Constraining the CME Core's Heating and Energy Budget with SOHO/UVCS

[1]**Maurice Wilson**
maurice.wilson@cfa.harvard.edu

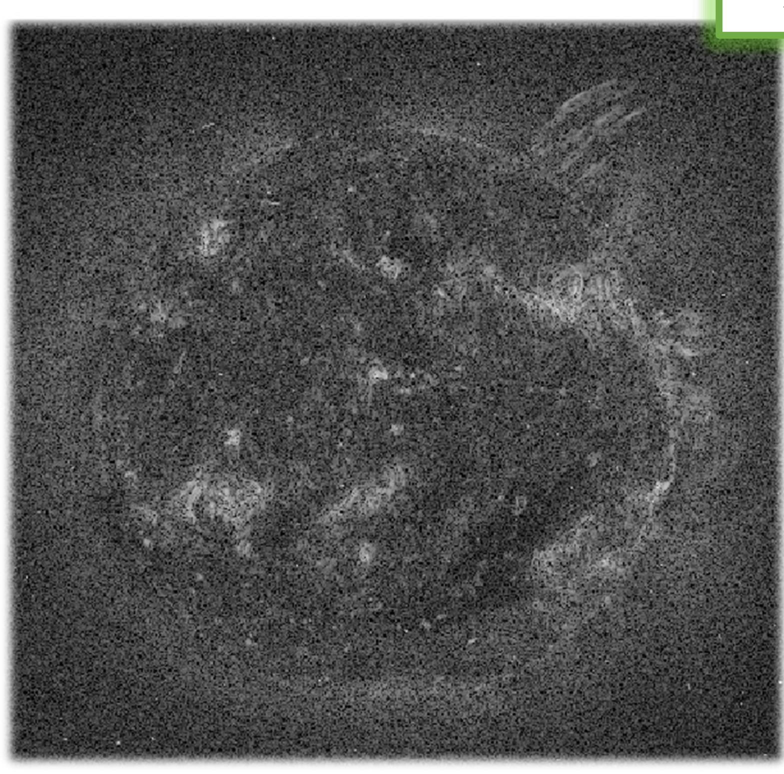
[1]John Raymond, [2]Susan Lepri, [3]Roberto Lionello,
[1]Nick Murphy, [1]Katharine Reeves, [1]Chengcai Shen

[1]Center for Astrophysics, Harvard & Smithsonian, 60 Garden St, Cambridge, MA 02138, USA
[2]Department of Climate and Space Sciences and Engineering, University of Michigan, Ann Arbor, MI 48109, USA
[3]Predictive Science Incorporated, 9990 Mesa Rim Rd. Suite 170, San Diego, CA 92121, USA

We describe the energy budget of a coronal mass ejection (CME) observed on 1999 May 17 with the SOHO/UVCS instrument. We constrain the physical properties of the CME's core material as a function of height along the corona by using the spectra and photometry taken by the single-slit coronagraph spectrometer at heliocentric distances of 2.6 and 3.1 solar radii. We use plasma diagnostics from intensity ratios, such as the O VI doublet, to determine the velocity, density, and temperature of the core material.

