A Model Oscillator of Irregular Stellar Variability

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Stellar pulsation is one of the condidates for strong mass loss from red giant stars. Recent investigations have shown sporadic outbursts of the pulsation can eject a considerable mass from the stars. Such a sporadic increase of the amplitudes seems to have a connection with the irregularity found in the pulsations. Recently the iregular propreties in stellar pulsation are investigated in the relation to nonlinear dynamics(see for instance Perdang, 1985). Unfortunately no single model oscillator of a star of which the equilibrium state is dynamically stable had been found. In the present paper, we shall discuss a simple oscillator which shows period-doubling and chaotic, that is, irregular oscillations.

We consider a model oscillator as

$$dx/dt = y, \quad dy/dt = Ax+z+my,$$
$$dz/dt = -Bdx/dt-pz-qy+syz \,, \qquad (1)$$

where x, y and z are the displacement from an equilibrium state, the velocity and additional forces defined by the thierd equation, respectively. The coefficients, A, B, m, p, q and s are constants. When m, p, q and s equal zero, the system of the equations shows an adiabatic oscillation for $B > A$. We restrict ourselves for the case of dynamical stability as $B-A+q-mp > 0$.

When the system is pulsationally unstable and in secular stabitlity, we can have the period two limit cycles and succeeding period-doubling for the change of p. The values of the parameters are, for instance, as follows:

i) $A=-0.5$, $B=0.5$, $m=0.5$, $q=0.5$, $s=1$, $p=3$,
ii) $A=4$, $B=5$, $m=-0.5$, $q=-0.7$, $s=5$, $p=-0.06$,

where the values of p are given at the period two limit cycles. For the case of i) where it is convenient to compare with the Rossler equation (1966), we have the period-doubling as the increase of p.

For ii), the system of equations is rewritten in the equivalent form as follows:

$$dx/dt = y, \quad dy/dt = Ax+z,$$
$$dz/dt = -By+ax+bz+(n_0+n_1z+n_2y)y, \qquad (2)$$

which corresponds to the equations derived from the one-zone model for stellar pulsation (Baker, 1966). We find that the limit cycles of equation (2) corresponding to that of equation (1) appear and chaos occurs again for the change of b.

The detailed results will be published in Tanaka and Takeuti (1987). The results show that the system of equations with nonlinear nonadiabatic terms behaves as a simple oscillator which produces irregular and chaotic oscillations.

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