Can Shocks Explain the X-ray Activity in Cepheids?

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Observations

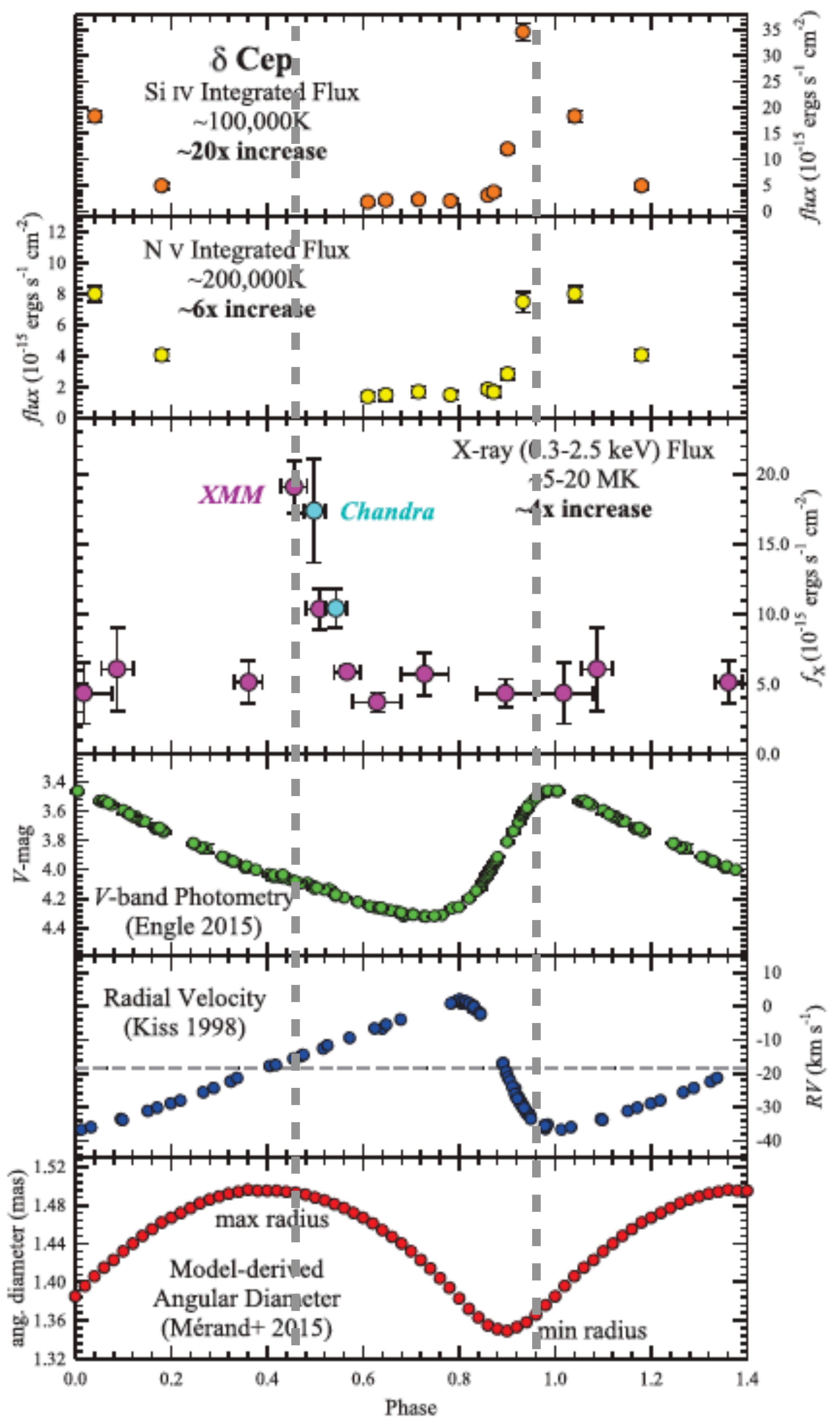


Figure 1 Observational summary of chromospheric (FUV, top 2 panels) and coronal (X-rays, 3rd panel) variations for δ Cep against its pulsation phase with different instruments. Also illustrated as a function of the pulsation phase are the V-band light curve (4th panel), radial velocity (5th panel), and the star's angular diameter, (bottom) (**Engle et al., ApJ, 838, 2017**).

