

Mid-Infrared Wide-Field Surveyor

Toward the Next Redshift Frontier

 $z=14.18$

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in collaboration with

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P. Stahl, C. Hopkins, S. Cheney, T. Lis (NASA Marshall Space Flight Center)

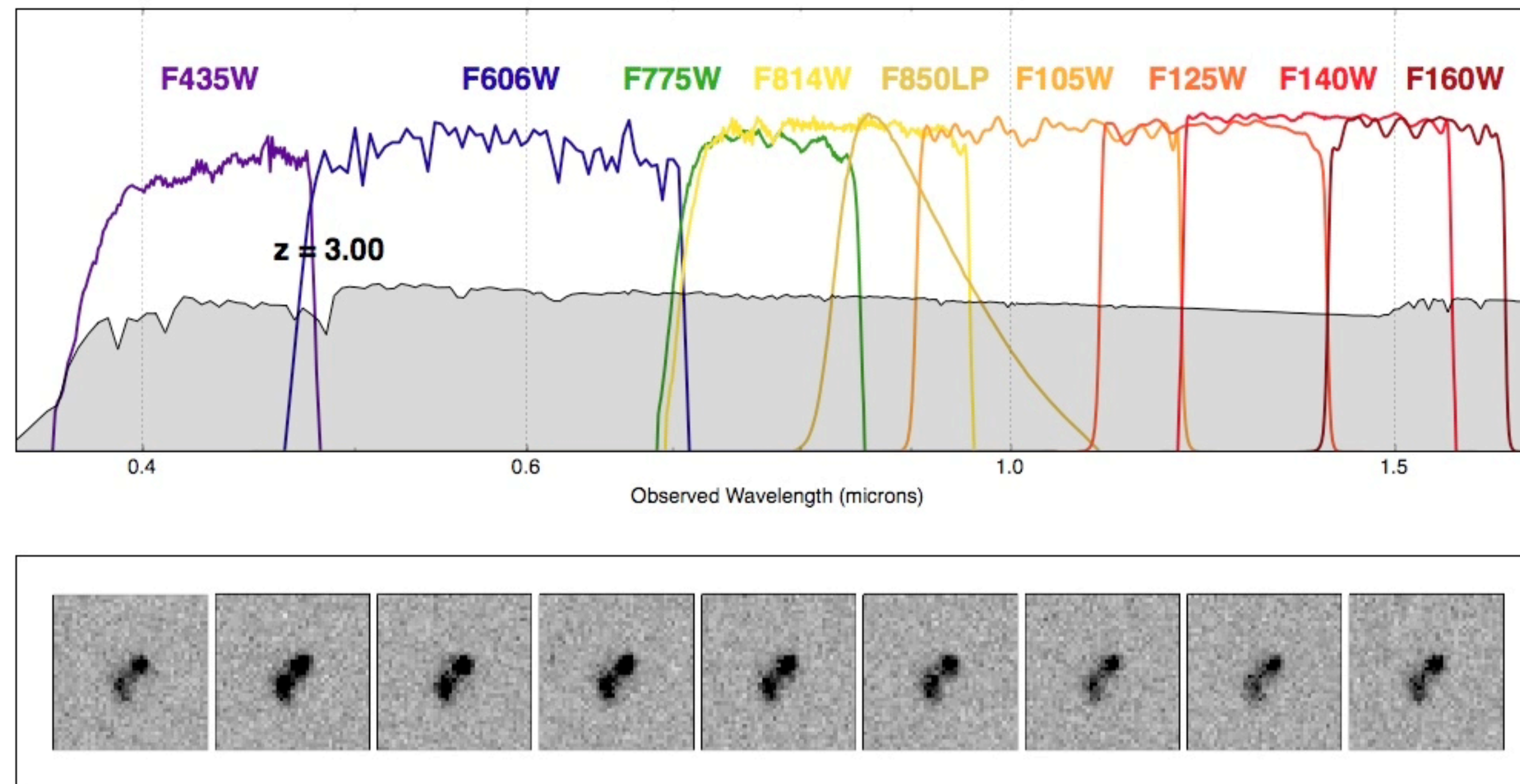
A. Inoue (Waseda University); Y. Harikane, Y. Ono (University of Tokyo)

Main Takeaways

- A Roman-like mid-infrared wide-field surveyor, in combination with Roman, will detect **tens/hundreds of UV-luminous galaxies at $z > 13$** , opening up the next redshift frontier.
- The mission is conservative technically, built on well-established technology, so **a speedy development (~10 yr) will allow follow-up observations by JWST**, which is expected to operate until ~2040.
- **L2** version → my talk; **Beyond-zodi** version → next talk by Gary Melnick

How to Find the Most Distant Galaxies?

Dropout technique with Lyman break ($912 \text{ \AA}$) & Ly α break ($1216 \text{ \AA}$)

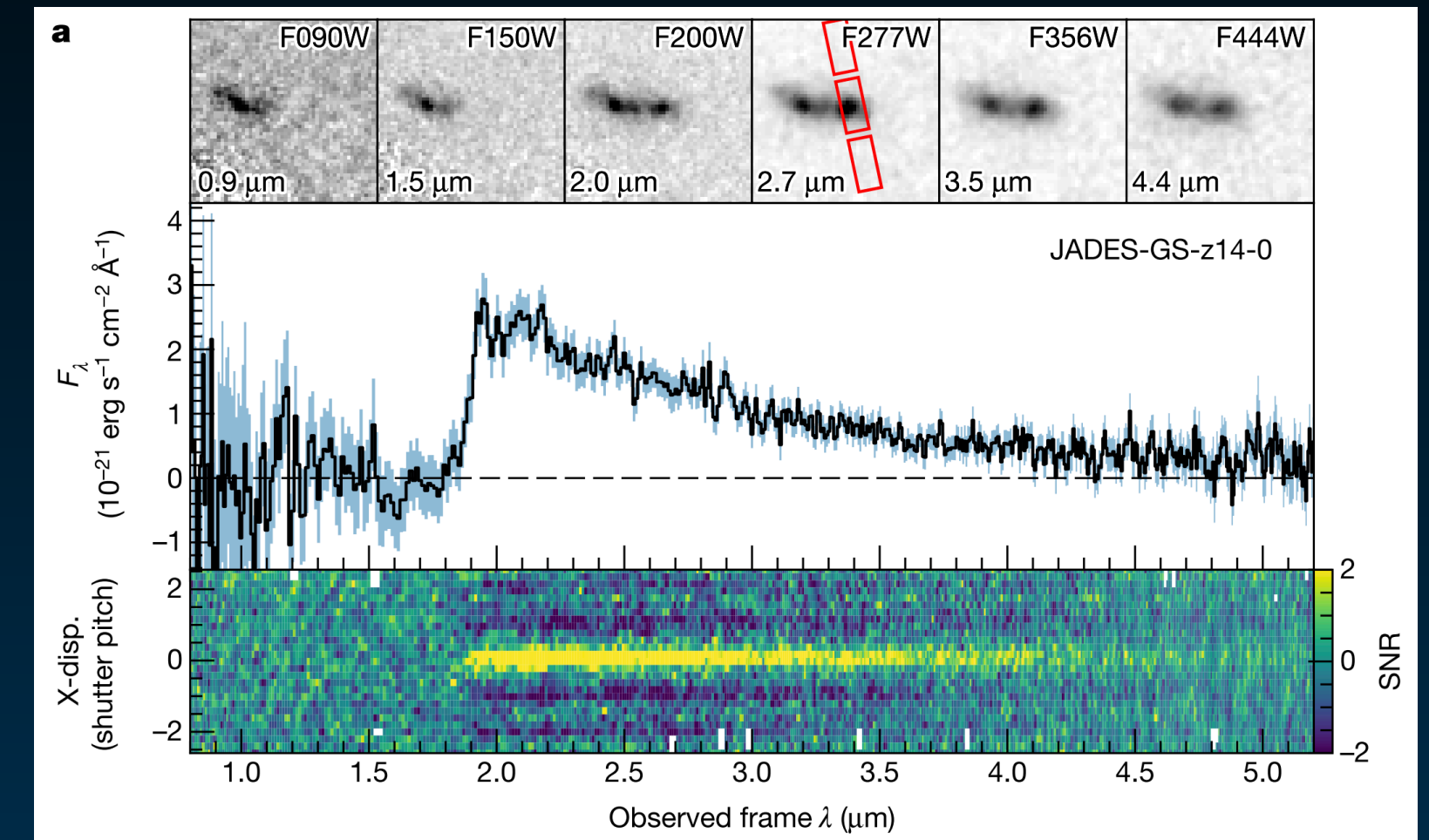
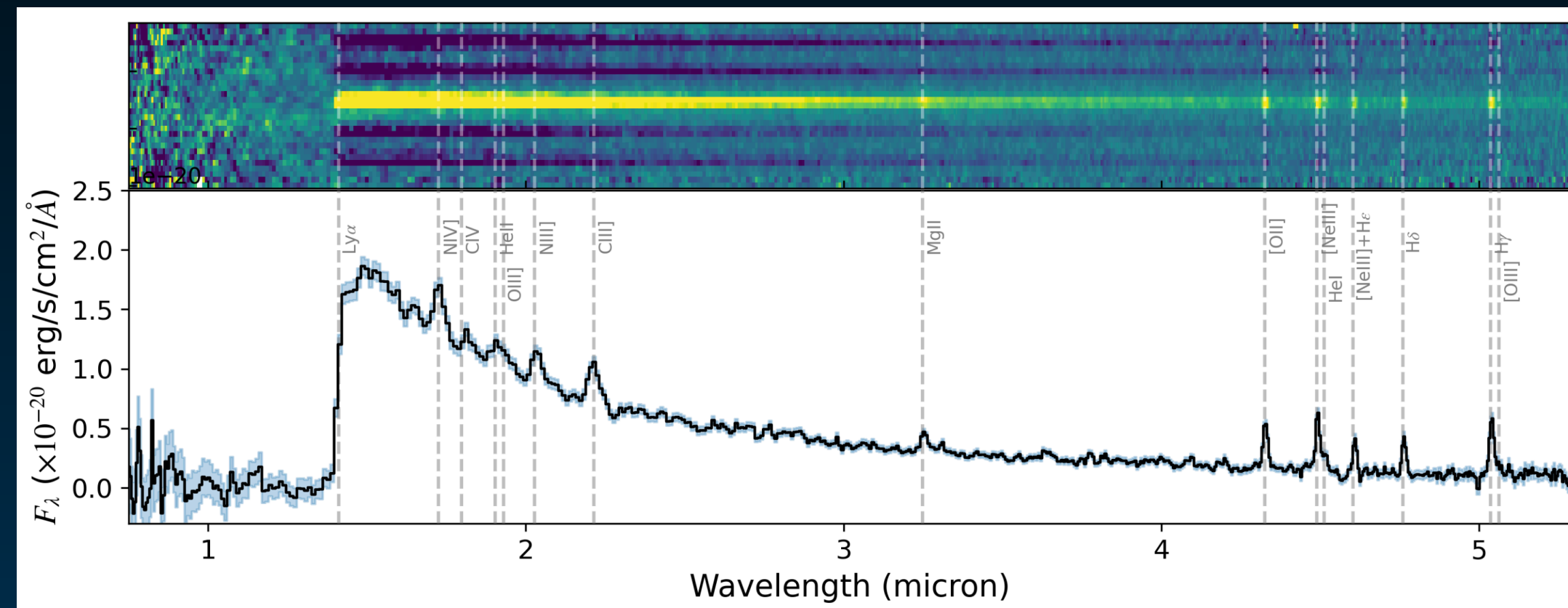
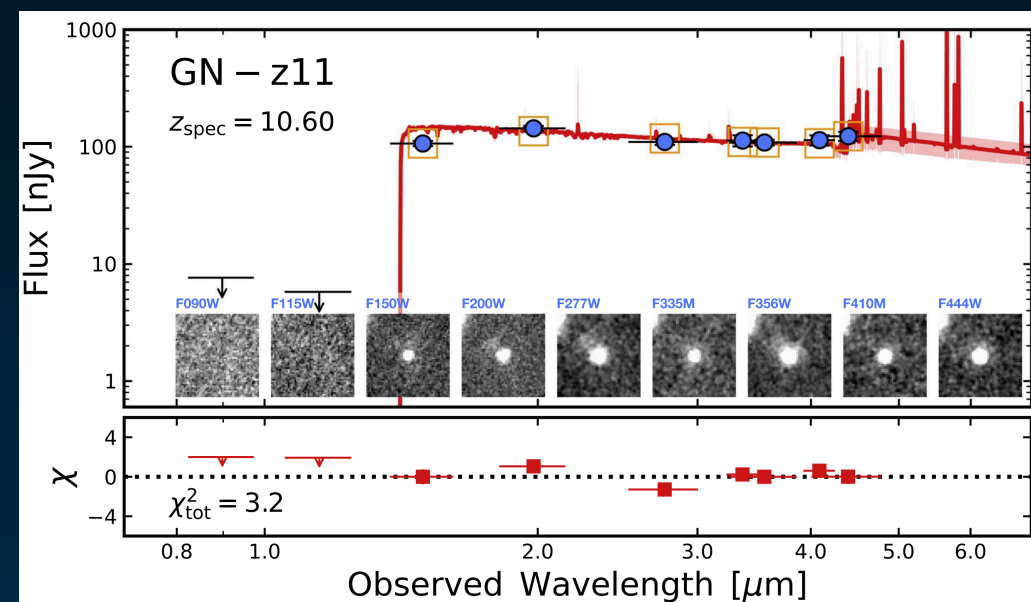


From the XDF Project (xdf.ucolick.org)

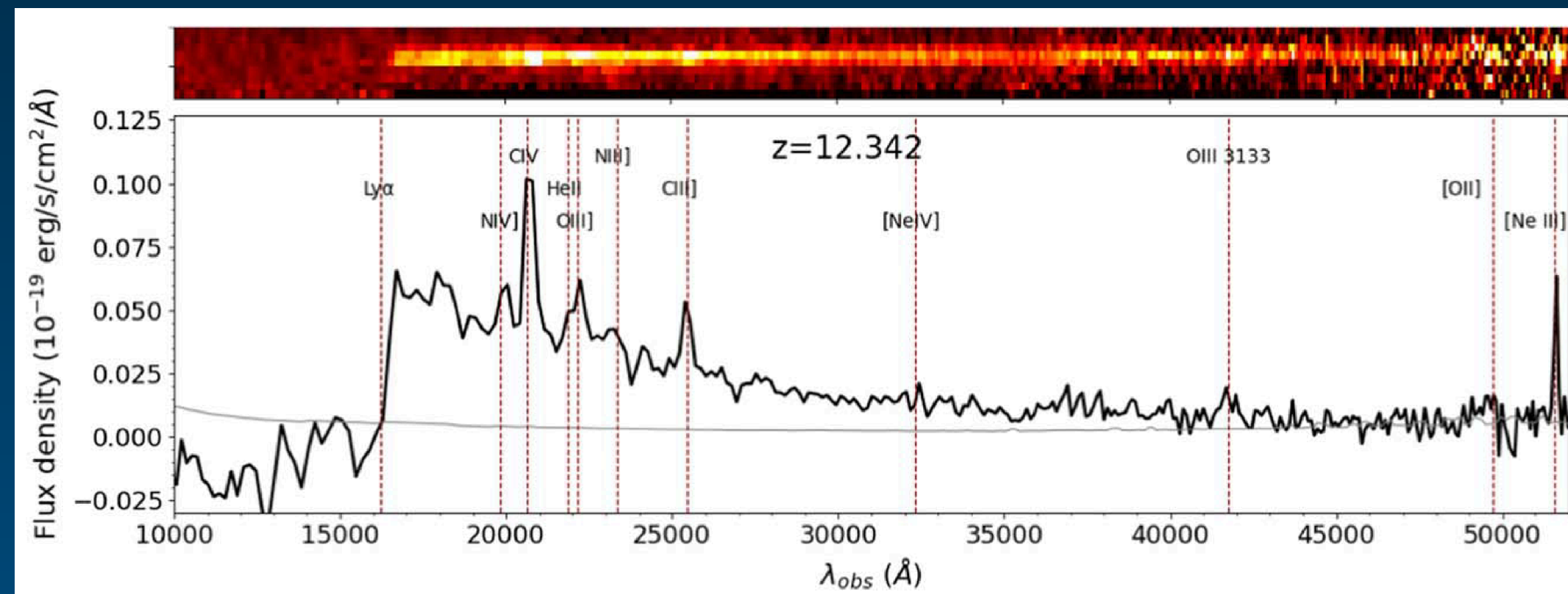
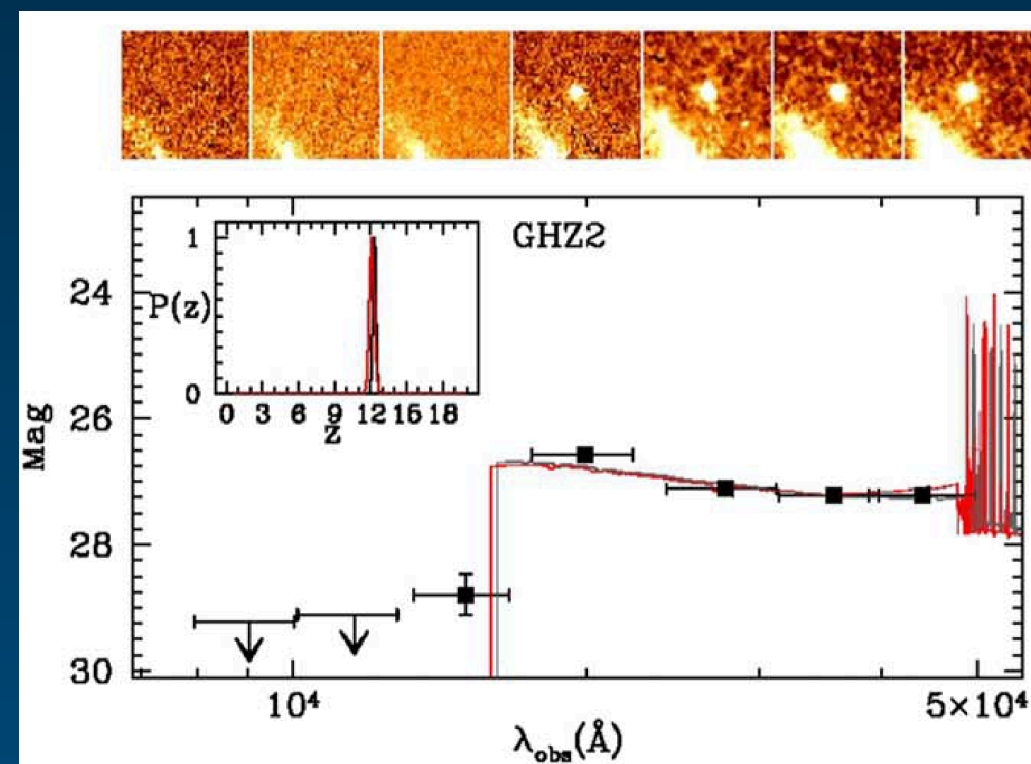
Redshift Frontier with JWST