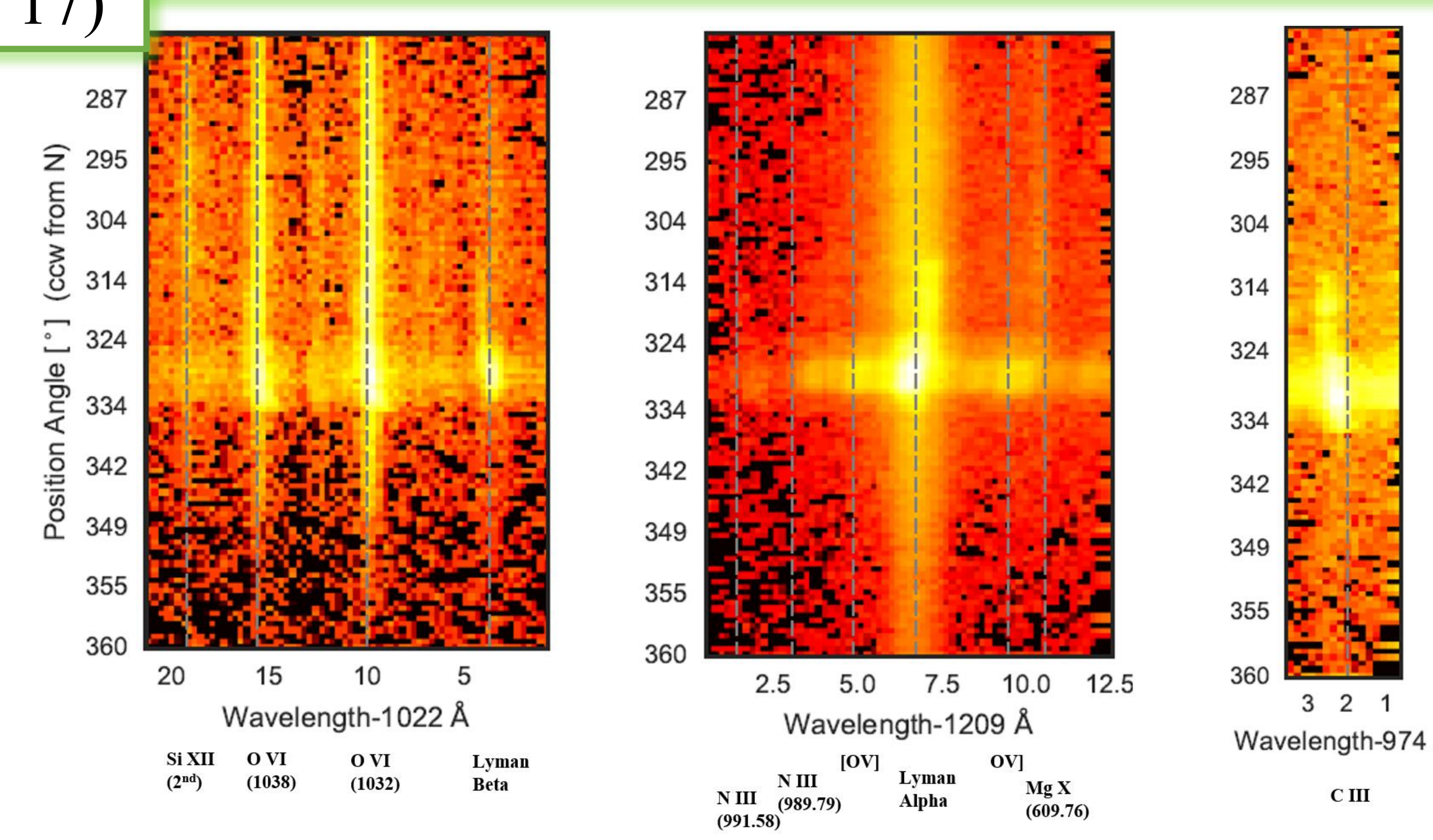
We perform non-equilibrium ionization calculations to determine the ionization states and focus primarily on H I, O V, O VI, and C III. Using these observationally constrained physical properties, we deduce the initial conditions of the CME with respect to the various plasma heating parameterizations we investigated. Amongst the four ions we accounted for, we find that the CME core's velocity is about 250 km/s, and its cumulative heating energy is comparable to its kinetic energy.

