

OJALÁ (Optimising J-PAS Astronomy for Large-scale Analysis)

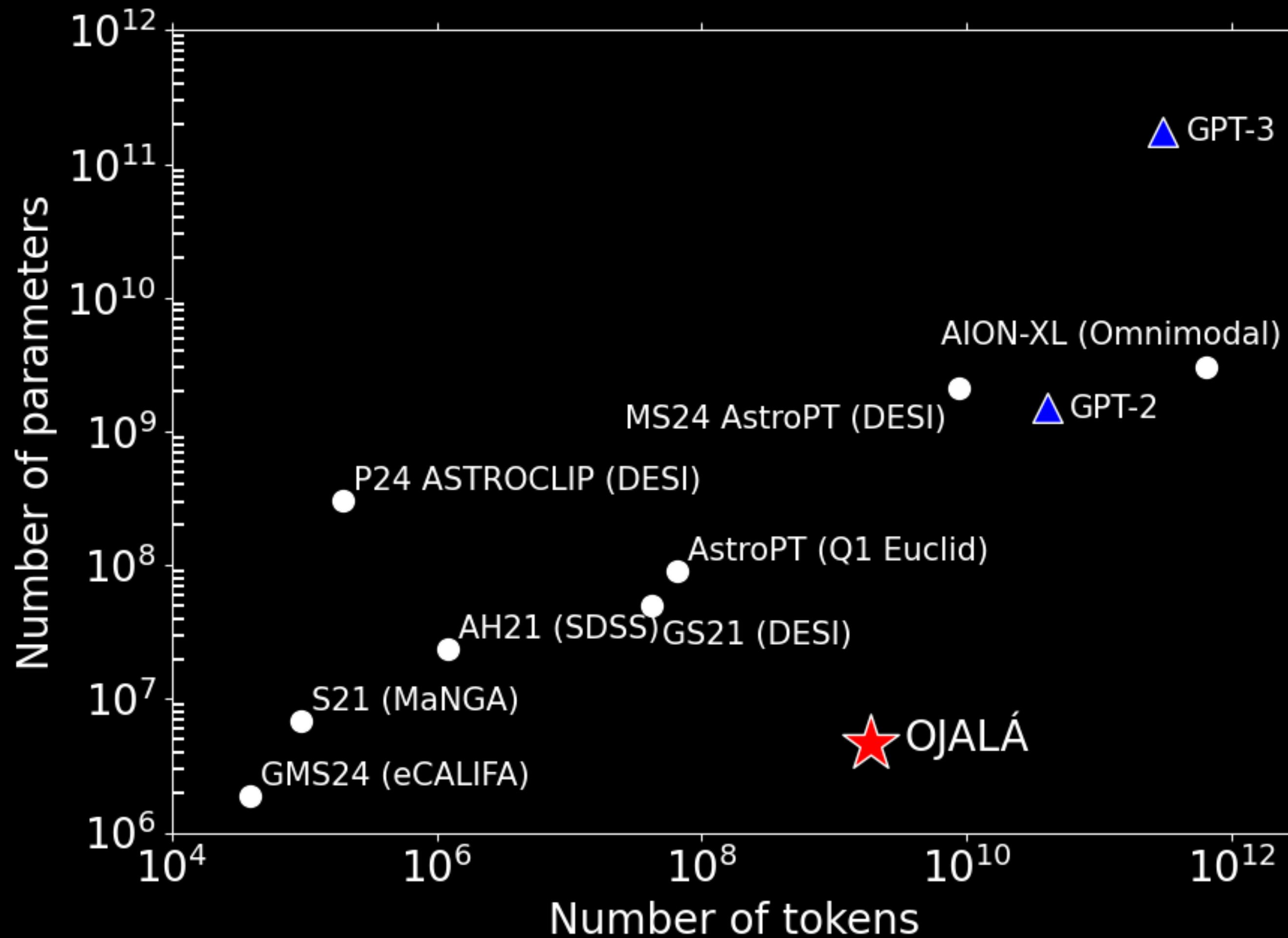
*A foundation model for the SED of galaxies, QSO and stars in
the J-PAS survey*

Ginés Martínez Solaeche

AfAS, 27 April 2026, Botswana



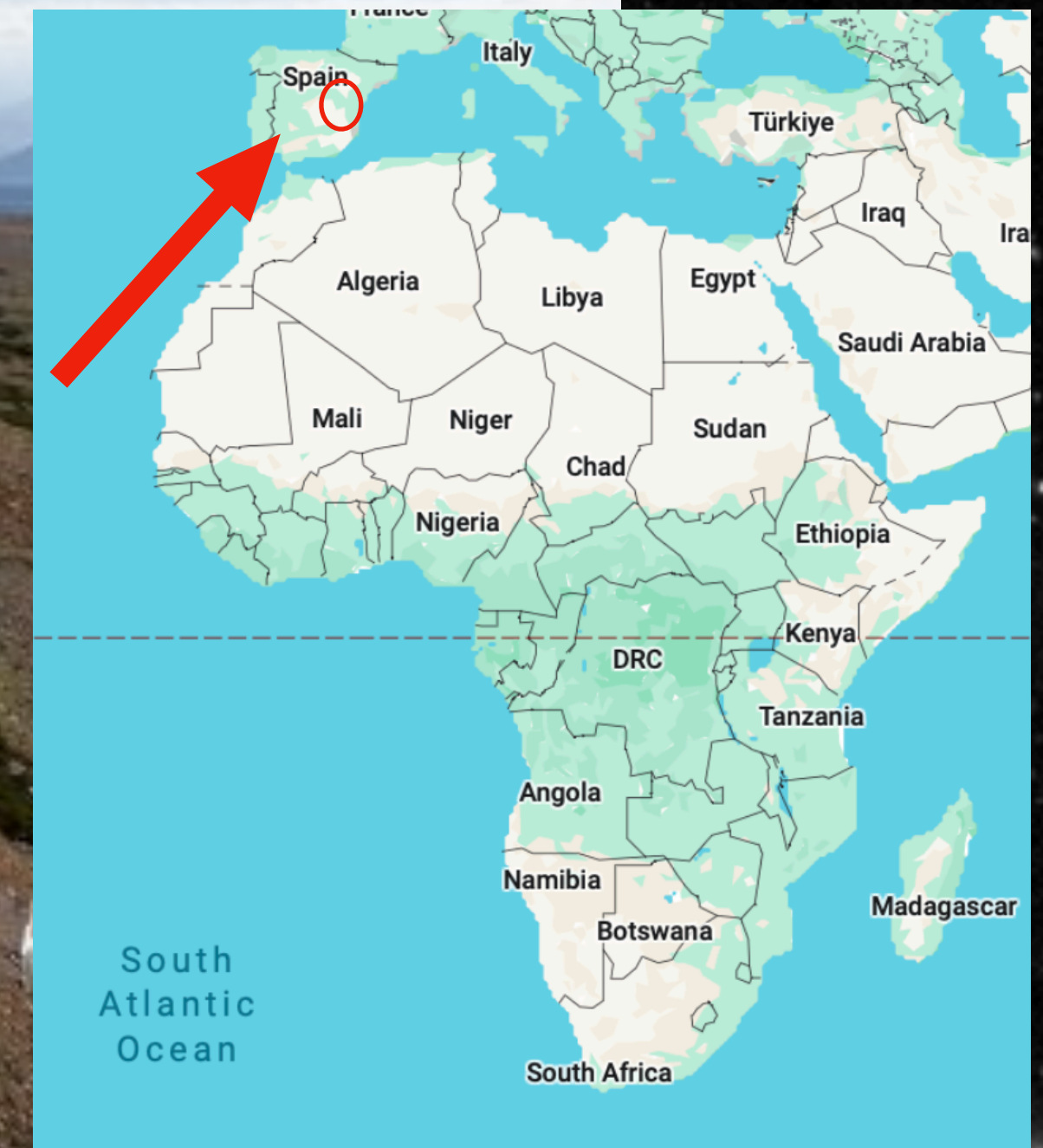
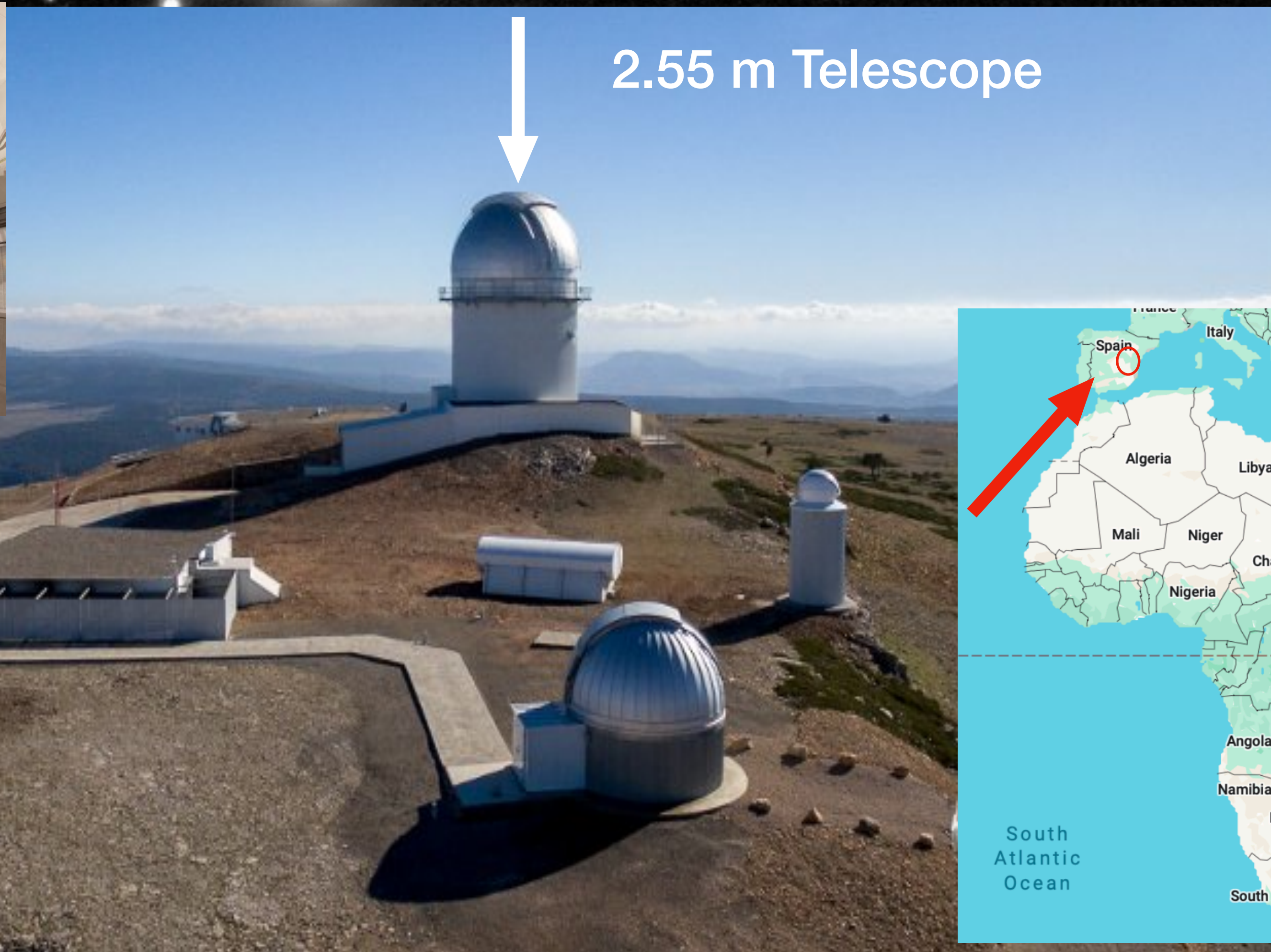
Foundation model in astronomy, the scaling laws



“A foundation model is a large deep learning model train on vast dataset that can be applied across a wide range of use cases”

- AH21 – Hayat et al. (2021)
- S21 – Sarmiento et al. (2021)
- GS21 – Stein et al. (2021)
- GMS24 – Martínez-Solaache et al. (2024)
- P24 – Parker et al. (2024)
- MS24 – Smith et al. (2024)
- S25 – Siudek et al. (2025)
- AION-XL – Parker et al. (2025)

J-PAS: Javalambre Physics of the Accelerating Universe Astrophysical Survey



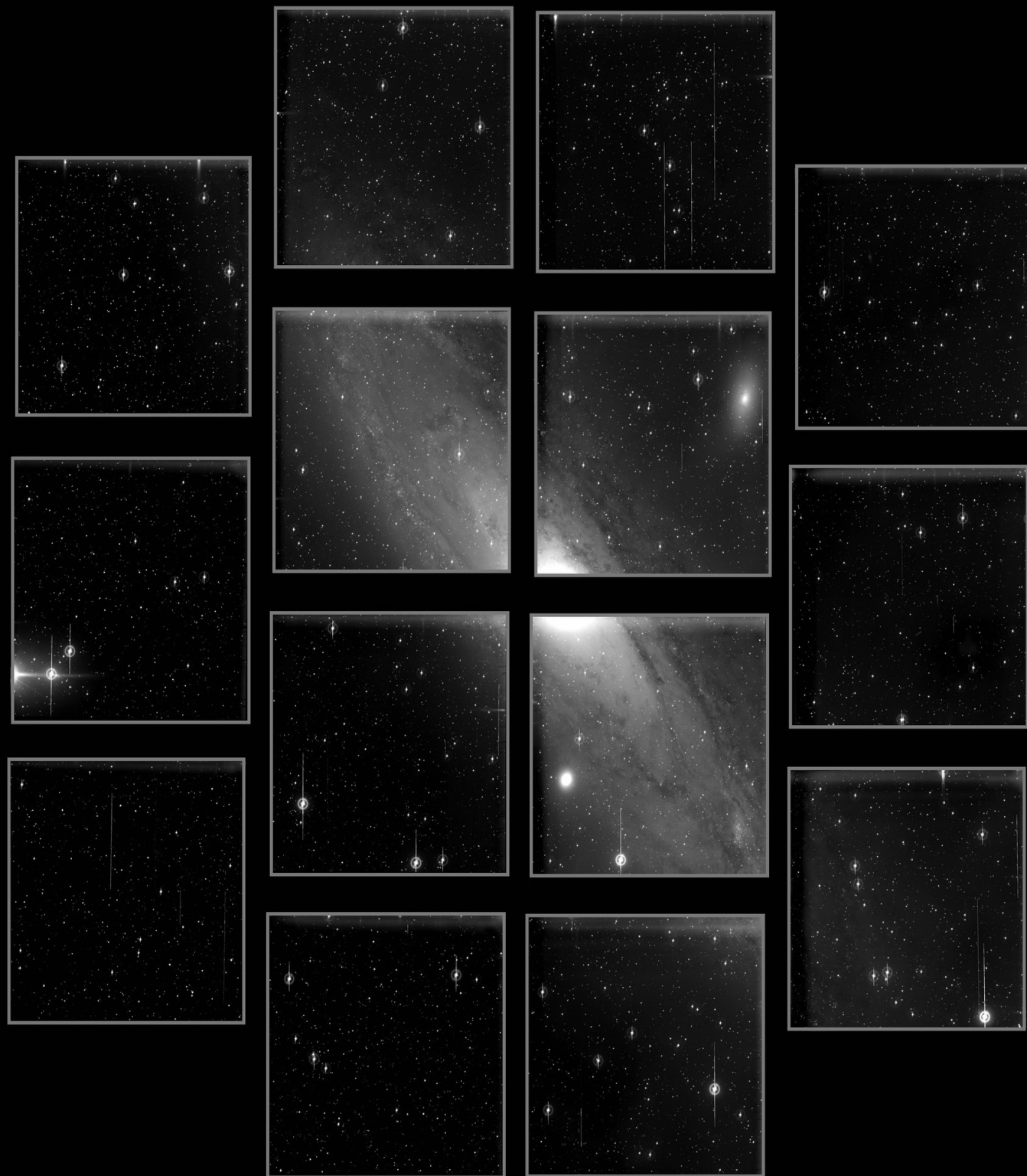
OAJ - Observatorio Astrofísico de Javalambre, Teruel (Spain)



