EXTREMELY HIGH VELOCITY OUTFLOWS (EHVO) IN QUASARS

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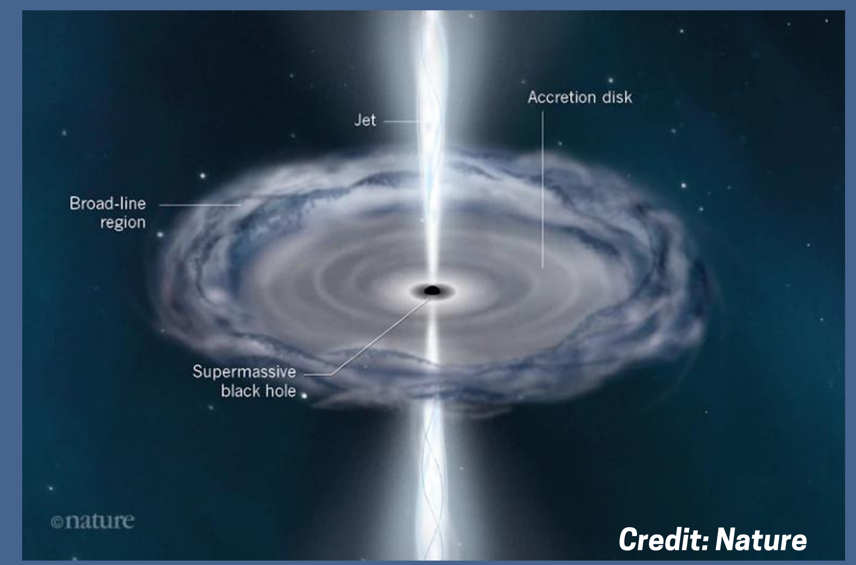
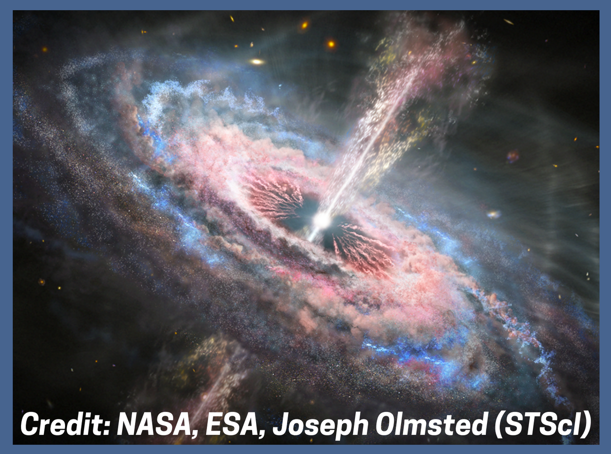
What are Quasars?

A **quasar** comprises a **supermassive black hole** at the center of galaxies with an **accretion disk**, surrounded by hot gas and dust.





Outflows occur when a body of gas is launched from the quasar.
We observe outflows by **absorption troughs** in a spectrum.

Our sample of quasar spectra is from the **Sloan Digital Sky Survey** or **SDSS** quasar catalog.

What is a BAL quasar?

BAL stands for **Broad Absorption Line** . For our project, a BAL quasar is defined as a quasar with broad absorption at speeds up to **25,000 km/s**.

What is an EHVO?