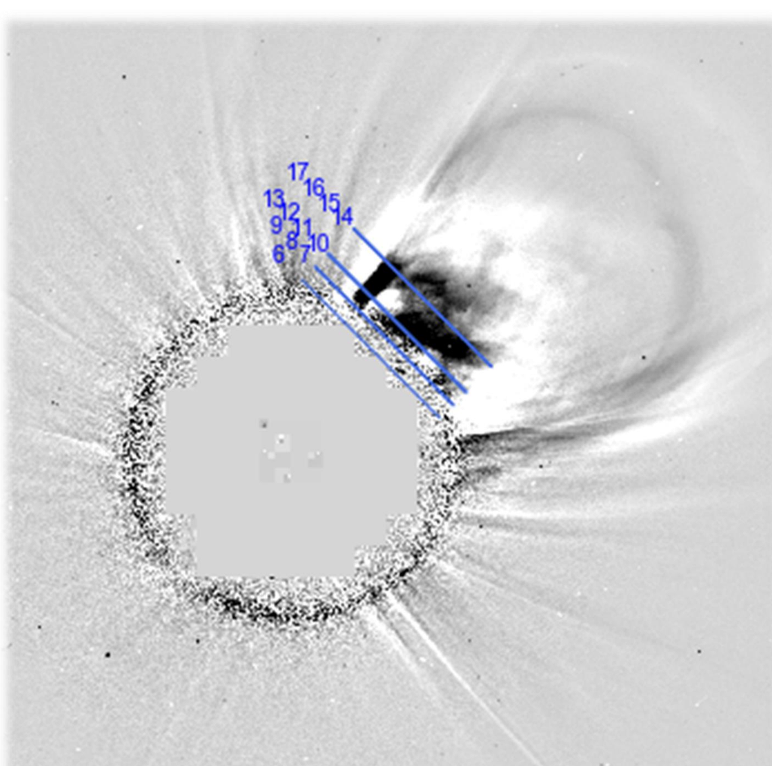
Photometry and Spectra of CME (1999 May 17)



EIT 195 Angstrom difference image of initial eruption provided rough lower limits on velocity of CME core.

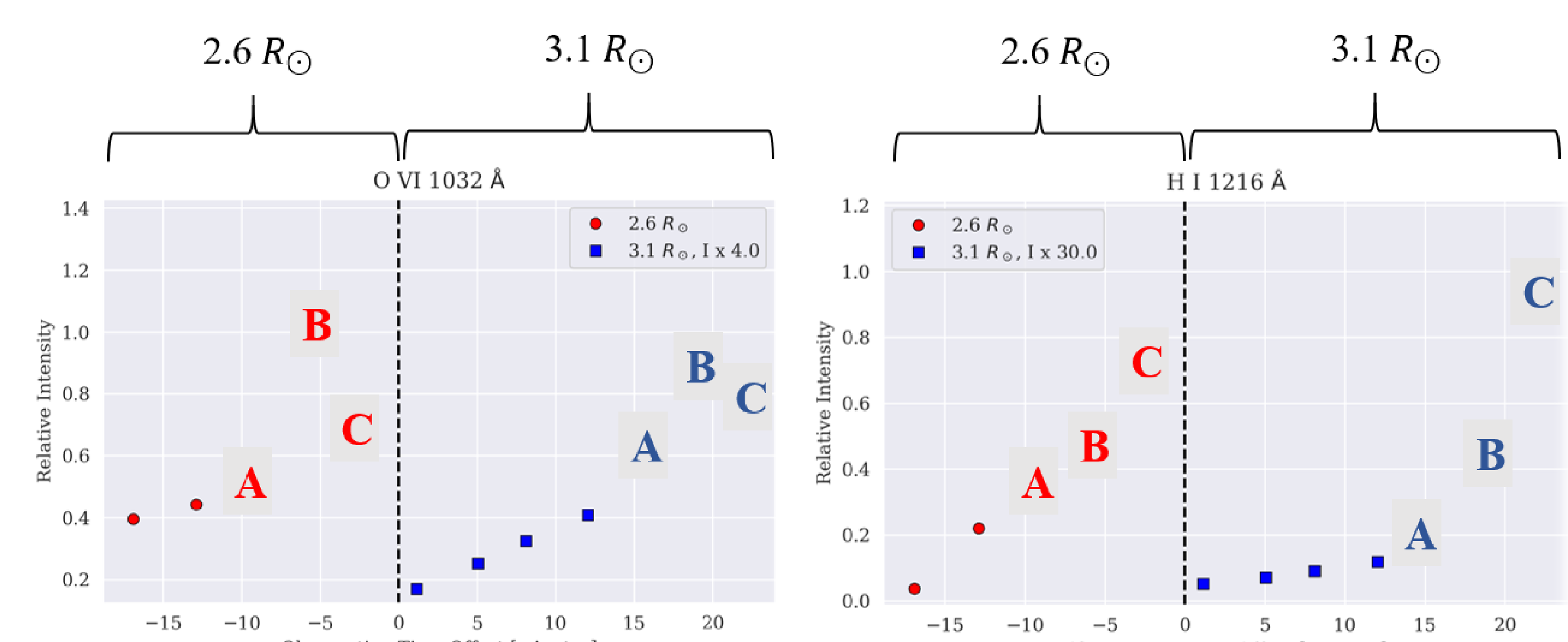
UVCS panels showing photometry in spatial/vertical direction and spectra in wavelength/horizontal direction. Emission for H I, O V, O VI, C III and more ions are present in this CME.





