Lithium Abundance Estimates from Absorption Lines in Classical Novae

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Abstract

The "lithium problem" originates from a mismatch between the higher amounts of lithium found in young stars and the lower amounts predicted by the Big Bang nucleosynthesis(BBN). This disparity implied that lithium production was coming from sources other than BBN. Izzo et al. (2015) showed that novae can contribute to the galactic lithium abundance by discovering lithium for the first time in Nova V1369 Cen. This project will build on their work by examining more spectra and analyzing additional absorption lines to validate Izzo's claims. The equivalent width and radial velocity of the absorption lines associated with the potential nova will be plotted as a function of time since outburst.

Introduction

The "lithium problem" has been an on-going problem in astrophysics concerning the mismatch between the observed lithium abundances in the oldest stars in our galaxy and the predictions from BBN. According to BBN, only trace amounts of Li should have been produced in the early universe, yet observations of metal-poor stars show that lithium levels roughly three times higher than the expected value. Three primary astrophysical sites have been proposed as major lithium contributors:

- Asymptotic giant branch (AGB) stars: Aging stars in their final phases, the actual contribution from AGB stars remains uncertain since the lithium they produce may be destroyed in later stellar phases.
- Galactic cosmic-ray spallation: They produce lithium via fragmentation of material due to the impact of accelerated protons, leading to expulsion of nucleons; Lemoine et al. 1998.
- Classical Novae: A notable aspect of nova nucleosynthesis is the beryllium-transport mechanism, as proposed by Starrfield et al. (1978), in which the extreme temperatures during the explosion generate radioactive Be, which later decays into Li.

Classical novae are thermonuclear explosions occurring on the surface of white dwarfs in binary systems, where material accreted from a companion star undergoes runaway fusion reactions. These explosive events eject processed material into the interstellar medium at high velocities, enriching the galaxy with new heavy elements.

