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Evidence for Broad Line Region Outflows and Their Impact on Black Hole Masses

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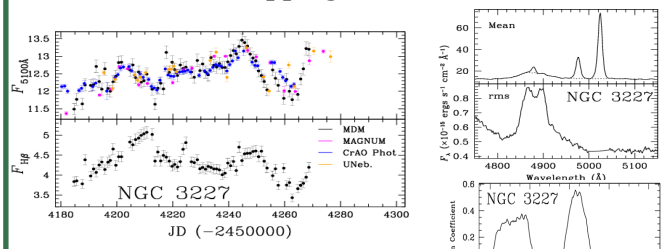
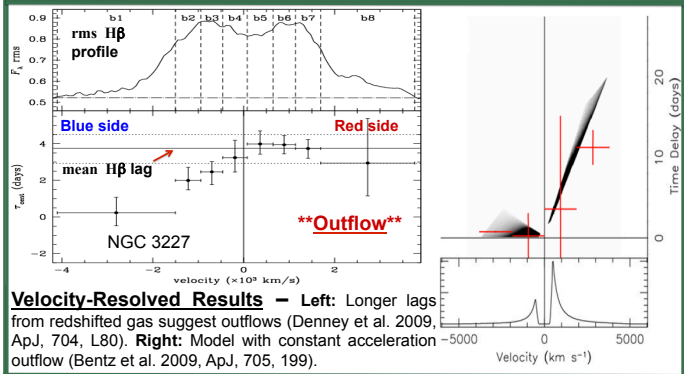
ABSTRACT – Recent velocity-resolved reverberation mapping results have shown indications of possible outflowing gas from the Hβ emitting region of the broad line region (BLR) around NGC 3227 (Denney et al. 2009, 2010). We show a preliminary velocity-delay map (VDM) from these data that suggests the 2D gas motions could not be fully and accurately interpreted from the 1D velocity-resolved reverberation mapping signal. From the VDM, an outflow component to the emission remains possible but appears to be in addition to an underlying, disk-line BLR structure consistent in size to the measured reverberation lag. The black hole mass derived from this data is therefore secure from any uncertainties possibly derived from gravitationally unbound gas contributing to the emission. Additionally, we demonstrate that BLR emission from the CIV λ1549 broad emission line can reliably be used as a virial black hole mass estimator. The presence of self-absorption, blueshifts, and asymmetries observed in CIV, and possibly connected with outflows, has raised questions in the literature regarding the reliability of using this line for mass estimates. However, we exhibit our new results that CIV-based masses are in agreement with those of Hβ when **(1)** data quality is made a priority and **(2)** a color-correction is applied to the mass estimates.

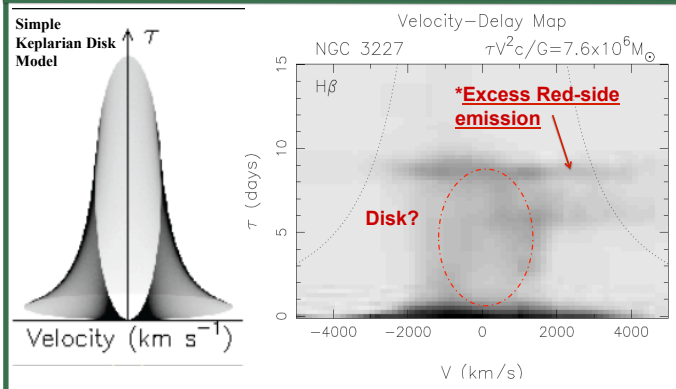
Reverberation Mapping of NGC 3227 – Outflow?



Basic Reverberation Results – Left: Continuum (F_{5100A}) and Hβ Light Curves. **Right Top:** Mean and rms spectra. **Right Bottom:** Cross correlation function for Hβ; centroids of values $r > 0.8\ r_{max}$ gives Hβ lag of 3.8±0.8 days (Denney et al. 2010, ApJ, 721, 715).

