Core and Wing Densities of Asymmetric Coronal Spectral Profiles: Implications for the Mass Supply of the Corona

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Motivation

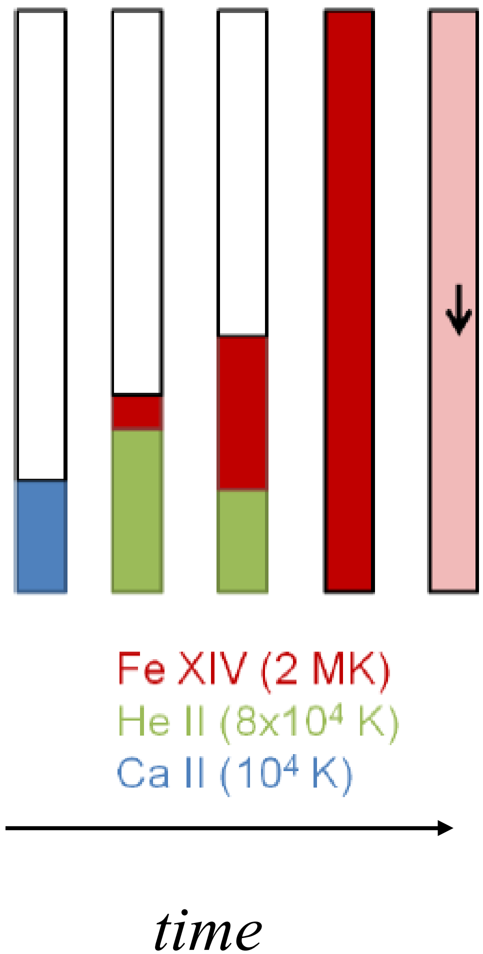
- *Excess emission (enhancement or component) at blue-wings of TR and coronal spectral lines at v> 50 km/s (e.g., Hara et al. 2008; De Pontieu et al. 2007, 2008, 2011, Martinez-Sukora et al. 2011,2013; McIntosh et al. 2012; Bryans et al. 2009; Peter 2010; Dolla & Zhukov 2011; Tian et al. 2010,2011; Brooks and Warren 2012; Doschek 2012)*

- *Implications for the mass supply of the corona*

- *Determine the nb/ncore ratio using the Fe XIV density diagnostic ratio from EIS observations and compare with theoretical predictions from type II spicules and coronal nanoflares*

nb/ncore for type II spicules

mass conservation; Klimchuk 2012



$$n_b \delta h_s = n_{core} h_{core} A$$

$$0.05 \leq \delta \leq 1$$

$$h_s = 10000 km$$

$$A \in [1, 3]$$

$$h_{core} = 50000\, km.$$

$$\frac{n_b}{n_{core}} \in [15, 333]$$

n_b/n_{core} for nanoflares (analytic)

$$n_b \approx n_*(T_*/T)$$

*~ constant pressure during evap; * end of evap Cargill et al. 2012*

$$n_c = (T/T_*)^{1/2} n_*$$

radiative cooling n ~T^(1/2)

$$n_b/n_c = (T_*/T)^{3/2} = (T_*/T_m)^{3/2} (T_m/T)^{3/2}$$

$$T_*/T_m = (\tau_c/\tau_r)^{1/6}$$

Tm,τc τr → end of nanoflare

$$\frac{n_b}{n_{core}} \in [0.4, 6.4]$$

nb/ncore for nanoflares (simul)

- *Calculate a grid of 1D HD time-dependent nanoflare simulations for loops with length 50 & 100 Mm*