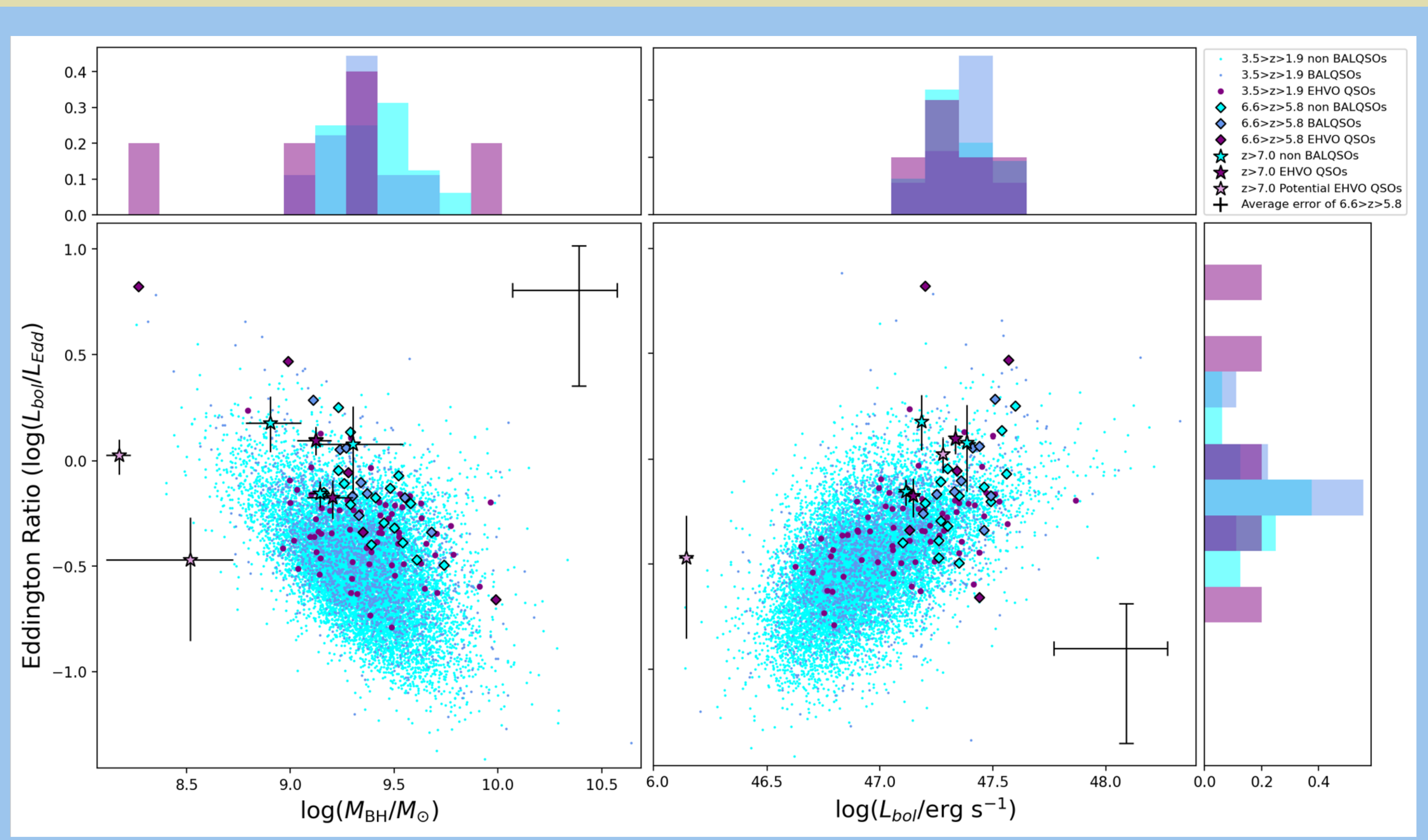
Some quasars show **Extremely High Velocity Outflows** (EHVOs), which consist of gas propelled away from the supermassive black holes at speeds greater than **10% the speed of light.**

Do EHVOs and their properties evolve across cosmic time?

In this project, we study the properties of quasars with **EHVOs**, BALs, and non-BALs, and compared them within multiple redshift (z) ranges to learn whether they evolve. The physical properties we focus on are: **black hole mass** (M_{BH}), **luminosity** of the quasar over the entire spectrum (called bolometric luminosity or L_{bol}), and the **Eddington ratio**, which is the efficiency of the quasar accretion disk.