JADES-GS-z14-0@z=14.18 (Carniani+24)

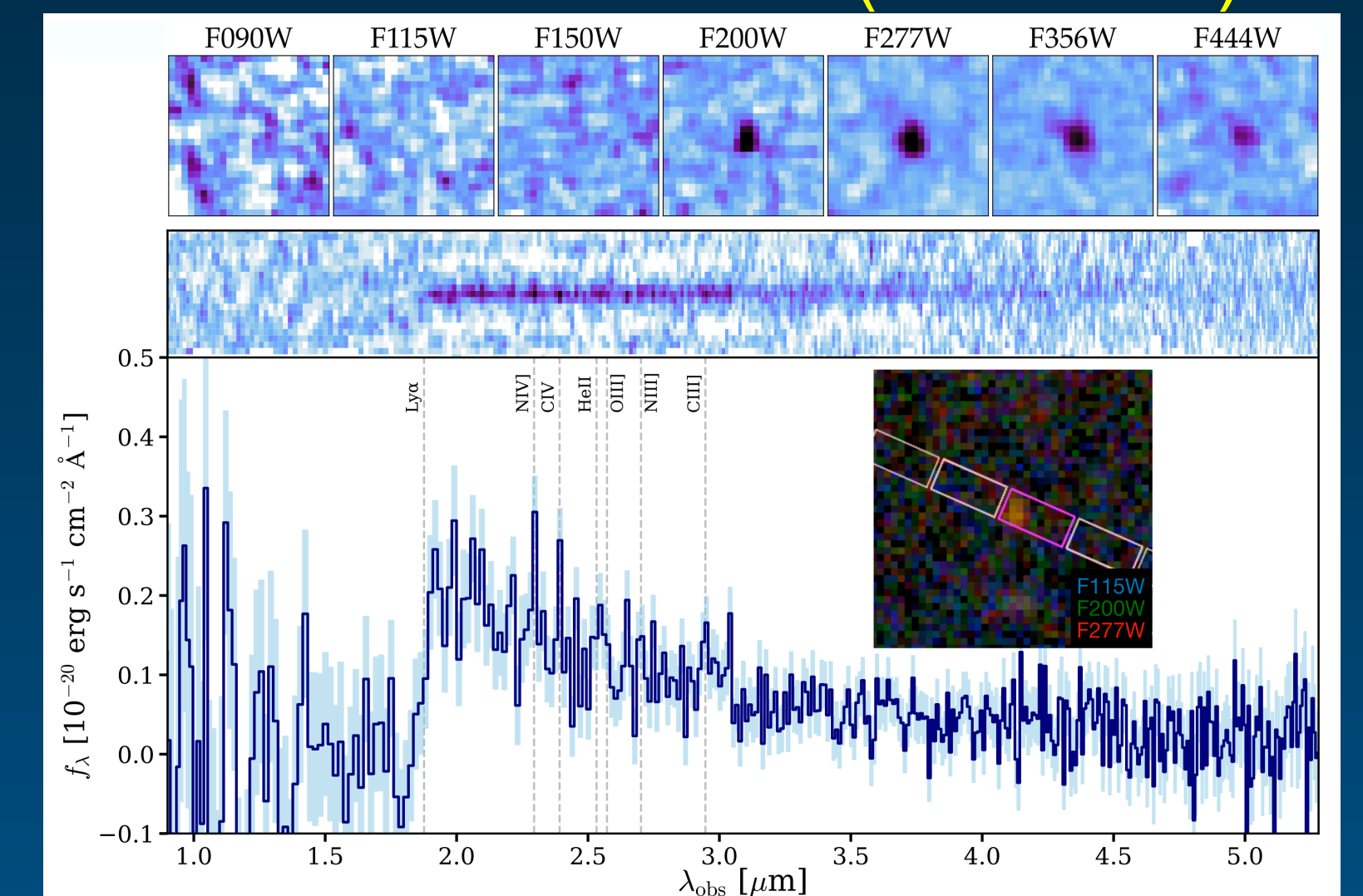
GN-z11@z=10.60 (Bunker+23; Tacchella+23)



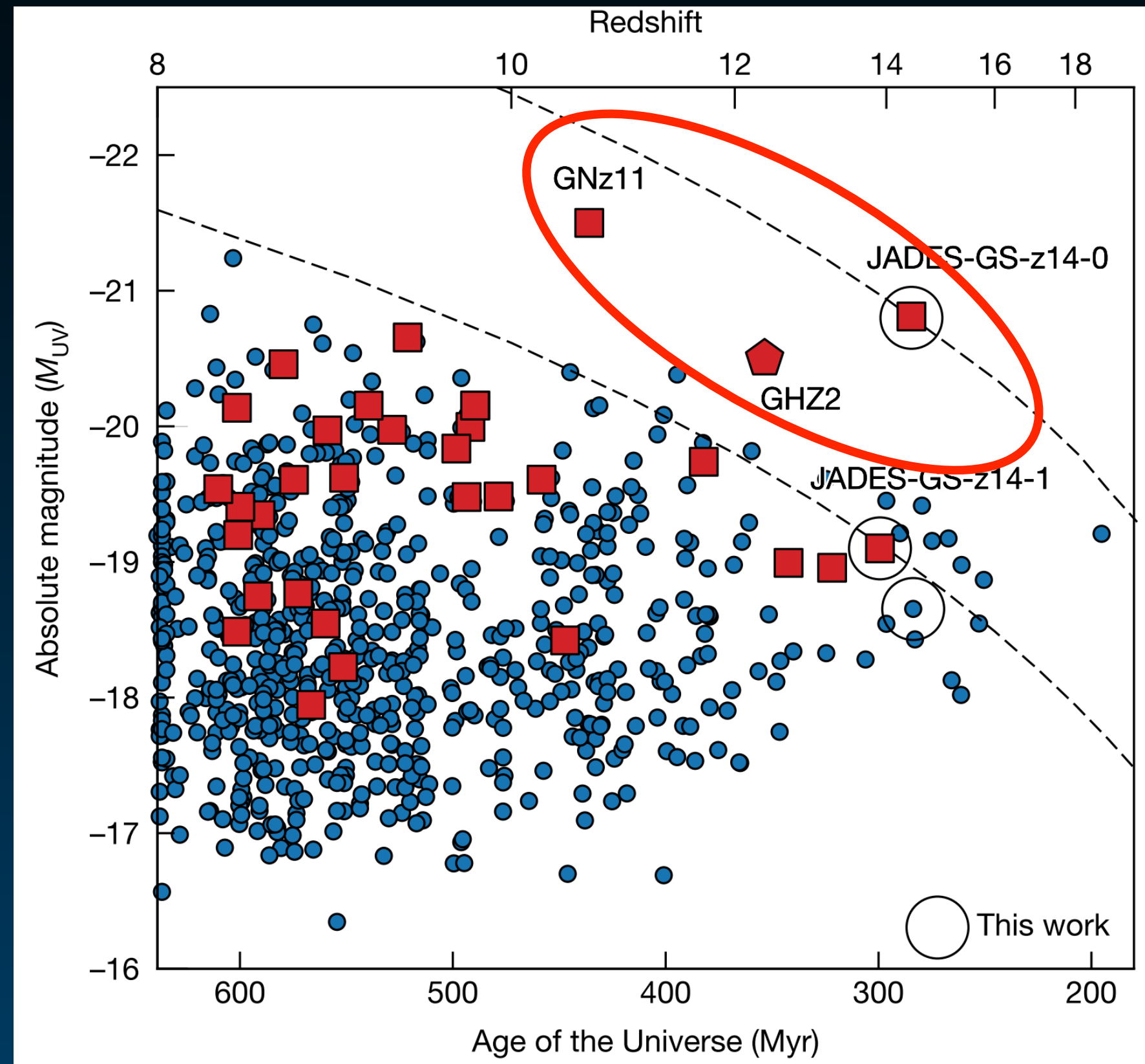
GHZ2/GLASS-z12@z=12.34 (Castellano+24)



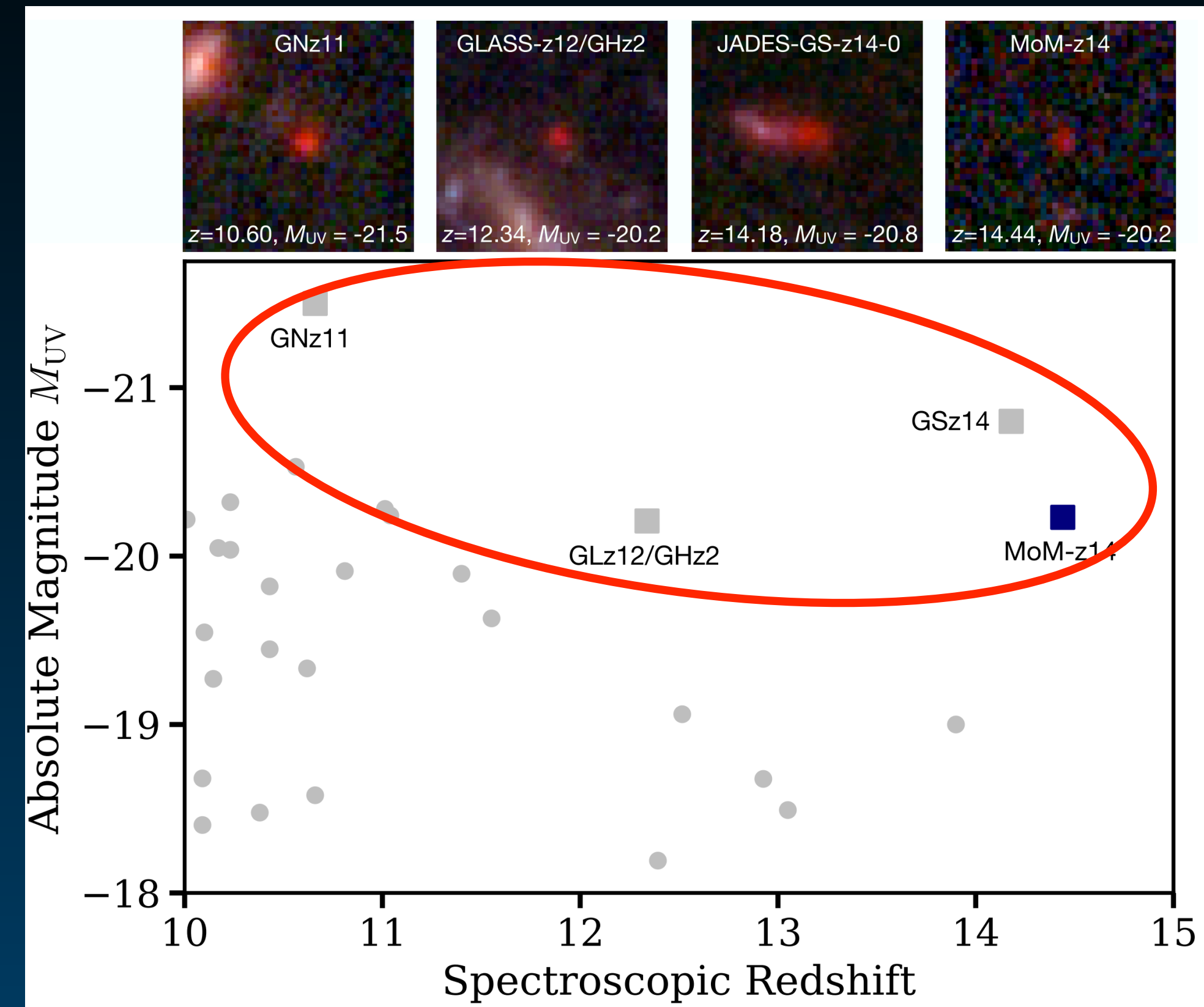
MoM z-14@z=14.44 (Naidu+25)