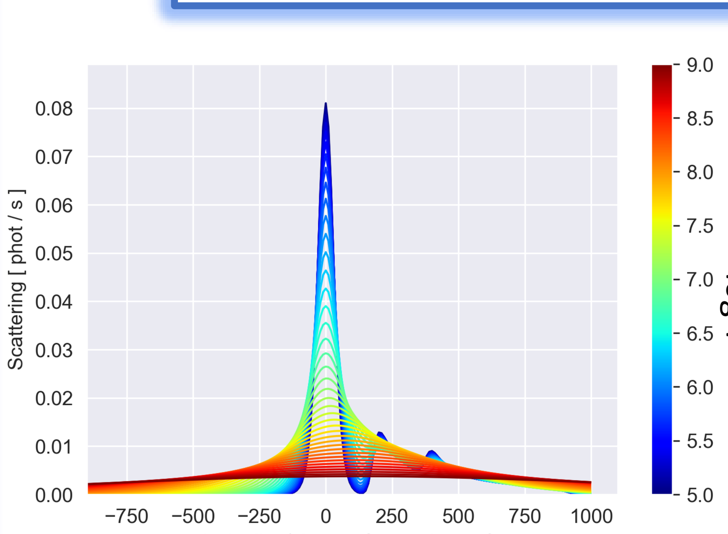
LASCO difference image of CME front/edge, void, and core. The **UVCS single slit** is overlayed via the UVCS images taken within +/- 20 min. of the LASCO image.

UVCS intensity light curves when slit aperture is observing at heliocentric distances $d_H = 2.6\ R_\odot$ and $3.1\ R_\odot$. We analyze Structures A, B, and C observed within our CME.