We study 3 samples at different redshifts: ● **Low-z (3.5>z>1.9)** SDSS data[7]; ◆ **Mid-z (6.6>z>5.8)** X-shooter data[2], and ★ **High-z (z>7)** data; we used the complete list by Dr. Sarah Bosman[3] and searched the literature finding data for 7 sources.

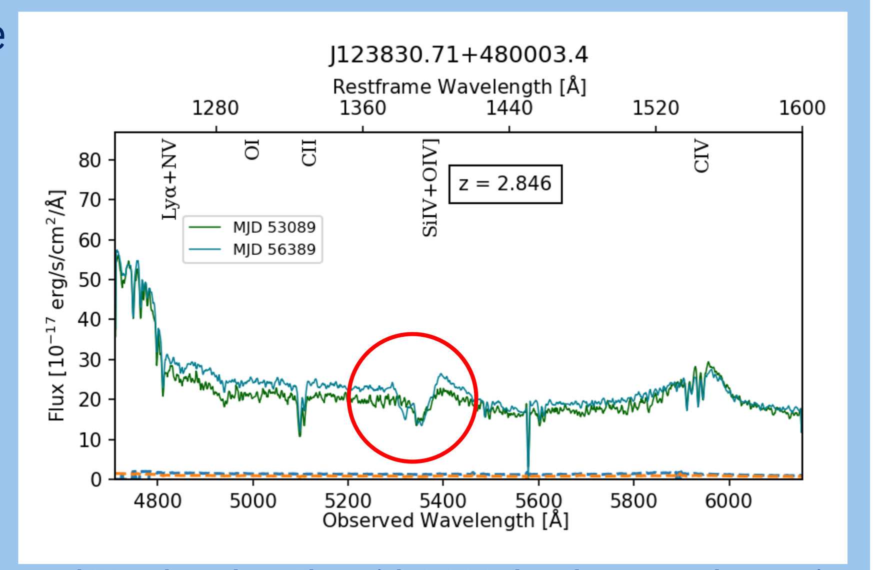
- In the low-z sample, **EHVOs** appear in the most luminous quasars and those with larger Eddington ratios, but their distribution of M_{BH} matched the values of other quasars.
- The **EHVOs** at mid-z show a large spread of values of Eddington ratios and M_{BH} relative to non-BALQSOs and BALQSOs. However, their L_{bol} values overlap with the values of the sample.
- At high-z, the samples are small, but the **EHVOs** seem to show similar L_{bol} overall to the rest of the sample, and lower M_{BH} and slightly lower Eddington ratios.



Note: While the scatter plot shows all mentioned data, the histograms only show the 6.6>z>5.8 data.

Why do some EHVOs show 'weird' variability?

EHVOs vary between observations[5]. In some cases, such as the one shown on the right, the minimum part of the trough remains the same as the surrounding trough and continuum changes. We call this **'weird' variability**.



