Incidence and energetics of Active Galactic Nuclei (AGN) winds in the distant Universe

Musiimenta et al. (2023), 679, A84
Musiimenta et al. 2024, arXiv:2401.17299

Blessing MUSIIMENTA
University of Bologna

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2024 Australian/eROSITA-DE Joint Collaboration Workshop, 26/03/2024

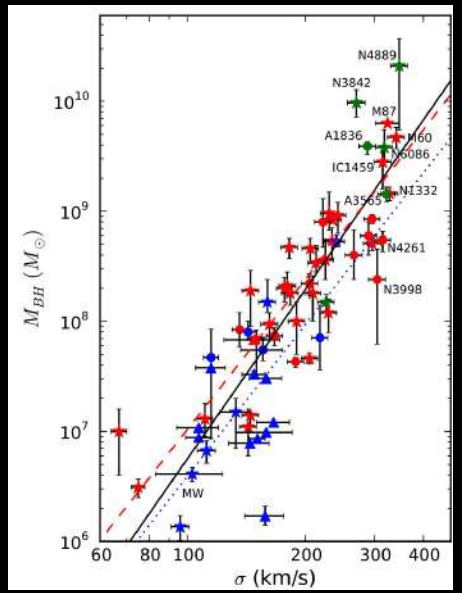
AGN feedback: why do we care?

➢ AGN play a crucial role in galaxy formation and evolution

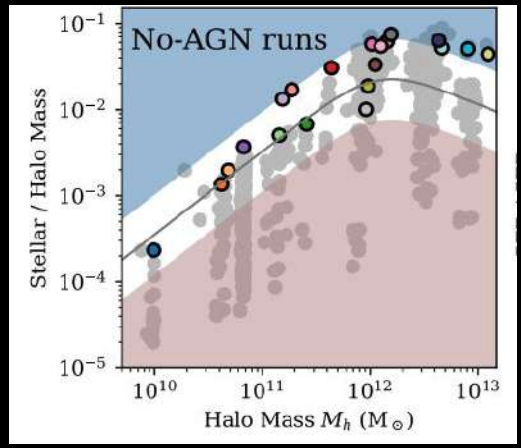
- ❑ Explains
  - Galaxy/BH scaling relation
  - Galaxy luminosity functions
  - Star formation efficiencies
  - Galaxy morphology and colours, etc

(DiMatteo+2005, Hopkins+2006,Dubois+2016).

- ❑ Effect of AGNs on galaxy evolution still not understood.



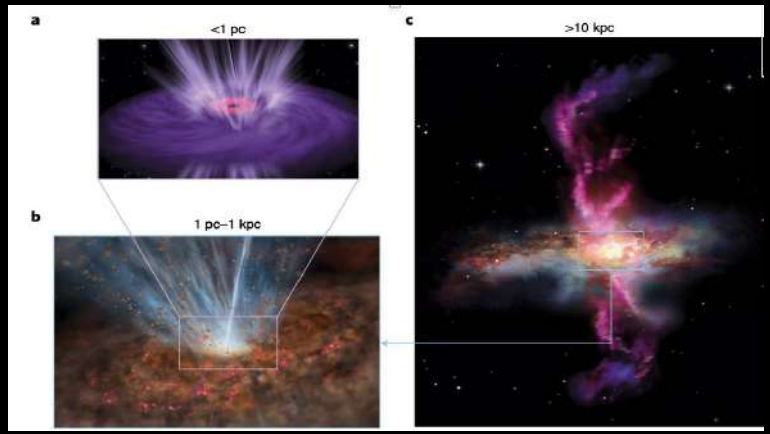
McConnell+2011

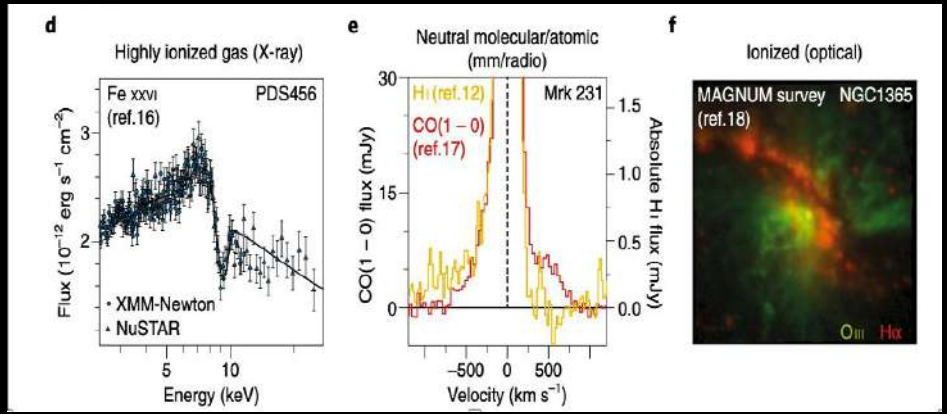


Wellons+2022

AGN feedback: AGN outflows

- Outflows in form of winds or jets.
- Complexity of outflows





Cicone+2018

AGN feedback: Properties of AGN with outflows

Characterised by their luminous, obscured, and dust-enshrouded environments, as predicted by theoretical models

Properties of QSO in feedback/outflows

- Physical:
  - Moderate N_H, obscured and 'dusty'
  - Accretion close to Eddington limit
- Observed:
  - X-ray+IR luminous
  - Faint optical

→ Red colours

- Blow-out phase is short and sources are rare: need large area surveys to efficiently select them.
- Innovative selection methods and dedicated observations are usually necessary.

Goal:

Develop an approach to isolate red, obscured and highly accreting QSO at z~0.5-3, search for the presence of ionised outflows and assess the effect of AGN outflows to their host galaxies by comparison with simulations.

