Discovery of an Accelerating Quasar Wind with the Sloan Digital Sky Survey

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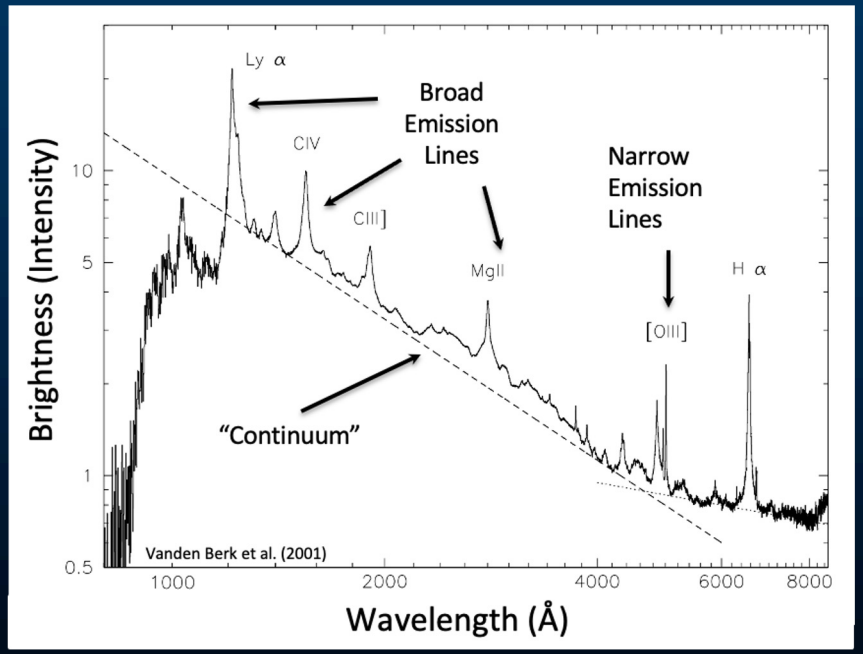
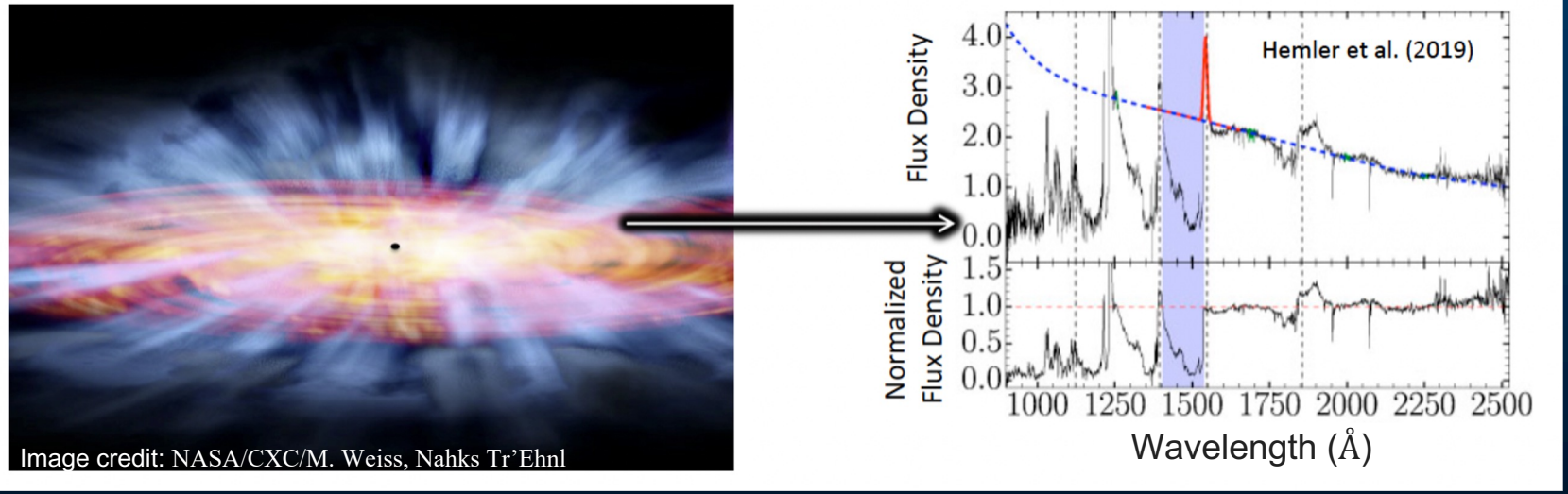
Quasars and Their Spectra



Quasars are supermassive black holes (SMBHs) that have a hot, luminous accretion disk that emits radiation across much of the electromagnetic spectrum.