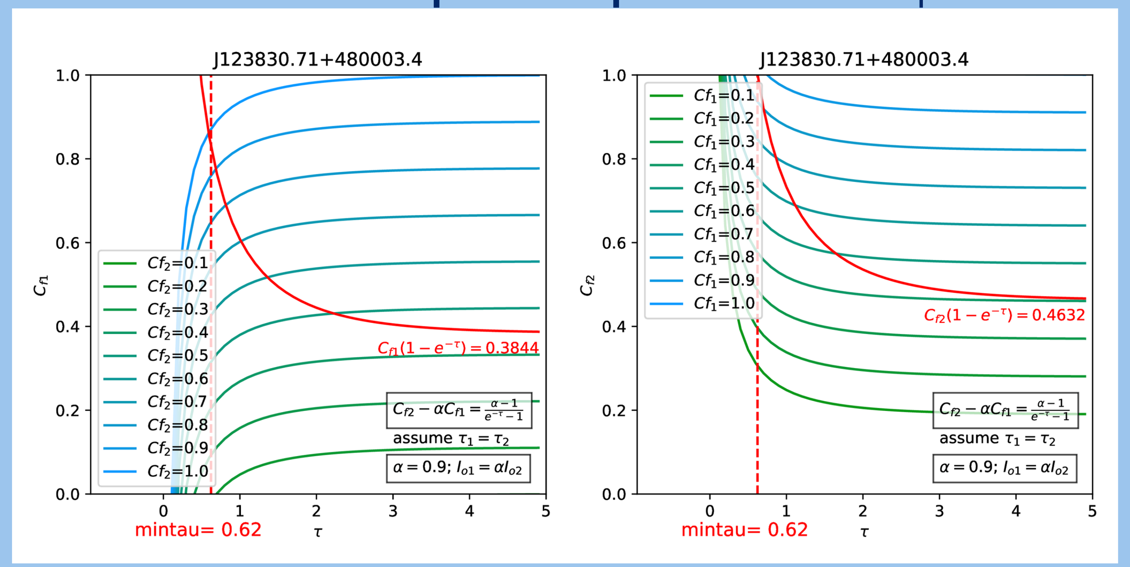
Observed Wavelength vs Flux with 3,300 days between observations

We studied how this special case helps us constrain the values of:

- coverage fraction(C_f): how much the accretion disk is covered by the gas[1],
- optical depth(τ): how opaque that gas is.

We use the equation[4]: $(1 - C_{f1})I_{o1} + C_{f1} I_{o1} e^{-\tau_1} = (1 - C_{f2})I_{o2} + C_{f2} I_{o2} e^{-\tau_2}$ and fix the **optical depth** to be the same between the two observation to find all possible values (green to blue lines in graph below),

and use observational values from spectra (solid **red** line) to constrain actual values. The dashed **red** line is the minimum **optical depth** that can explain observation data.



Graphs of coverage fraction of each observation vs. optical depth

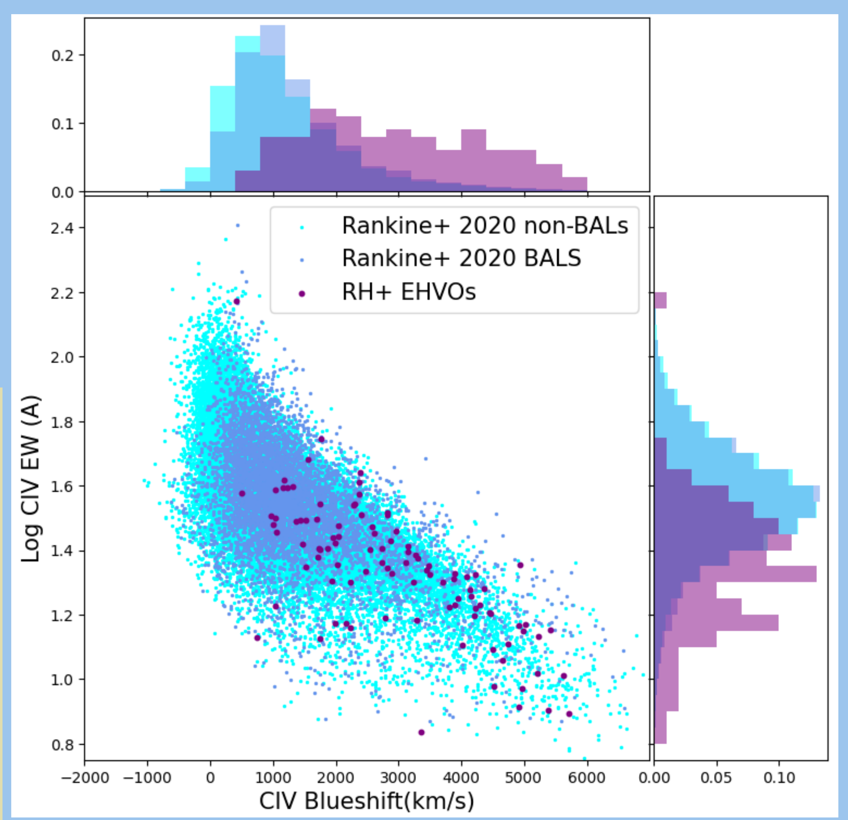
- The minimum optical depth value that is consistent with the data is larger than **0.6**, which indicates the lines are close to **saturation**.
- As the optical depth increases, the **minimum coverage fraction** of the first observation is **~0.4**, and the second observation is **~0.5**.

