Galaxy Evolution and the Intergalactic Medium
TMT Science Forum
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Feedback and the Physics of Star Formation Quenching

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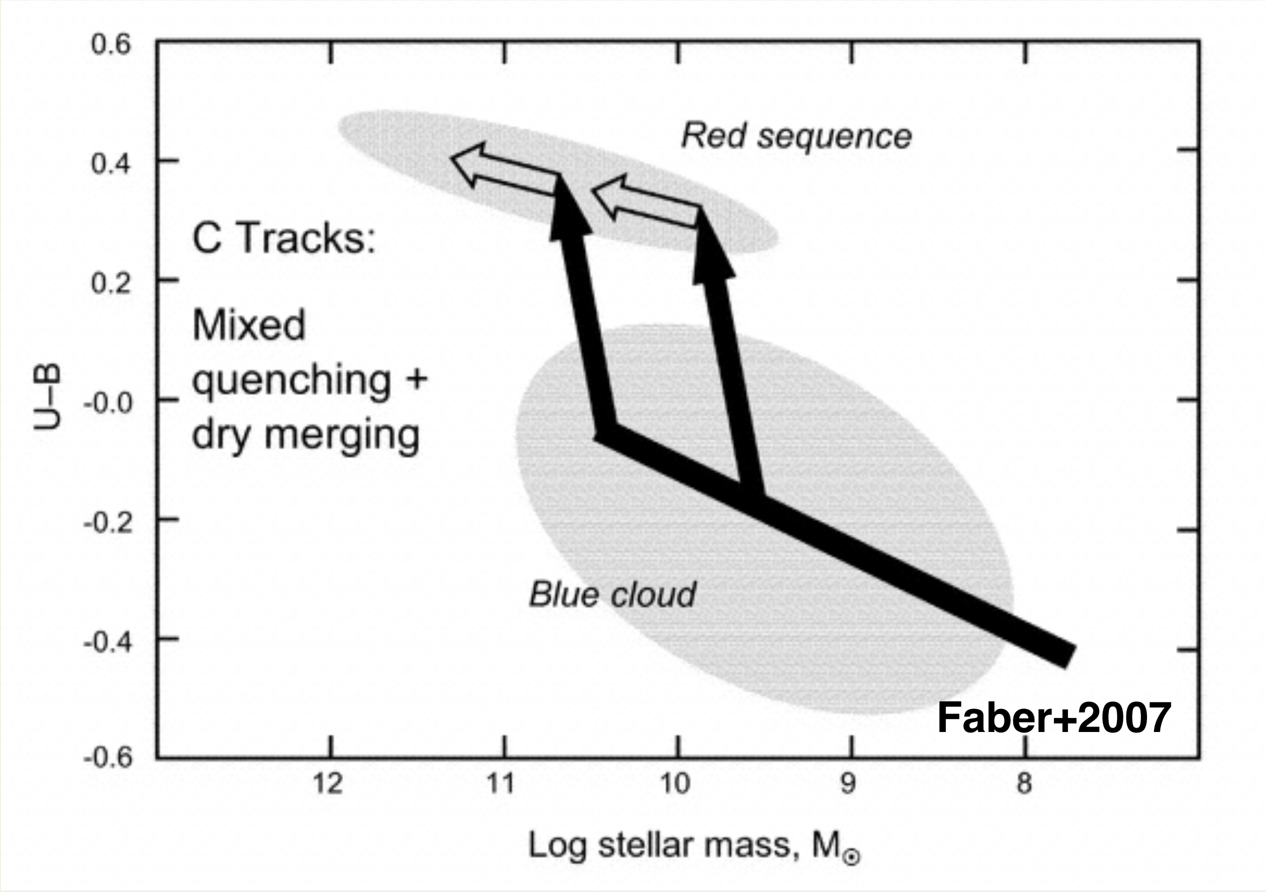
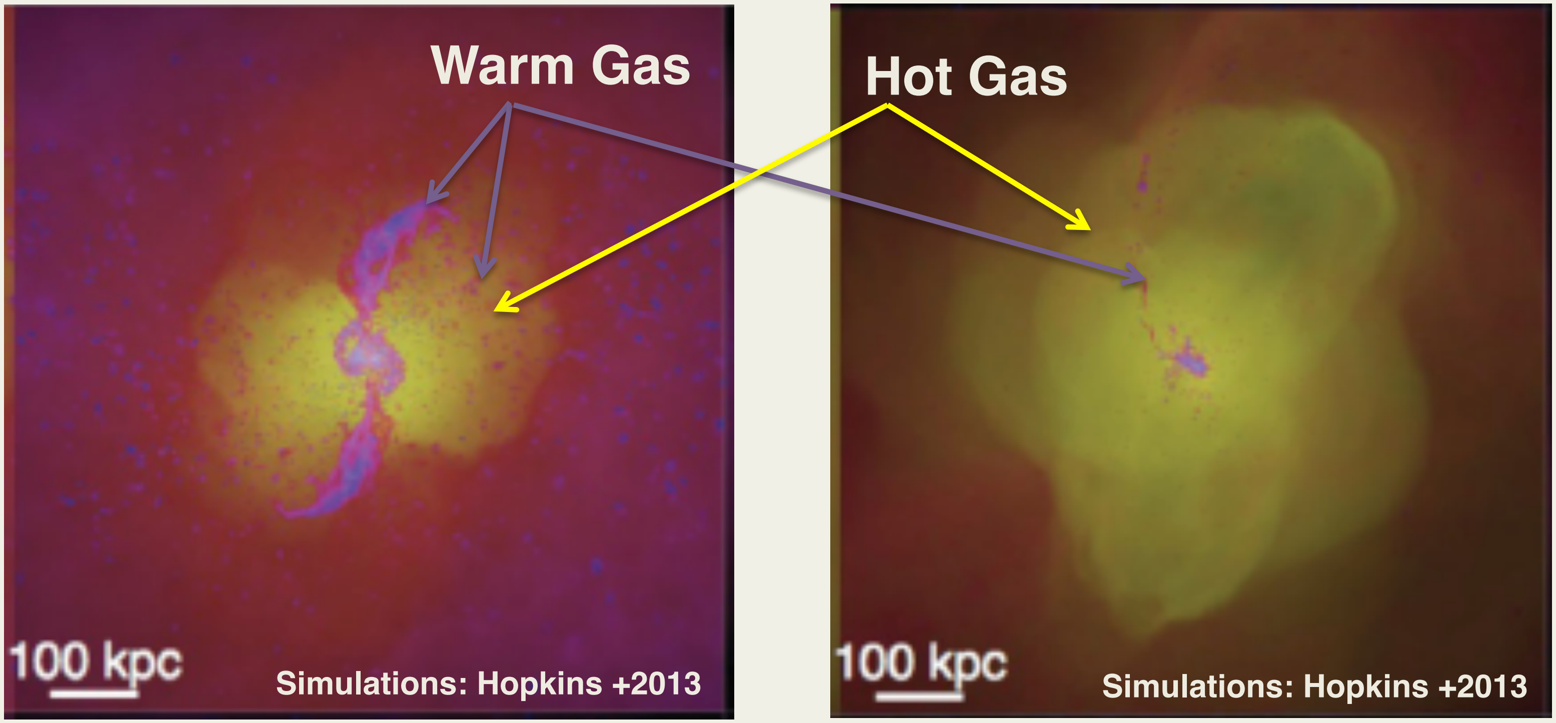
Galaxy Evolution Circa 2007