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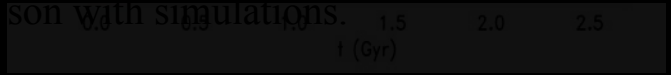

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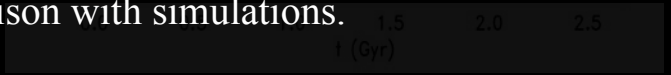
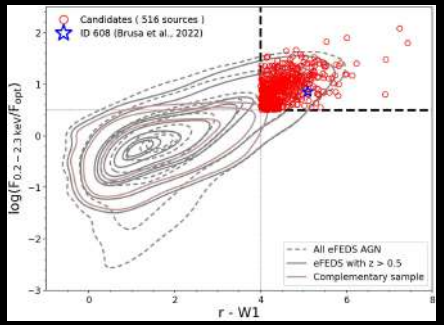
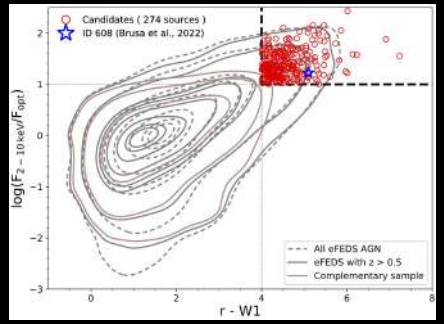


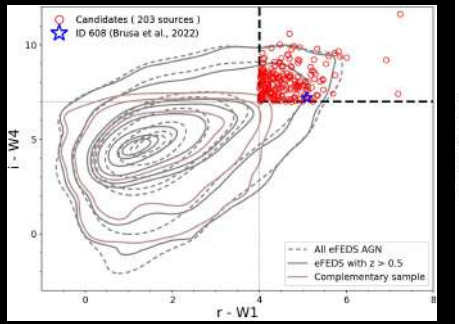
Selection of AGN in the feedback phase (z>0.5) from eFEDS

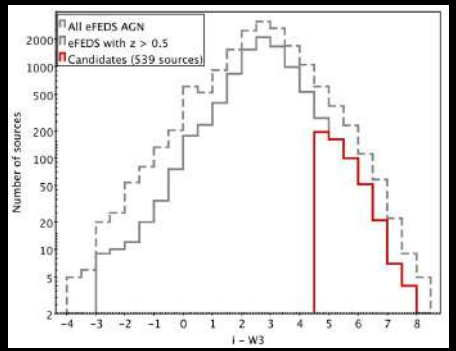
Musiimenta et al. (2023), 679, A84

Color selection methods





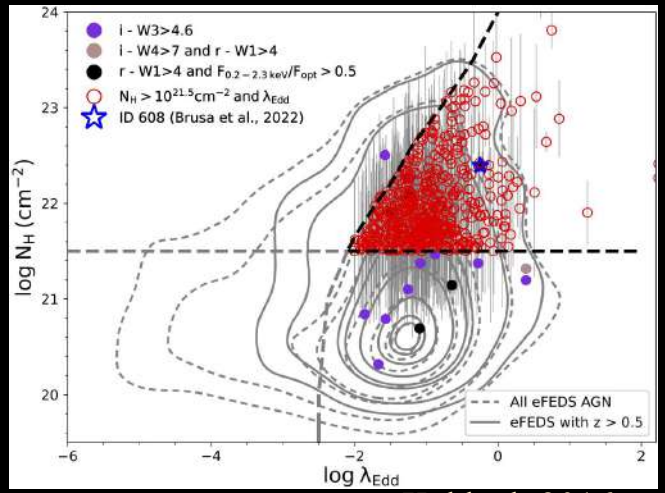




Perna+2015, Brusa+2022, Zakamska+2016, Vayner+2021, perrotta+2019

853 sources

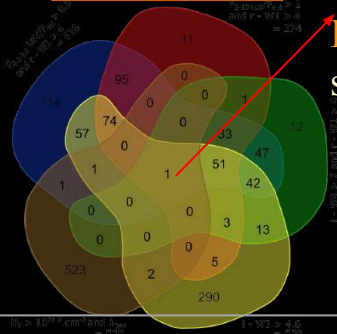
X-ray and optical spectral propertiies



528 sources

Kakkad+2016, Lansbury+2020

ID608 (Follow up study in later slides)

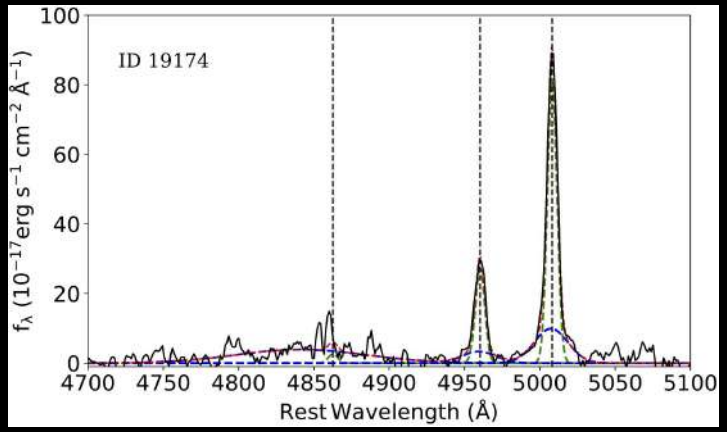


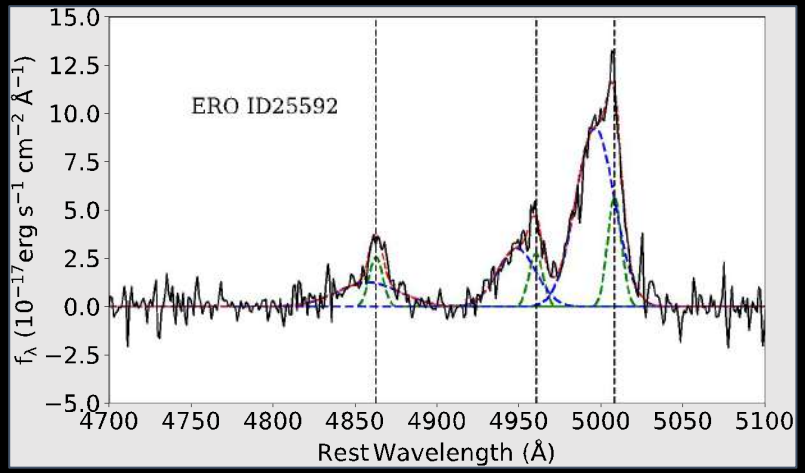
~1400 candidates isolated

Tracing ionized outflows

Musiimenta et al. (2023), 679, A84

- Available SDSS spectra at 0.5<z<1: 80 sources
  - Spectra fitting using PyQSOFit (Guo+2018,Shen+2019).
- ~50 sources with good quality spectra.