Quasar Winds and Broad Absorption Lines



- Quasar winds are visible as broad absorption lines (BALs) in quasar spectra
- BALs are variable over time, and we can use that variability to learn about the physical conditions within the outflow.
- Winds are a way for the quasar to interact with the rest of the galaxy that it lives in and are thus potentially important for galaxy evolution!

The SDSS-V Black Hole Mapper Reverberation Mapping Project

The Black Hole Mapper (BHM) is observing thousands of quasars all over the sky with SDSS telescopes!

As a part of a specific monitoring project called the BHM Reverberation Mapping Project, we are monitoring five quasar fields; each field contains ~400 quasars.

We will obtain ~175 observations of these fields over 6-7 years.

A few hundred of these quasars are expected to have BALs.

One of these fields, called the SDSS-RM field, has been observed as a part of previous SDSS programs since 2014.

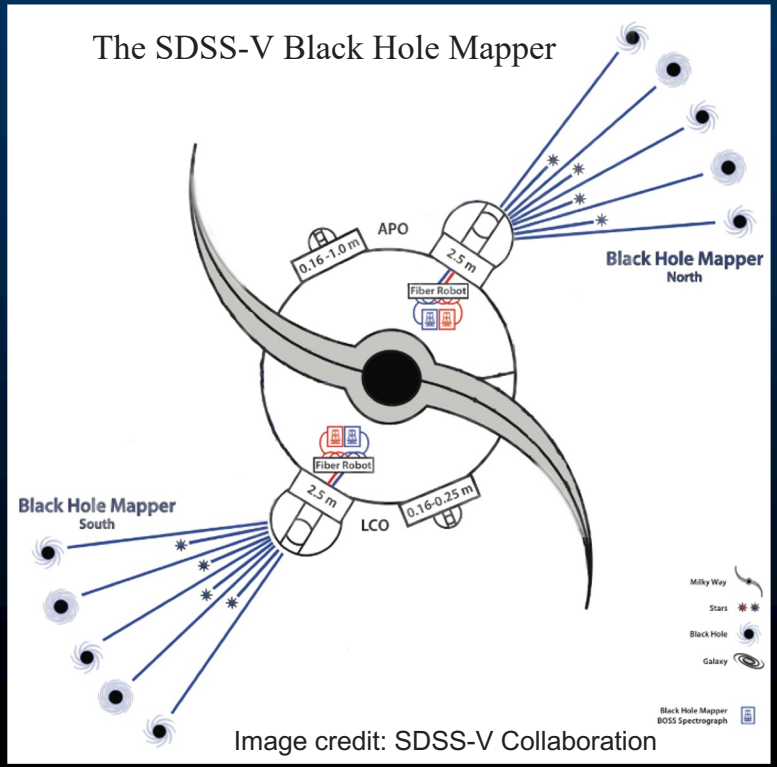
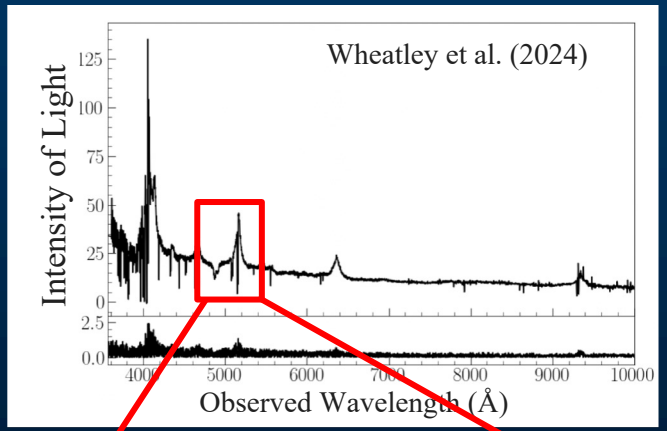
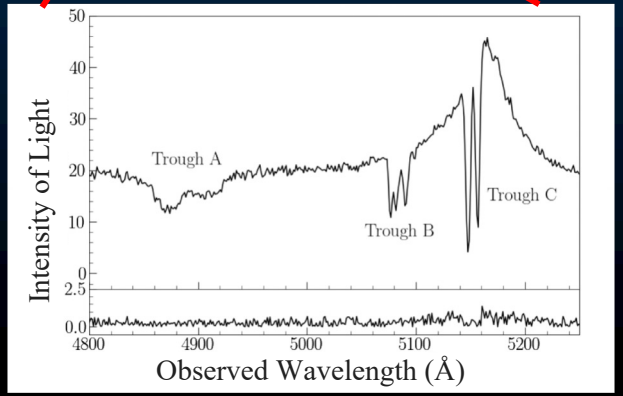