- Half the mass in z=0 galaxies was assembled at z < 1.
- The typical mass of a star-forming galaxy remained constant.
- The stellar mass on the red sequence grew.
- The cosmic star formation rate density plummeted.
- *The timing of mass assembly vs. quenching star formation was unclear.*



(Possible) Picture of a Galaxy in 2025



- We missed most of the galactic baryons (circa 20th century).
- Should have realized that star formation is globally regulated by gas accretion (short gas consumption times).

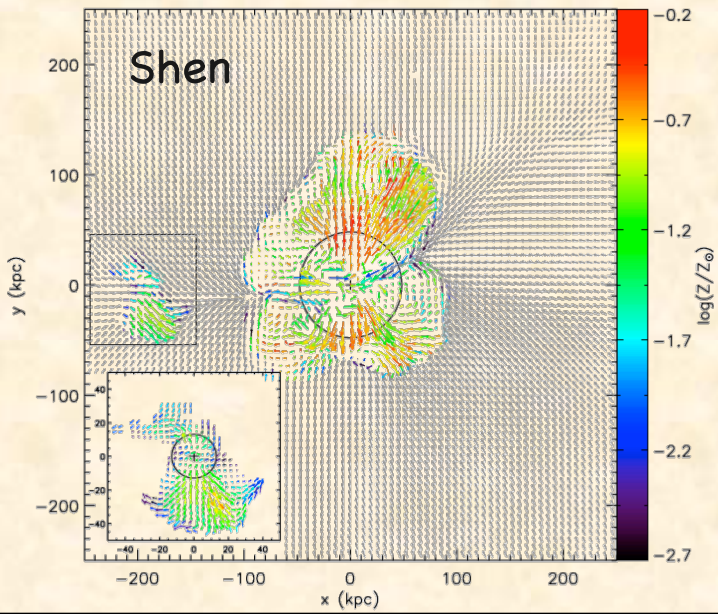
Studying Feedback with TMT
1. Science Drivers

- How do properties of circumgalactic gas influence the rate of accretion onto galactic disks?
- How does the mass ejection rate from galaxies vary with galaxy mass and cosmic time?
- How does the coupling among the various feedback processes shape the efficiency of mass and metal ejection from galaxies?
- Which physical processes dominate the acceleration of galactic winds?
- Why is the characteristic stellar mass independent of redshift?
- Why is star formation most efficient in galaxy's simlar in mass to the Milky Way?
- How does environment affect the cycling of matter between galaxies and their surroundings?