Do EHVOs also show outflows in emission?

This project is an extension of a previous study[8] by using a larger sample of 100 EHVOs.

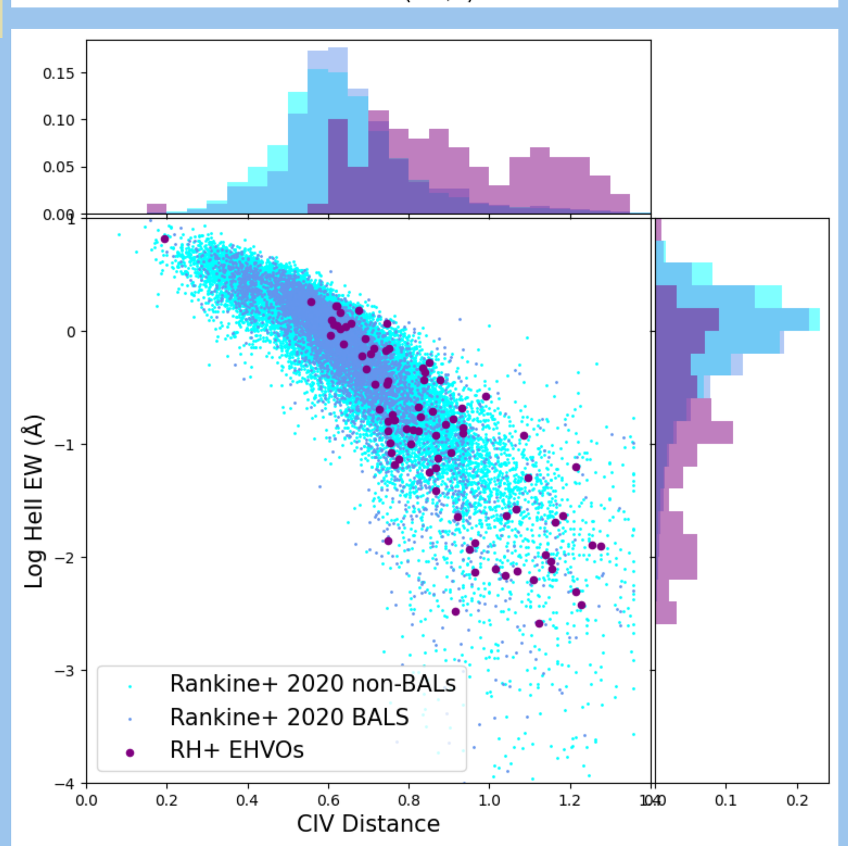
- The parent sample is divided into BALs (blue dots) and Non-BALs (aqua dots);
- The **purple** dots are **EHVOs** from a previous study[7] and our current work[9].

Connection Between Absorption and Emission



Our study finds that **EHVOs quasars have larger blueshifts of the CIV emission line** than the parent sample, suggesting a **connection between emission and absorption outflowing signatures** for these extreme outflows.

- **C IV** distance is a metric describing the distance along a best-fit curve through the C IV space;
- **He II λ1640 EW** is an indicator of the strength of the ionizing spectral energy distribution (SED).



There seems to be an **upper limit** for the He II EW of EHVOs, suggesting that there is an **SED hardness above which EHVOs cannot be driven**.

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