Image credit: SDSS-V Collaboration

The Quasar SBS 1408+544





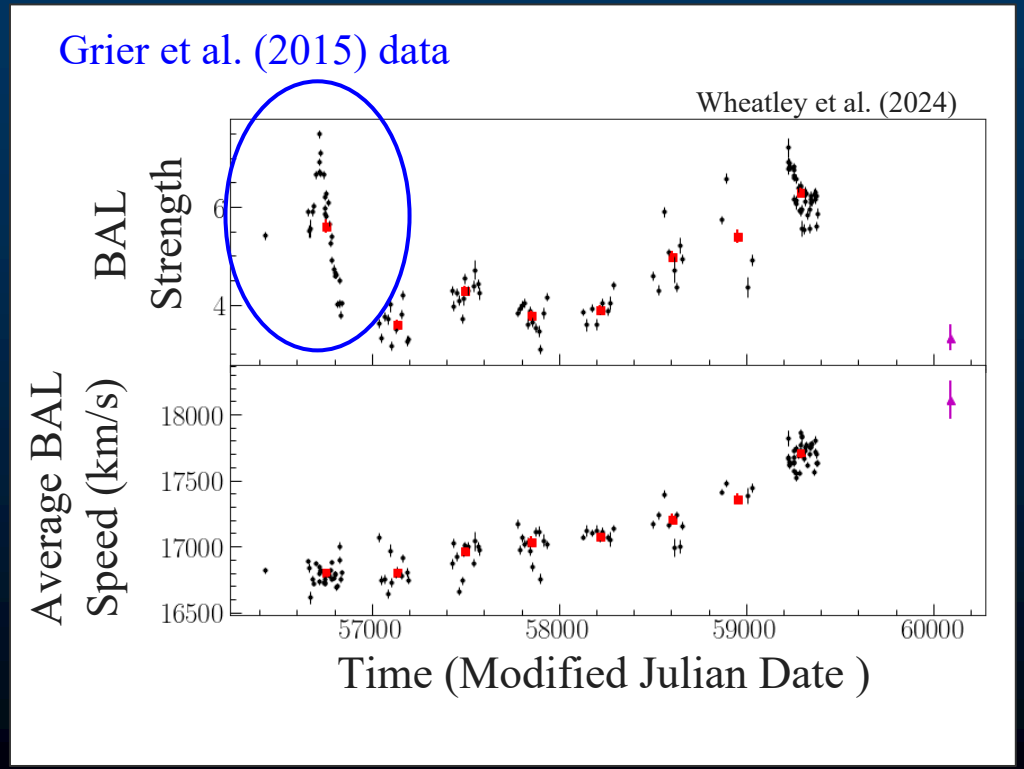
- This quasar is in the SDSS-RM field, which is one of the BHM-RM quasar fields we are still monitoring!
- Also known as SDSS-RM 613
- Redshift: 2.337
- Light travel time: ~10 billion years
- Has a wind made of gaseous carbon that produces a BAL in its spectra
- Wind speed: > 10,000 miles per second (~37 million mph)