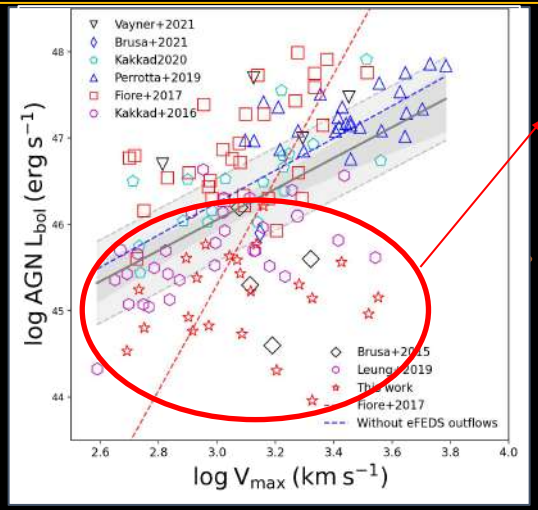


- ➢ Identified **23/50** outflows (~45 %)
- ➢ FWHM ~ 600 - 2800 km/s
- ➢ 17/27 sources are also best fit with two components but at lower significance (excluded in the final outflows detected sample).

Outflow fraction may be as high as 80%.

AGN outflow scaling relations

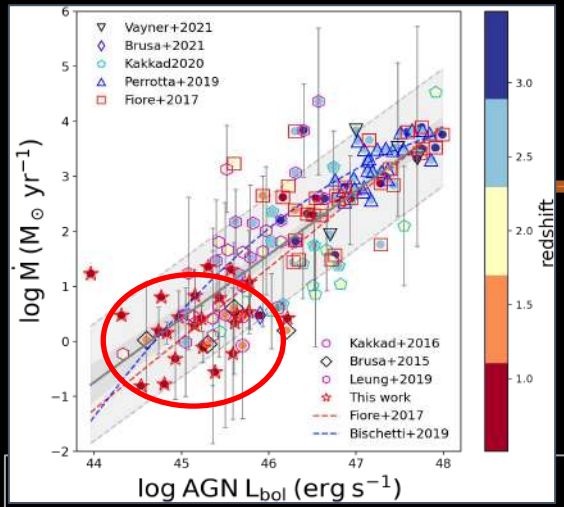
Musiimenta et al. (2023), 679, A84



Weak/no correlation

- X-ray active is best tracer of fastest phase of winds
- Their velocity doesn't depend only on L_{bol}

Importance of "sample selections"



Strong correlation

Large scatter: mass outflow rate also depends on other factors (Ramos Almeida+2022)

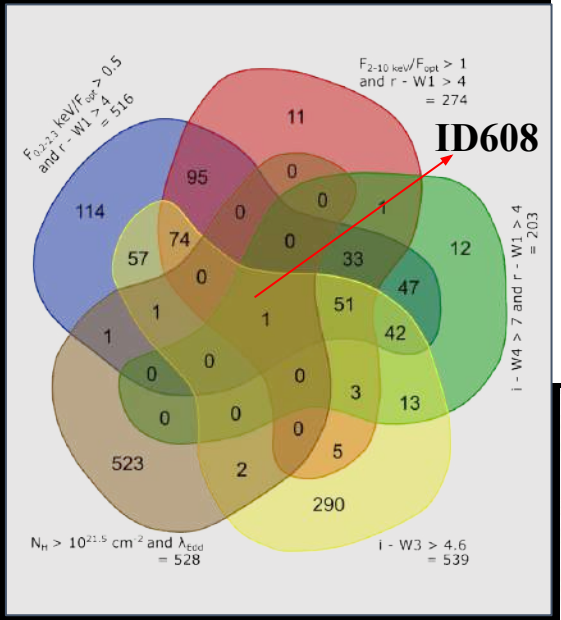
- ➢ Mass outflow rate of 0.2 –23 $M_\odot yr^{-1}$

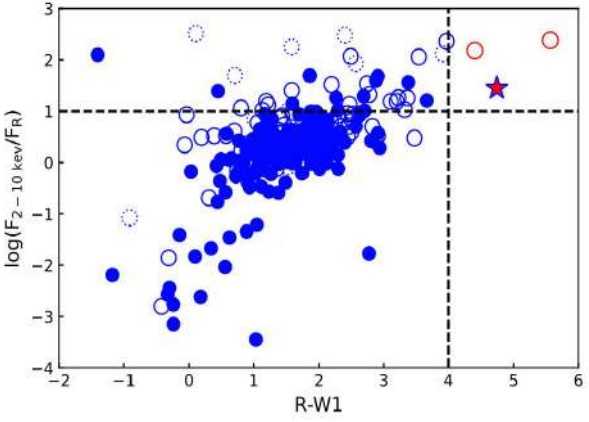
  Kinetic power of 40 - 44 erg s^{-1}
- ➢ Kinetic coupling efficiencies 1-10% (in 30% of the sample)
- ➢ Indicating that the outflow is **very relevant** from the **energetic point of view.**

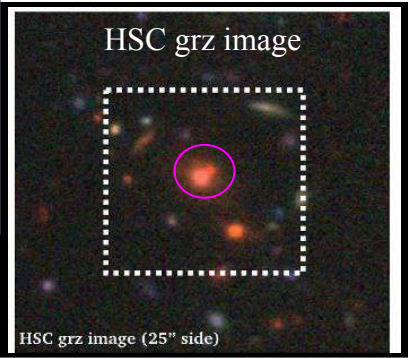
Ionised AGN outflows in the Goldfish galaxy - The illuminating and interacting red quasar eFEDSJ091157.4+014327 (ID608) at z ~0.6 (Musiimenta+2024, arXiv:2401.17299)