- *Generate synthetic 264 & 274 profiles*

- *Analyze them as for the observational data (see afterwards)*

$$\frac{n_b}{n_{core}} \in [0.44, 1.01]$$

nb/ncore for type II spicules & nanoflares

$$\frac{n_b}{n_{core}} \in [15, 333]$$

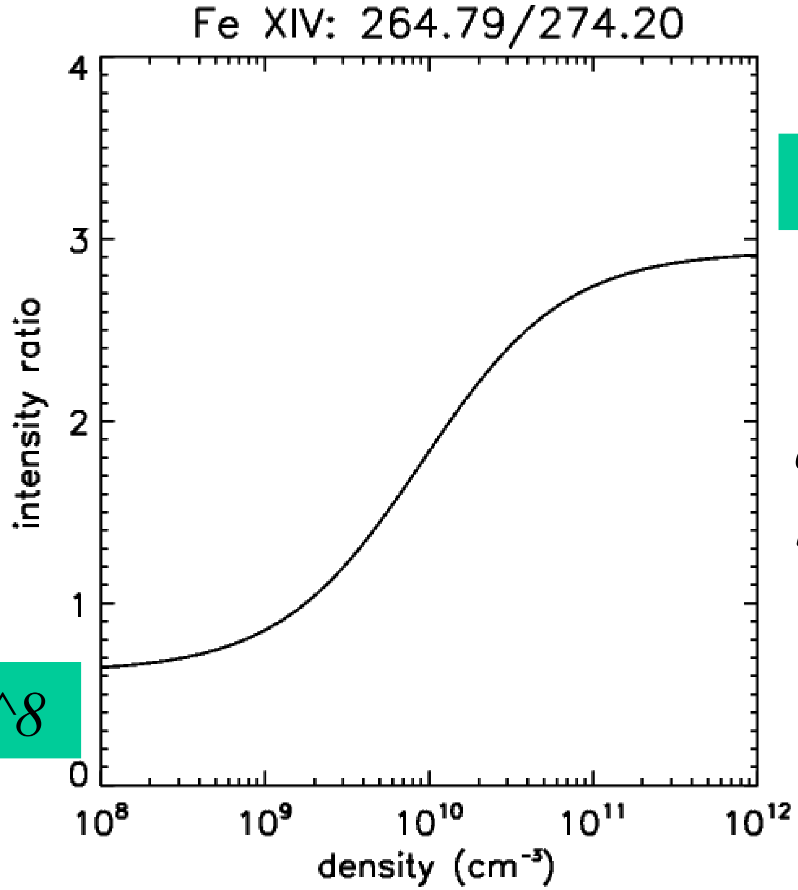
Type II spicules

$$\frac{n_b}{n_{core}} \in [0.4, 6.4]$$

Nanoflares

n_b/n_{core} sensitive diagnostic

Fe XIV 264.79/274.20 density diagnostic



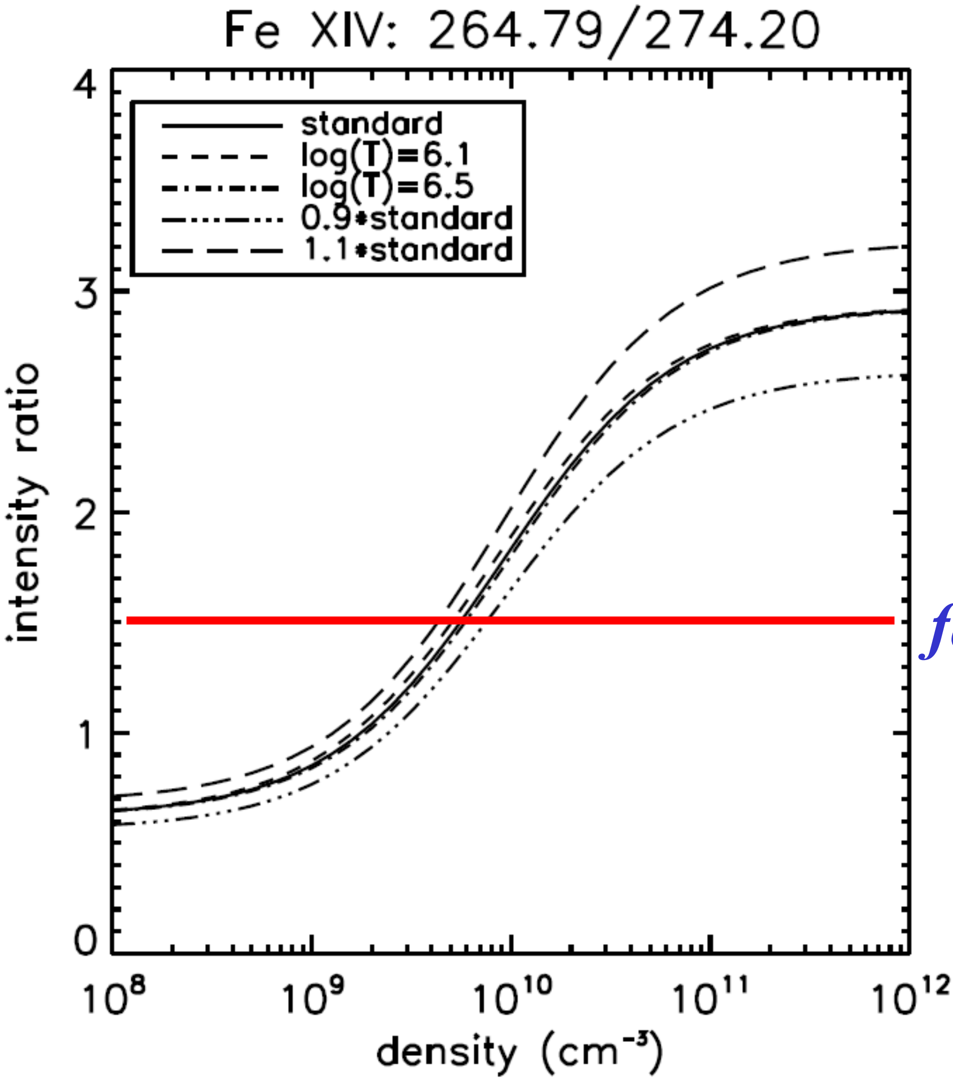
high ratio: n>=10^12

CHIANTI 7.1; Landi et al. 2013; log(T)=6.3

low ratio: n<=10^8

(Known) Blends:
Fe XI 264.77 → max(Fe XI 264.77)=0.043(Fe XI 188.23)*
Si VII 274.18 → max(Si VII 274.18)=0.25(Si VII 275.35)*
Further analysis for cases for which ***blends are < 10 %*** *of the Fe XIV lines*