Over-Abundance of Luminous ($M_{UV} < -20$) Galaxies at $z > 10$



From Carniani+2025



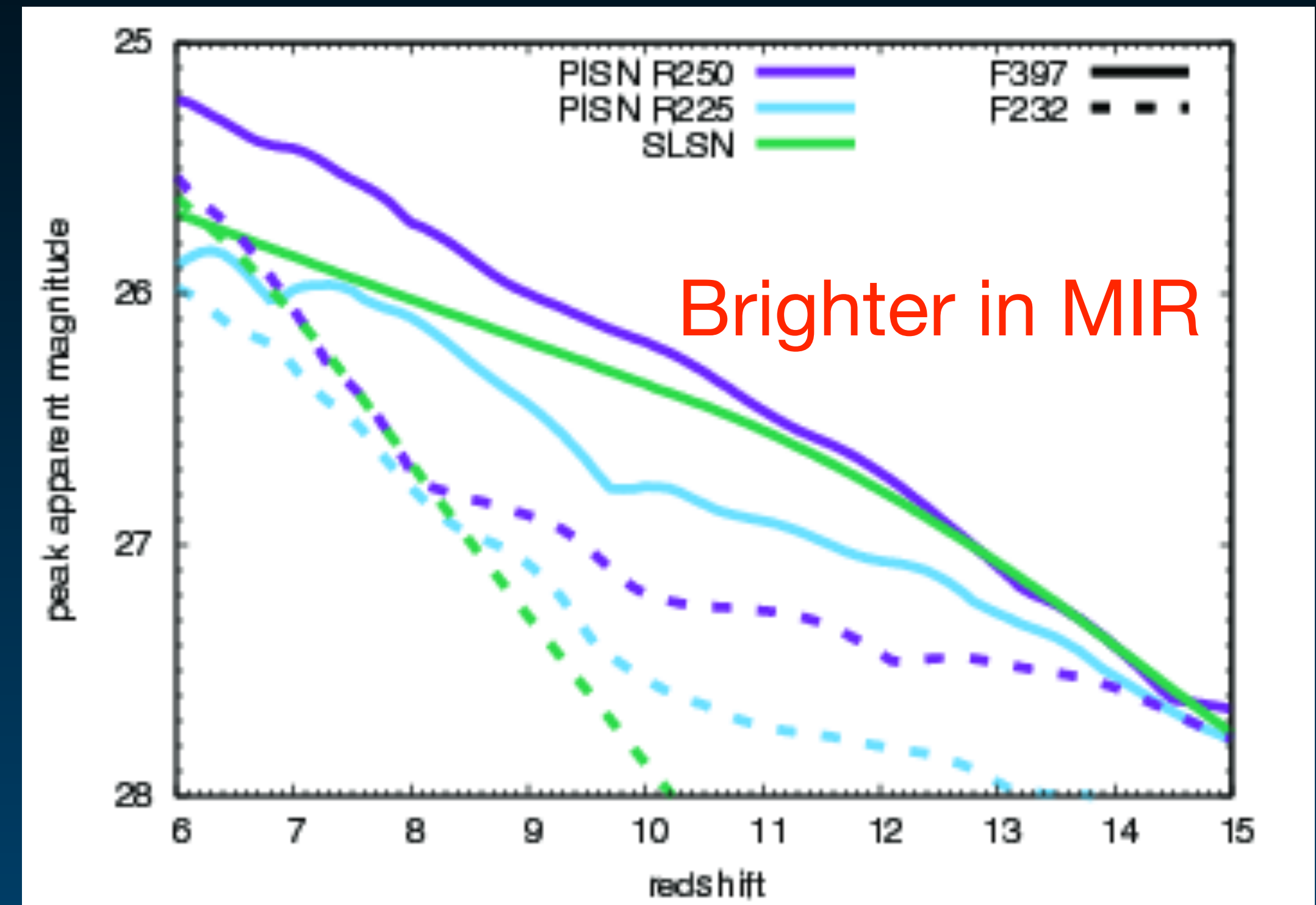
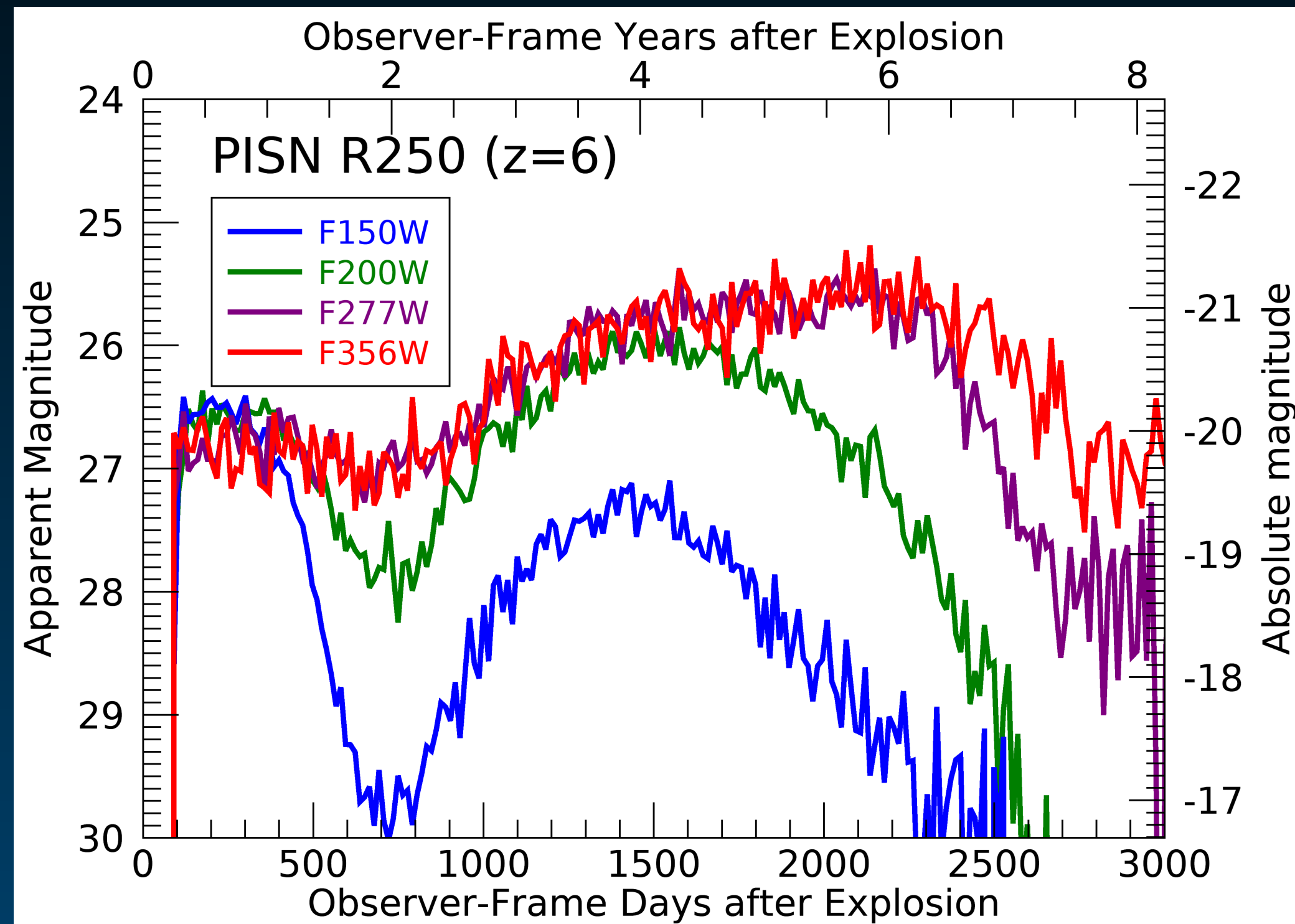
From Naidu+2025

Higher SF efficiency? Bursty SF? Feedback-free SF? Top-heavy IMF?
Low dust attenuation? AGN?

→ Whatever the reason, we expect to see luminous galaxies at $z > 10$!

High-Redshift Transients

Search for pair-instability (i.e., massive Pop-III) supernovae

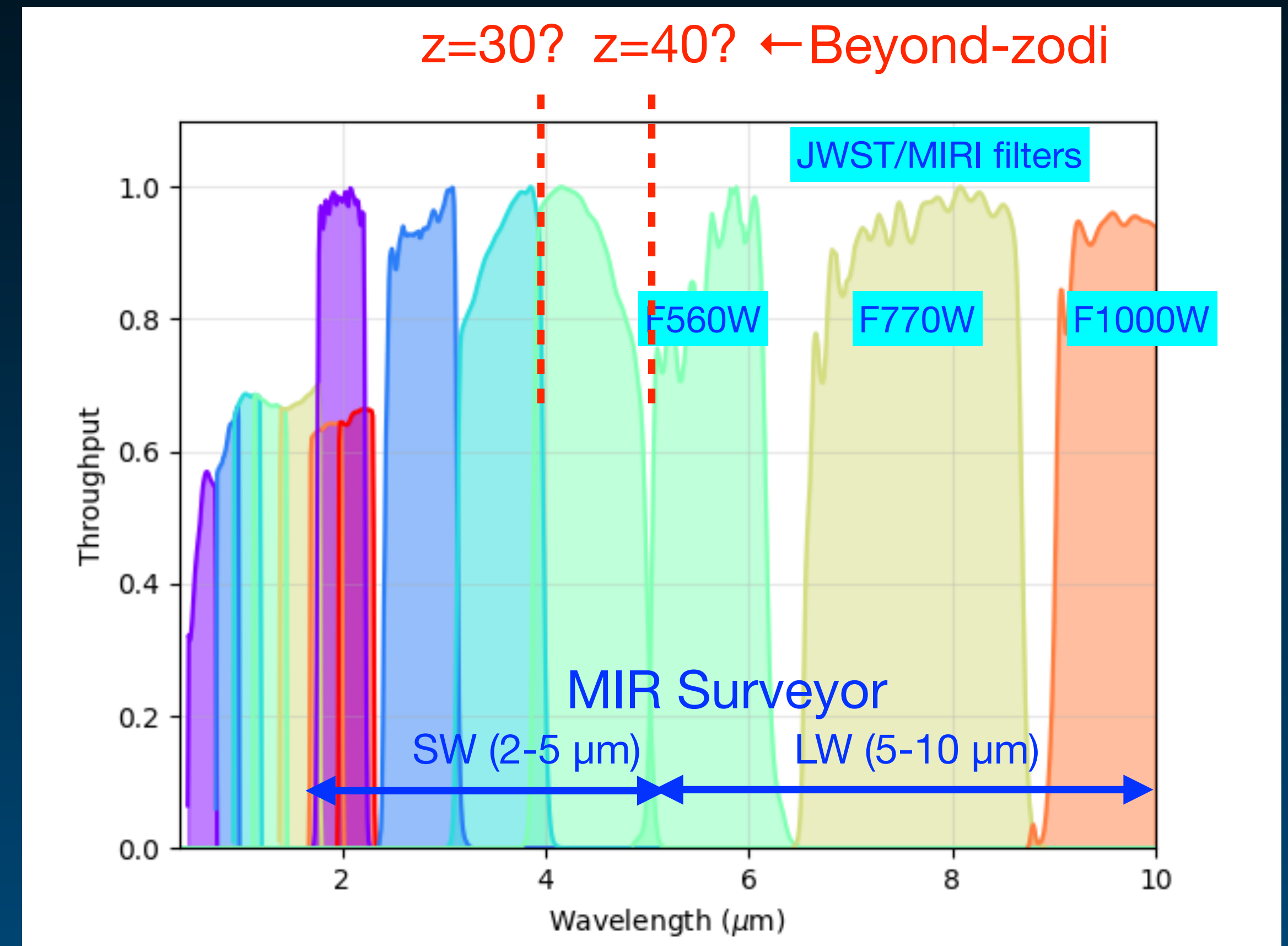
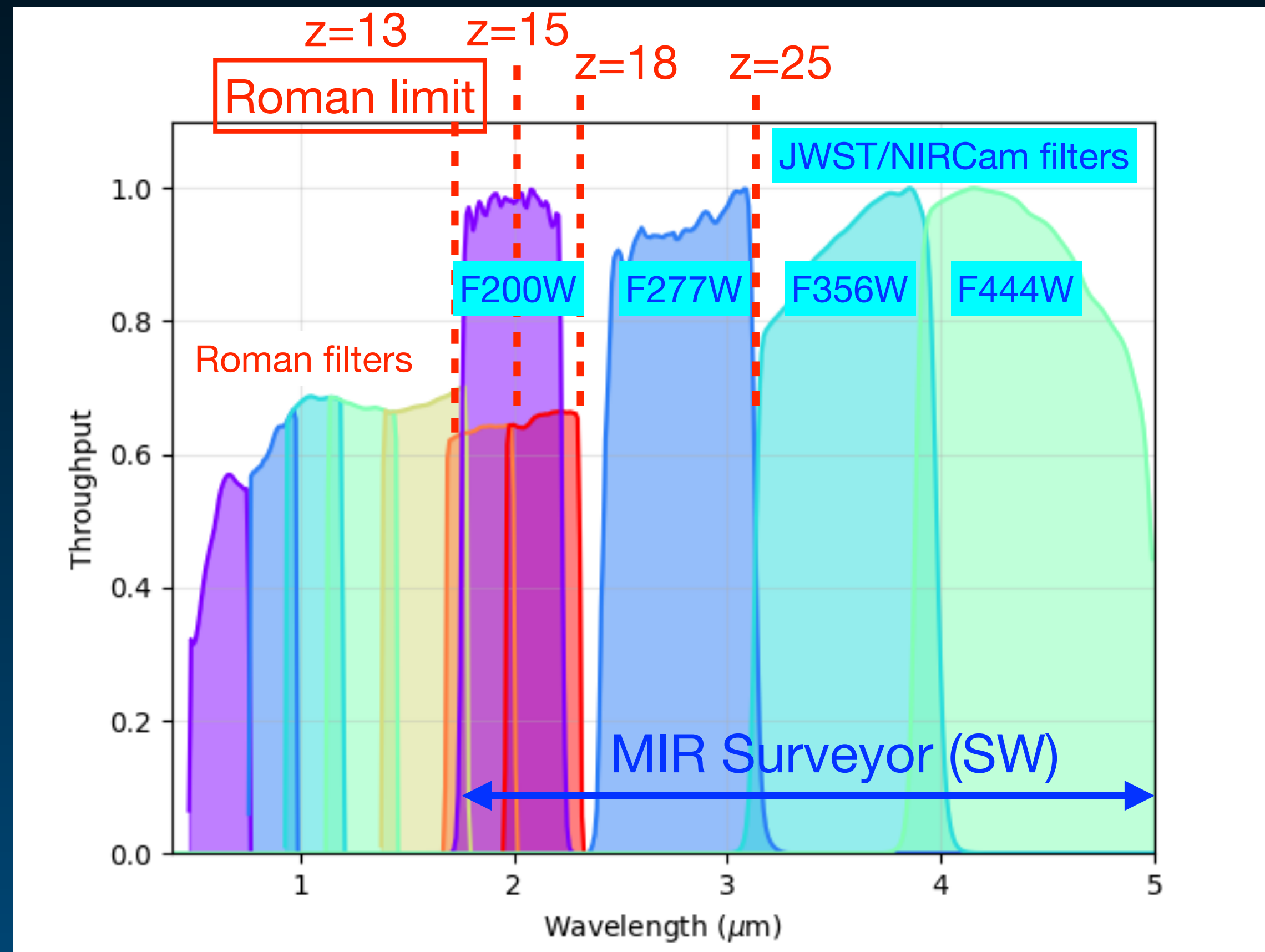


PISNe are bright and slowly varying → Should be detectable at $z > 10$
(MIR survey is also sensitive to dust-obscured transients/SNe at lower- z)

Mid-Infrared Wide-Field Surveyor

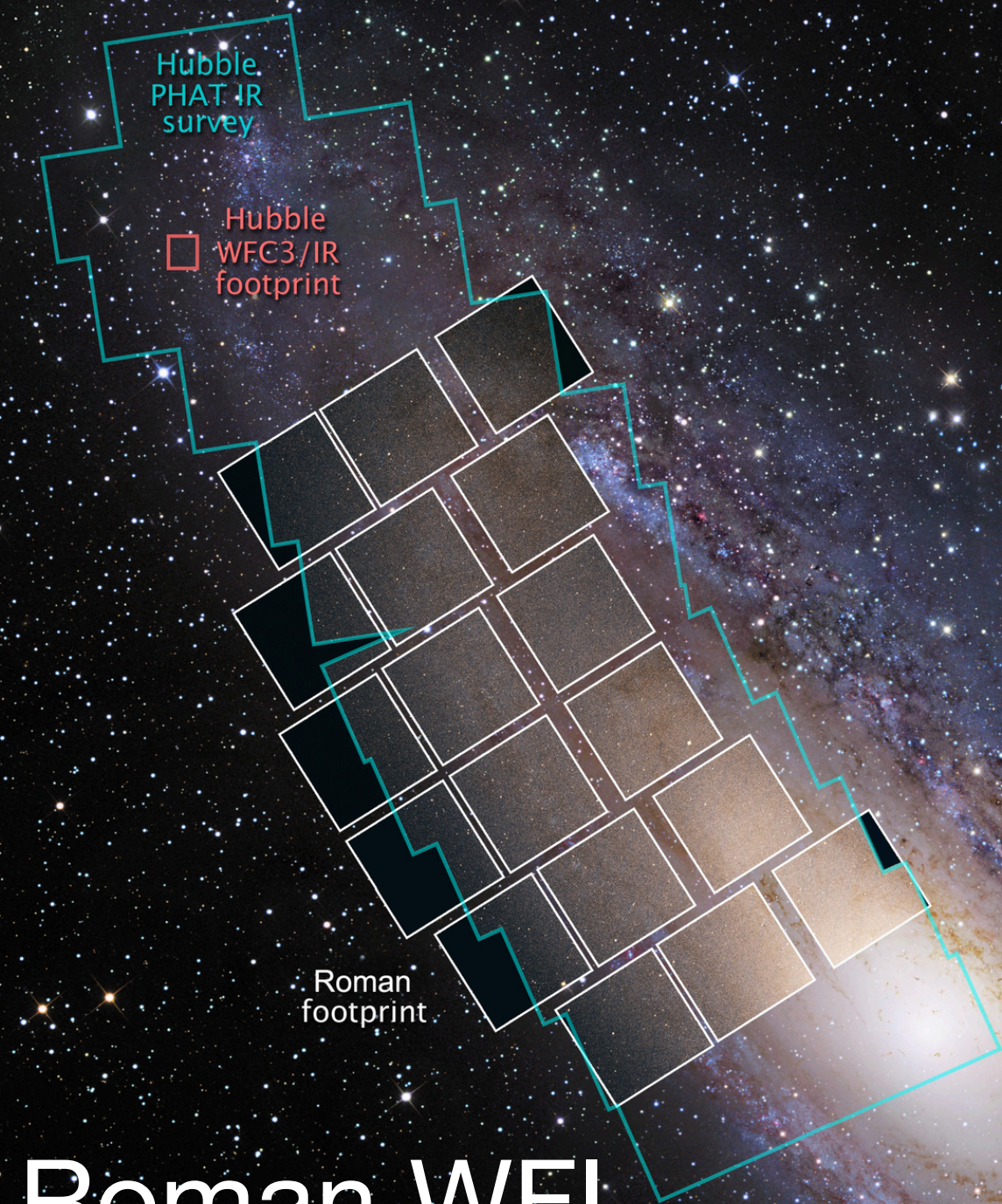
Toward the Next Redshift Frontier ($z > 13$)