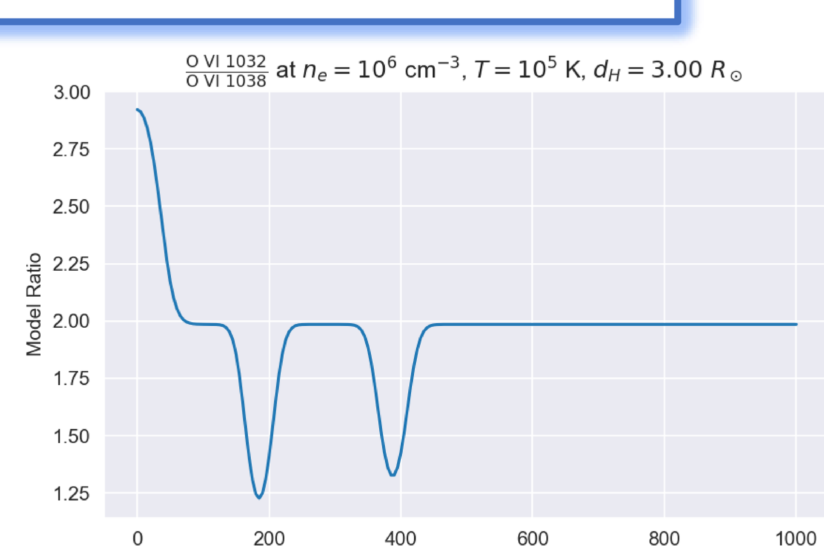


Plasma Diagnostics from Intensity Ratios

Collisional Excitation vs. Radiative Excitation



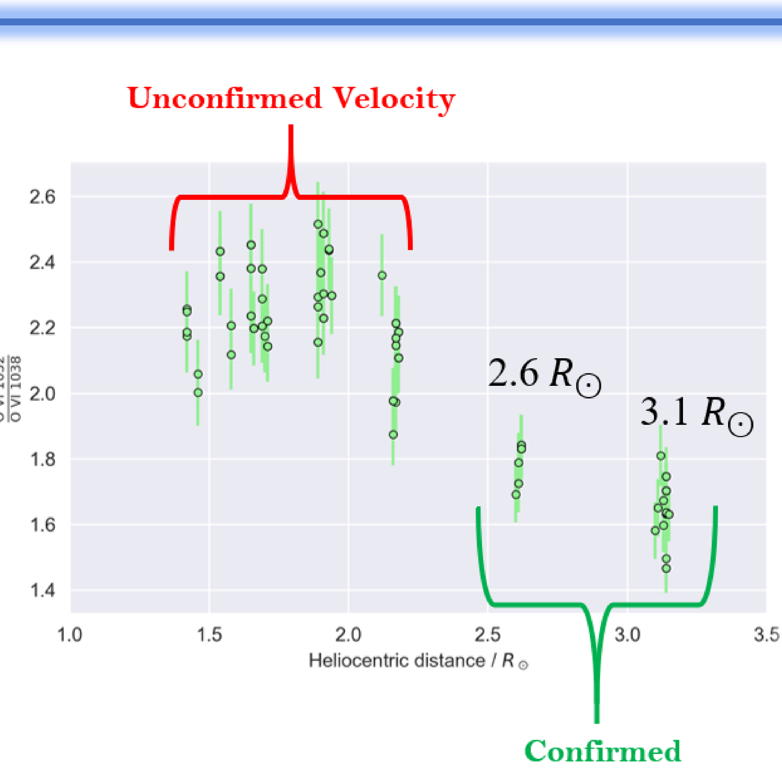
O VI 1038 resonant scattering with 2 bumps from Doppler shifted C II emission (from chromosphere) resonating with O VI (from the CME) at 1038.