Simulating Pulsation Driven Shocks

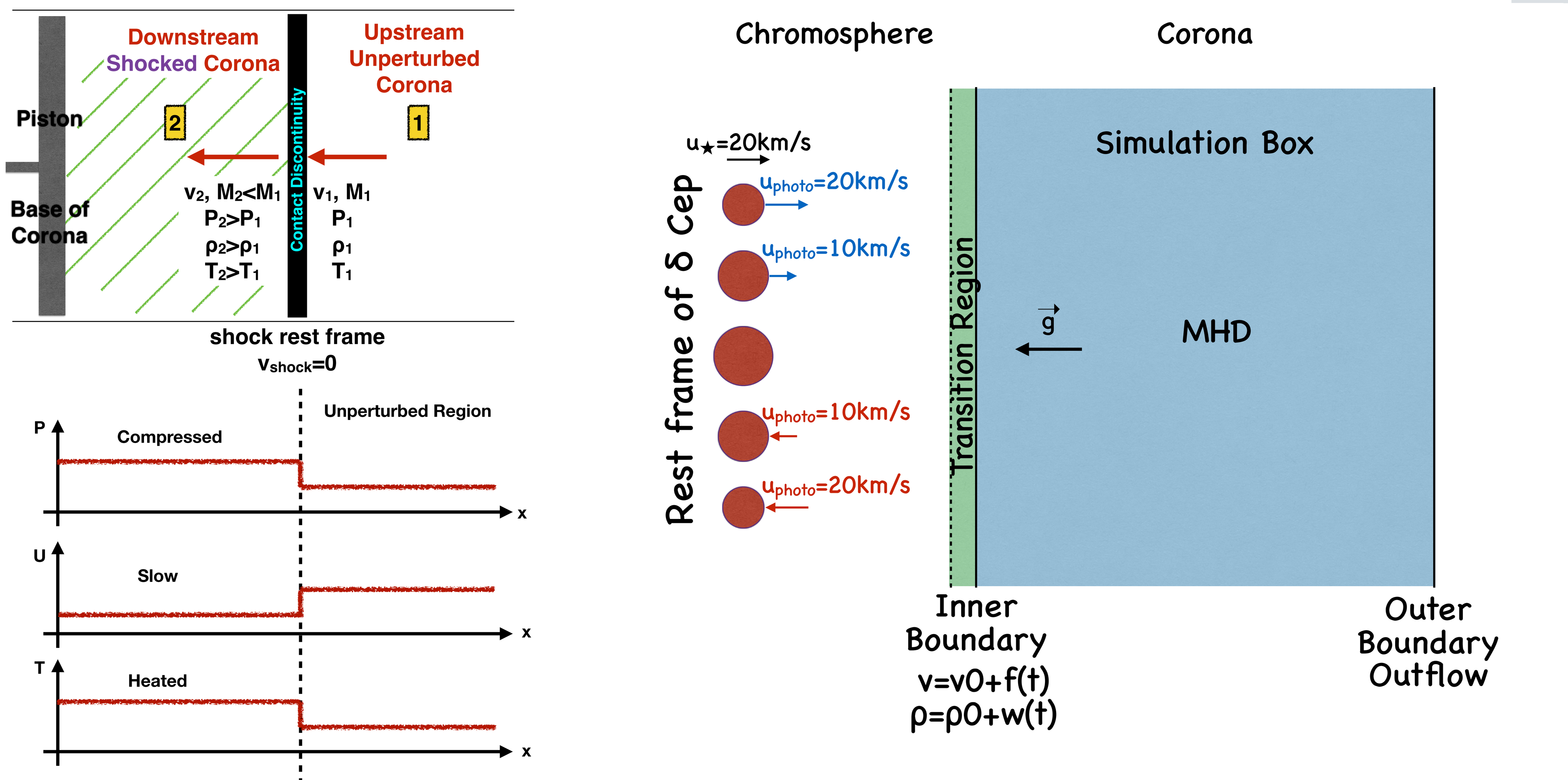