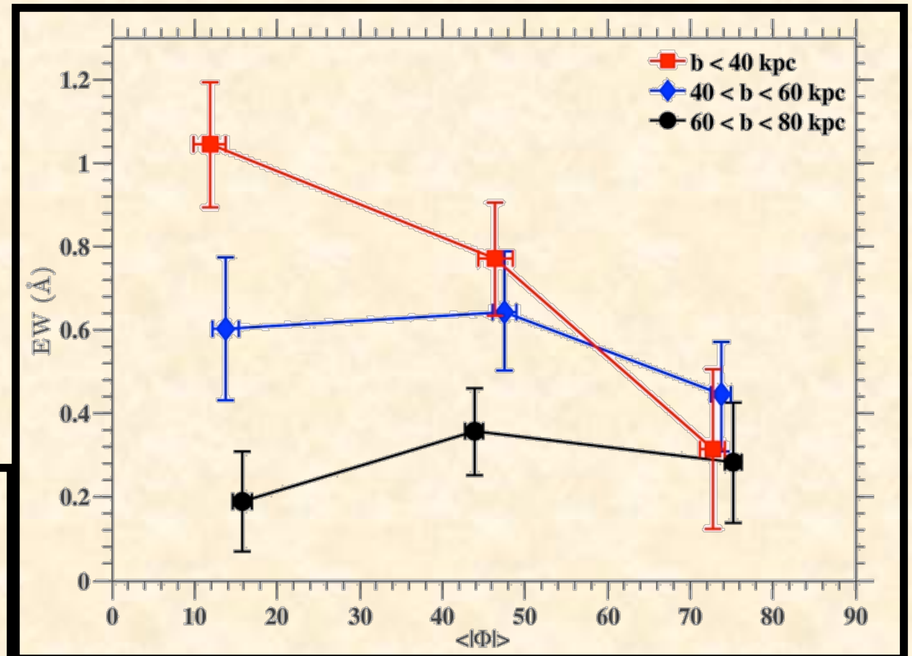
Studying Feedback with TMT
2. Observational Programs

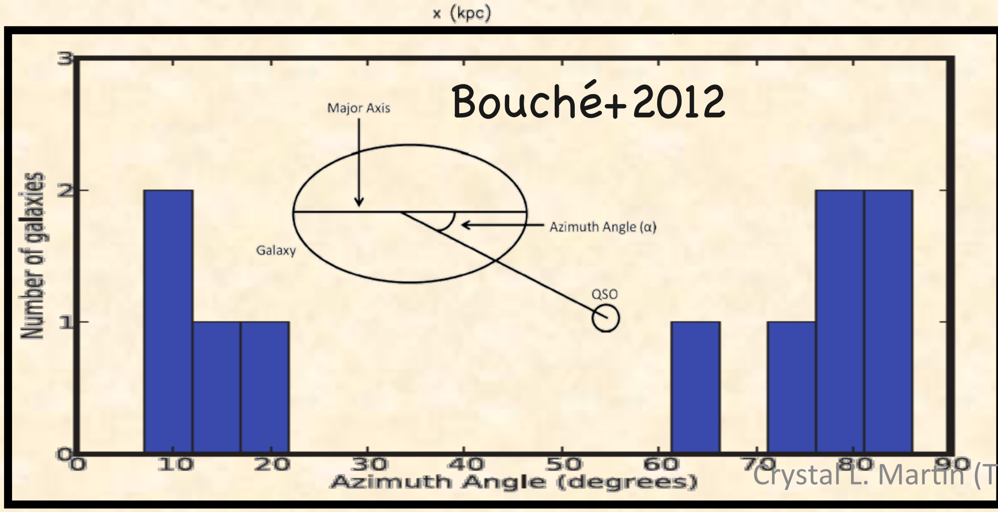
1. Probing halos with multiple sightlines towards background quasars AND galaxies
2. Resolving absorption line profiles
3. Resolving emission line profiles

Orientation of Quasar Sightlines Determines Physical Origin of <u>Strong</u> Absorption



zCOSMOS Stacks (Bordoloi+2011)





