Extreme Outflows in Extremely Red Quasars

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Summary:

- ERQs have a unique suite of peculiar broad emission-line properties including large rest equivalent widths (REW(CIV) > 100A), "wingless" line profiles, and exotic line flux ratios like NV > Lyα, very large NV/CIV and SiIV/CIV, and strong AlIII 1870A. (**Figures 1 & 2**).
- ERQs typically have extreme high-velocity [OIII] λ5007 lines with FWHMs and blueshifted wings up to ~5000 km/s (**Figure 2**) that identify powerful outflows on galactic scales > 1 kpc (based on photoionization analysis, Zakamska et al. 2016, Perrotta et al. in prep.)
- ERQs have a high incidence of BALs, 30–68%, compared to 14% in other BOSS quasars. **Figure 3** shows examples of ERQs with BALs that were not identified in the BOSS quasar catalog because the spectra are so dominated by the strong broad emission lines.
- ERQs also have a high incidence of large CIV emission-line blueshifts, with shifts > 2500 km/s roughly fifty times more common than normal quasars, reaching 8739 km/s (**Figure 4**).
- We argue that the exotic line properties of ERQs are related to unusually powerful/extended outflows that encompass most of the line-forming regions and, perhaps, the dusty torus. The emission-line blueshifts and large REWs (unprecedented in luminous quasars) might arise from outflow-dominated broad-line regions that are vertically extended above the accretion disk where they intercept and reprocess more of the quasar continuum flux.

Introduction:

Dust-reddened quasars are candidate young objects that might drive galaxy-wide blowouts during early stages of galaxy evolution. Our team has discovered a unique population of extremely red quasars (ERQs; Ross et al. 2015, Hamann et al. 2017) at redshifts 2.0 < z < 3.4 and high luminosities L ~ 10^{47} ergs/s in the SDSS-III BOSS survey. ERQs are defined simply by red colors across the rest-frame UV to mid-IR (i−W3 > 4.6AB from SDSS and WISE). However, using the BOSS spectra and quasar catalog (Paris et al. 2017), new spectra from the VLT-XShooter and Keck-NIRSPEC, and a new catalog of CIV 1549A and NV 1240A emission-line data for 216,188 BOSS quasars, we find that ERQs are unlike any known quasar population, with exotic emission and absorption-line properties that might all be related to unusually powerful outflows. Here we summarize the outflow results.