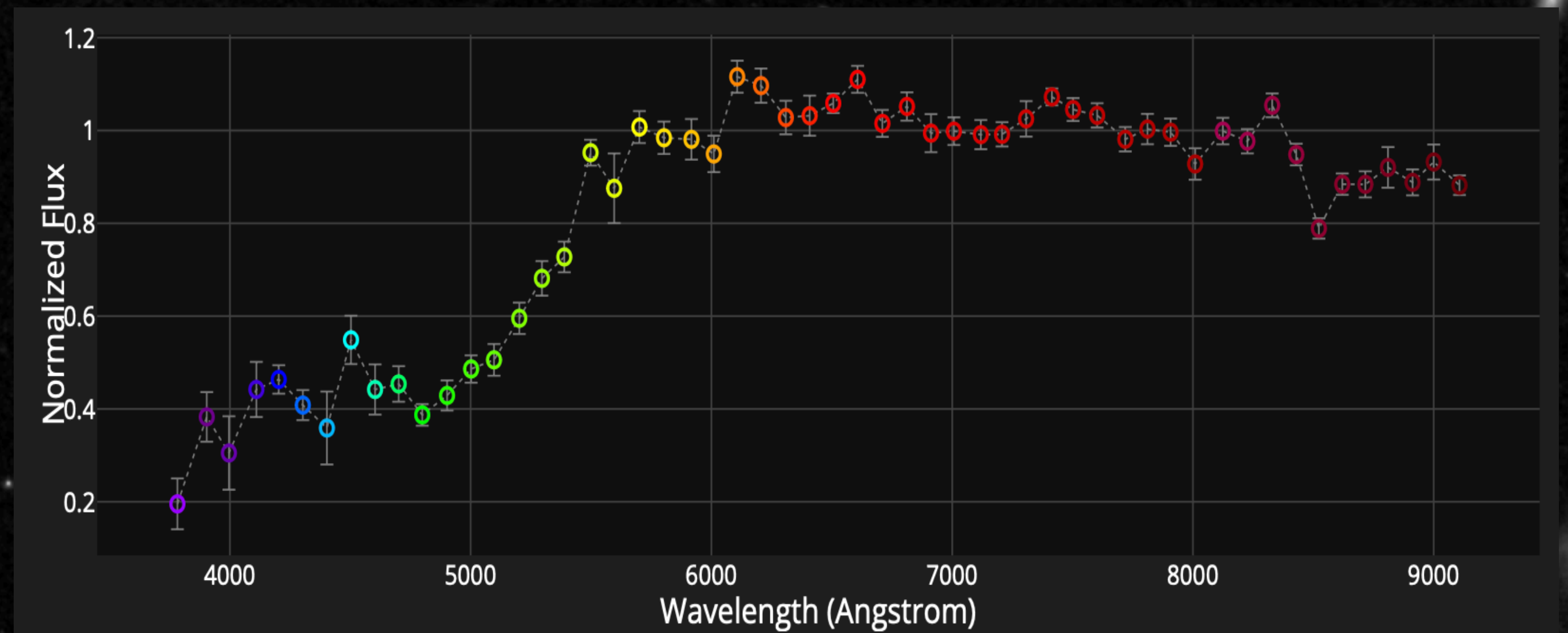
Instituto de Astrofísica de Andalucía, IAA-CSIC



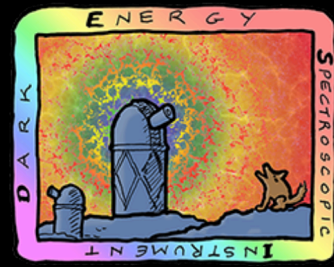
J-PAS: Javalambre Physics of the Accelerating Universe Astrophysical Survey



Andromeda Galaxy (M31), Technical First Light Image 29/06/2020. JPCam@JST/T250 - Observatorio Astrofísico de Javalambre (OAJ)

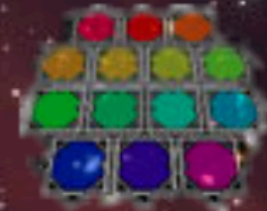
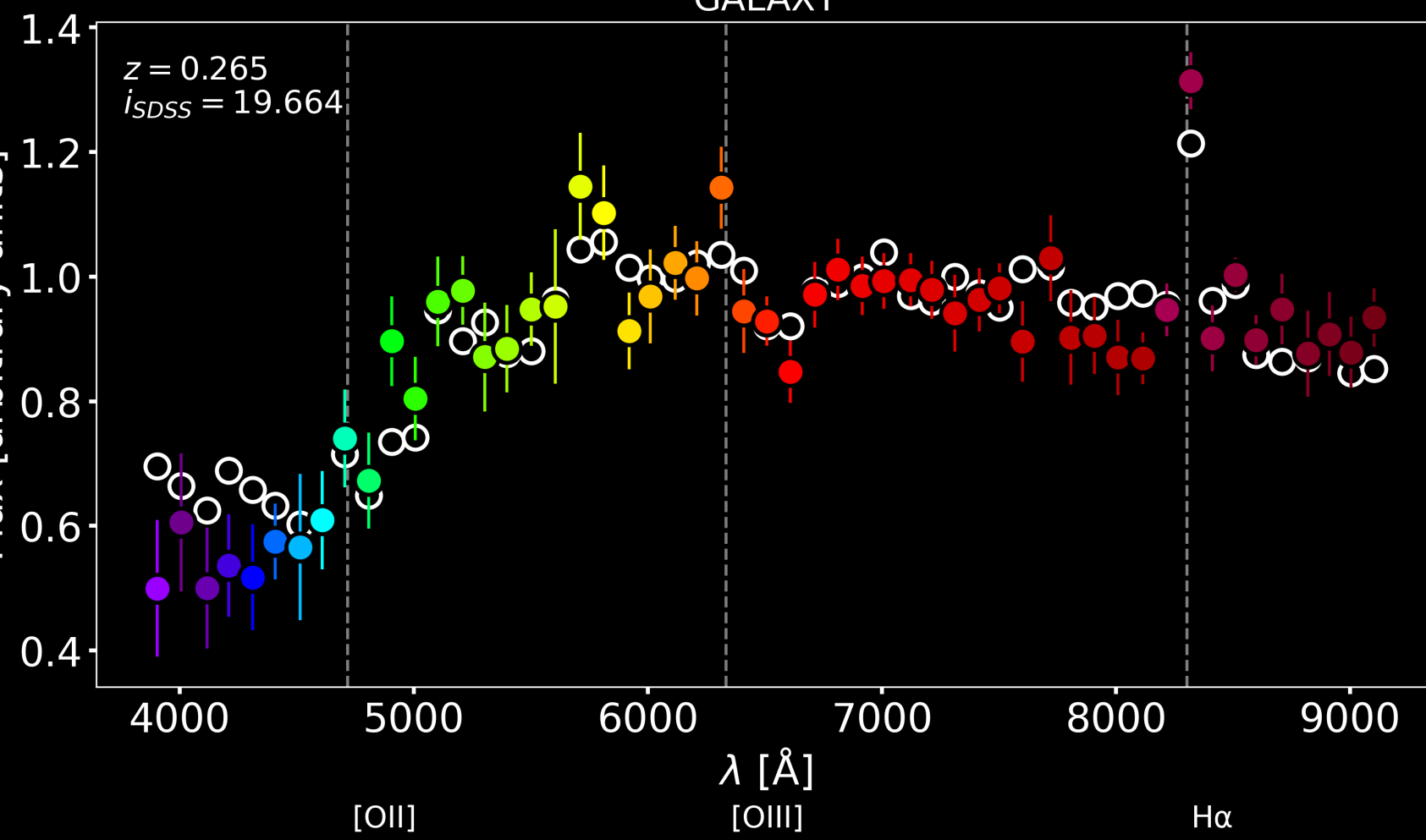


