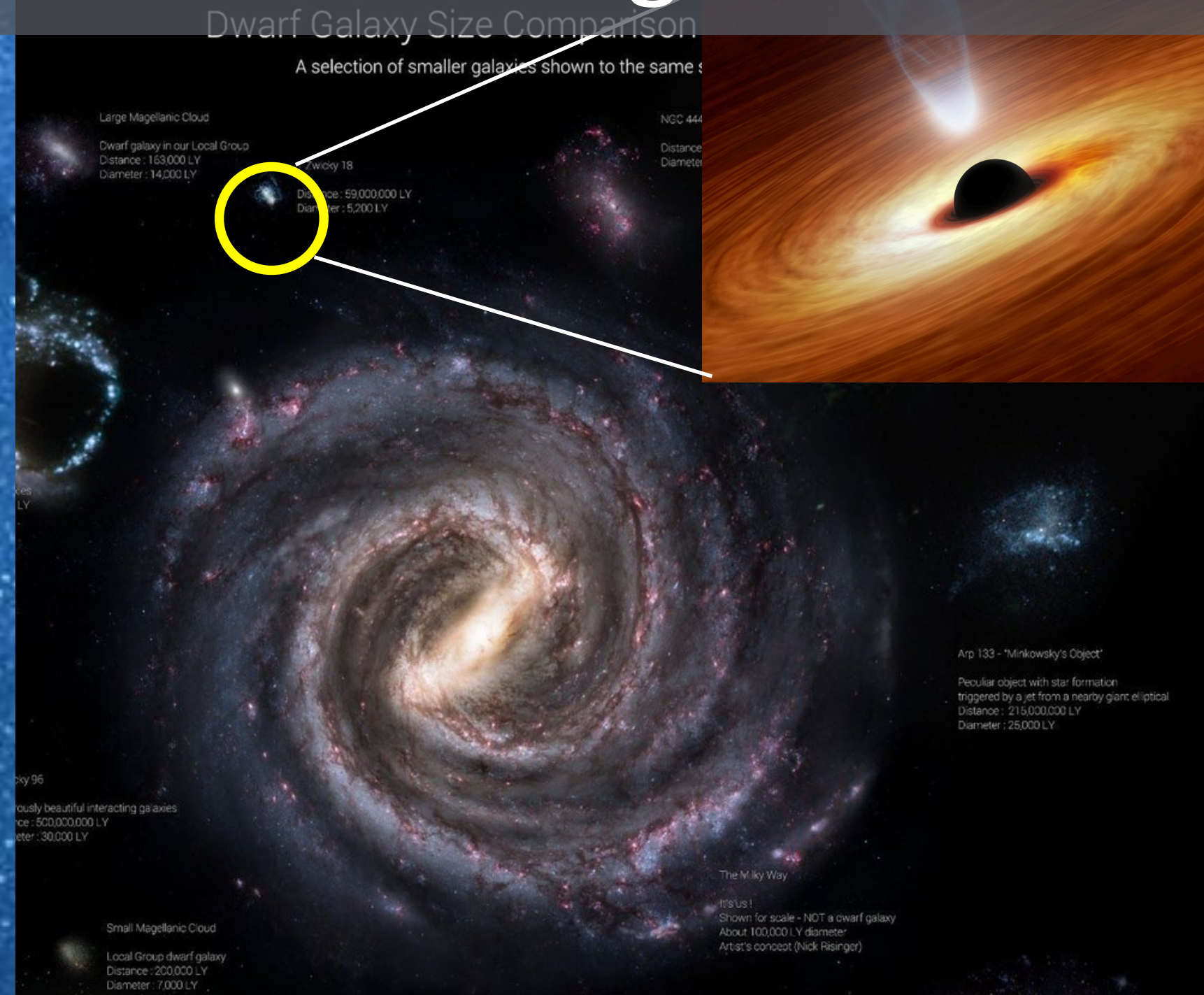
TMT Webinar on August 19th, 2026

TMT観測が明らかにする 超巨大ブラックホール種族

Kohei Ichikawa (市川幸平)
(Tohoku University, Japan)

TMT観測が明らかにする 超巨大ブラックホール種族

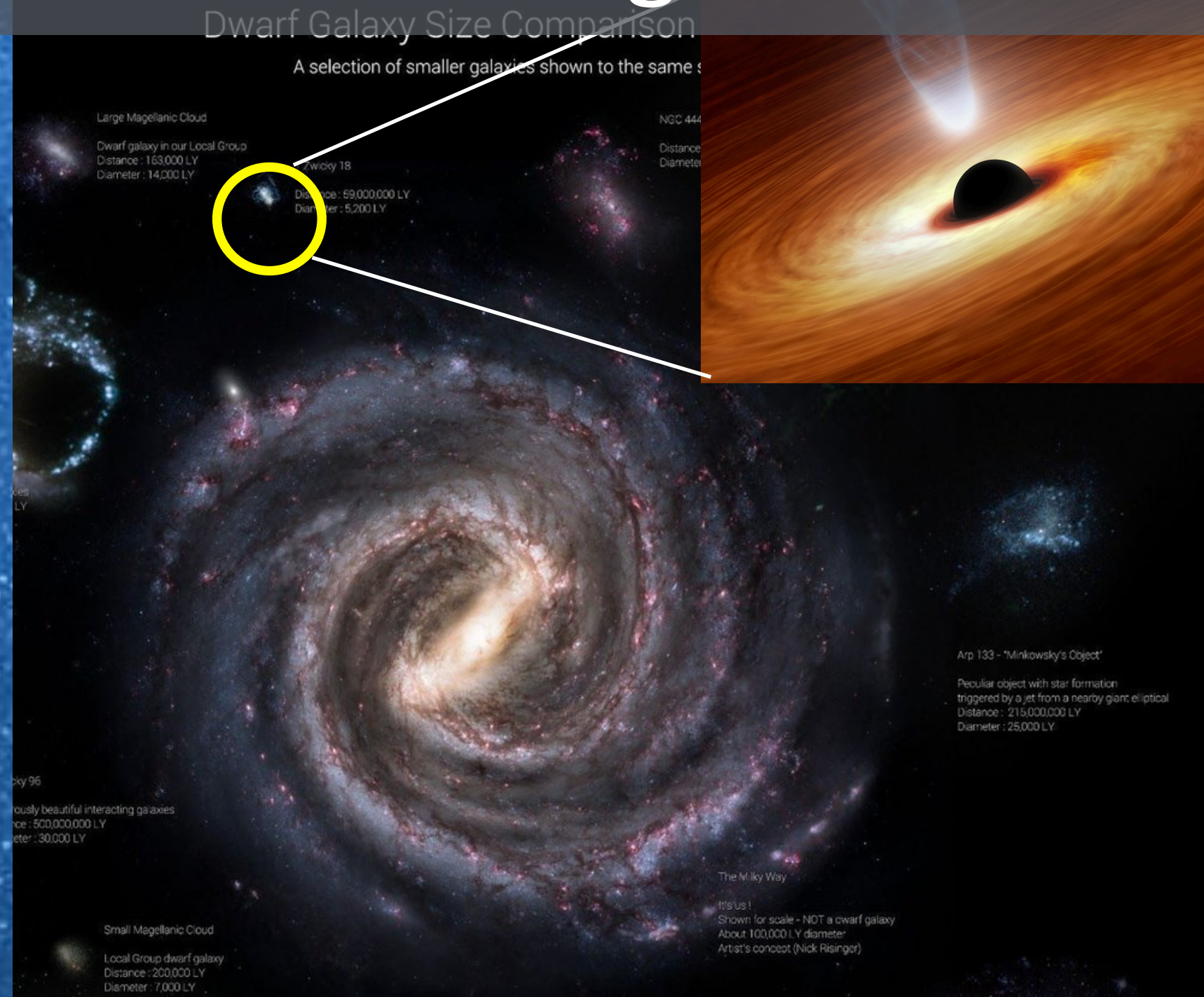
Intermediate-mass BHs in low-mass galaxies



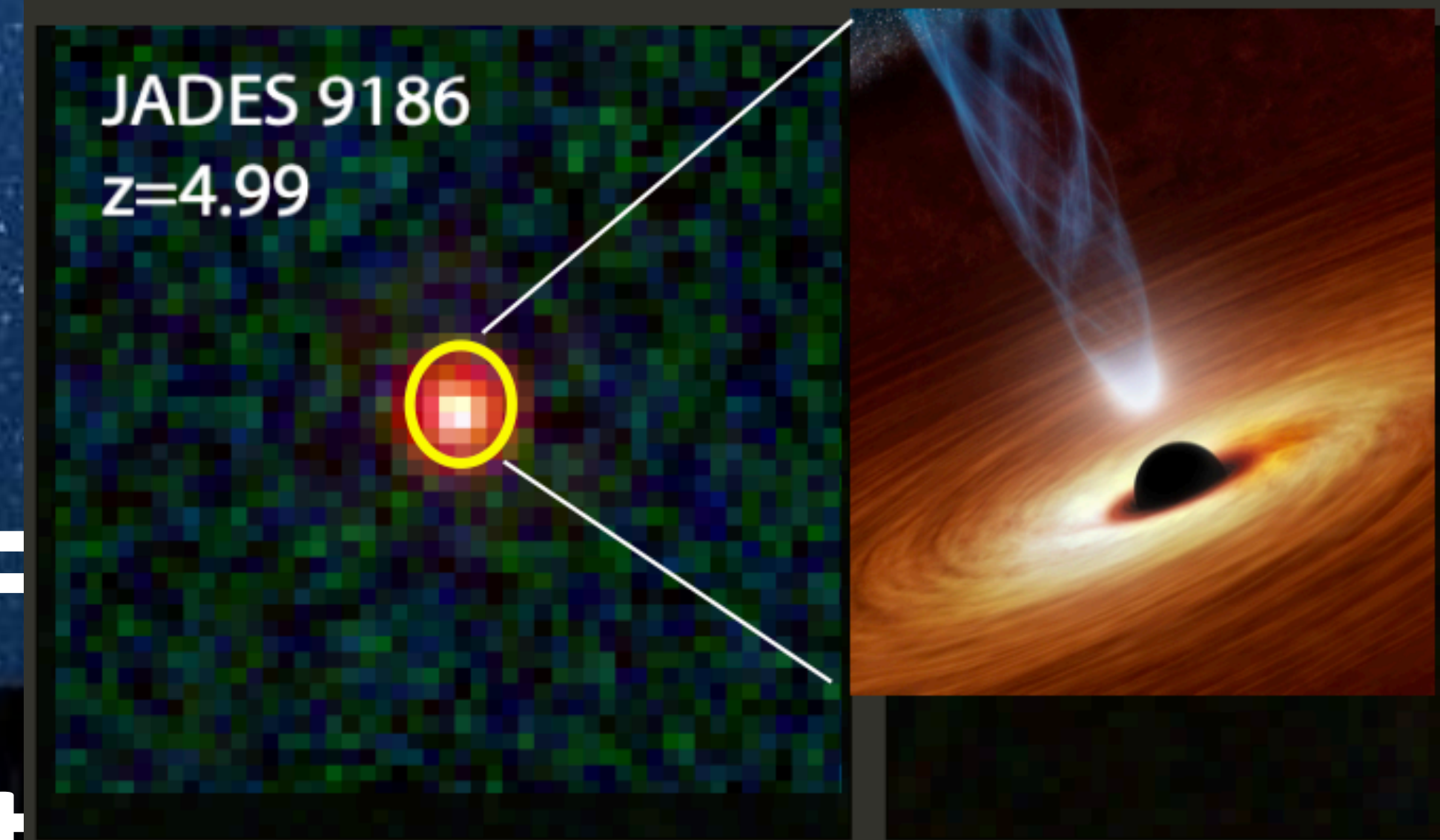
Shikawa (市川幸平)
University, Japan)

TMT観測が明らかにする 超巨大ブラックホール種族

Intermediate-mass BHs in low-mass galaxies



Low-z Little Red Dots (LRDs)

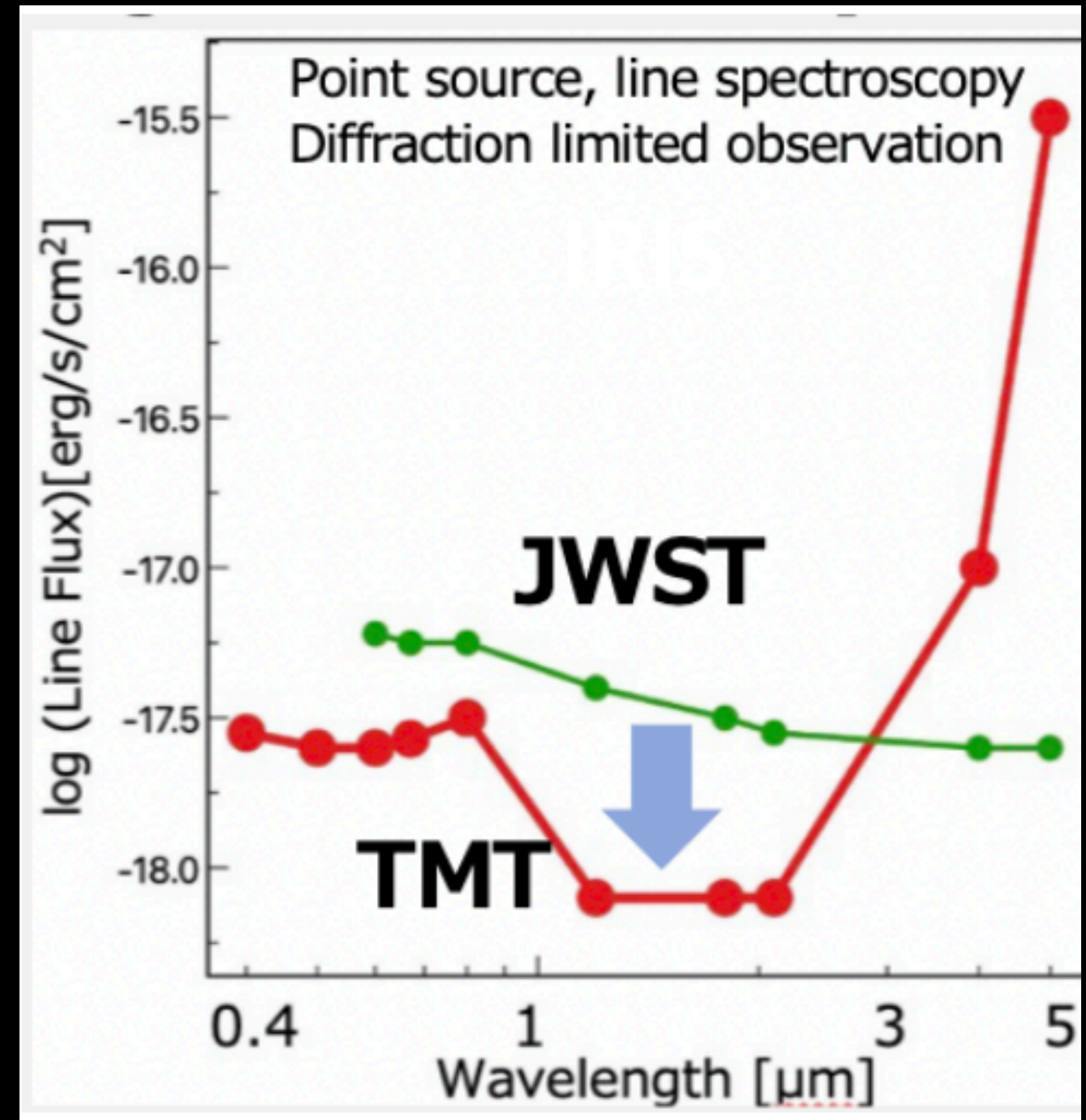


Shikawa (T)
University, Japan,

Unique parameter space of TMT

Higher sensitivity than JWST at $\lambda < 3 \mu\text{m}$

Spectroscopic sensitivity

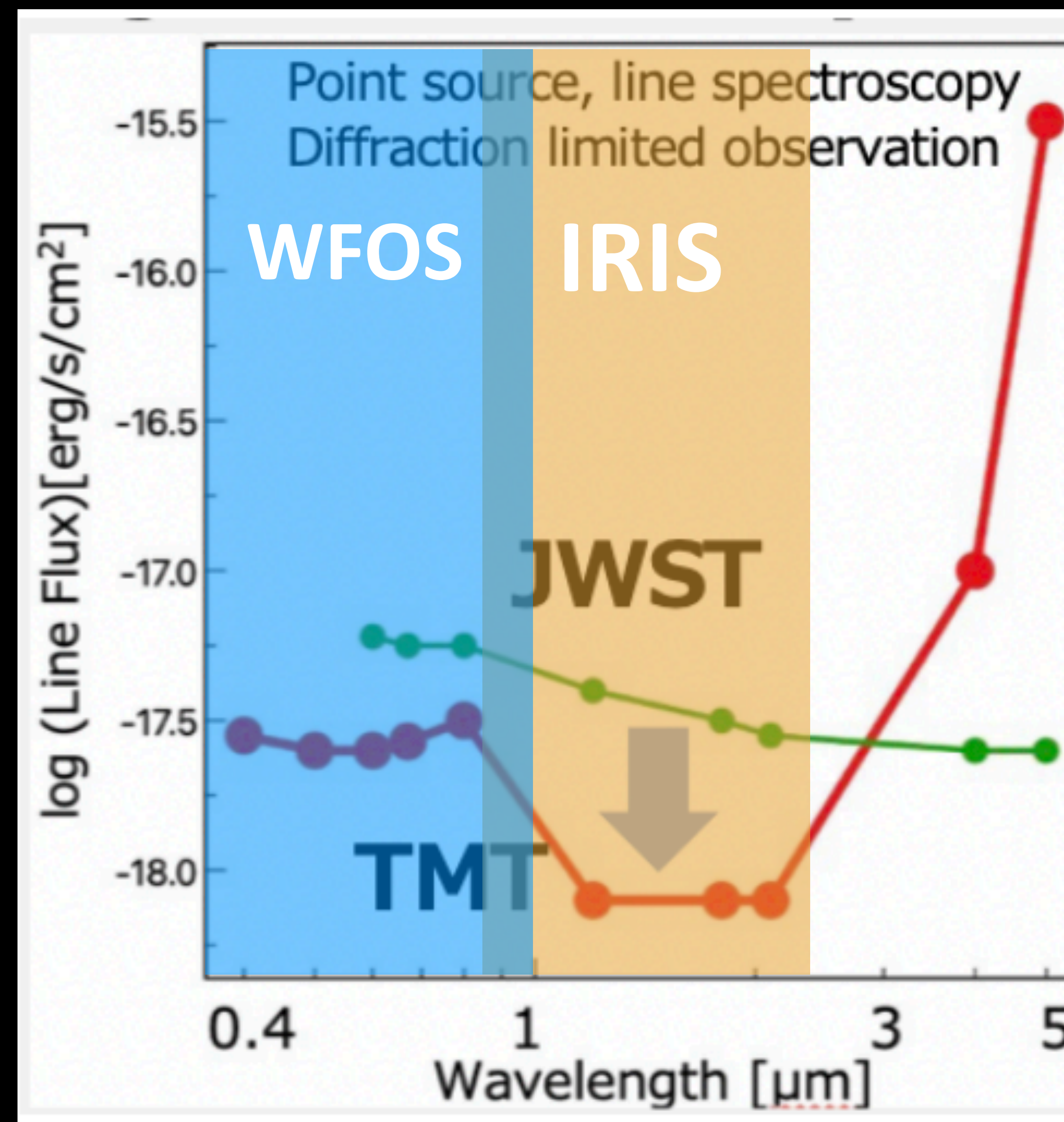


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TMT can obtain “spectra”
of Subaru/HSC image sources
(down to $\sim 25\text{-}26 \text{ mag at } < 1 \mu\text{m}$)

Spectroscopic sensitivity



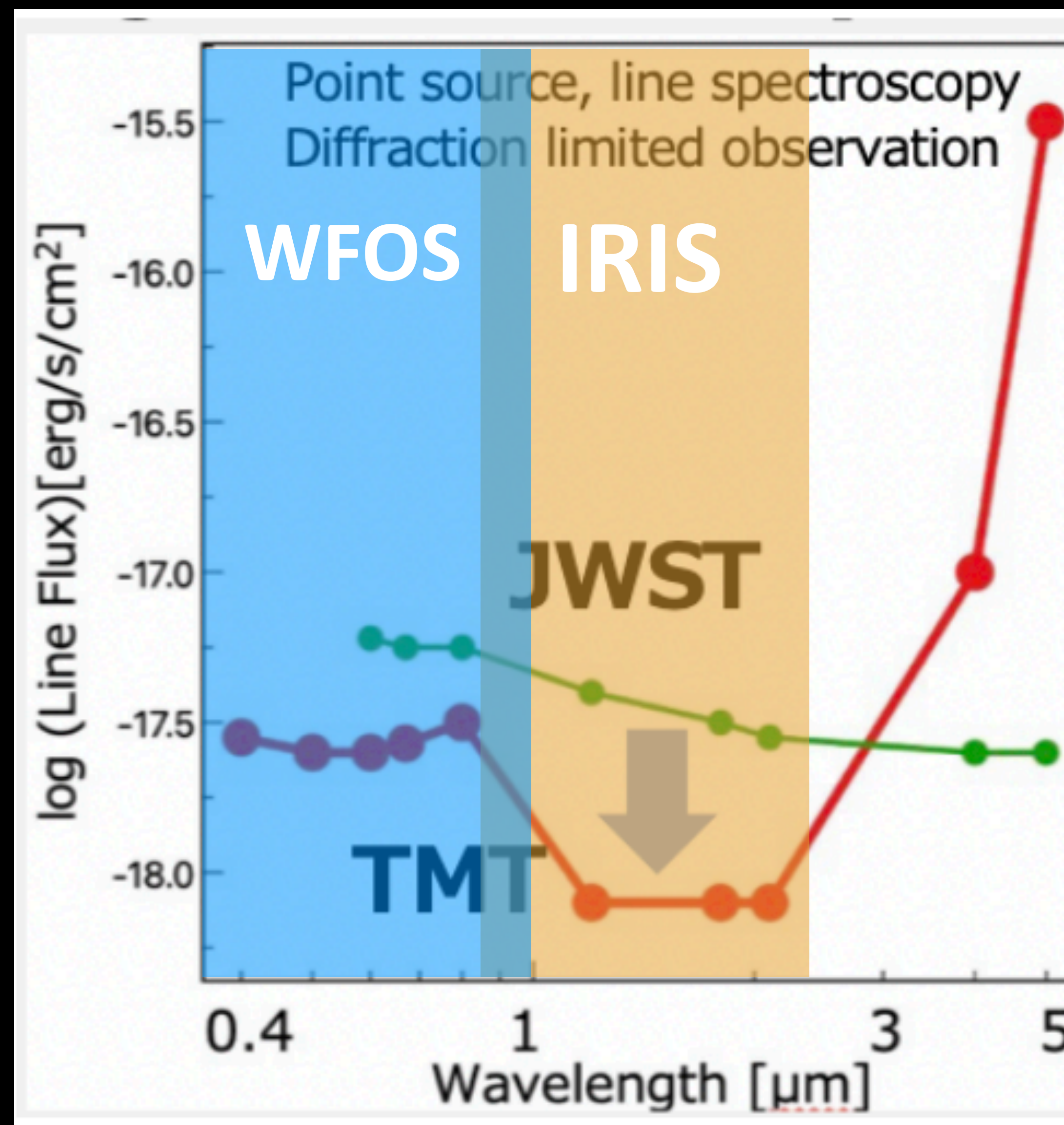
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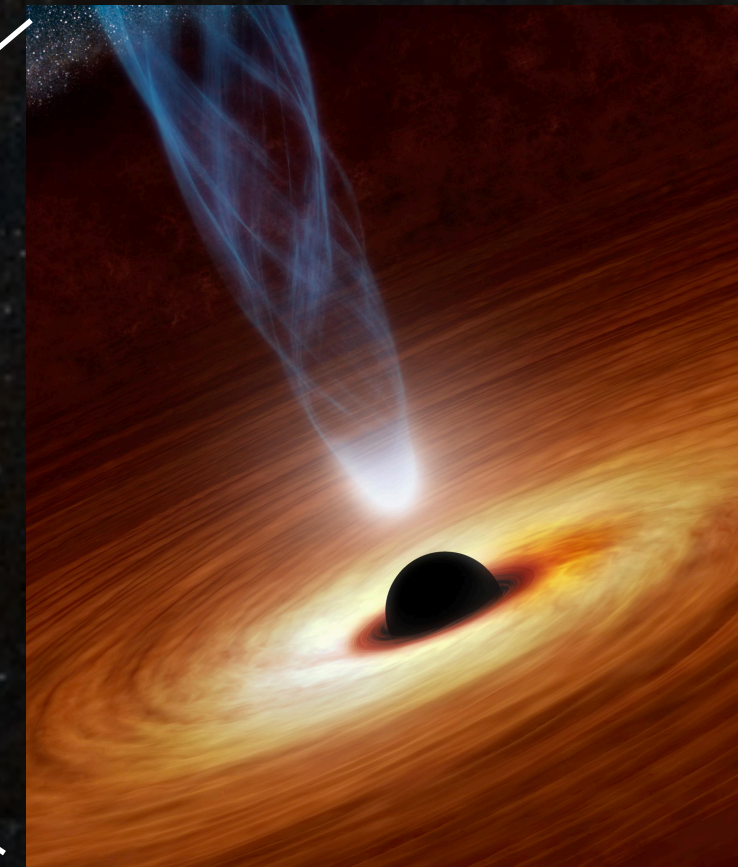
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**“Discovery with Subaru,
follow-up with TMT”**
for rare populations, including AGN

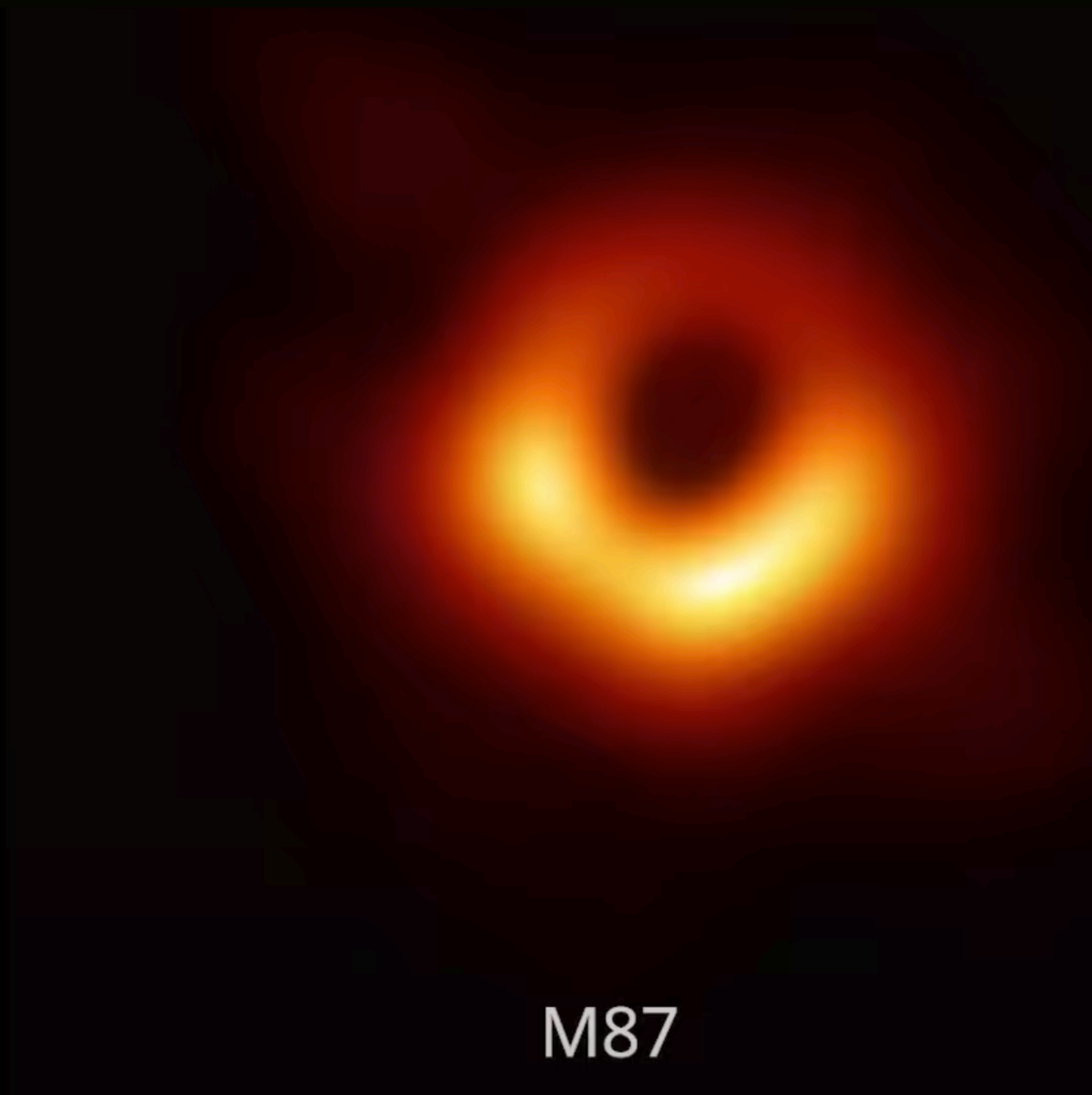
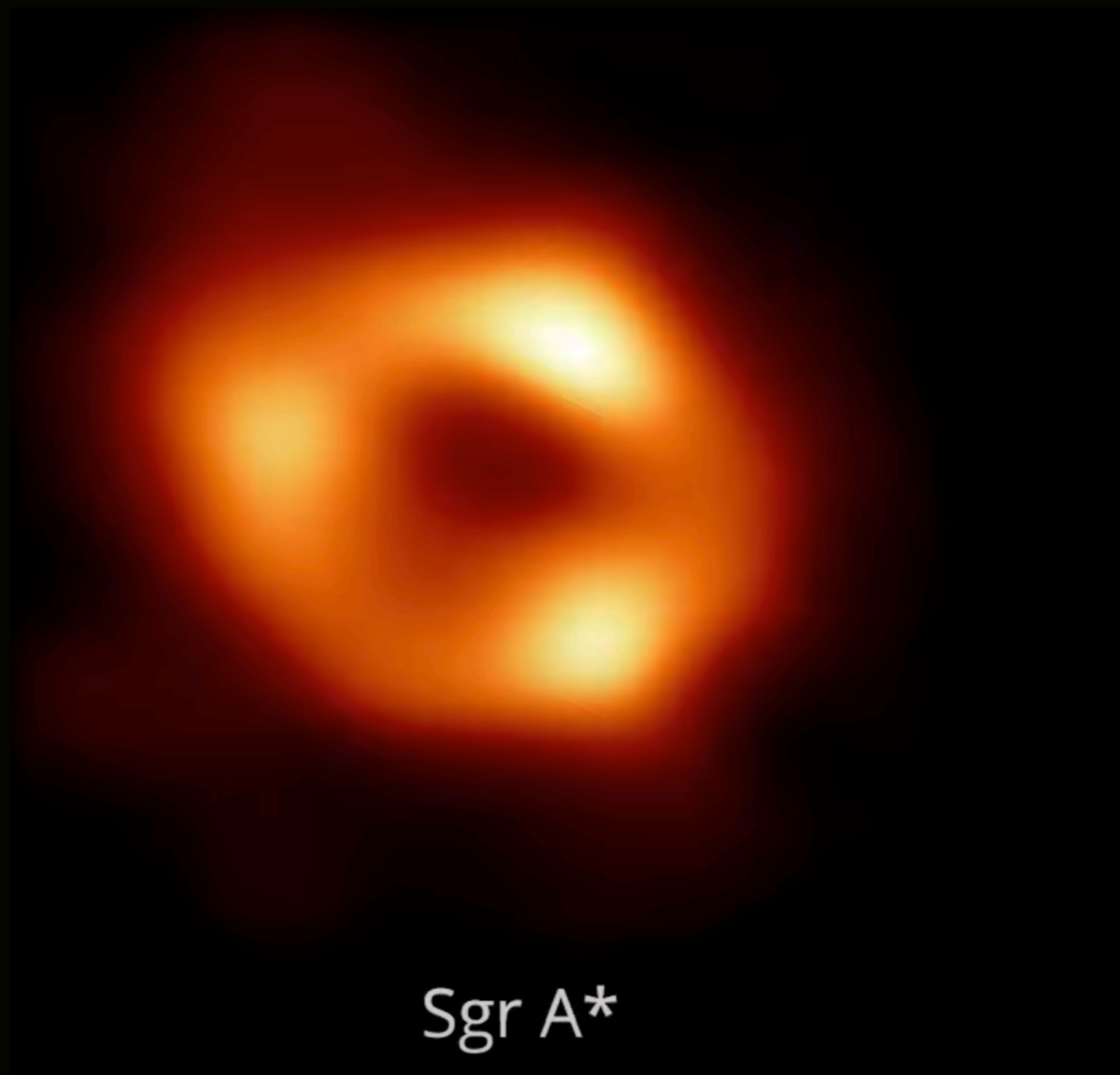
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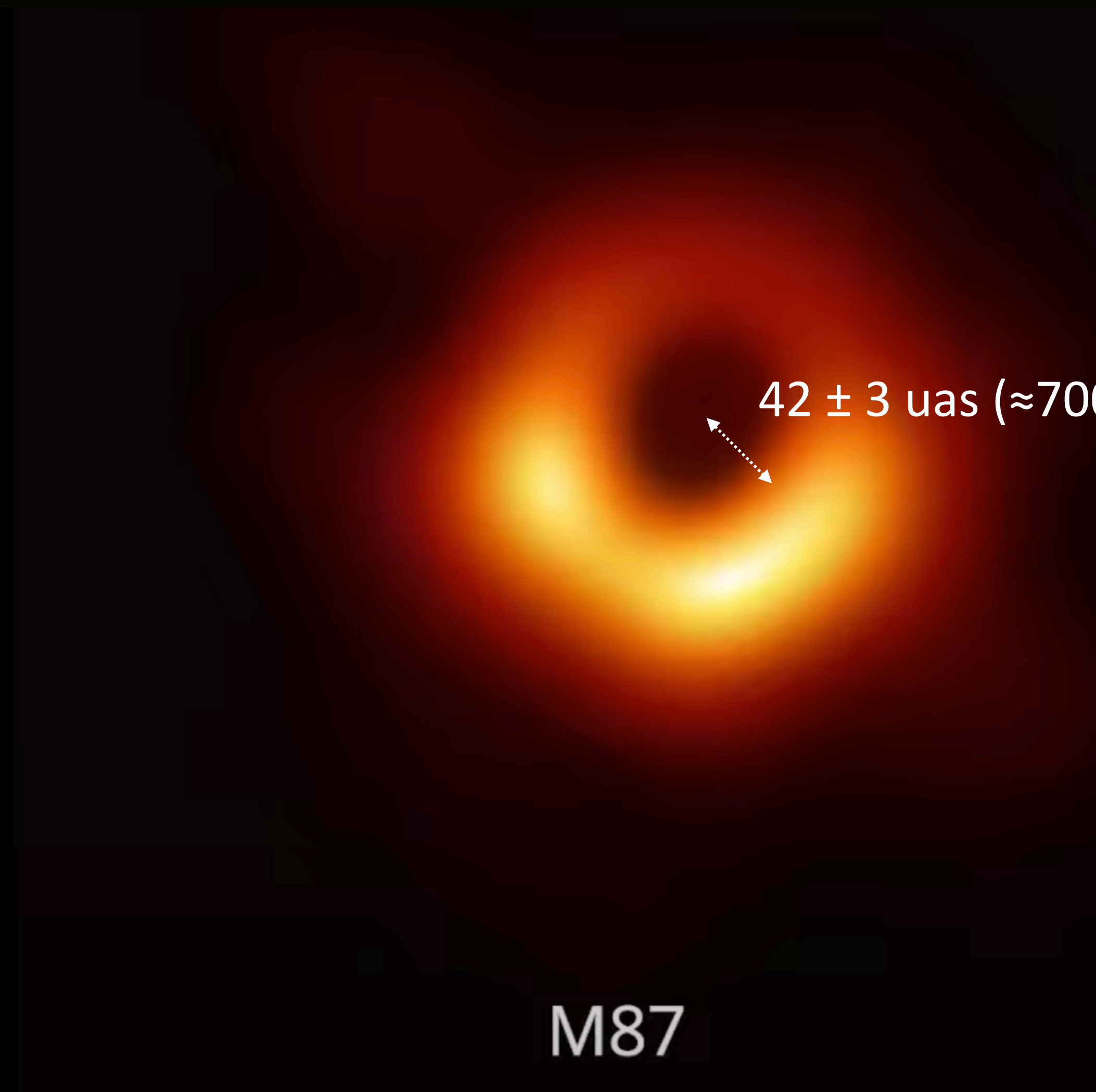
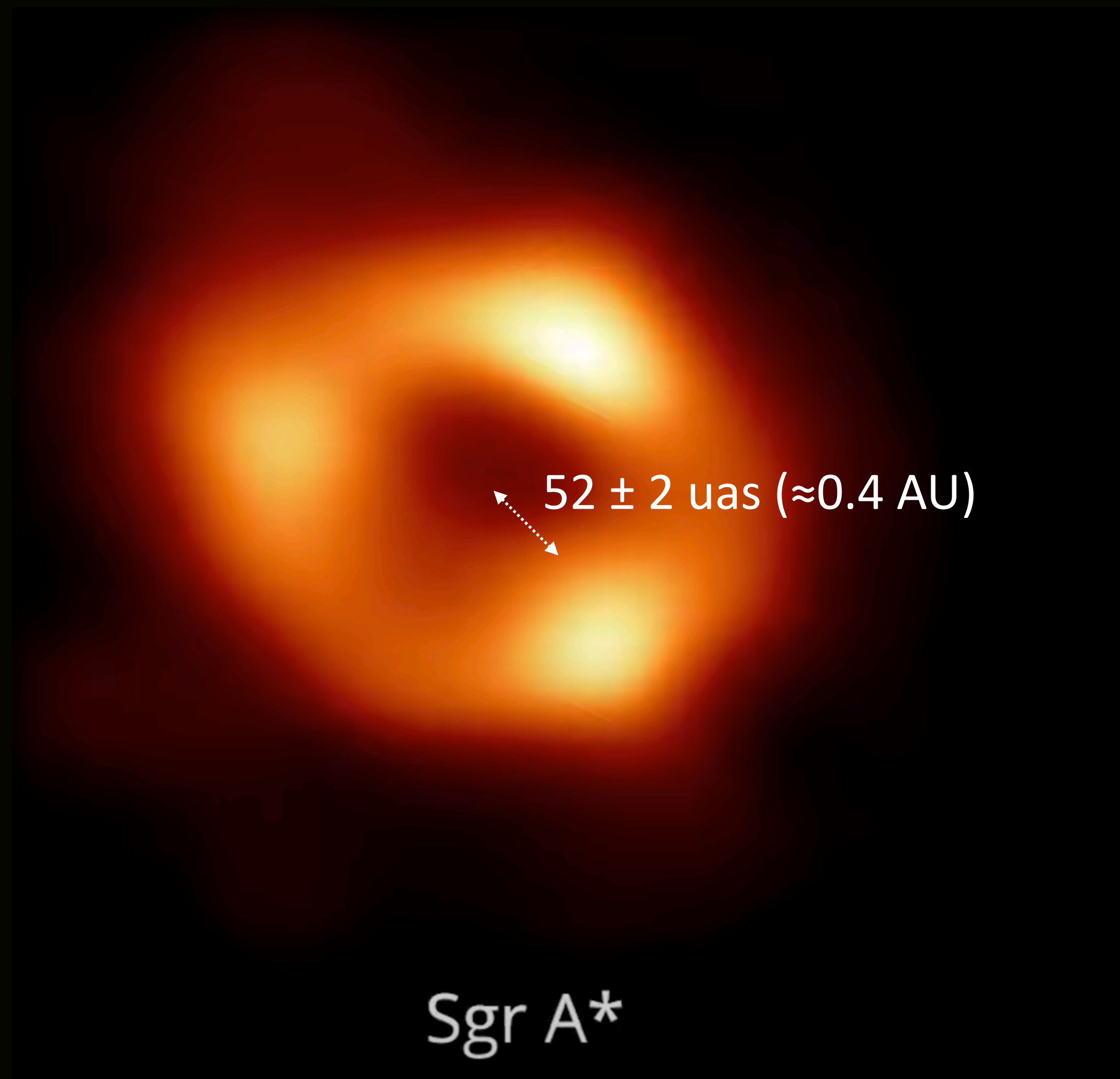