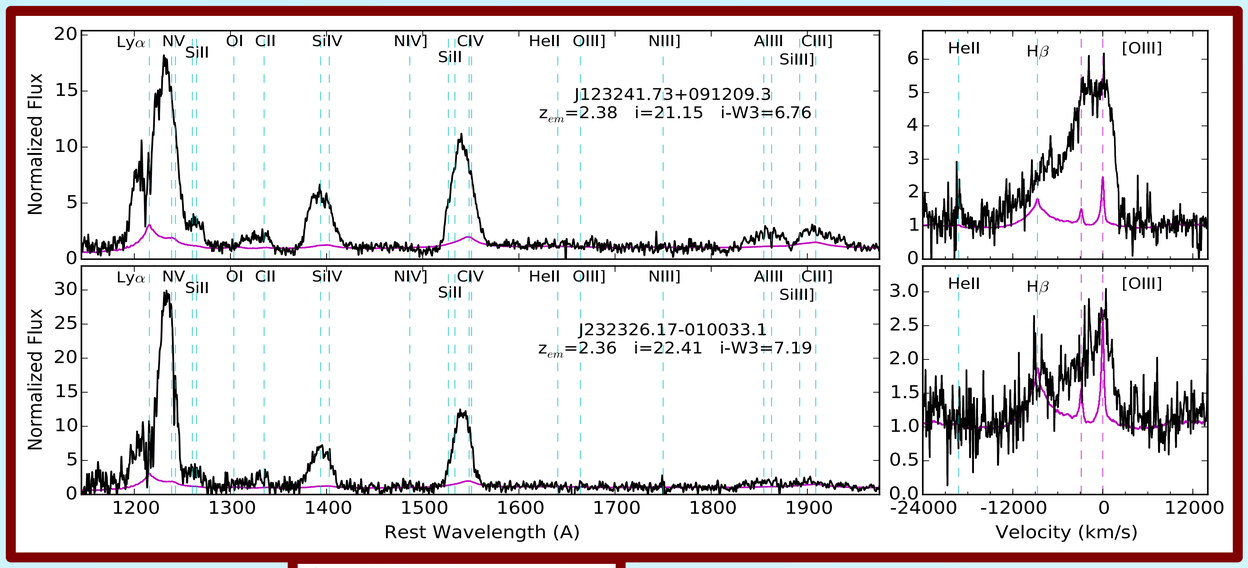

Figure 2. Normalized spectra of two ERQs (black curves) in the rest UV (left panels) and velocity profiles of [OIII] 5007,4959 and Hβ (right). The magenta curves show the SDSS composite of normal quasars for comparison (from vanden Berk et al. 2001, scaled to match the ERQs in the continuum). The [OIII] lines in the ERQs have broad blue wings and FWHMs both reaching 5000 km/s (Zakamska et al. 2016). The UV broad emission lines are also peculiar with extreme large REW(CIV) > 225A, broad "wingless" profiles, CIV blueshifts > 2700 km/s, weak BAL signatures (J123241+09), and unusual flux ratios including NV > Lyα.

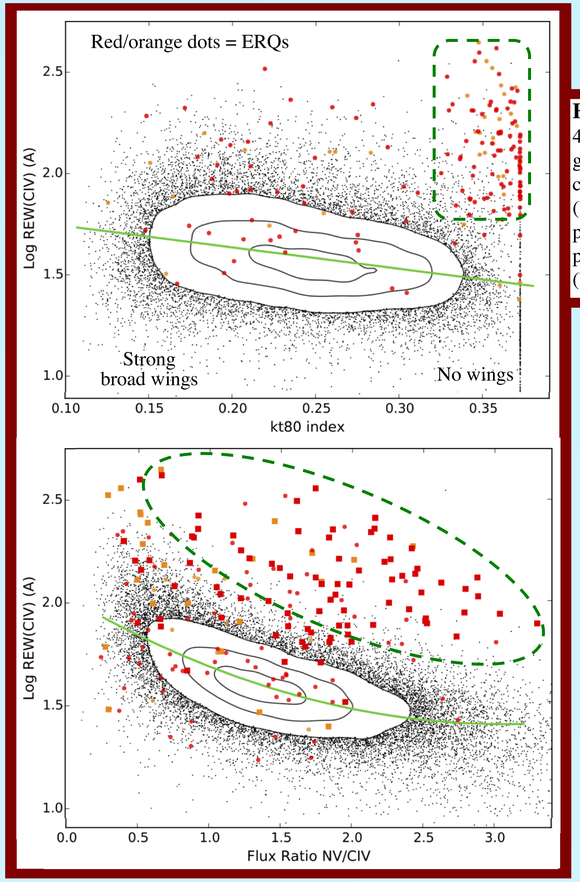

Figure 1. ERQs defined by i-W3 > 4.6 (red/orange dots mostly in the green dashed regions) are outliers compared to normal BOSS quasars (black dots and contours) in these plots showing CIV kurtosis kt80 (top panel) and line flux ratio NV/CIV (bottom) versus log REW(CIV).

