Chaos in Pulsating Variable Stars: Preliminary Analysis of Photometric Photometry and Observational Constraints of Detection

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Abstract

Chaos theory has been applied to a variety of variable stars, but few convincing candidates for chaos have been identified. Here, well-established analysis methods have been applied to some very extensive data sets of rapidly oscillating Ap (roAp) stars and one white dwarf. It it shown that in spite of the amount of data, the signal-to-noise ratio makes positive detection of chaos extremely difficult, especially due to scintillation noise. A new form of dimension computation is presented and discussed. Simple models were constructed to show what noise levels can be tolerated before the detection of chaos is no longer possible and comparisons are drawn with data that could be obtained in the future from space. The lack of phase and amplitude stability in HD 134214 and mode switching in HD217522 and HD 137949 are pointed out as the possible results of chaos, making frequent monitoring of roAp stars desirable.

1. Present and future hopes of detecting chaos

One of the best-established means of calculating a fractal dimension is via the method of Grasberger and Procaccia (1983). I propose here an alternative method of dimension calculation, which makes use of only the existing data, even with gaps. As remarked earlier by Theiler (1987), it is unnecessary to compute the correlation distance from every point to every other point to adequately estimate the correlation dimension. It has been possible to make use of this to get a good dimension estimate.

Experiments with artificial data show that for detecting chaos, S/N levels of 10^5 or 10^6 will be needed. Long, uninterrupted data sets are necessary and hence satellite data, e.g. PRISMA, offer the best promise.

The evidence of irregular periodicity in pulsating variables implies the possibility that chaos may be responsible. In particular, the roAp stars HD 137949 and HD 217522 have undergone mode switching. HD 134214 seems to be unstable both in period and phase over many years.

References:

Grasberger, P. and Procaccia, I., 1983, Phys. Rev. A, **28**, 2591.
Theiler, J., 1987, Phys. Rev. A, **36**, 4456.

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