-Gas accreting event into Supermassive black holes

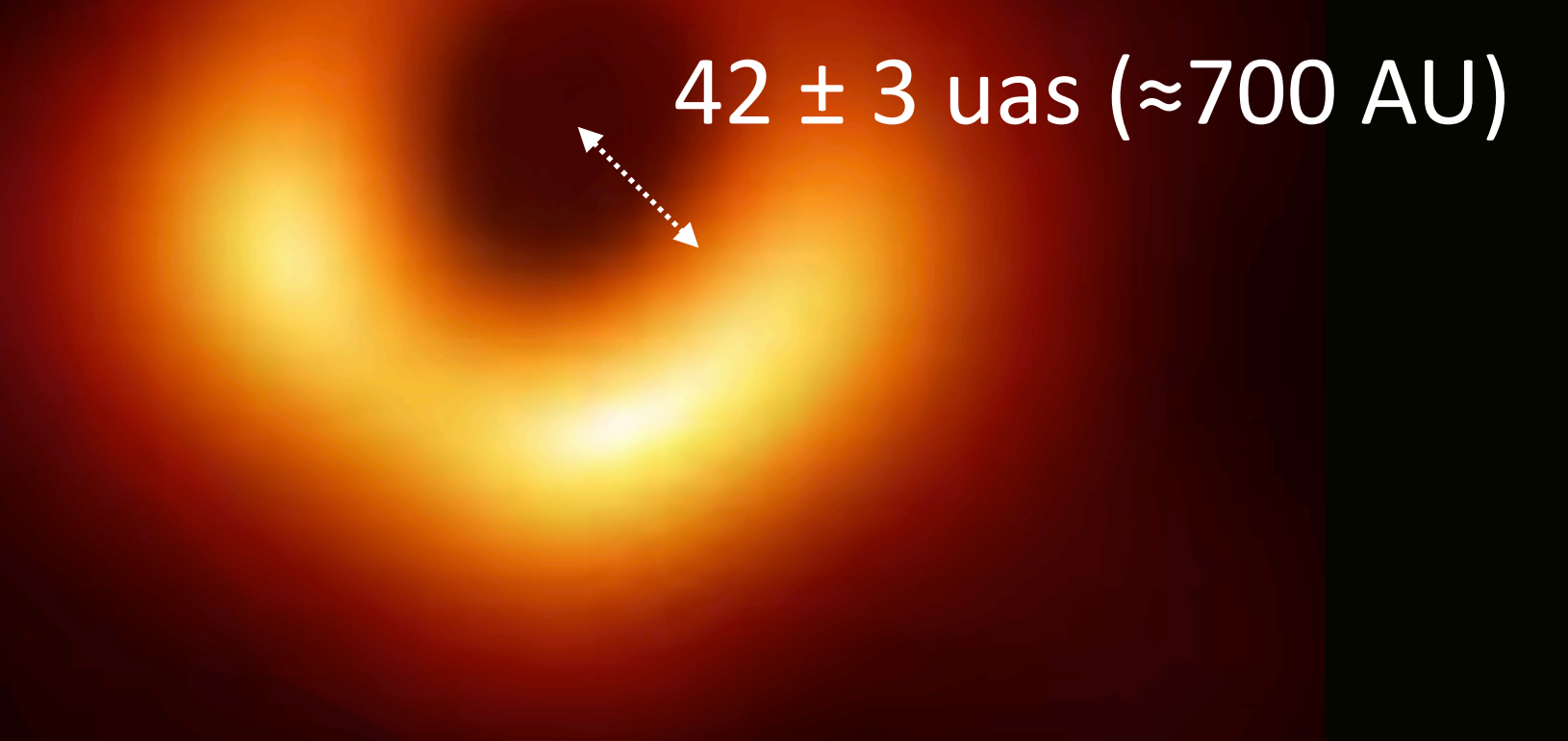






$$M_{\text{BH}} = 4 \times 10^6 M_{\text{Sun}}$$

Sgr A*

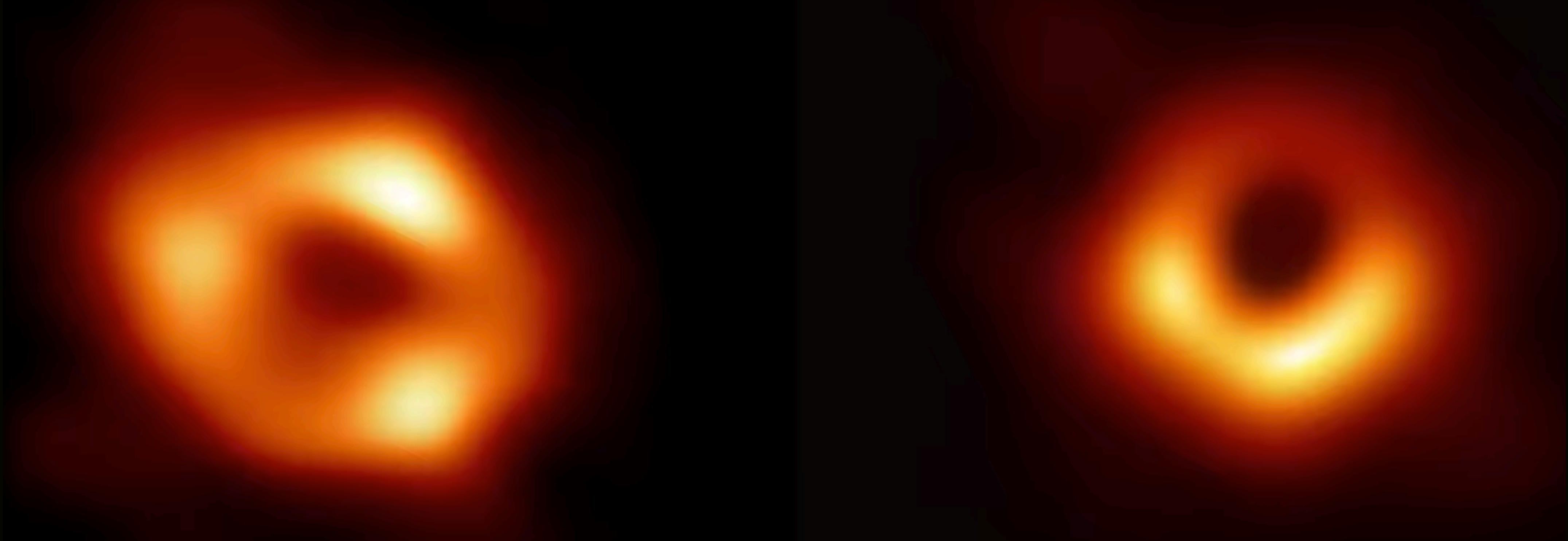


$$M_{\text{BH}} = 6 \times 10^9 M_{\text{Sun}}$$

M87

Mass of supermassive black holes (SMBHs) is huge: $10^6\text{-}10^9 M_{\text{Sun}}$

Question: How were SMBHs born and grown across the cosmic time?



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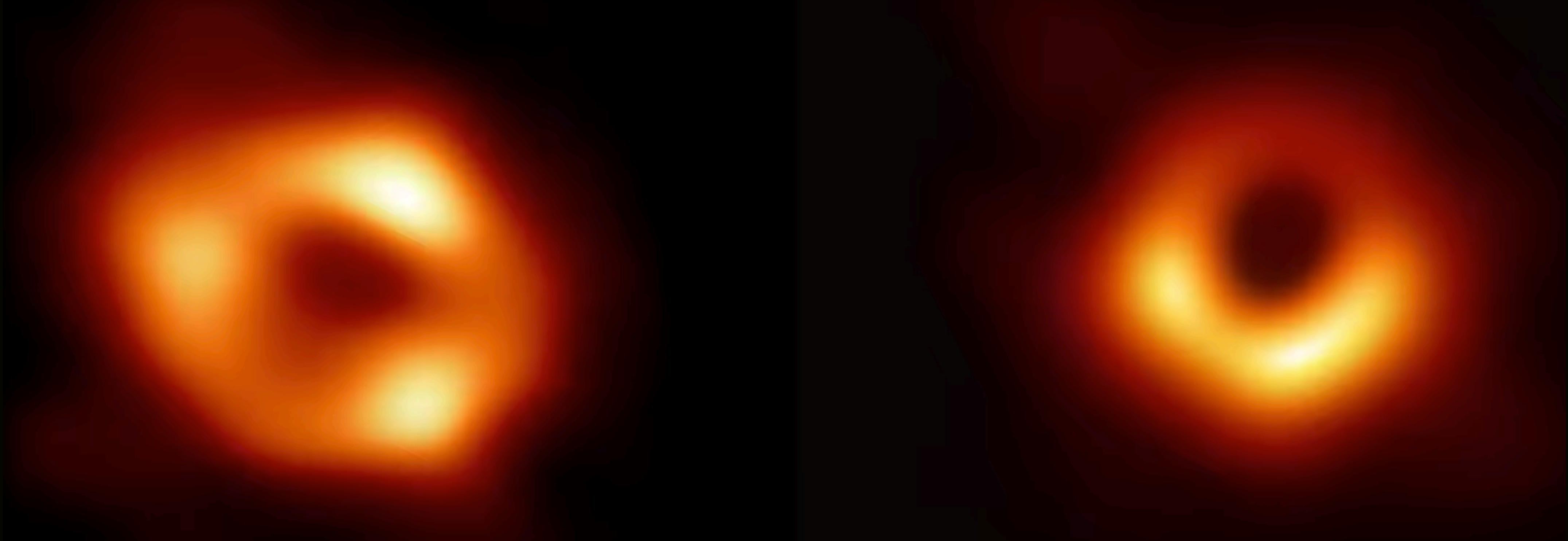
Today's topics

$M_{\text{BH}} = 6 \times 10^9 M_{\text{Sun}}$

1. “intermediate-mass” BHs with $M_{\text{BH}} < 10^6 M_{\text{Sun}}$
2. “1st-generation” SMBHs (through low- z LRDs)

Mass of supermassive black holes (SMBHs) is huge: $10^6\text{-}10^9 M_{\text{Sun}}$

Question: How were SMBHs born and grown across the cosmic time?


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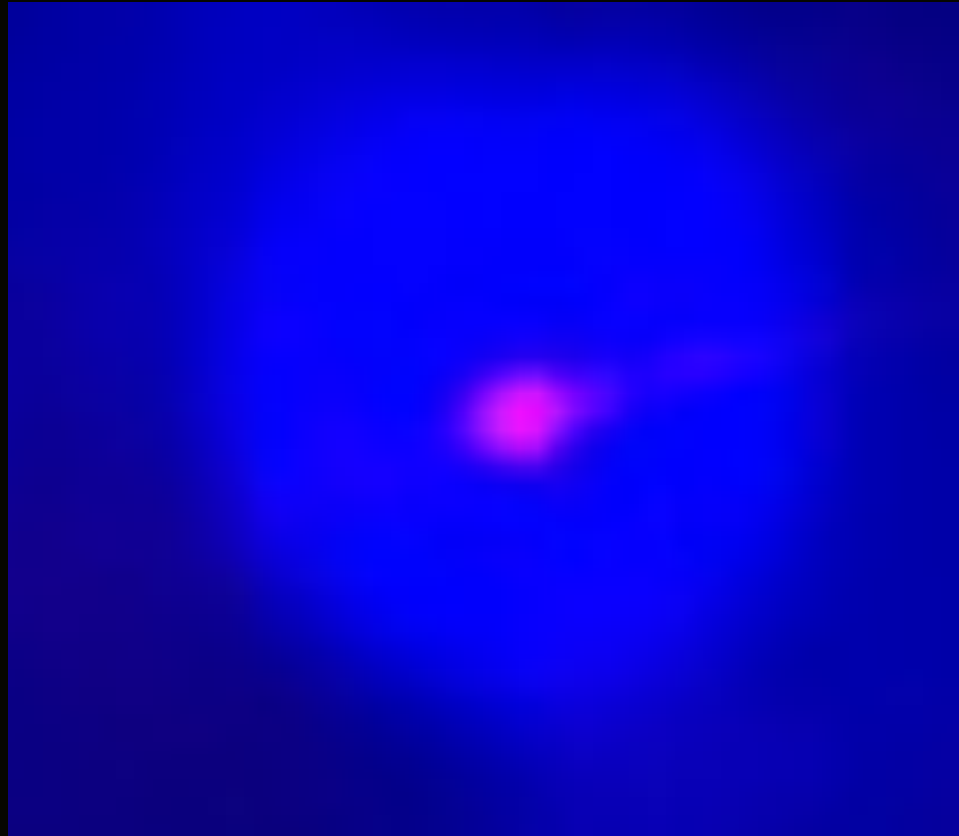
M87

Let's search AGN and quasars (QSOs) across the cosmic time!

But... How can we find them?

AGN are bright at all wavelengths

radio (MHz-GHz)



radio core

mid-infrared



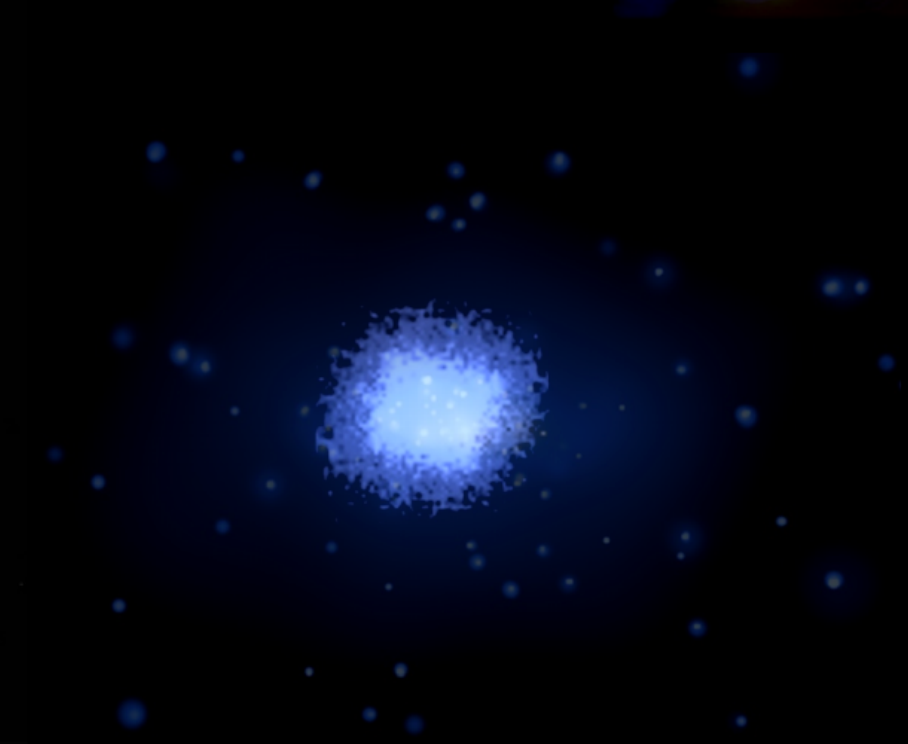
dust torus

optical



accretion
disk

soft X-rays

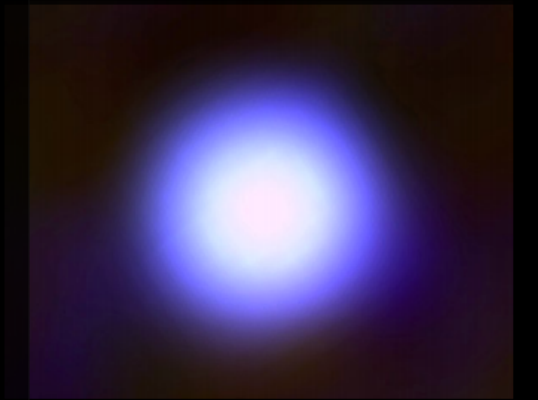


< 10 keV

from R. Hickox's talk at elusive AGN workshop

corona

hard X-rays

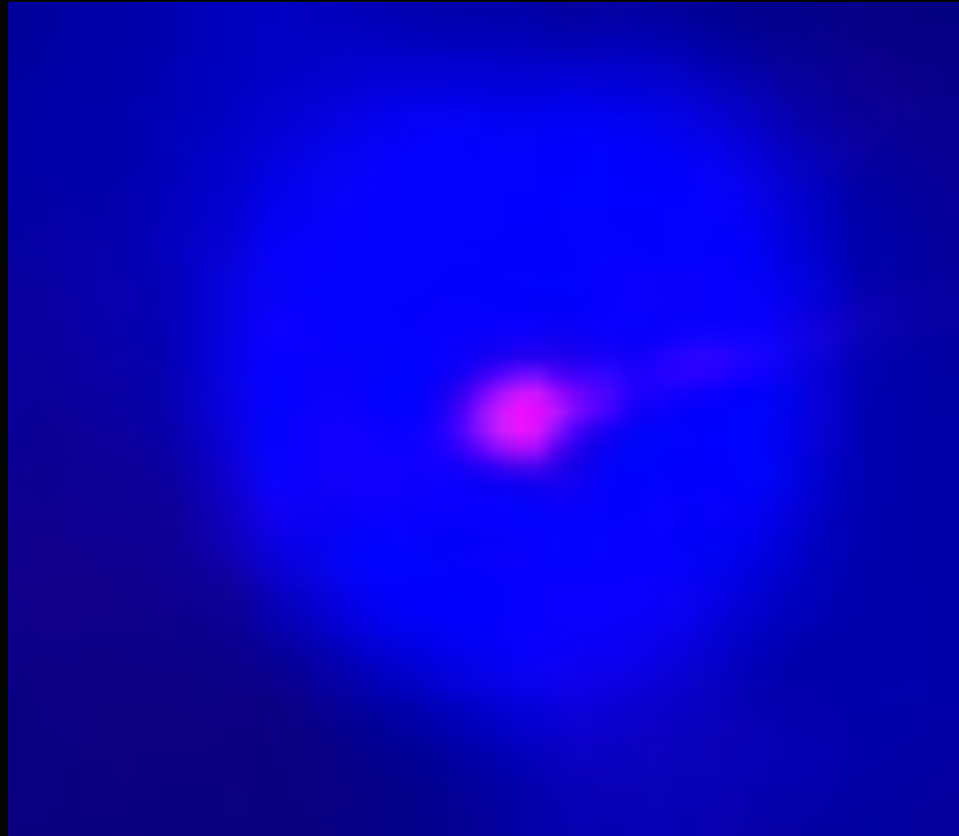


> 10 keV

small scale
(<10 pc)

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radio (MHz-GHz)



radio core

mid-infrared



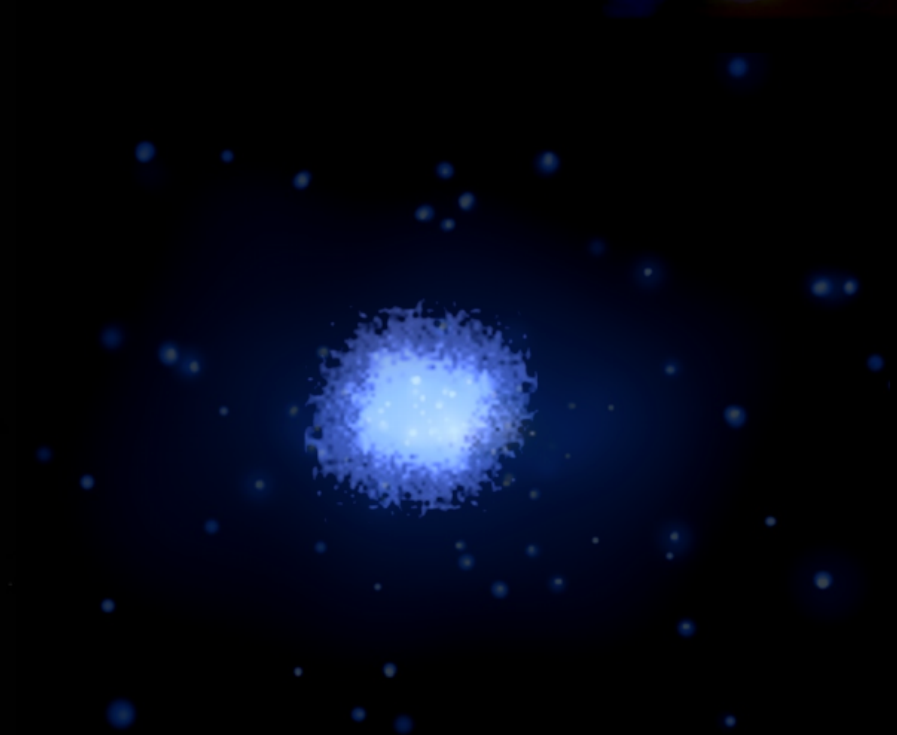
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AGN are rare

*X-ray; Ueda et al. (2014); IR: Delvecchio et al. (2014);
Optical-UV: Matsuoka et al. (2018)*

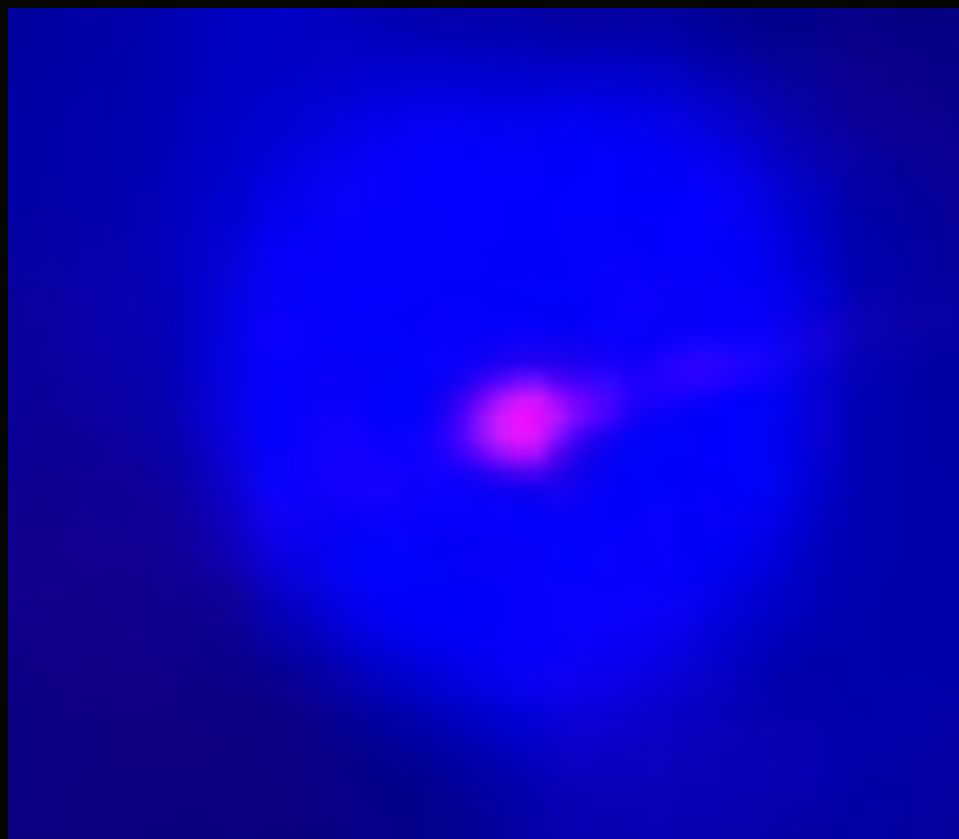
$n_{\text{AGN}} \sim 10^{-4}-10^{-5} \text{ Mpc}^{-3}$ (Low-L AGN)

$n_{\text{QSO}} \sim 10^{-5}-10^{-8} \text{ Mpc}^{-3}$ (high-L AGN)

($N_{\text{QSO}} = 0.1 \text{ deg}^{-2}$ at $z \sim 6$)

AGN are bright at all wavelengths

radio (MHz-GHz)



radio core

mid-infrared



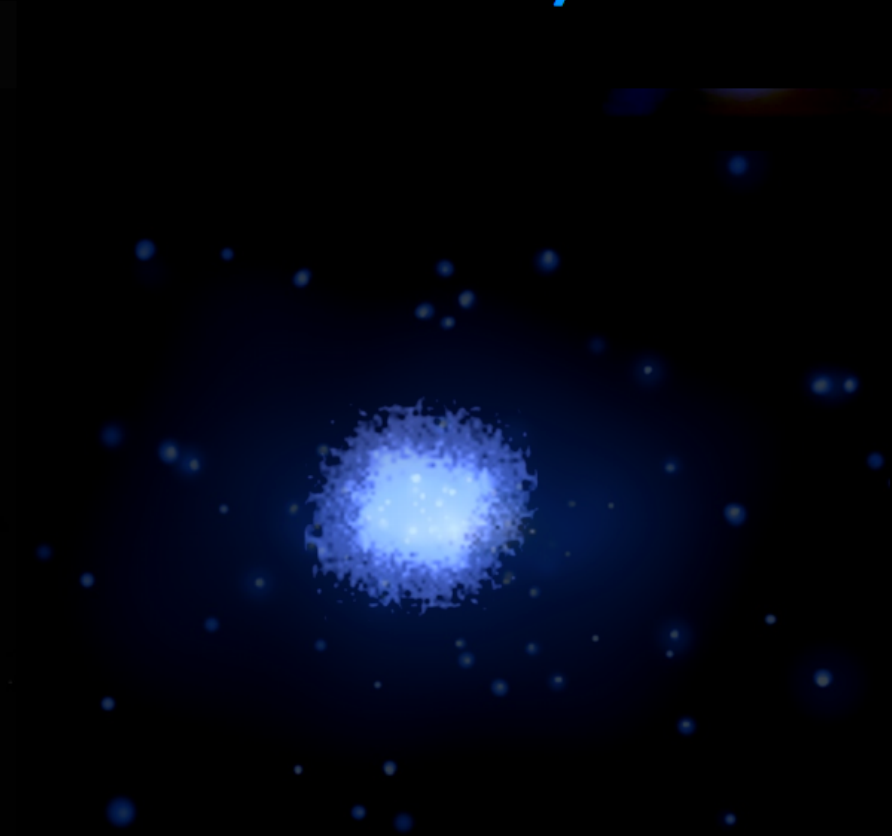
dust torus

optical



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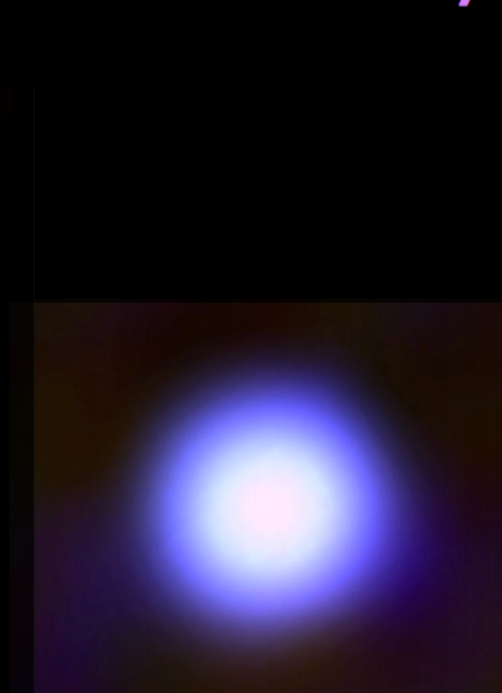
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AGN are rare

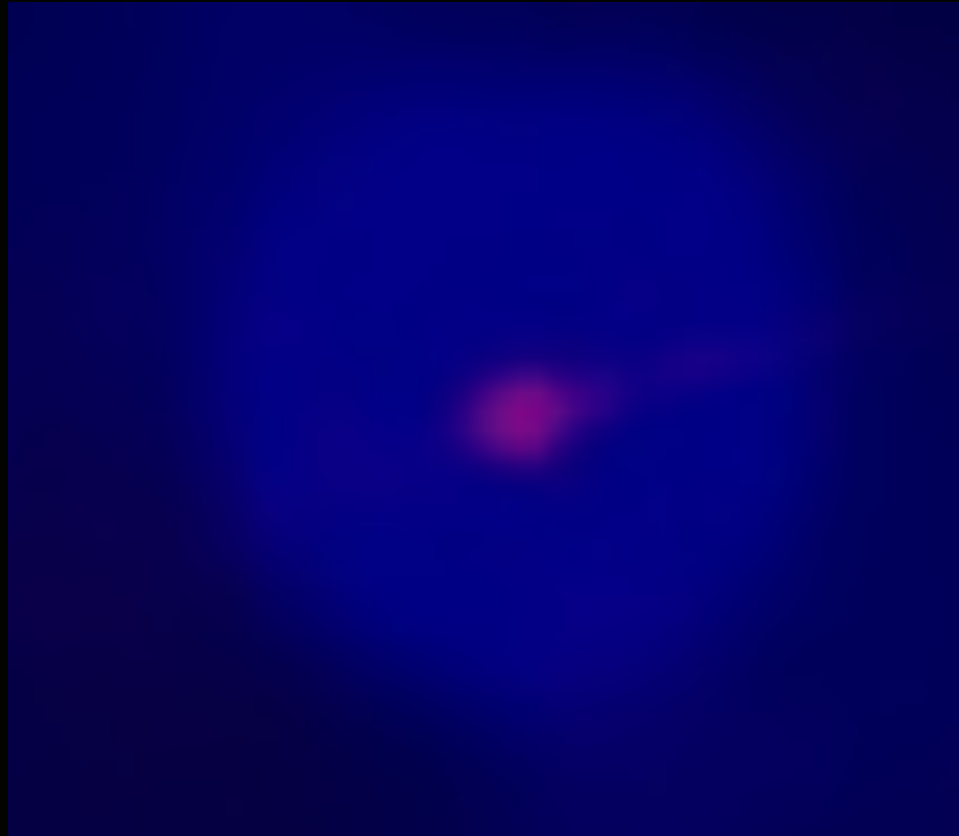
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 $n_{\text{QSO}} \sim 10^{-5}-10^{-6} \text{ Mpc}^{-3}$ (high-L AGN)
($N_{\text{QSO}} = 0.1 \text{ deg}^{-2}$ at $z \sim 6$)

We need: "Sensitivity" and "Area"
Large Survey volume (large ΔV)
 $\Delta V = L$ (depth) x S (wide area)

Which wavelength should we use to find rare AGN?