(Filter passbands from stsynphot)



Longer-wavelength data will also help characterize lower- z galaxies (e.g., stellar mass)

Simulated Roman Observation of Andromeda (M31)



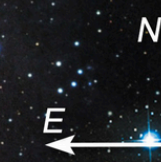
Roman WFI
0.28 deg²



MIR Surveyor
0.25 deg²

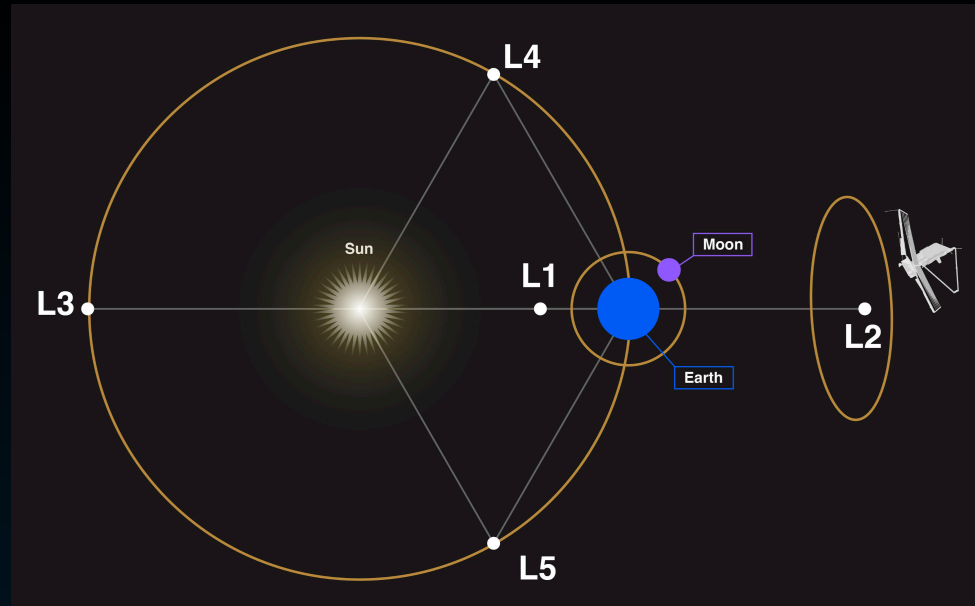


0.5 deg

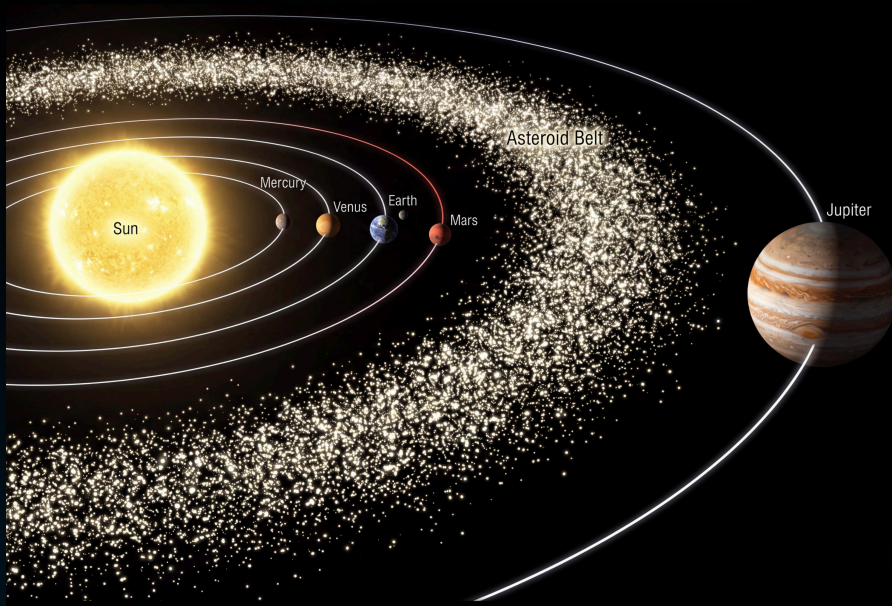


Background Sky: Digitized Sky Survey and R. Gendler
Moon: NASA/GSFC/ASU/Lunar Reconnaissance Orbiter

20,000 light-years
6,200 parsecs 27'



Mission Concept



Telescope	D=2m at < 40 K
Orbit	Sun-Earth L2 Halo (→ beyond zodi)

Next talk by
G. Melnick

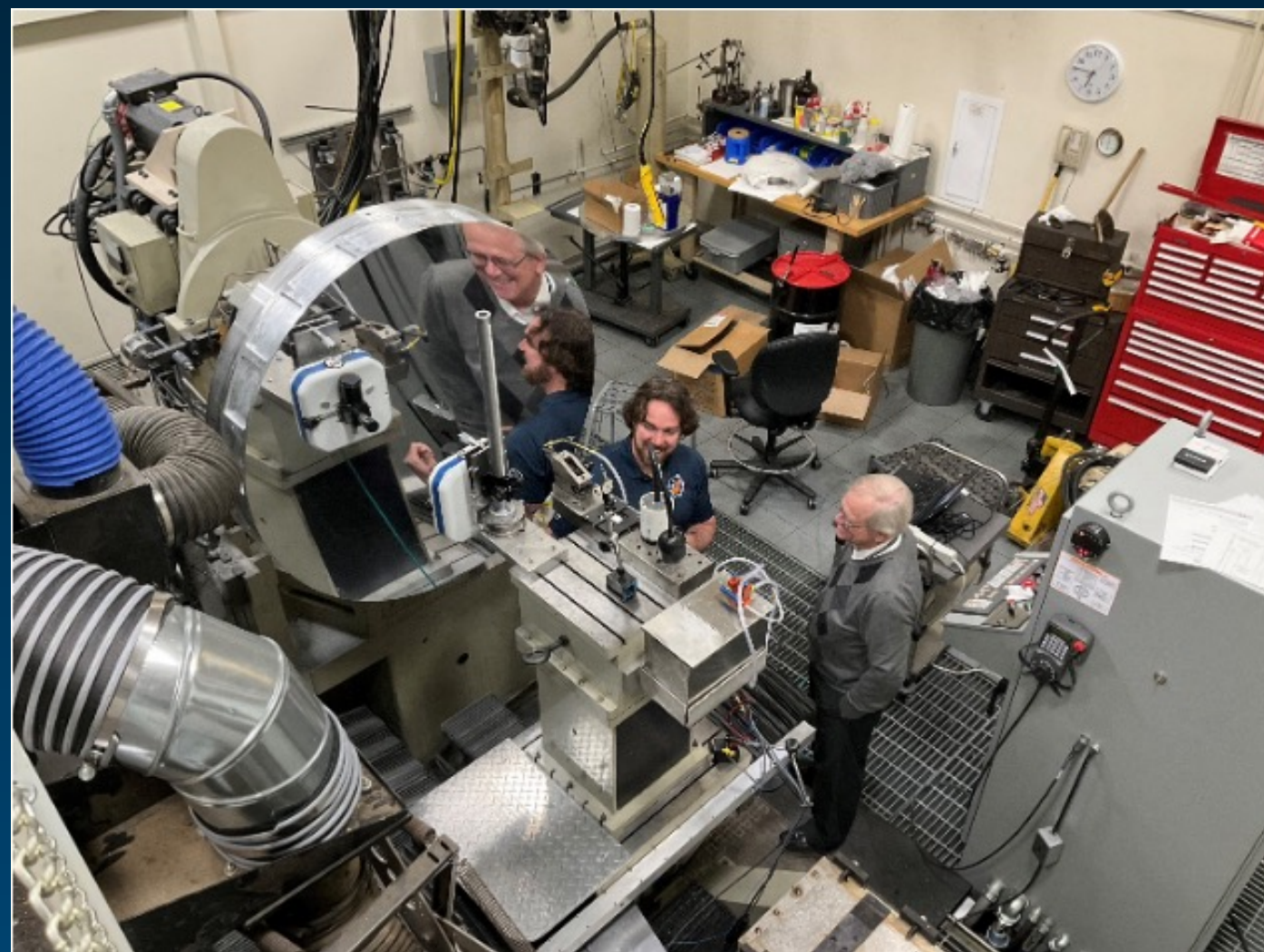
	SW (2-5 μm)	LW (5-10 μm)
Detectors	4 x H4RG (4096 ²)	4 x H2RG (2048 ²)
Pixel scale (arcsec)	0.22	0.44
Field of view (deg²)	0.25	0.25
Sensitivity (AB mag; 5σ, 1hr)	26.4 @ 3 μm	23.4 @ 7 μm
→ beyond zodi (5 AU)	~28 @ 3 μm	~28 @ 7 μm
Grism Slitless Spectroscopy	R~1000-1500	R~TBS

Mirror Production & Testing

(e.g., NASA Marshall Space Flight Center = MSFC)

Diamond Turning

M40 can turn normal incidence mirror up to D=2m

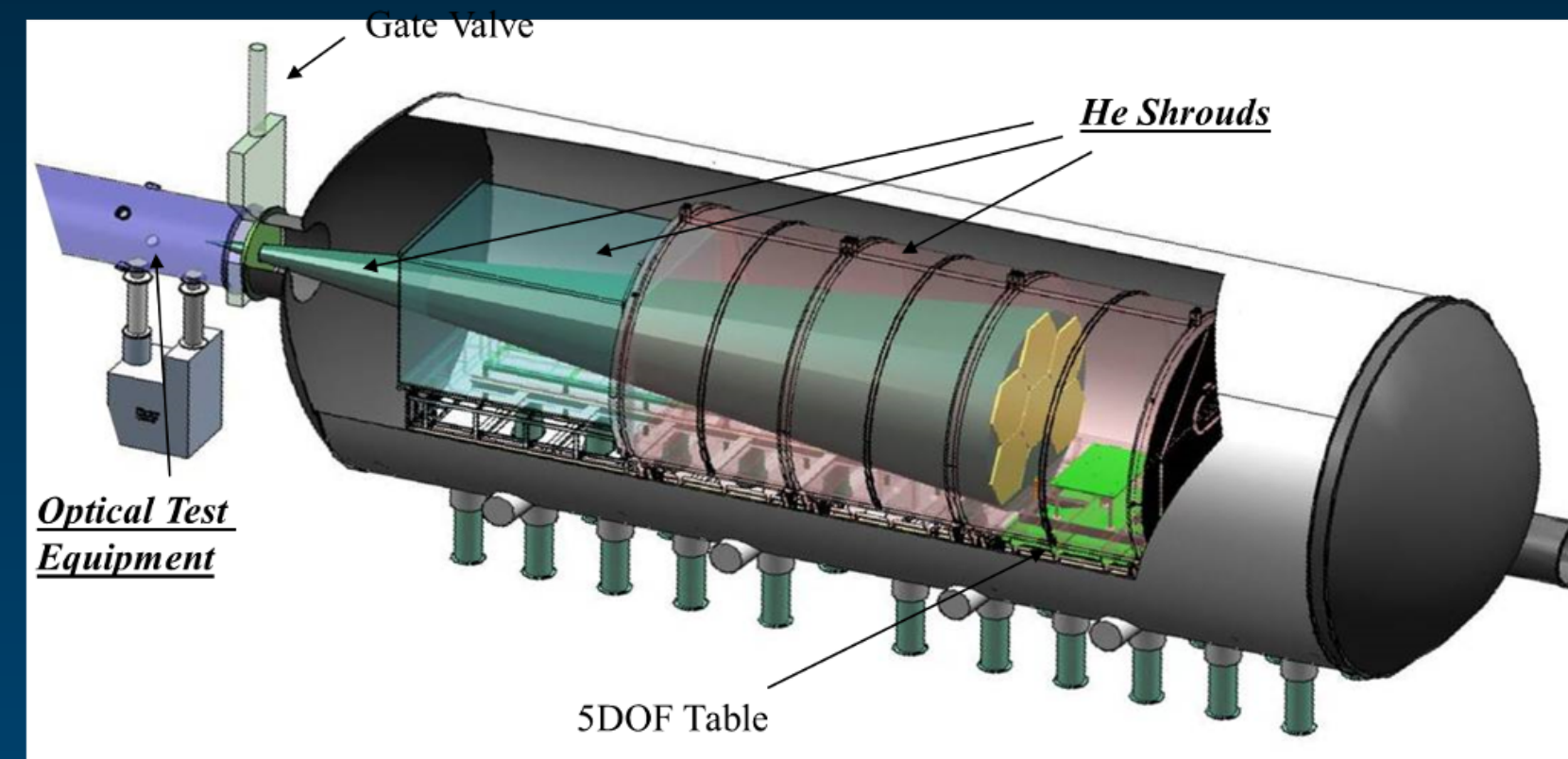


D=1.2m aluminum mirror on Moore M-40

X-Ray and Cryogenic Test Facility (XRCF)

Chamber is D=7m and 23-m long

Cryo-tested and certified JWST flight mirrors



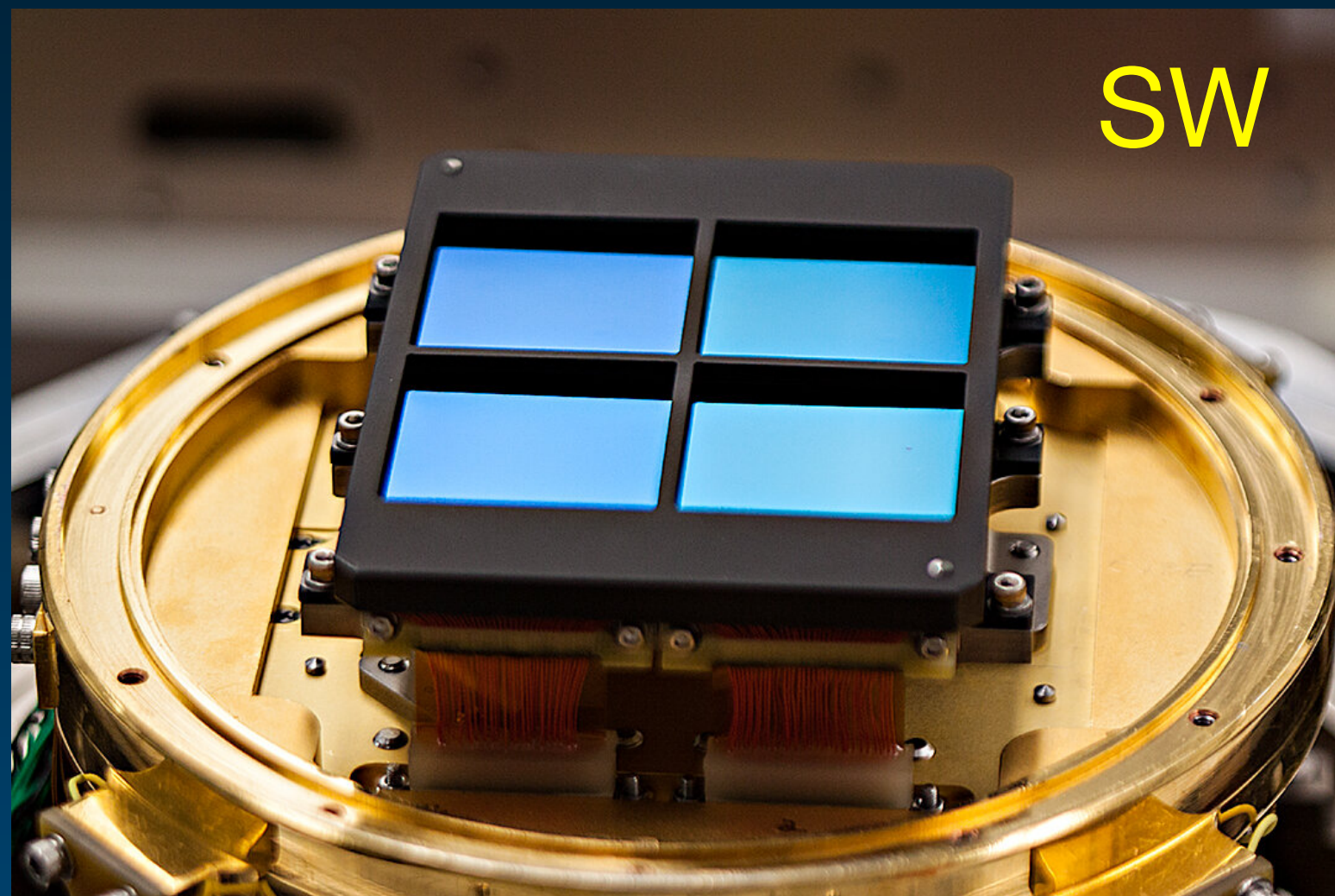
In addition to thermal vacuum testing of payloads, MSFC can vibration and acoustic test payloads.