About ID608

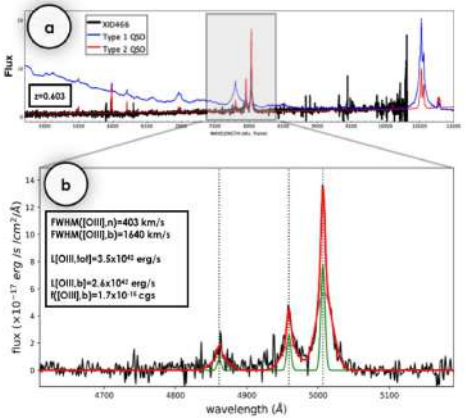
Red colors and obscured







Broad and redshifted [OIII] component



Brusa+2022, Musiimenta+2023

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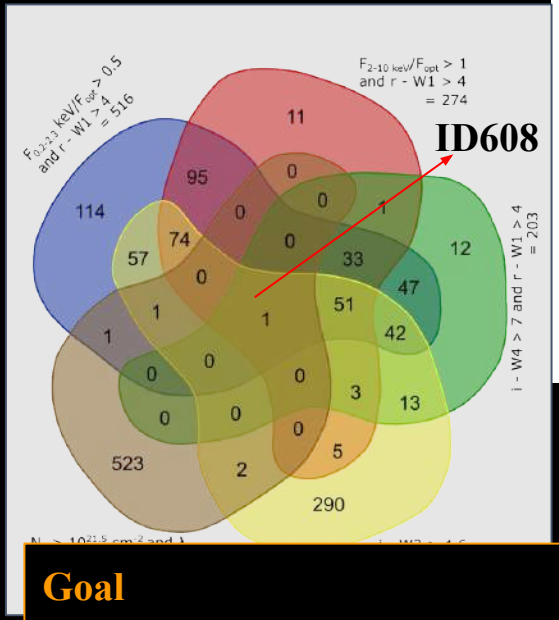

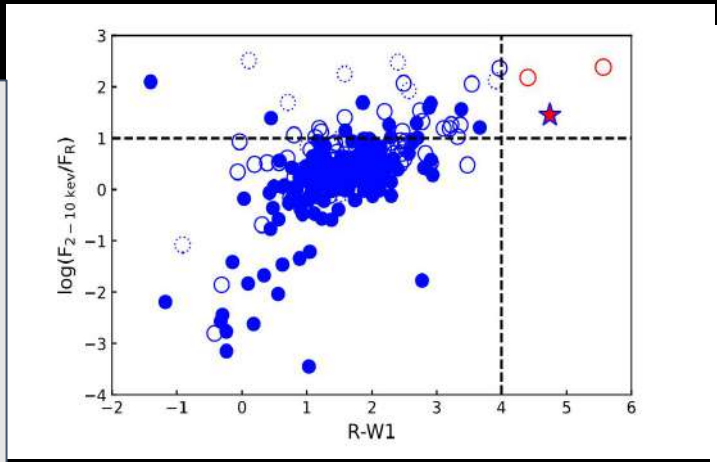

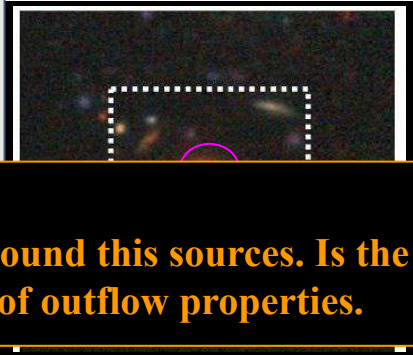

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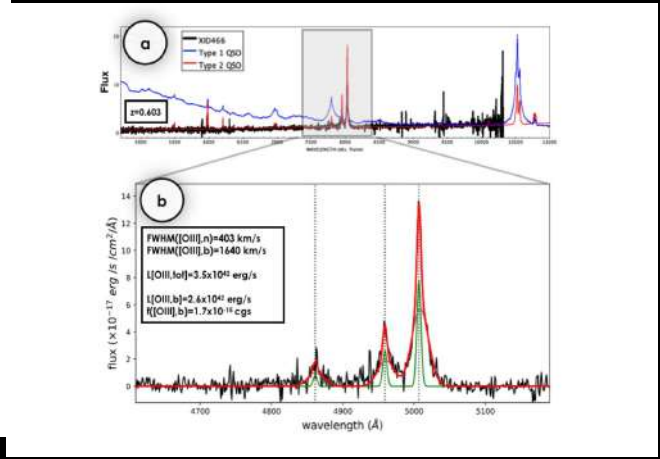


Goal

- **Explore environment around this sources. Is the quasar located in a merging system?**
- **Accurate measurement of outflow properties.**