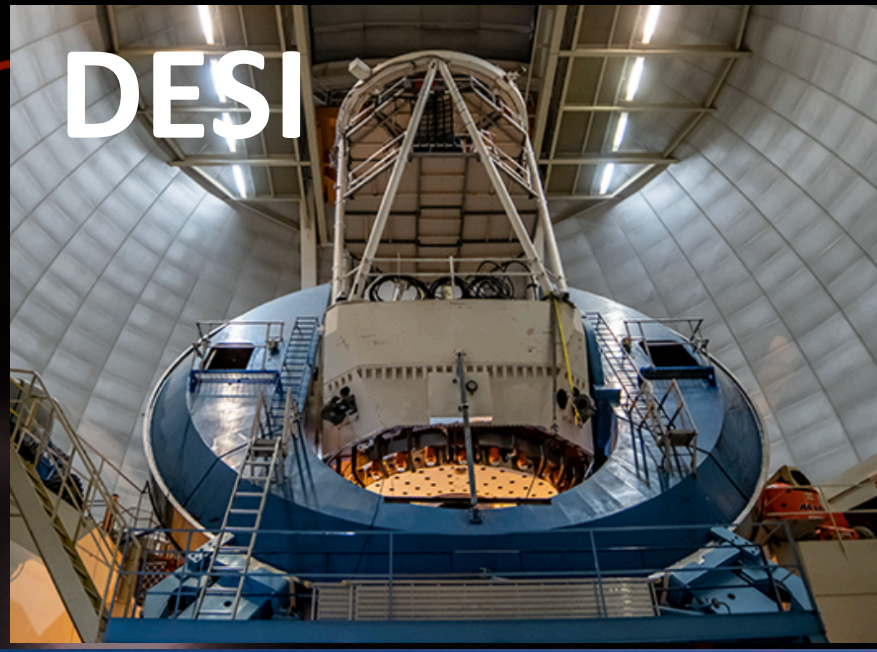
radio (MHz-GHz)



radio core

mid-ir

DESI



Subaru



HSC:

1.2 deg²/shot,
SSP survey: 1200 deg²

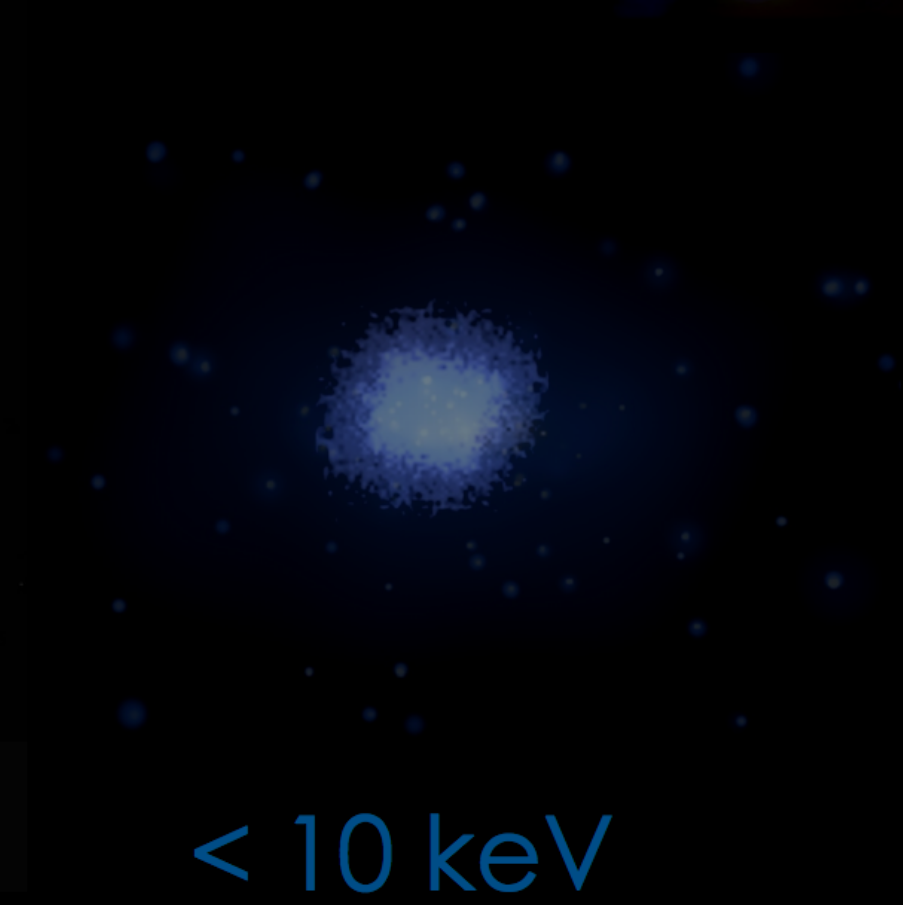
dust torus

optical



accretion
disk

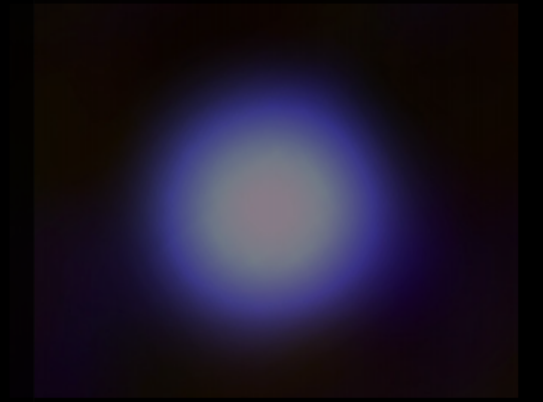
soft X-rays



< 10 keV

corona

hard X-rays

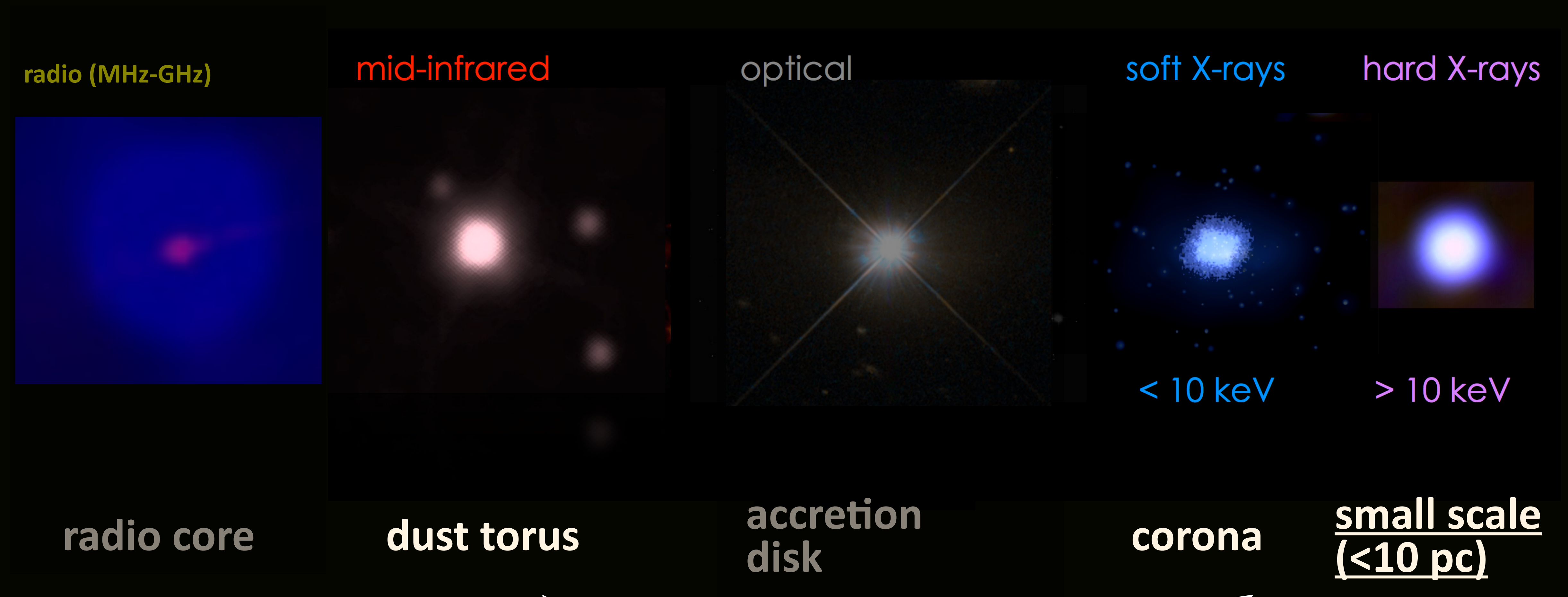


> 10 keV

small scale
(<10 pc)

High-sensitivity & Wide-area
=> (rare) high-z QSO search
(but we miss obscured QSO)

Which wavelength should we use to find rare AGN?

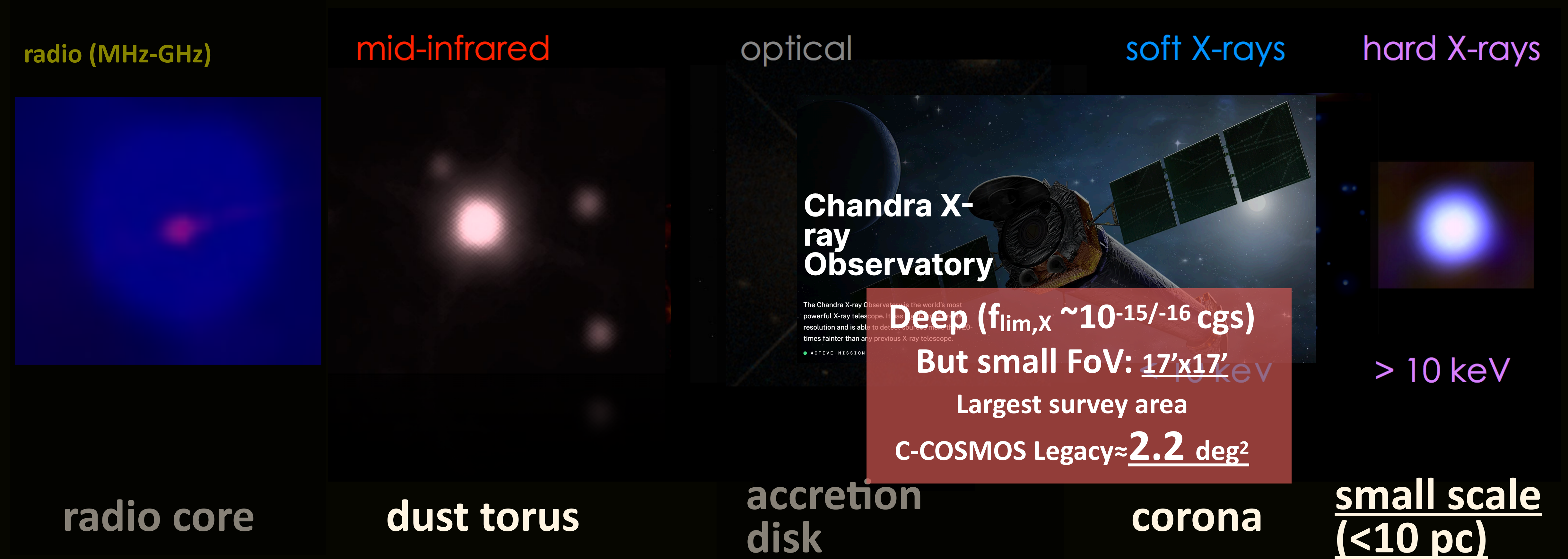


Strong against absorption

=> obscured AGN search at $z < 3$

(but survey/sensitivity are limited=> very few $z > 4$ X/IR based AGN discovery)

Which wavelength should we use to find rare AGN?



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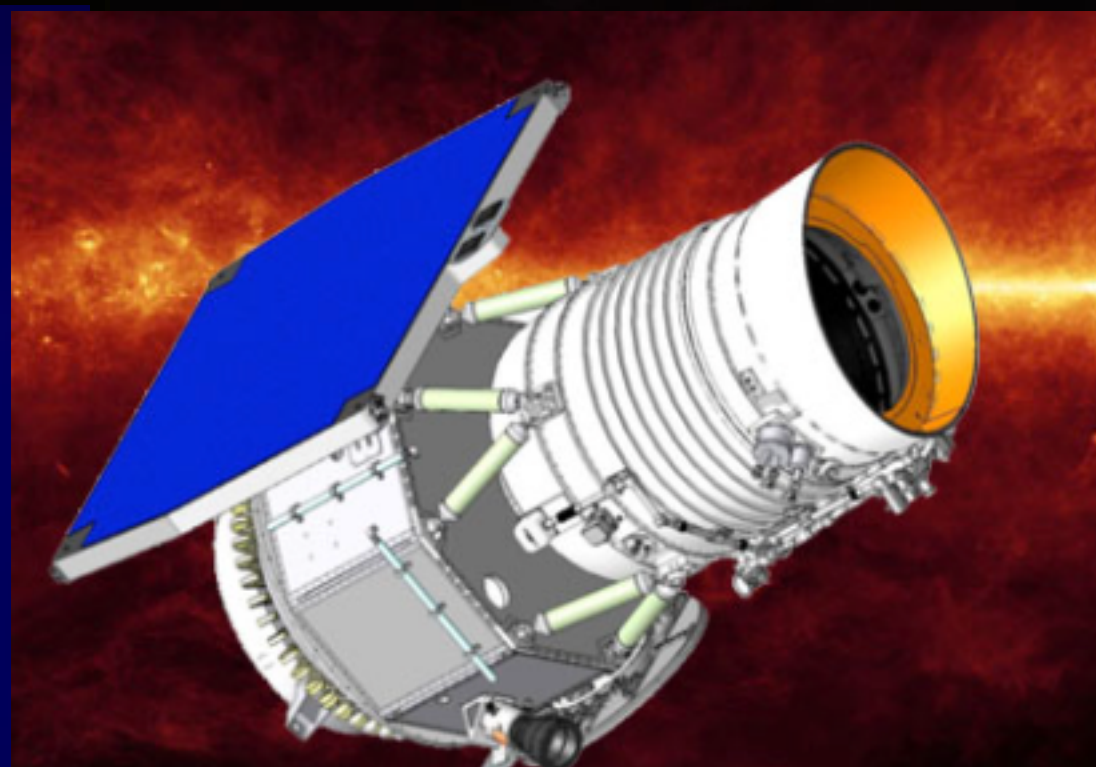
Which wavelength should we use to find rare AGN?

radio (MHz-GHz)



radio core

mid-infrared



WISE (3-22 μ m)
all-sky but
W1 (3.4 μ m) $\sim$ 19 AB mag

dust torus

optical



accretion
disk

soft X-rays



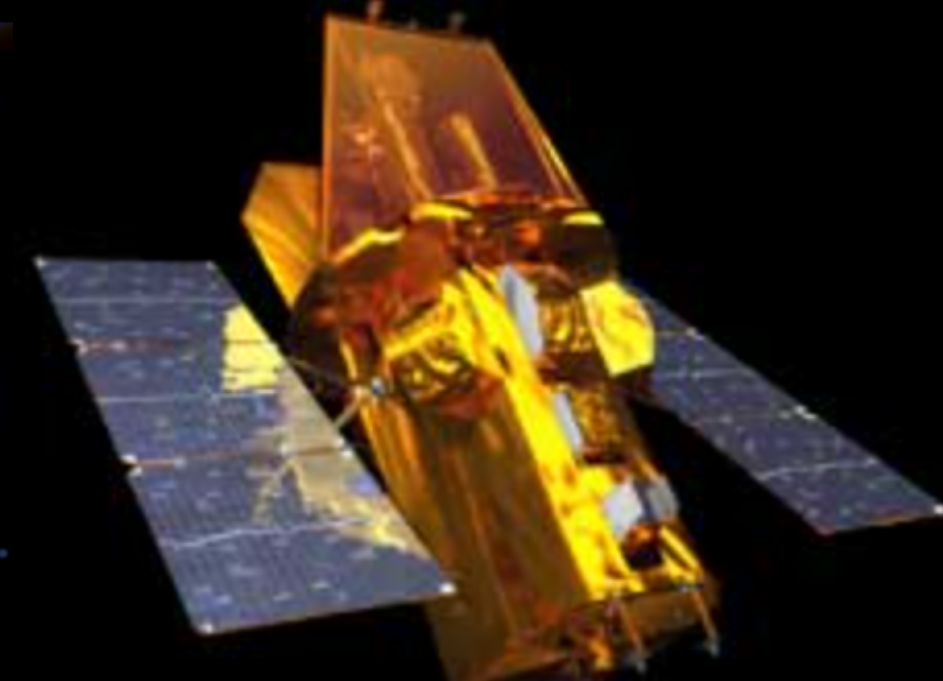
Chandra X-ray Observatory
The Chandra X-ray Observatory is the world's most powerful X-ray telescope. It has eight-times greater resolution and is able to detect sources more than 20-times fainter than any previous X-ray telescope.
ACTIVE MISSION

Deep ($f_{\text{lim},X} \sim 10^{-15}/^{-16}$ cgs)
But small FoV: 17'x17'

Largest survey area
C-COSMOS Legacy $\approx$ 2.2 deg²

corona

hard X-rays



Swift/BAT
> all-sky but
 $f_{\text{lim},X} \sim 10^{-11}$ cgs

BASS Survey



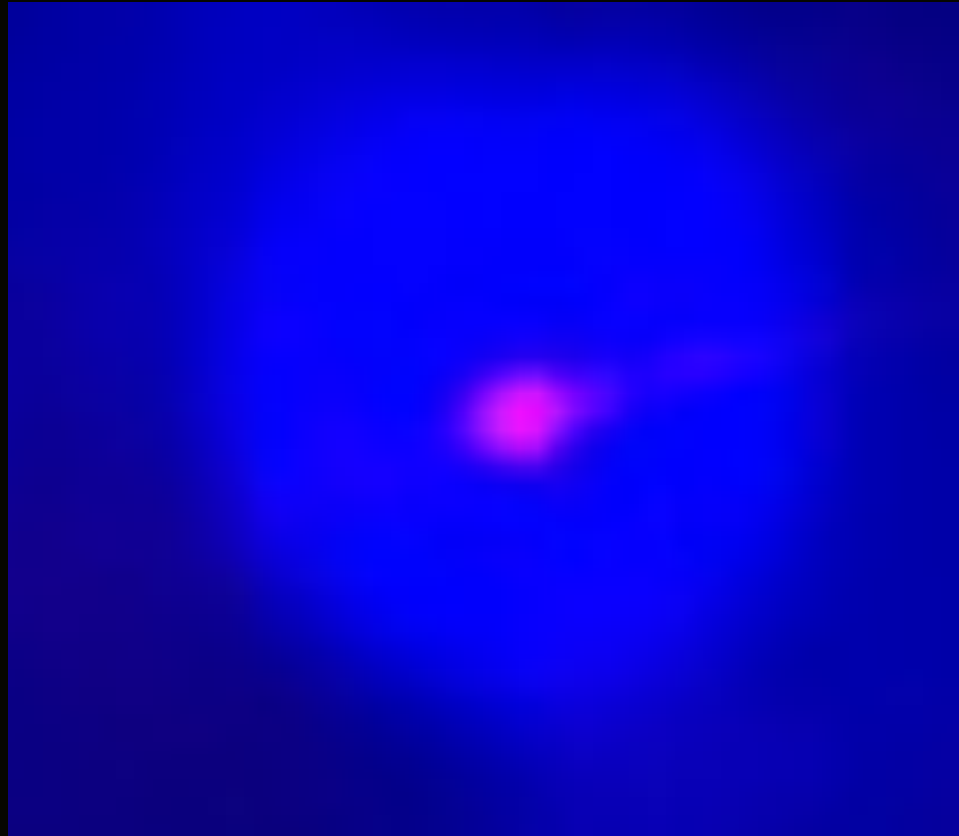
Strong against absorption

=> obscured AGN search at $z < 3$

(but survey/sensitivity are limited=> very few $z > 4$ X/IR based AGN discovery)

Which wavelength should we use to find rare (and obscured) AGN?

radio (MHz-GHz)



radio core
(and jet/lobe)

mid-infrared



dust torus

optical



accretion
disk

soft X-rays



< 10 keV

corona

hard X-rays



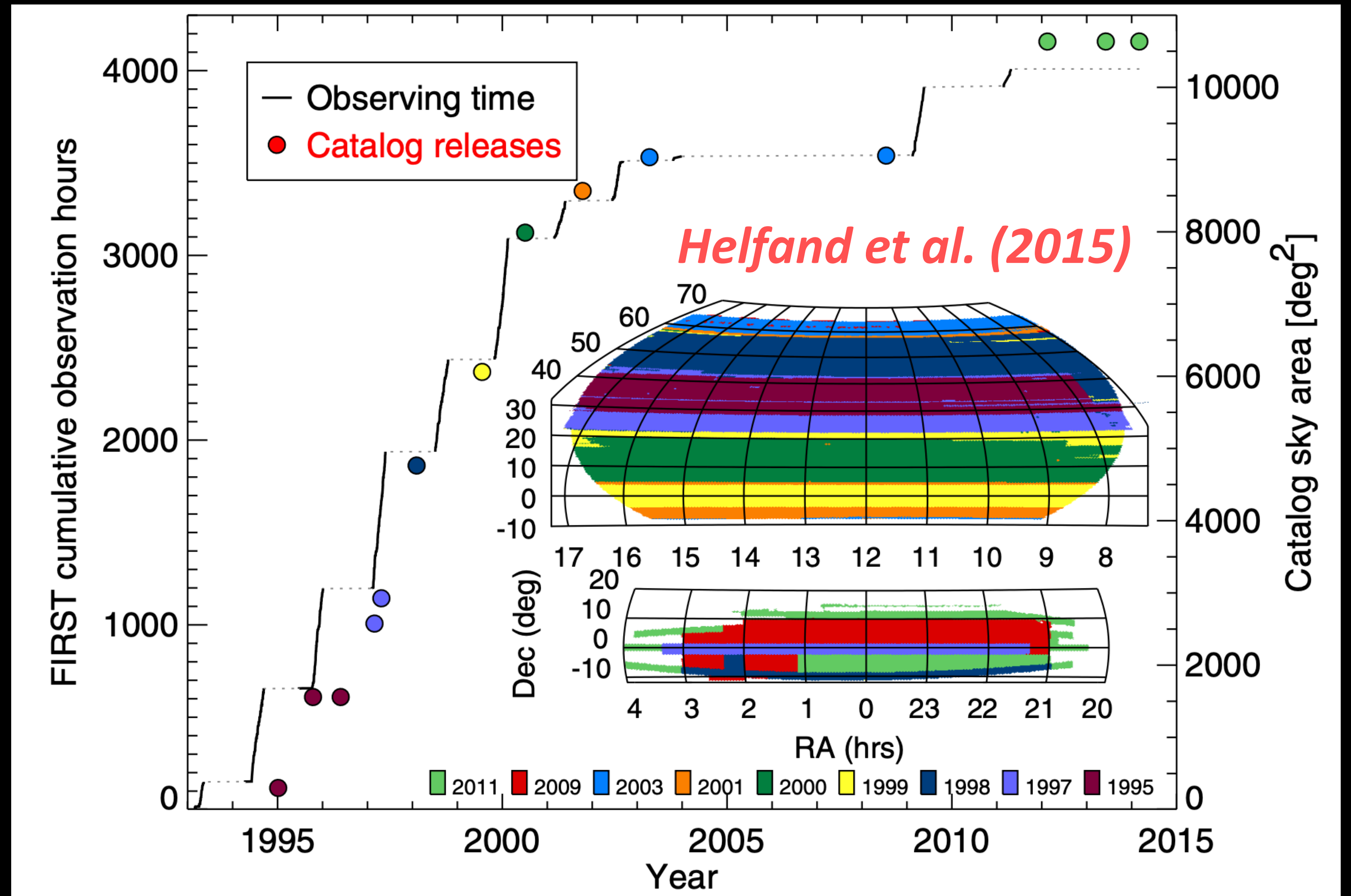
> 10 keV

small scale
(<10 pc)

Strong against absorption & Wide survey area
(Today's talk)

History of wide-area radio surveys (1995-2015)

2 Giants: NVSS and VLA/FIRST radio surveys ($\nu=1.4$ GHz, $f_{\nu,7\sigma\text{lim}}=1$ mJy, $>10^4$ deg²)



History of wide-area radio surveys (1995-2015)

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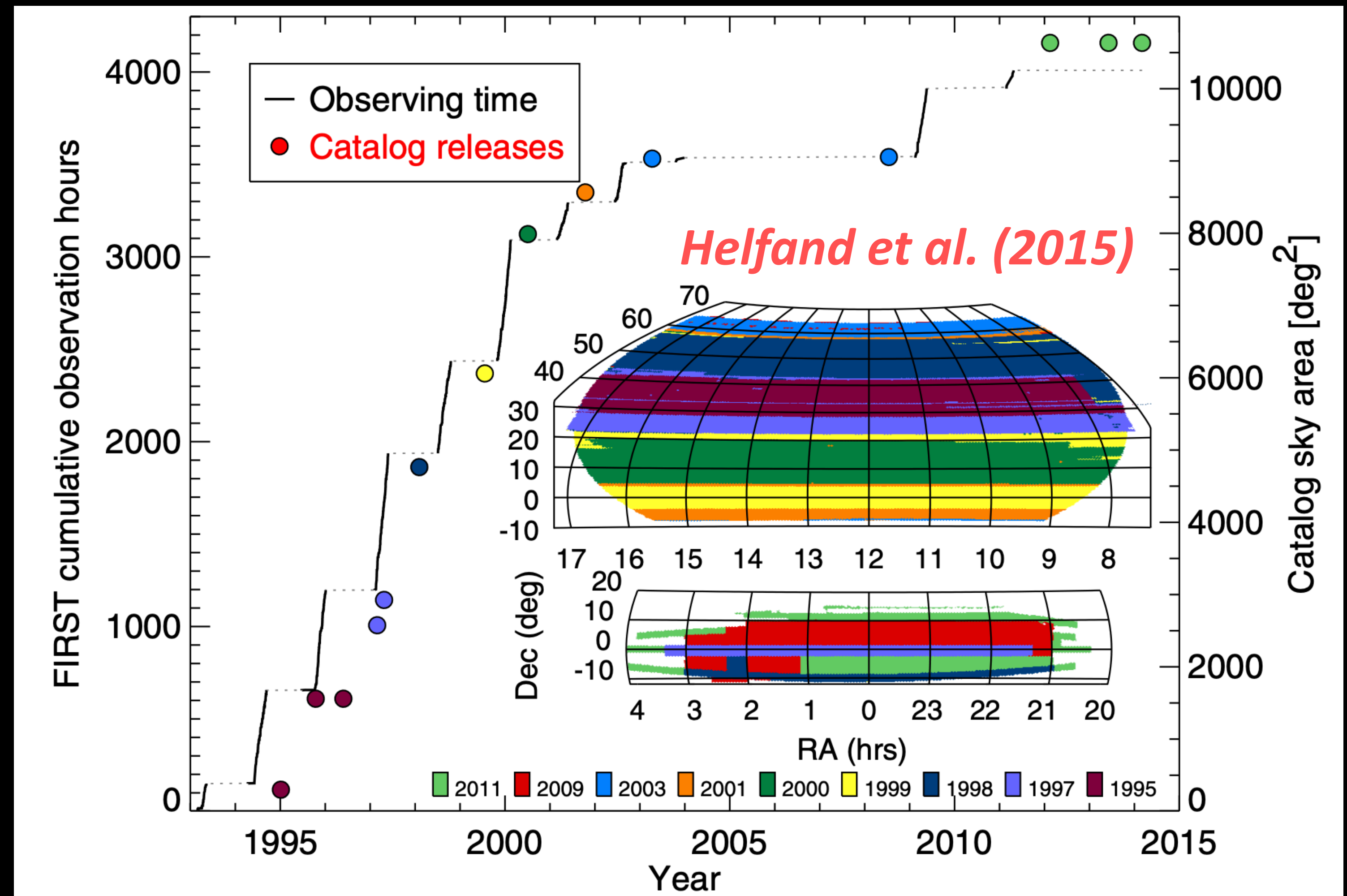
of sources:

950k in 10575 deg²

=> density ~ 90 deg⁻²

Resolution

6.5 arcsec



uniform distribution in the sky => extragalactic => radio AGN!

History of wide-area radio surveys (1995-2015)

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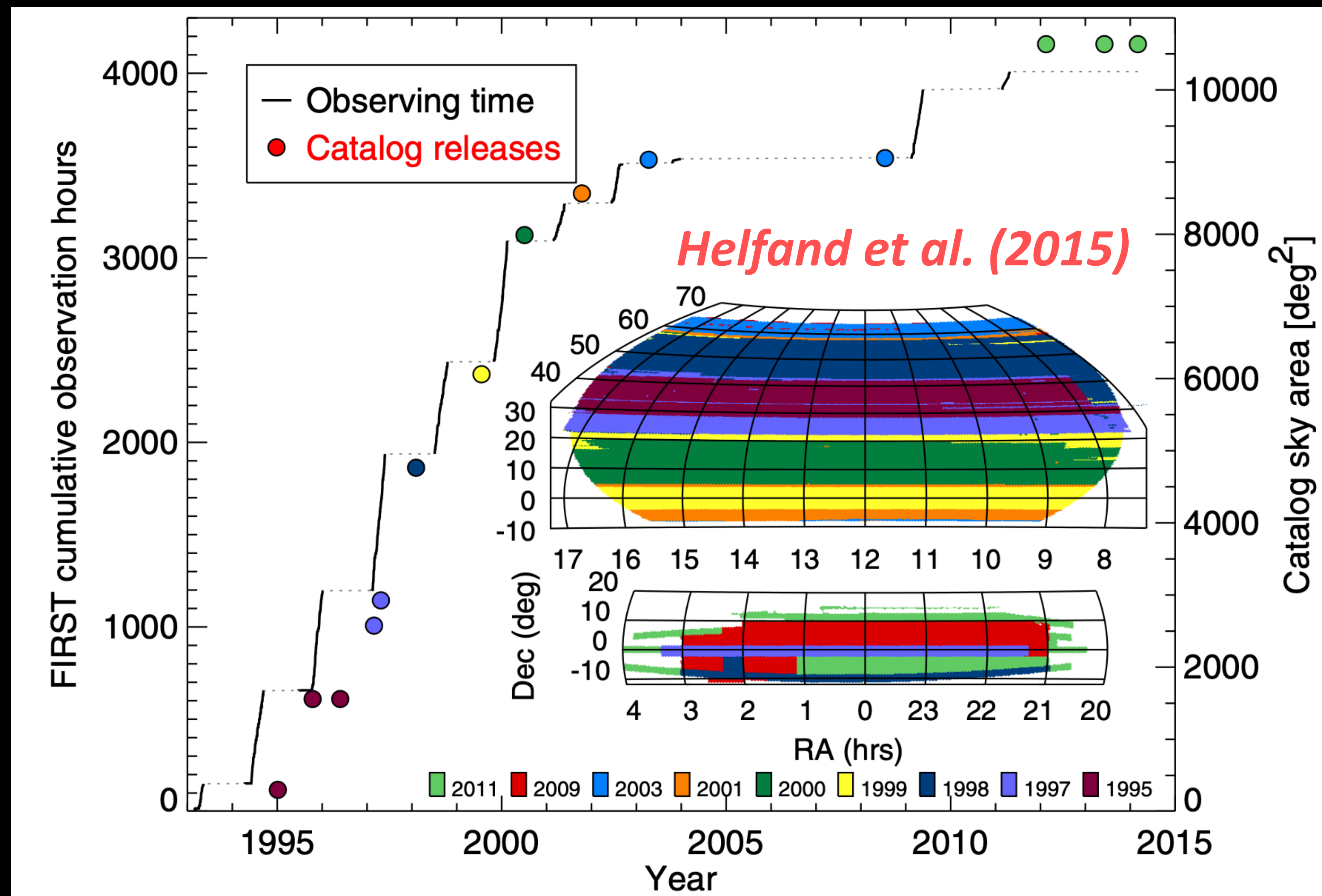
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Q: What fraction have known optical counterparts?