Measurement

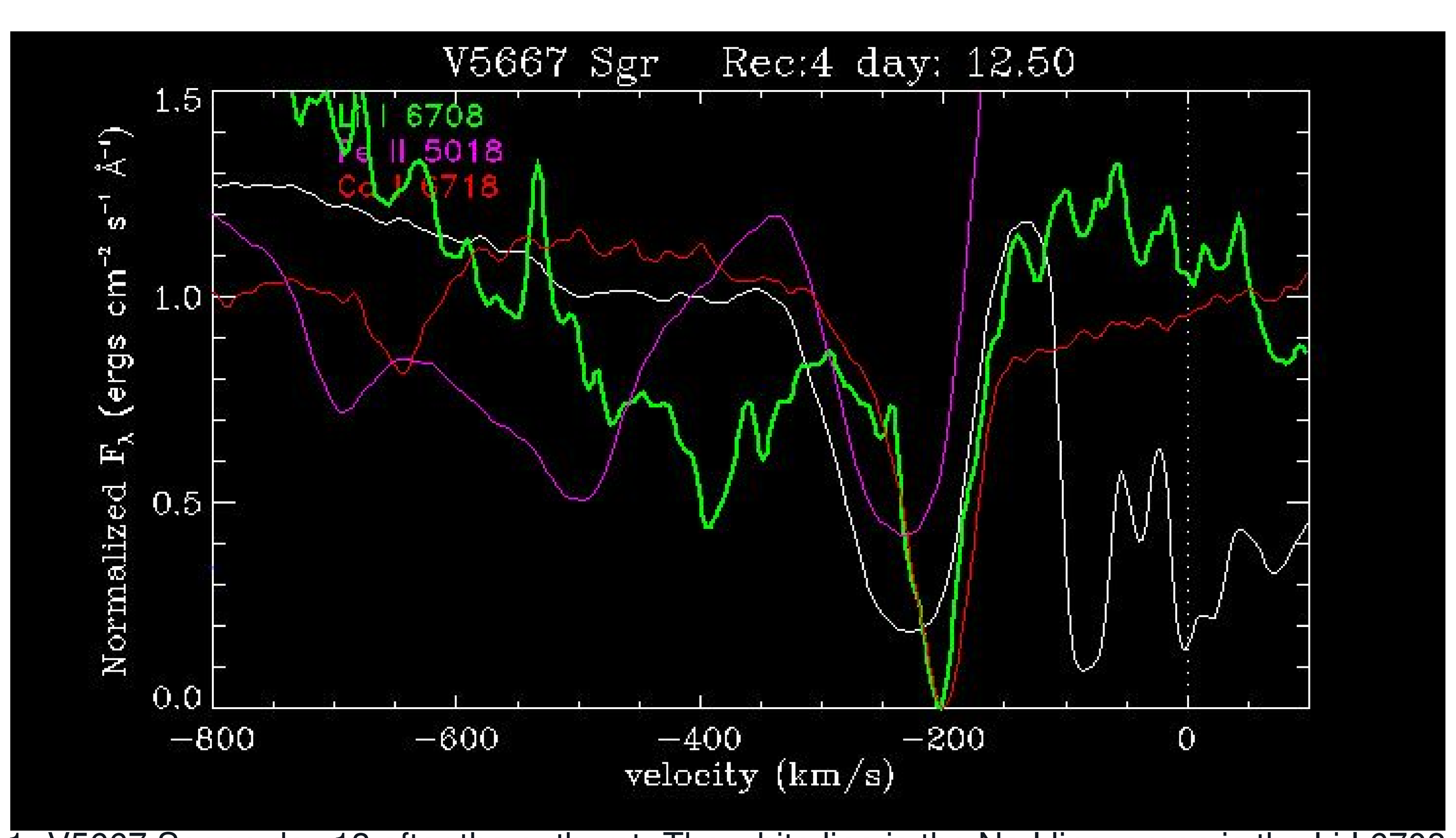

Fig. 1: V5667 Sgr on day 13 after the outburst. The white line is the Na I line, green is the Li I 6708 line, purple is the Fe II 5018 line, and red is the Ca I 6718 line. Notice that the absorption features all line up at around -225 km/s, which verifies that these absorption lines are real. Fe II appears broader compared to Li I due to their high temperatures(8000K)

Results

Among dozens of novae we examined, we are confident to show that two slow classical novae—V5667 Sgr and V5668 Sgr (both erupted in March 2015) displayed clear lithium absorption in their ejecta.

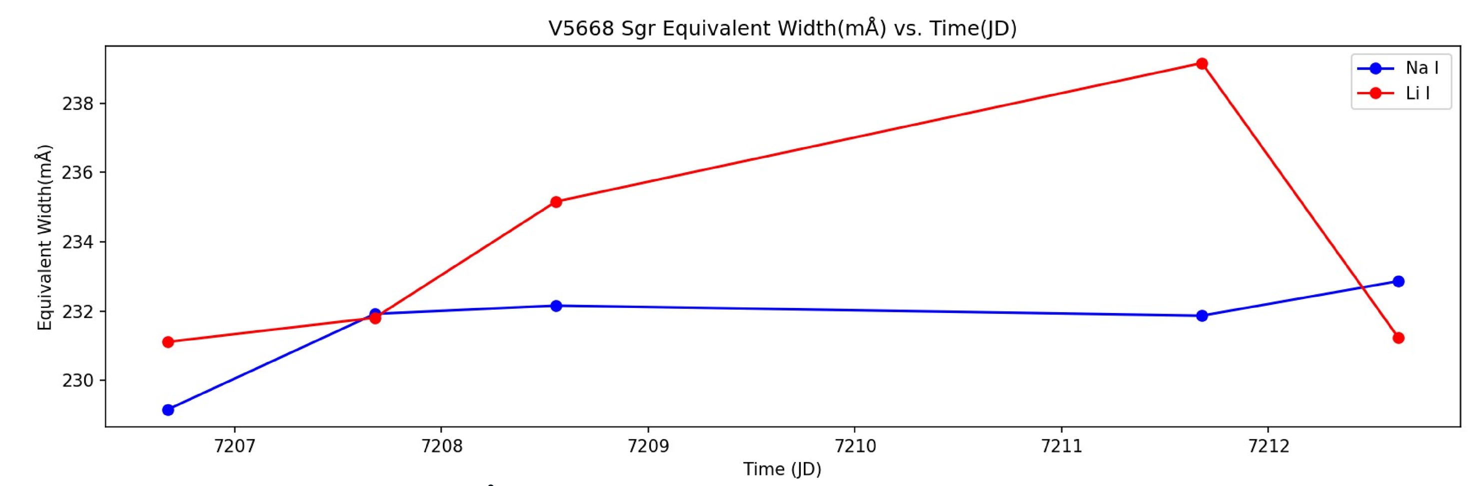

Fig. 2: The equivalent width in mÅ vs. time in JD for V5668 Sgr. Notice that the equivalent widths for Na I and Li I are pretty much the same, which suggests that they were in the same ejecta.

