Title: Investigating the Structure of the Largest Pulsating Crystallized White Dwarf WD J004917.14252556.8

Scientific Justification *Be sure to include overall significance to astronomy. For standard proposals limit text to one page with figures, captions and references on no more than two additional pages.*

The discovery of WD J004917.14-252556.8, the largest known pulsating white dwarf, has opened a compelling avenue for scientific exploration. Our proposed investigation aims to leverage Gemini time-series photometry over consecutive days to validate and comprehend the pulsar timing of this celestial object. Previous investigations show the presence of multi-periodic variability that requires further study to quantize. Through a systematic collection of extensive follow-up time-series photometric data on this exceptional target, we anticipate uncovering a considerable array of additional pulsation modes. These newfound modes hold the promise to address the existing challenges posed by degeneracies in asteroseismic fits, allowing for a more precise understanding of the internal structure of a 1.3 solar mass crystallized white dwarf. This unique target has a crystallized fraction that expected to be 99%. By probing the interior of this unique stellar remnant, our study aims to offer invaluable insights into the fundamental mechanisms governing the evolution and behavior of such evolved stellar objects.

Rowan et al. (2019) and Vincent et al. (2020) have identified three potential pulsating white dwarf candidates, each with a mass exceeding 1.05 solar masses. However, these candidates lack follow-up spectroscopic analysis in existing literature, displaying variations at singular dominant periods of 330, 357, and 809 seconds, respectively. This observed behavior aligns with the known photometric variations exhibited by rapidly rotating white dwarfs (as noted by Pshirkov et al. 2020 and Caiazzo et al. 2021), potentially mimicking ZZ Ceti white dwarfs (as suggested by Kilic et al. 2021b). To conclusively ascertain whether these three targets are indeed DA white dwarfs demonstrating multi-periodic photometric variations due to pulsations, further spectroscopic analysis and time-series photometry are imperative.

Understanding the evolutionary pathways of stars is crucial. Most stars evolving in isolation culminate as CO core white dwarfs (Fontaine et al. 2001). However, mass transfer within binary systems can alter a star's evolution, resulting in the formation of low-mass white dwarfs featuring helium cores and masses below approximately 0.45 solar masses. Conversely, stars with off-center carbon ignition in a degenerate CO core exceeding 1.06 solar masses should lead to the creation of ONe core white dwarfs (Murai et al. 1968). Nonetheless, binary mergers may also yield CO core white dwarfs within the same mass range (as discussed by Althaus et al. 2021, albeit contested by Schwab 2021). Unfortunately, observational constraints regarding the core composition of white dwarfs remain incredibly challenging.

Hence, a comprehensive study incorporating spectroscopic analysis and detailed time-series photometry is vital to confirm the nature of these potential pulsating white dwarf candidates and shed light on the diverse evolutionary pathways leading to the formation of white dwarfs with varied core compositions and masses.

The study of asteroseismology presents an unparalleled opportunity to delve into the internal structure of massive, crystallized white dwarfs such as J0049-2525. This exploration, however, hinges on detecting a substantial number of g-modes with consecutive radial orders. The variations in periods and their spacings are contingent upon factors like mass, effective temperature, hydrogen envelope mass, and the proportion of crystallized mass. In the case of J0049-2525, our observations from APO and Gemini have revealed only two prominent modes, rendering the identification of a singular seismic solution impossible. Consequently, we've outlined several plausible solutions that align with the observed characteristics of this star. Nevertheless, to resolve the ambiguities in the asteroseismic interpretations, it's imperative to detect a significant number of additional pulsation modes.

To achieve this, we advocate for extensive follow-up time-series photometry campaigns specifically targeting this unique celestial target. The acquisition of a more comprehensive dataset, featuring a diverse array of pulsation modes, holds the key to overcoming the degeneracies encountered in the asteroseismic fits. This concerted effort will not only enable a more refined understanding of the internal structure of J0049-2525 but also pave the way for breakthroughs in our comprehension of massive, crystallized white dwarfs through the lens of asteroseismology.