Scattering of solar disk emission line profiles: ratio > 2.0

Collisional components: ratio = 2.0

Collisional with resonant Doppler pumping: ratio < 2.0

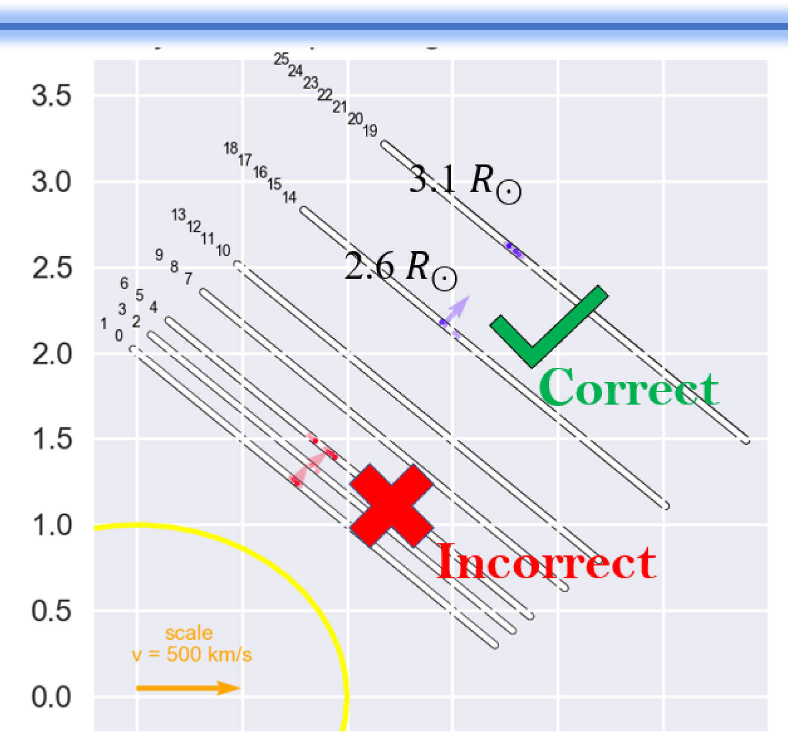


Observed O VI intensity ratios.

Ratios > 2.0 → v < 70 km/s

Ratios = 2.0 → v is unknown

Ratios < 2.0 → v ~ 200 or ~ 400 km/s

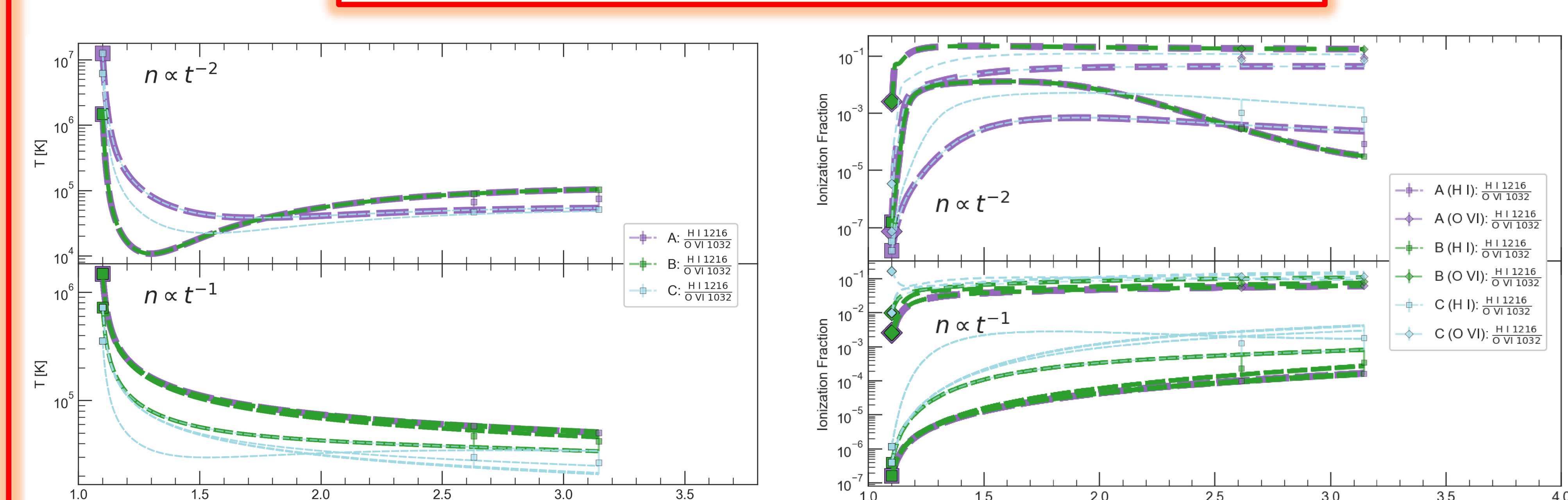


POS v vectors from UVCS slit photometry (and LOS v from spectra) confirm that the CME core's v ~ 250 km/s near 3.0 $R_\odot$.