History of wide-area radio surveys (1995-2015)

Table 2								
FIRST Matches with External Catalogs								
FIRST	Subset	External	Match	Match	Position rms σ^c		Position Mean Offset ^d	
Subset	Percentage ^a	Catalog	Radius	Percentage ^b	Δ R.A.	Δ Decl.	Δ R.A.	Δ Decl.
(1)	(2)	(3)	(arcsec)	(%)	(arcsec)	(arcsec)	(arcsec)	(arcsec)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
All	100.0	NVSS	15	54.9	5.46	5.59	-0.009 ± 0.008	0.064 ± 0.008
Isolated ^e	73.0	NVSS	15	50.6	4.64	4.89	-0.011 ± 0.008	0.066 ± 0.008
All	100.0	2MASS	2	8.0	0.42	0.43	0.021 ± 0.002	0.007 ± 0.002
Pt ^f	37.1	2MASS	2	8.3	0.34	0.34	0.020 ± 0.002	0.006 ± 0.002
Pt, bright ^g	4.9	2MASS	2	6.8	0.23	0.23	0.022 ± 0.004	0.009 ± 0.004
All	93.0 ^h	SDSS all	2	32.9	0.36	0.37	0.021 ± 0.001	0.016 ± 0.001
all	93.0	SDSS galaxy ⁱ	2	26.5	0.38	0.39	0.021 ± 0.001	0.016 ± 0.001
All	93.0	SDSS star ^j	2	6.3	0.26	0.28	0.023 ± 0.001	0.014 ± 0.001
Pt	35.3	SDSS all	2	38.2	0.28	0.28	0.020 ± 0.001	0.014 ± 0.001
Pt	35.3	SDSS galaxy	2	29.6	0.30	0.30	0.020 ± 0.001	0.015 ± 0.001
Pt	35.3	SDSS star	2	8.6	0.21	0.22	0.022 ± 0.001	0.012 ± 0.001
Pt, bright	4.7	SDSS all	2	41.0	0.17	0.17	0.022 ± 0.001	0.012 ± 0.001
Pt, bright	4.7	SDSS galaxy	2	23.4	0.19	0.19	0.020 ± 0.002	0.013 ± 0.002
Pt, bright	4.7	SDSS star	2	17.7	0.15	0.16	0.025 ± 0.002	0.011 ± 0.002
JVLA ^k , isolated	4.5	NVSS	15	52.0	4.62	4.99	0.005 ± 0.030	0.179 ± 0.031
JVLA	6.4	2MASS	2	6.7	0.47	0.49	0.000 ± 0.007	-0.029 ± 0.008
JVLA	99.3	SDSS all	2	28.4	0.40	0.44	0.002 ± 0.003	-0.009 ± 0.003

Helfand et al. (2015)
(See also Ivezić et al. 2002)

History of wide-area radio surveys (1995-2015)

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JVLA	99.3	SDSS all	2	28.4	0.40	0.44	0.002 ± 0.003	-0.009 ± 0.003

Only 33% of FIRST radio sources have known optical counterparts
=> Remaining ~70% are still not explored (and many are likely AGN!) => Many known unknowns!

History of wide-area radio surveys (2015-)

7(!) yrs after WERGS DR1, new wide-area radio surveys are underway

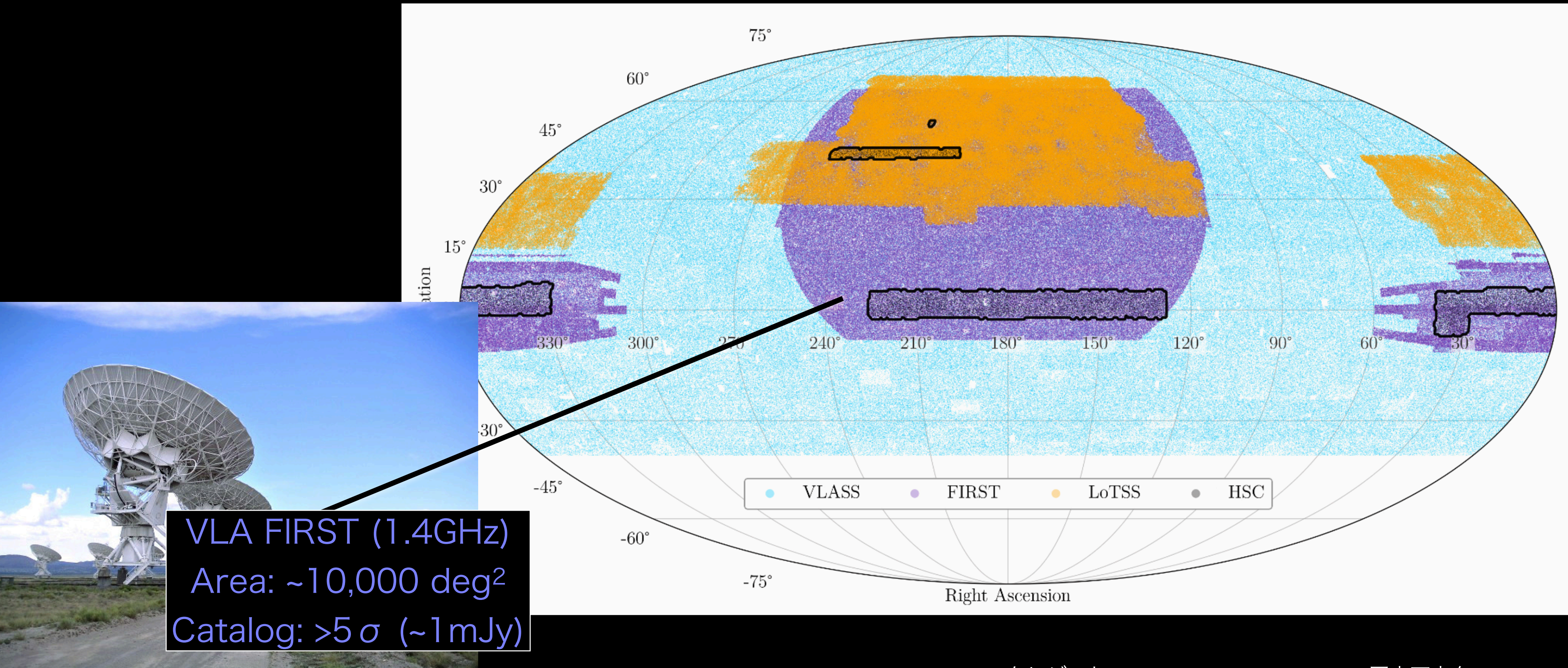


Image: Hajor (CC BY-SA 3.0)

クレジット : Dr. Vera Maria Passegger/国立天文台

History of wide-area radio surveys (2015-)

LoFAR (144 MHz) and VLASS (3GHz) radio surveys are ongoing

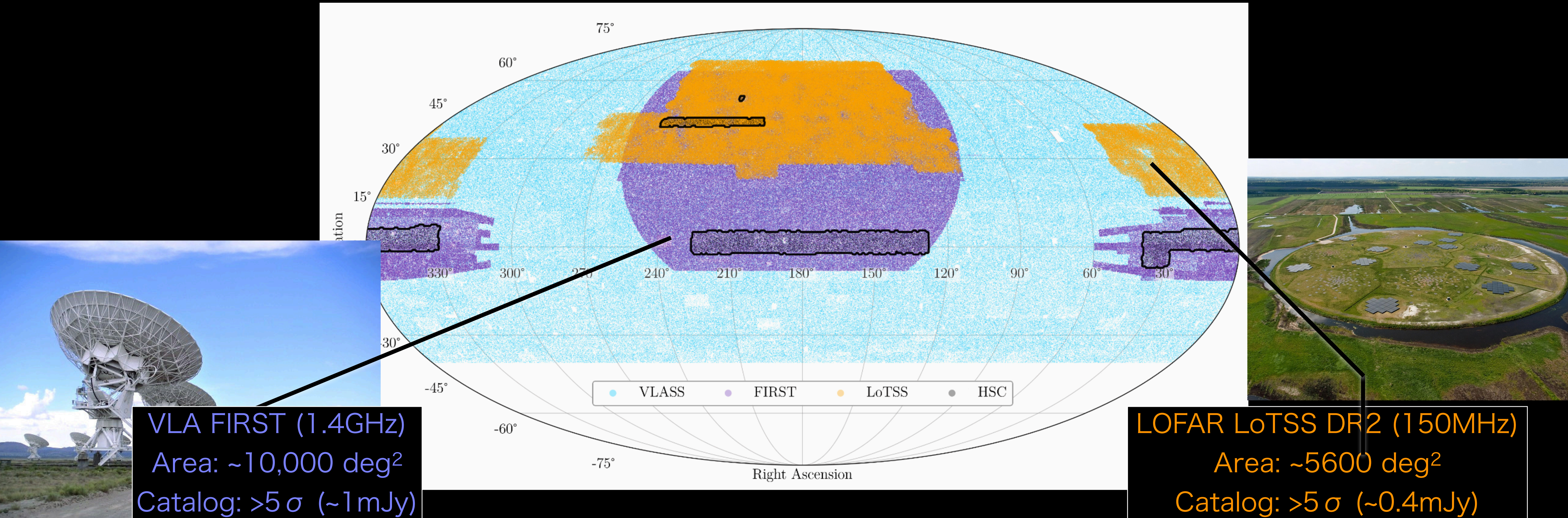


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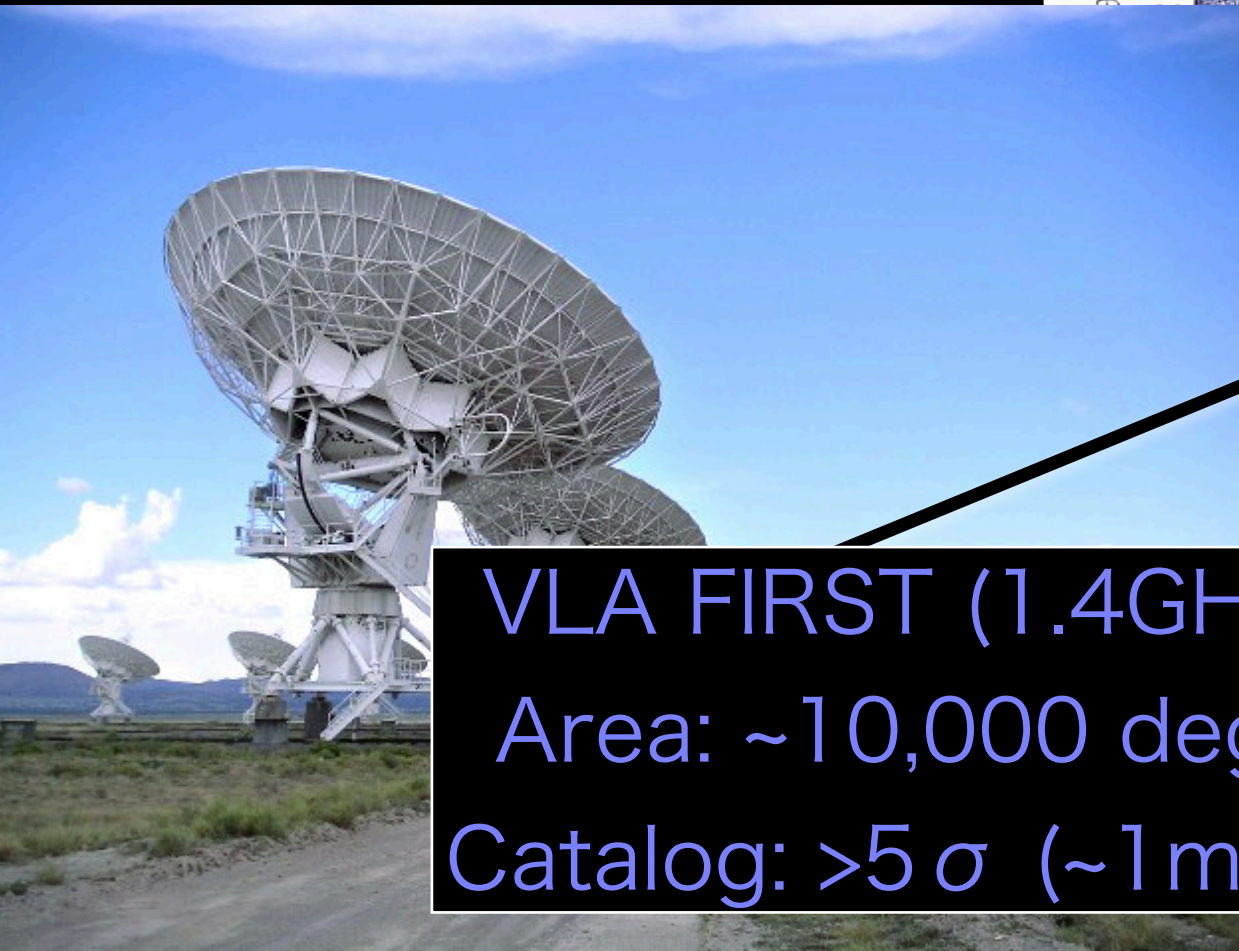
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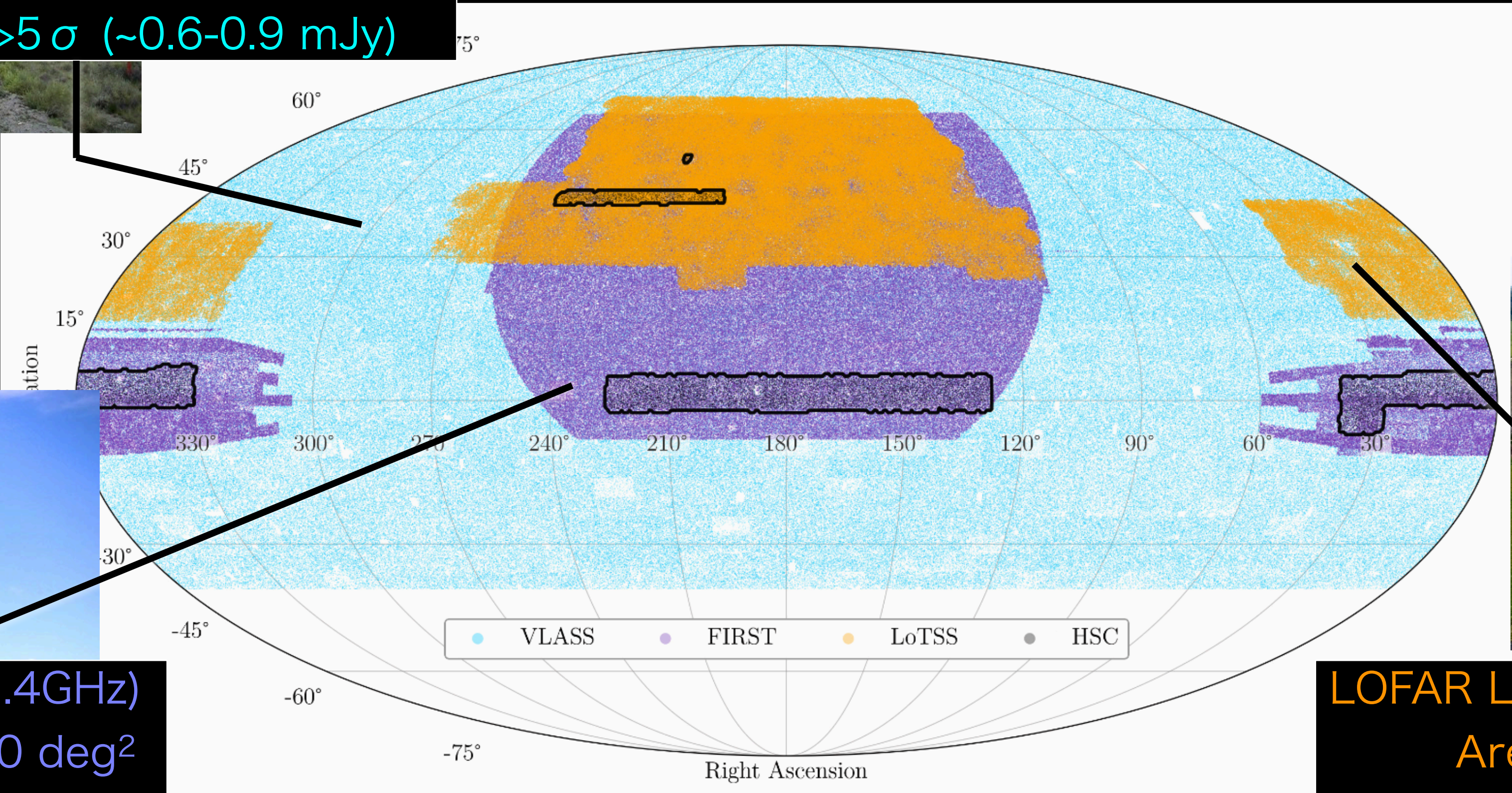
Now we get wider area, multi-frequency (100-3GHz)
SED for radio AGN



VLA VLASS (3GHz)
Area: 34,000 deg² (3 epochs)
Catalog: $>5\sigma$ (~0.6-0.9 mJy)



VLA FIRST (1.4GHz)
Area: ~10,000 deg²
Catalog: $>5\sigma$ (~1mJy)



LOFAR LoTSS DR2 (150MHz)
Area: ~5600 deg²
Catalog: $>5\sigma$ (~0.4mJy)

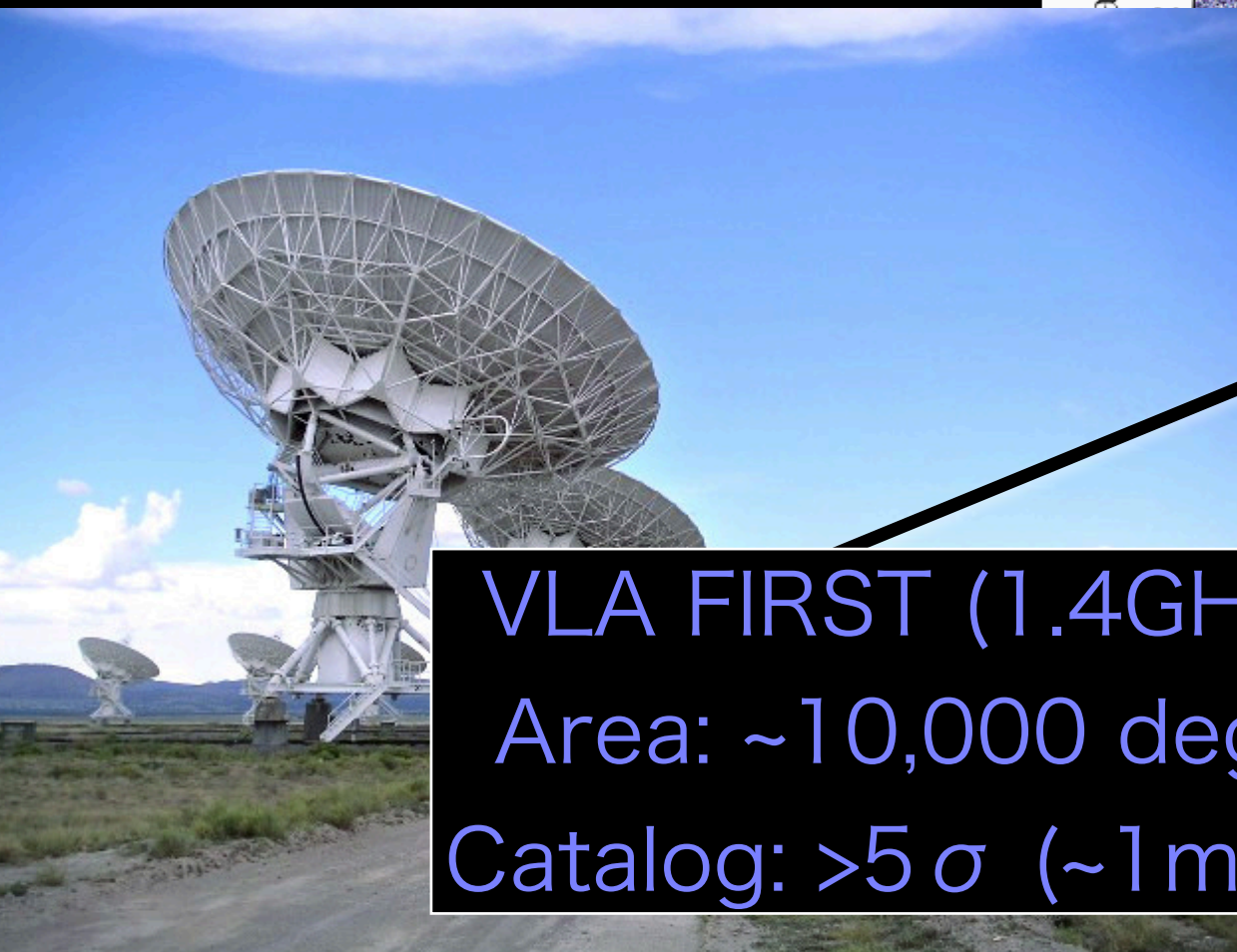
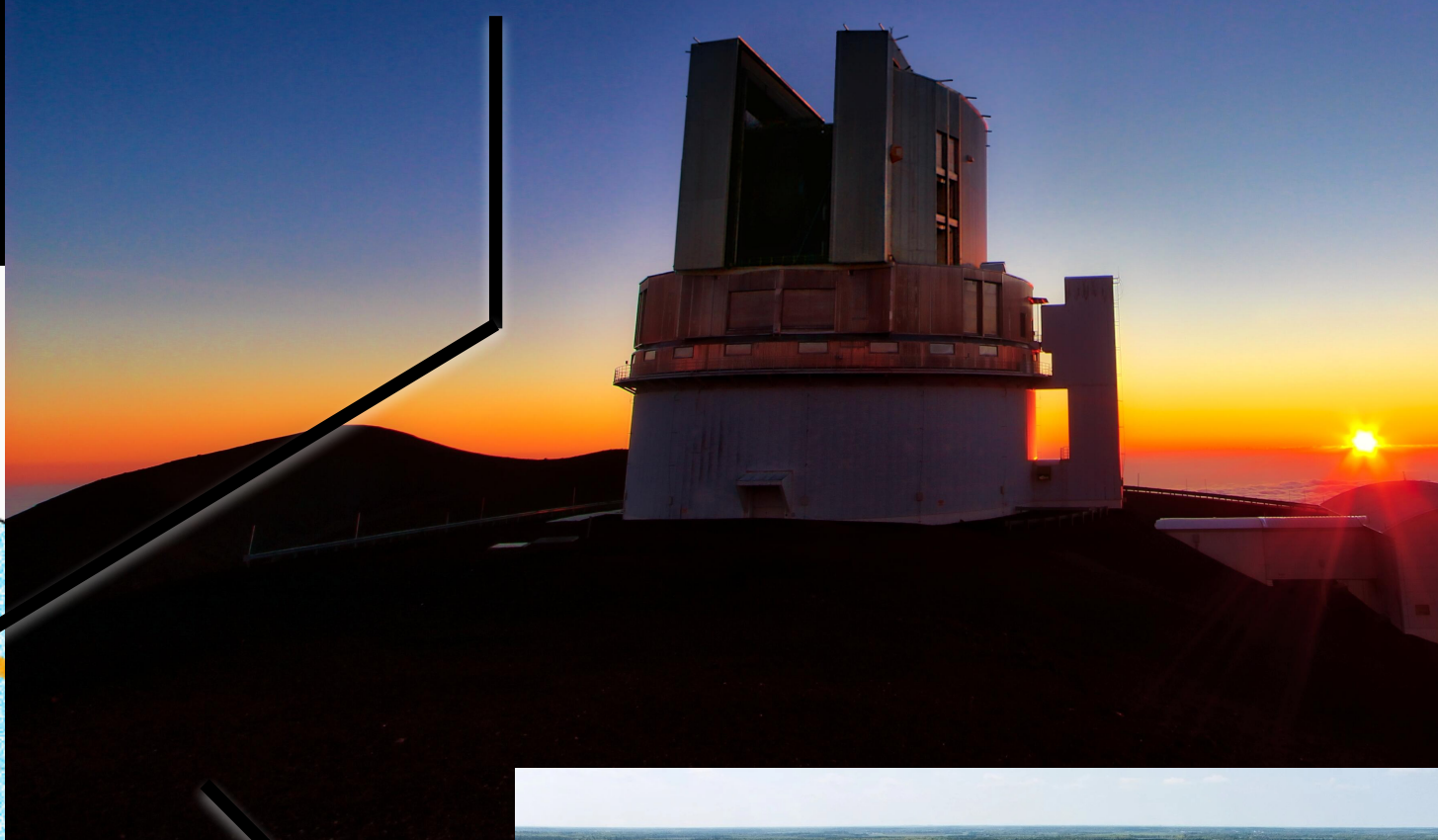
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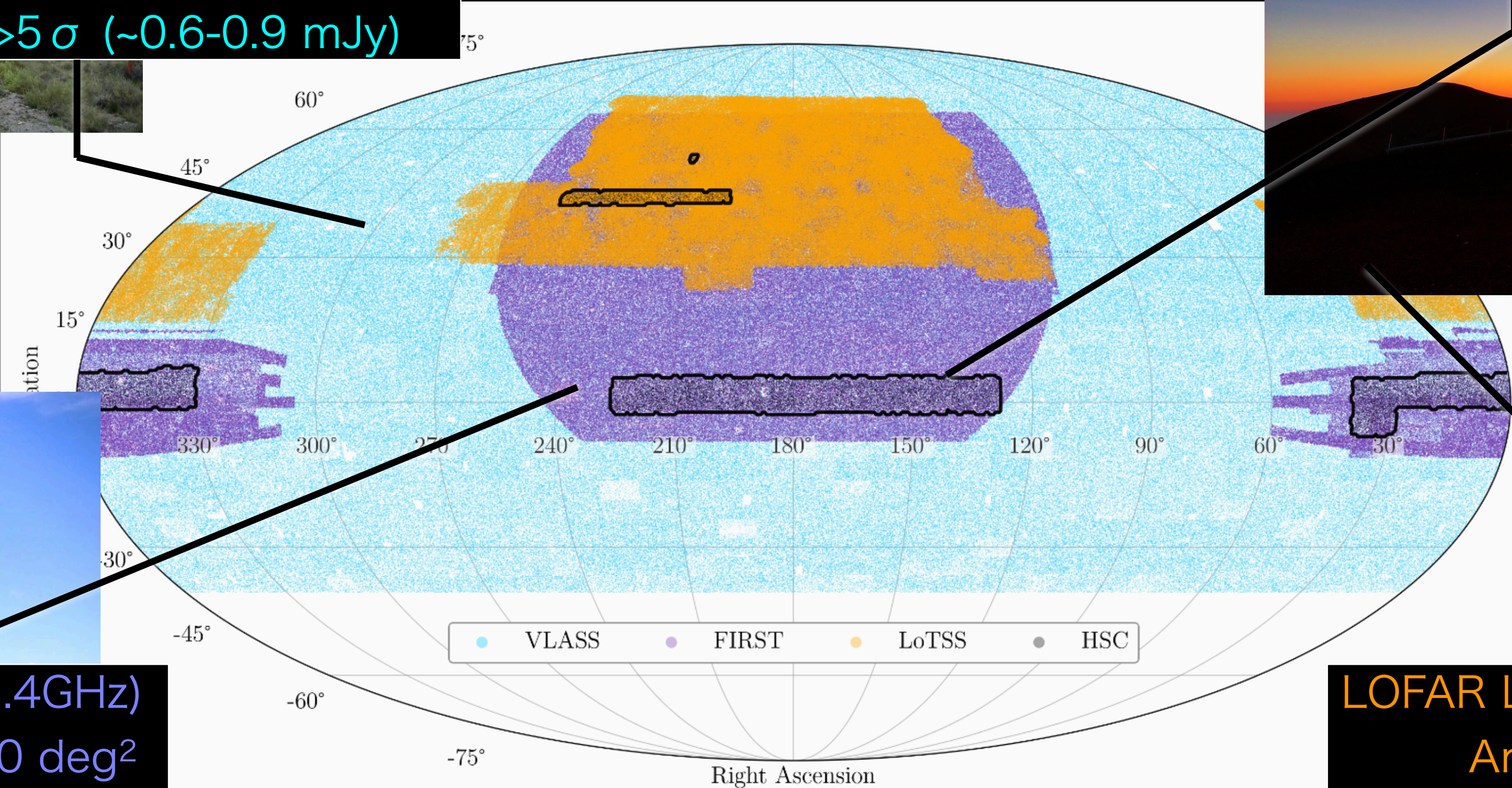


VLA VLASS (3GHz)
Area: **34,000** deg² (3 epochs)
Catalog: $>5\sigma$ (~0.6-0.9 mJy)

Subaru HSC-SSP Final DR (23B) (grizy)
Area: ~1200 deg² (Wide in Wide/Deep/UD)
Mag limit: i~26.2 (5σ , 2" aperture)



VLA FIRST (1.4GHz)
Area: ~10,000 deg²
Catalog: $>5\sigma$ (~1mJy)



LOFAR LoTSS DR2 (150MHz)
Area: ~5600 deg²
Catalog: $>5\sigma$ (~0.4mJy)

History of wide-area radio surveys (2015-)

LoFAR (144 MHz) and VLASS (3GHz) radio surveys are ongoing

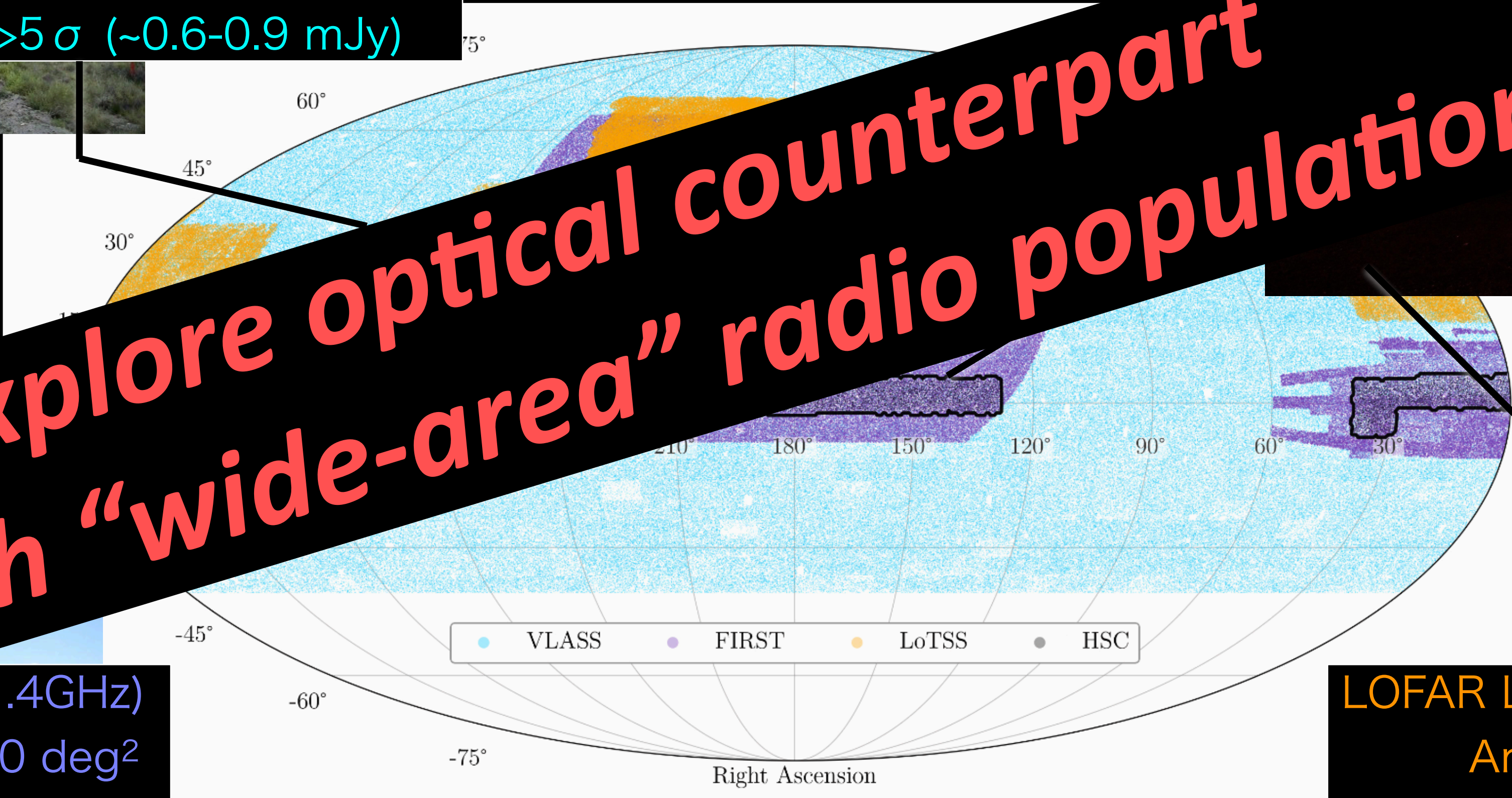


VLA VLASS (3GHz)
Area: **34,000** deg² (3 epochs)
Catalog: $>5\sigma$ (~0.6-0.9 mJy)

