

What Can Make a Contact Binary Star Explode?

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Introduction

Contact binary stars orbit each other so closely that they share a common atmosphere. For millions of years, these stars orbit without significant change. Eventually, an as yet unknown mechanism causes them to spiral together, merge, and explode.

Three years ago, we identified a contact binary system, KIC 9832227, which we observe to be spiraling inwards, and which we now predict will explode in the year 2022, give or take a year. *This was the first ever prediction of a nova outburst.* We are using this opportunity to try to discover the mechanism behind stellar mergers. To explore this question this summer, we studied our system more intensively using both optical and X-ray telescopes. We determined a more accurate shape with the PHOEBE software package (see Fig. 1). And we began a survey of the shapes

of other contact binary stars to compare their characteristics to those of our system.

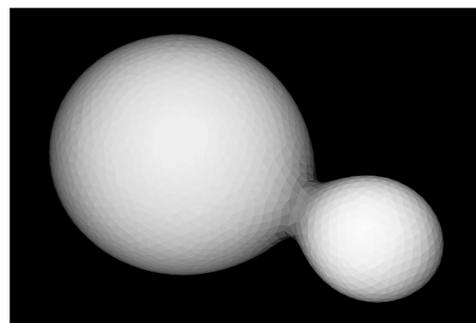


Fig. 1. Our reconstruction of KIC 9832227 from PHOEBE analysis of brightness and spectral variations.



Timing Update

The key test of our merger hypothesis is how the eclipse timing changes through the years (see Fig. 2). As of last summer, all alternative interpretations of this plot could be ruled out except for a massive white dwarf companion star. Hence our first task for the summer was to extend this plot with an additional year of data. We find that KIC 9832227 is closely following our predictions.

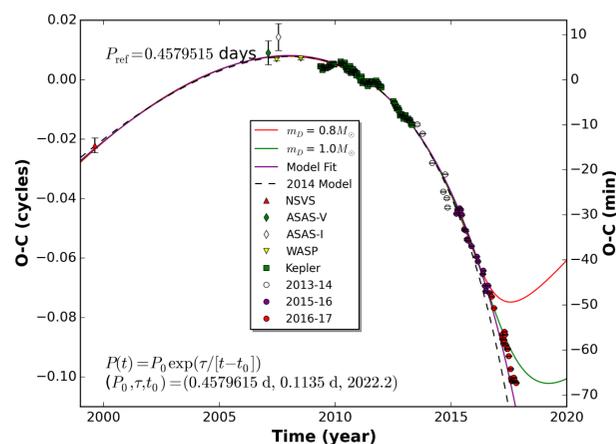


Fig. 2. Time of eclipse relative to a constant orbital period. Concave down curvature indicates a decreasing period. The purple line is our 2016 model fit. Subsequent data (red circles) are consistent with the merger prediction. They now rule out the alternative hypothesis of a white dwarf companion star of size 0.8 solar masses.

Merger Mechanism

Fillout Factor:

The degree of contact in a contact binary is called the fillout factor (Fig. 3). At the upper extreme, the surface approaches L_2 (on the left in Fig. 3), the point at which the outward centrifugal force balances the attractive gravitational force. Material reaching L_2 flows away from the binary, driving the stars closer together.

We are using PHOEBE to determine fillout factors for hundreds of contact binaries from the Kepler spacecraft data catalog. We predict that we will find our system has an exceptionally high fillout factor.

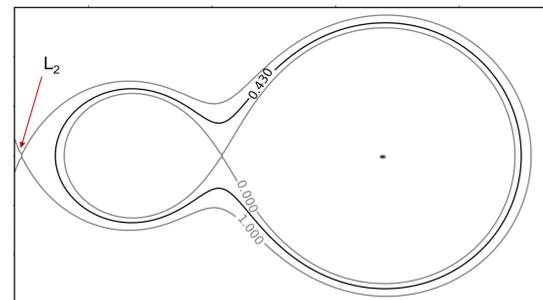


Fig. 3. The black line is a cross section through the equator of our star. The gray lines show the range of possible shapes for contact stars. The fillout factor is a parameter from 0 to 1 indicating the degree of contact of the binary. Our fillout factor is 0.43.

A Leaky Chromosphere?

The region immediately above a star's surface is called the chromosphere (see Fig. 4). In this region, the density drops exponentially by a factor of a million or more. High temperature material in the outer chromosphere would emit X-rays. Fig. 5 shows our new X-ray image of KIC 9832227. The strong detection suggests the presence of a significant chromosphere there. We suggest a merger mechanism may be that chromospheric material lost through L_2 drives the binary closer together. This in turn pushes L_2 into a denser portion of the chromosphere driving the binary together more quickly. This results in the runaway change in the orbital period that is observed.



Fig. 4. In the 2017 eclipse, part of our Sun's chromosphere is seen as pink protrusions. Photo credit: John VantLand.

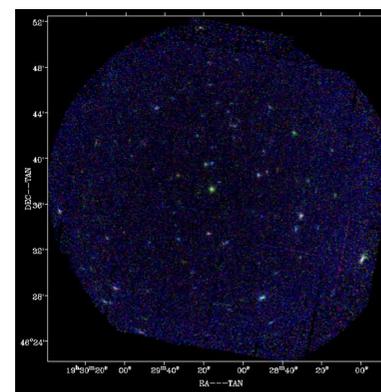


Fig. 5. KIC 9832227 is the bright green spot in the center of this XMM-Newton satellite X-ray image.

What To Look For



Fig. 6. A Hubble Space Telescope image of a red nova, V838 Mon, that exploded in 2002.



Fig. 7. A star chart showing the location of KIC 9832227, with a hand at arm's length for scale. All stars in this chart are bright enough to be seen with the unaided eye. At the outburst peak in 2022, we expect our star's brightness to be similar to those of the cross in the constellation Cygnus.

Reference

Molnar et al. 2017. "Prediction of a Red Nova Outburst in KIC 9832227". *Astrophysical Journal*, 840,1.