At low heights in corona, there is discrepancy in v estimates. Therefore, it is unknown.

Numerical Modelling Results

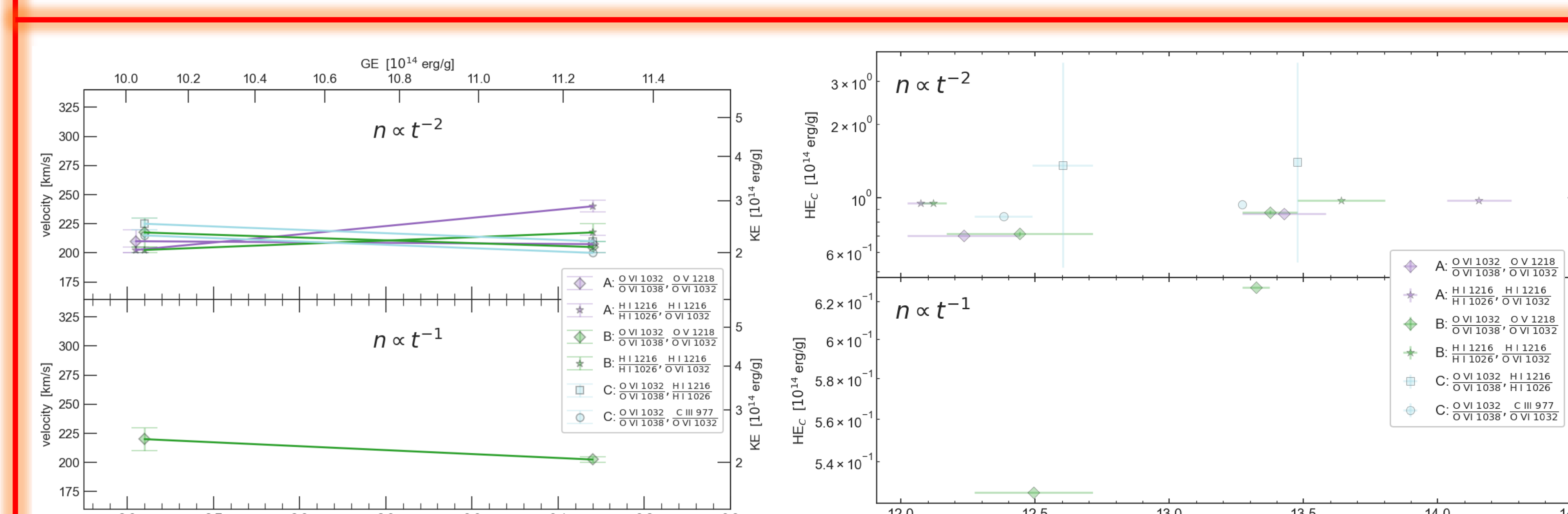
Physical Conditions, Heating, and Energy Budget



Our models assume a self-similar expansion rate: $n \propto t^{-\alpha}$, $\alpha = 3, 2,$ or 1

We utilize 1 of our 5 heating parameterizations to counteract a CME's radiative and expansion cooling.

Resultant models are shown here after being constrained by our observed (UVCS) intensity ratios at 2.6 and 3.1 $R_\odot$. In this example, it is only the $\frac{\text{H I 1216}}{\text{O VI 1032}}$ ratio that is used as a constraint.



We use multiple ratios simultaneously (at both 2.6 and 3.1 $R_\odot$) to robustly determine the physical conditions and energy budget of the CME core plasma.

The cumulative heating energy (HE$_C$) is comparable to the KE and the gravitational potential energy.

Thus, heating energy should be included in physical models of CMEs, and more coronagraph spectrometers are needed:

- UVSC Pathfinder mission
- LOCKYER mission