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LUMINOSITY VARIATIONS IN POST-AGB STARS

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ABSTRACT

We have measured the variations in luminosity of several known Post-AGB stars (as well as several candidates) relative to nearby non-variable stars. The typical behavior of these variations is described and an attempt is made to discern their periodicity, if any such periodicity exists. Luminosity variations were found to be on the order of a few hundredths to a few tenths of a magnitude for the stars that were surveyed, with occasional fluctuations of up to a magnitude. The variations tended to be color-independent, and occured on timescales ranging nearly continuously from a few days to more than a year. No clear periodic behavior was found in any star in our sample.

Subject headings: Stars: AGB and Post-AGB – Stars: variables: general – Methods: observational – Techniques: photometric

1. INTRODUCTION

There is a stage between the Asymptotic Giant Branch (AGB) and the Planetary Nebula (PN) phase of a star's life known as the Post-AGB (PAGB) phase. The Post-AGB phase, also known as the Pre-Planetary Nebula (PPN) phase, lasts for a few thousand years (Volk and Kwok 1988) and is less throughly understood than the other stages of stellar evolution.

Post-AGB stars consist of a central star surrounded by a shell of gas and dust. This arrangement produces a double-peaked spectral energy distribution, with one peak at visible or near-infrared wavelengths caused by the central star itself, and the other in the mid or far-infrared caused by the shell of cool dust that obscures the star (Fujii et al. 2002).

Stars evolving along the Asymptotic Giant Branch suffer mass loss on the order of 10^{-7}-10^{-4} $M_{\odot}yr^{-1}$, and can eventually lose 50-70% of their original mass (Volk and Kwok 1988). This material forms a roughly spherically symmetric shell around the star. Once the atmosphere around the star is reduced to about 10^{-3} $M_{\odot}$, it becomes so disrupted that further mass loss becomes impossible (Volk and Kwok 1988). During this process the central star contracts and heats up. When mass loss is complete and the central star reaches $5\times10^{3}K$, the star leaves the AGB and enters the Post-AGB phase (**?**).

During the Post-AGB phase, the central star continues to heat up, though it does not yet reach the 3×10^{4} K necessary to ionize it's circumstellar envelope (Volk and Kwok 1988; Van Winckel 2003). The gas and dust that was ejected from the star during the AGB phase, no longer replenished by the central star, forms an expanding shell with the star at its center. Although initially roughly spherically symmetric, high velocity winds emitted from the central star's poles alter the shell's morphology until it becomes axially symmetric (Volk and Kwok 1988). Although it is not hot enough to ionize gas, the central star can scatter enough light from it's shell to produce a reflection nebula. These nebulae are optically thick at visible wavelengths, sometimes to the point that direct observation of the central star is impossible. Since the winds from the central star have scoured away the dust and gas in the polar regions of the circumstellar shell, visible light can escape into space in conical beams emanating from the poles. This leads to the hourglass shape of famous PPN's like the Egg Nebula (Volk and Kwok 1988). Light that is emmited away from the poles of the star is absorbed by the dust in the circumstellar envelope and re-emitted in the infrared, thus making Post-AGB stars very luminous in the infrared.

Eventually, the central star reaches the 3×10^{4} K necessary to produce enough ultraviolet radiation to ionize the surrounding envelope (Van Winckel 2003). The reflection nebula now becomes an emission nebula, and the PPN becomes a PN. This process must take less than 10^{4} years, or the density of the circumstellar envelope will have fallen below what is necessary to from a Planetary Nebula (Volk and Kwok 1988). When this occurs, the result is sometimes called a "Lazy Planetary Nebula".