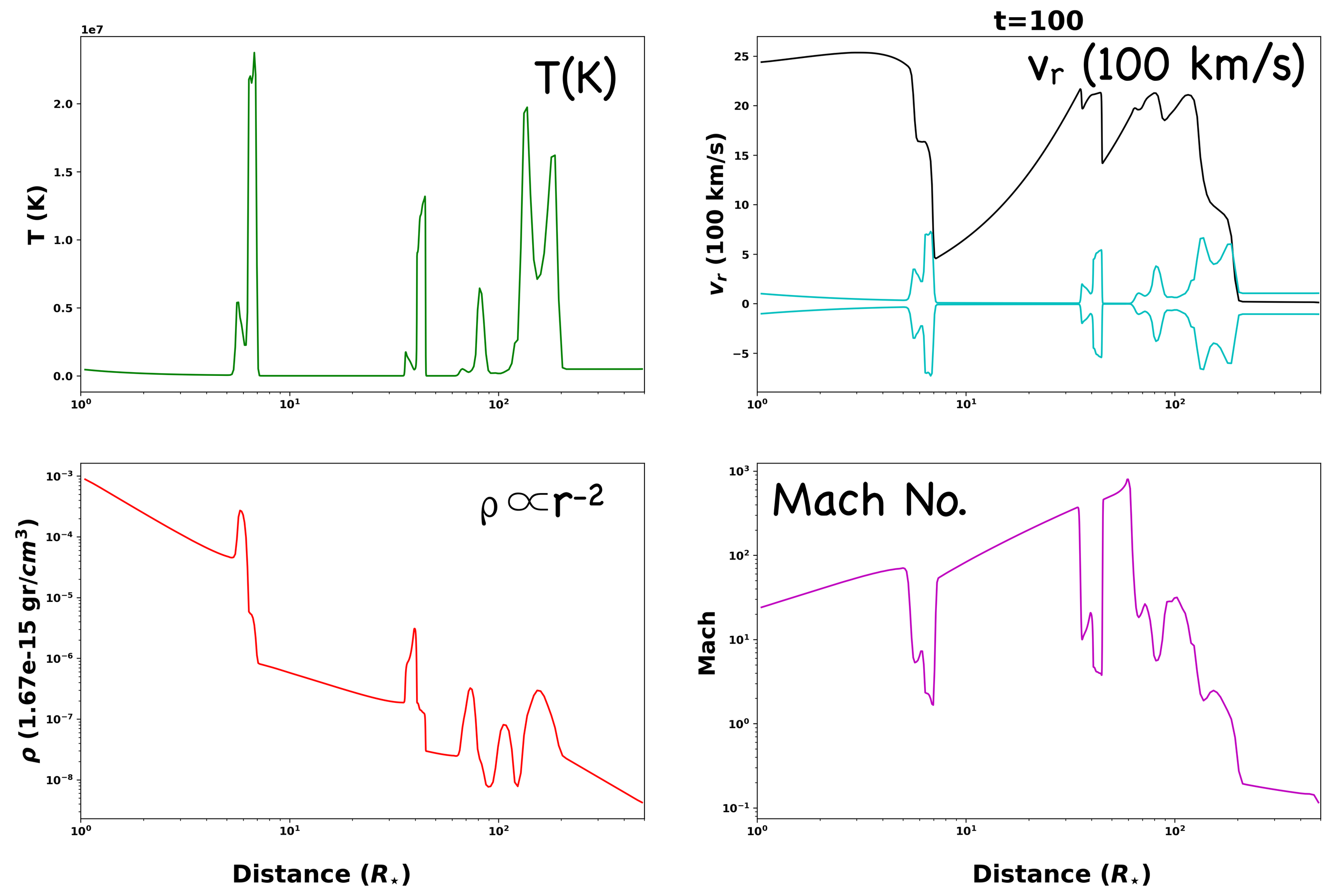
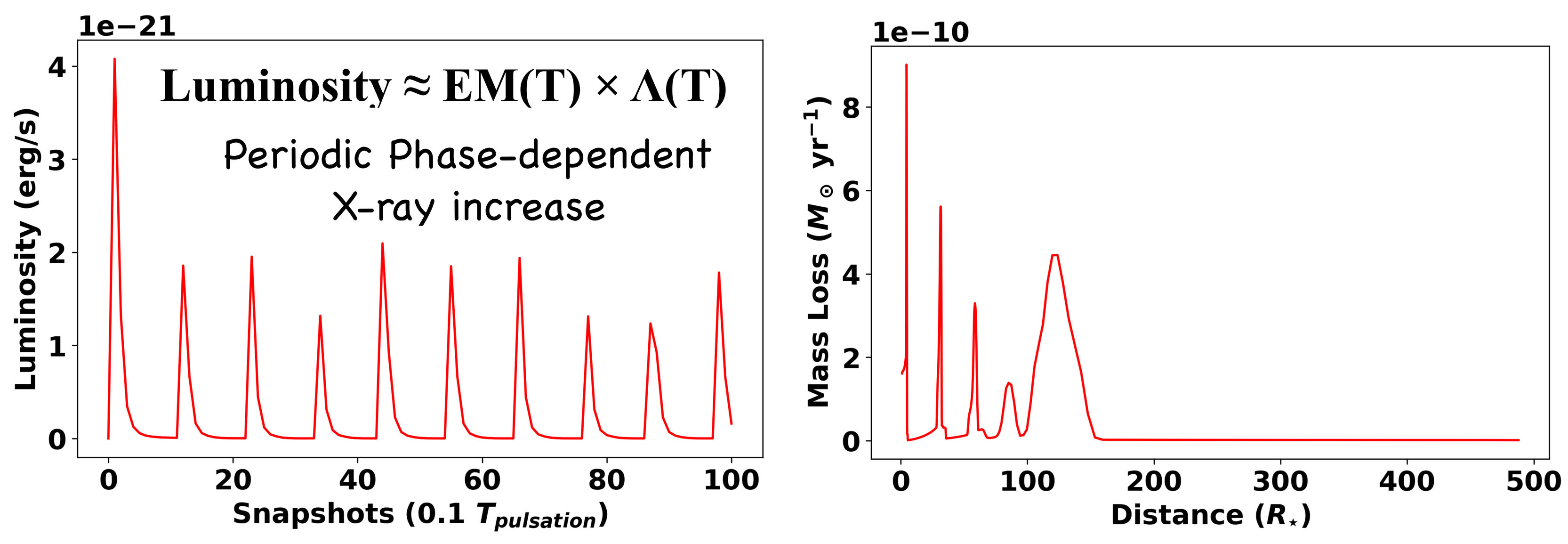