Impact of blends, different T on density diagnostic



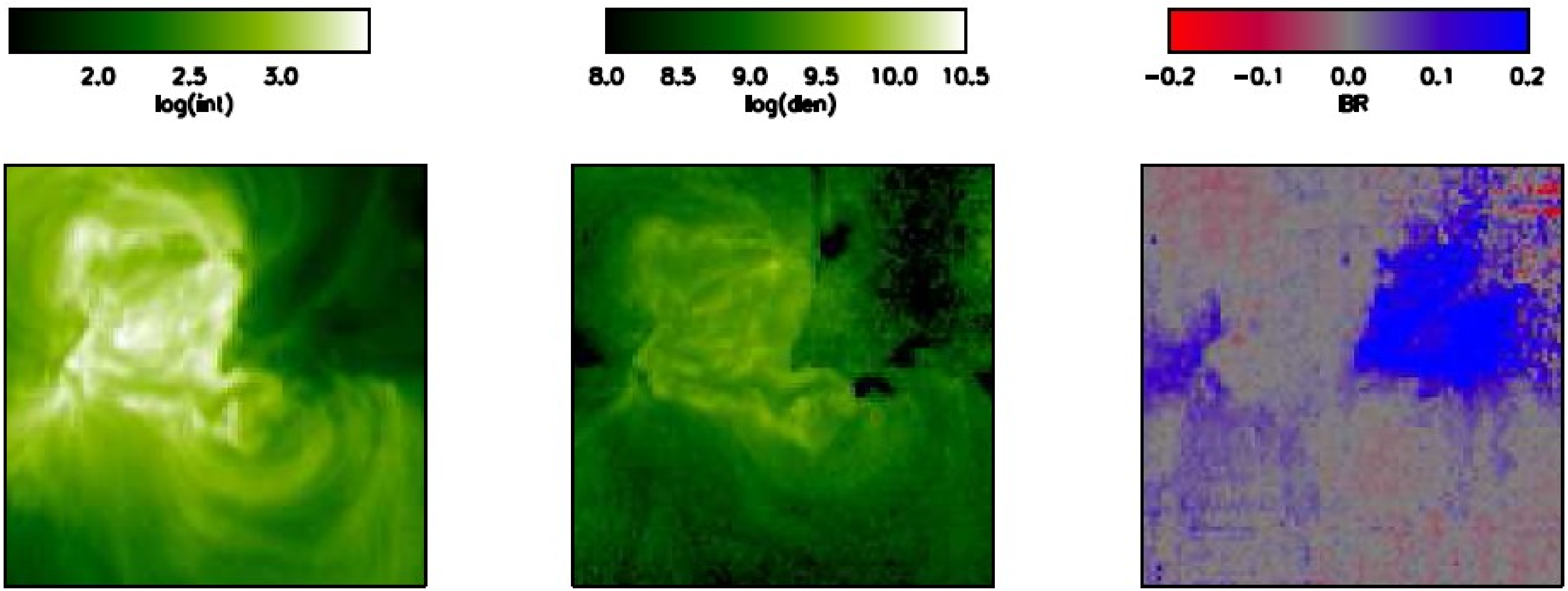
factor ~ 2 uncertainty in density

Analysis Method

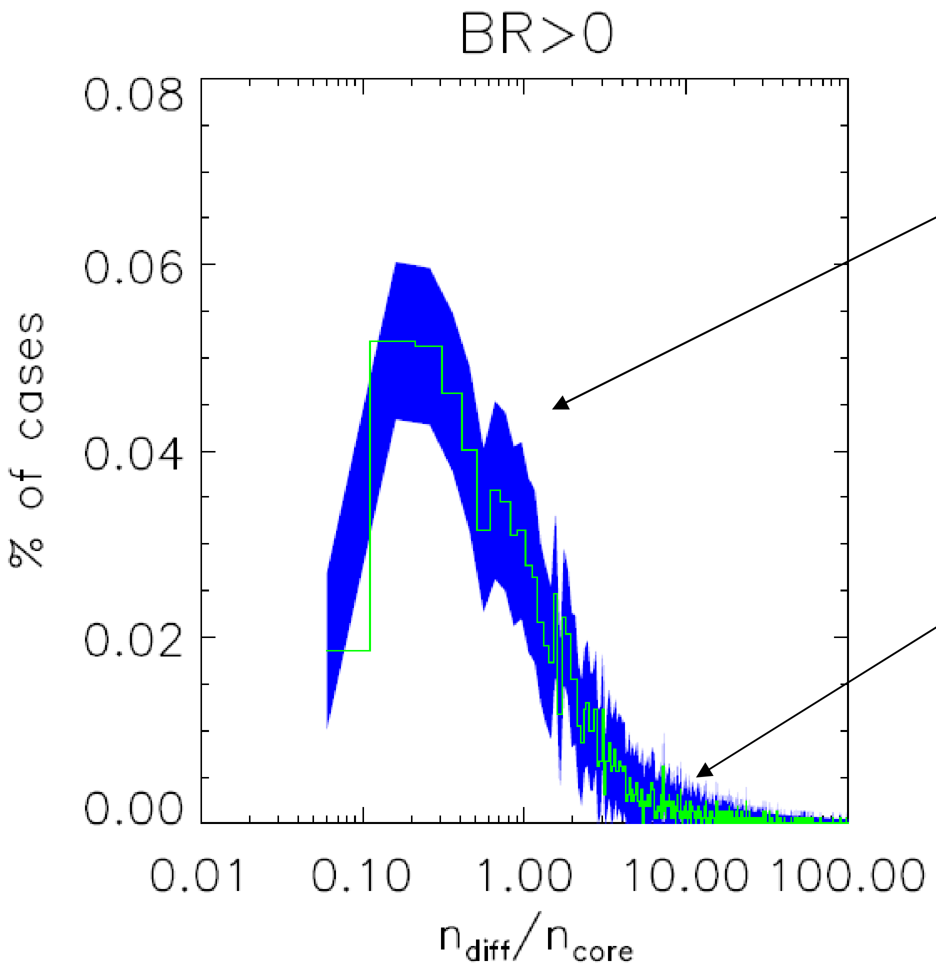
- *EIS observations during 2006-2007*
- *3x3 macropixels*
- *Spline (x50) original profiles & find peak intensity location*
- *Use new spline scheme (Klimchuk, Patsourakos, Tripathi 2013) ----- iterative scheme conserving I*

- *Determine I_B [-150,-50] & I_R [50, 150] km/s*
- *Determine I_c [-30, 30] km/s*
- *$BR=(I_B- I_R)/ I_c$*
- *If BR>0 (or BR<0) for both 264 & 274 → calculate n_b (n_r) & n_c*

