What can we learn about eruptive prominences with the Extreme Ultraviolet Imager on Solar Orbiter?

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Abstract

EUI (Extreme Ultraviolet Imager) will monitor the low atmosphere counterparts of large-scale solar eruptive events such as CMEs. As such it will ideally be suited to study prominence eruptions. Here we are interested in investigating what we may learn from data returned by the High Resolution Imagers (HRI) in the Lyman α channel, and the Full-Sun Imager (FSI) working at the 304 Å EUV passband.

Context

Observations at 304 Å can be used to make a diagnostic of the prominence plasma by comparing data with non-LTE radiative transfer calculations (Labrosse & McGlinchey 2012). These calculations must take into account the strong Doppler dimming effect on the He II resonance line induced by the outwards radial motion of the structure when it erupts.

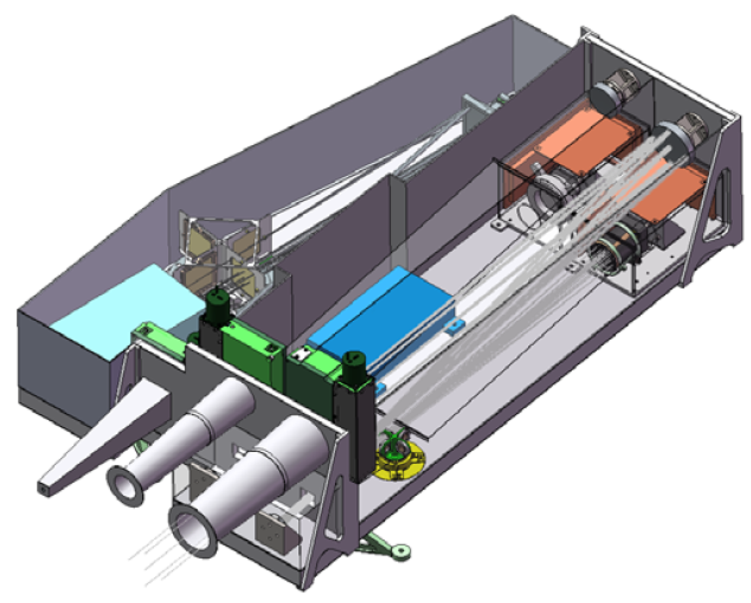
Previous calculations have shown that the Lyman α resonance line of hydrogen is also sensitive to the Doppler dimming effect.

EUI offers a good opportunity to use both lines simultaneously at high-resolution and out of the ecliptic plane to study - among other phenomena - prominence eruptions.

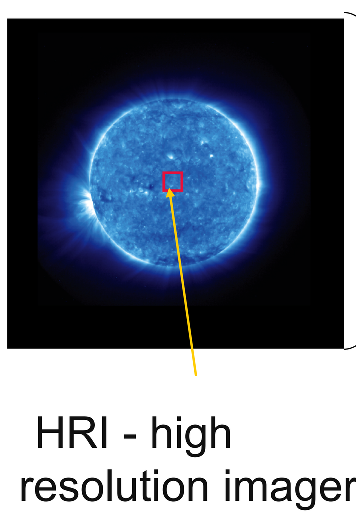
Here we present new radiative transfer calculations combining results on both hydrogen and helium resonance lines emitted by moving prominences, addressing the question of what we can learn from these observations.

Extreme Ultraviolet Imager on Solar Orbiter

EUI will provide image sequences of the solar atmospheric layers above the photosphere, thereby providing an indispensable link between the solar surface and outer corona that ultimately shapes the characteristics of the interplanetary medium. Scientific topics to be addressed include monitoring the low atmosphere counterparts of large-scale solar eruptive events such as CMEs and the study of fine-scale processes in the solar atmosphere. EUI will also provide the first-ever images of the Sun from an out-of-ecliptic viewpoint (up to 34° of solar latitude during the extended mission phase).



