The Origin of Metals in Extremely Low Mass White Dwarfs

Charlotte Wood[1], Stephen Lawrence[1], Mukremin Kilic[2], Alexandros Gianninas[2], Sara Barber[2]

Hofstra University Dept. of Physics & Astronomy[1]; Homer L. Dodge Dept. of Physics & Astronomy, University of Oklahoma[2]

INTRODUCTION

Extremely low mass white dwarfs (ELM WDs) are characterized by having a mass $M \leq 0.25\ M_{Sun}$ or by having surface gravities of $5.0 < \log g < 7.0$. All ELM WDs found to date are formed in short period binary systems (P < 1 day), as the age of the universe is not large enough for them to have been made through single star evolution. The ELM WDs with a surface gravity $\log g < 6.0$ all show the Ca K absorption line at 3933 angstroms with concentrations as much as Ca/H ~ 10^{-5}. In their higher mass counterparts, this presence of Ca is explained by the active accretion of material onto the star from a circumstellar debris disk. It is suspected that the same process explains the Ca presence in ELM WDs. Since they are in tight binaries, such a disk would have to be circumbinary.

PROCESS

If a debris disk is present, then it will be easily detectable through an excess of flux at infrared wavelengths. We looked at the photometry of 22 ELM WDs that show the Ca absorption line using data from the Spitzer Space Telescope IRAC channels 1 & 2, SDSS, GALEX, WISE (2 filters), 2MASS, and UKIDSS. This gave us a range of points from UV to IR at 4.5 microns to fit a model spectrum of the star to. Original data was taken from Spitzer and archival magnitude data was taken from the other sources. The flux (mJy) of each target was found at each wavelength and plotted on a log-log plot of Flux (mJy) vs. Wavelength (microns). The model spectra were scaled from actual flux to apparent flux to fit the observed data. They take into account the emission from the WD only, so emission from a disk would show up as an IR point above the model.

Disk models were fit to all targets using the same model that describes debris disks around singular WDs. The disk model and an addition of the two models were plotted on the same graph. Of the 22 targets, nine had a disk model that fit the excess IR better than the original model. Of those nine, only one had a statistically significant excess in the infrared at 4.5 microns.

RESULTS

The graphs below are for J2132+0754, the target with a significant IRAC 2 point and a viable disk model.