Base Observation:11 Dec 2007



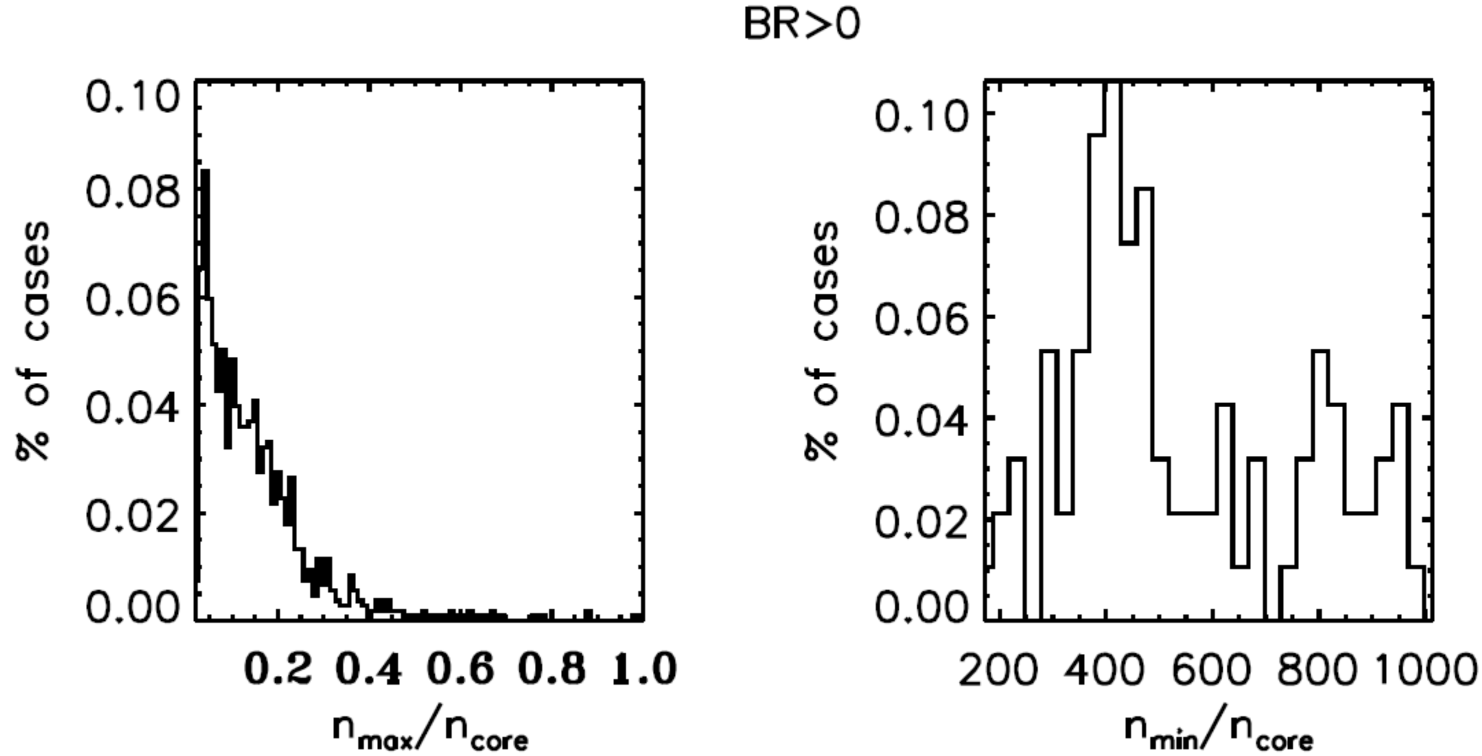
nb/ncore for base observation (41.3 % of cases)