Subaru HSC-SSP Final DR (23B) (grizy)
Area: ~1200 deg² (Wide in Wide/Deep/UD)
Mag limit: $i\sim 26.2$ (5σ , 2" aperture)



FIRST (1.4GHz)
Area: ~10,000 deg²
Catalog: $>5\sigma$ (~1mJy)



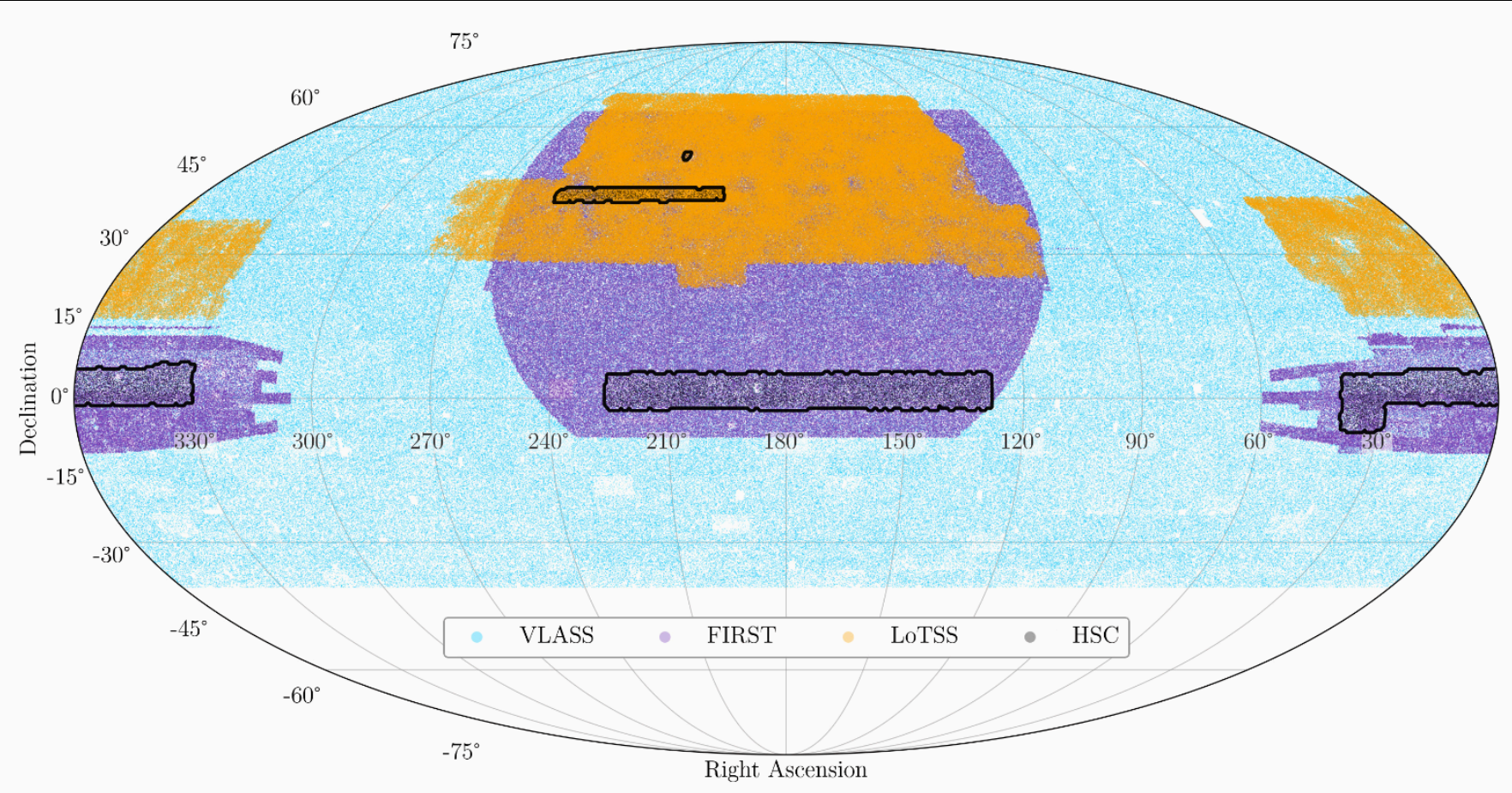
LOFAR LoTSS DR2 (150MHz)
Area: ~5600 deg²
Catalog: $>5\sigma$ (~0.4mJy)

WERGS DR2: VLASS(+FIRST+LoFAR) x HSC radio AGN



WERGS DR2 (*Uchiyama, KI+*)

22,000 sources/1200 deg²

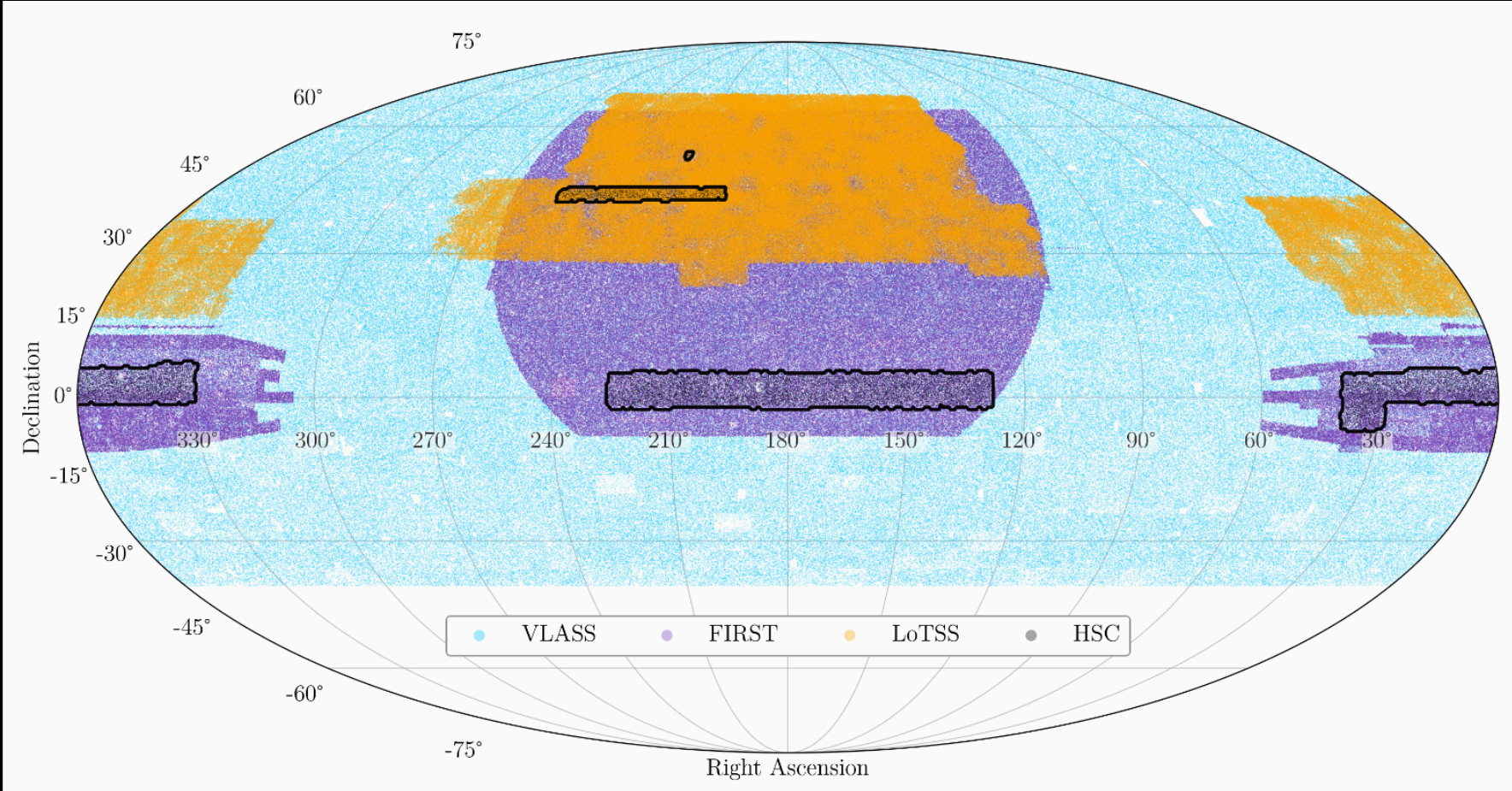


Optical counterparts: > 60%

WERGS DR2: VLASS(+FIRST+LoFAR) x HSC radio AGN

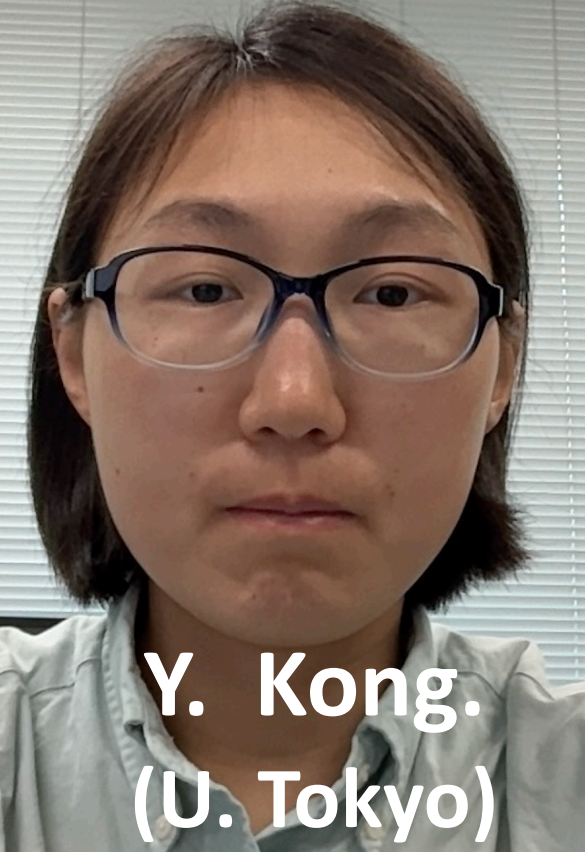
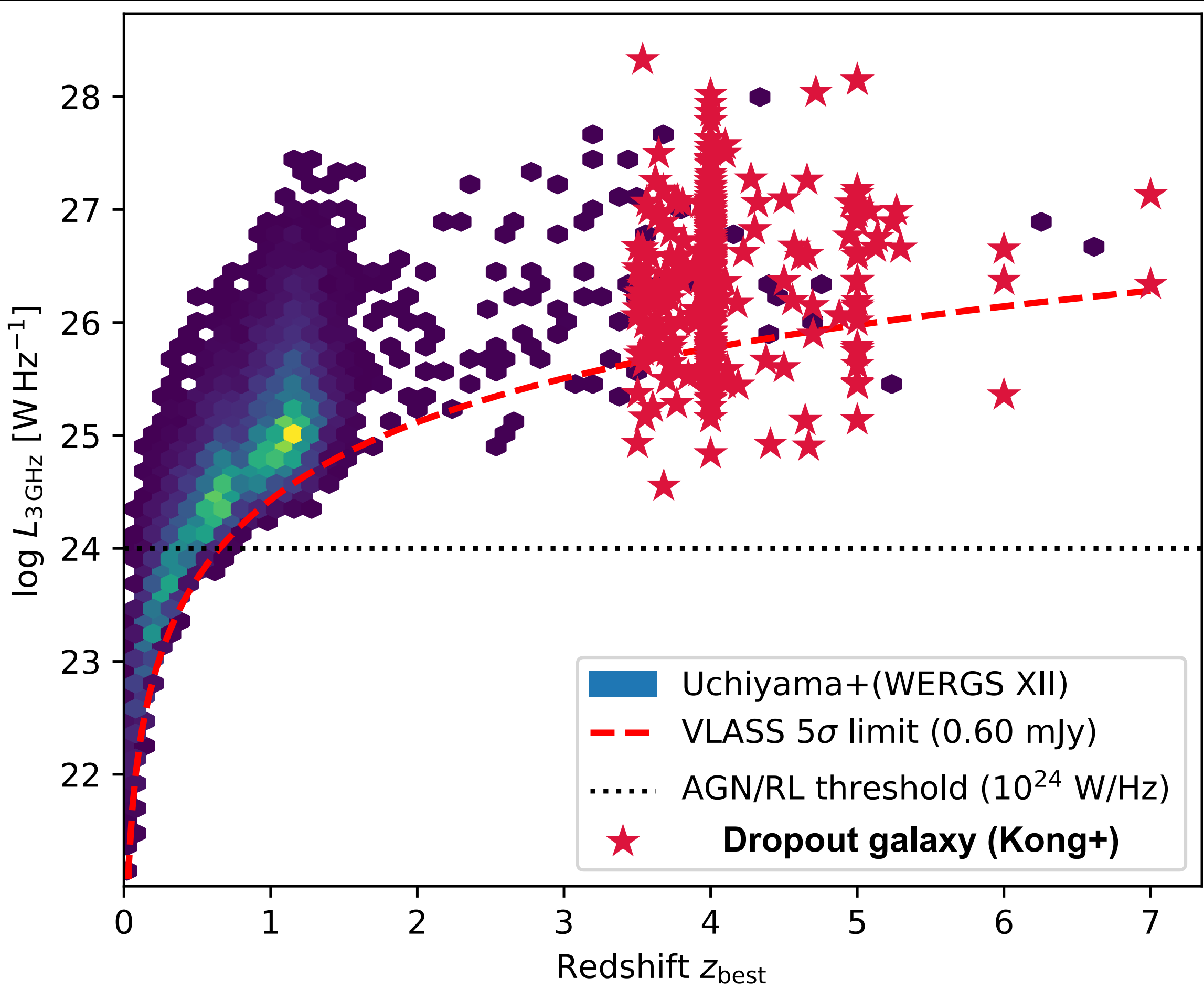


WERGS DR2 (Uchiyama, KI+)
22,000 sources/1200 deg²



Optical counterparts: > 60%

WERGS DR2: Uchiyama, KI et al. *ApJS* in press.(arXiv: 2603.27953)
Drop-out sources: Kong, KI, et al. submitted (arXiv: 2603.28044)



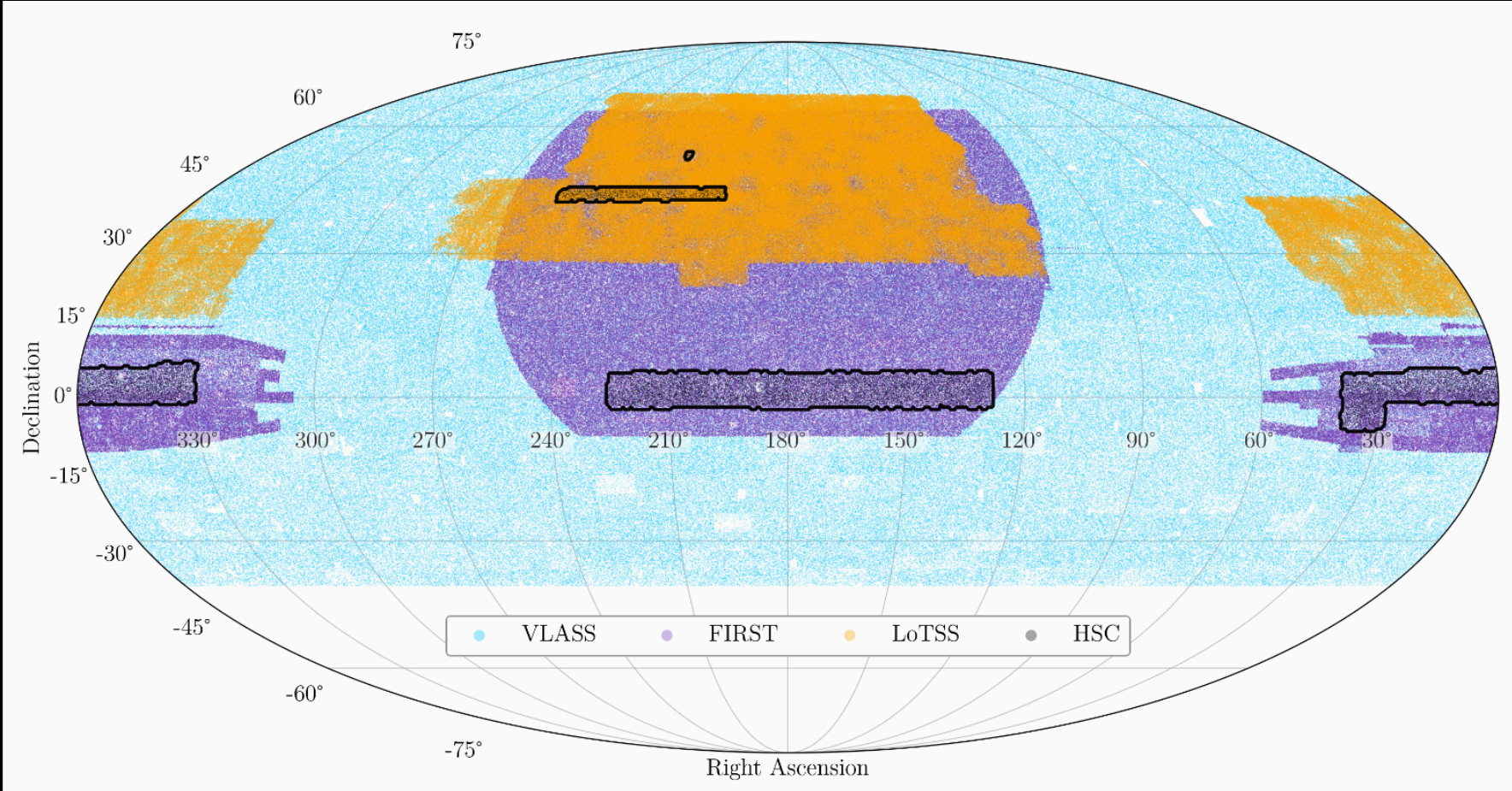
H. Uchiyama
(Hosei U.)

Y. Kong.
(U. Tokyo)

WERGS DR2: VLASS(+FIRST+LoFAR) x HSC radio AGN

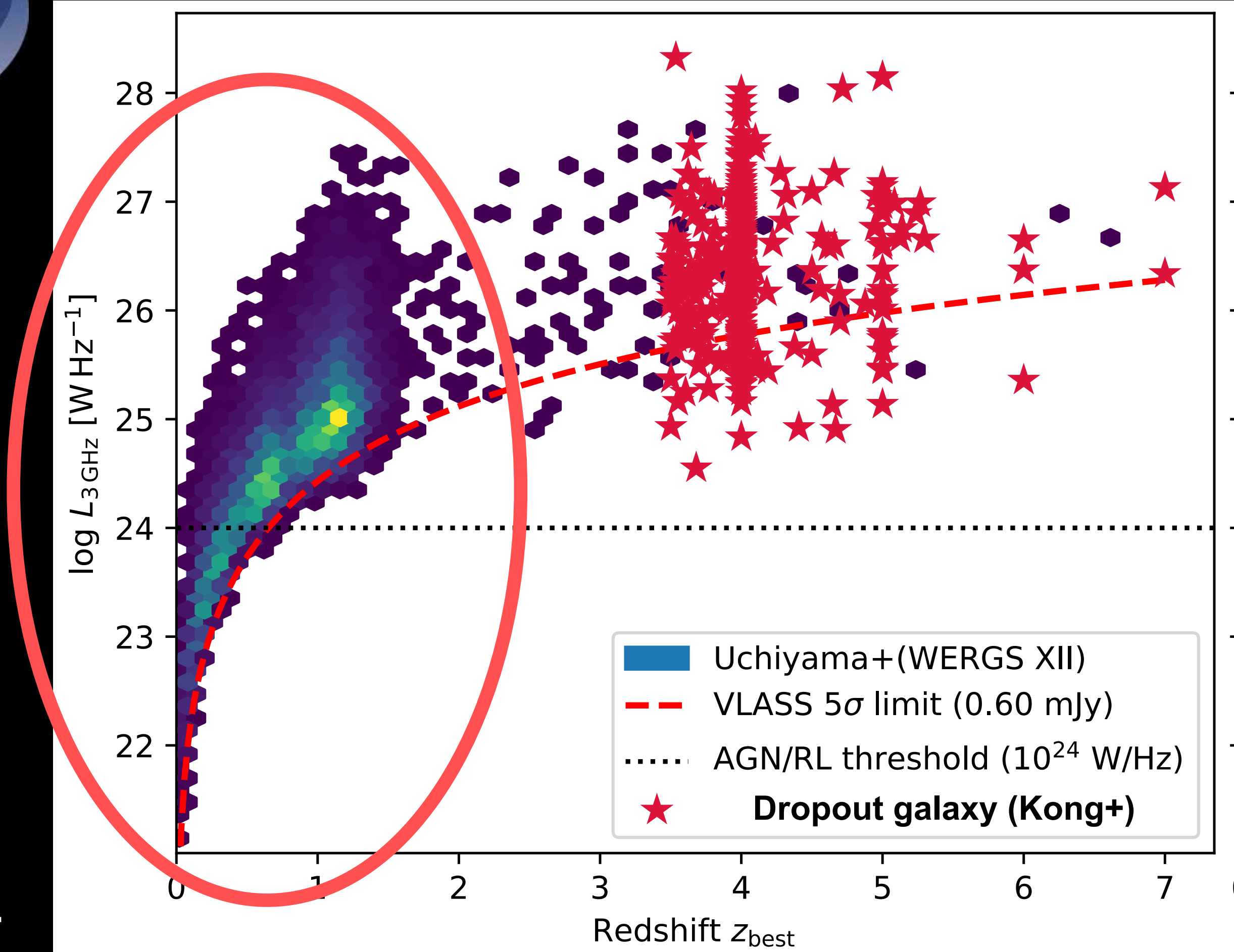


WERGS DR2 (Uchiyama, KI+)
22,000 sources/1200 deg²



Optical counterparts: > 60%

WERGS DR2: Uchiyama, KI et al. ApJS in press.(arXiv: 2603.27953)
Drop-out sources: Kong, KI, et al. submitted (arXiv: 2603.28044)



H. Uchiyama
(Hosei U.)

Y. Kong.
(U. Tokyo)

*Low-z radio-loud AGN (0.5<z<1.5)
=> What properties do they have?*

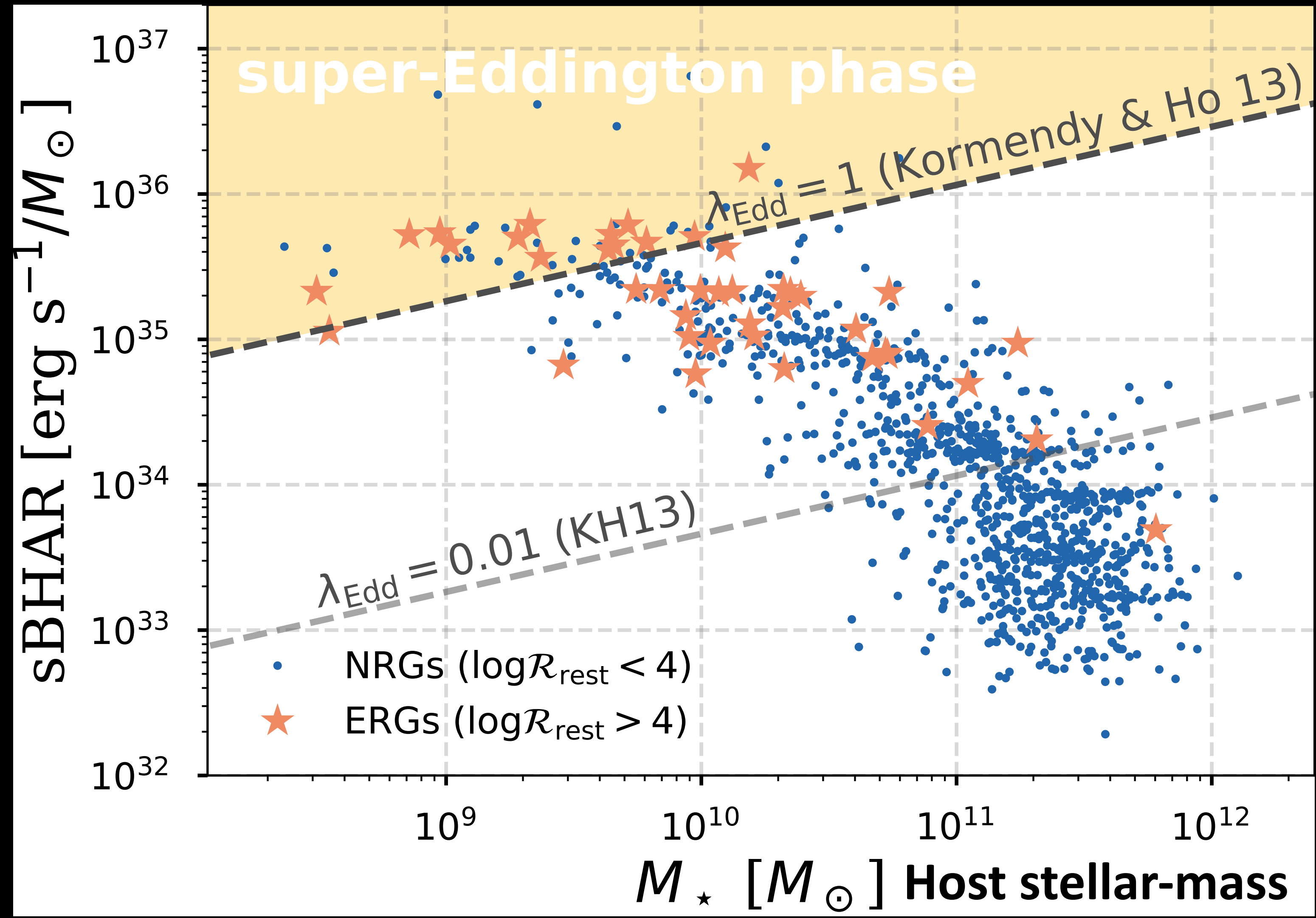
BH properties of WERGS: sBHAR($\sim \lambda_{\text{Edd}}$) vs. M_*

☑ specific BH Accretion Rate (sBHAR)= L_{AGN}/M_* $\propto L_{\text{AGN}}/M_{\text{BH}}$: (rough) indicator of λ_{Edd}

BH accretion rate

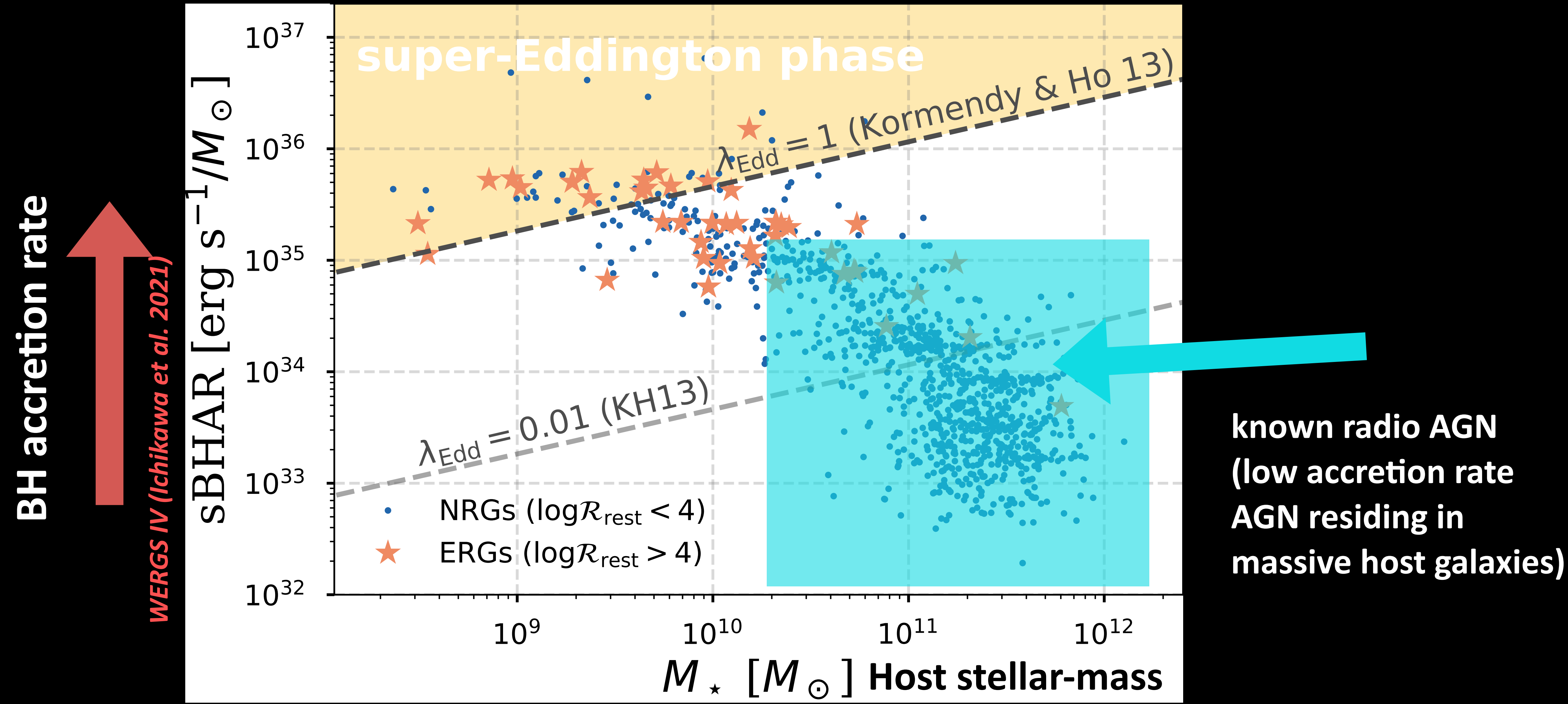
↑

WERGS IV (Ichikawa et al. 2021)



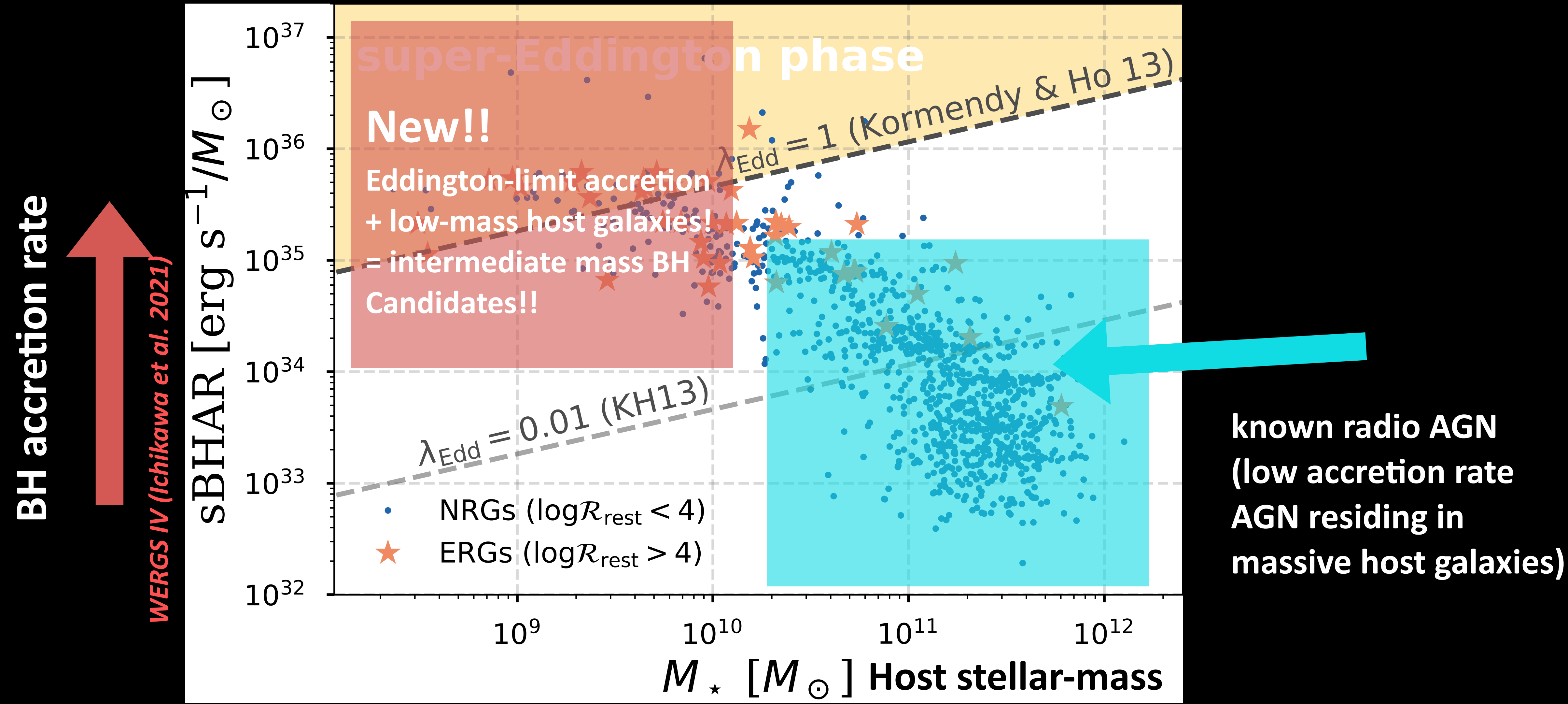
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SMBH properties of WERGS: sBHAR($\sim \lambda_{\text{Edd}}$) vs. M_*

☑ specific BH Accretion Rate (sBHAR)= L_{AGN}/M_* $\propto L_{\text{AGN}}/M_{\text{BH}}$: (rough) indicator of λ_{Edd}



New “intermediate” mass ($M_{\text{BH}} < 10^6 M_{\text{Sun}}$) BH candidates!