High Resolution Imager: Lyman α
Subsec-100s cadence
Pixel=100km@ perihelion
High Resolution Imager:
Fe IX/X 17.4
1-100s cadence
Pixel=100km@ perihelion
Full Sun Imager:
Fe IX/X 17.4 & He II:30.4
10-600s cadence
Pixel=860km@ perihelion



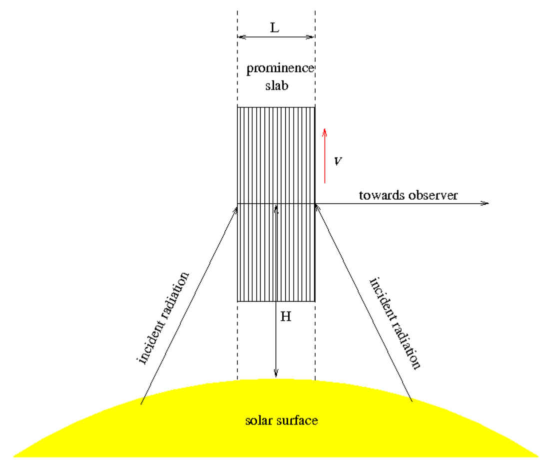
FSI - full Sun imager

HRI - high resolution imager

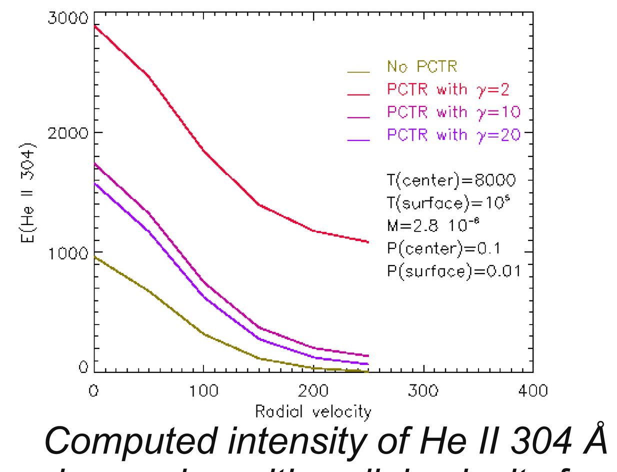
See poster by Louise Harra and the EUI team

Doppler dimming

Modelling predicts that when a solar prominence erupts into the corona, the intensity of the He II line at 304 Å will decrease as a function of the radial velocity of the plasma (e.g. Labrosse et al 2008). This predicted change in the radiation output is due to the **Doppler dimming effect**. Doppler dimming is the decrease in intensity of an atomic resonance line that is pumped by external radiation, when the plasma in which it forms moves so that the pump line is Doppler shifted out of resonance (in the moving frame). Doppler dimming is widely used to diagnose the solar wind speed.