Figure 2 *Left*: Graph of shocked and unperturbed corona due to normal shock wave triggered by pulsation at the shock's reference frame. *Right*: Simulation setup.

Figure 3 One dimensional hydrodynamic (HD) simulation results with the MHD astrophysical code **PLUTO** (**Mignone 2014, J. Comput. Phys., 270, 784**) in spherical geometry with radiative cooling. Starting from a solar like corona pulsation-driven shock waves are produced & the plasma reaches T~2x10^7 K, as inferred by X-ray observations.





- 1 shock ≈10^{-10} M$_\odot$
- Assuming 1 shock per pulsation period (≈5 d)
- In a year ≈73 shocks carry ≈4x10^{-8} M⊙ yr^{-1}

Figure 4 *Left*: X-ray Luminosity profile over 10 pulsation cycles in $T_{Pulsation}$ period. *Right*: Mass flux over a few cycles. Shocks start merging after some distance.

Summary

- **Observations** of different Cepheids capture an X-ray peak corresponding to a temperature increase of a factor 4 takes place shortly after maximum radius in the pulsation phase at an altitude of about 10% the stellar radius.
- The **question** then becomes what is the mechanism able to produce the energy required by the X-rays at that height: **Shocks or Reconnection?**
- Here we focus on the hydrodynamic regime (no magnetic fields). **HD simulations** of a 1D stratified atmosphere in spherical geometry, including optically thin radiative losses and synthetic X-ray light curves indicate that under specific conditions pulsation driven shock can reproduce the observed the X-ray profile. The mass loss we estimate is of the order: 3.65×10^{-8} M⊙ yr^{-1} and is in agreement with Circumstellar Envelope observations.
- **Future steps**: We are working on simulating reconnection effects to explore the flare scenario.

References

1. Engle et al., ApJ, 838, 2017
2. Mignone 2014, J. Comput. Phys., 270, 784