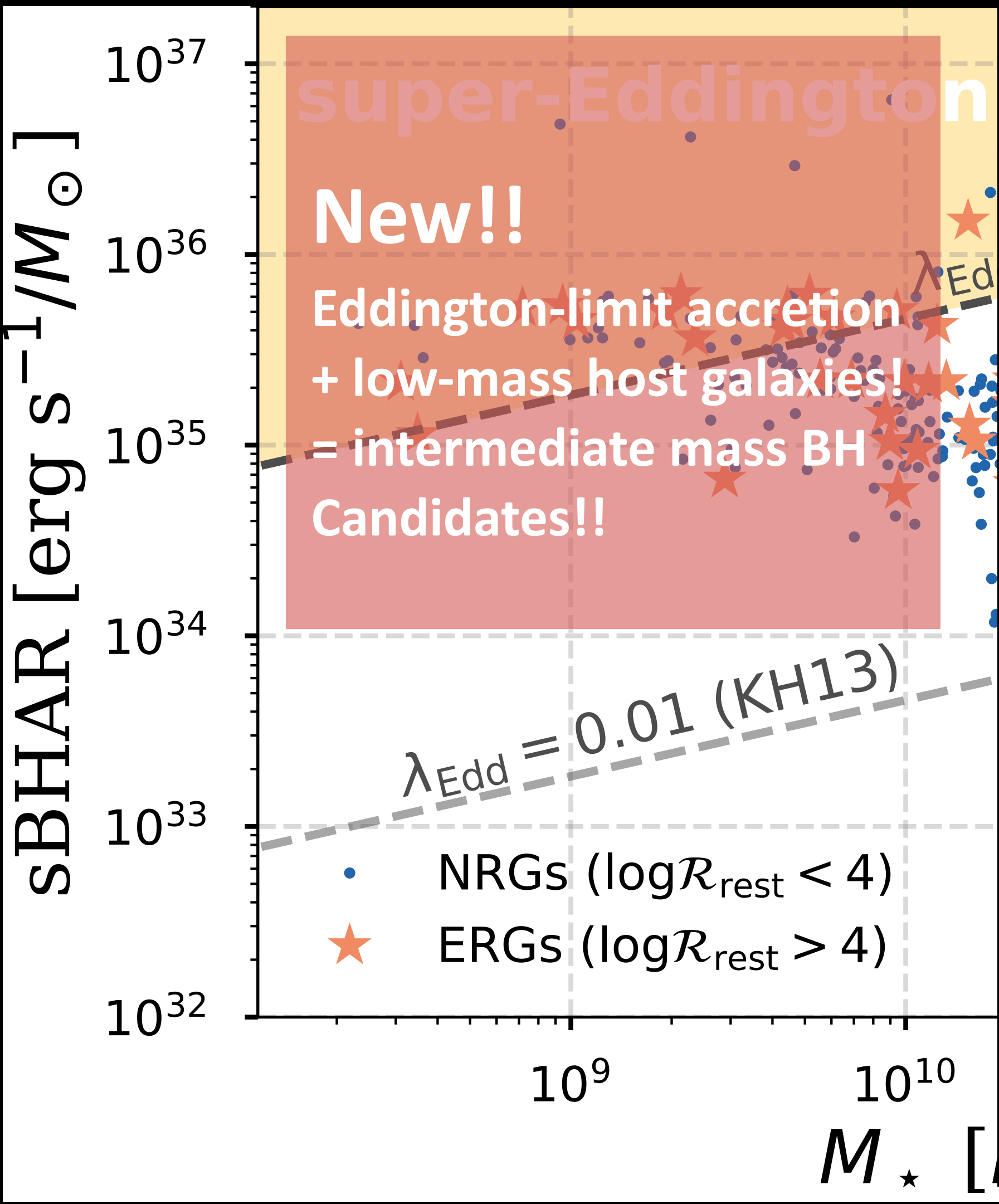
SMBH properties of WERGS: sBHAR($\sim$

☑ specific BH Accretion Rate (sBHAR)= L_{AGN}/M

BH accretion rate

↑

WERGS IV (Ichikawa et al. 2021)

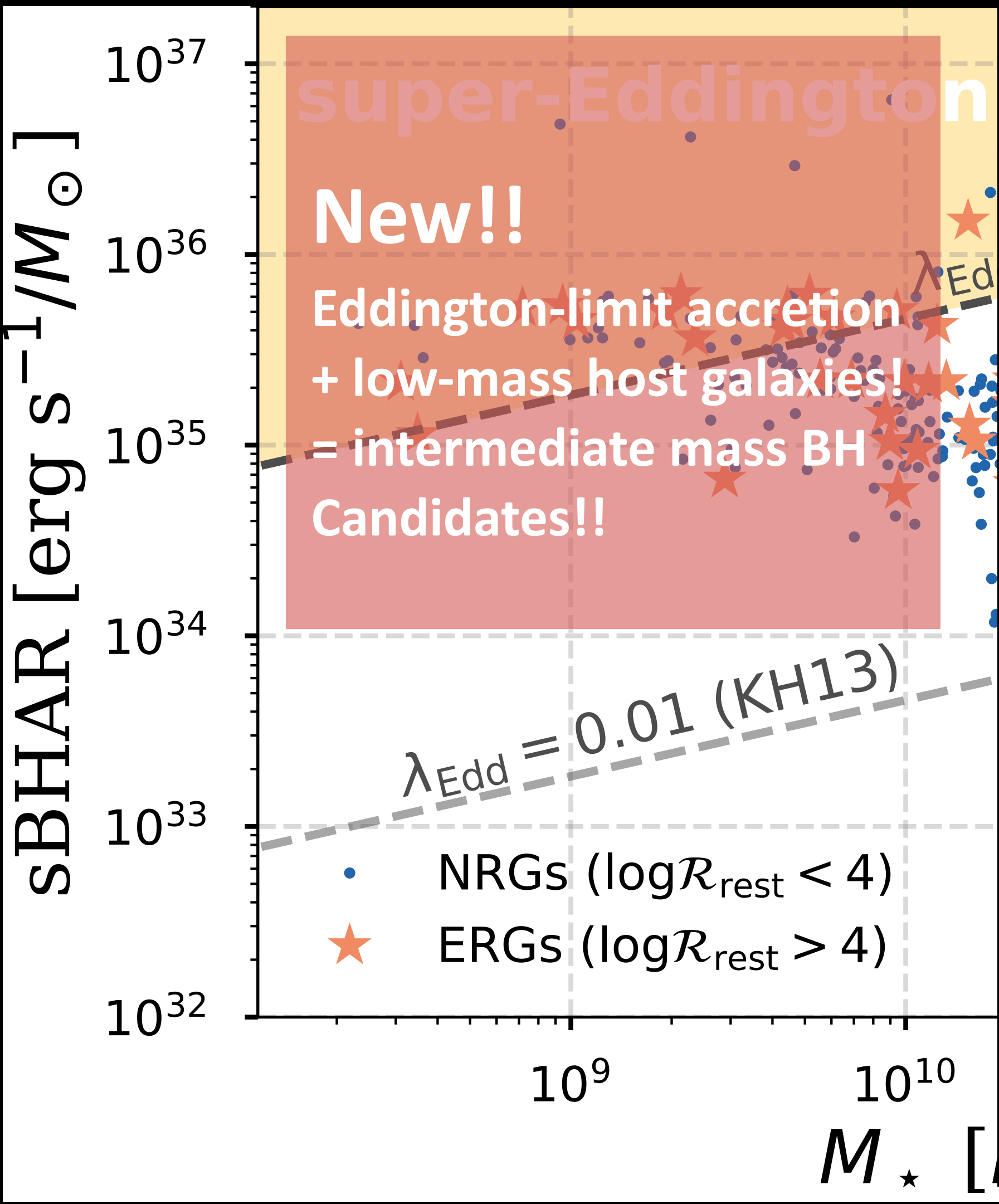


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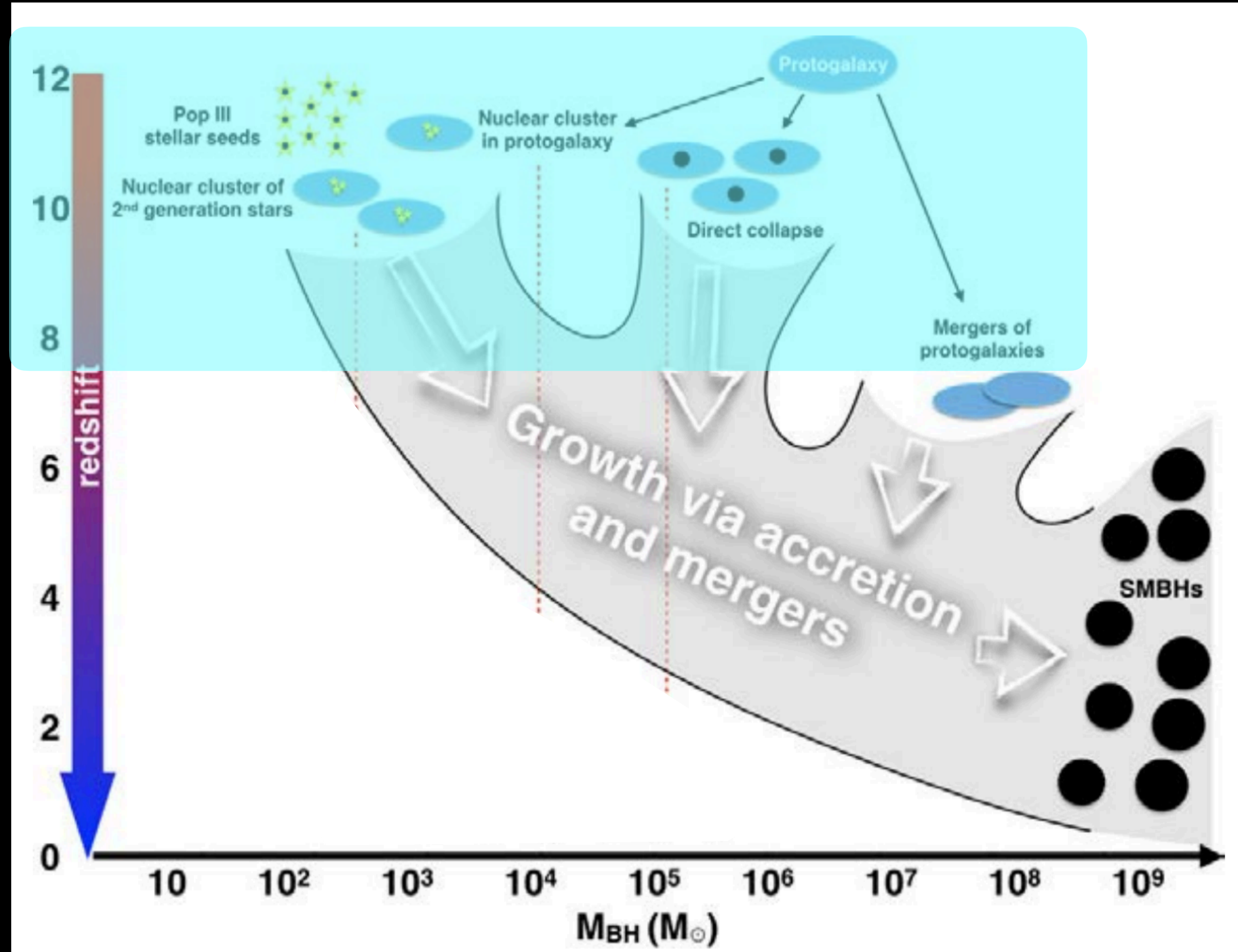
BH accretion rate
↑
WERGS IV (Ichikawa et al. 2021)



Most are $i > 24$ mag => TMT will unveil M_{BH} of inter-mediate mass BH for the first-time!!

New pathway to search massive BHs

1st gen.
BH growth

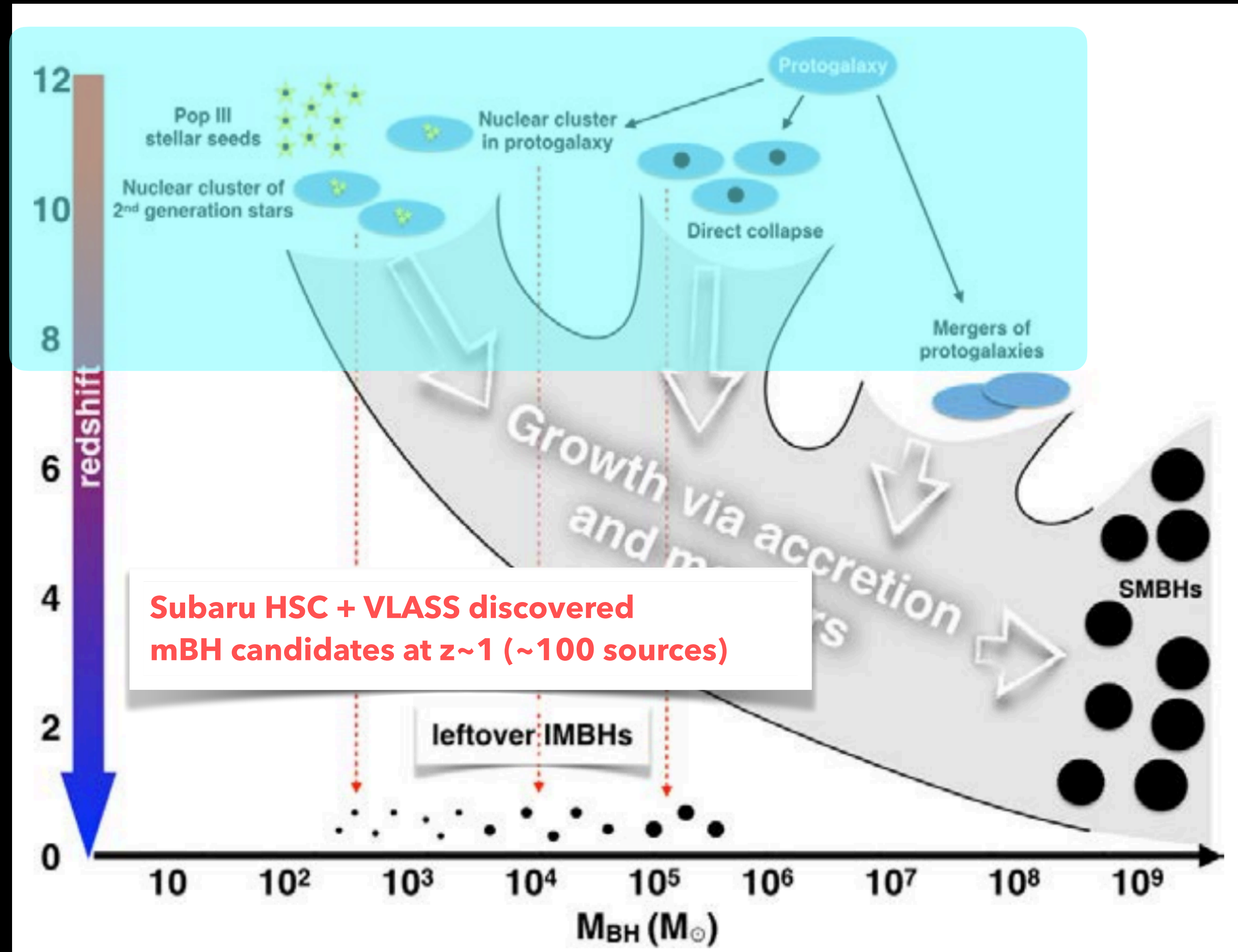


New pathway to search massive BHs

optical+Radio survey reveals rapidly growing mBHs in dwarf galaxies!

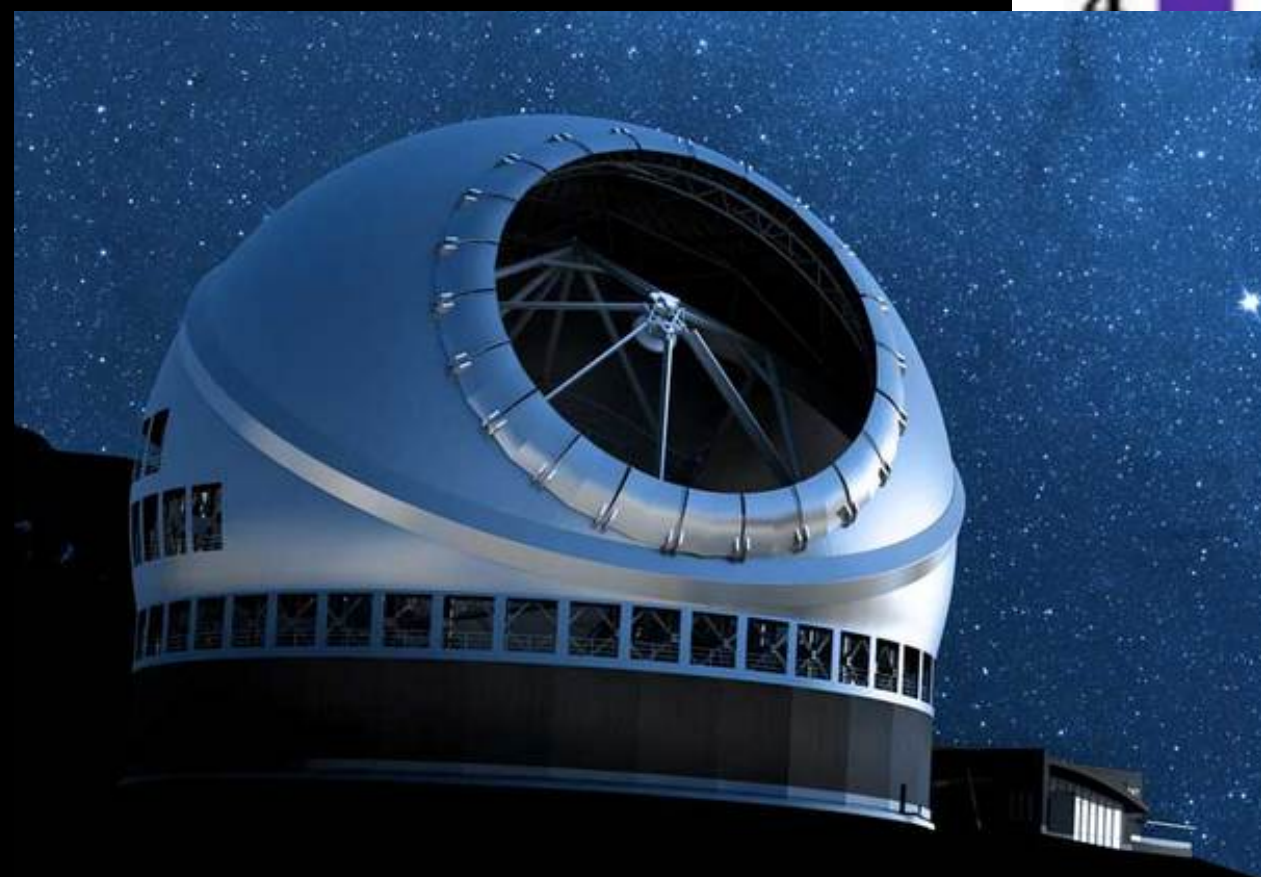
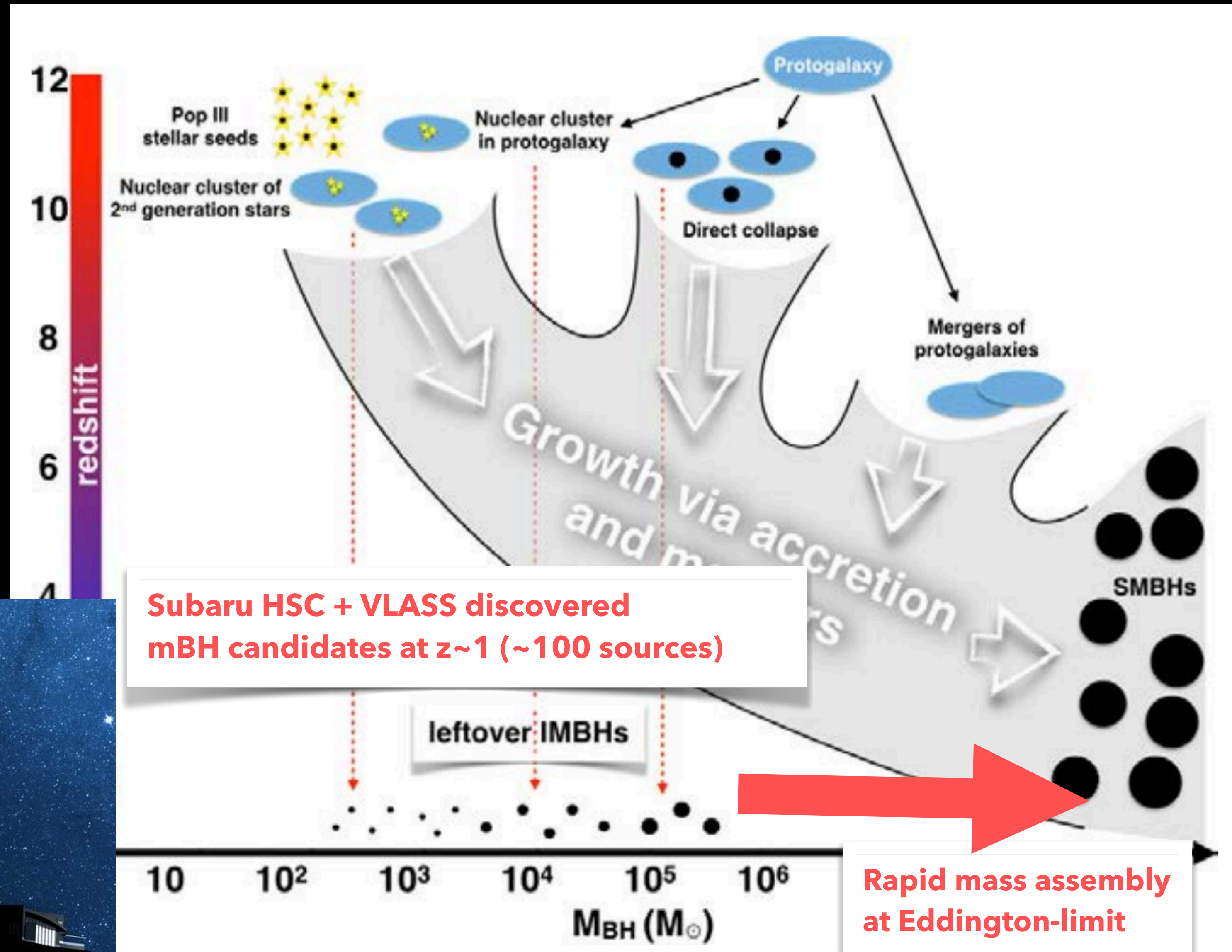
1st gen.
BH growth

Leftover
IMBHs?



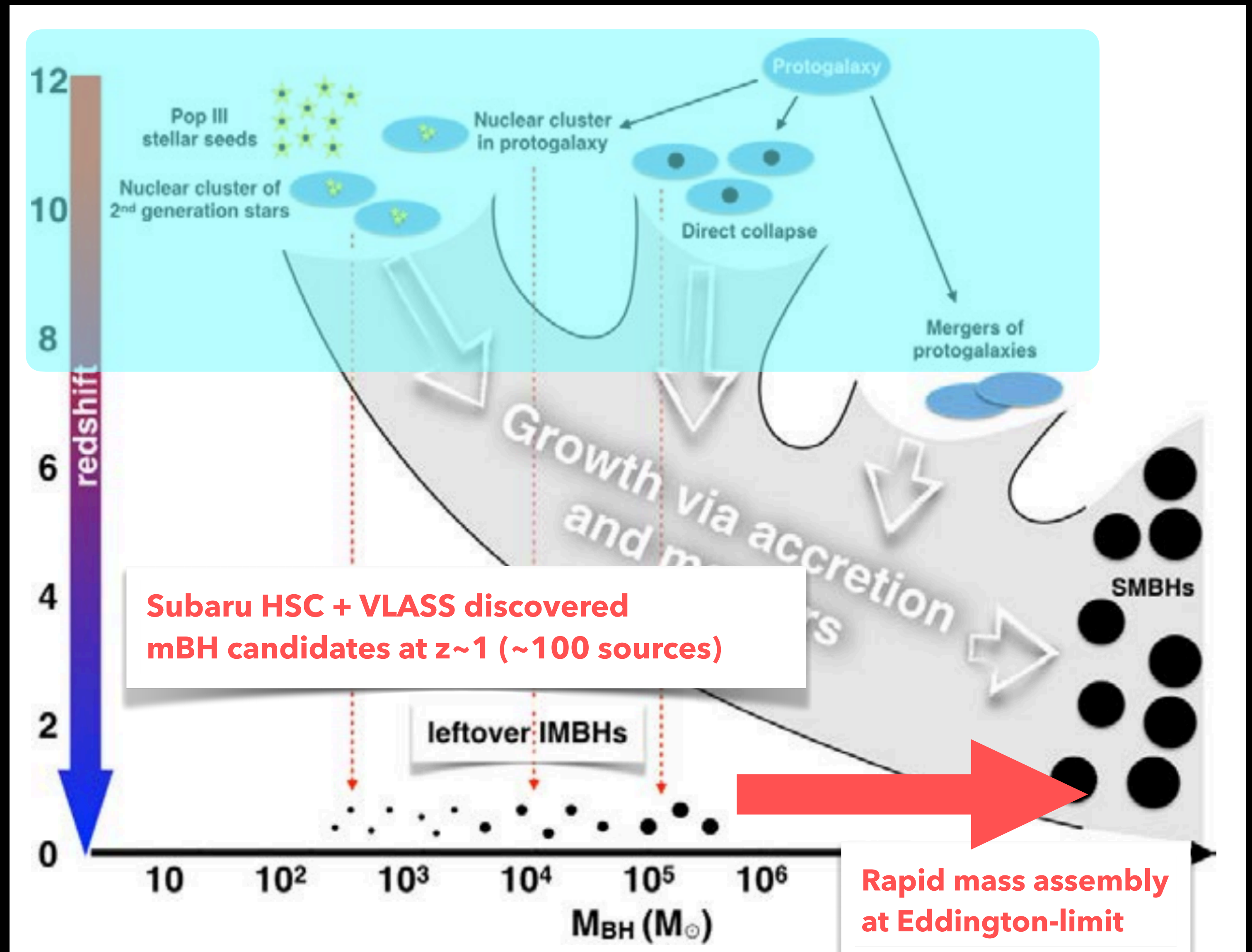
New pathway to search massive BHs, and they are rapidly growing!

optical+Radio survey reveals rapidly growing mBHs in dwarf galaxies!



Next step... To Little Red Dots (LRDs)

No hope
for finding
“first” BHs?





Little Red Dots (LRDs)

Little Red Dots (LRDs): popular source after JWST launch

ADS text search result as of August 18th, 2026

QUICK FIELD: [Author](#) [First Author](#) [Abstract](#) [Year](#) [Fulltext](#) [All](#)

full:"Little Red Dots"

Little Red Dots (LRDs): popular source after JWST launch

ADS text search result as of August 18th, 2026

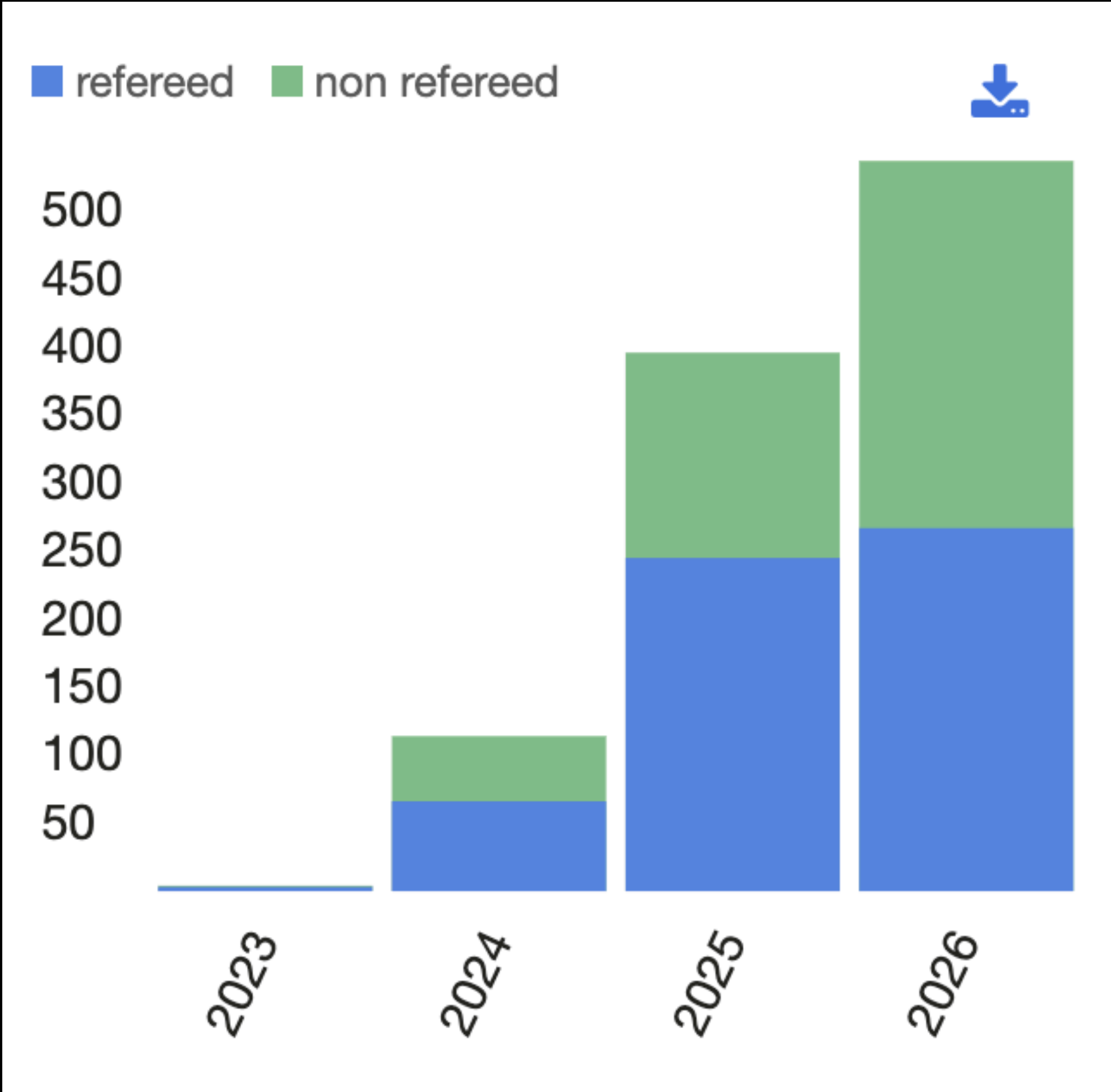
QUICK FIELD: [Author](#) [First Author](#) [Abstract](#) [Year](#) [Fulltext](#) [All](#)

full:"Little Red Dots"

Your search returned **1,054** results

Little Red Dots (LRDs): popular source after JWST launch

ADS text search result as of August 18th, 2026



LRDs become popular since 2023/2024, report by JWST
Now 500 paper/8month => 16 papers mention about LRDs/week

Little Red Dots (LRDs): popular source after JWST launch

Top cited papers in 2025 (ApJ/L)

Top Cited
The Rise of Faint, Red Active Galactic Nuclei at $z > 4$: A Sample of Little Red Dots in the JWST Extragalactic Legacy Fields Dale D. Kocevski <i>et al</i> 2025 <i>ApJ</i> 986 126
Extremely Dense Gas around Little Red Dots and High-redshift Active Galactic Nuclei: A Nonstellar Origin of the Balmer Break and Absorption Features Kohei Inayoshi and Roberto Maiolino 2025 <i>ApJL</i> 980 L27
Status Report on the Chicago-Carnegie Hubble Program (CCHP): Measurement of the Hubble Constant Using the Hubble and James Webb Space Telescopes Wendy L. Freedman <i>et al</i> 2025 <i>ApJ</i> 985 203
RUBIES: JWST/NIRSpec Confirmation of an Infrared-luminous, Broad-line Little Red Dot with an Ionized Outflow Bingjie Wang <i>et al</i> 2025 <i>ApJ</i> 984 121
JWST, ALMA, and Keck Spectroscopic Constraints on the UV Luminosity Functions at $z \sim 7\text{--}14$: Clumpiness and Compactness of the Brightest Galaxies in the Early Universe Yuichi Harikane <i>et al</i> 2025 <i>ApJ</i> 980 138



Little Red Dots (LRDs): popular source after JWST launch

Top cited papers in 2025 (ApJ/L)