The Quasar SBS 1408+544

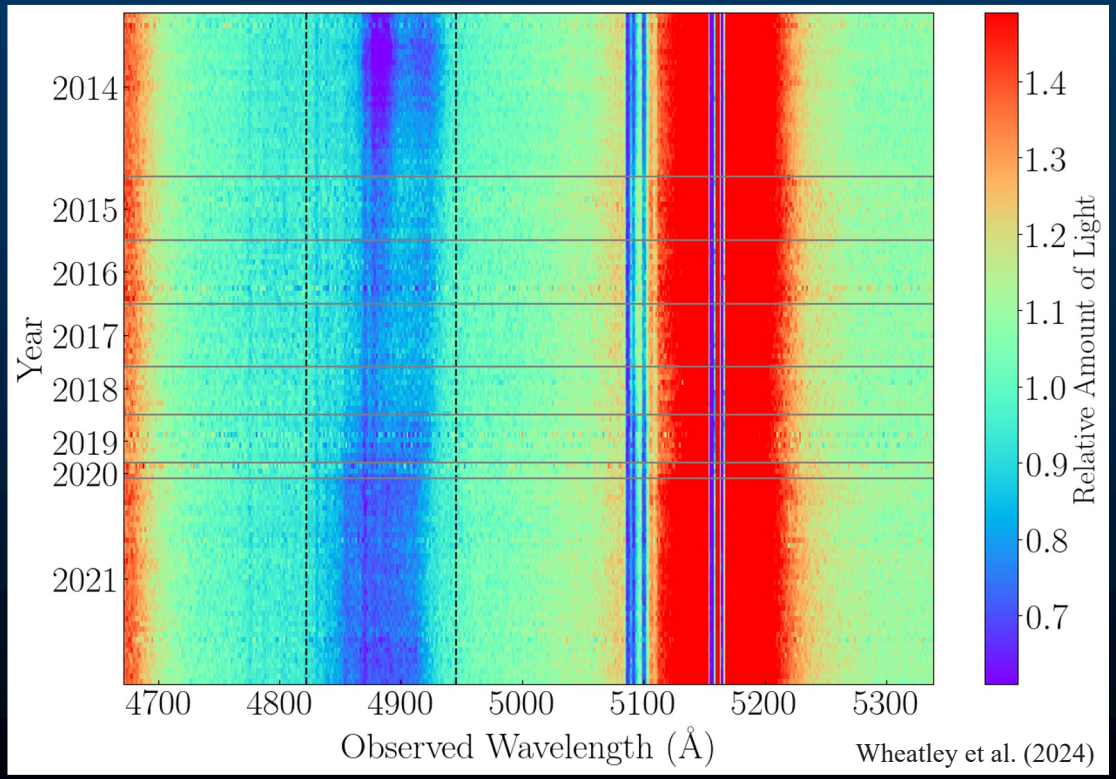
- This quasar was studied by Grier et al. (2015) with 6 months of data and found to have surprisingly strong, fast variability in the strength of its BAL.

- We re-examined this quasar with 8 years of data and found that it was continuing to vary and also that the entire outflow was shifting to higher velocities -- it was accelerating!

This was unexpected, as only a handful of other tentative acceleration cases have been reported!



Acceleration and Variability in Shape



The observed shift in velocity is around 800 km/sec (~2 million mph)!

Why is this important?

- This is the first time we have had enough data to effectively determine the acceleration of a quasar outflow on both long and short timescales.

- Our work suggests that acceleration may actually be common in quasar winds, but we haven’t been able to detect it at high confidence until now!

- Acceleration is predicted by many quasar-wind models -- our detection will further constrain these models, which inform our understanding of how winds affect the quasar host galaxy.

- **Future work:** With this detection in hand, we will be searching for acceleration in the rest of our BAL quasars monitored by the BHM-RM program, of which there are expected to be ~200!

Thank you!

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This work was published today in the Astrophysical Journal:

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And will appear on the arXiv this evening!