Building the training set, J-PAS mocks



DARK ENERGY
SPECTROSCOPIC
INSTRUMENT

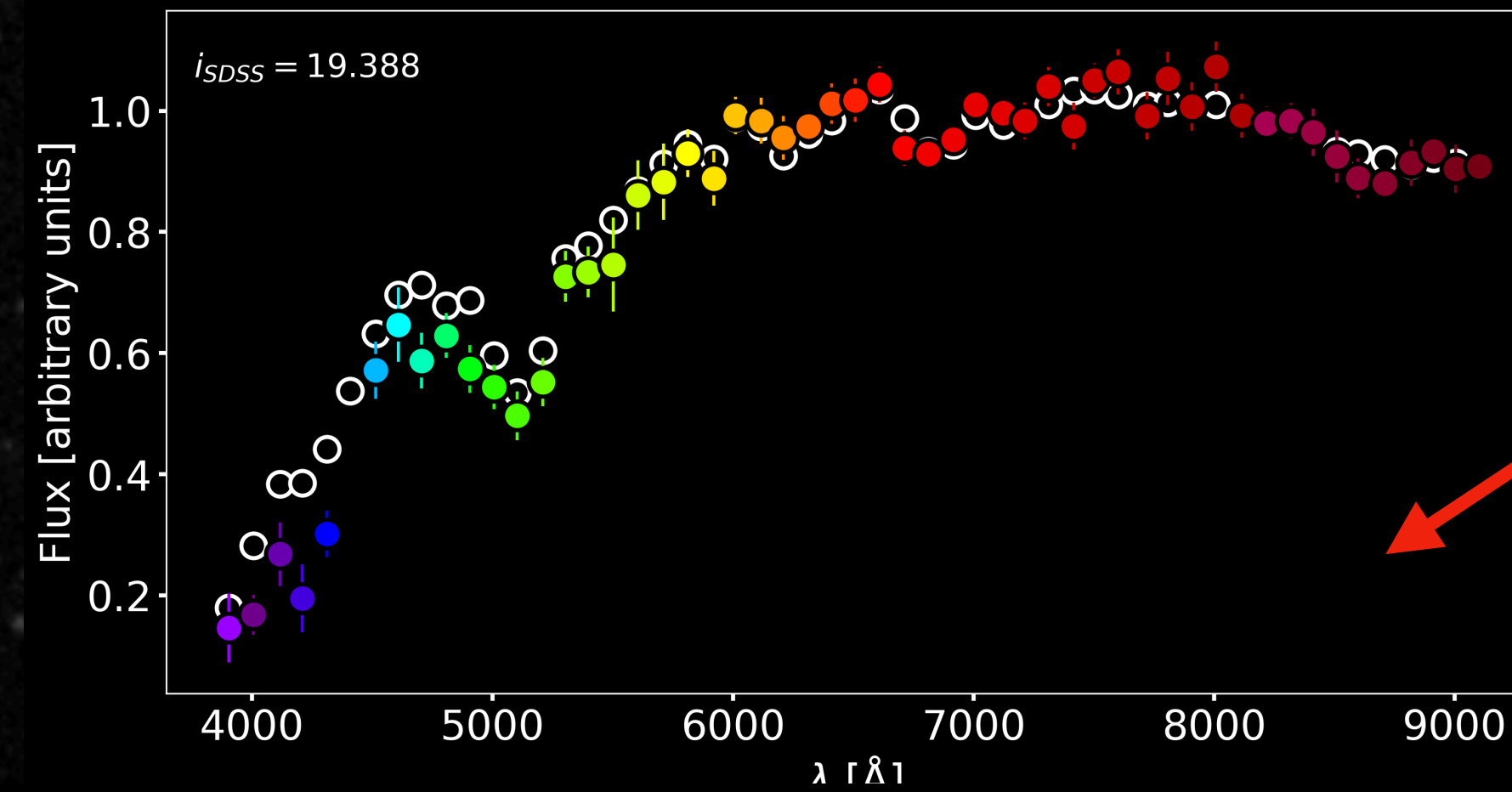
GALAXY



J-PAS

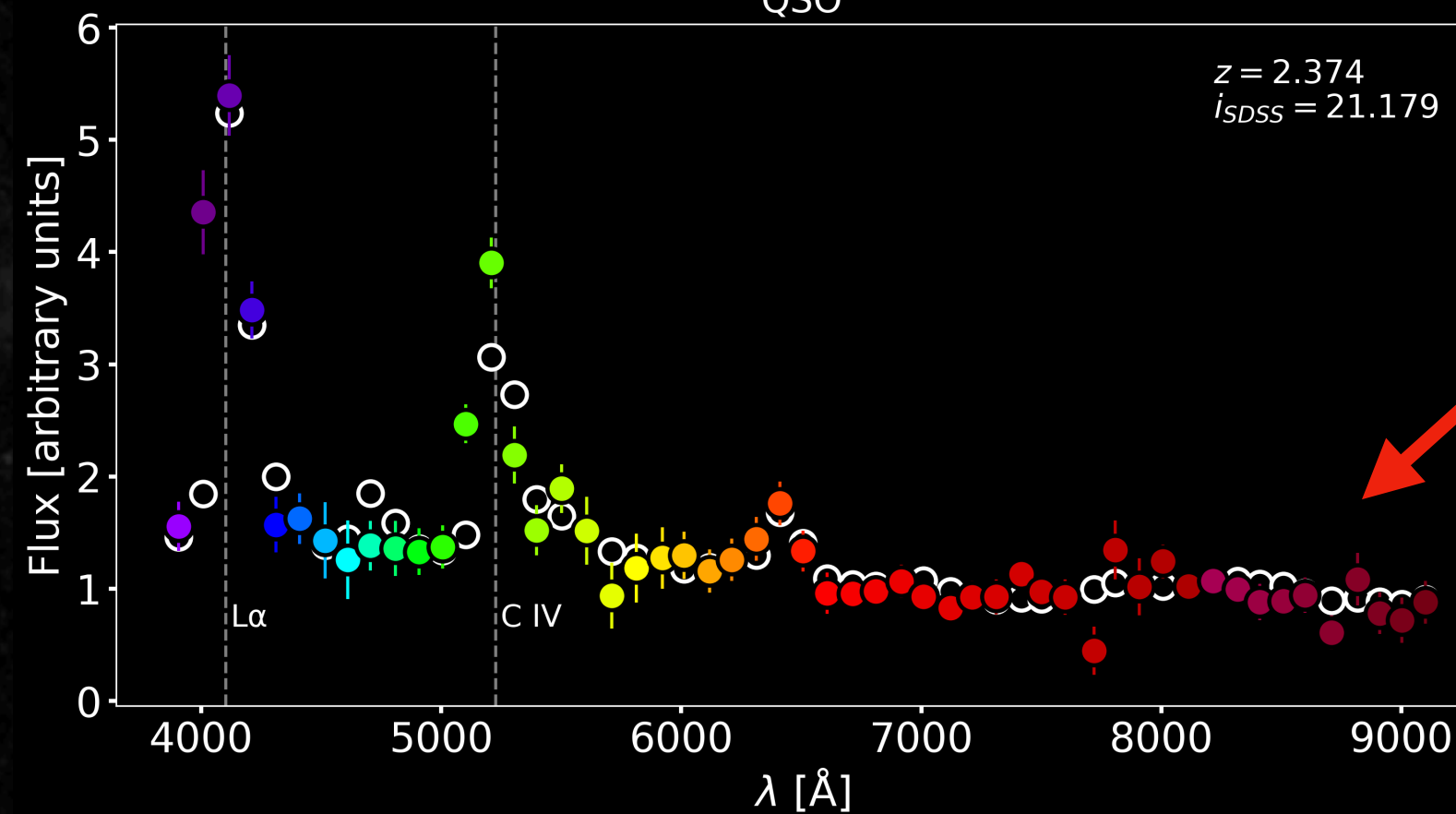
Javalambre Physics of the Accelerating
Universe Astrophysical Survey

STAR



20M Objects!

QSO



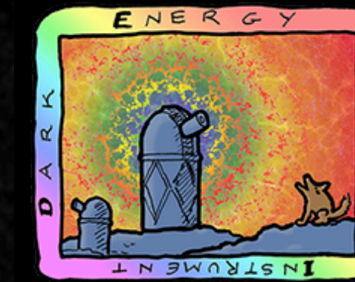
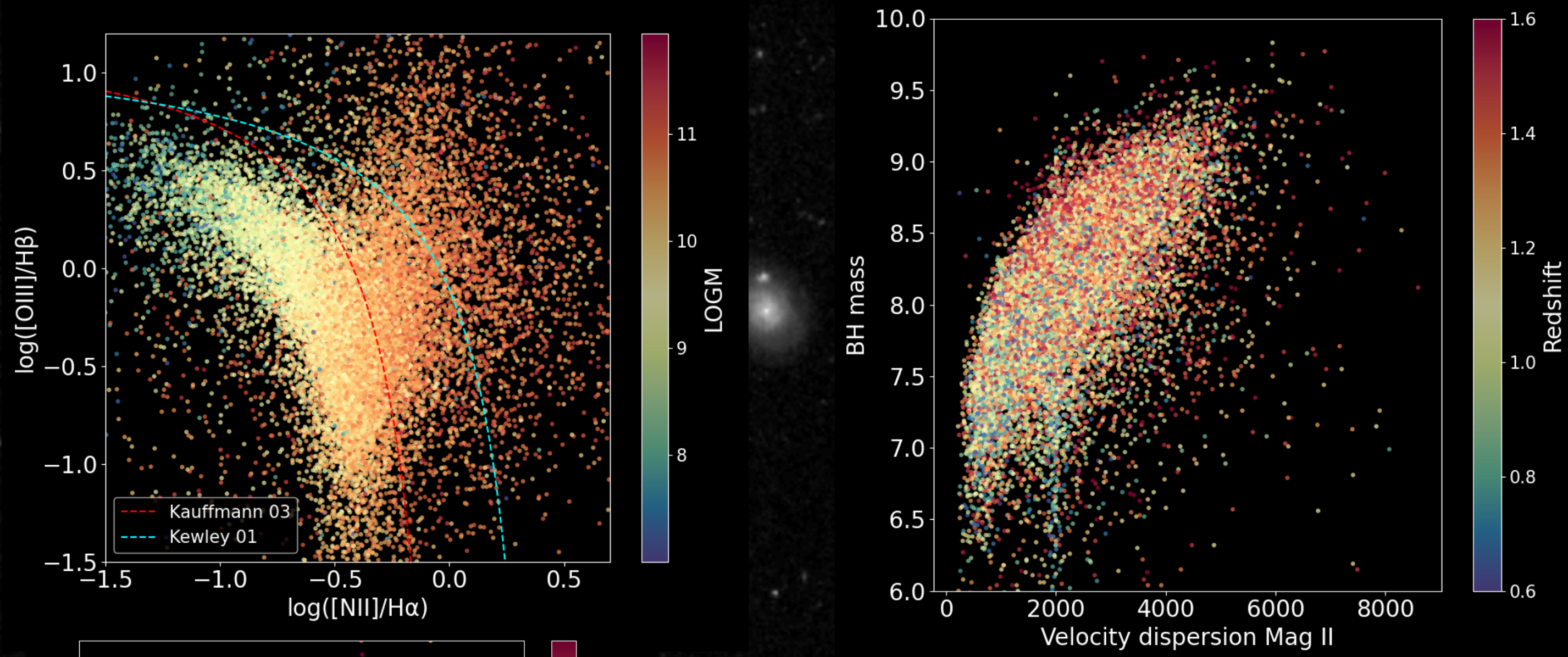
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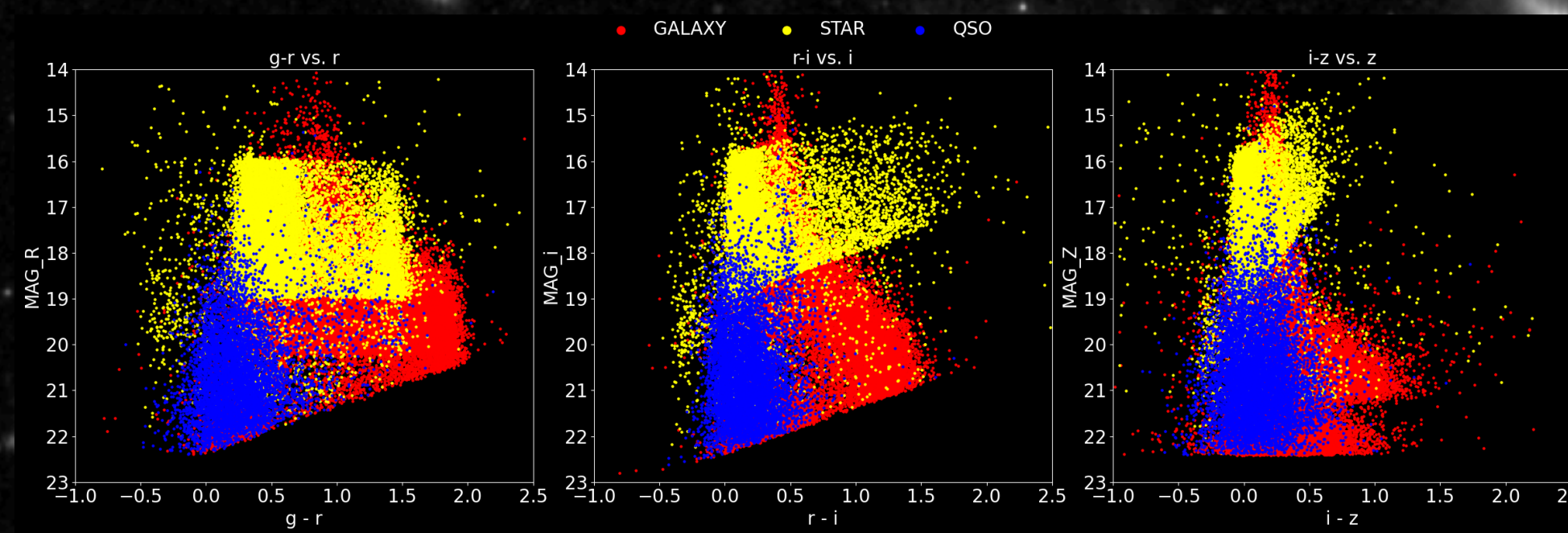
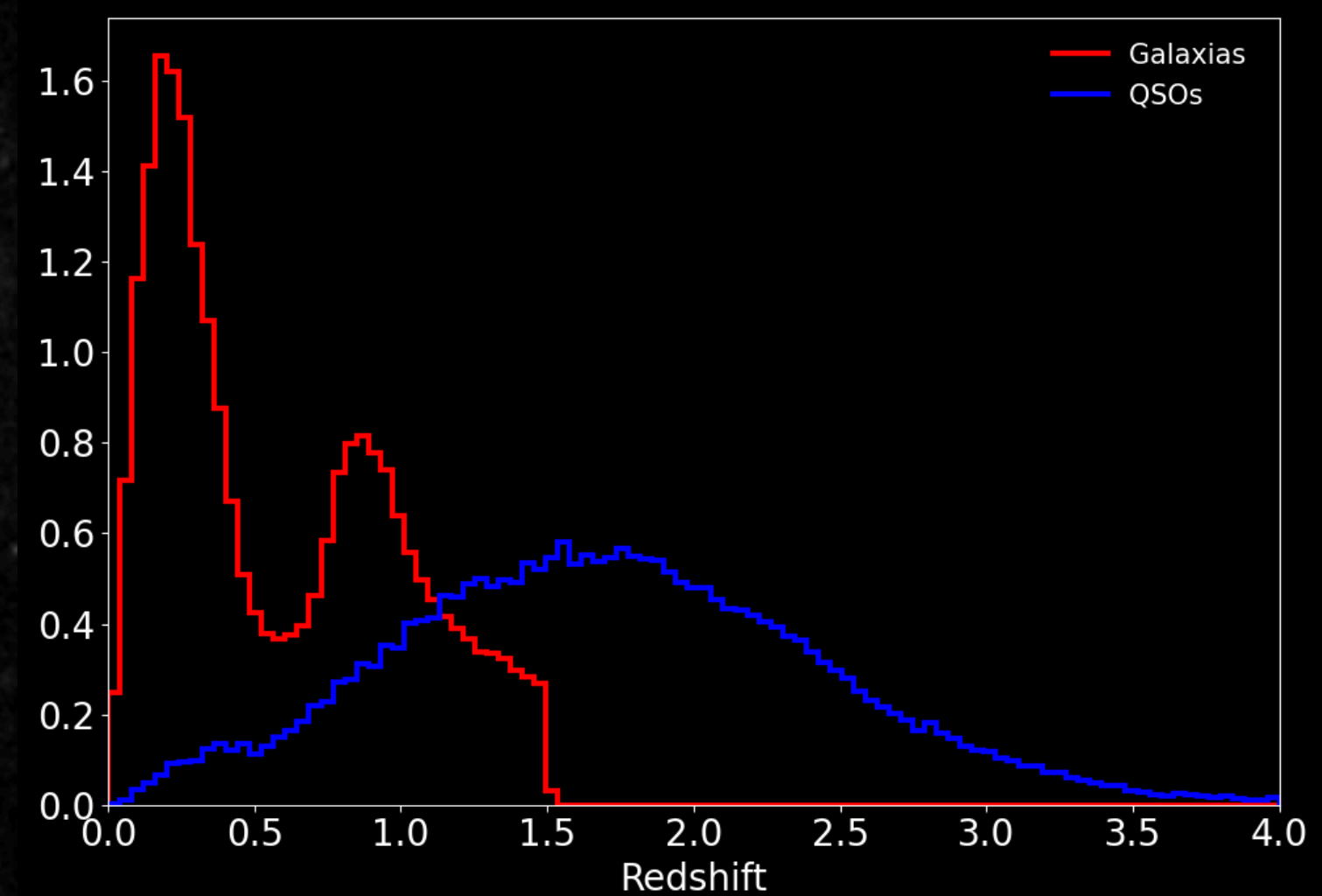
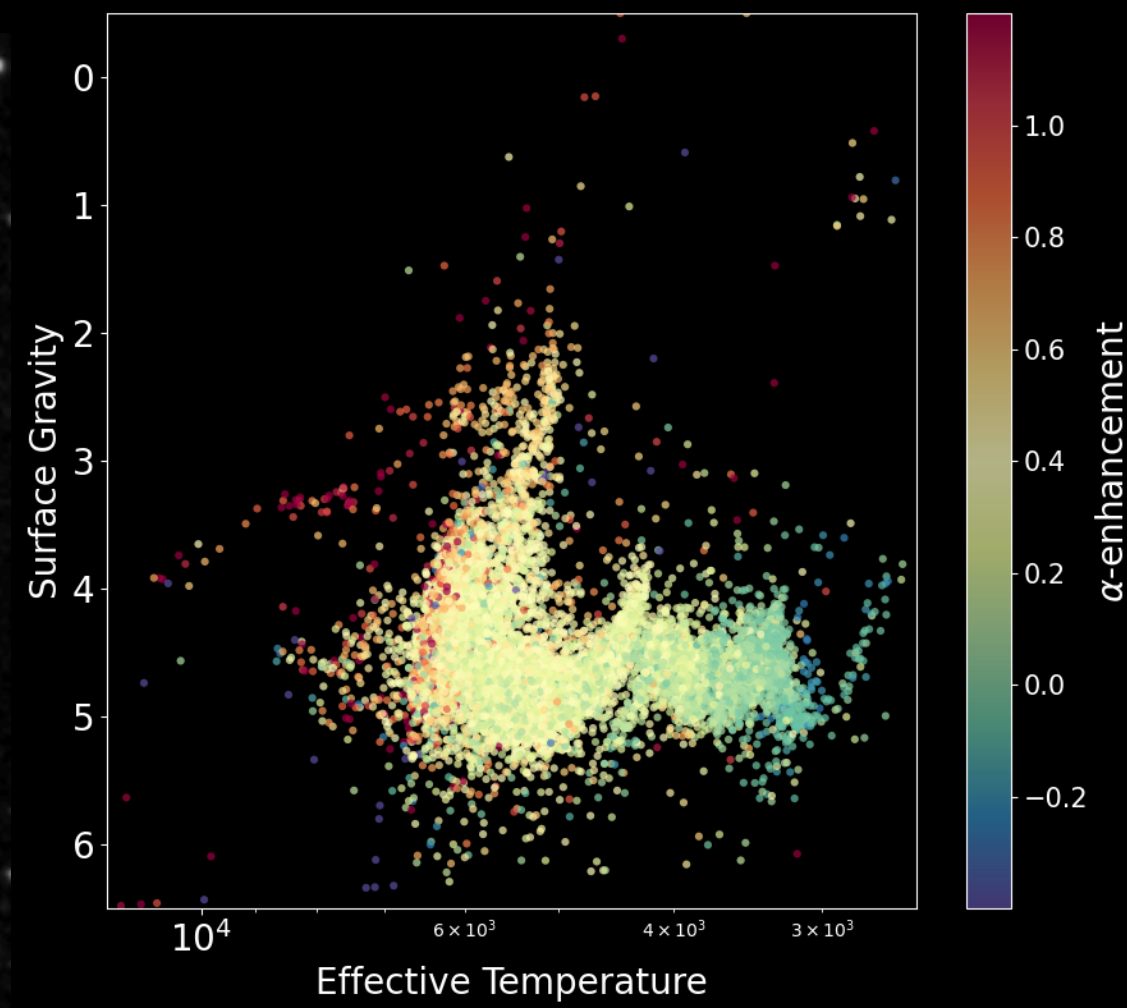
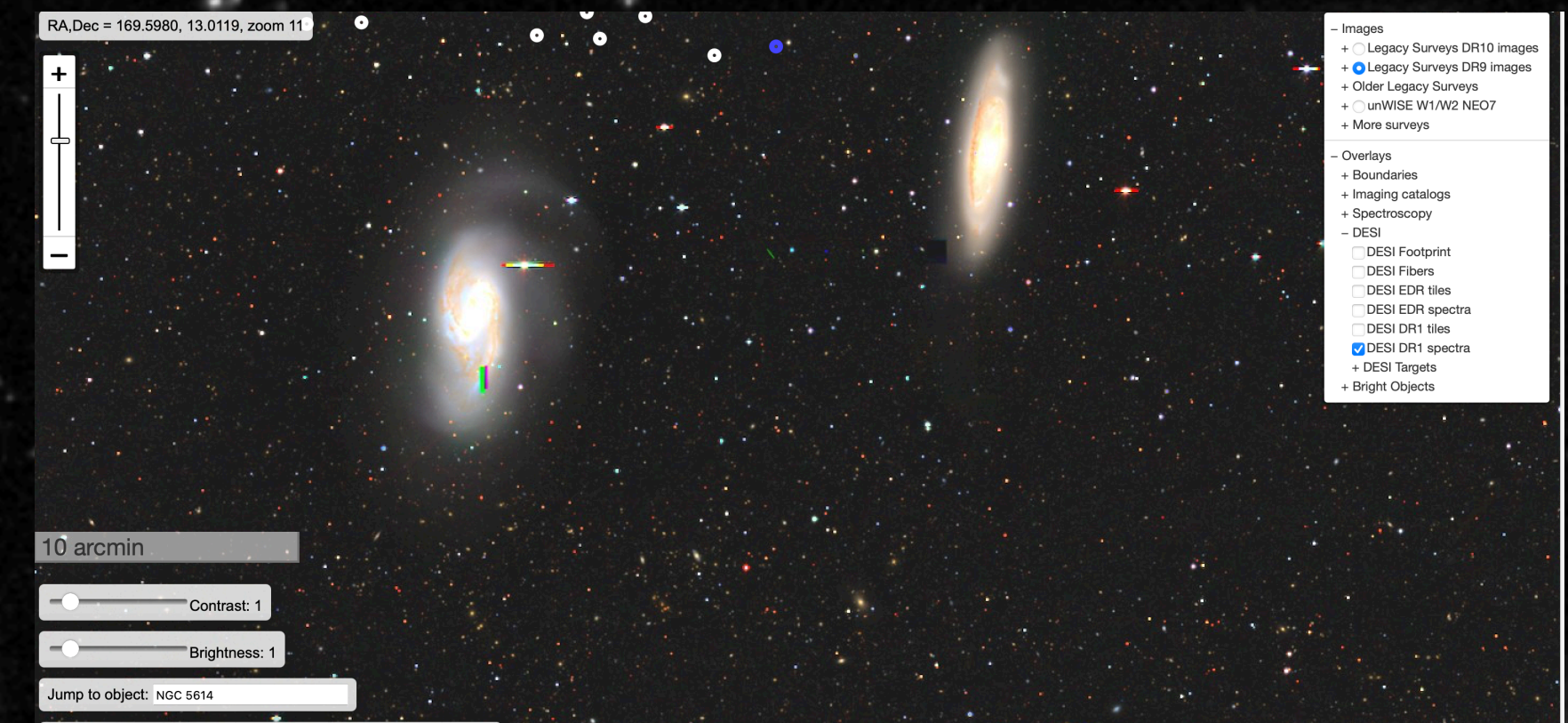
Building the training set, DESI DR1 Value-added catalogues