3/5 are the papers on LRDs



Top Cited
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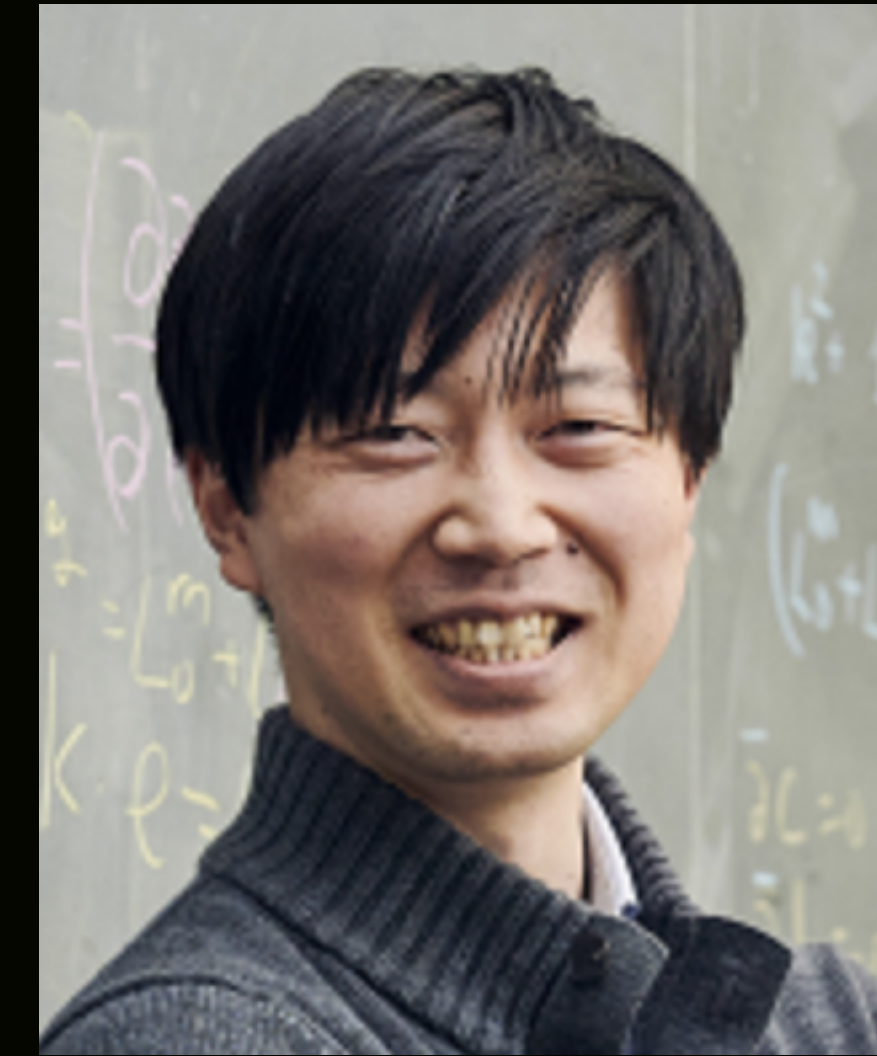
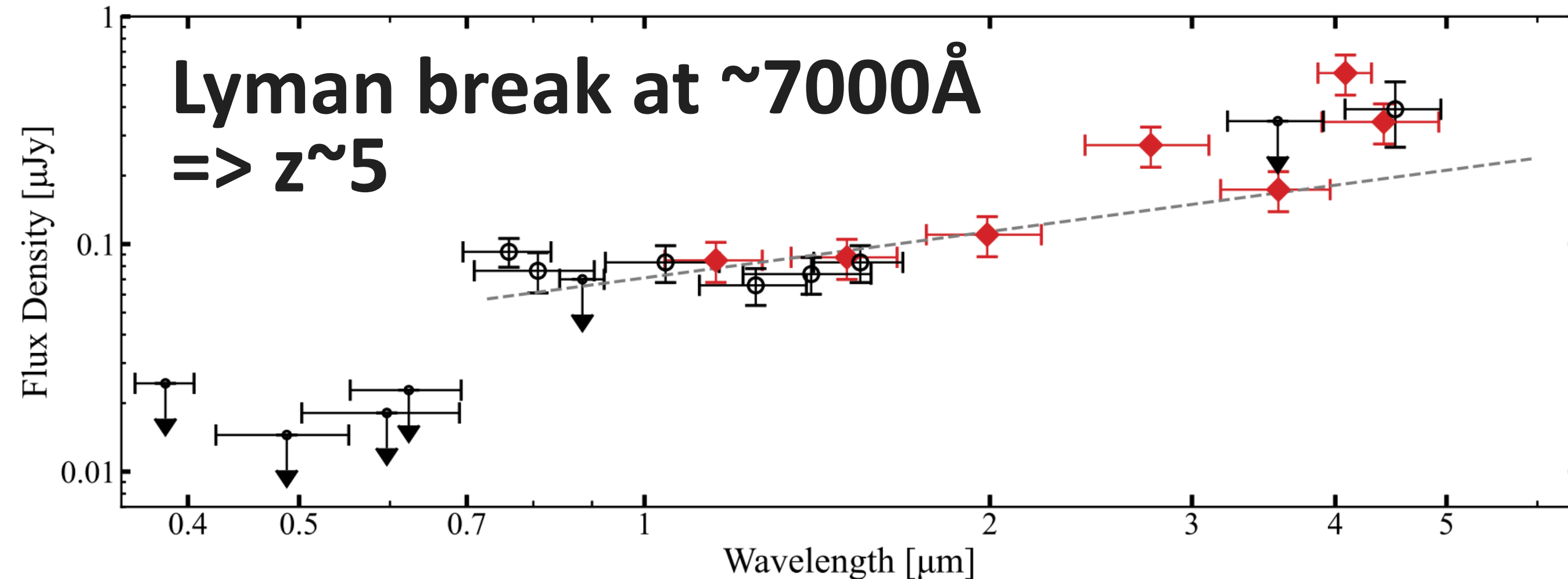
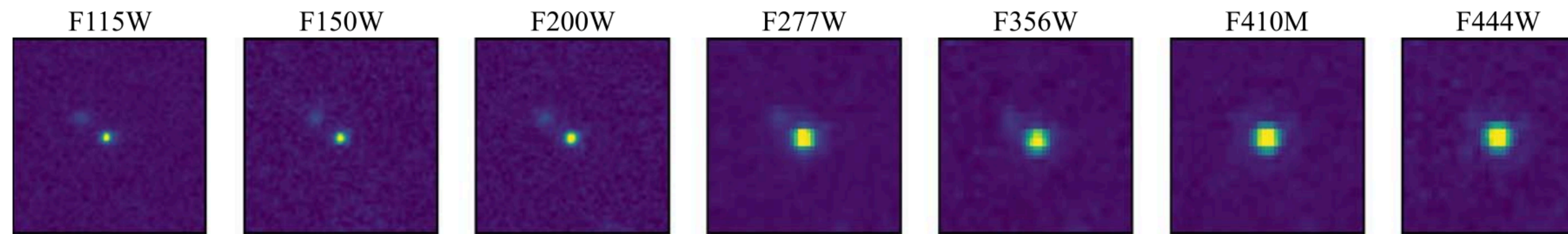
Galaxies and Cosmology

What are LRDs?

Discovery of compact (and red) sources

1. Very compact (<100 pc at $z \sim 5$)

Onoue+ in CEERS field (<0.1 deg²)!



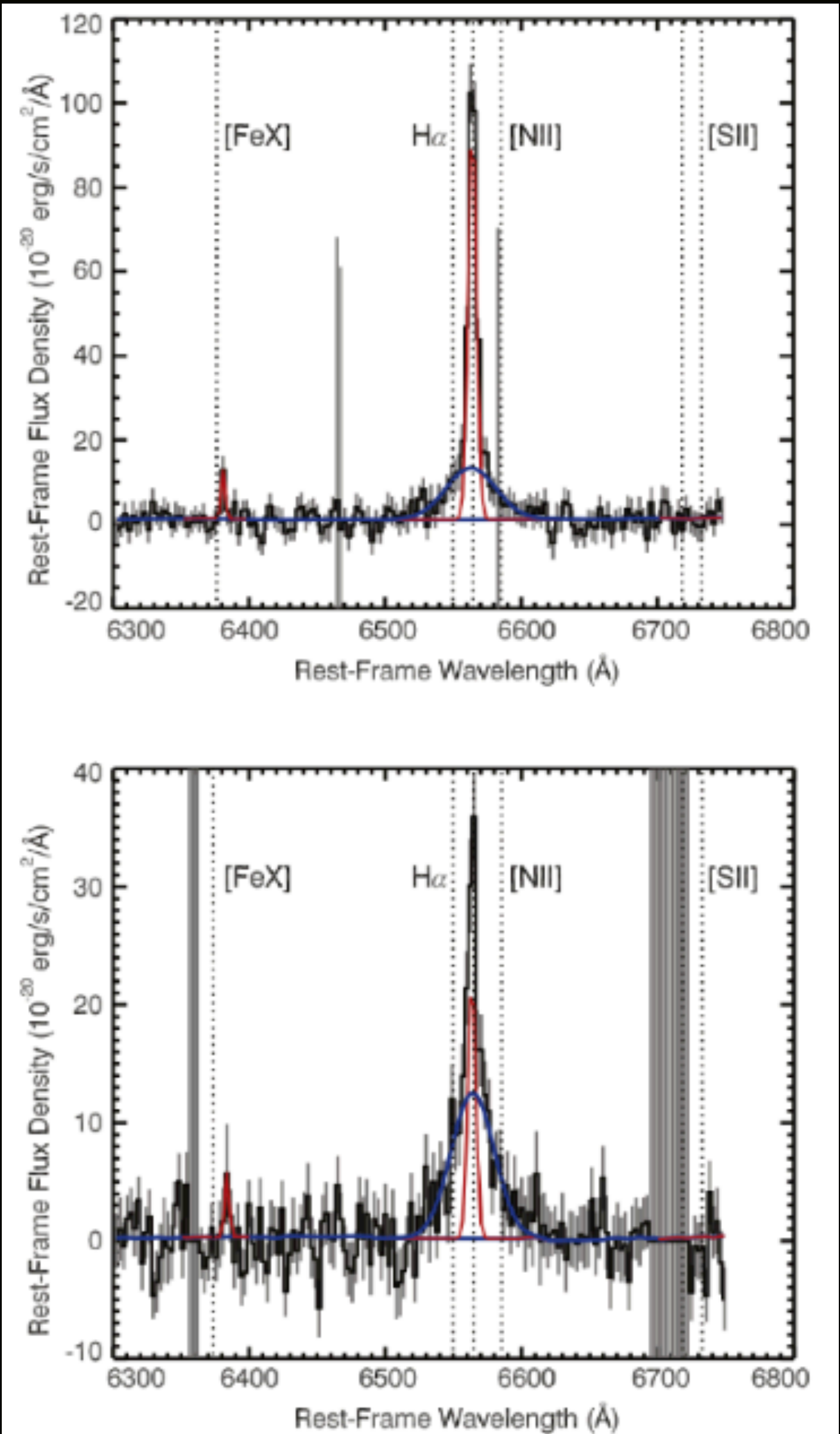
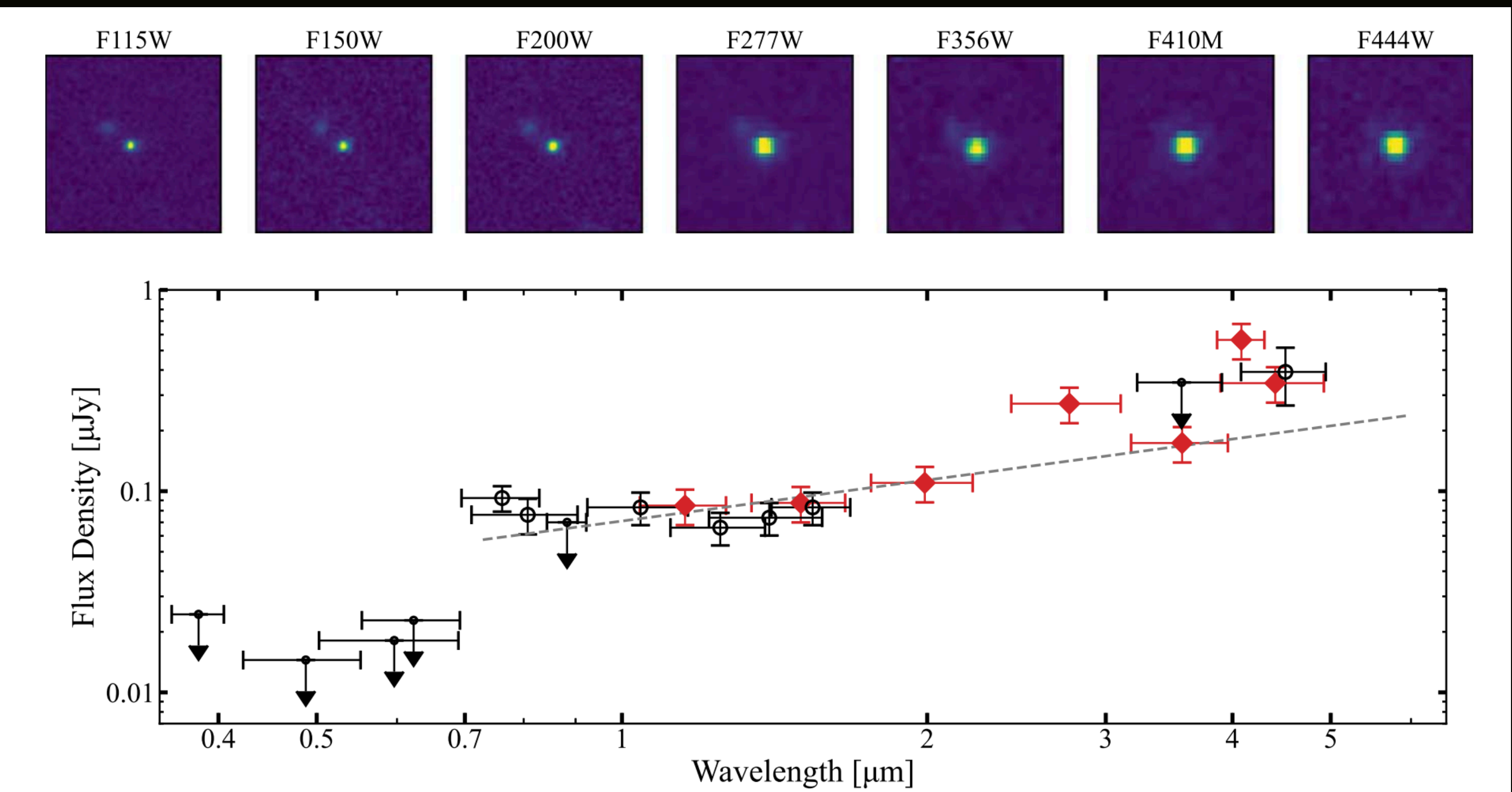
M. Onoue (Waseda U)
He found this source during
quarantine at hotel in Beijing

JWST can spatially resolve galaxies if they locate at $z \sim 5$
 $\Rightarrow$ AGN? (or, very compact nuclear starburst?)

Discovery of compact (and red) sources => AGN

1. Very compact (<100 pc at $z \sim 5$)

Onoue+ in CEERS field (<0.1 deg²)!

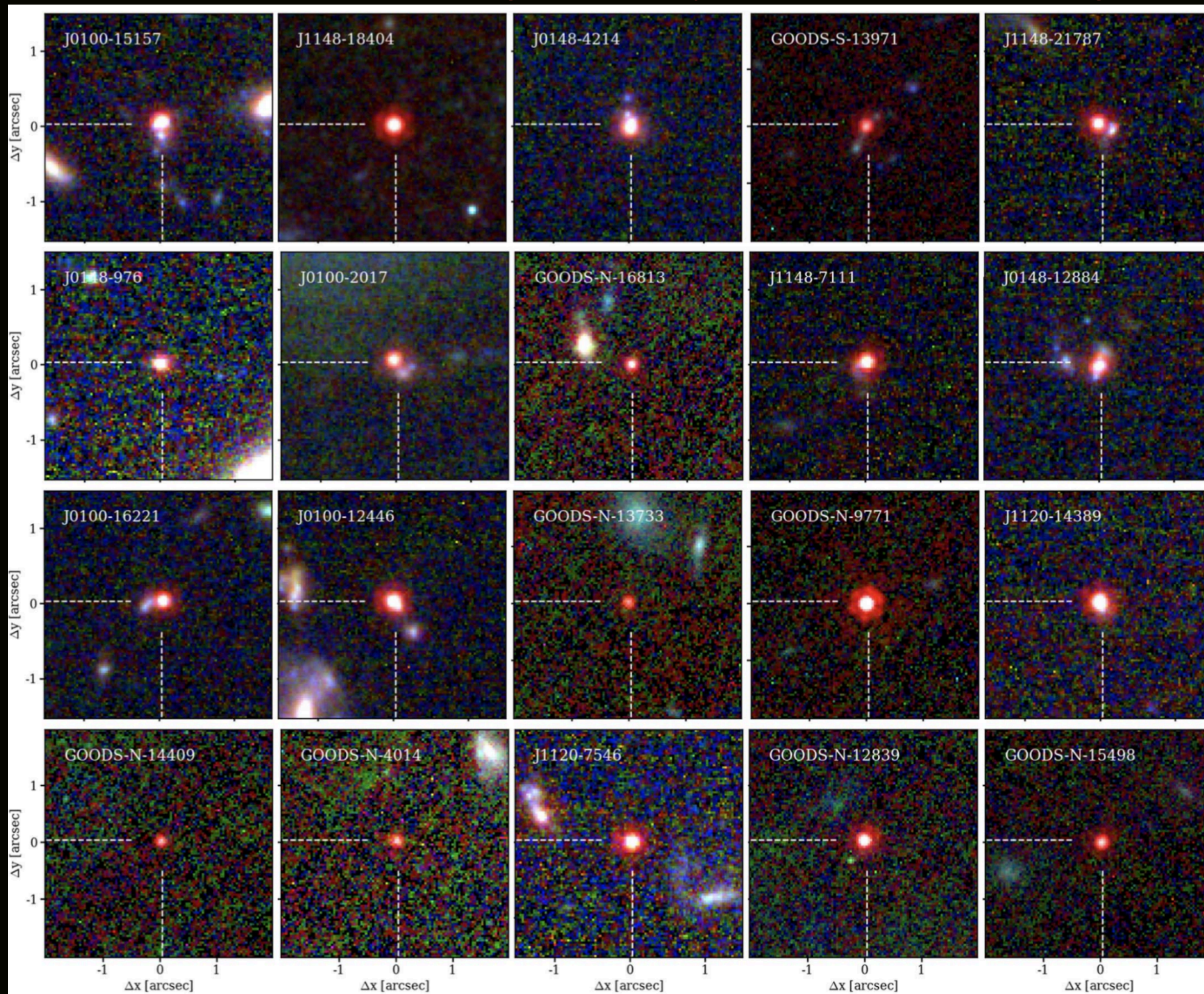


JWST can spatially resolve galaxies
If they locate at $z \sim 5$ => AGN!!

Little Red Dots: JWST compact + red color

1. Very compact (<100 pc at $z \sim 5$)

Matthee+24 (see also Labbe+23, original studies from Onoue+23) in <0.1 deg² area!



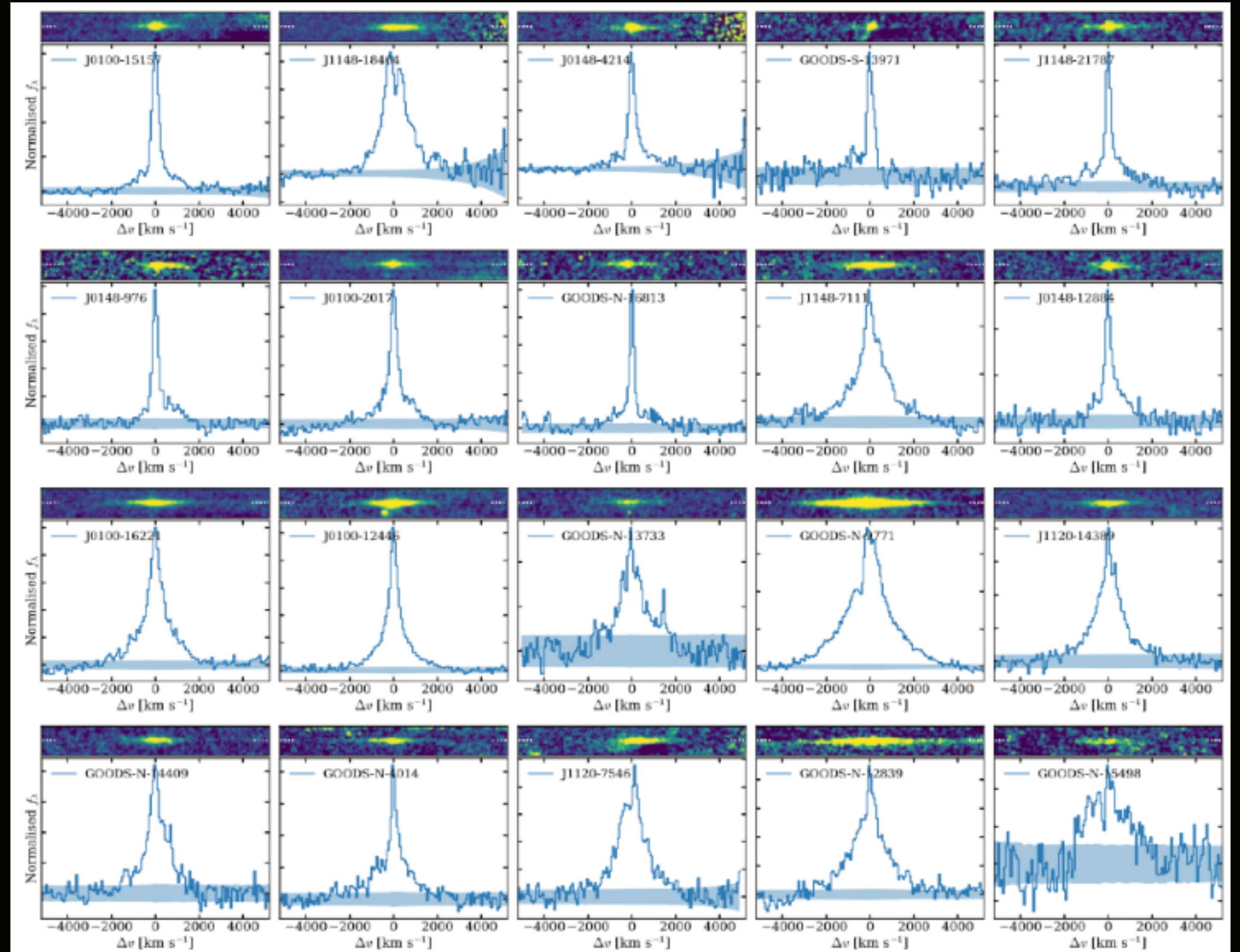
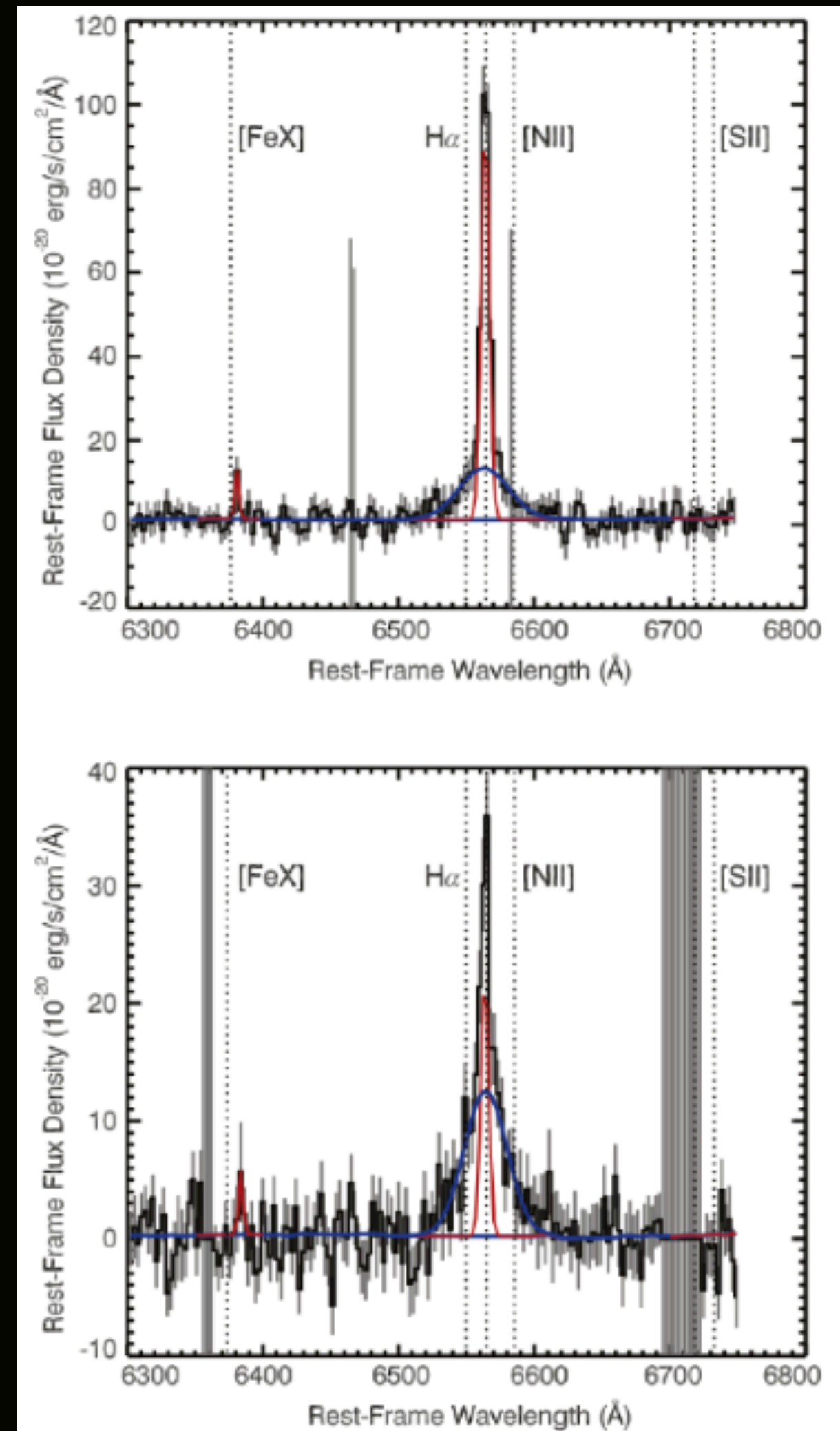
Key point:

They are discovered in JWST fields
w/ ~ 100 arcmin² ~ 0.03 deg²
(Very small fields...!!)

=> If all LRDs are AGN,
too many SMBHs!

Little Red Dots have Balmer broad emissions => Likely AGN

Detection rate of Balmer broad lines (BLR): **>80%** with low-Res. Prism ($R \sim 100-500$)
(e.g., Greene+24)



Kocevski+23 (see also Onoue+23)

Matthee+24 (see also Harikane+23)

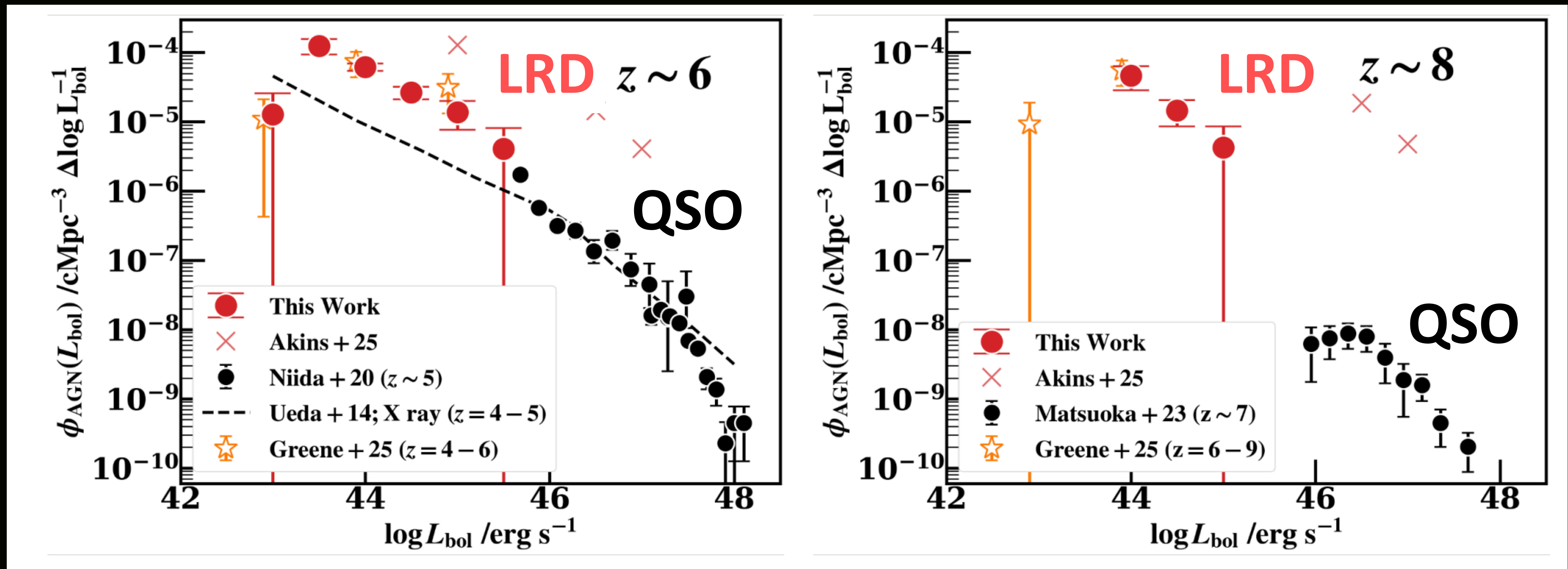
Too many SMBHs are confirmed... But how many...?