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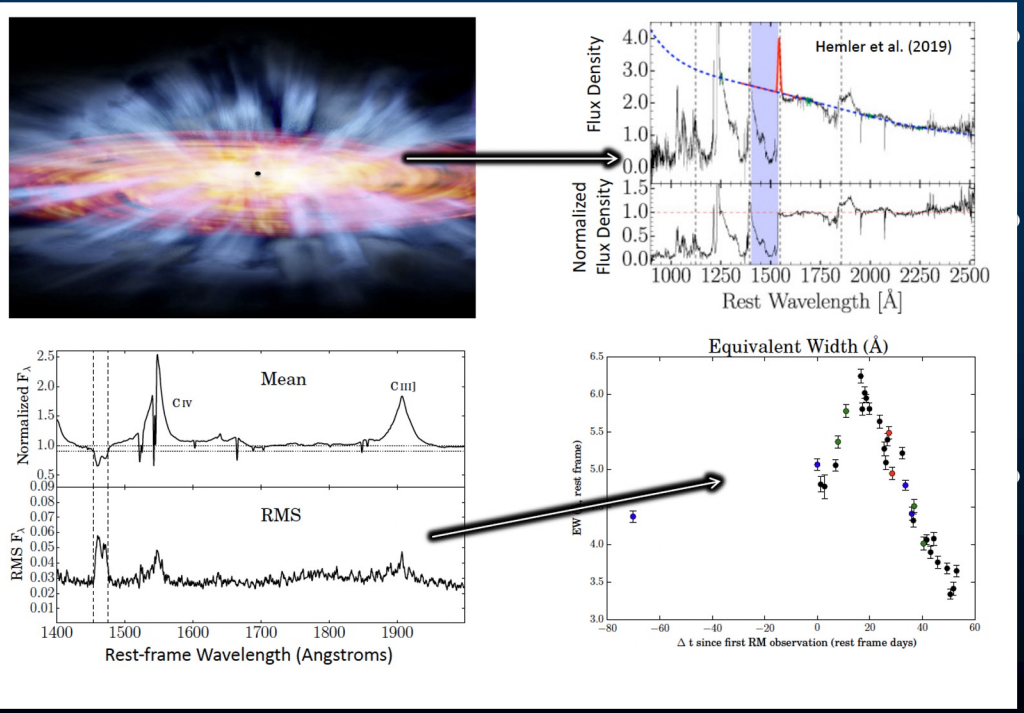
Additional Information:

- Quasars are supermassive black holes (SMBHs) that are continuously pulling matter towards the center.
- The SMBHs in quasars have a hot, luminous accretion disk that emits radiation across much of the electromagnetic spectrum
- Quasars usually have broad emission lines in their spectra produced by fast-moving gas near/just beyond the accretion disk
- Quasars often have outflows, or winds, launched from the accretion disks, that, given enough energy, can travel far beyond the immediate reach of the SMBH.
- These quasar winds may affect galaxy evolution by providing “feedback” to the host galaxy, which can greatly impact star formation and other galactic dynamics.

Outflow and Broad Absorption Lines (BALs)



Quasar winds are visible as broad absorption lines (BALs) in quasar spectra

- If the absorption feature spans over 2000 kms^{-1} in velocity width, the absorption feature is considered a BAL.

BALs are variable over time, and we can use that variability to learn about the physical conditions within the outflow, as well as the physical mechanisms that produce the winds.

Roughly a dozen or so reports of BAL acceleration exist in the literature, but those reports generally include only 2-3 spectra spread over several years (one study had 5 spectra). It is often difficult to disentangle “acceleration” from general “variability” with these data.

The Black Hole Mapper Reverberation Mapping Project

We began observing a quasar field known as the “SDSS-RM” field in 2014, with 850 quasars in it.

In 2021, SDSS-V Black Hole Mapper Reverberation Mapping Program (BHM-RM) began: a program geared at obtaining repeat spectra of quasars. The main goal of this program is to measure the masses of supermassive black holes in about a thousand quasars at a wide range of distances from us. In addition to three new fields, BHM-RM continued to observe many of the quasars in the SDSS-RM field.

•The BHM-RM program aims to obtain 175 spectroscopic observations per field between 2021-2027.

•The program is also obtaining supplementary photometry via private and national observing resources – and LSST, once it’s running!

Our BAL quasar in this study is one of the ones that has been observed since 2014.

RM-613 Investigation

- SBS 1408+544 (also known as RM 613) has been observed since 2014. It was first investigated in Grier et al. (2015, ApJ, 806, 1) using 32 epochs of data from 2014. Its CIV BAL showed strong variability on timescales as short as 1.20 days, shorter than had ever before been reported in a BAL.
- This quasar was also included in the study of Hemler et al. (2019, ApJ, 872, 1), who confirmed the short-timescale variability.
- By the time of our study, we had acquired 132 total spectra, which were cropped, redshifted, corrected, and normalized.
- We then measured the equivalent width, depth, and centroid velocity as a function of time and learned that the centroid velocity was systematically shifting towards faster velocities -- we were not expecting this!
- A statistical analysis was also performed to certify that our results of acceleration were not from a line profile or shape change factor, and truly from the acceleration of the outflow.
    - Interpolated Cross Correlation Function (ICCF), Cross Correlation Centroid Distribution (CCCD), and Cross Correlation Peak Distribution (CCPD)