Focal Plane

JWST, Roman, and NEO Surveyor heritage

JWST/NIRCam

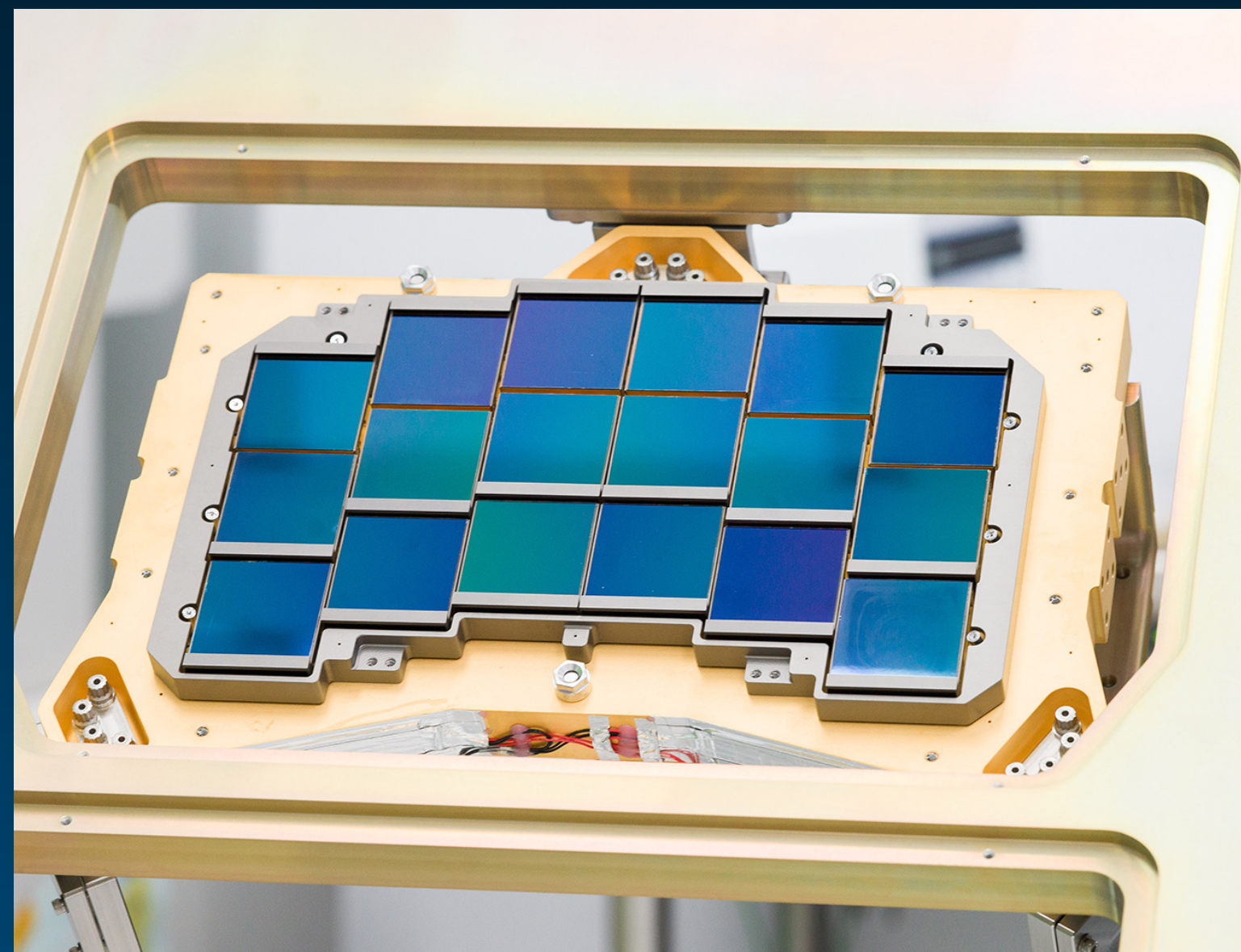
4 x H2RG (SW) x 2 modules
1 x H2RG (LW)