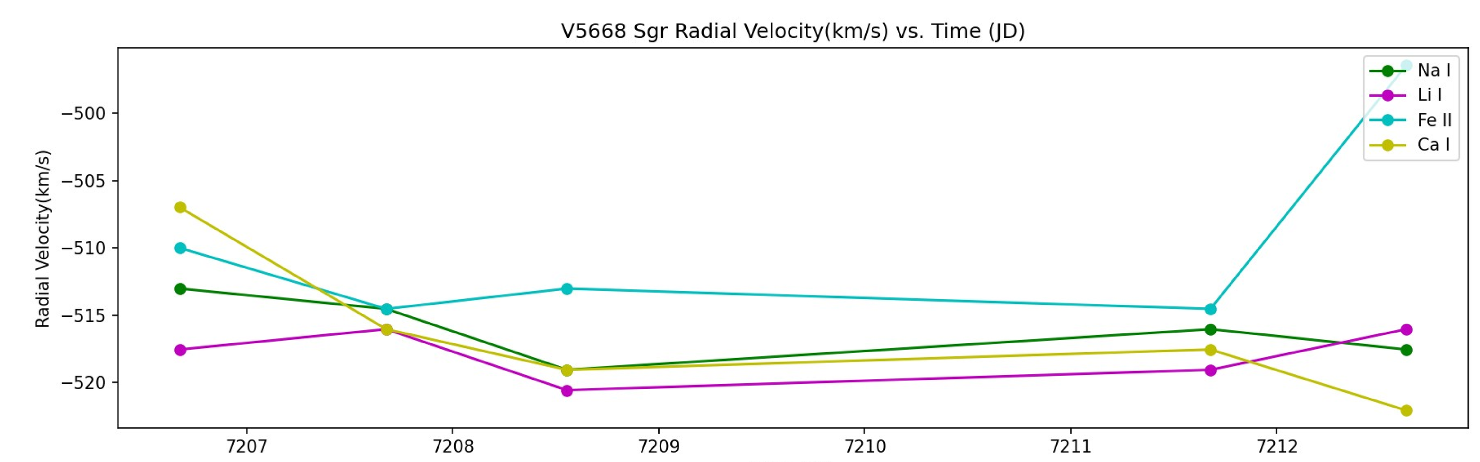

Fig. 3: The radial velocity vs. time in JD for V5668 Sgr. Notice that the radial velocity for Na I and Li I, Fe II, and Ca I are pretty much the same, which suggests they are moving at the same velocity(same ejecta).

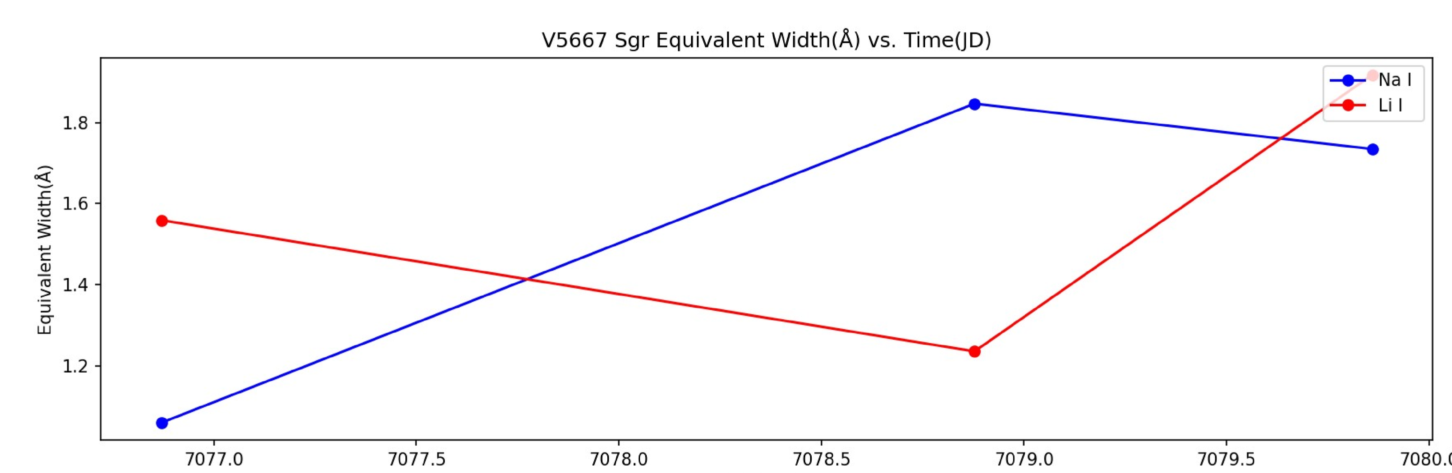

Fig. 4: The equivalent width in Å vs. time in JD for V5667 Sgr. Notice that the equivalent widths for Na I and Li I are pretty much the same, which suggests that they were in the same ejecta.