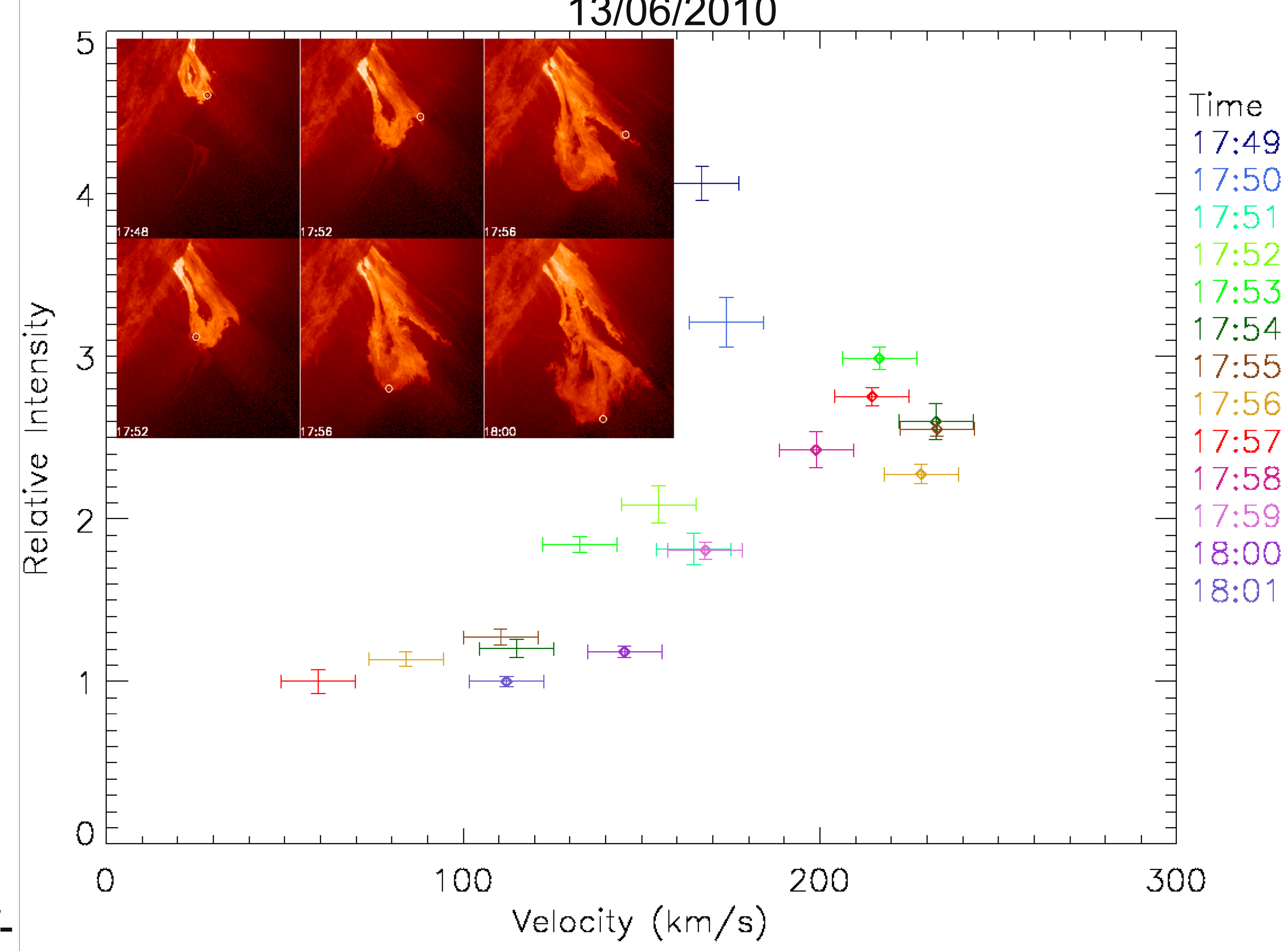
Sketch of 1D prominence model.



Computed intensity of He II 304 Å decreasing with radial velocity for various prominence models (Labrosse et al. 2008).

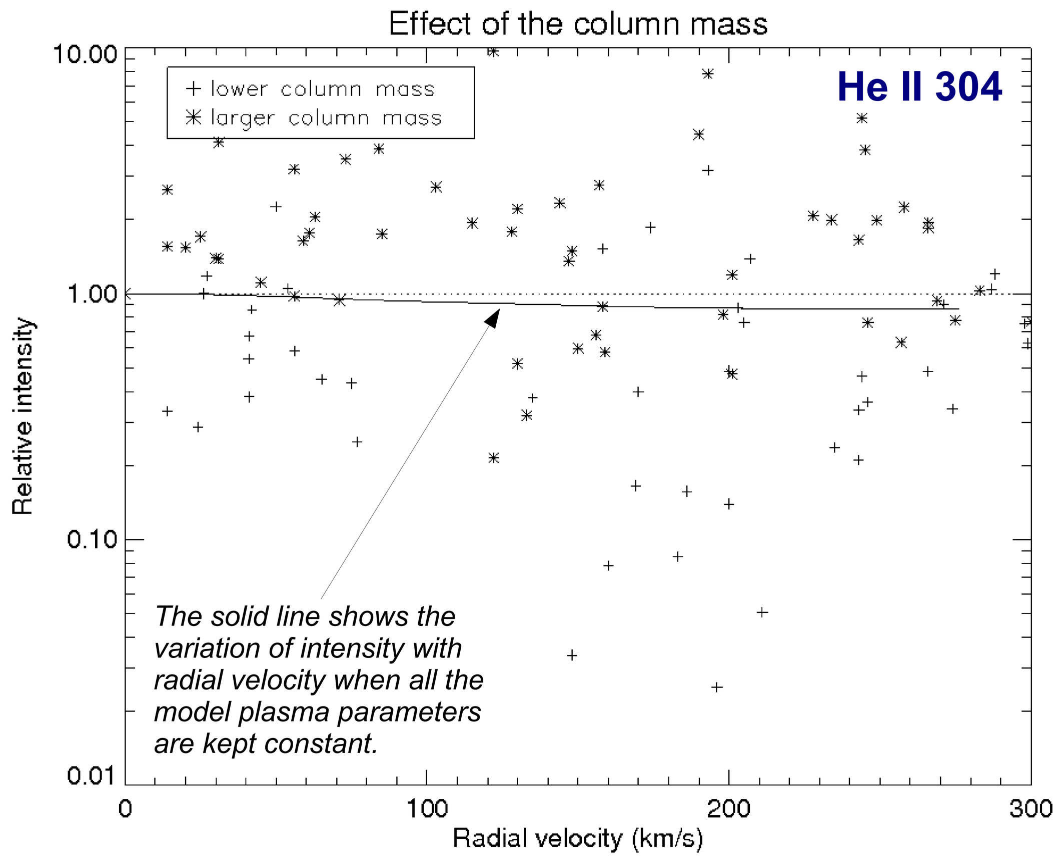
Analysis of SDO/AIA observations in He II 304 Å

