Progress in coronal seismology

B. Roberts
Mathematical Institute, University of St Andrews, St Andrews, Fife KY16 9SS, Scotland, UK
email: bernie@mcs.st-and.ac.uk

Abstract. Coronal seismology is now a well developed area of solar physics, even though many questions remain for resolution. Here we take stock of the progress made since the first direct imaging of oscillating loops was achieved through TRACE spacecraft observations in 1999.

Keywords. Sun: oscillations, MHD waves, coronal seismology

1. Introduction

Coronal seismology is a marriage of theory and observations with the aim of producing a detailed knowledge of physical parameters in the corona. It aims to estimate such quantities as the magnetic field strength in a coronal loop, the width of the loop and the steepness of its density or magnetic field profile across the loop, or the longitudinal density scale height along the loop. Also, it offers the prospect of determining the thermal, viscous or ohmic damping coefficients of the coronal plasma. All these quantities are difficult to obtain by direct measurement, so coronal seismology offers an important way of progressing in their determination. The subject exploits observations of coronal oscillations by matching such observations to predicted theoretical results derived for a model loop. The same ideas may be applied elsewhere in the solar atmosphere, including the photosphere or chromosphere and in prominences, and indeed in stellar atmospheres.

The seismology we describe is based upon a magnetohydrodynamic description of the plasma. So, although there are natural similarities with helioseismology there are also significant differences: helioseismology is in the main built upon the behaviour of a single wave, the sound wave, whereas magnetohydrodynamic (MHD) seismology in principle draws on the properties of three waves – the slow and fast magnetoacoustic waves and the Alfvén wave.

It is of interest to examine how coronal seismology began. Uchida (1970), exploring theoretically the behaviour of fast waves in a complex magnetic field for the purpose of explaining observed Moreton waves, suggested that when combined with a knowledge of the density distribution in a stratified corona this work could be exploited to obtain a “seismological diagnosis” of the distribution of magnetic field in the corona. This provides a global estimate of a mean coronal atmosphere (see also Uchida 1968, 1973, 1974). A recent discussion of global coronal seismology is given in Ballai, Erdélyi & Pintér (2005).

The suggestion that oscillations could be used as a means of local coronal seismology was made in Roberts, Edwin & Benz (1984), independently of the work of Uchida. Exploiting the theory of oscillations of a magnetic flux tube embedded in a magnetised atmosphere (Edwin & Roberts 1983), Roberts, Edwin & Benz (1984) suggested that “magnetoacoustic oscillations provide a potentially useful diagnostic tool for determining physical conditions in the inhomogeneous corona”. The authors commented that the combination of theory and observations provides “a valuable diagnostic tool for in situ conditions in the corona”, allowing determinations of the local Alfvén speed and spatial dimension of the coronal inhomogeneity that forms a loop.