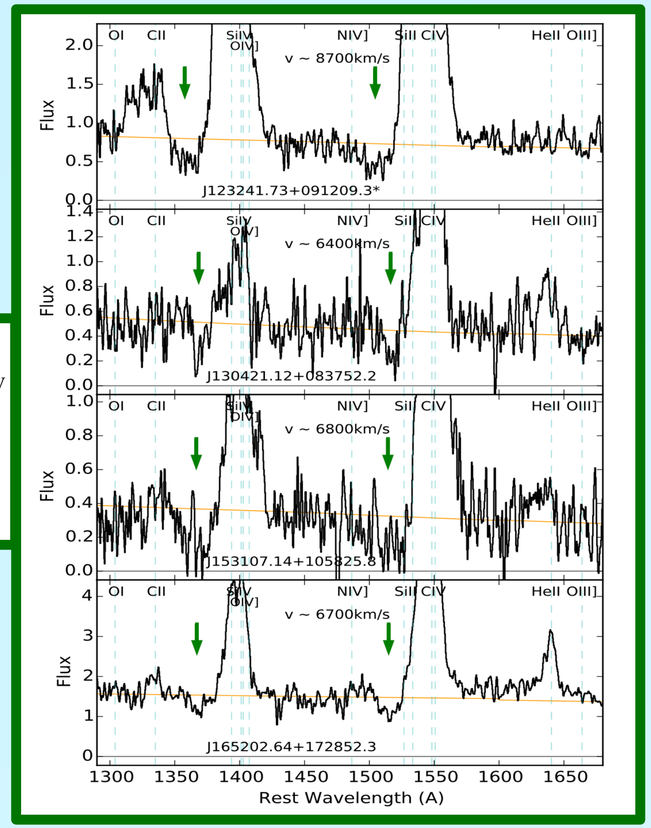

Figure 3. BOSS spectra of 4 ERQs showing examples of BALs or BAL-like outflow features in CIV and SiIV not flagged in the BOSS quasar catalog (due to the unusual spectra; compare J123241+09 here to Figure 2 above). The BALs are marked by green arrows with the velocities indicated above near CIV.

References:

- Hamann, F., et al. 2017, MNRAS, 464, 3431
- Paris, I., et al. 2017, A&A, 597, 79
- Perrotta, S., et al. 2017, in prep.
- Ross, N., et al. 2015, MNRAS, 453, 3932
- Vanden Berk, D.E., et al. 2001, ApJ, 122,549
- Zakamska, N.L., et al. 2016, MNRAS, 459, 3144

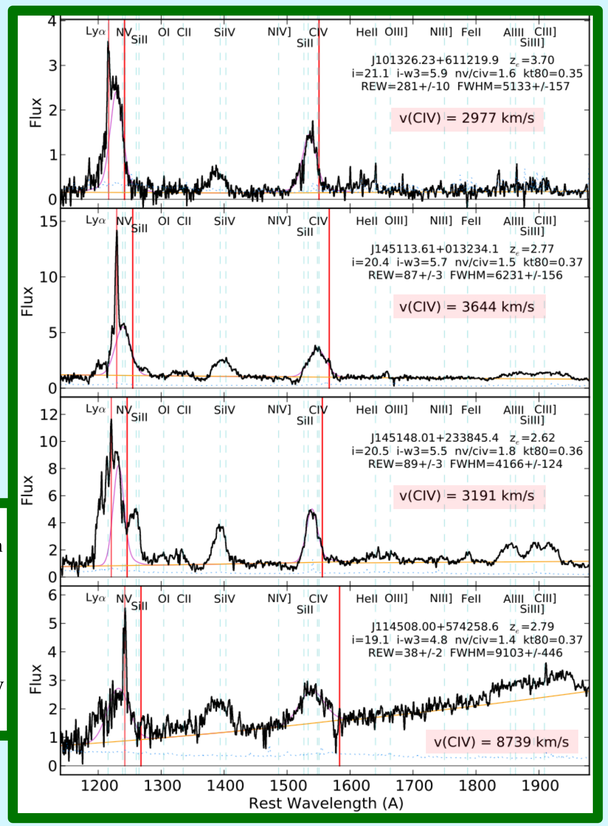

Figure 4. BOSS spectra of 4 ERQs with large CIV blueshifts, listed in each panel as 'v(CIV) = '. Vertical red lines mark peculiar narrow Lyα emission spikes (that might arise from extended halos from a blowout or infall) used define v ~ 0 in the quasar frame. The corresponding positions in NV and CIV reveal large blueshifts >~ 3000 km/s.