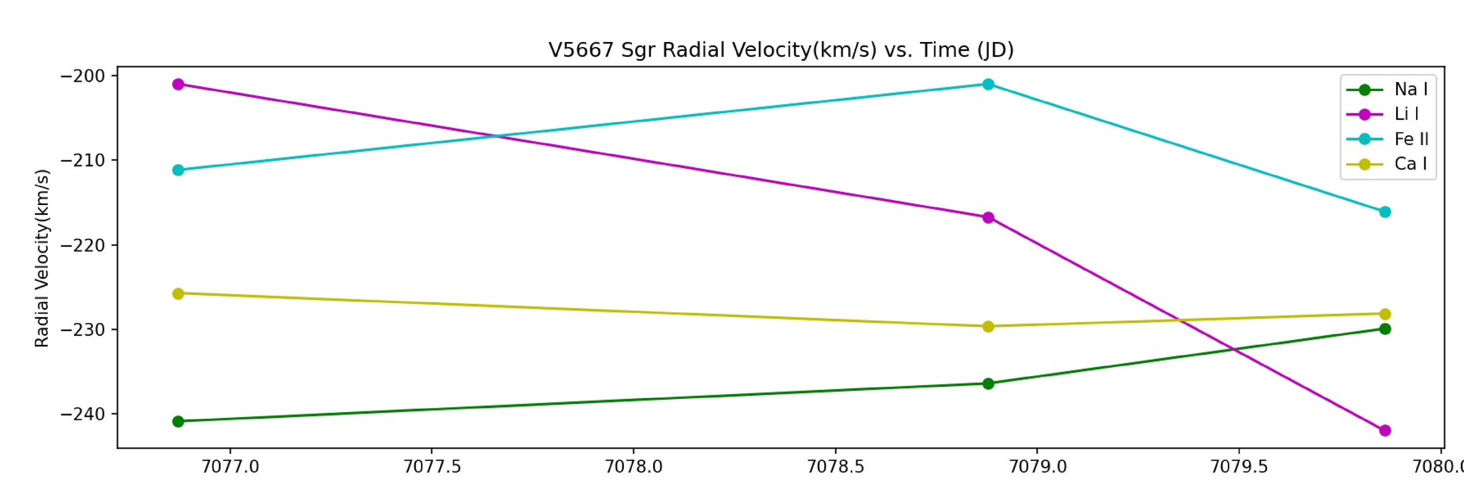

Fig. 5: The radial velocity vs. time in JD for V5667 Sgr. Notice that the radial velocity for Na I and Li I, Fe II, and Ca I are pretty much the same, which suggests they are moving at the same velocity(same ejecta).

Conclusion

The presence Li I 6708 Å line in both V5668 Sgr and V5667 Sgr is supported by the alignment of other well-known spectral lines, including Fe II, Ca I, and Na I, which serve as reliable reference markers in the same wavelength region. The absorption characteristics of these lines displayed consistent radial velocities, validating their source in the nova ejecta and offering proof of lithium's presence. The presence of lithium was only detected for a limited number of days due to the dilution of ejecta, as the material expelled from the explosion spread over a larger area due to the expansion of the ejecta.

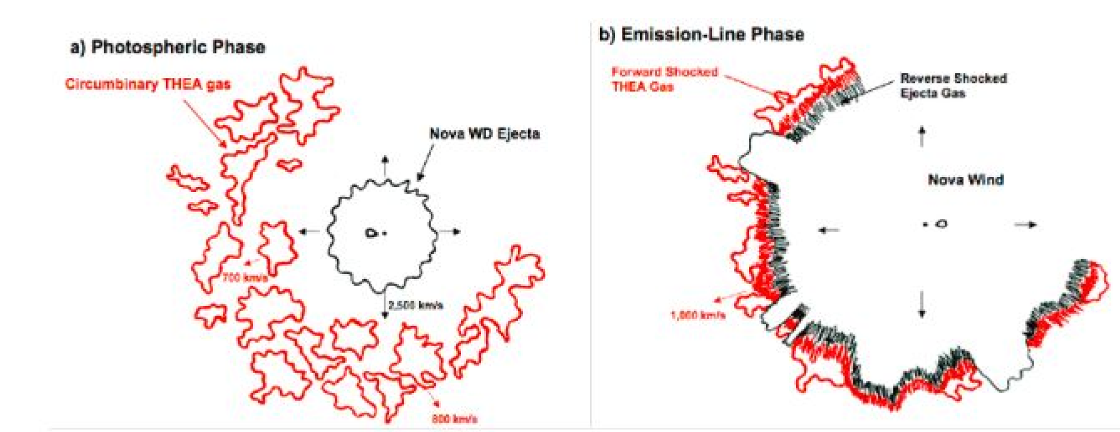

Figure 2. Schematic representation of (a) the photosphere phase before collision, and (b) the forbidden line phase with the shock heated gas after the collision.

Fig. 6: From Robert Williams & Elena Mason 2009

Work To Be Done

Future research should focus on determining lithium abundances in classical novae from the equivalent widths of the Li I 6708 Å line, while considering possible interference from Na I, Fe II, and Ca I lines. Additionally, the cause of why some novae (e.g., V5668 Sgr, V5667 Sgr) exhibit clear lithium presence while others do not remains unresolved. The reappearance of the lithium line a few days after dilution should also be investigated, though a few potential explanations already exist.

Acknowledgments

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