SW: 0.6-2.3 μm
LW: 2.4-5.0 μm

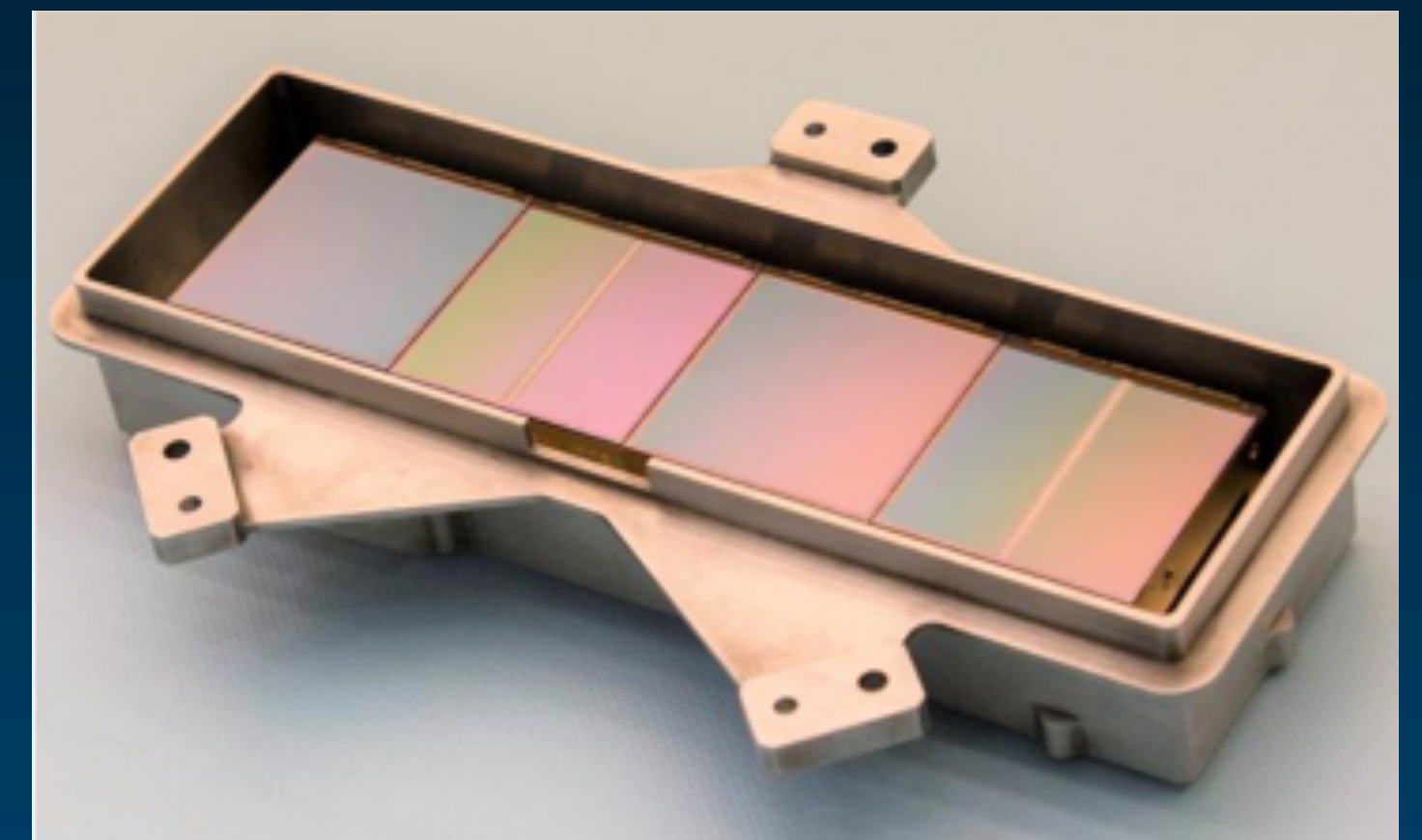
Nancy Grace Roman

18 x H4RG-10



NEO Surveyor

(4 x H2RG) x 2 channels



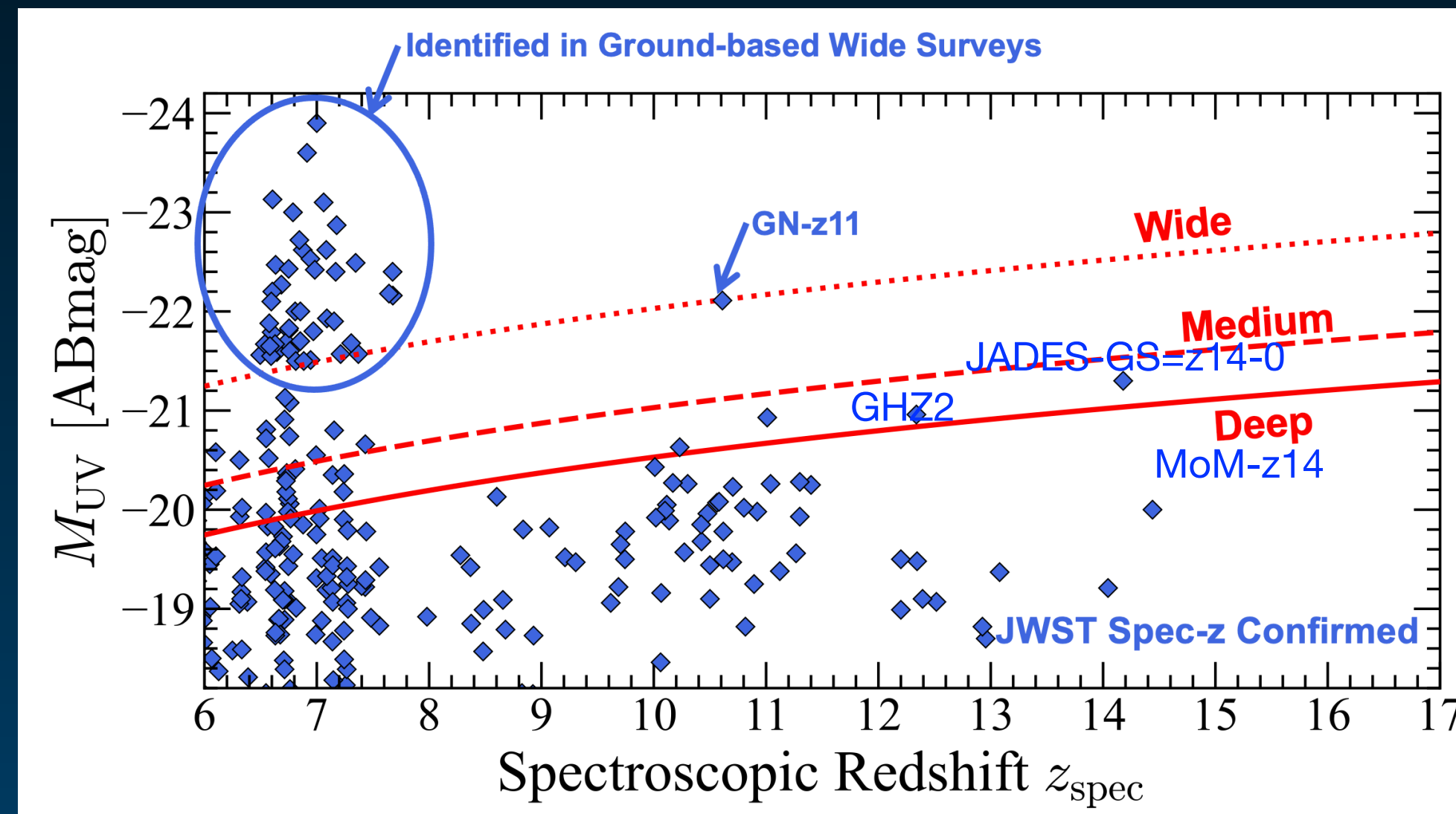
NC1: 4.0-5.2 μm
NC2: 6.0-10.0 μm

Example Survey Plan

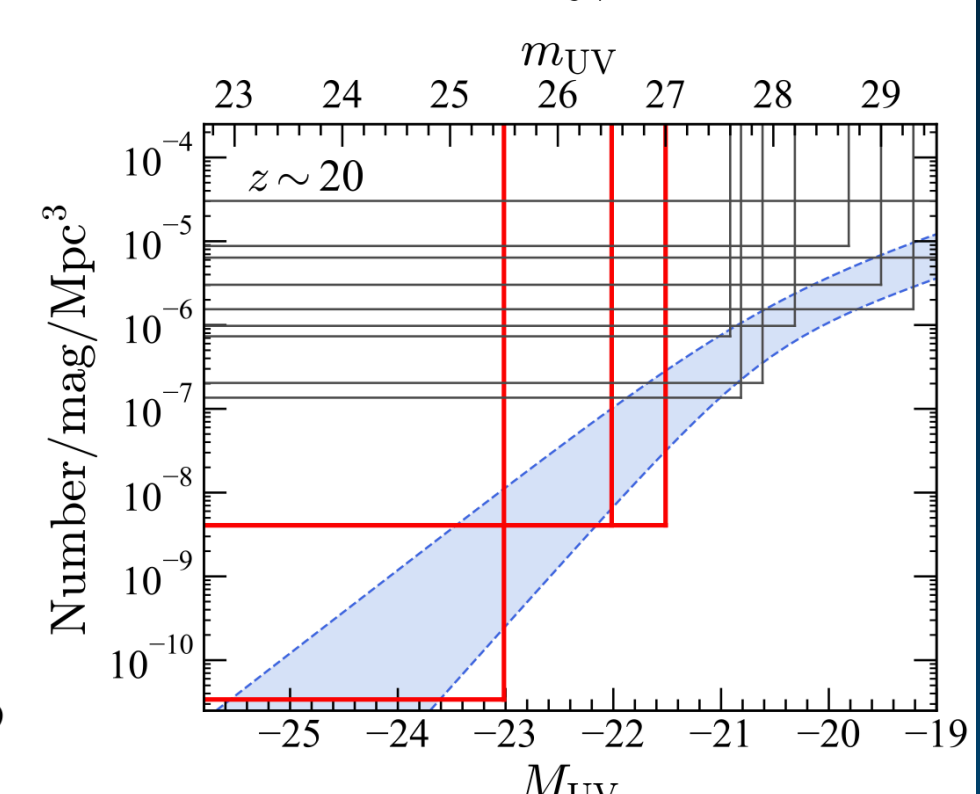
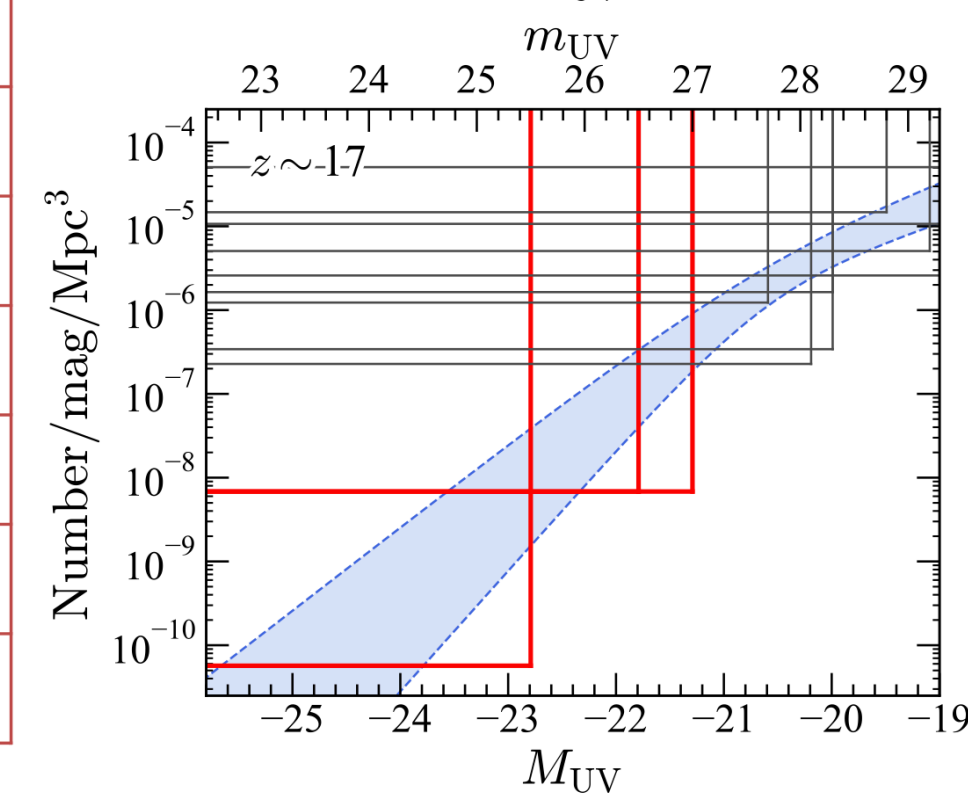
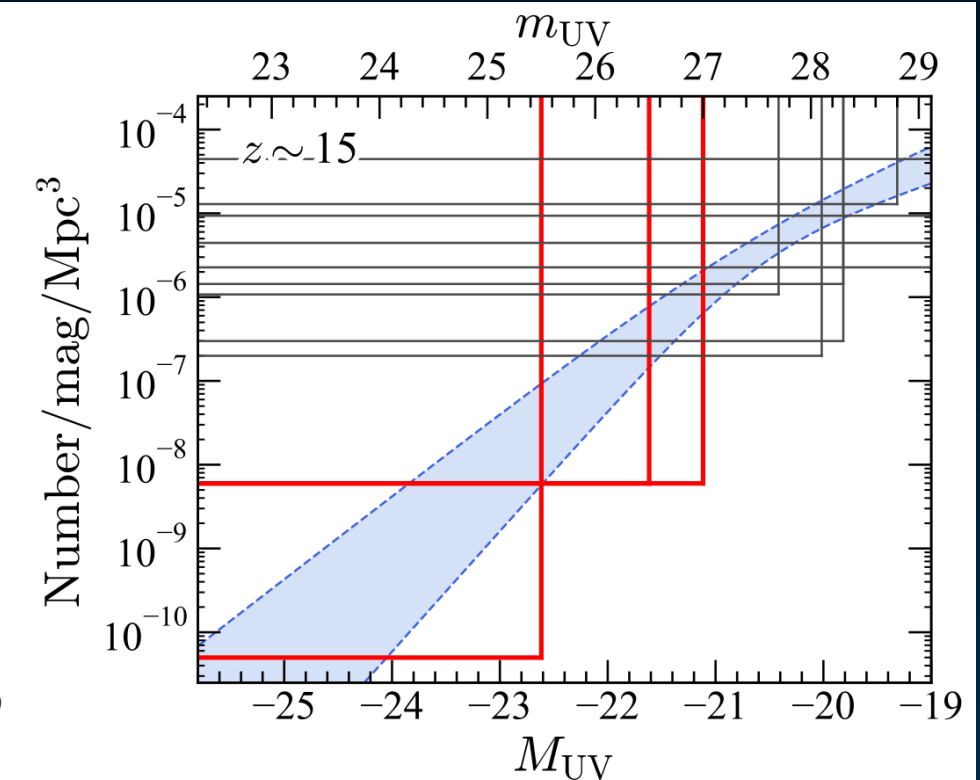
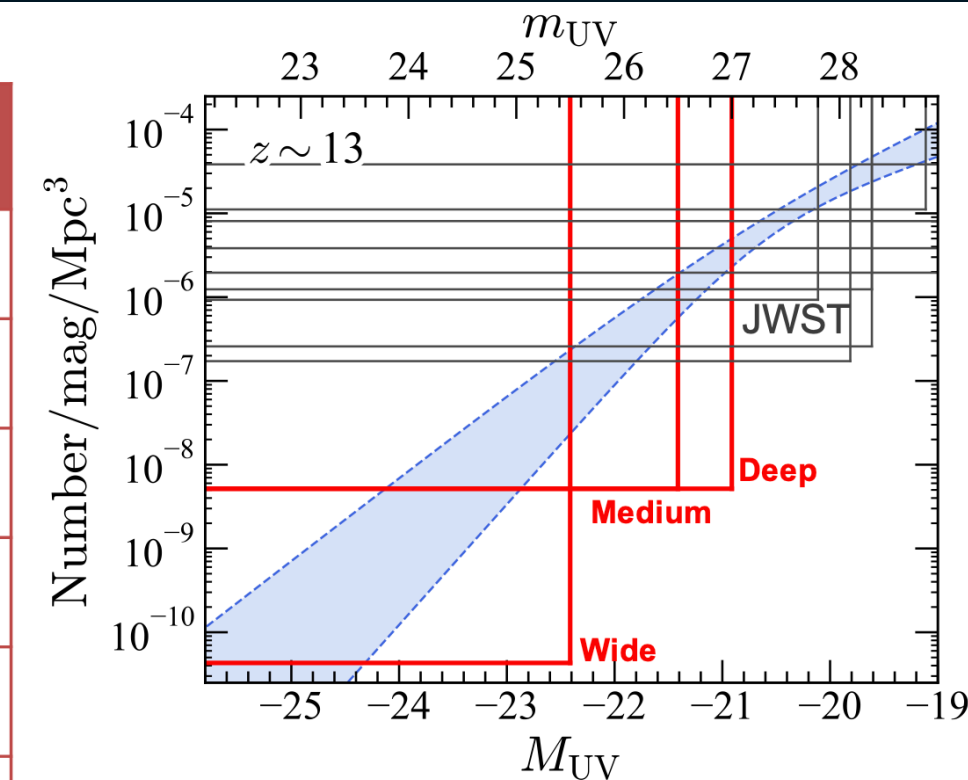
MIR Surveyor	Deep ($T_{\text{int}} = 3 \text{ hrs}$)	Medium ($T_{\text{int}} = 1.2 \text{ hrs}$)	Wide ($T_{\text{int}} = 0.19 \text{ hrs}$)
Area (deg ²)	~20	~20	~2400
3 μm (5σ , AB)	27	26.5	25.5
7 μm (5σ , AB)	25	24	22.5
Roman	Ultra Deep+HLTDS ($T_{\text{int}} = 2.5 \text{ hrs}$)	Deep ($T_{\text{int}} = 1.2 \text{ hrs}$)	Medium ($T_{\text{int}} = 0.18 \text{ hrs}$)
Area (deg ²)	~20	~20	~2400
H (5σ , AB)	28.0	27.5	26.4

Prediction (L2)

MIR Surveyor can probe rare luminous galaxies not sampled by JWST surveys.



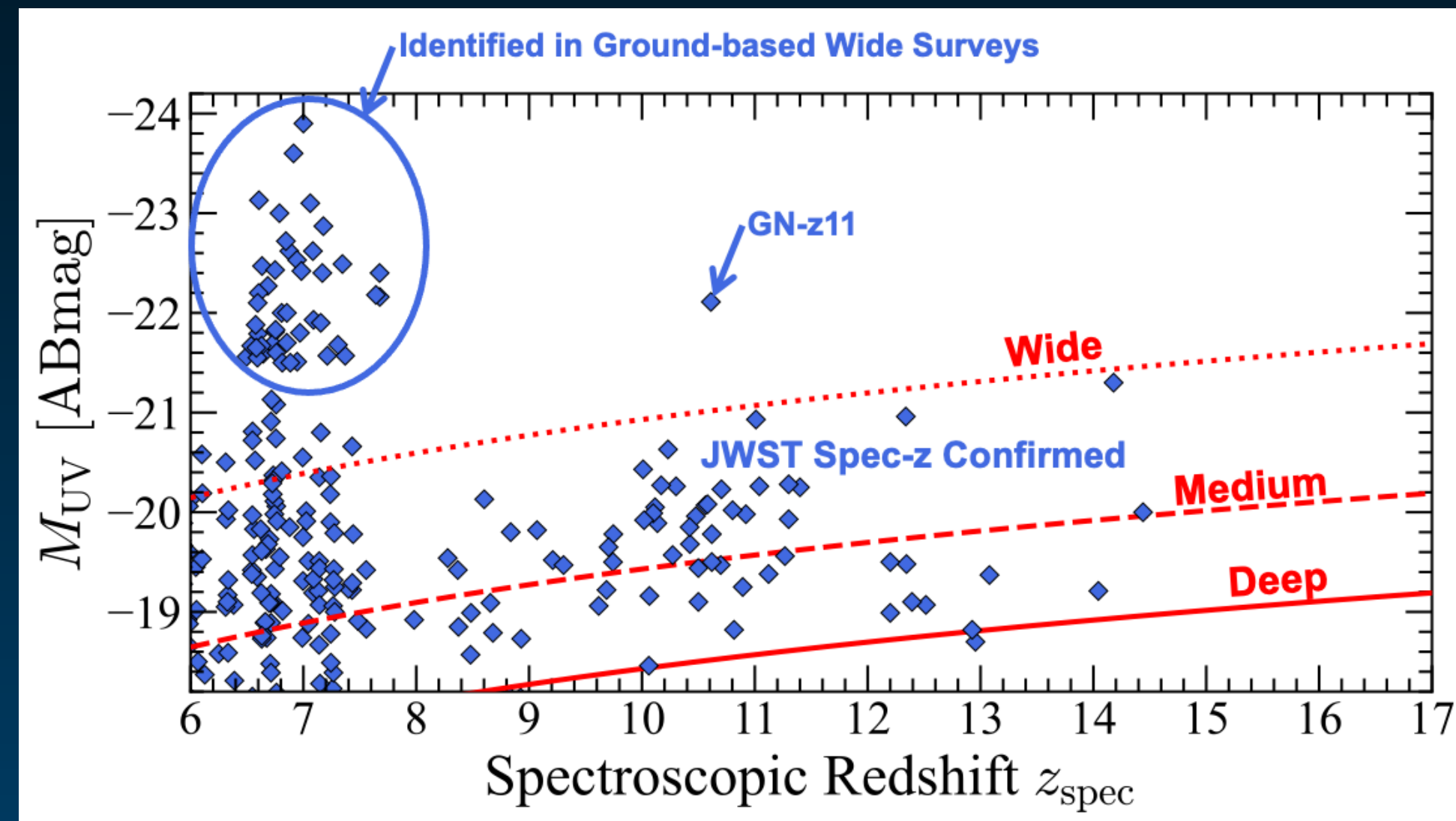
z	Survey	Number from H25	Number from W25
12-14	Deep	278	737
	Medium	40	192
	Wide	186	2689
14-16	Deep	64	261
	Medium	9	67
	Wide	39	908
16-18	Deep	16	98
	Medium	2	25
	Wide	9	327
18-22	Deep	4	50
	Medium	1	12
	Wide	2	156



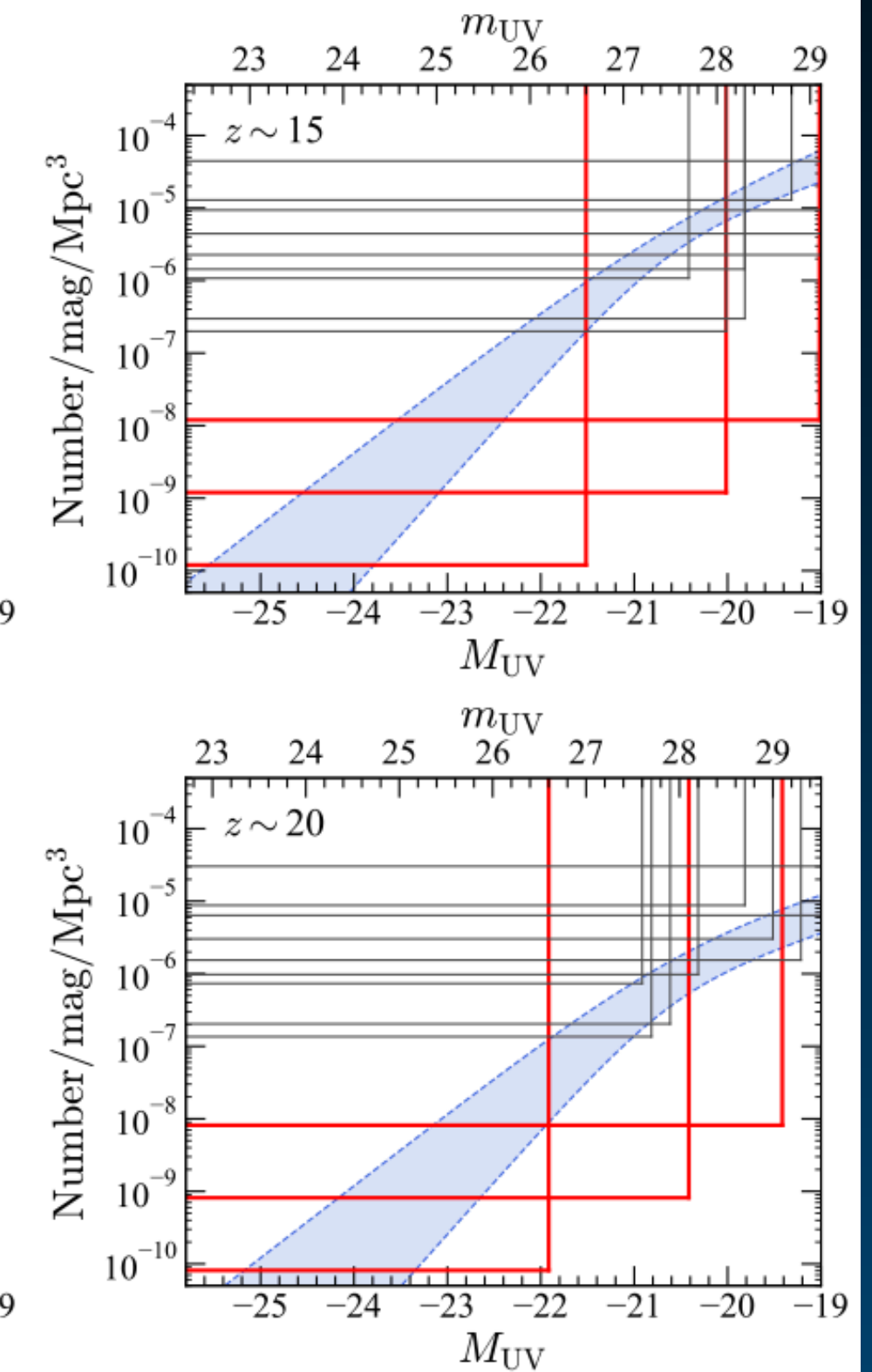
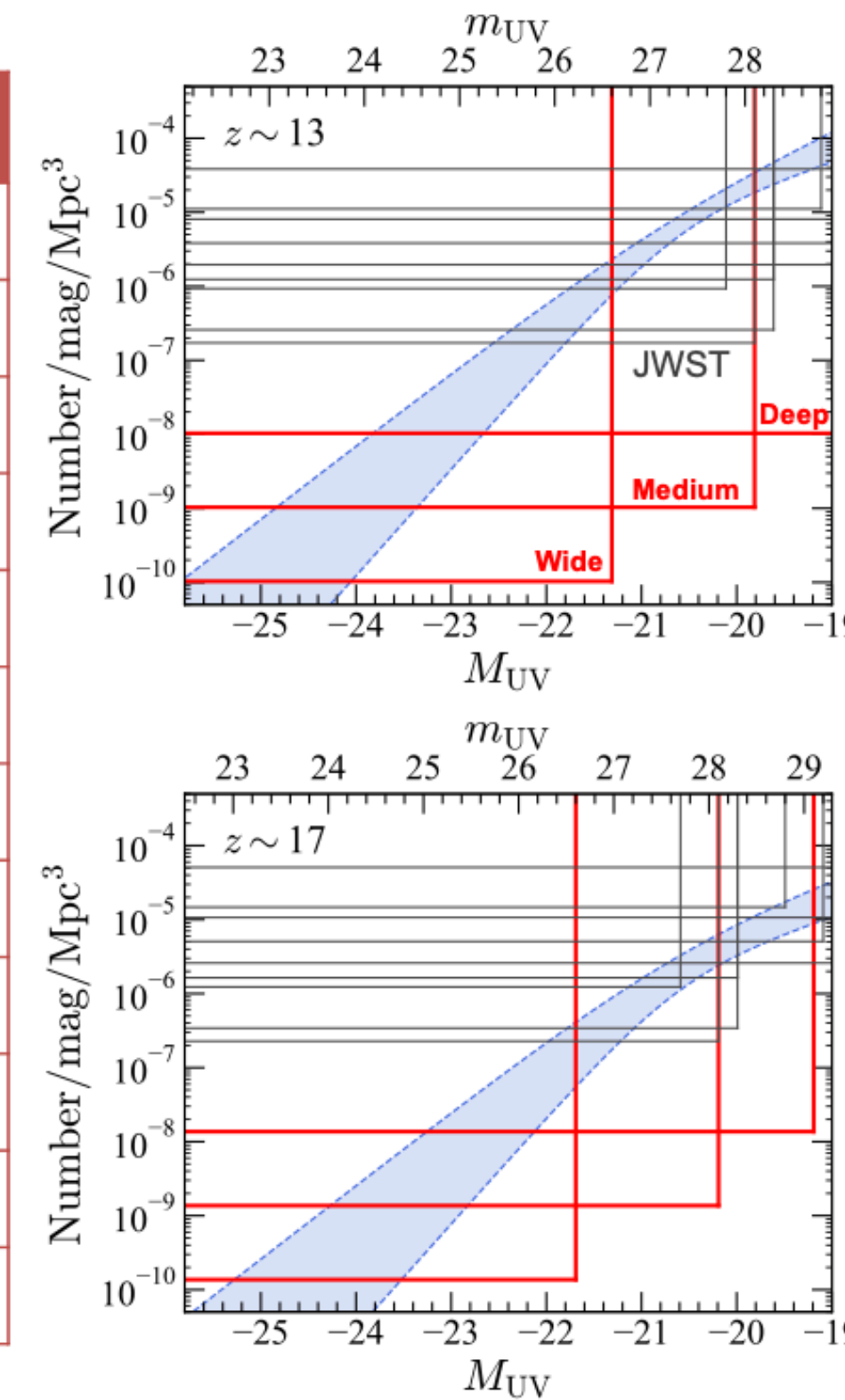
Next redshift frontier!