MUSE observation

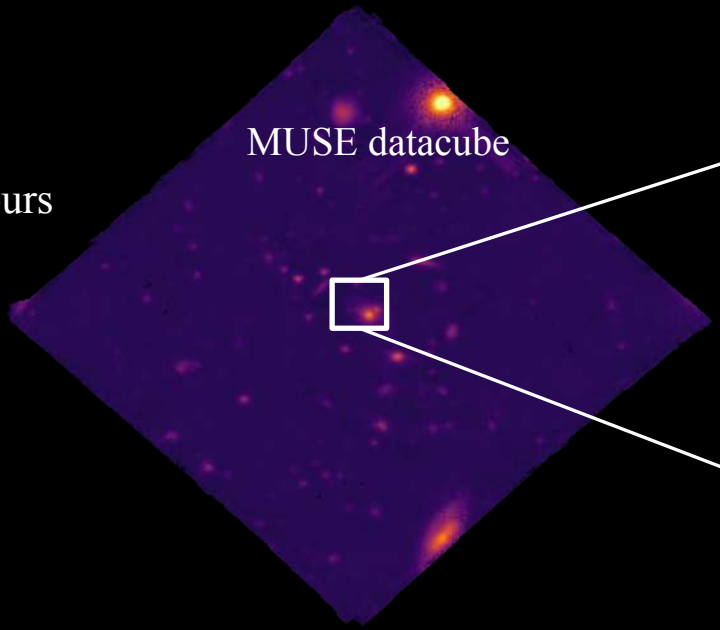
Musiimenta+2024, arXiv:2401.17299

Observations: 5 nights for 6.1 hours

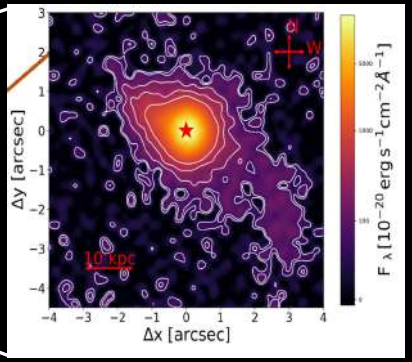
Spectral resolution, R ~ 2800

Pixel size = 0.2 arcsec

Field of view = 1x1 arcmin^2

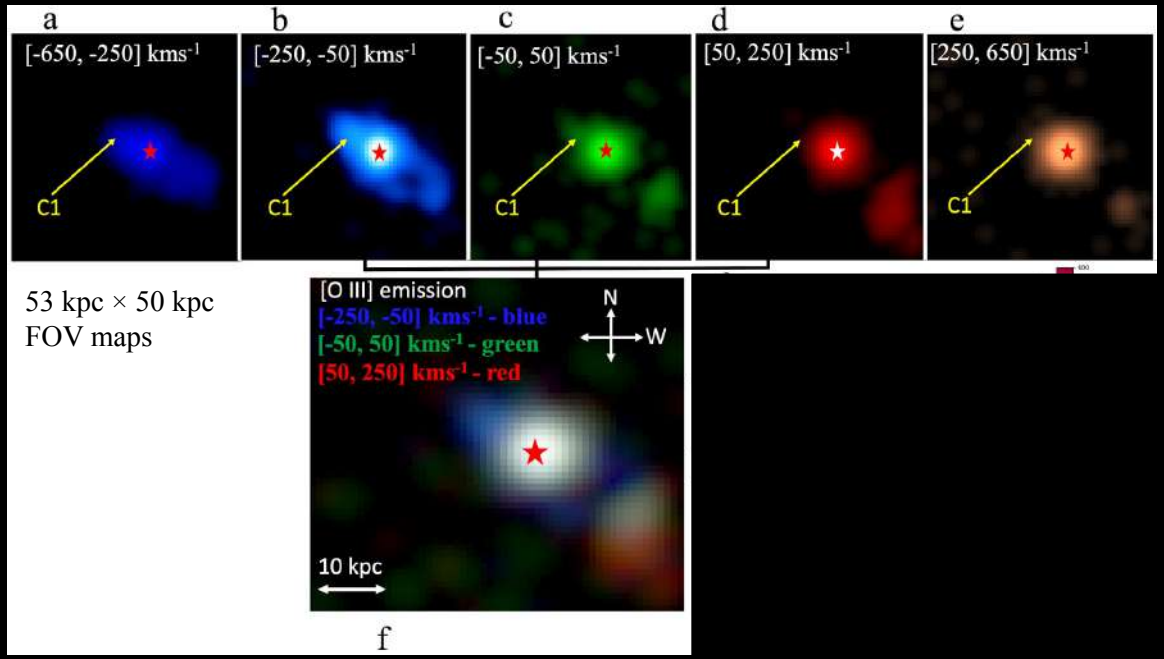


The Goldfish galaxy



Gas distribution, structures and companion galaxies (C)

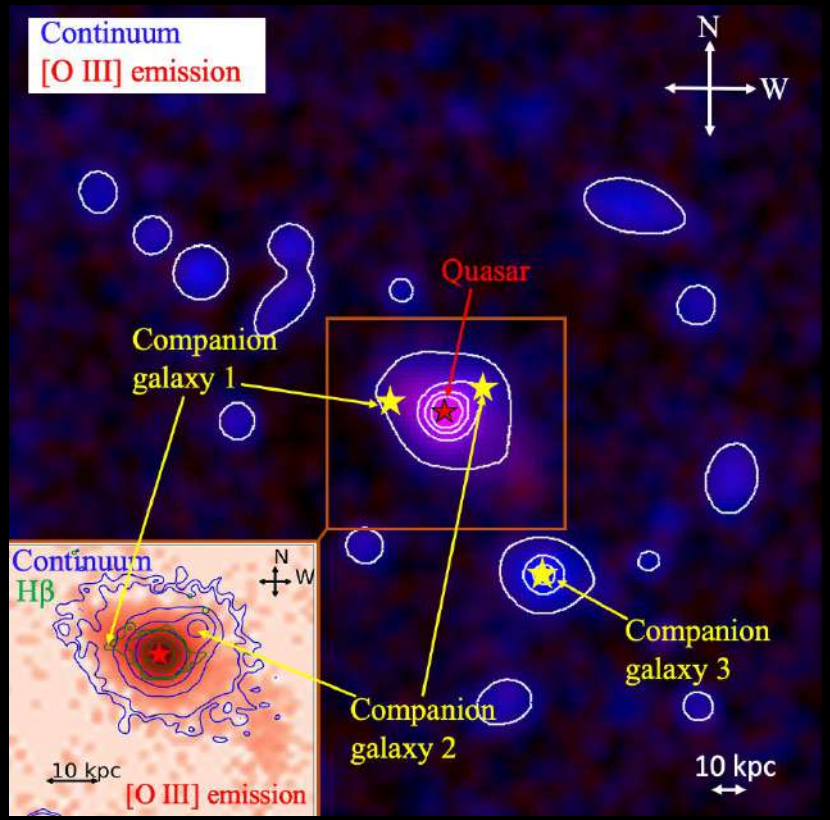
Musiimenta+2024, arXiv:2401.17299



- [-650,-250] km/s: extended emission towards SW and NE.
- [-250,-50] km/s: second peak in NE, bubble-like extended emission towards SW.
- [-50,50] km/s: centered emission
- [50,250] km/s: emission in SW
- [250,650] km/s: centered emission

Searching for companion galaxies (C)