One of the difficulties of researching Post-AGB stars is their relative scarcity. The whole Post-AGB phase lasts less than 10^{4} years (Volk and Kwok 1988), a minute fraction of the total lifetime of a star. Consequently, the chances that any given star just happens to be going through it's Post-AGB phase at this time is quite small. Additionally, radiation emitted by Post-AGB stars in the visible part of the spectrum is mostly absorbed by the star's circumstellar shell and then re-emitted in the infrared. This made the detection of Post-AGB stars difficult until the maturation of infrared astronomy and the beginning of space based observations with the launch of the Infrared Astronomical Satellite (IRAS) in 1983.

Variability in Post-AGB stars was first detected observationally in FG Sagittae in 1978 by C. A. Whitney (Whitney 1978). The luminosities of Post-AGB stars may vary in periodic or semi-periodic cycles. Stars evolving through the the Post-AGB phase cross the high-luminosity end of the popu-

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TABLE 1
STAR TABLE

Index	Star Name	Spectral	Typical Amplitude of Variation (ΔM)*				Variability Group	Comments
		Type	B	V	R	I	Number	
1	AAVSO 1742+50	F31b	0.11(.003)	0.07(.003)	0.04(.002)	0.06(.002)	1	
2	AG+10 909	F5Iab	0.71(.005)	0.16(.003)	0.10(.003)	0.60(.002)	2	Sharp peak, long period of variation
3	AI CMi	G5Iab	0.42(.002)	0.35(.002)	0.26(.002)	0.18(.003)	1	
4	ALS 5112	B1IIIpe	0.09(.018)	0.09(.006)	0.06(.002)	0.09(.004)	2	
5	ALS 10547	F3Ib	0.08(.007)	0.03(.012)	0.03(.005)	0.04(.003)	2	No variation seen outside of noise
6	BD-11 4747	A3V	0.09(.010)	0.04(.007)	0.01(.008)	0.02(.006)	3	No variation seen outside of noise in R and I filters
7	BD-18 2290	F6Ib/II	0.15(.002)	0.11(.002)	0.05(.002)	0.07(.002)	2	
8	CCDM J20113		0.14(.010)	0.03(.005)	0.02(.005)	0.01(.005)	2	
9	CW Leo		N/A	N/A	0.03(.012)	1.93(.004)	1	Long period, decreasing amplitude, increasing slope
10	DO 41288		0.11(.007)	0.07(.010)	0.03(.017)	0.06(.032)	2	
11	Frosty Leo		0.17(.012)	0.06(.005)	0.03(.005)	0.05(.005)	2	
12	GLMP 74	G0Ia	0.06(.015)	0.06(.004)	0.03(.005)	0.05(.004)	2	
13	GLMP 117	G	0.06(.008)	0.07(.006)	0.04(.006)	0.07(.006)	3	little variation outside of noise, increasing slope
14	GLMP 182**		0.16(.004)	0.05(.003)	0.01(.004)	0.02(.006)	3	Decreasing slope
15	GLMP 192		0.18(.003)	0.12(.004)	0.06(.003)	0.12(.004)	1	Clear minimum, long period of variation
16	GLMP 669	Ge	0.05(.015)	0.03(.099)	0.02(.098)	0.04(.105)	3	
17	GLMP 963		0.25(.006)	0.31(.003)	0.15(.003)	0.25(.002)	2	
18	GLMP 1012		0.10(.011)	0.07(.004)	0.04(.003)	0.06(.003)	3	
19	GLMP 1013		0.06(.021)	0.05(.010)	0.03(.007)	0.04(.006)	3	
20	GLMP 1044		N/A	0.58(.013)	0.01(.008)	0.02(.005)	2	
21	GLMP 1078	G2Ia	0.17(.043)	0.06(.048)	0.04(.062)	0.09(.116)	3	
22	HD 335675	F5	0.11(.006)	0.08(.005)	0.04(.004)	0.05(.005)	2	Minimum, long period of variation, but large errors
23	V354 Lac	G5Ia	0.34(.006)	0.25(.003)	0.13(.005)	0.22(.005)	2	Extreme short period variation
24	V1302 Aql**	F8Ia	0.11(.008)	0.37(.005)	0.05(.004)	0.09(.008)	2	Long period
25	V1427 Aql	G5Ia	0.10(.004)	0.06(.005)	0.03(.006)	0.04(.004)	1	Increasing slope
26	V2324 Cyg	Fe	0.07(.004)	0.04(.003)	0.03(.003)	0.04(.003)	2	
27	V5112 Sgr	F2/F3Iab	0.09(.003)	0.07(.003)	0.04(.003)	0.03(.003)	2	