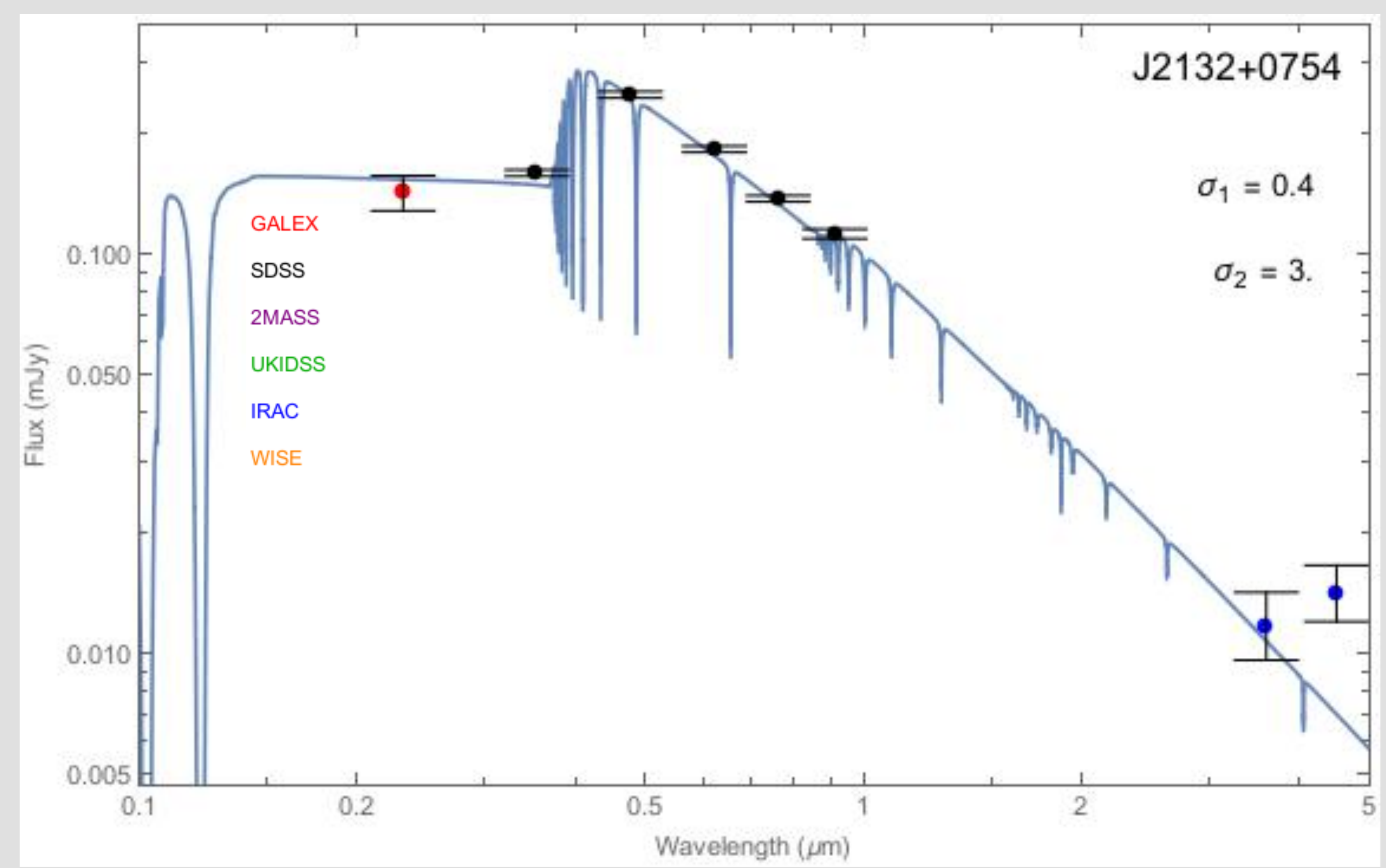

Fig. 1: observed flux and model spectrum. Reported significances for IRAC 1 & 2 (blue points).