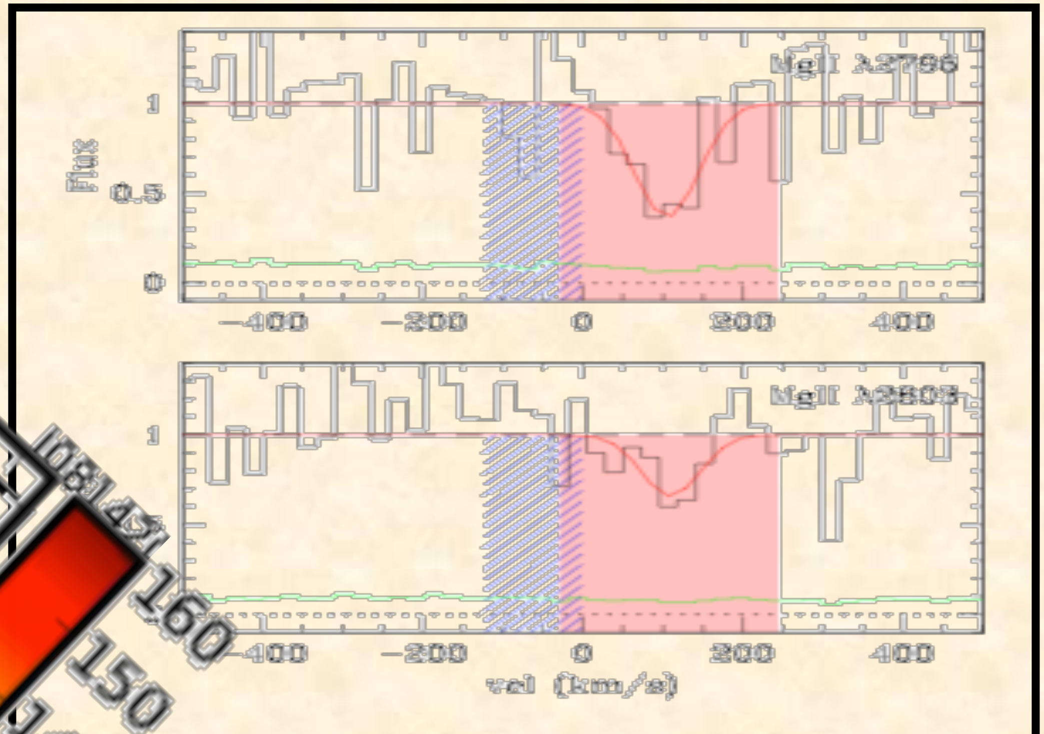
Minor Axis Sightlines

Major Axis Sightlines

Quasars Probing Galactic Outflows

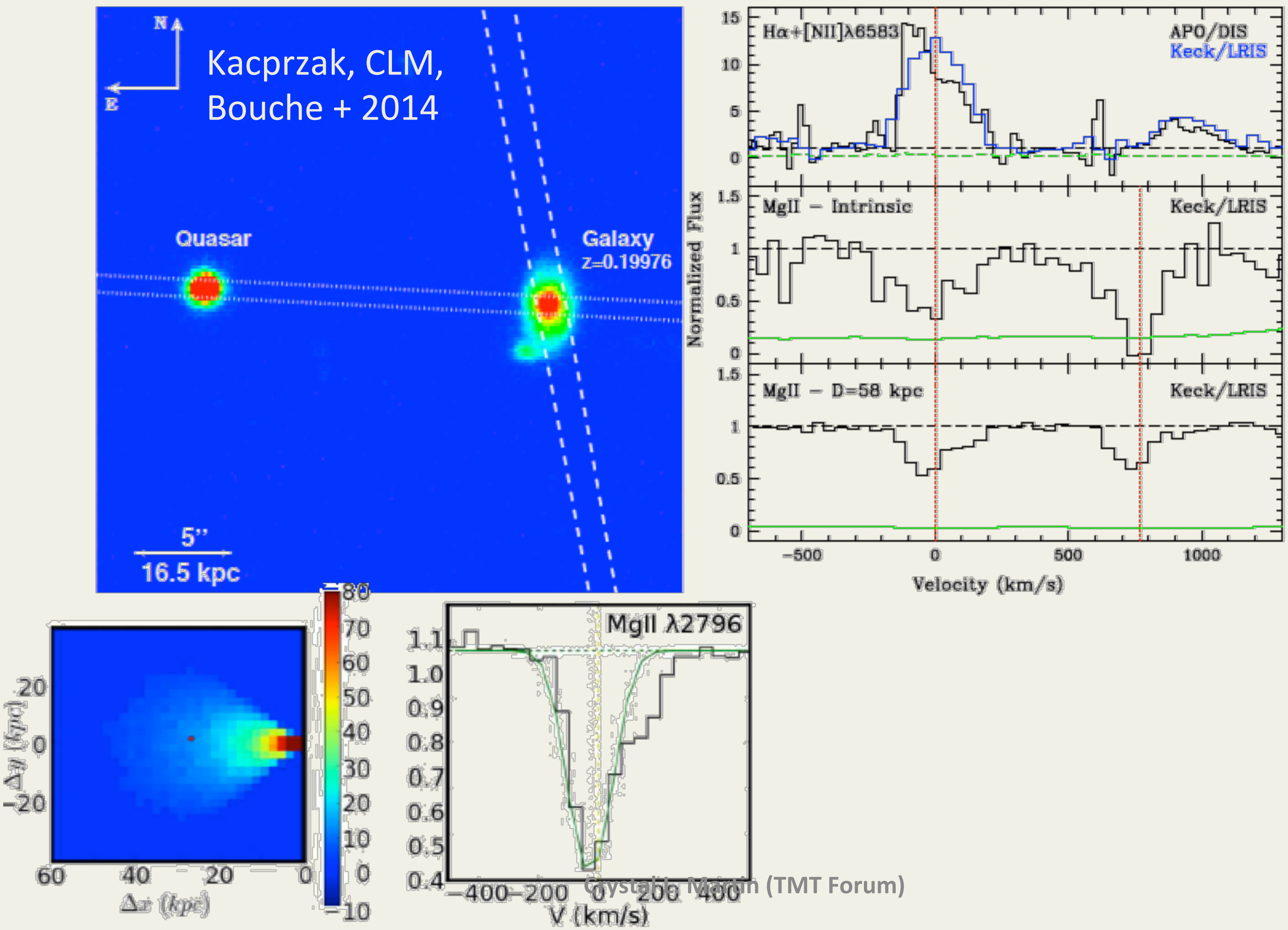
J081420+282408 G1:

Bouché+2012 (also Barton & Cooke 2009; Kacprzak+2011)



- Mg II kinematics [illegible] with outflow (red) but not disk model (blue).
- Impact parameter [illegible] the location of the absorbing gas.
- Mass loading [illegible] 1.3 ~ 0.3 with empirical N(HI) -- N(MgII) relation; rises to [illegible] photoionization model

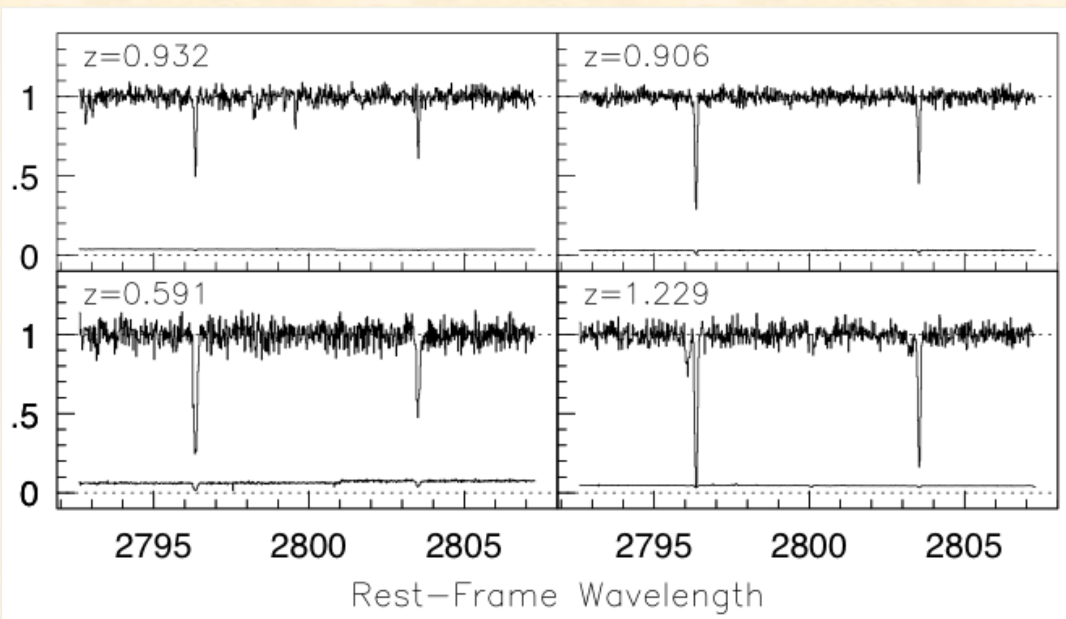
Combining Halo Sightlines & Galaxy Sightlines Provides Redundancy in Outflow Modeling