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Legacy Surveys DR9 Photometric Catalogs for DESI Targets



OJALÁ: A transformer based model, data handling

OBSERVATIONS



1.- J-PAS FLUXES: J0378, J0390, J0400, J0410 ... J0890, J0900, J0910

2.- DESI LEGACY MAGNITUDES: , G,R,I,Z + MORPHTYPE

TARGETS



1.- SPECTYPE: STAR, QSO, GALAXY

2.- GALAXY PARAMETERS : LOGM, EWs, Z_GAL

3.- STELLAR PARAMETERS : TEFF, LOGG, ALPHAFE, FEH

4.- QSO PARAMETERS : Z_QSO, BH_MASS

Transformer based model, the context



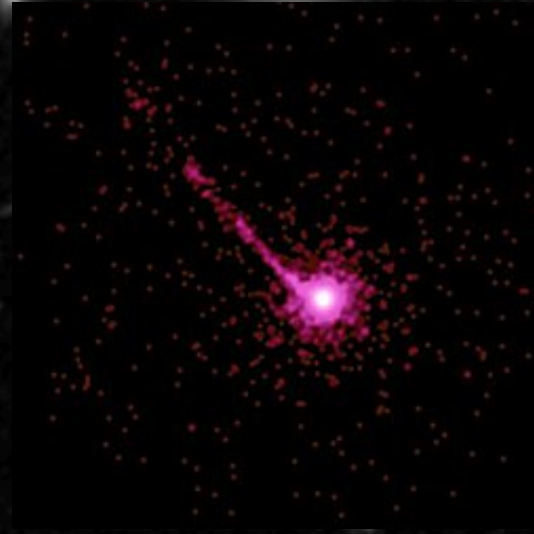
J0670, J0660, J0890, J0530,
J0490, MAG_G, MAG_Z,
HALPHA_6562_EW



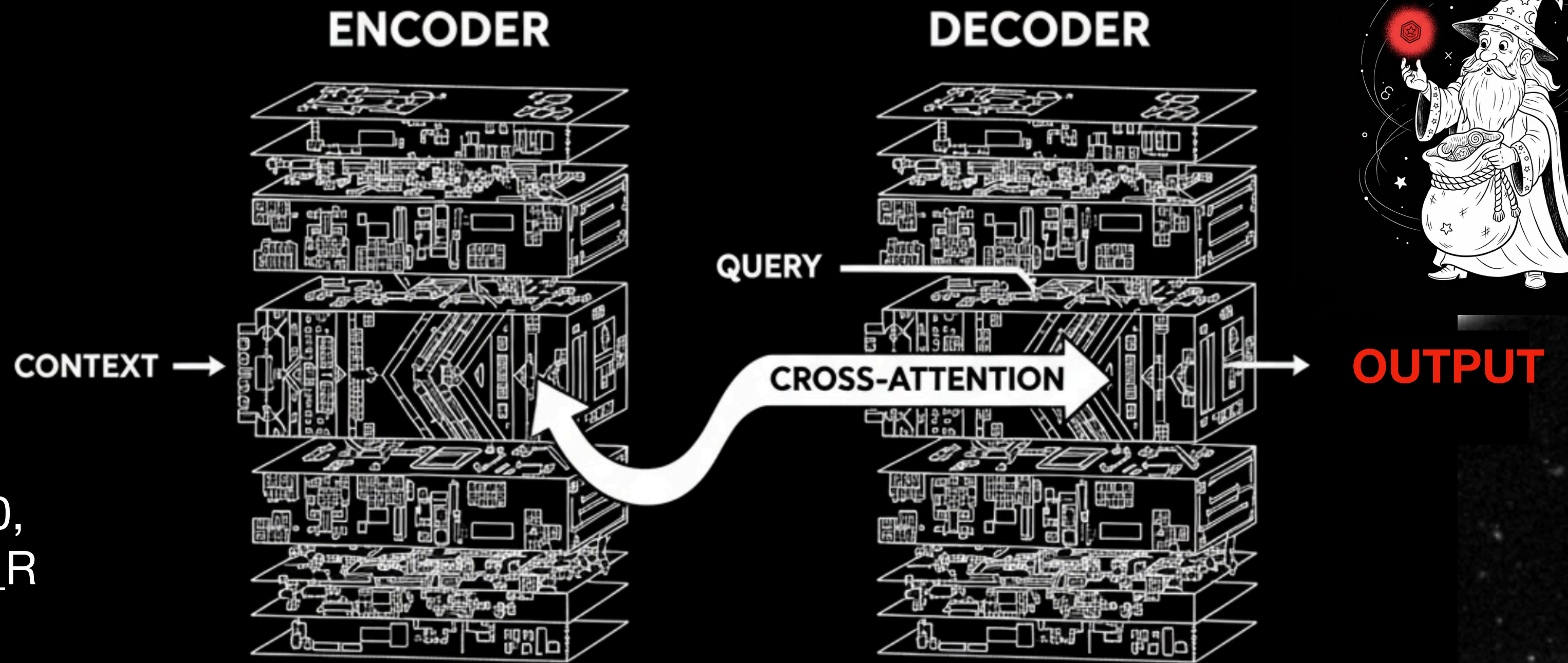
J0660, J0890, J0530, J0730
MAG_I, MAG_G, MAG_Z
TEFF



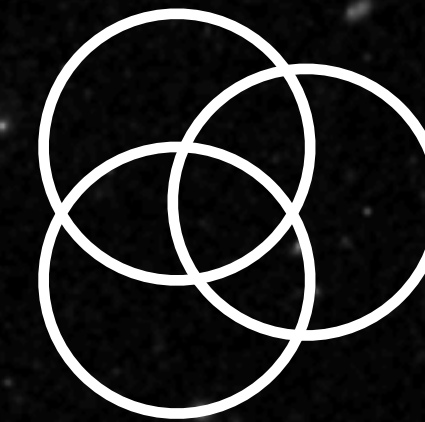
J0630, GALAXY, J0890, J0530,
J0730, LOGM, Z_GAL, MAG_R
J0890



J0630, J0910, J0890, J0530,
J0730, MAG_i, MAG_R
QSO



We do not need to have all tokens defined for each object. Instead of using the crossmatch, we can train on the union!



Transformer based model, the training objective



J0670, J0660, J0890, J0530,
J0490, MAG_G, MAG_Z,
HALPHA_6562_EW

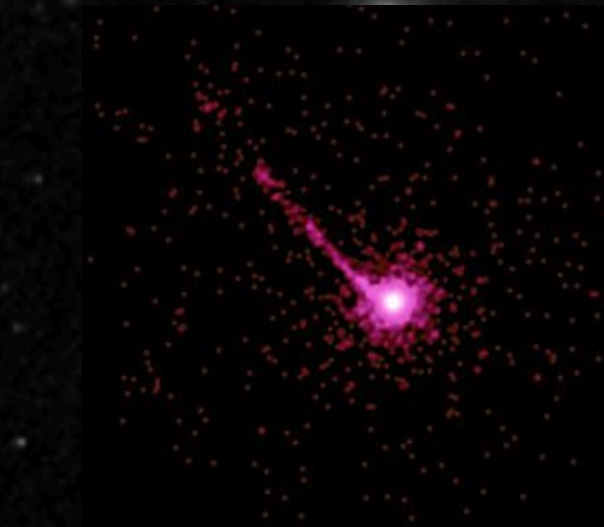
$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{Task}} + \mathcal{L}_{\text{DA}}$$



J0660, J0890, J0530, J0730
MAG_I, MAG_G, MAG_Z
TEFF



J0630, GALAXY, J0890, J0530,
J0730, LOGM, Z_GAL, MAG_R
J0890



J0630, J0910, J0890, J0530,
J0730, MAG_i, MAG_R
QSO

Transformer based model, the training objective



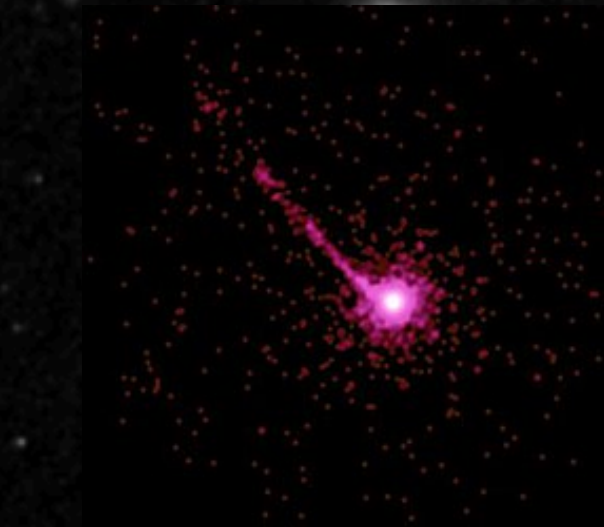
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J0490, MAG_G, MAG_Z,
HALPHA_6562_EW