Prediction (Beyond-zodi)

Huge increase in #detections (thousands)!



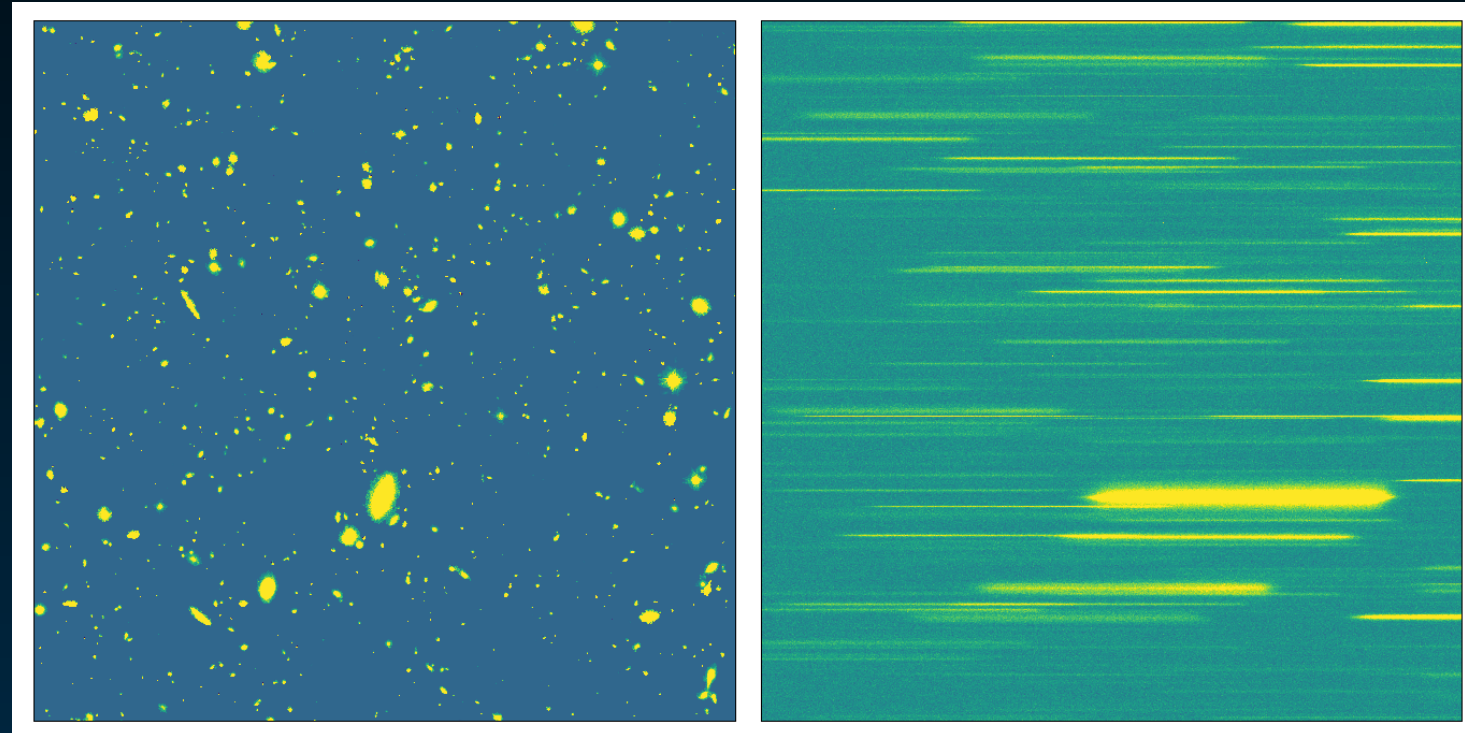
z	Survey	Number from H25	Number from W25
12-14	Deep	6139	14700
	Medium	10916	20746
	Wide	2722	11825
14-16	Deep	1504	3719
	Medium	3104	7458
	Wide	595	4137
16-18	Deep	497	1402
	Medium	914	2887
	Wide	142	1540
18-22	Deep	200	732
	Medium	309	1539
	Wide	38	764



BUT needs ~1 mag deeper Roman data for each tier (Deep/Medium/Wide).

Wide Field Imager + Grism WFSS

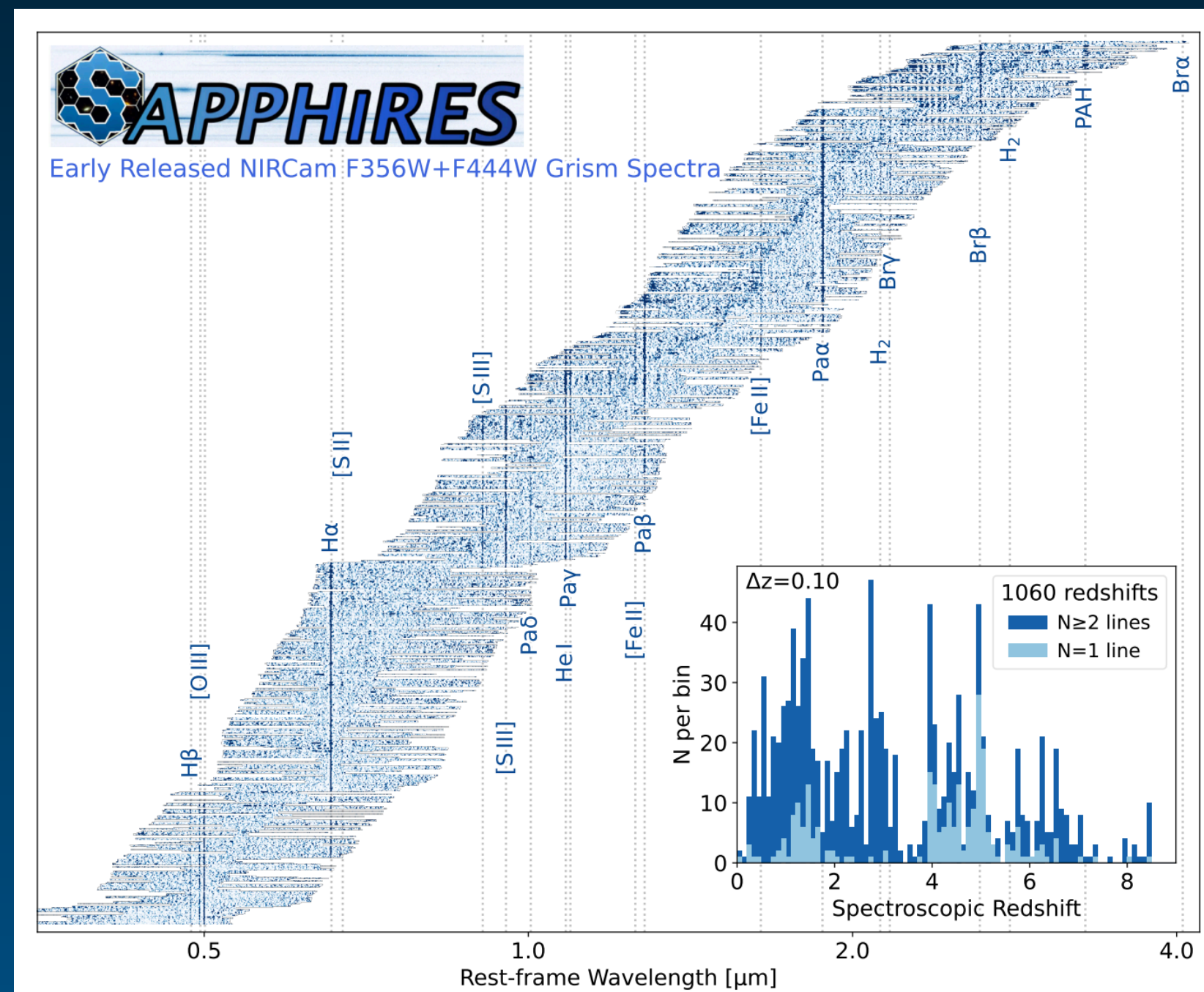
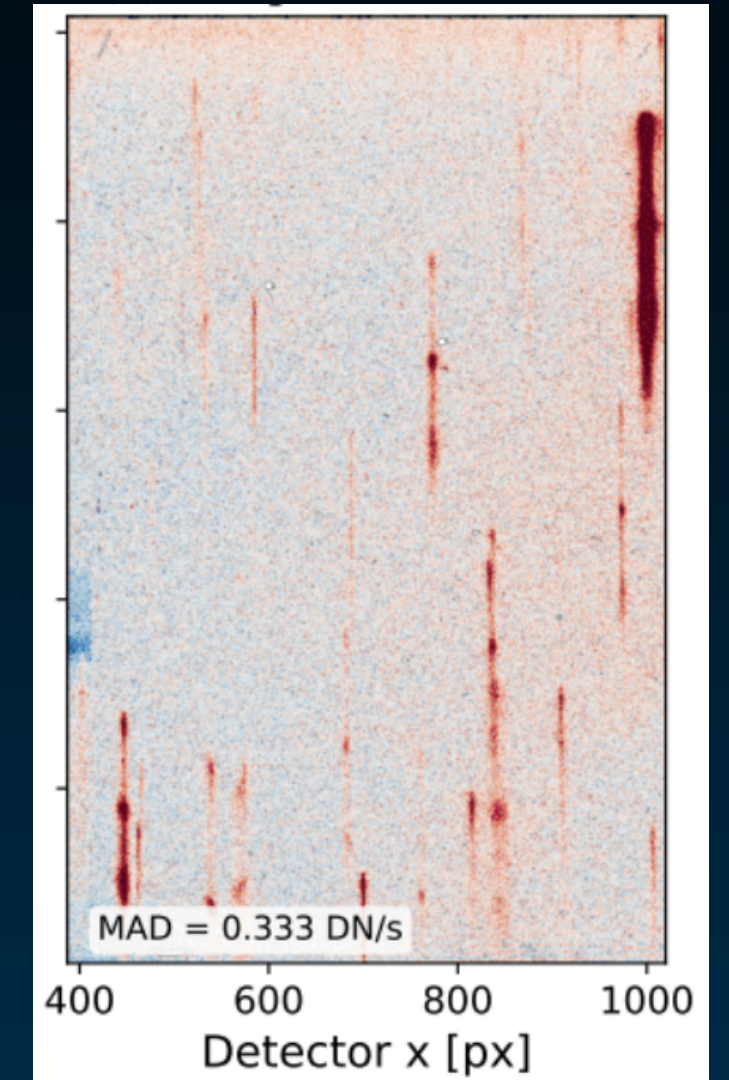
JWST NIRCam/Grism WFSS (2.5-5 μm ; $R\sim 1600$)



JWST MIRI/Grism
WFSS
(5-14 μm ; $R\sim 100$)

GOODS-N/S
public parallel data

F. Sun+2026 (in prep)

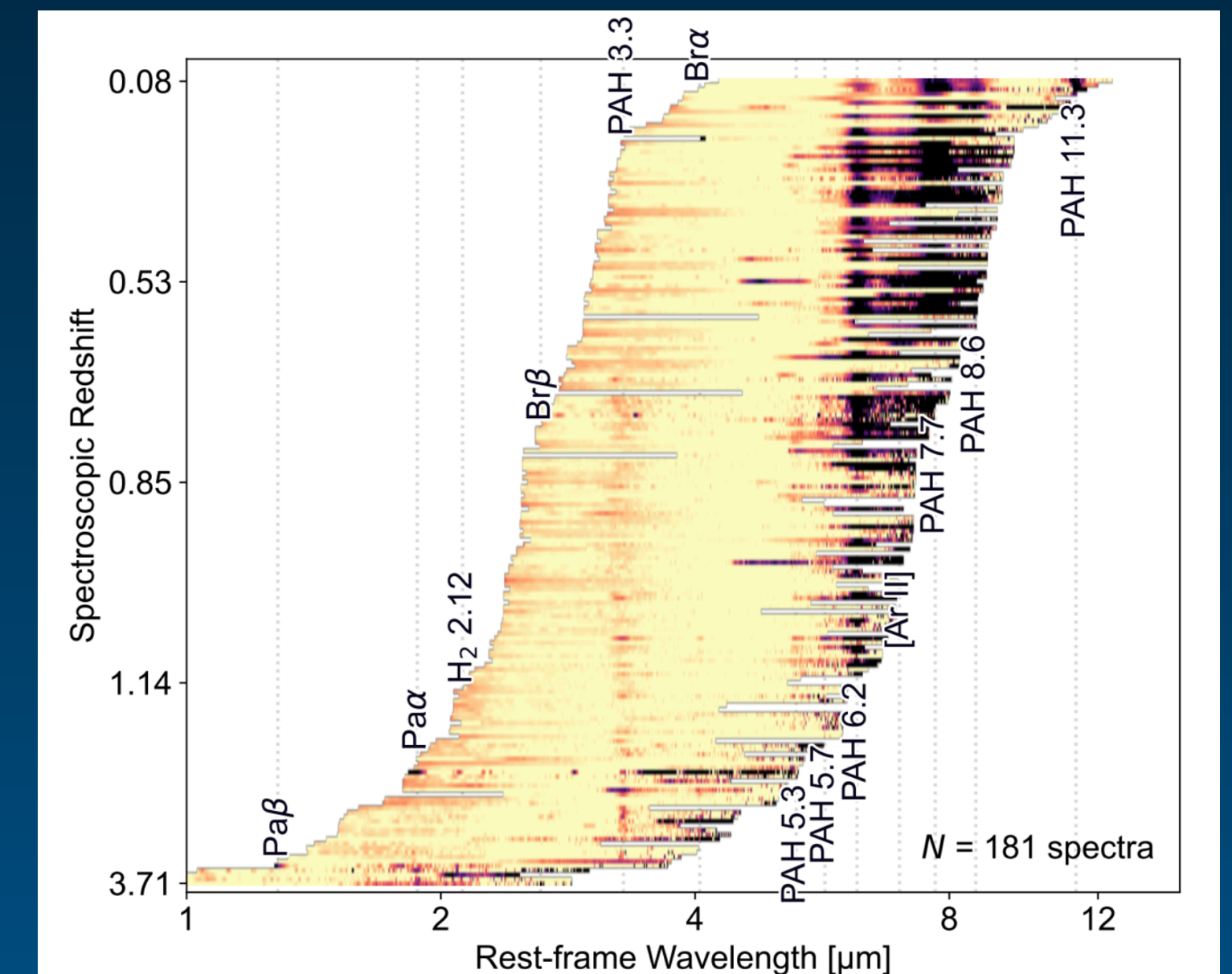


SAPPHIRES

~700-hr pure-parallel
program (PI: Egami)