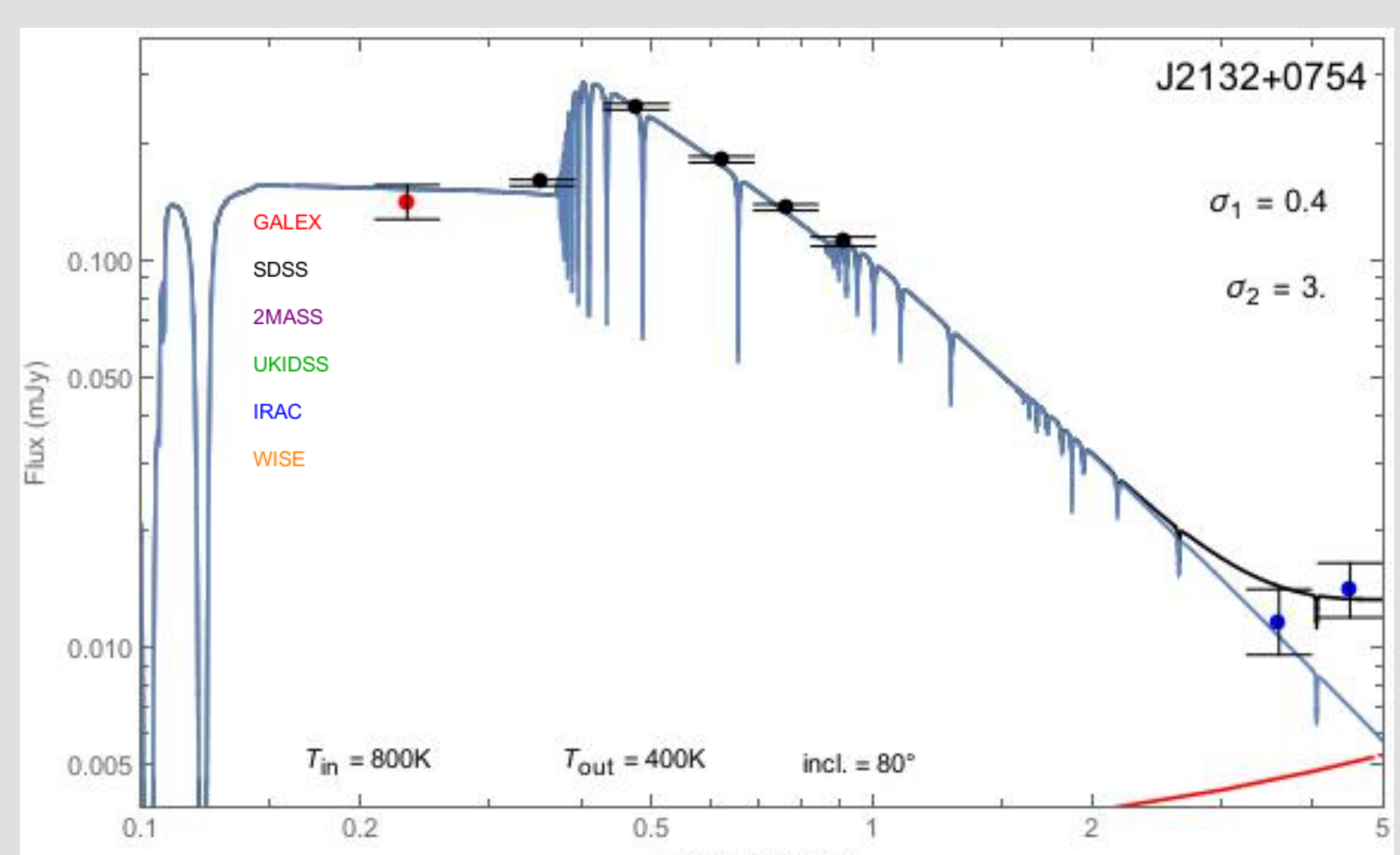

Fig. 2: observed flux, model spectrum (blue), disk model (red), and combined model (black).

CONCLUSION

The disk model that best fit this particular target has an inner temperature, T_{in} = 800 K, an outer temperature, T_{out} = 400 K, and an inclination of 80° (almost edge on). Since ELM WDs are in tight binaries, a disk would have to be around both stars. If the inner radius, R_{in}, is smaller than the orbital separation of the stars, then this disk is not possible. The inner radius of the disk is determined by the following equation:

$$R_{in} = R_{star} * \left[\left(\frac{T_{in}}{T_{star}}\right)^{4/3} \left(\frac{3\pi}{2}\right)^{1/3}\right]^{-1}$$

Jura et al. 2003 Eq. (1) [rearranged]

With a radius R_{star} = 0.068 R_{Sun} and a temperature T_{star} = 13788 K, we get a corresponding inner radius R_{in} = 1.808 R_{sun}. The orbital separation of this particular binary sytem is 1.7456 R_{Sun}, so this disk is plausible.

Although it appears this disk can exist, the results are only based off of one significant data point. To further confirm that this disk is there, more data will need to be taken deeper in the infrared. There are currently no instruments available to obtain this data until the James Webb Space Telescope launches in October 2018.

REFERENCES

Gianninas, A., et al. 2014, ApJ, 781, 104
Jura, M., et al. 2003, ApJL, 584, L91