*Error values for a typical single observation are given in parentheses
**Note that GLMP 182 and V1302 Aql have recently been reclassified as red giants, and are no longer candidates for Post-AGB status

lation II Cepheid Instability Strip (Zalewski 1993; Volk and Kwok 1988; Van Winckel 2003), and several RV Tauri variable stars are thought to be Post-AGB stars (Volk and Kwok 1988).

An extensive search by Garcia-Lario et. al. (1997) identified a number of objects within the IRAS database as early Post-AGB stars (still obscured by thick circumstellar envelopes) and highly evolved Post-AGB stars that show little or none of the infrared excess that would be created by the presence of a circumstellar shell. The stars that we observed consisted of a subset of the Garcia-Lario et. al. (1997) Post-AGB stars. The subset consisted of stars that were listed as Post-AGB stars in SIMBAD and had declinations greater than the -30 degree limit imposed by the latitudes of the SARA and ETSU observatories.

2. OBSERVATIONS

Most of our data were taken with the SARA 0.9m telescope at Kitt Peak National Observatory in Tucson, Arizona, using either an Apogee Alta U42, U55, or AP7 CCD camera. The remainder was taken using an ST-9 camera mounted on the 14" Schmidt Cassegrain telescope at the Harry D. Powell Observatory on the grounds of East Tennessee State University in Johnson City, Tennessee. Whenever possible, data were taken with B,V,R, and I filters, but the low luminosity of some sources occasionally prevented us from procuring usable data with the B or V filters.

After bias, dark, and flat calibration, the difference in magnitude between each Post-AGB star and a nearby nonvariable comparison star was calculated for each CCD image using the MIRA software package. Since the comparison star's absolute magnitude does not change over time, the differential magnitude obtained in this process can be used to measure the variations in the Post-AGB star's luminosity with time.

The current data set spans a period of three and a half years, starting in the fall of 2003 and ending in the early summer of 2007. Unfortunately, many of the stars that were surveyed lie in the plane of the galaxy and were sometimes too low in the southern sky to be observed from the mid-northern latitudes from which we took our data. This led to large gaps in the data for several stars.

A SCARGLE based algorithm was used to generate power spectra for each of the stars' light curves in order to search for any periodicity in the stars' luminosity variations. No clear indication of periodicity was detected in any of the stars discussed here.

3. DISCUSSION

The majority of the stars that were observed exhibited some sign of variability. Typical amplitudes for ΔM varied from a few hundredths to a few tenths of a magnitude, though variations of up to a magnitude did occur on occasion (see Table 1). The time scale of these variations spanned everything from a few days to on the order of a year. It is possible that these variations result from radial pulsations of the central star, small scale mass loss events, thermal fluctuations on the star's surface due to the presence of convection cells, or intermittent obscurations of the central star by the circumstellar envelope. Little color dependence was detected, with amplitudes in B,V,R, and I typically the same in magnitude. Our errors, which were mainly simple photon noise, tended to be on the order of a few millimagnitudes for a single observation.