J0660, J0890, J0530, J0730
MAG_I, MAG_G, MAG_Z
TEFF



J0630, GALAXY, J0890, J0530,
J0730, LOGM, Z_GAL, MAG_R
J0890



J0630, J0910, J0890, J0530,
J0730, MAG_i, MAG_R
QSO

$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{Task}} + \mathcal{L}_{\text{DA}}$$

$$\mathcal{L}_{\text{Task}} = \mathcal{L}_{\text{reg}} + \mathcal{L}_{\text{cls}}$$

Transformer based model, the training objective



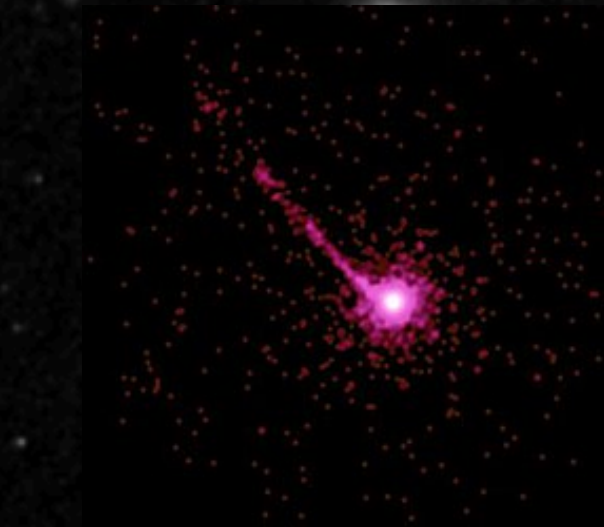
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J0490, MAG_G, MAG_Z,
HALPHA_6562_EW



J0660, J0890, J0530, J0730
MAG_I, MAG_G, MAG_Z
TEFF



J0630, GALAXY, J0890, J0530,
J0730, LOGM, Z_GAL, MAG_R
J0890



J0630, J0910, J0890, J0530,
J0730, MAG_i, MAG_R
QSO

$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{Task}} + \mathcal{L}_{\text{DA}}$$

$$\mathcal{L}_{\text{Task}} = \mathcal{L}_{\text{reg}} + \mathcal{L}_{\text{cls}}$$

$$\mathcal{L}_{\text{reg}} = \frac{1}{N_{\text{reg}}} \sum_i \left(\frac{(y_i^{\text{true}} - y_i^{\text{pred}})^2}{2\sigma_{\text{total},i}^2} + \frac{1}{2} \log(\sigma_{\text{total},i}^2) \right)$$

$$\sigma_{\text{total},i}^2 = \sigma_{\text{pred},i}^2 + \sigma_{\text{data},i}^2$$

Transformer based model, the training objective



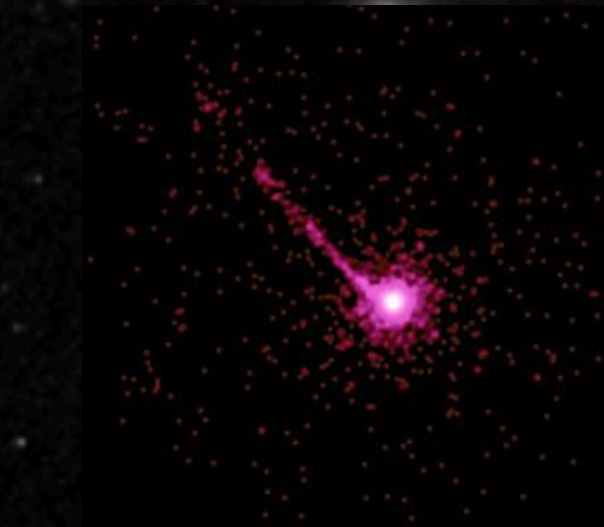
J0670, J0660, J0890, J0530,
J0490, MAG_G, MAG_Z,
HALPHA_6562_EW



J0660, J0890, J0530, J0730
MAG_I, MAG_G, MAG_Z
TEFF



J0630, GALAXY, J0890, J0530,
J0730, LOGM, Z_GAL, MAG_R
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J0630, J0910, J0890, J0530,
J0730, MAG_i, MAG_R
QSO

$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{Task}} + \mathcal{L}_{\text{DA}}$$

$$\mathcal{L}_{\text{Task}} = \mathcal{L}_{\text{reg}} + \mathcal{L}_{\text{cls}}$$

$$\mathcal{L}_{\text{cls}} = \frac{1}{N_{\text{cls}}} \sum_{i=1}^{N_{\text{cls}}} \left(- \sum_{c=1}^C y_{i,c}^{\text{true}} \log(\hat{y}_{i,c}^{\text{pred}}) \right)$$

Transformer based model, the training objective



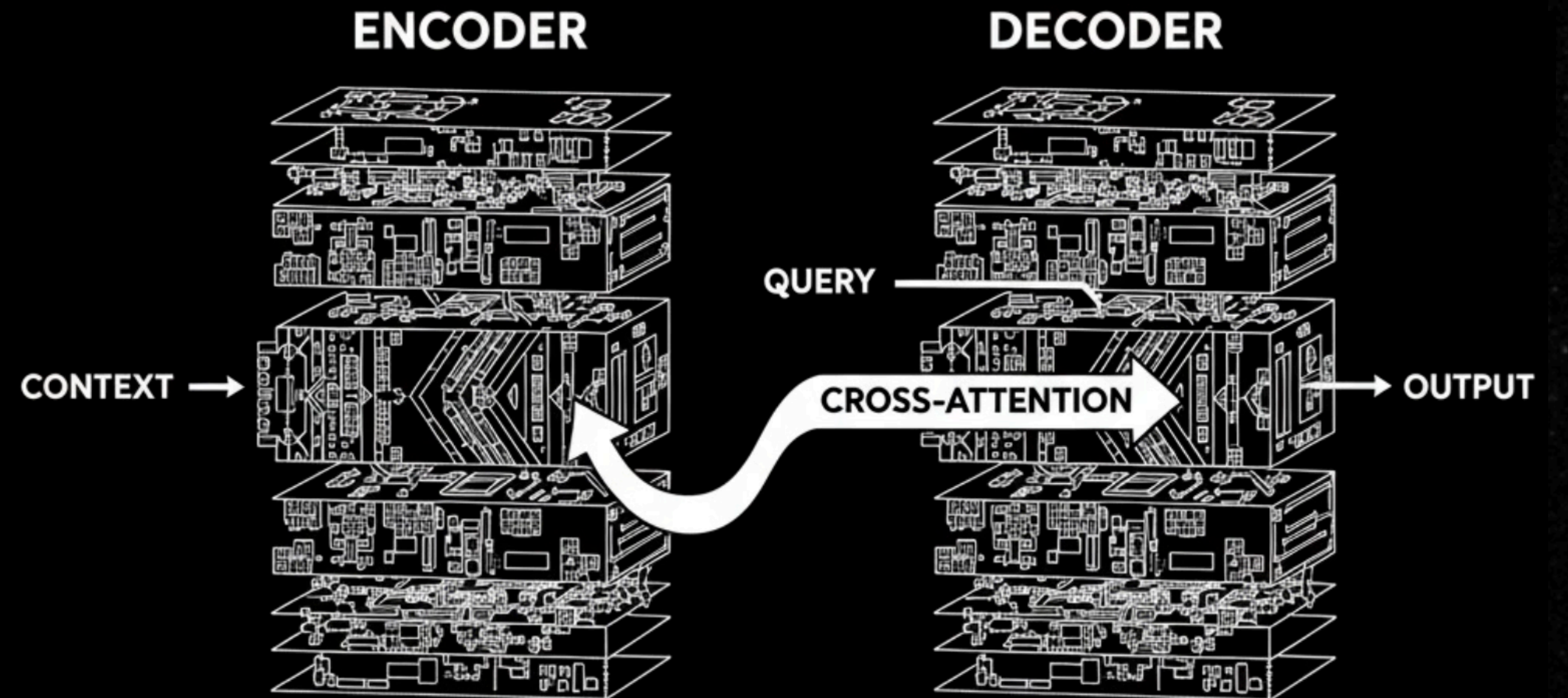
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HALPHA_6562_EW

$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{Task}} + \mathcal{L}_{\text{DA}}$$

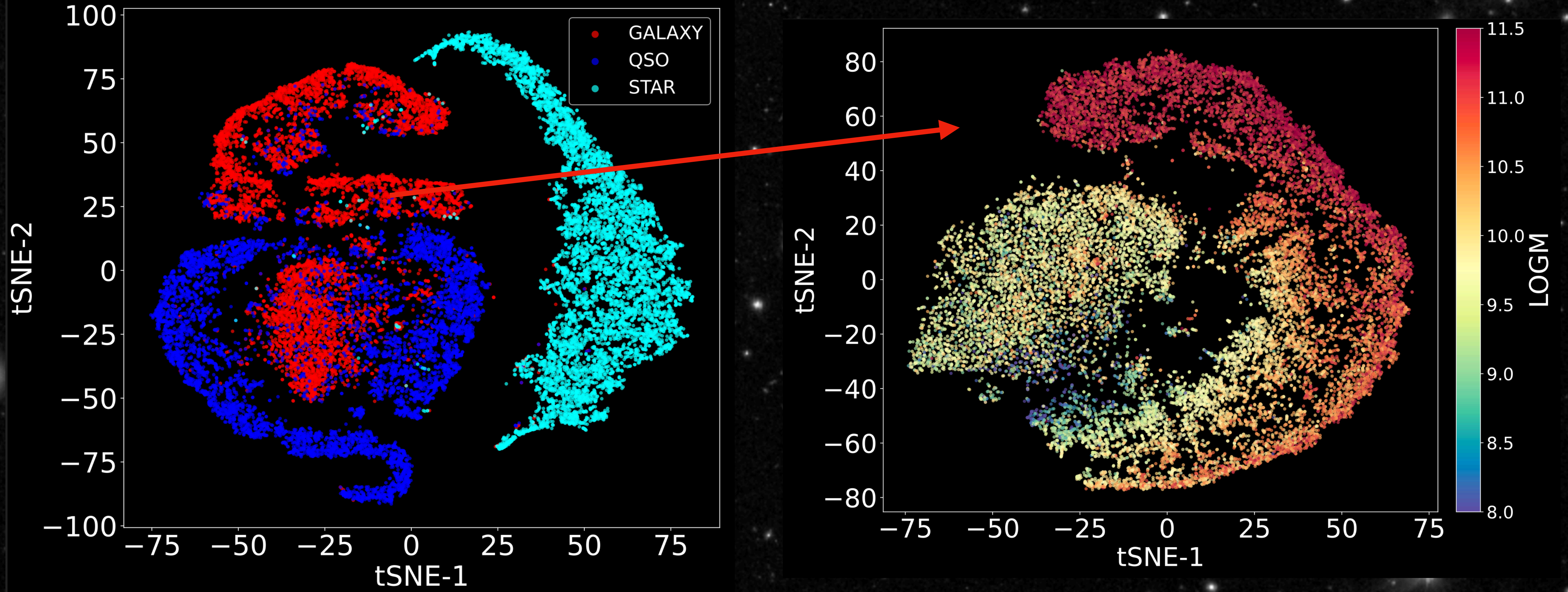
J0660, J0890, J0530, J0730
MAG_I, MAG_G, MAG_Z
TEFF