Early Release Data
~2 NIRCam pointings
~50 hrs
→ ~1000 spectra

F. Sun+2025

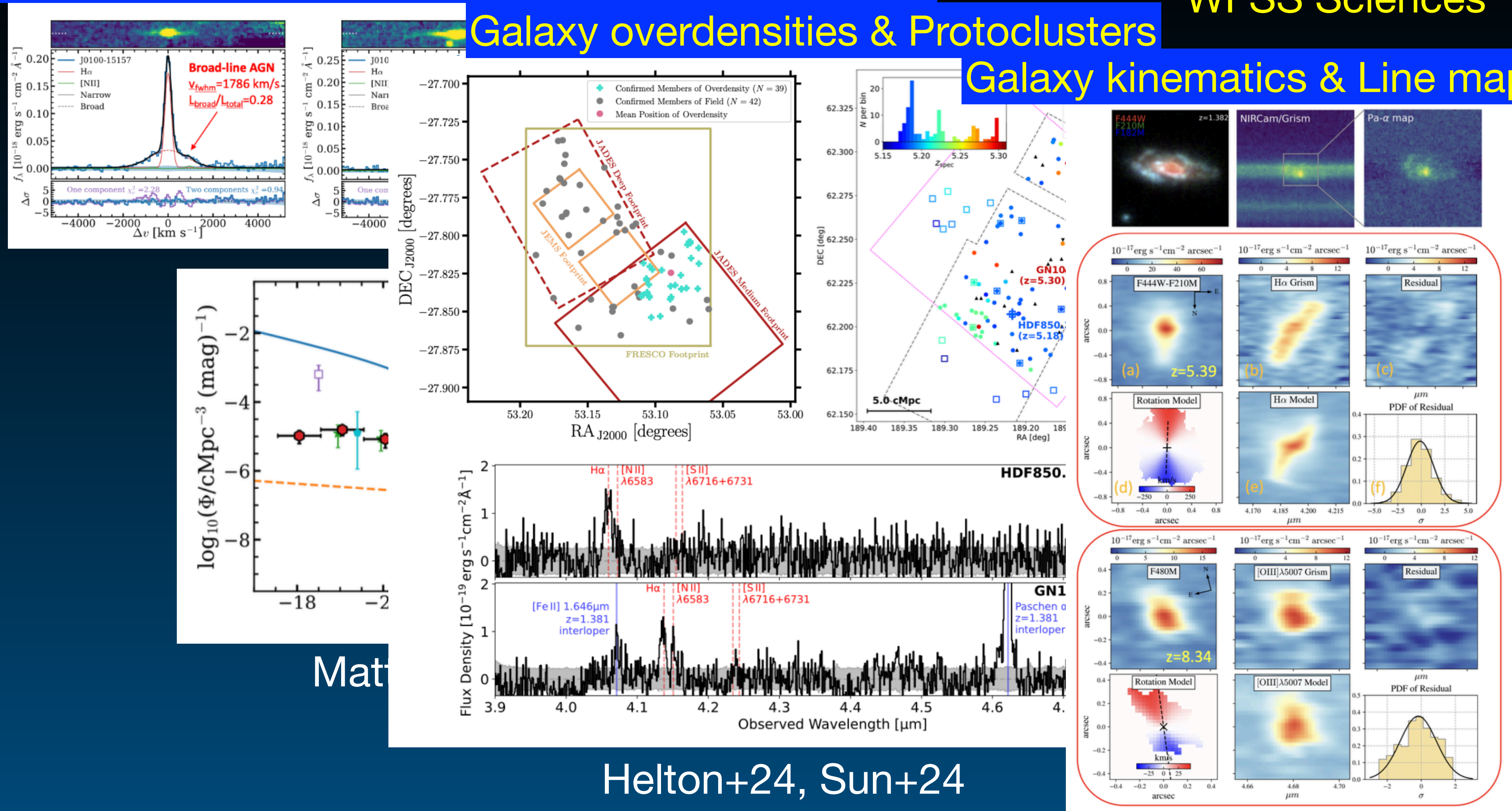


Broad-line AGN survey (incl. Little Red Dots=LRDs)

WFSS Sciences

Galaxy overdensities & Protoclusters

Galaxy kinematics & Line mapping



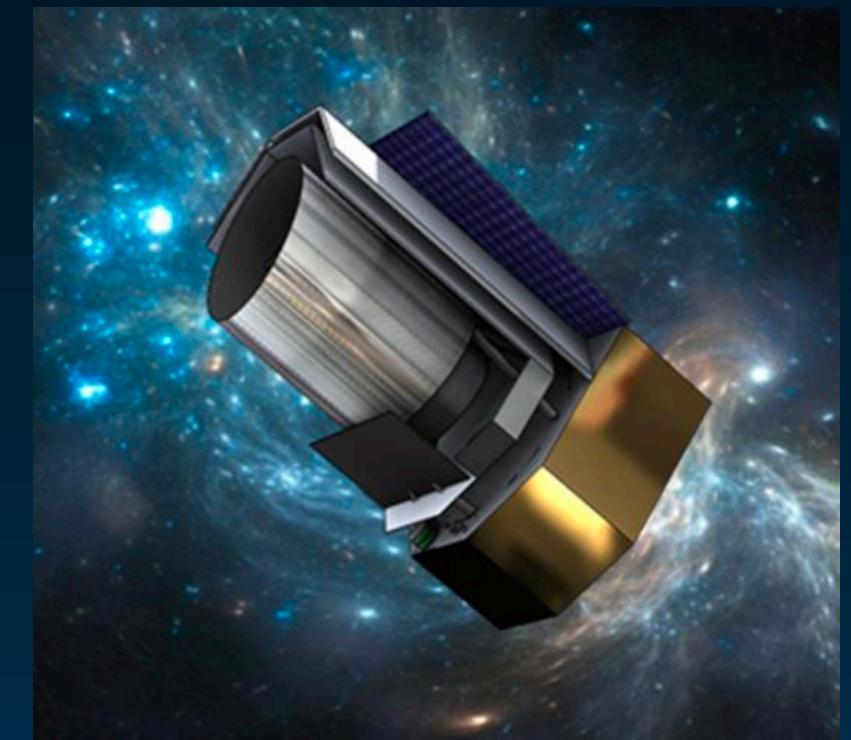
Mat

Helton+24, Sun+24

Li+23

Possible Collaboration with ISAS/JAXA

- Mid-IR survey mission is one of the high-priority projects for ISAS/JAXA in their road map.
 - GREX-PLUS (Galaxy Reionization EXplorer and PLanetary Universe Spectrometer; D=1m mid-IR telescope@L2) has been funded for a concept study by ISAS/JAXA, which is on-going.
 - However, the next mission opportunity is currently under discussion.
 - The ISAS/JAXA funding would allow only a D=1m mission.
- Collaboration between NASA and ISAS/JAXA will allow a larger mission with much greater scientific impact (e.g., D=2m@L2 or beyond zodi) through sharing of cost, expertise, and resources.



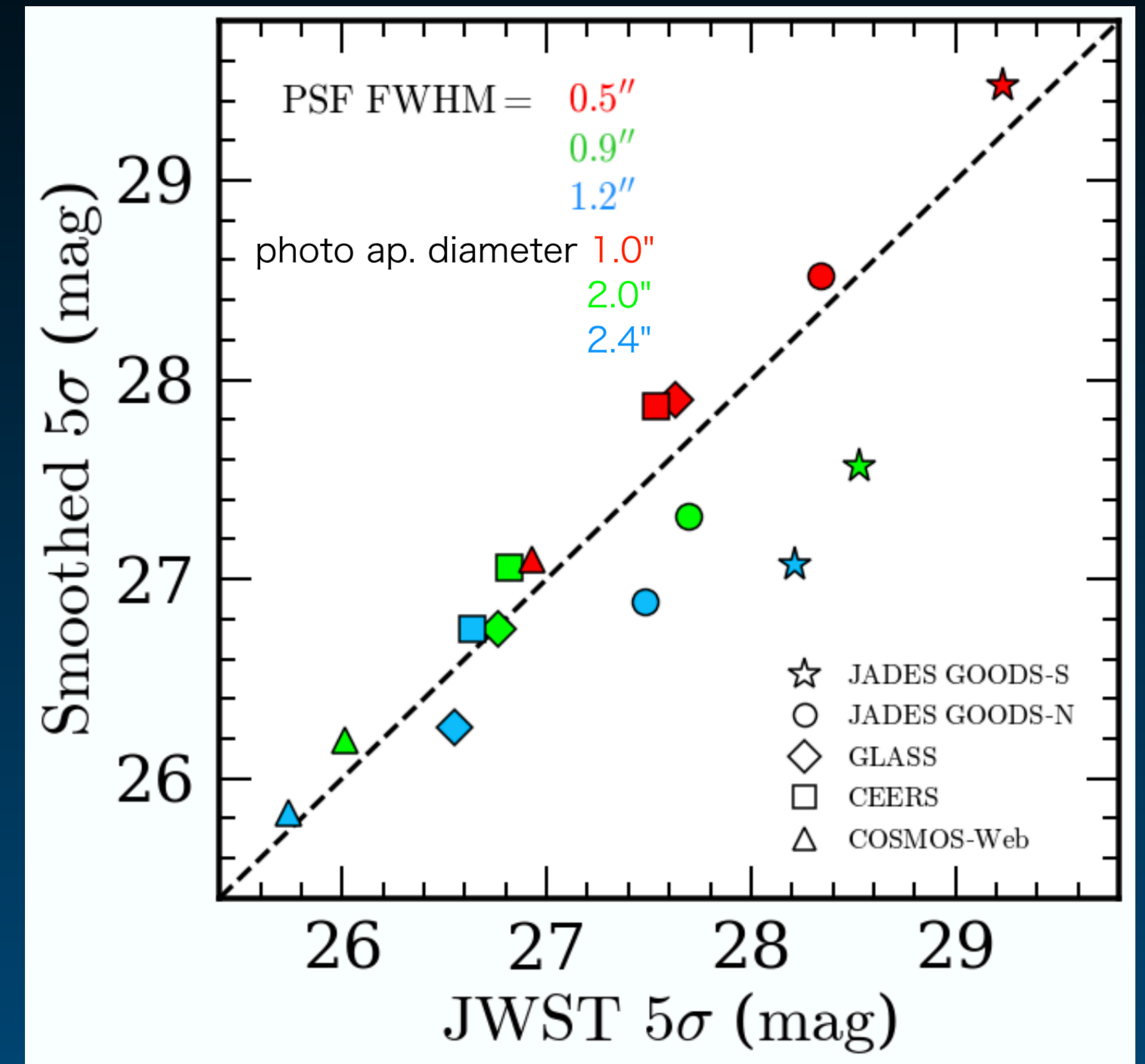
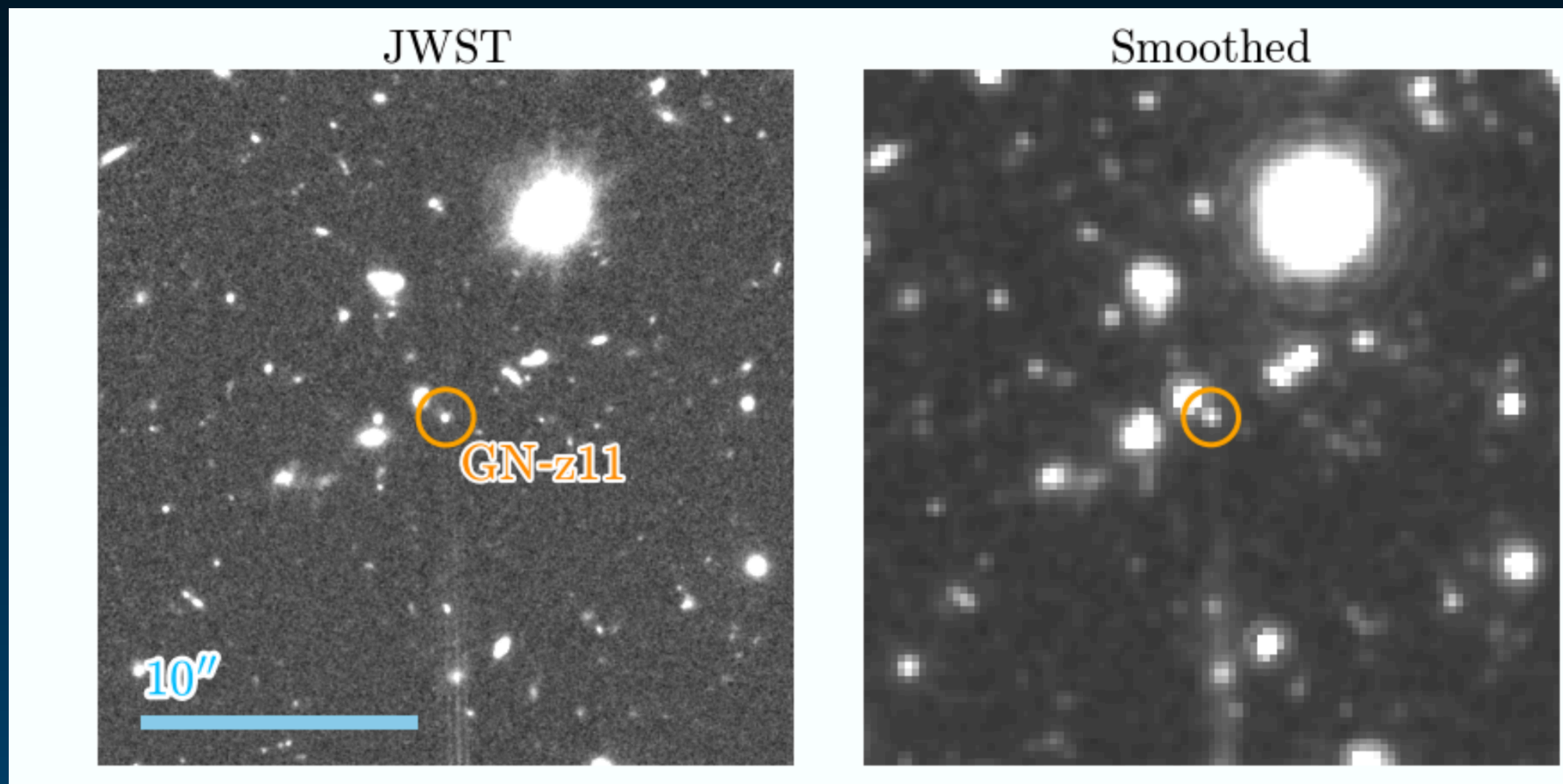
GREX-PLUS

Summary

- Roman-like mid-IR wide-field surveyor mission with a $D=2\text{m}$ passively cooled ($<40\text{ K}$) telescope will detect **luminous $z>13$ galaxies in tens/hundreds, opening up the next redshift frontier** (and will likely detect Pop-III SNe at $z>6$ for the first time).
- Using grisms, we can easily implement **Wide Field Slitless Spectroscopy (WFSS) mode**, which turns out to be extremely powerful with JWST (and likely with Roman).
- **Follow-up observations with JWST and ALMA** will allow us to study the physical properties of detected galaxies in detail.
 - **This motivates a speedy preparation (e.g., ~ 10 yrs) since JWST will be available only up to ~ 2040 .** This is likely possible because this mission is conservative technically, built on available technology.
- Possible collaboration with ISAS/JAXA may be explored.

Back-up Slides

Confusion limits



Source confusion is not an issue down to ~29 mag