Four prominence eruptions were studied in Labrosse & McGlinchey (2012). One case is shown below.



For each event, a feature in the prominence plasma was chosen that could be tracked confidently through many images. The observed intensities shown above are normalised by the intensity corresponding to the lowest velocity. These normalised intensities can then be compared to radiative transfer calculations out of local thermodynamic equilibrium. For this 13th June 2010 event, an increase in He II line intensity is observed as velocity increases. Is this in contradiction with the predicted Doppler dimming of the line intensity?

To answer this, more realistic calculations were carried out to allow for an evolution of the plasma parameters.



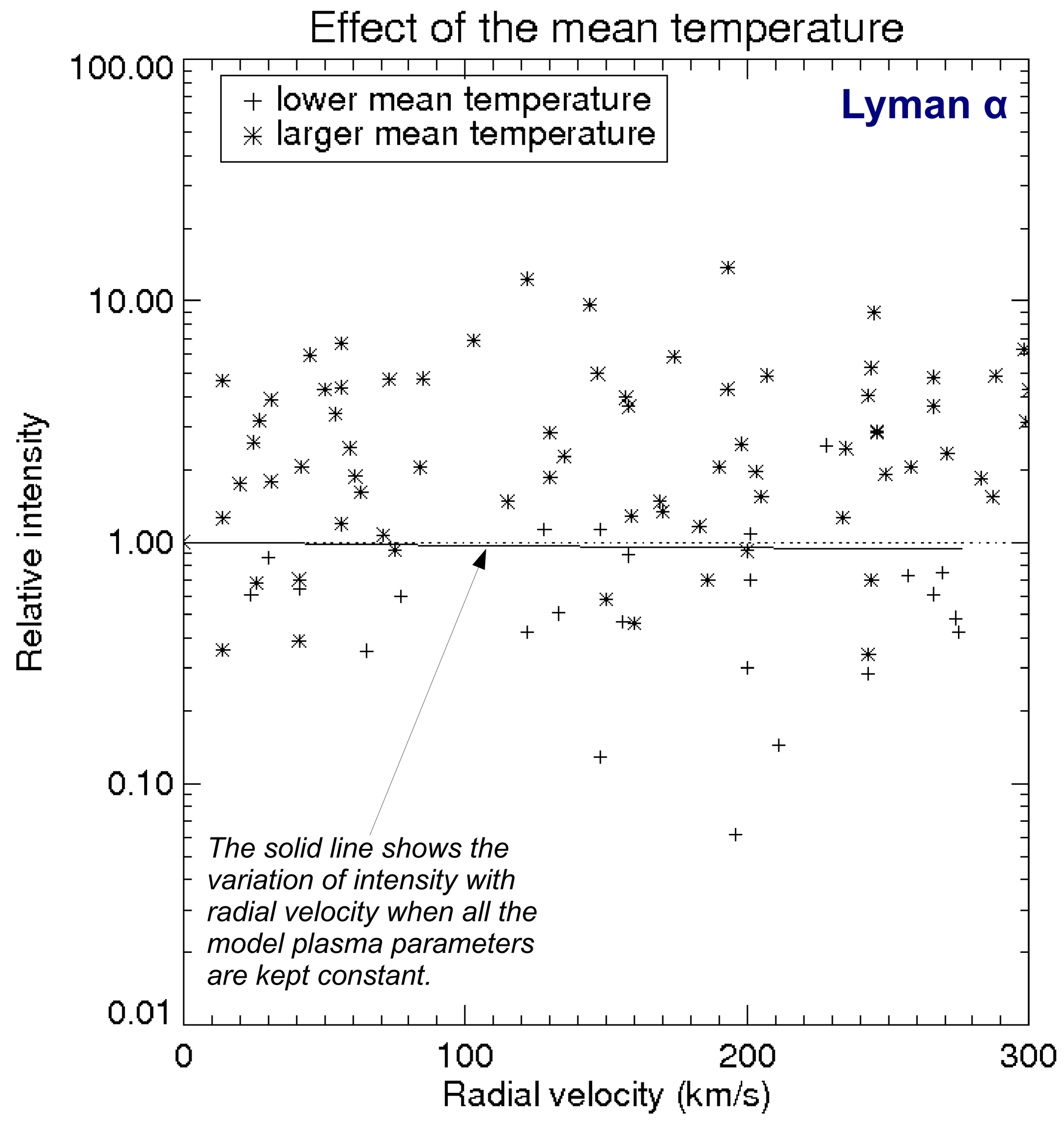
The above figure shows that when the plasma parameters are allowed to vary during the eruption, there are roughly the same number of models where the He II line intensity increases with radial velocity as models where the intensity decreases with radial velocity. For the higher intensity models, 79% have a larger column mass than the reference model, and for the dimmer models 67% have a smaller column mass than the reference model.