J0630, GALAXY, J0890, J0530,
J0730, LOGM, Z_GAL, MAG_R
J0890

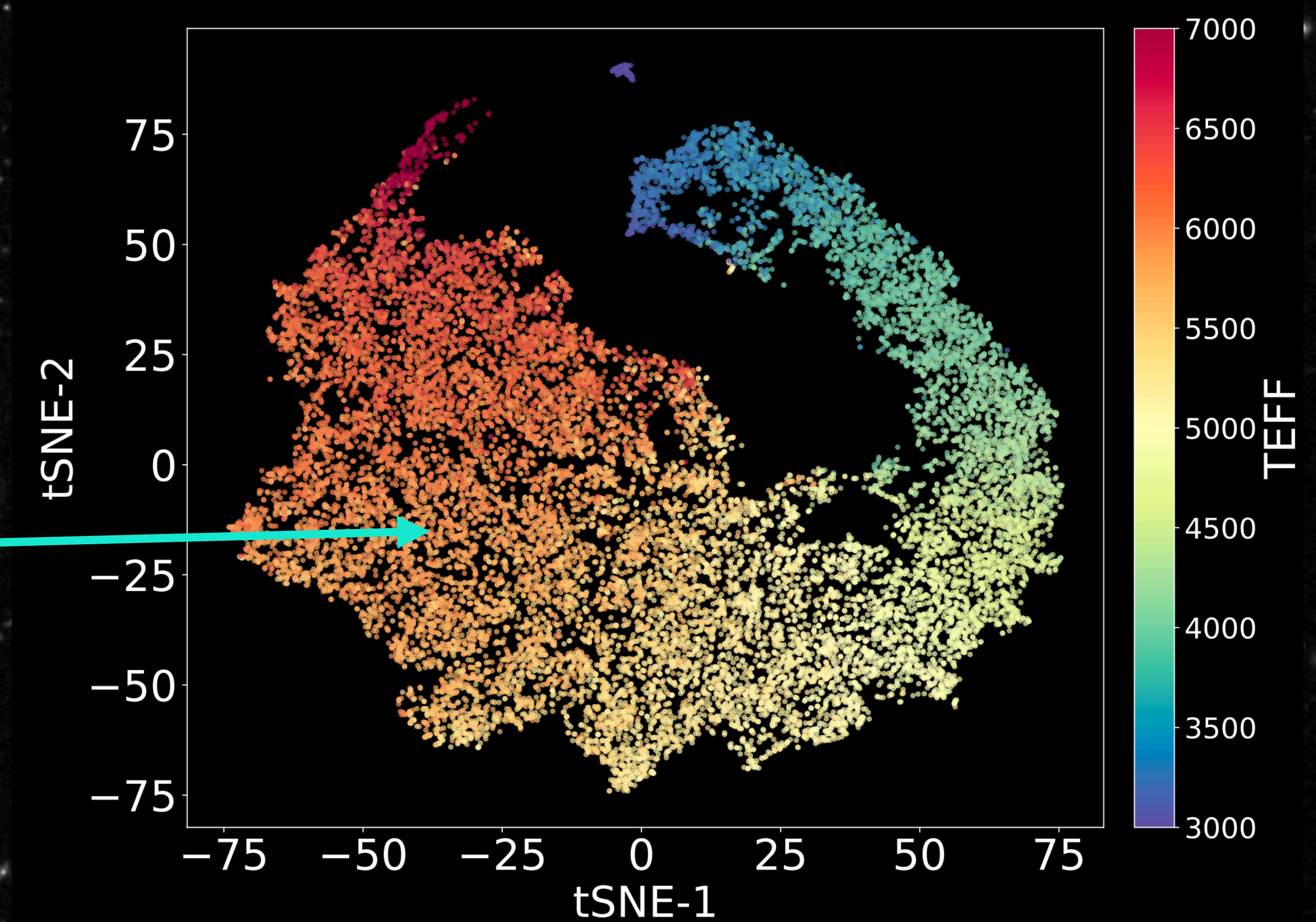
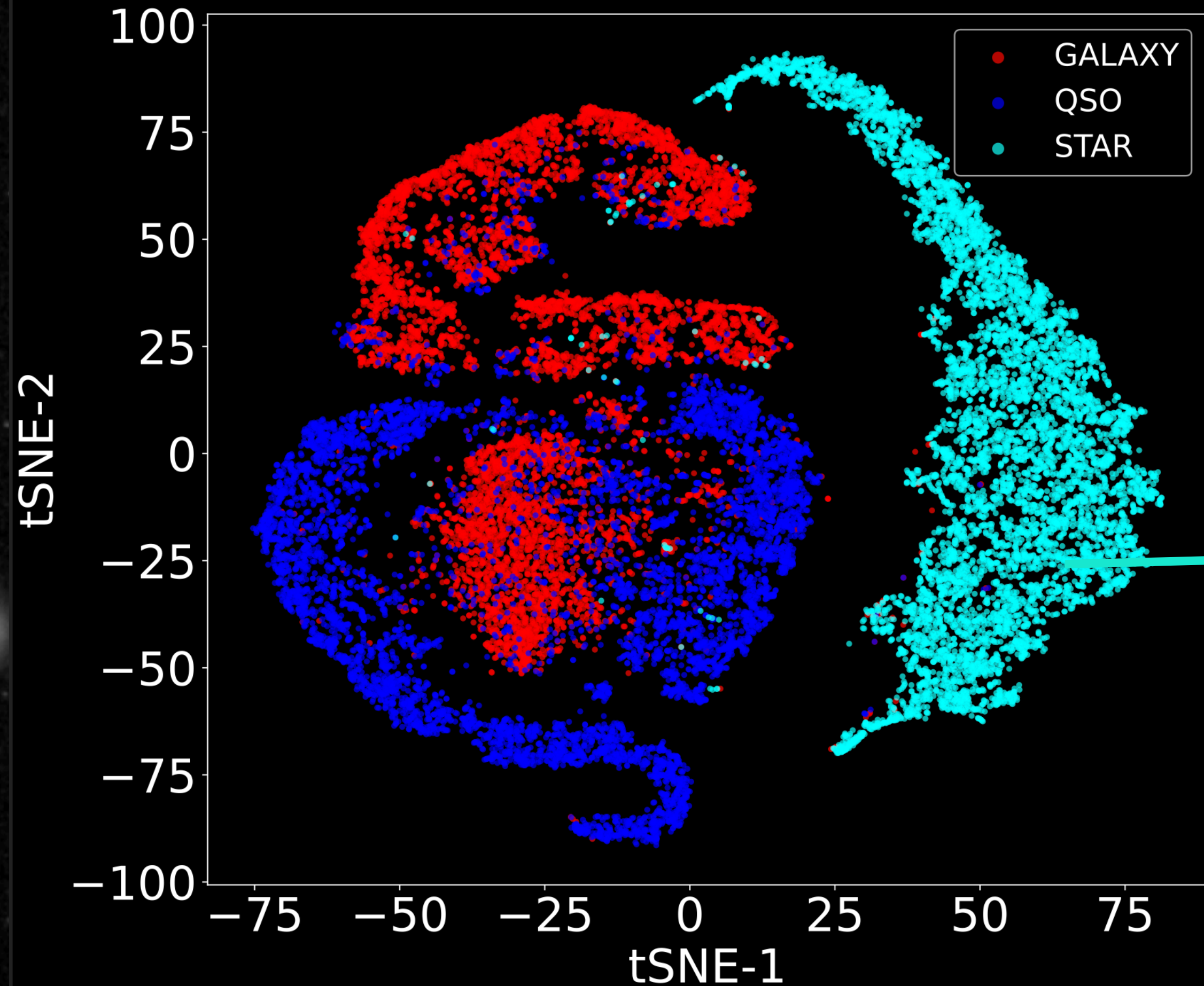
J0630, J0910, J0890, J0530,
J0730, MAG_i, MAG_R
QSO



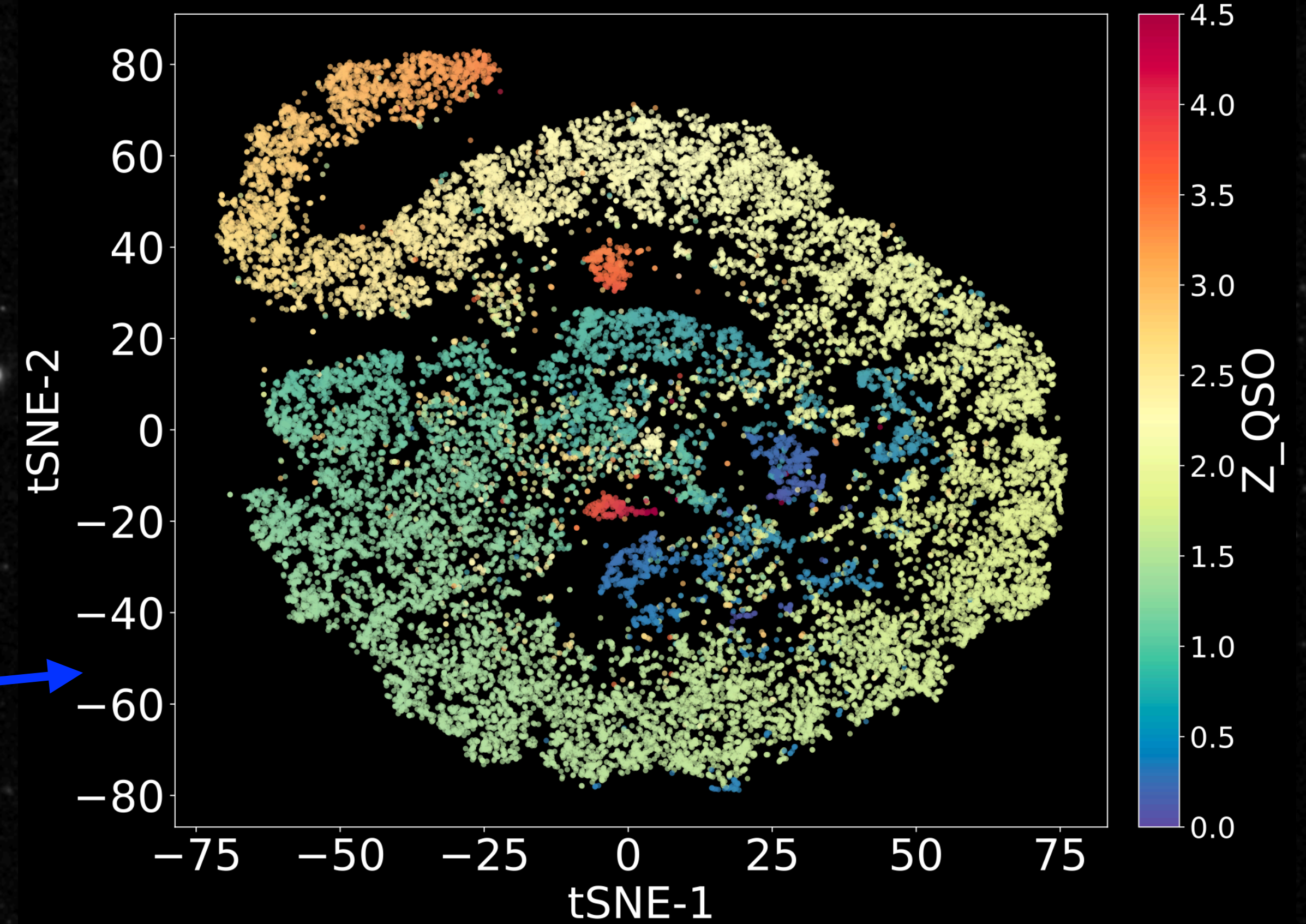
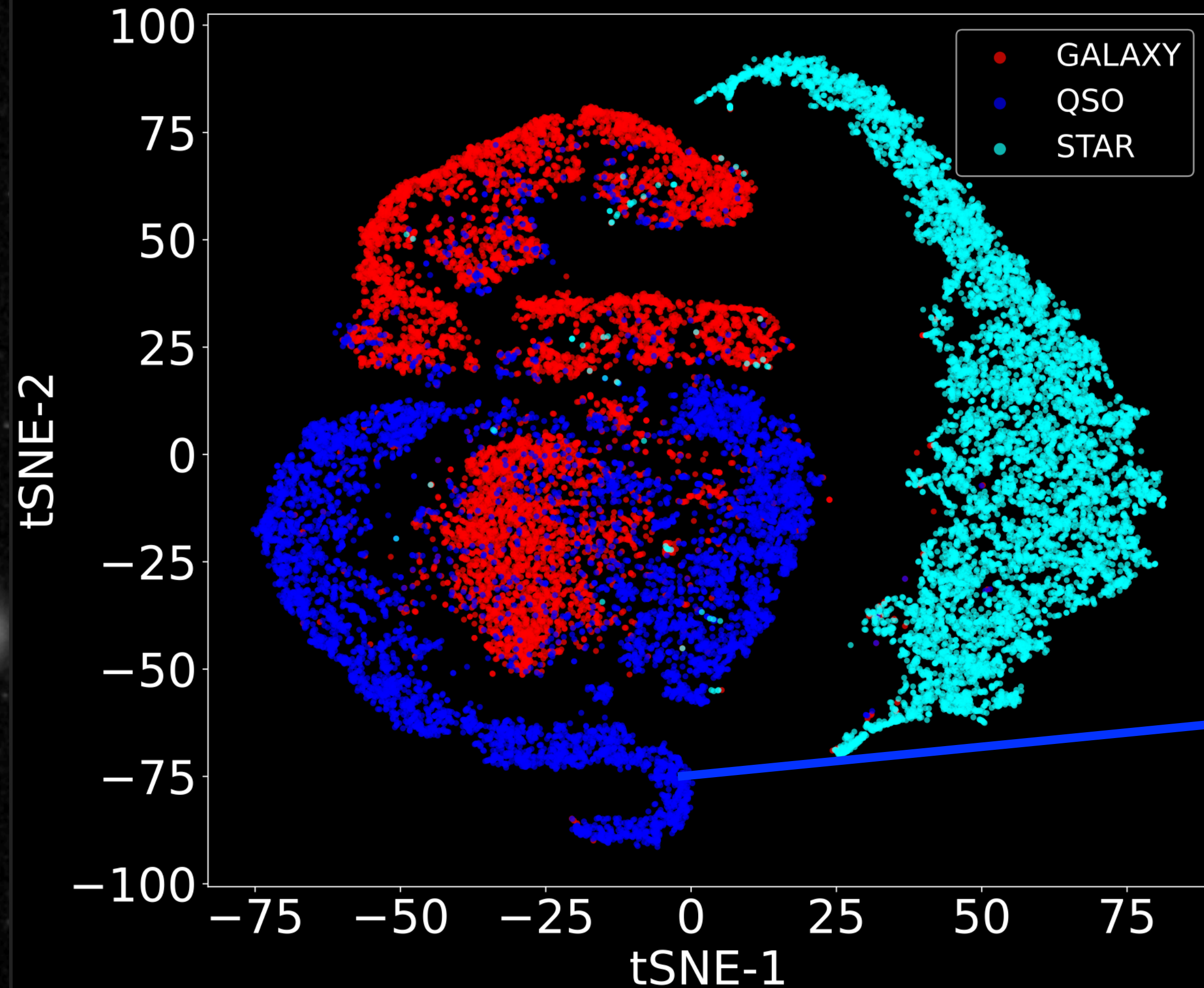
Transformer based model, the encoder representation



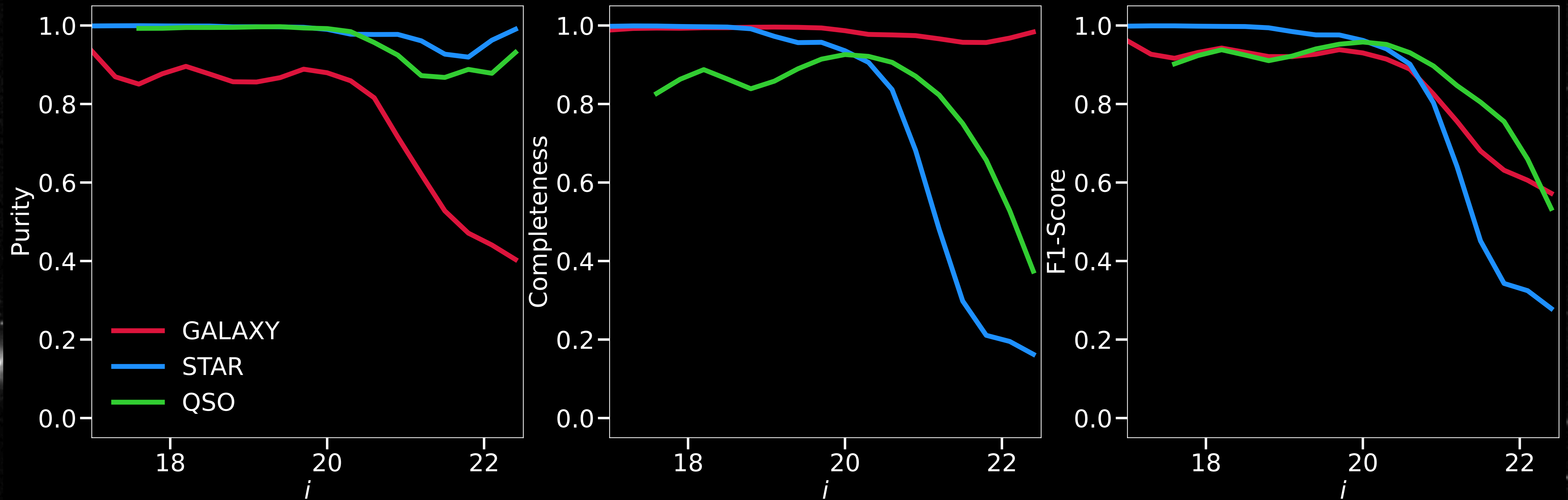
Transformer based model, the encoder representation