Low density ratio not consistent with type II spicules; OK with nanoflares

High density ratio consistent with type II spicules

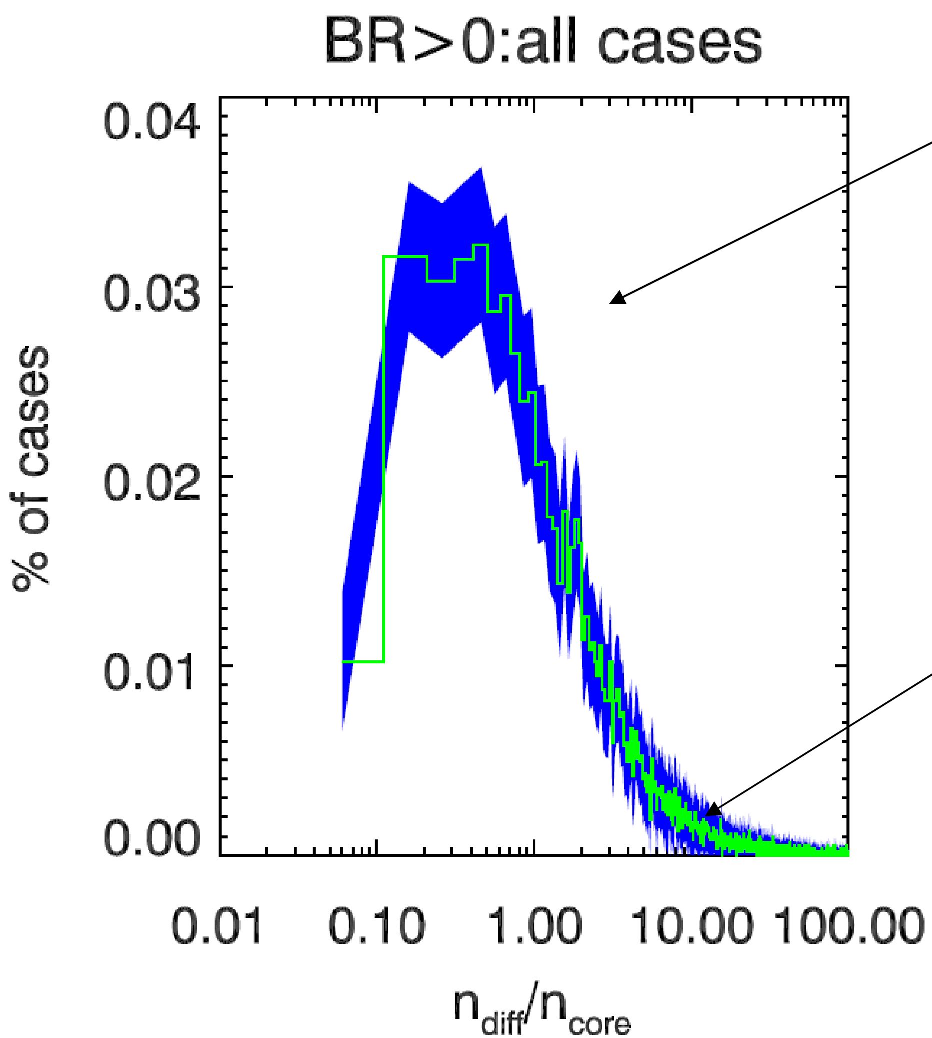
nb/ncore for low/high limit of intensity ratios



densities <= 10^8 cm-3
14.6 % of points

densities >= 10^12 cm^-3
2.9% of points
consistent with type II's

nb/ncore for 8 datasets (21.2-41.3% of points)



Low density ratio not consistent with type II spicules; OK with nanoflares

High density ratio consistent with type II spicules

Discussion-Conclusions I

- *n_b/n_{core} sensitive diagnostic of mass supply*

- *n_b/n_{core} bulk ~ 1; too low for type II spicules- OK nanoflares*

- *$n_b/n_{core} \gg 1$ in tail; consistent with type II spicules*

- *high ratio limit ($n_b/n_{core} \gg 1$) ; consistent with type II spicules too few points*

- *low ratio limit ($n_b/n_{core} \ll 1$); not consistent with type II- OK nanoflares*

Discussion-Conclusions II

- *How about red-wing enhancements (16.6 % of base observation) ? Not due to standard radiative cooling & draining (too slow) (e.g., Bradshaw and Cargill 2010).*
- *Catastrophic cooling and coronal rain? (e.g., Antiochos et al. 1999, Schrijver 2001; Karpen et al. 2011; Muller et al. 2004;Antolin et al. 2012) Rapid Redshifted Excursions? Sekse et al. 2013*

- *Pushing limits of observations → "mixed" asymmetries (18.4-35.9 %)?*

- *Non-equilbrium ionization density diagnostics of rapidly evolving plasmas (Doyle et al. 2012; Olluri et al. 2013 --- factor 10 off for O IV)*
- *Develop MHD-based scalings for nb/nc*

- *Sub-arcsecond spectral diagnostics: IRIS, VERIS, LEMUR*
  resolve high speed upflow & core components on plane of sky like done for jets (e.g., Chifor et al. 2008; Tian et al. 2010)