Principal Component Analysis of LMC RR Lyraes

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ABSTRACT

We present a Principal Component Analysis (PCA) of 4000 RR Lyrae stars in a nearby galaxy, the Large Magellanic Cloud (LMC). The PCA method allows a much more efficient description of the non-linear structure of the light curves of these variable stars than existing Fourier methods. We also show that this sample of stars exhibit Period-Color properties that can be explained by a simple application of the Stefan Bolztmann law and a consideration of the relative location of the photosphere and the hydrogen ionization front (HIF). We briefly discuss the applications of these results.

INTRODUCTION

- RR Lyrae stars are intrinsically variable stars which vary in brightness with regular periods of the order of hours. This variation in brightness is called a light curve. Their period of oscillation is related to their absolute brightness.
- RR Lyrae stars are also the oldest objects in the Universe and knowledge of their age leads to constraints on the age of the Universe.
- Thus knowledge of the absolute brightness of RR Lyraes leads to information about both their distance from Earth and their age - both are vitally important to know in order to discriminate between different theories about the origin, structure and fate of our Universe.
- The absolute brightness of RR Lyraes is related to the non-linear structure of their light curves.
- It is important to have accurate, efficient measures of this non-linear structure.
- Previous methods for quantifying the non-linear structure of RR Lyrae light curves use Fourier decomposition ie., the light curve is written as

$$V = A_0 + \sum_{k=1}^{kk=N} A_k sin(k\omega t + \phi_k),$$

where A_0 is the mean brightness, A_k, ϕ_k are the amplitudes and phases of the harmonics respectively.

- Typically, N is of the order of 6, so that 17 parameters are needed to describe the non-linear structure. Further the different A_k are all correltaed with each other.

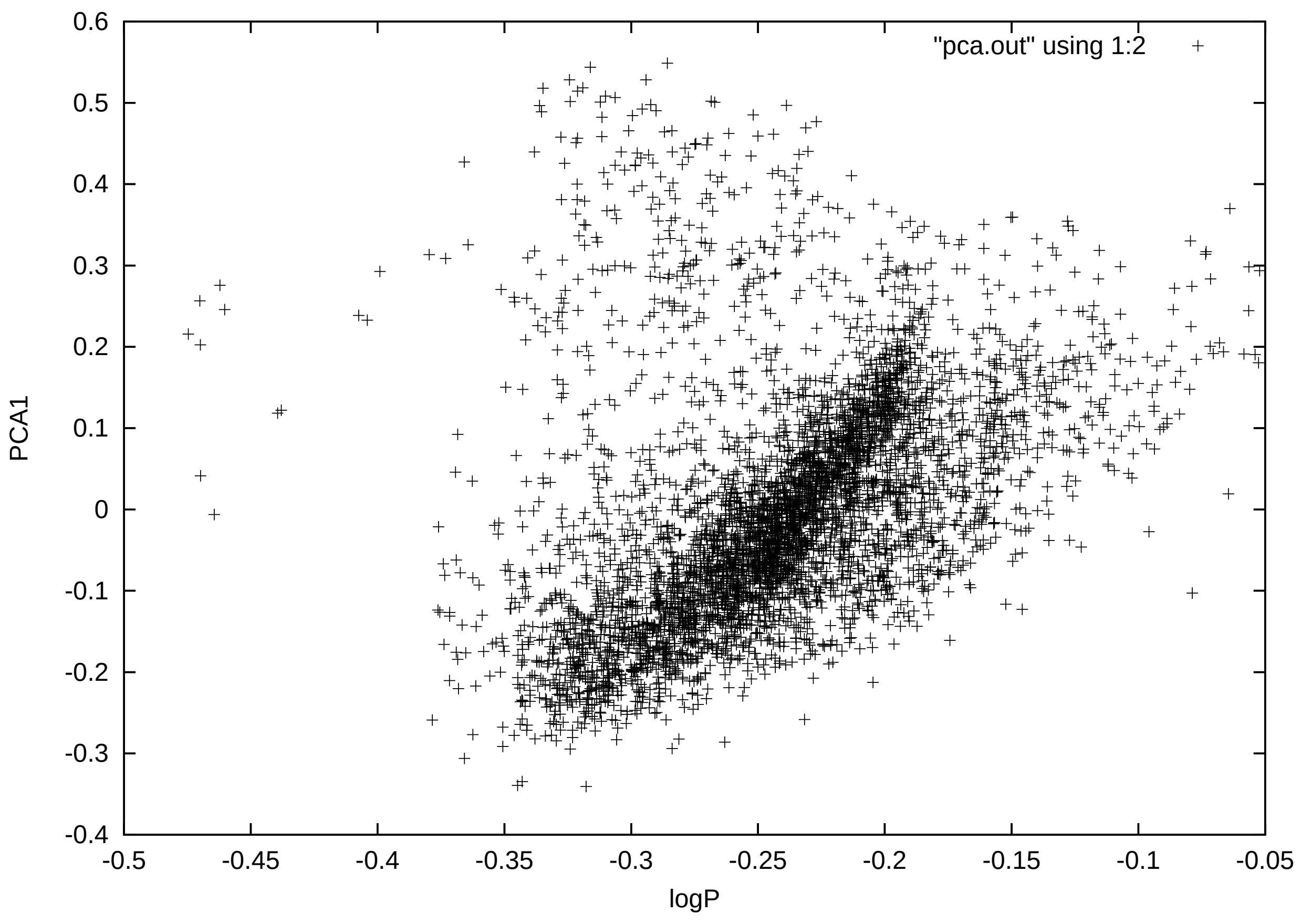

Figure 1 – LMC PL (top) and PC (bottom) Relations.