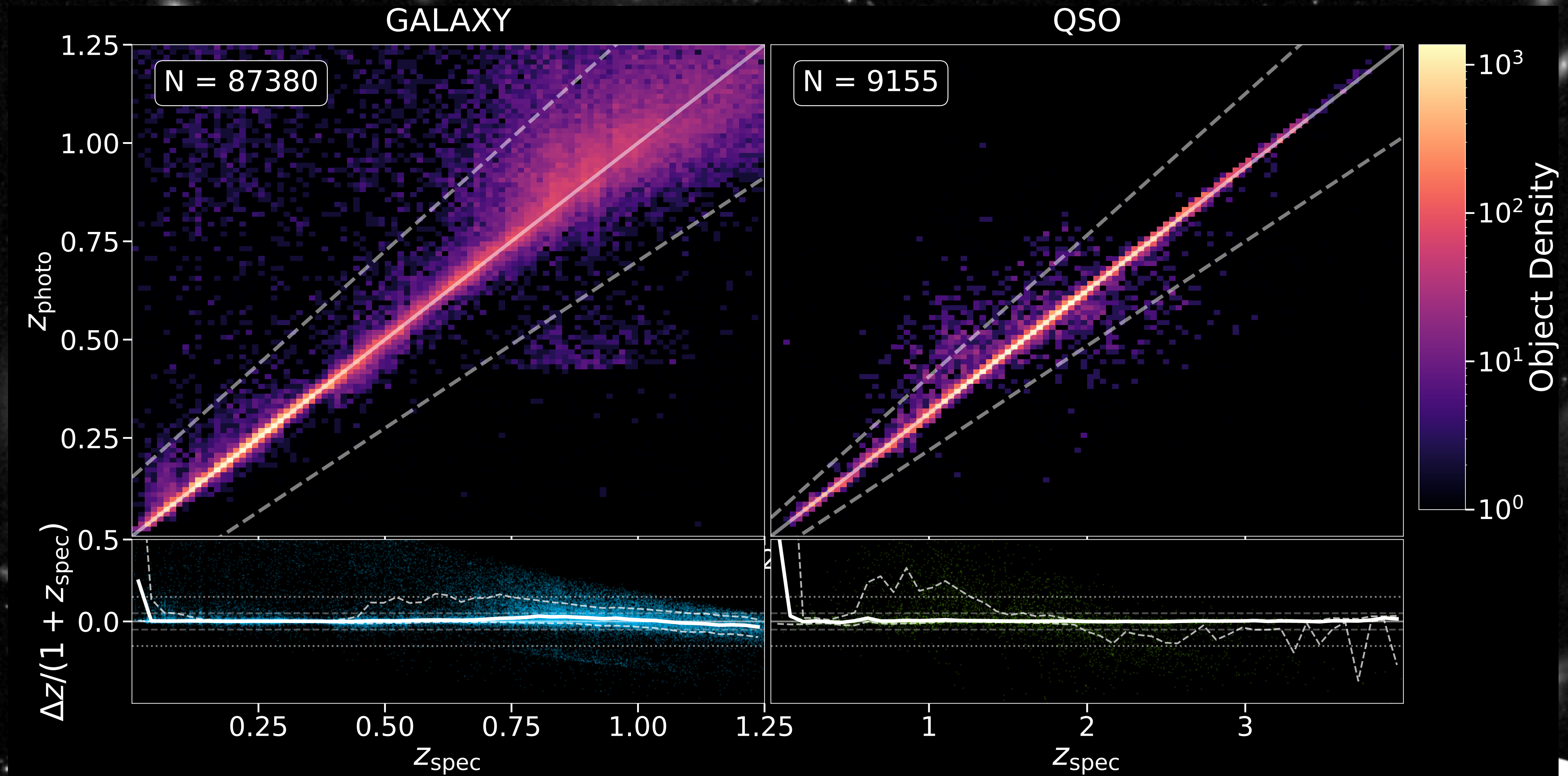
Transformer based model, the encoder representation



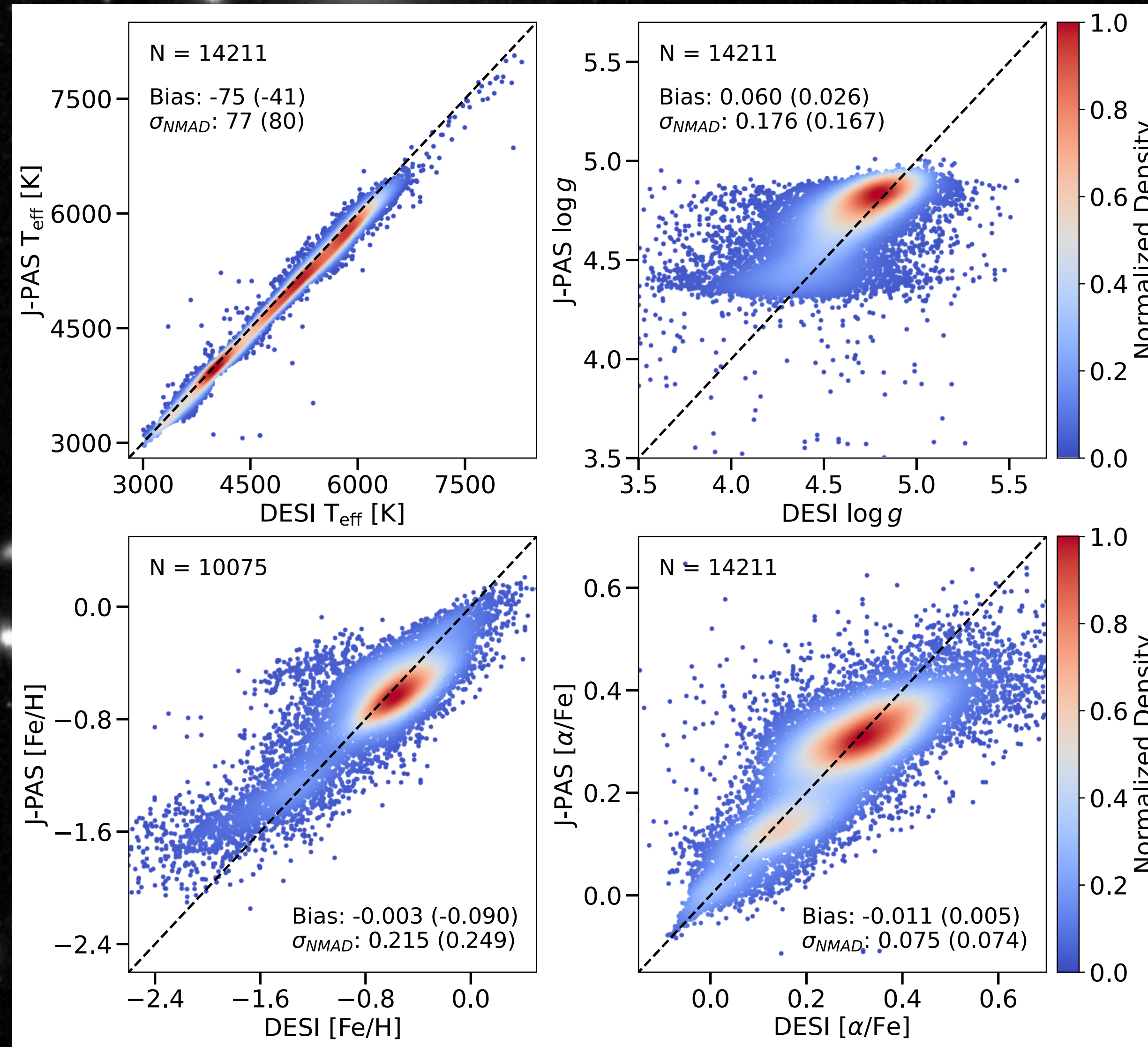
Object Classification in the DESI x J-PAS area



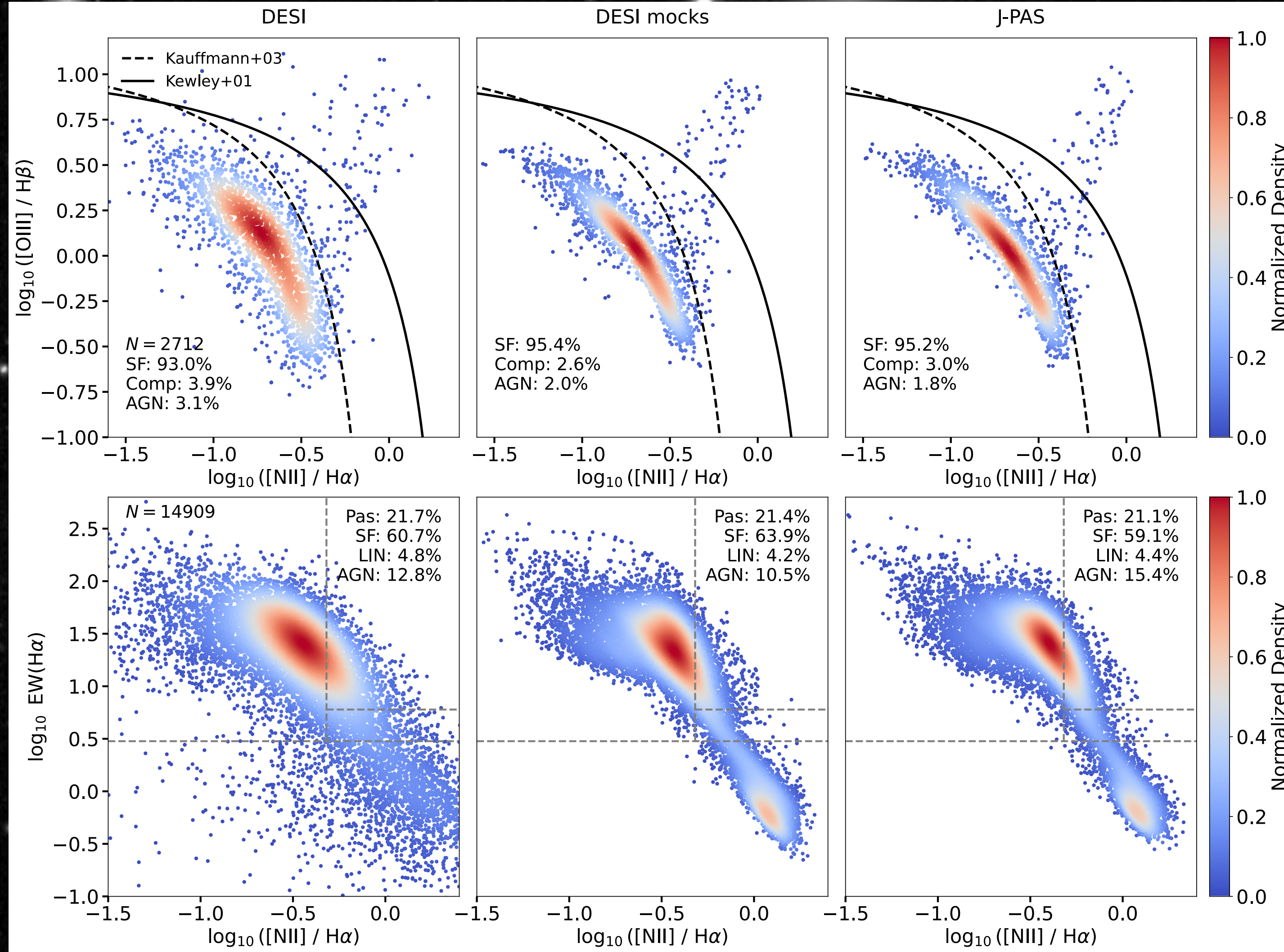
Redshift predictions in the DESI x J-PAS area