Too many Little Red Dots at $z \geq 5$

$N_{\text{LRD}} \sim 1000$ sources, $n_{\text{LRD}} \sim 1\text{-}10\%$ of whole LBGs ($n_{\text{LRD}} \sim 10\text{-}1000 n_{\text{QSO}}$)

$n_{\text{LRD}} \sim 10 n_{\text{X-ray,AGN}}$ (Giallongo+19)

Compiling Umeda+24 (see also Greene+23, Kocevski+23, Matthee+23, Akins+2024, Kokorev+24)

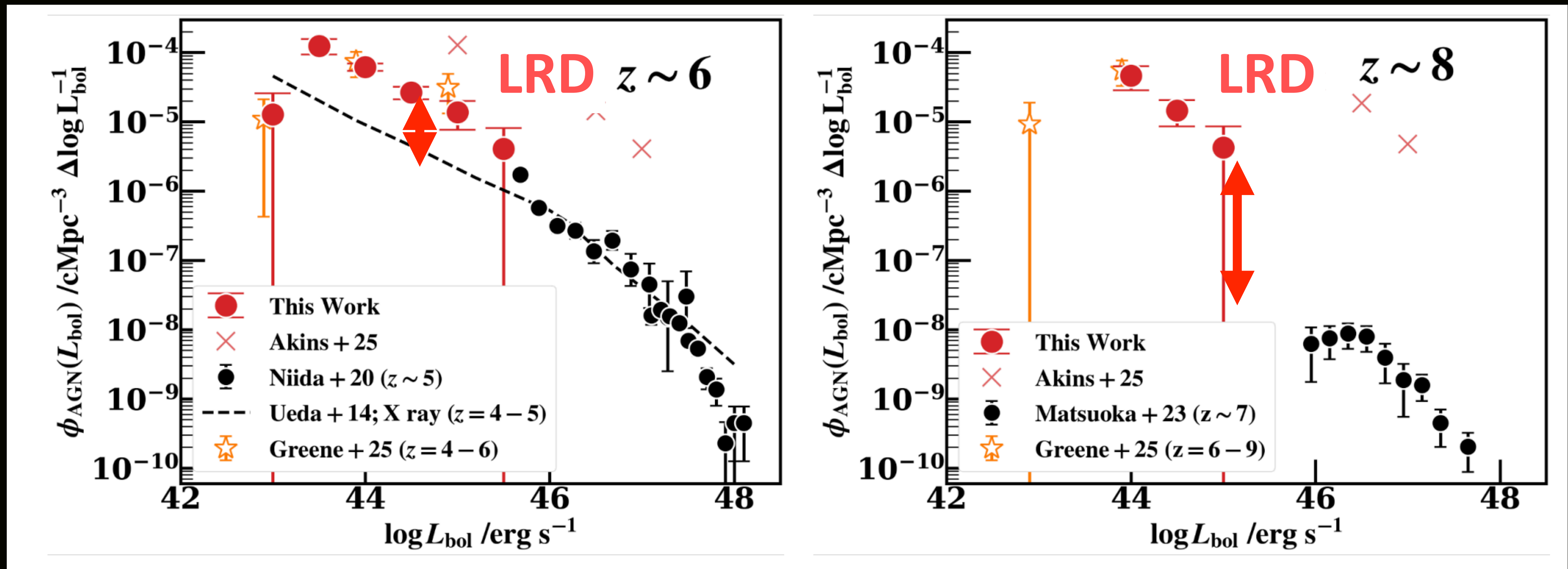


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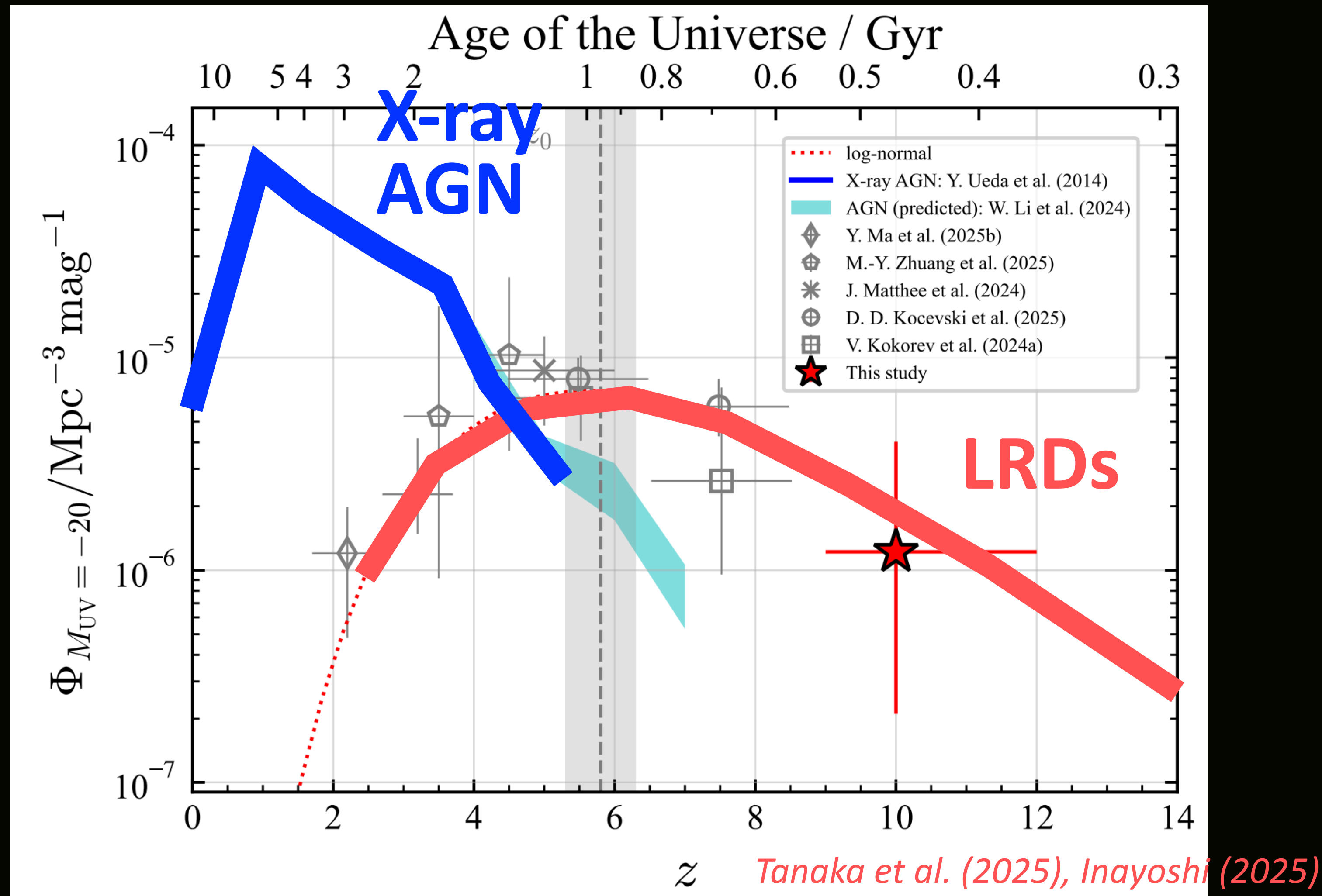
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Compiling Umeda+24 (see also Greene+23, Kocevski+23, Matthee+23, Akins+2024, Kokorev+24)



Gap btw. LRDs and QSOs increase w/ redshift

Number density of LRDs show a peak at $z \sim 7-8$

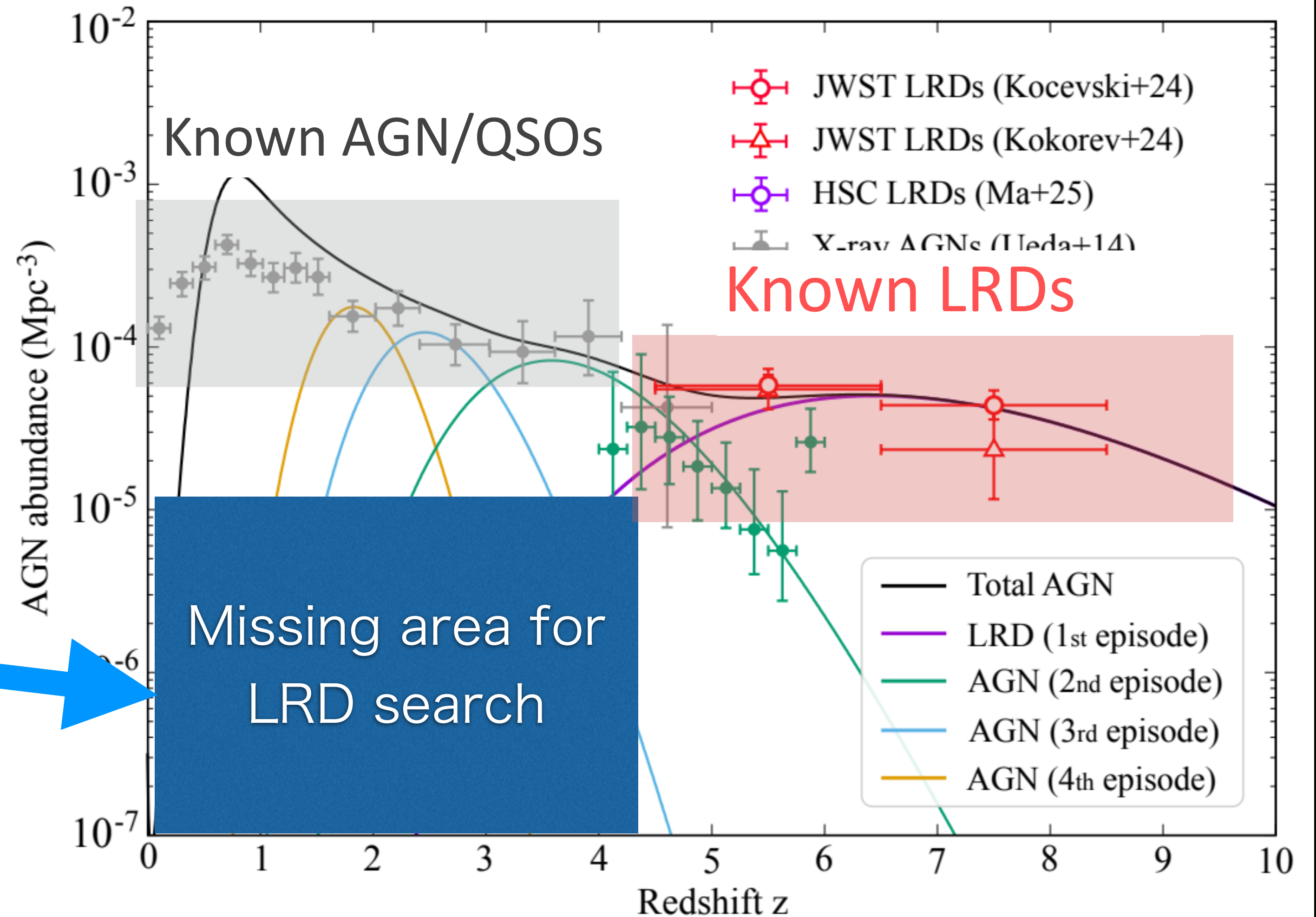


1. LRDs are more abundant than AGN/QSO at $z > 5$, peaked at $z \sim 7-8$
2. LRD can exist only in high- z , and shows a possible cut off at $z < 5 \Rightarrow$ 1st generation BH growth?

How do LRDs evolve across cosmic time?

Early LRD search suggests LRD/AGN fraction would decrease exponentially at $z < 5$

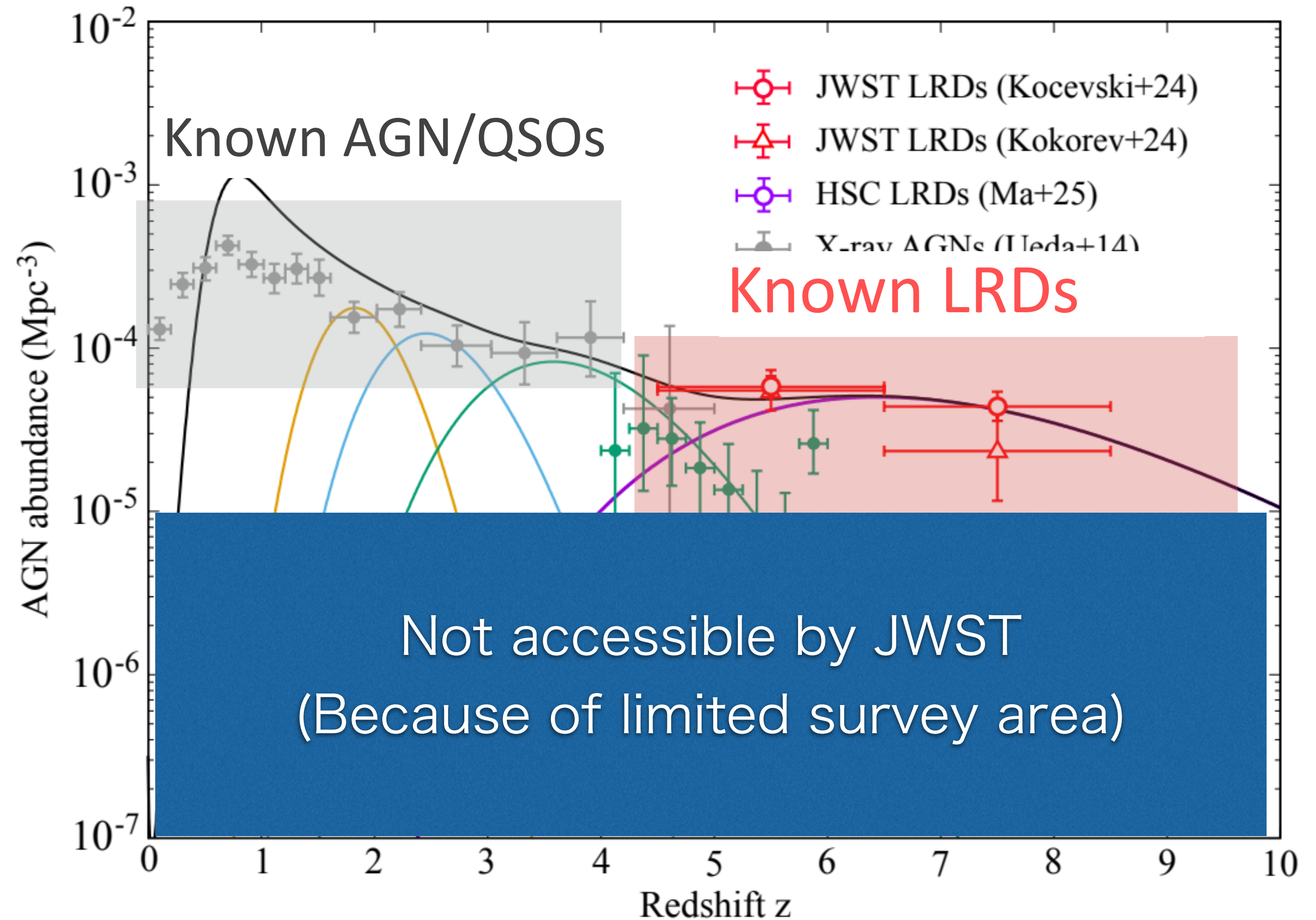
We want to know here



How do LRDs evolve across cosmic time?

LRD/AGN fraction would decrease exponentially at $z < 5$

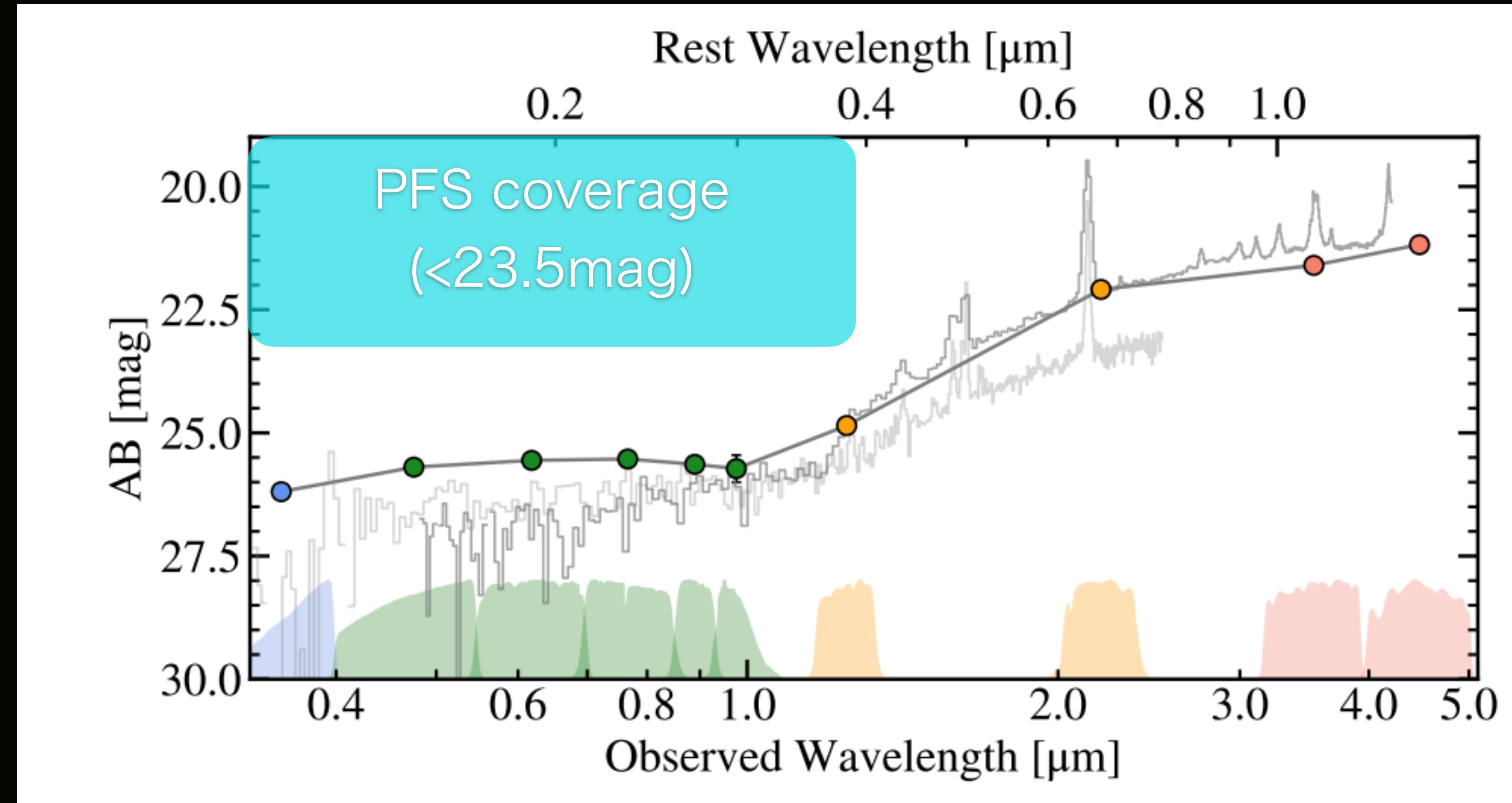
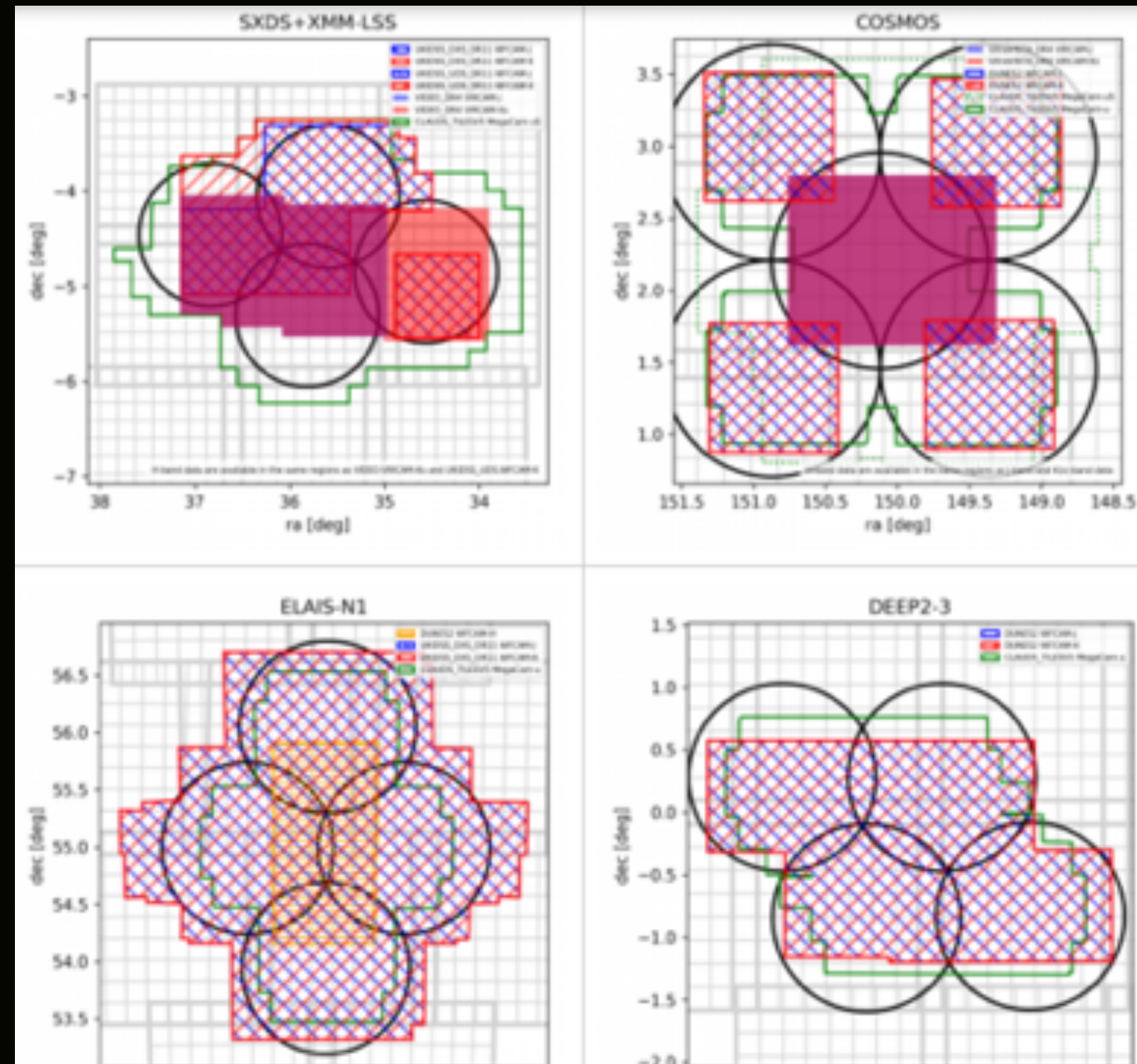
Searching with JWST
($\sim 100 \text{ arcmin}^2 \sim 0.03 \text{ deg}^2$)
is no longer the best option.
Let's search using
“Wide-area” surveys



Low-z LRD searches at $z \sim 2-3$ in HSC/DUD field ($\sim 17 \text{ deg}^2$)

Subaru/HSC-SSP Deep $\sim 17 \text{ deg}^2$

Ma et al. (2026a,b)

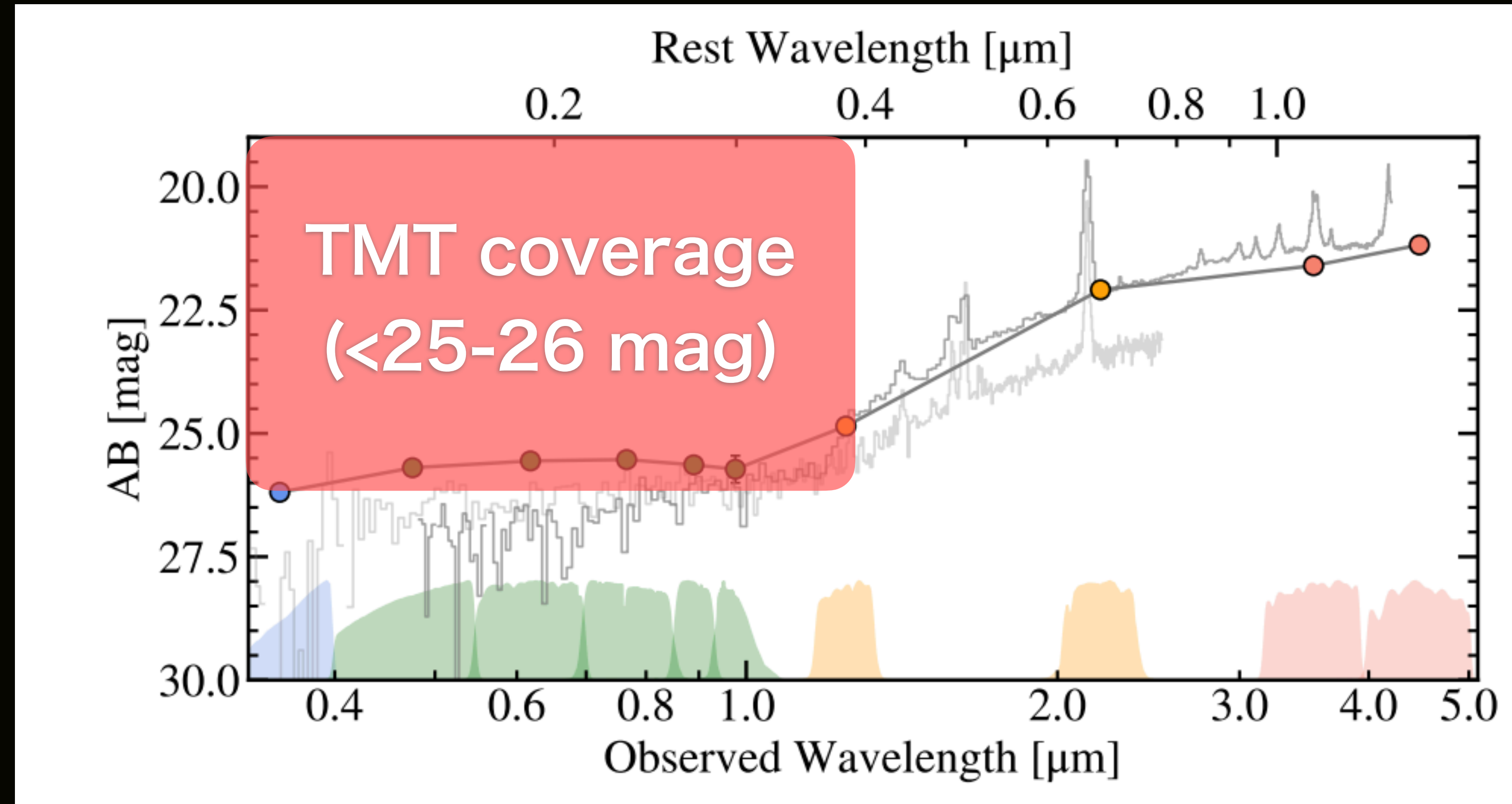
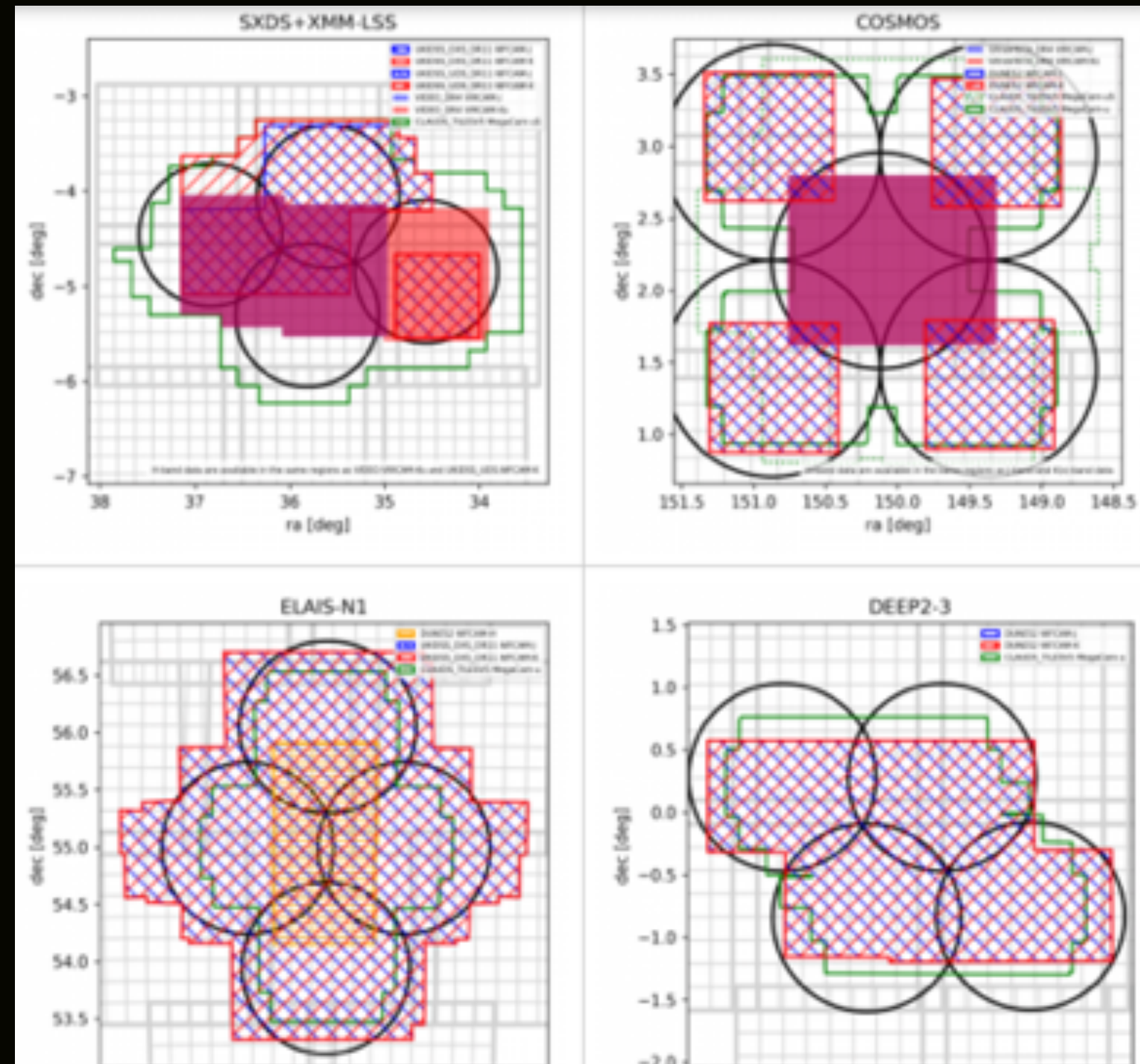


~ 340 low-z LRD candidates $\Rightarrow$ Most sources are $>24 \text{ mag}$
(only one spectroscopic confirmed source)

Low-z LRD searches at $z \sim 2-3$ in HSC/DUD field ($\sim 17 \text{ deg}^2$)

Subaru/HSC-SSP Deep $\sim 17 \text{ deg}^2$

Ma et al. (2026a,b)

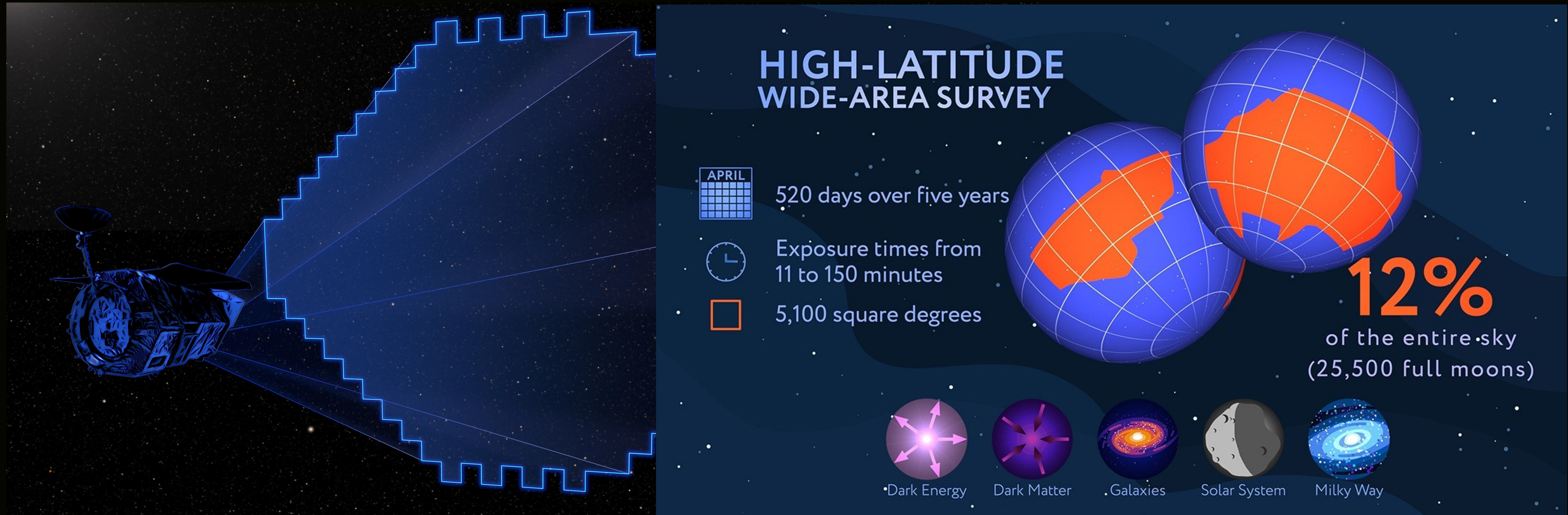


TMT can obtain spectra for low-z LRDs, covering “v”-shape

Low-z LRD searches at $z \sim 2-3$ via Roman (and Euclid)

Roman NIR+LSST (or HSC intensive) will find low-z LRD candidates

5100 deg² = x300 of HSC D/UD field => 10^{4-5} low-z LRD candidates



PFS will cover bright end (<23 mag) and TMT will cover faint end (>23 mag)

Conclusions (intermediate mass BH)

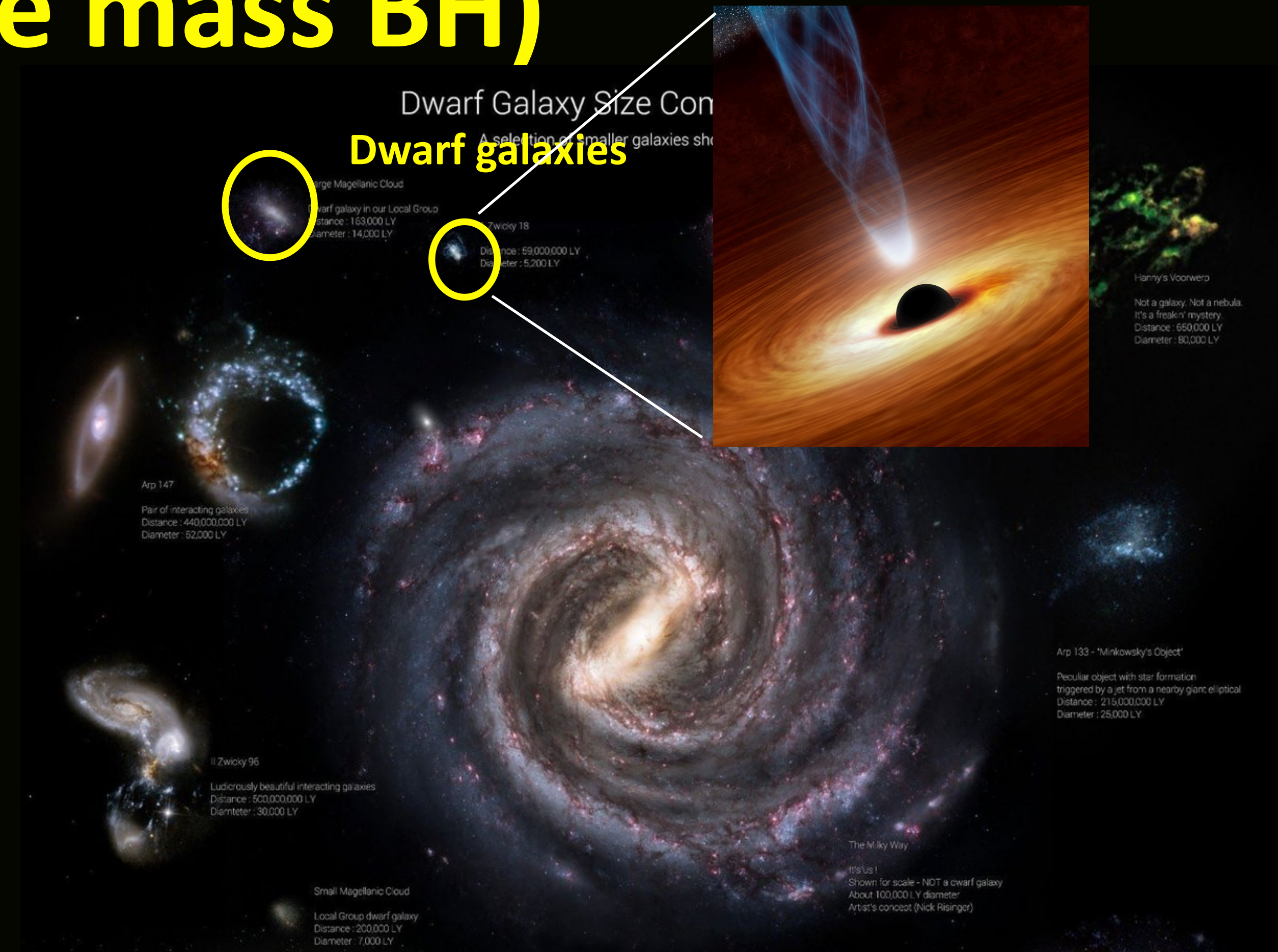
Wide-area radio x HSC

=> intermediate mass BH candidates

(but they are faint, w/ $i > 24$ mag

TMT can obtain spectra

=> reliable BH mass measurements
(through $H\alpha/\beta$ or $MgII2800$)



Conclusions (low-z LRD)

Wide-area radio x HSC

=> intermediate mass BH candidates
(but they are faint, w/ $i > 24$ mag)

TMT can obtain spectra

=> reliable BH mass measurements
(through $H\alpha/\beta$ or $MgII2800$)

Wide-area optical

=> low-z LRD candidates (but faint)

TMT can obtain spectra up to $z < 2$

=> reliable $H\alpha$ + V-shape