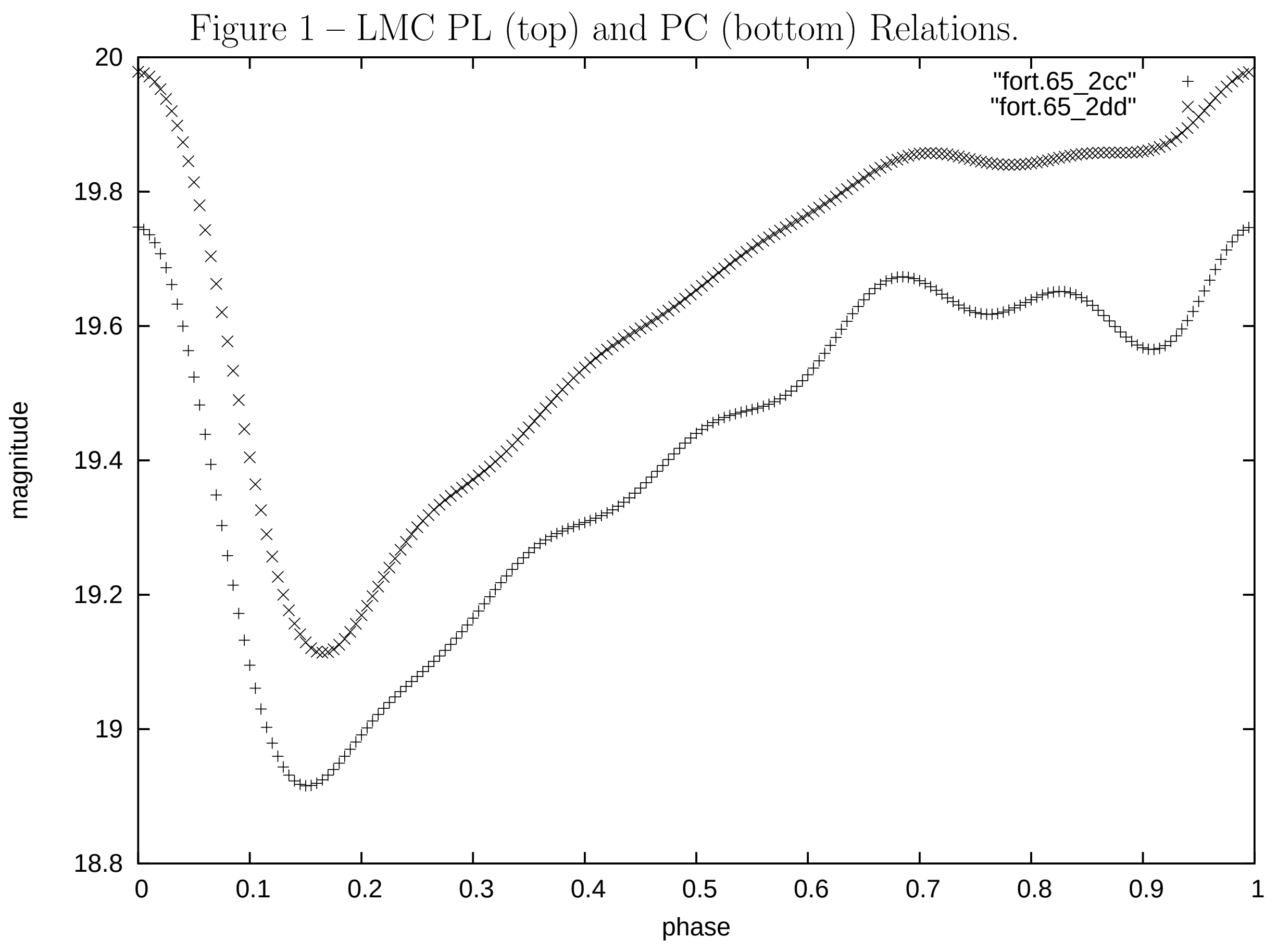

Figure 2 – The "distance" to the hydrogen ionization front.

PRINCIPAL COMPONENT ANALYSIS

- PCA is a method of reducing the dimensionality of the dataset. We write each light curve as a sum of "elementary" light curves, $V = \Sigma_{i=1}^{N}(PCi.L_i(t))$.
- Here PC_i is the i^{th} PC coefficient and $L_i(t)$ is the i^{th} elementary light curve.
- Here with N equal to about 4, we can explain more than 99.9% of the light curve variation. Further, each Principal Component is orhtogonal to other componenst and hence carry independent information.
- Both the PC's and elementary light curves $L_i(t)$ are determined from the data.
- Figure 1 displays the first Principal Component, PC_1, plotted against log period.
- We see a well defined "feather" with some "outliers". Of interest is how the light curve changes in going from the feather to the outlier regions.

CONCLUSION

- Either side has greater amplitude than feather.
- Above feather the amplitude is less. Below feather amplitude is greater.
- Stars lower in the feather have a greater amplitude.
- Figure 2 displays some sample light curves "in and outside" the feather.
- Higher amplitude means redder color at maximum light.
- This can be understood by a simple application of the Stefan Bolztmann law and the interaction of the photosphere and the hydrogen ionization front (HIF) as outlined in Kanbur and Fernando (2005).
- These results are applicable in the RR Lyrae Oosterhoff dichotomy.
- And in developing estimates of the age of the Universe.

ACKNOWLEDGEMENT: GAF would like to acknowledge SCAC for their grant contribution to the project. SMK would like to acknowledge HST grant HST-AR-10673.

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