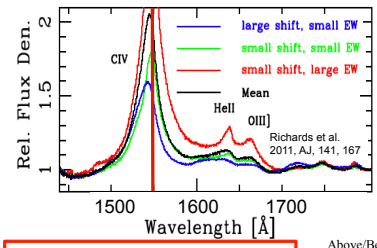


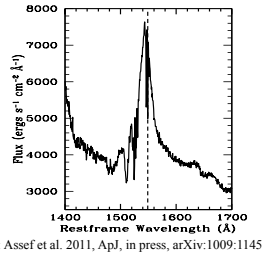
Velocity-Resolved Results – Left: Longer lags from redshifted gas suggest outflows (Denney et al. 2009, ApJ, 704, L80). **Right:** Model with constant acceleration outflow (Bentz et al. 2009, ApJ, 705, 199).



Velocity-Delay Map Results – *Preliminary* velocity-delay map (*right*) shows that the Hβ response resembles an underlying Keplarian disk-like origin with additional excess emission on the red side of the profile, likely responsible for the apparent "outflow" signature. More work is planned to model possible explanations for this excess emission, which could still include outflows.

Is CIV a Reliable Black Hole Mass Indicator?



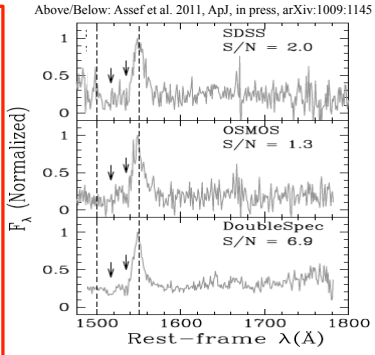


Above/Below: Assef et al. 2011, ApJ, in press, arXiv:1009:1145

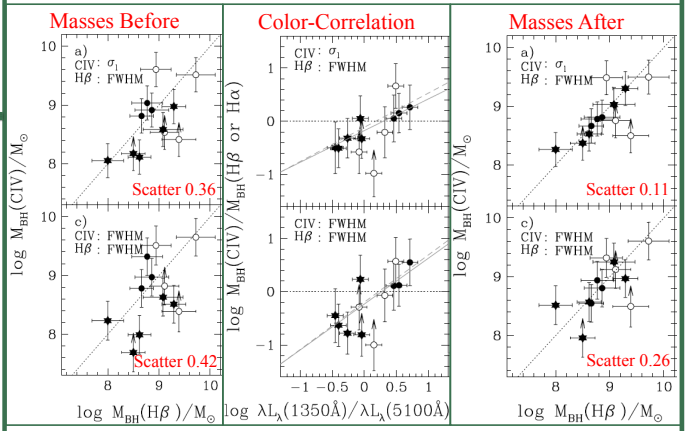
Problems (potential):
1. Profile blueshifts (top: left & right)
2. Line Blending (top left)
3. Self-absorption (top right)
4. Outflows?

Problems (definite):
1. Heterogeneous data mining from the literature
2. UN-Identified absorption! (right)

Solutions:
1. High S/N, moderate resolution data!!
2. Homogeneous data handling!
3. Functional fits to line profiles – only where necessary
4. Luminosity color correlation correction (below)



Results: CIV A-OK



Using a sample of high-redshift lensed quasars from the CASTLES project with observed-frame UV or optical and near-IR spectra, we searched for possible biases between supermassive black hole (BH) mass estimates based on the CIV, Hα and Hβ broad emission lines. We find evidence for the importance of consistent data analysis methods and use of high S/N spectra. While we otherwise find no systematic offsets between CIV and Balmer line mass estimates, we do find that the residuals between them are strongly correlated with the ratio of the UV and optical continuum luminosities. Removing this dependency reduces the scatter between the UV- and optical-based BH mass estimates by a factor of approximately 2. See Assef et al. 2011, ApJ, in press, arXiv: 1009:1145.

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