Musiimenta+2024, arXiv:2401.17299



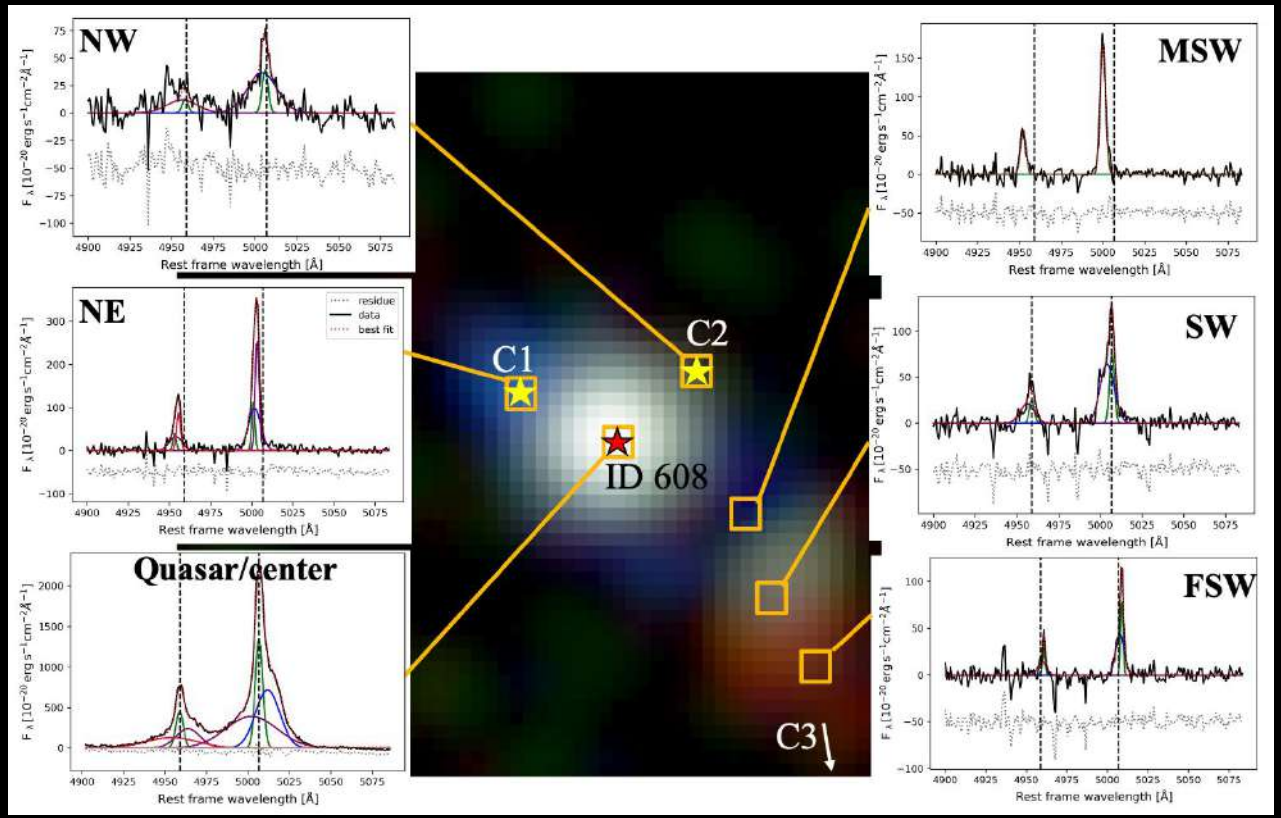
201 × 201 kpc FOV map

A **complex interacting system possibly merging** with three other galaxies that are within ~ 50 kpc.

[O III] emission line fitting: different regions

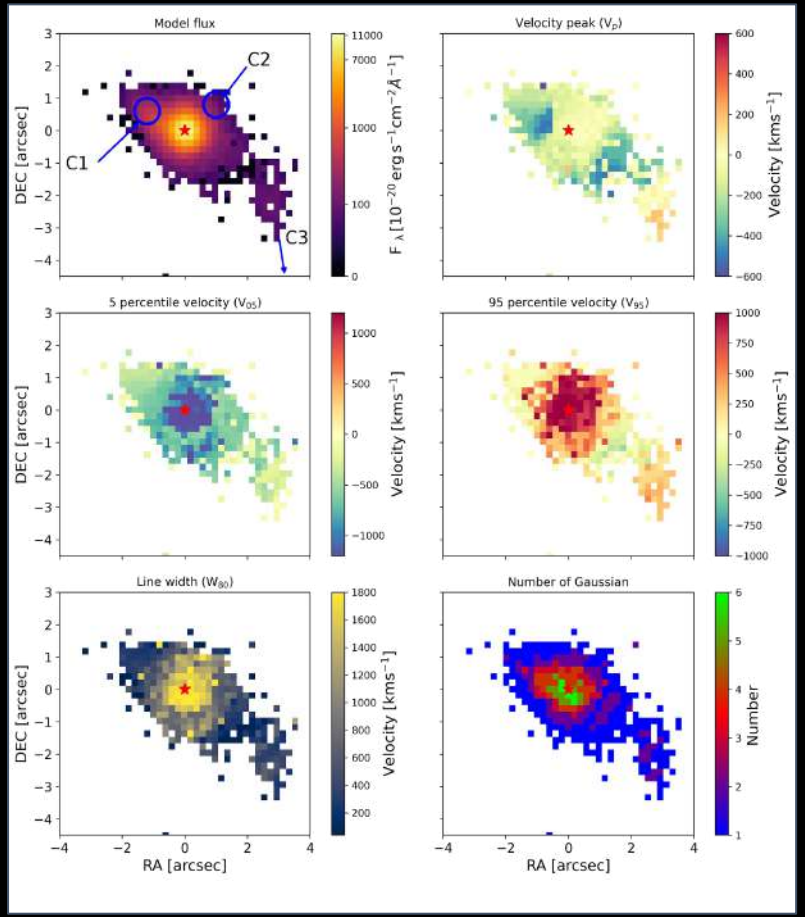
Musiimenta+2024, arXiv:2401.17299

- Multiple Gaussian fitting
- Non-parametric analysis



[O III] emission line fitting: Kinematic

Musiimenta+2024, arXiv:2401.17299



- 5 percentile velocity (V_{05}) = negative outflow velocities. **Up to -1200 km/s.**
- 95 percentile velocity (V_{95}) = positive outflow velocities. **Up to 1000 km/s.**
- W80 (V_{90}-V_{10}) = velocity dispersion. **In the range 600 - 1800 km/s.**

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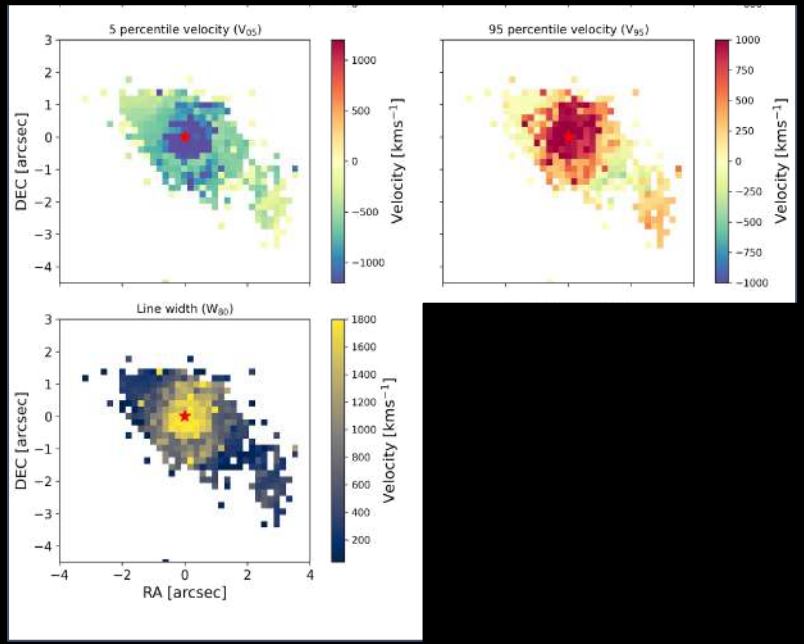