The Labrosse & McGlinchey (2012) calculations therefore give an idea of how variations of the physical conditions in the prominence plasma can affect the radiative output of He II resonance lines.

It turns out that the main parameters that will determine whether the intensity of the He II line increases or decreases with radial velocity are the evolution of the **column mass**, and also the evolution of the **temperature** inside the prominence.

Computed Lyman α intensities

How can observations of the Lyman α line help? The Lyman α is also sensitive to the Doppler dimming effect in eruptive prominences (Gontikakis et al. 1997).



Our results (shown above) indicate that the **Lyman α line is more sensitive to the temperature** than the He II line. When all plasma parameters are allowed to vary during the eruption, the line intensity will increase if the mean temperature of the model increases as well in 94% of all cases, while 65% of the models with a lower intensity than that of the reference model also have a lower mean temperature.

The column mass, and its evolution during the eruption, is the next most important parameter that determines the evolution of the Lyman α intensity with the radial velocity.

Discussion

Using He II 304 **and** Lyman α observations of the same structure is promising: our calculations indicate that their intensities are both sensitive to the temperature of the prominence plasma and to the column mass (i.e. amount of material along line-of-sight) but in different ways. In prominences, the He II line is more sensitive to the column mass, while the Lyman α line is more sensitive to the temperature of the plasma.

By comparing observed and computed intensities of the two lines at different velocities we can therefore put **strong constraints** on the model parameters which correspond to the observations. It will be easy to deal with non-calibrated intensities by looking at relative variations of normalised intensities (with respect to some quiet conditions, e.g. before the onset of the eruption).

The plasma parameters (temperature, pressure) of the prominences can be found by minimizing the differences between the following observables / model input parameters:

- Intensity of the line,
- Radial velocity,
- Altitude of the prominence.

From this we can derive quantities (such as the ionisation degree) relevant for the modelling of wave propagation in prominences or for the modelling of prominence equilibrium.

Conclusion

EUI will observe the Sun and return unprecedented data in Lyman α and in He II 304. Both lines have huge potential in terms of diagnostics of the dynamic solar atmosphere. Careful modelling of the line formation mechanisms is key to unlock this potential.

Investigating eruptive prominences by comparing observed and computed intensities using the method described in this poster provides **a new way** for probing the physical conditions of the erupting prominence plasma.

References

Gontikakis et al., 1997, Sol. Phys., 172, 189

Labrosse & McGlinchey, 2012, A&A, 537, A100

Labrosse et al., 2008, Ann. Geophys., 26, 2961-2965

See also: UKSP Nugget #21