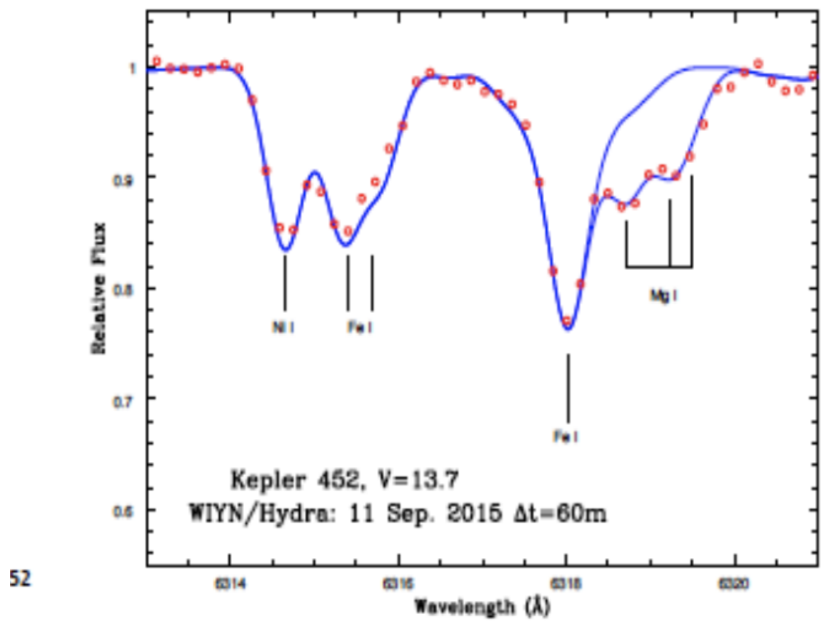

Figure 1: This is an example of embedded PDF figure

Experimental Design *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification?*

1. **Observation Dates**:
   - (previously used dates and still need to be calculated/trackedUT 2022 Dec 26 and 27 as part of the GS-2022B-DD-107 program.
2. **Instrumentation**:
   - Gemini GMOS for observations.
   - SDSS-g filter for data collection.
   - do we want to mention APO here?
3. **Data Collection**:
   - Back-to-back exposures: 121 and 215 with ± 7 s duration on Dec 26 and 27, respectively.
   - CCD chip binned by 4×4 for optimized image quality and efficiency.
   - Plate scale: 0.3200 pixel^{-1}, resulting in a 15.7 s overhead, with a 22.7 s effective cadence between consecutive exposures.
4. **Photometry Method**:
   - Selection of four reference stars brighter than J0049-2525 for relative photometry.
   - Reference stars for comparative analysis of variations in J0049-2525's luminosity.

Plan for Data Analysis:

1. **Data Calibration**:
   - Standard calibration processes: bias subtraction, flat-fielding, and correction for instrumental effects.
2. **Photometric Analysis**:
   - Relative photometry with selected reference stars to quantify brightness variations in J0049-2525.
   - Analysis of light curves to identify and characterize pulsation modes.
3. **Pulsation Mode Detection**:
   - Analysis of light curves to detect additional pulsation modes beyond the initially observed two significant modes.
   - Identification and cataloging of a more extensive range of pulsation frequencies for overcoming asteroseismic degeneracies.

Outcome and Recommendations:

- The study aims to expand observed pulsation modes in J0049-2525 for a better understanding of its internal structure.

- Based on the acquired data and analysis, recommendations for follow-up observations, such as increased cadence or alternative filters, may be proposed for further investigating the white dwarf's pulsation behavior.

References:

- Original Paper: "WD J004917.14252556.81, the Most Massive Pulsating White Dwarf"
- (4) References on White Dwarfs
- (2) WD Crystalline Structure
- (2) WD Pulsar Timing

Figures:

1. Light Curve
2. Gemini time-series photometry (Science Justification)
3. 4 Reference Star(s) info
4. Observation Schedule

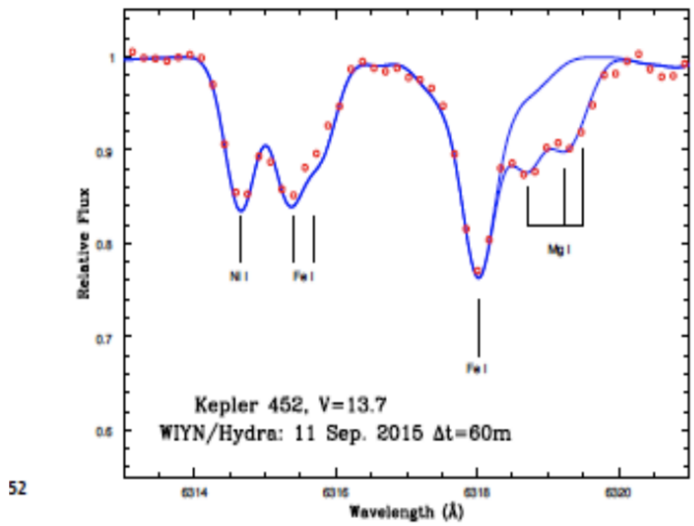

Figure 2: Placeholder figure: Gemini time-series photometry (Science Justification)