Stellar parameters predictions in the DESI x J-PAS area



BPT and WHAN diagrams

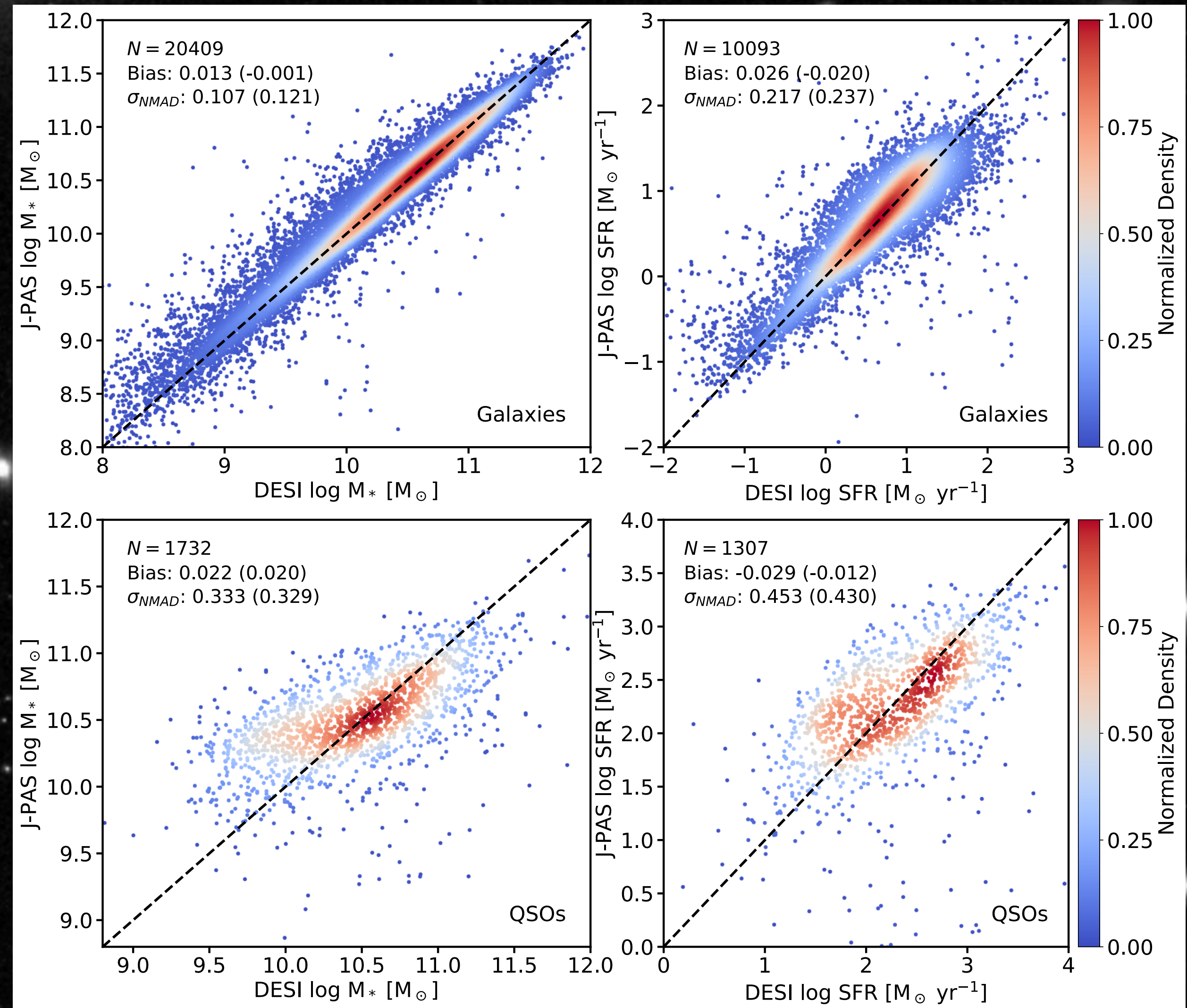
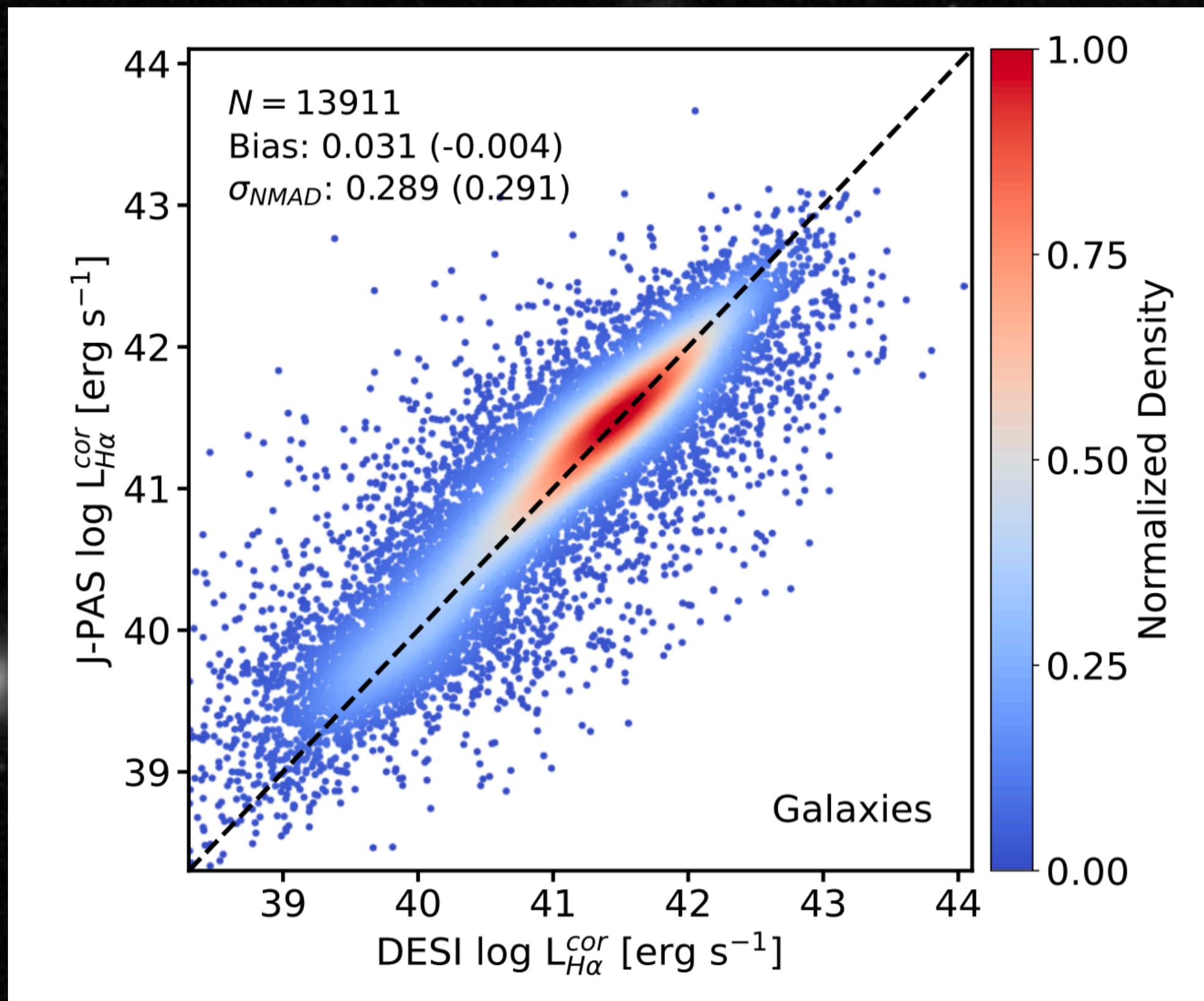


Line	Class	Pur (%)	Comp (%)	F1 (%)
Ke01	SF	67.4	99.8	80.5
	AGN	99.6	51.8	68.1
Ka03	SF	67.1	98.7	79.9
	AGN	97.6	51.6	67.5
S06	SF	63.8	95.0	76.3
	AGN	90.2	46.1	61.0

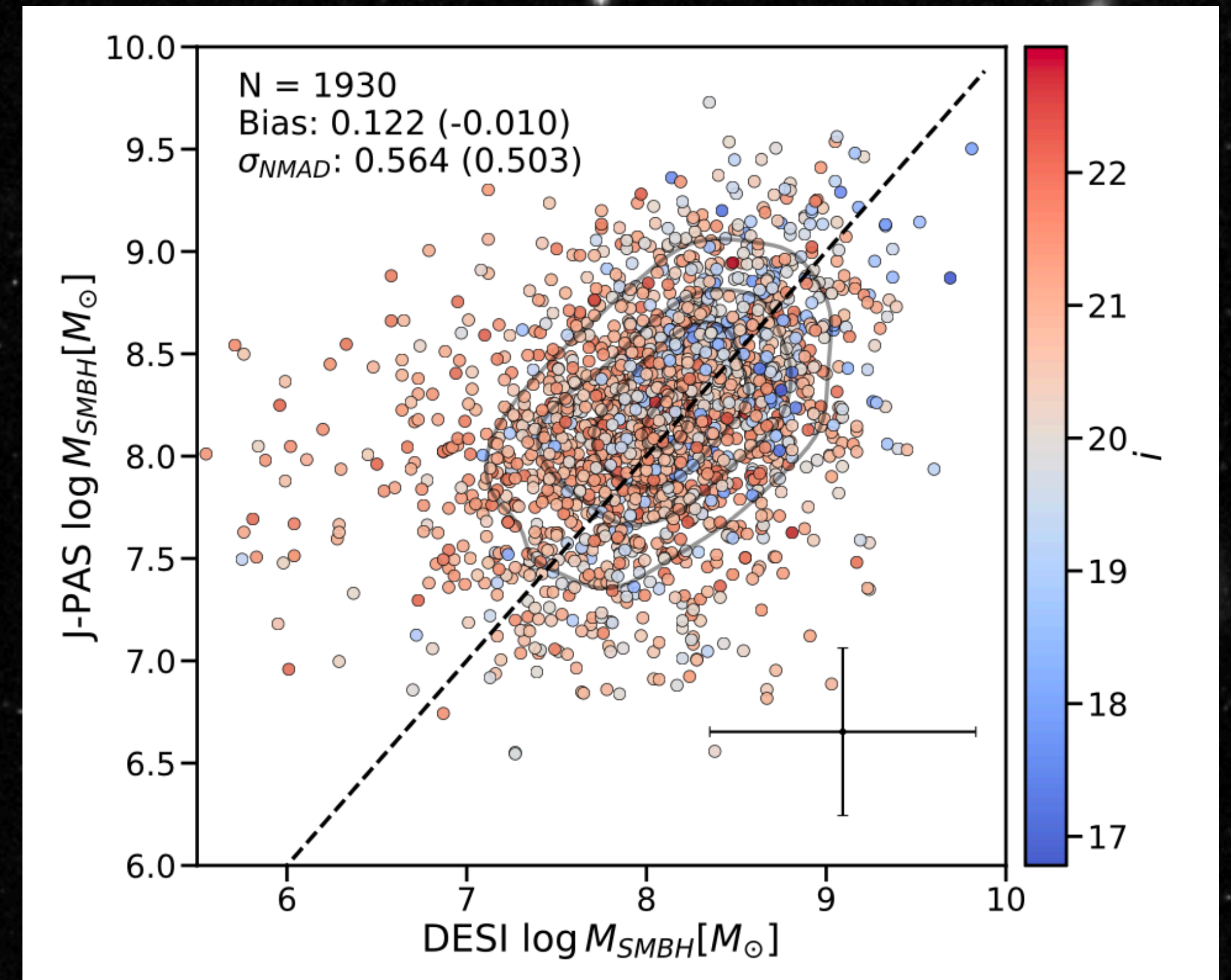
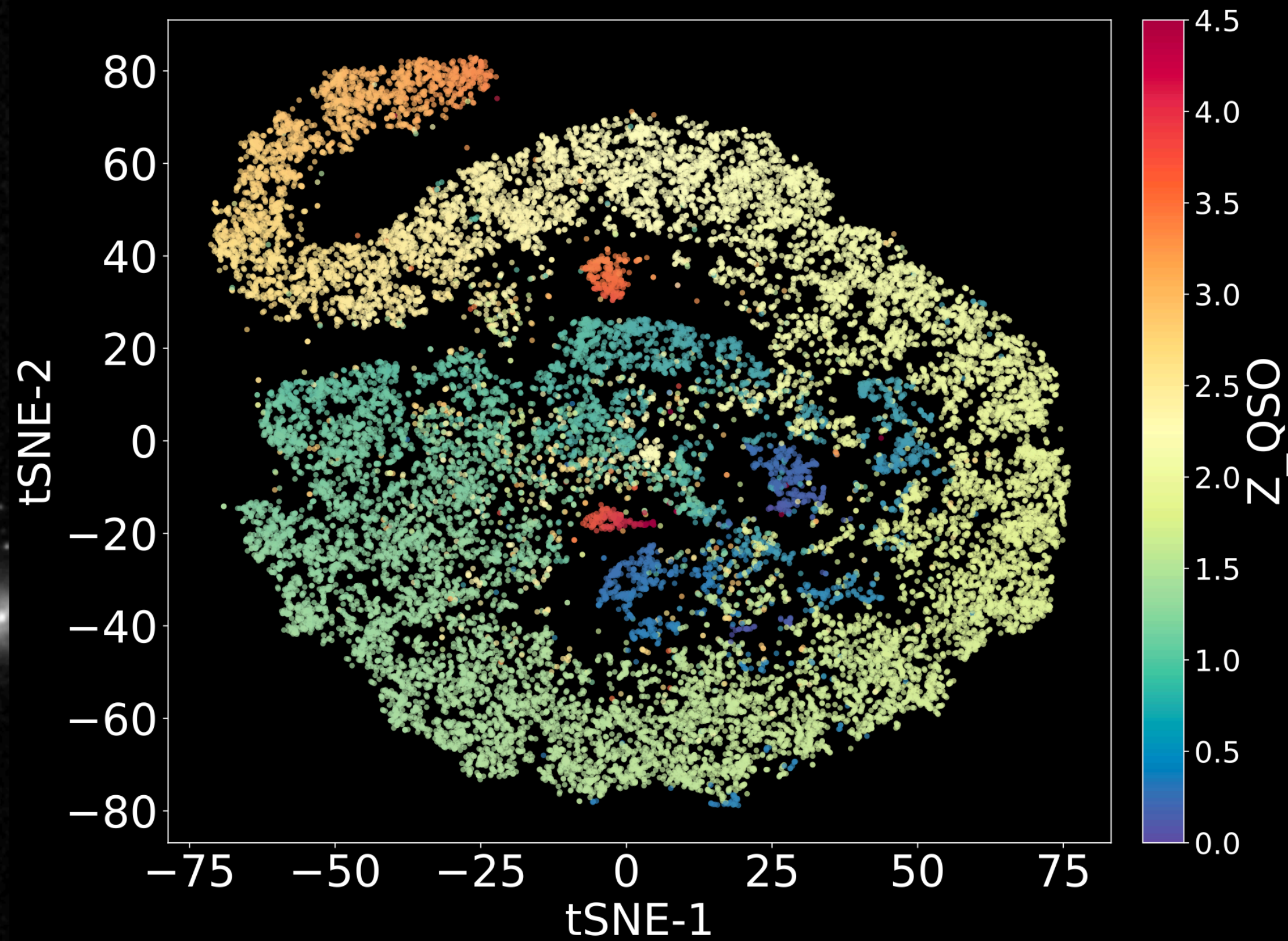
[NII]/H α	Class	Pur (%)	Comp (%)	F1 (%)
S06 (≤ 0.40)	Passive	93.4	88.5	90.9
	SF	83.0	81.1	82.1
	AGN	72.9	78.4	75.5
Ka03 (≤ 0.48)	Passive	90.7	88.5	89.6
	SF	76.2	89.2	82.2
	AGN	76.3	65.2	70.3
Ke01 (≤ 0.79)	Passive	82.7	88.5	85.5
	SF	55.0	97.9	70.4
	AGN	84.6	12.7	22.1



SFR and stellar mass



BH masses, finetuning OJALA



Conclusions

- 1.- OJALÁ is single **foundation model** simultaneously performs multiple predictive tasks (object classification and physical parameter regression).
- 2.- **High Processing Speed:** Capable of processing 1 million objects in approximately 45 minutes using a standard consumer CPU.
- 3.- **Flexibility:** OJALÁ can incorporate data across the EM spectrum
- 4.- OJALÁ can be **fine-tuned** to address your scientific goals with minimal additional training
- 5.- Other applications of OJALÁ include **outlier detections, similarity searches**, 2D maps of galaxy properties