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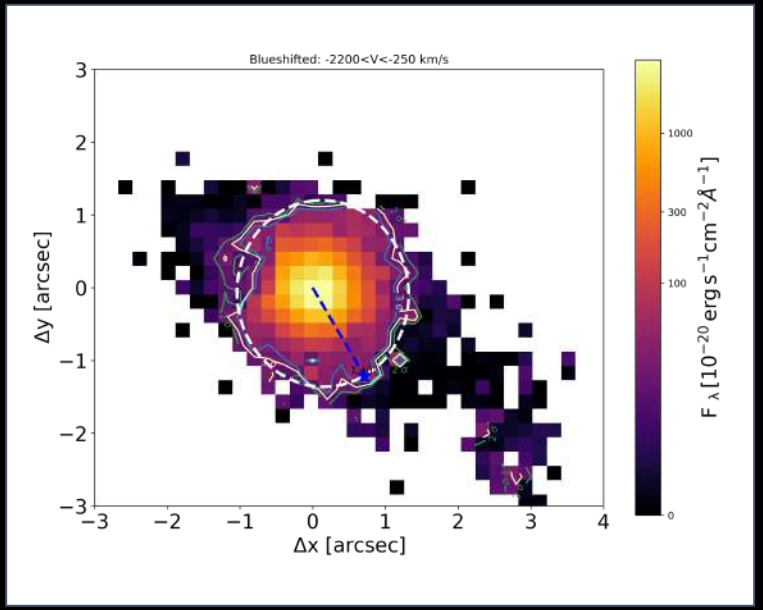
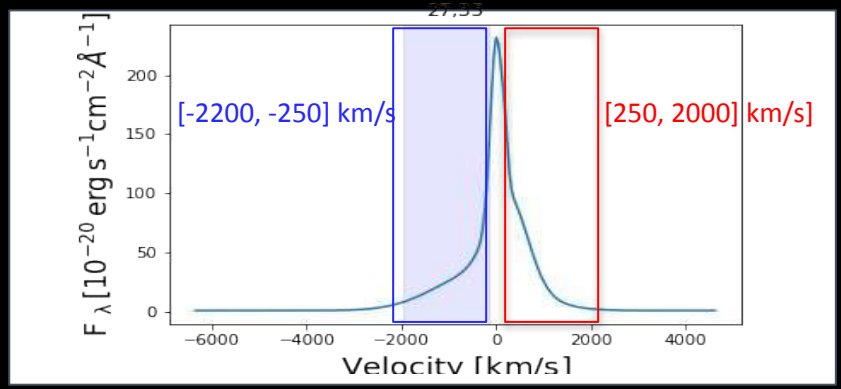
Outflow properties

Musiimenta+2024, arXiv:2401.17299

- Outflow mass, $M_{out} \propto \frac{L_{[O\ III]}}{n_e}$ assumed 500 cm^{-3}
- Mass outflow rate, $\dot{M} = k\ M_{out}\ \frac{V_{out}}{R_{out}}$





- L[O III] from sum of flux within 3σ ellipse
- Rout as distance from center to 3σ ellipse
- Vout as mean of V05 and V95 within 3σ ellipse

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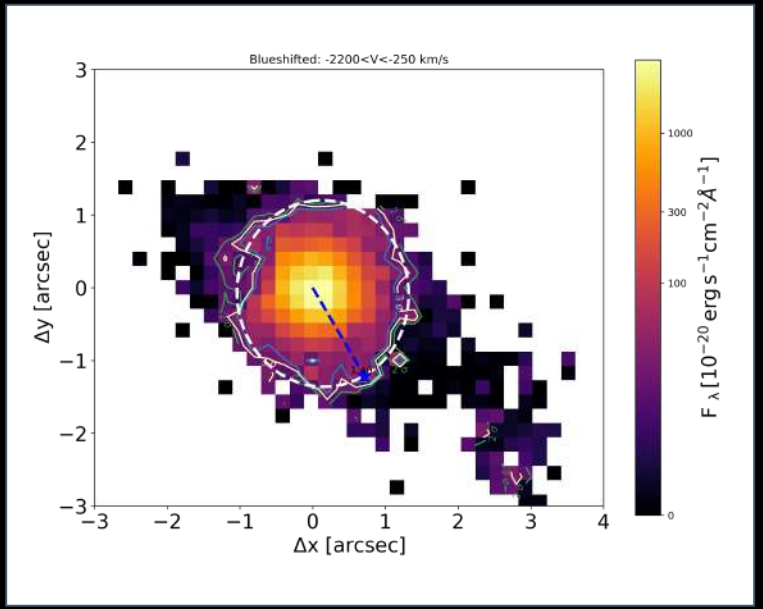

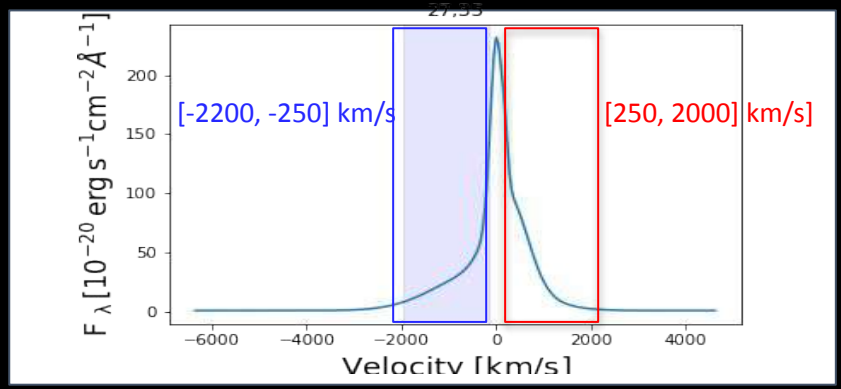

- Total mass outflow rate = 9.6 $M_\odot yr^{-1}$
- Total kinetic power = 1.9x10^{42} erg/s

- Kinetic coupling efficiency **too low (0.01-0.2%)**;
  - outflow **not very relevant from the energetic** point of view.
  - slightly consistent with theoretical predictions of **radiation-pressure-driven outflows**.
- Outflows are more likely **AGN-driven** than star formation-driven (mass loading is 4.8).