The Shape of the Absorption Troughs

- ***Martin & Bouche 2009 ApJ, 703, 1394***
- ***Optical - Near UV Spectra of z~0.3 Outflows.***
- ***Resolution ~ 100 km/s***

Mg II 2796, 2803 Doublet



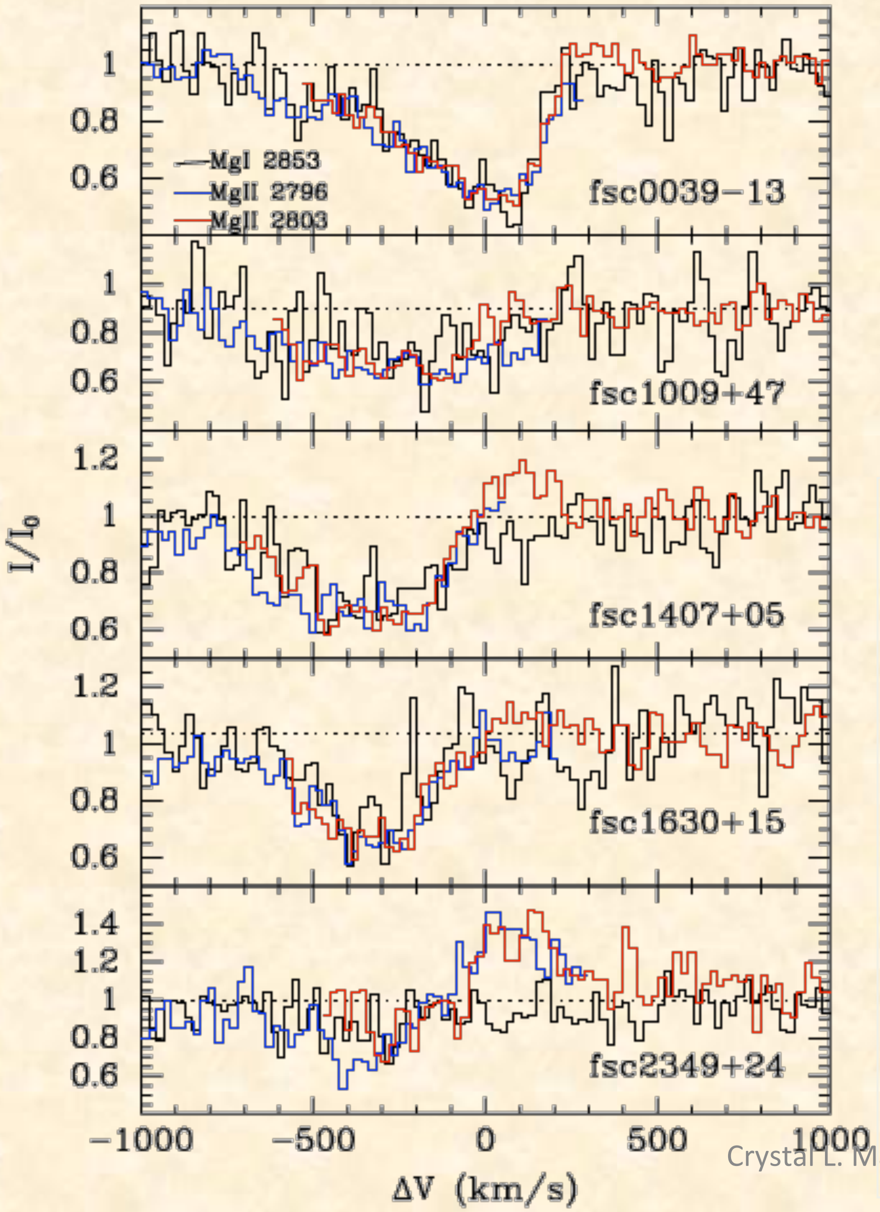
$$I_R(v) = I_0 e^{-\tau_R(v)}$$

$$I_B(v) = I_0 e^{-\tau_B(v)}$$

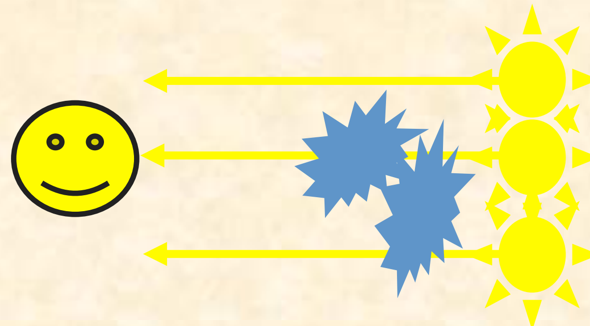
$$\tau_B = 2\tau_R$$

$$I_B(v) = I_R^2(v)$$

Velocity-Dependent Partial Covering



Redshift 0.3 starbursts
(Martin & Bouche 2009)