After studying the stars' light curves we assigned the stars a variability number corresponding to the type of luminosity variations that were seen. Group one consisted of stars that showed clear long term variations with possible intermittent periodicity. A good example of a star from this group is AI CMi (Figure 1). Group two consisted of stars that had short term variations in magnitude with no clear periodicity. V354 Lac (Figure 2) is one such star. The majority of the stars

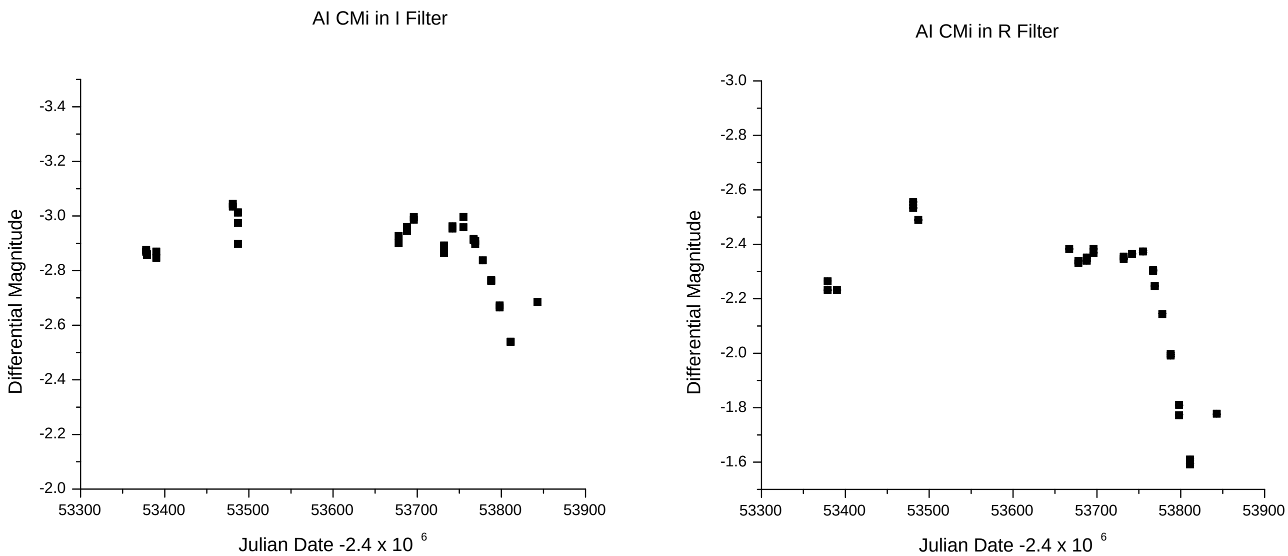

FIG. 1.— R and I filter light curves for AI CMi showing long term, large-scale magnitude variations.