Take away message and summary

- **eROSITA** is as a powerful discovery machine for AGN in the feedback phase.
- **Ionised winds** (kiloparsec scale) discovered in red and obscured sources.
- **Weak/no correlation** between outflow velocity and bolometric luminosity.
    - **Highlights the importance of sample selections**
- X-ray active,obscured is best tracer of fastest phase of winds

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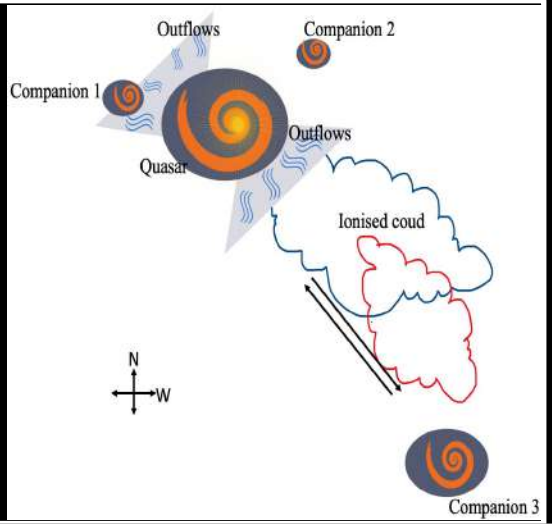
Employ machine learning to select these sources in eRASS1/5, characterise outflows and compile a sample for follow up studies (Musiimenta+in preparation)

- A **complex interacting** system, **possibly merging** with **three companion galaxies** within ~50 kpc away.
- **Extended ionised outflows** up to ~ 9.4 kpc with total mass outflow rate of 9.6 $M_{\odot} yr^{-1}$.
- The outflows in this quasar are likely **AGN - driven** than star formation driven.
- They are **less relevant** from the energetic point of view.



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Thank you for listening!

Questions?

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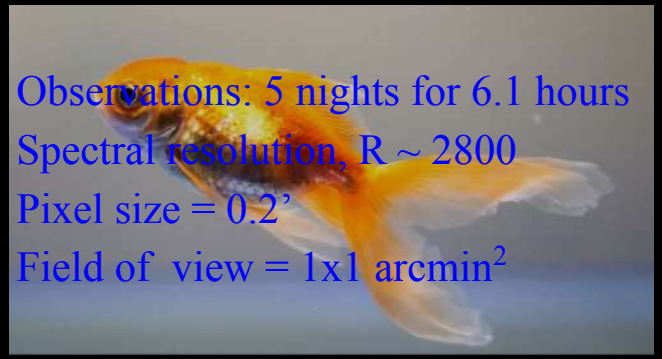
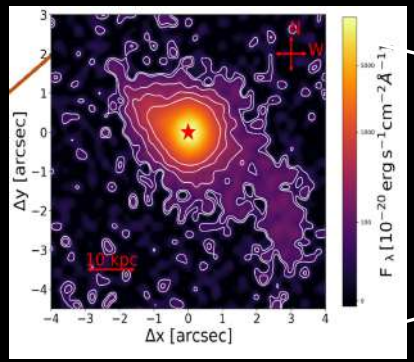
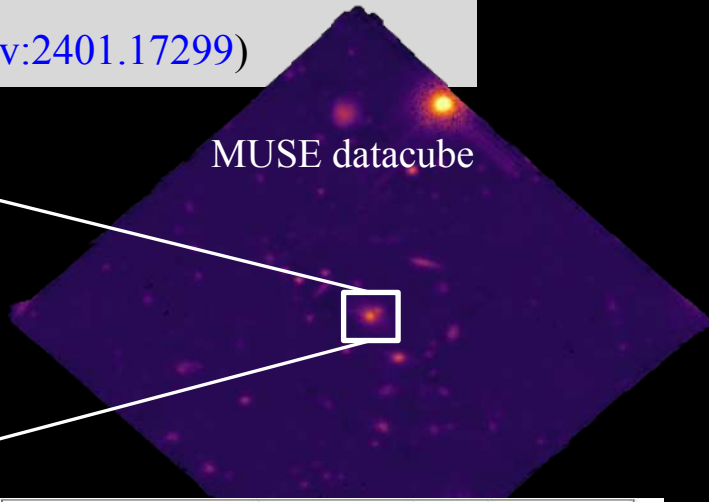
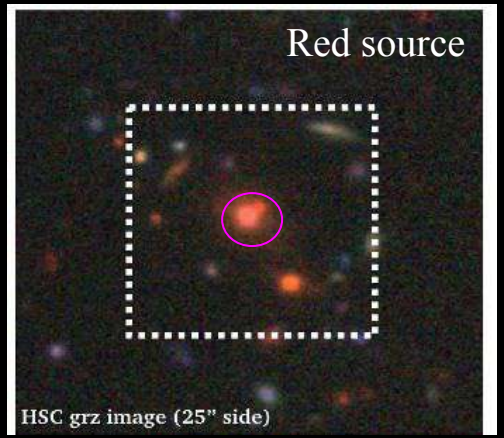


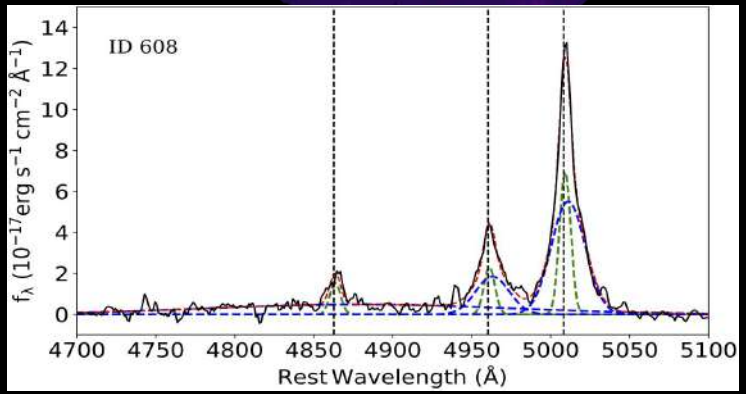
The Goldfish galaxy





- Z = 0.6031
- $L_{bol,AGN}$=7.8x10^{45} ergs^{-1}
- L_{bol}/L_{edd}=0.99
- X-ray type 2 nature
- Lx ~10^{44} ergs^{-1}
- N_H~2.7x10^{22} cm^{-2}





Brusa+2022, Musiimenta+2023