$$I_R(v)/I_0 = 1 - C_f(v) + C_f(v)e^{-\tau_R(v)}$$

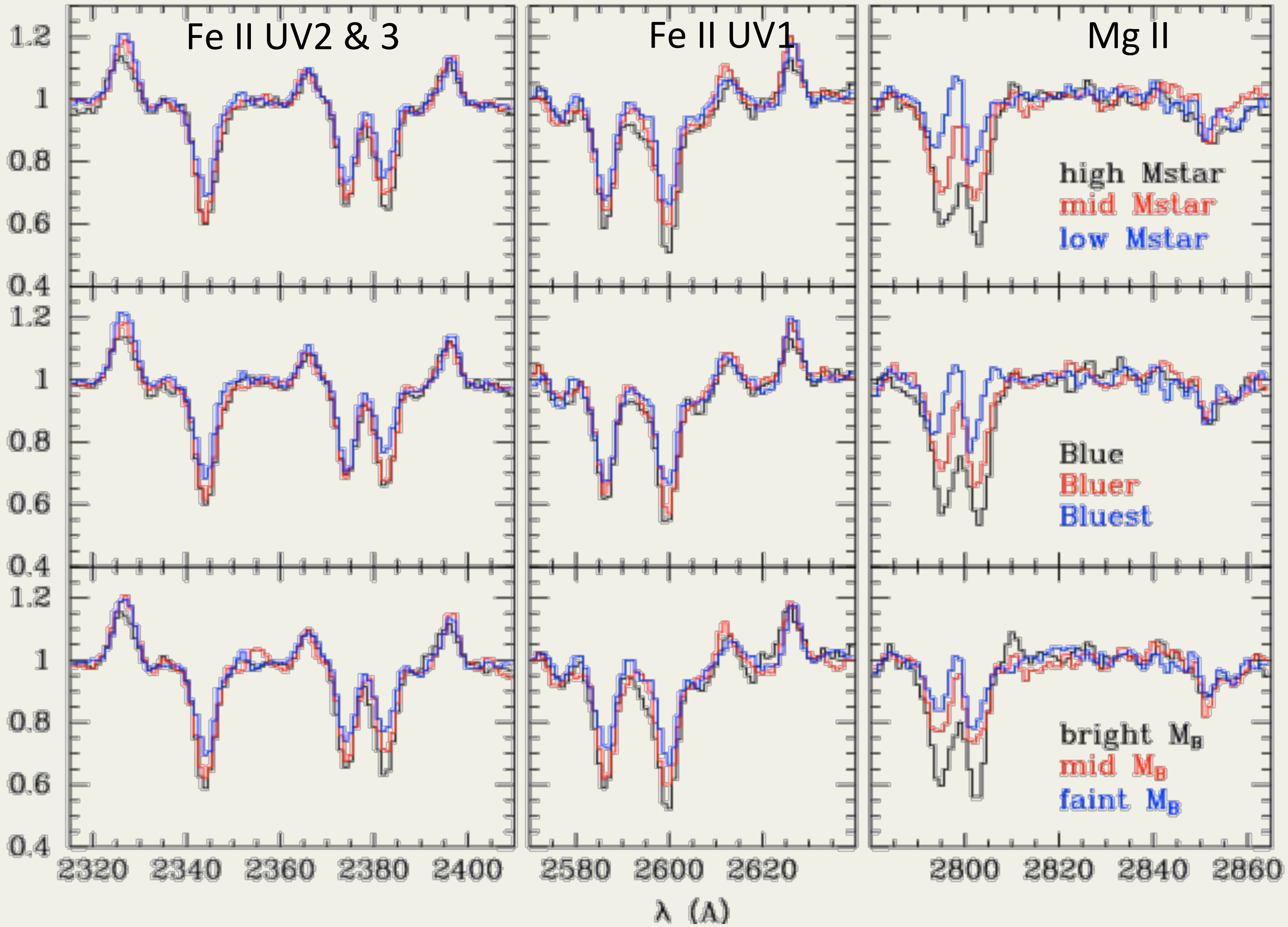
$$I_R(v)/I_0 = 1 - C_f(v) + C_f(v)e^{-2\tau_R(v)}$$

$$C(v) = \frac{I_R^2 - 2I_R + 1}{I_B - 2I_R + 1}$$

$$\tau(v) = ln\left(\frac{C(v)}{I_R(v) + C(v) - 1}\right)$$

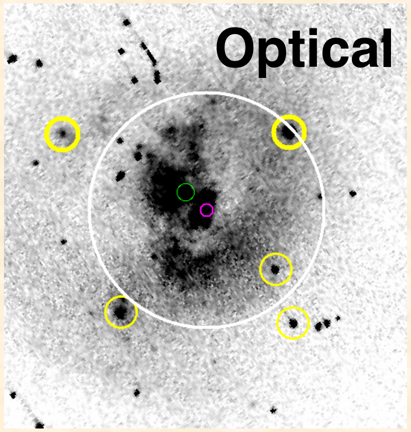
Outflow Properties in "Normal" Galaxies at z = 0.4 – 1.4

