



# Searching for Periodicity in Proto-Planetary Nebulae

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## Intro

- Proto-Planetary Nebulae (PPNe) are stars late in their evolution, between the red giant phase and the planetary nebula phase.
- PPNe have lost their outer layers, but are not yet hot enough to ionize the surrounding gas.
- PPNe are known to pulsate, with unusual and sometimes with multiple periods.

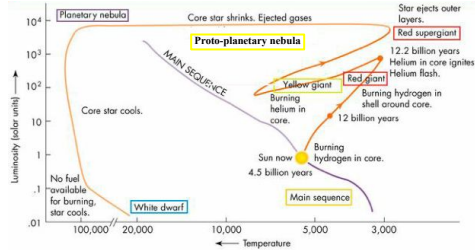


Figure 1: Stellar Evolution

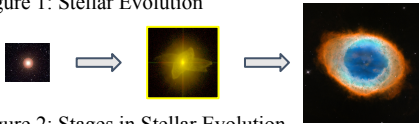


Figure 2: Stages in Stellar Evolution

- Our group has been one of the two main groups researching the light variability of these objects
- Our goal is to try to find periods to the pulsation in these stars so theorists can better understand their internal structure.

## Data

- All of our data come from the All Sky Automated Survey for Supernovae (ASAS-SN)
- Observations are made in the visual (V) and blue (g) filters
- We have researched 16 different PPNe
- Most of our data date from 2016 to present.

## Data Analysis

- To analyze our PPNe we plotted brightness versus time as light curves.
- Periods in our light curves were determined using Period04, which uses the fourier transformation to find most likely periodicities in the data.
- Period04 fits sine curves to the data and can continue to superimpose more sine curves for a better fit.
- We use a signal to noise ratio of 4 to determine if the periods are significant.

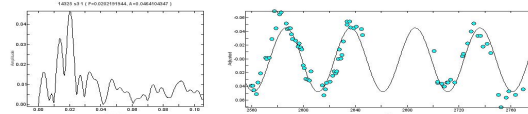


Figure 3: A frequency spectrum (left) with its primary frequency fit to one season of a light curve (right)

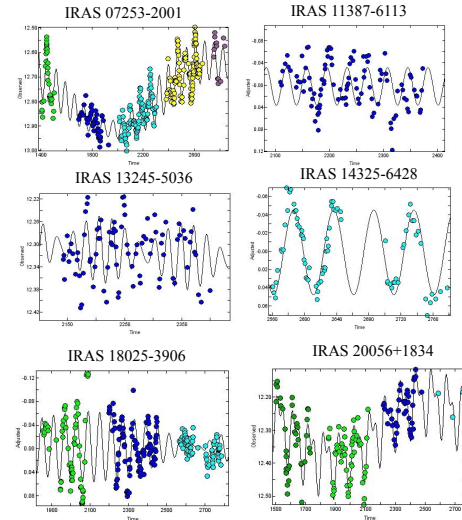
## Results

IRAS ID	Periods (days)	P2/P1	Comments
07253-2001	72.7 (0.1), 68.4 (0.2)	0.94	Plus longer period of 4.4 years.
11387-6113	37.4 (0.1)	-	
13245-5036	23.9 (0.1), 20.6 (0.1)	0.86	Linear decrease in brightness.
14325-6428	51.3 (0.2)	-	
18025-3906	58.7 (0.2), 55.6 (0.1)	0.95	
20056+1834	103.0 (0.3), 51.6 (0.1)	0.50	Plus longer period of 3.9 years.

- We found periods for 6 out of 8 PPNe analyzed thus far.
- Pulsation periods range from 21 to 103 days.
- Longer periods of multiple years may indicate a companion star.
- Good light curve fits were obtained (see Fig. 4).

## Light Curves

Below are the sine curve fits from Period04. Different colors indicate different years of observation; the same color indicates that all of the observations date from a single year. The data are fitted by 1 or more periods.



## References

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