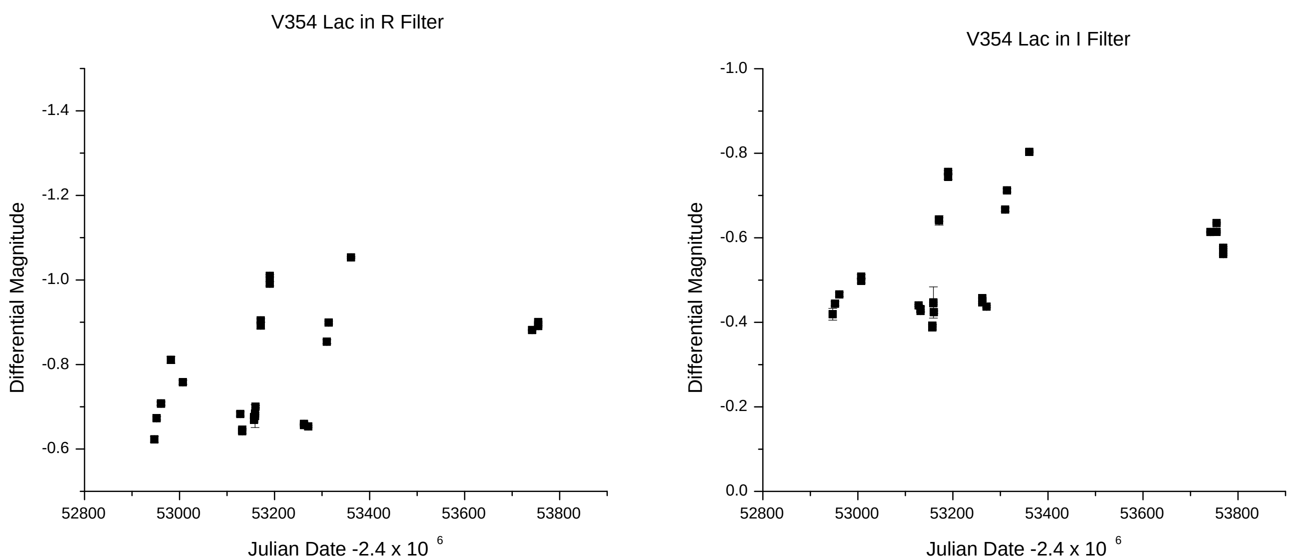

FIG. 2.— R and I filter light curves for V354 Lac showing short term, medium-scale magnitude variations.

that were observed fell into this group. Group three consisted of stars that showed no variation outside of noise. Figure 3 shows *R* and *I* filter light curves for BD-11 4747, which is a typical group three star.

Table 1 shows each star's name, it's spectral type (if currently known), typical values for ΔM for that star in B, V, R, and I filters (with the typical single observation error values in parentheses), the variability group number that the star was assigned, and any additional comments that might apply. It should be noted that two of the stars that appear in Table 1, GLMP 182 and V1302 Aql, have recently been reclassified as red giants and are no longer candidates for Post-AGB status.

4. ACKNOWLEDGMENTS

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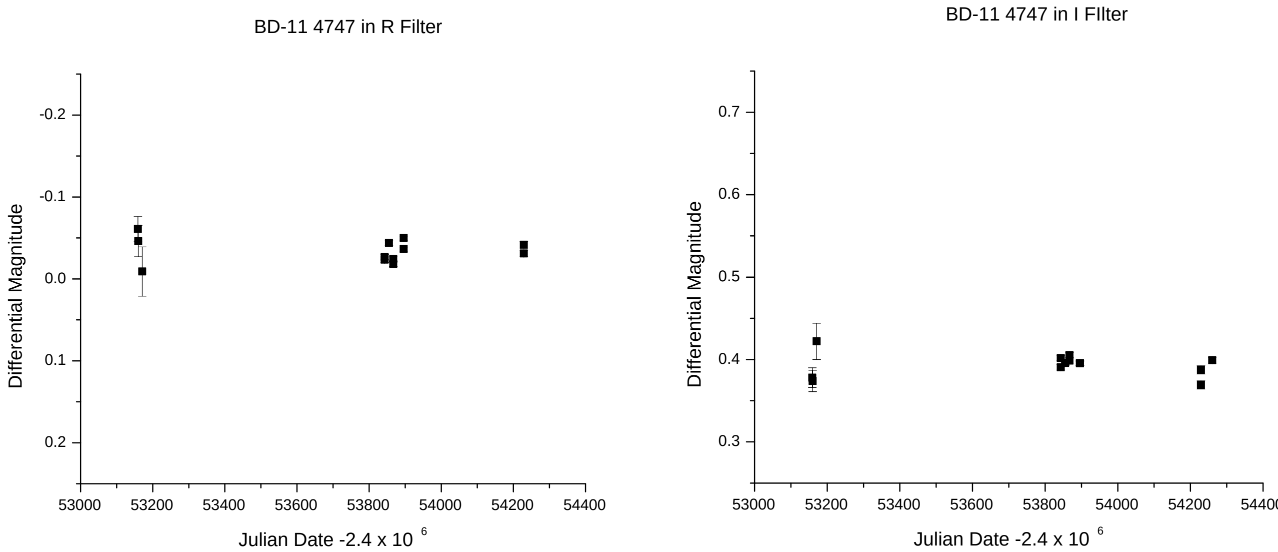

FIG. 3.— R and I filter light curves for BD-11 4747 showing little sign of variation outside of noise effects.

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