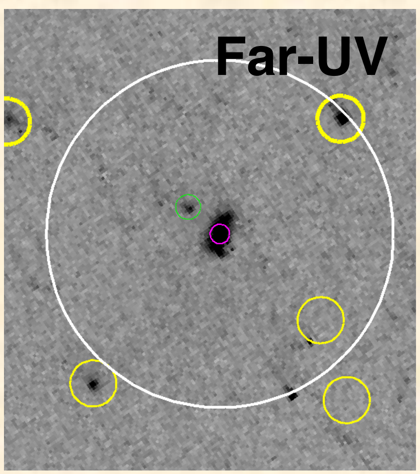
Near-UV Absorption Lines in 208 Spectra (CLM+2012)

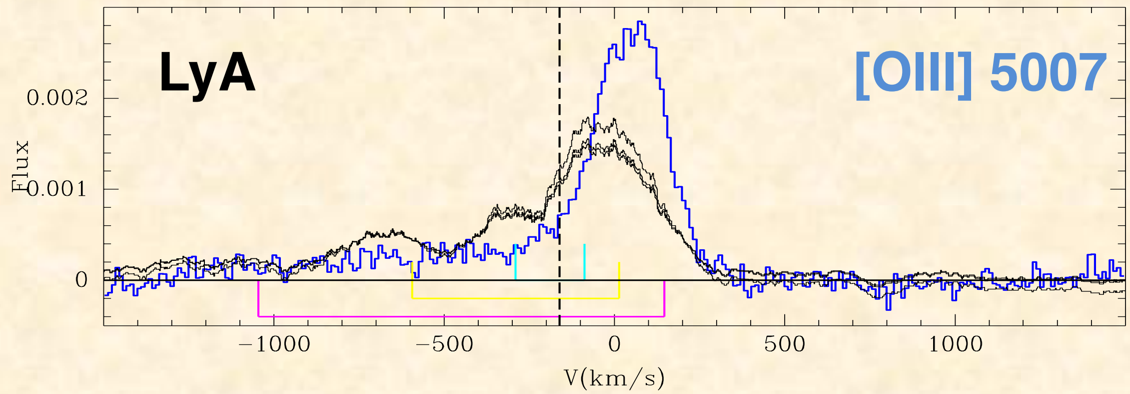


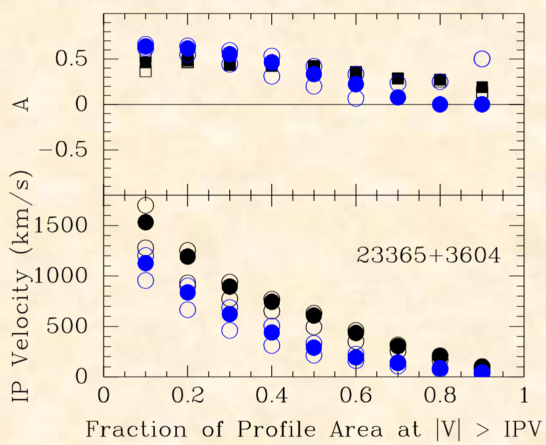
Resolving Fast Winds

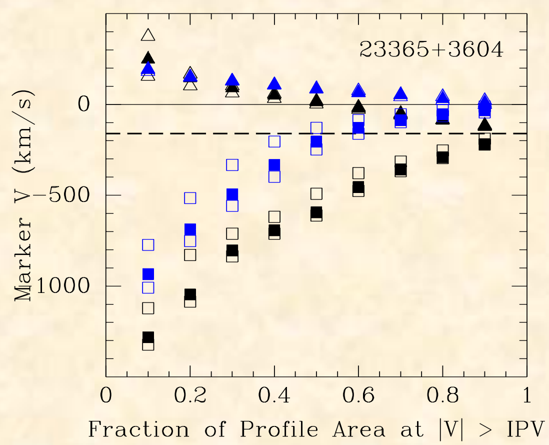
- High velocity winds likely trace gas condensing out of how wind.
- Only seen at high SFR surface density.











Martin+2014

High Velocity Dispersion Gas is Shock Excited

Kurt Soto + 2012a,b