Pulsation Properties of Hydrodynamic Models with Dimensional Analysis

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Abstract

We demonstrate that the dimension deduced from time series data of hydrodynamic models for chaotic pulsation is a function of luminosity. The dimension is proposed as a good quantity to guess stellar parameters and the physics of stellar envelopes like as the pulsation periods and light curve shapes used for regular variables.

1. Introduction

The dimensional analysis has been applied to time-series data to find chaotic nature and the dimension of the system which generates the time- series data (Atmanspacher et al., 1990). The method may be applied to data generated in theoretical models as well as observational data. In this report, we shall apply the dimensional analysis based on Grassberger and Procaccia (1983) to the data generated from hydrodynamic models for post-AGB stars(Aikawa, 1991, 1992).

The hydrodynamic models are constructed for irregular pulsation with small amplitudes observed in yellow supergiant stars(e.g. 89 Her, HD161796). There is evidence that some of them are post-Asymptotic Giant Branch stars (see, a current review by Fernie, 1992). The stellar parameters for the models are: $M = 0.8M_{\odot}, Te = 6300K$, with the Pop II composition. The luminosity is varied with a range from $3500L_{\odot}$ to $7000L_{\odot}$ as a control parameter. This sequence has been examined intensively by Aikawa(1992). For lower luminosities, the models show regular pulsation, and, on the other hand, the models with higher luminosities show chaotic pulsation.

We apply the dimensional analysis of Grassberger and Procaccia (1983) to data of time variation of photospheric magnitude of irregular pulsation.

2. Dimensional Analysis

A periodic attractor has the dimension D=1 as the result of dimensional analysis, and a quasi-periodic oscillation with two incommensurable frequencies has D=2. The dimension thus may be an indicator on degree of complexity of oscillations (Moon, 1987). In accordance with Grassberger and Procaccia, we first construct a pseudo-phase space from time-series of photospheric magnitude. Then, we calculate the correlation function in embedding space with dimension m=2 to 8. We use the total

https://doi.org/10.1017/S0252921100117336 Published online by Cambridge University Press

number of 8000 points for the time-span of 8000 days for each model and the time delay for the pseudo-phase space is estimated from the value for which the autocorrelation function first passes through zero.

The result is summarized in Table 1 (Embedding dimension 8 is not sufficient to get good convergences for higher luminosities, and so they are marked with :). It demonstrates clearly that the dimension is a function of luminosity. The model $4985L_{\odot}$ is a regular oscillator just below the transition luminosity from regular to irregular pulsation in the present model sequence. The model $5000L_{\odot}$ is weakly chaotic, and other higher luminosity models have well-developed chaos.

Table 1

Correlatión Dimension	
model($L/L_{\odot}$)	dimension
4985	1.5
5000	2.4
5500	3.0
6000	5.2:
6500	5.5:

3. Conclusions

We demonstrate that the geometric dimension deduced from dimensional analysis to time-series data for hydrodynamic models may be an indicator on stellar parameters. We may apply the same method to observational data. Fortunately modern data by photoelectric photometry have been accumulated for 89 Her and HD 161796, and within a few years, we will have sufficient data for this purpose for these stars.

References:

Aikawa, T. 1991, Astrophys. J.,**374**,700.

Aikawa, T. 1992, submitted to Mon. Not. Roy. astr. Soc.

Atmanspacher, H., Scheingraber, H. and Voges, W., 1989, in: *Data Analysis of Astronomy III*, eds. Gesú, V. Di. et al., p3.

Grassberger, P. and Procaccia, I., 1983, Phys. Rev. Lett., **50**, 346.

Fernie, J.D., 1992, in :*Luminous High-latitude Stars*, (An International Workshop at CfA), in press.

Moon, F.C., 1987, *Chaotic Vibrations*, John & Sons: New York.