Gregory proposed that increased heating, due to enhanced UV radiation around solar maximum, is most effective in the summer tropics and hemisphere. The meridional flow from summer to winter hemispheres is enhanced, and the solar modulation is thus transferred via Coriolis torque into the winter circulation, itself inherently variable. Other work[8,9] shows that this effect is detectable in the winter stratosphere and troposphere.

The third paper involves long-wave radiation. G. Reid and K. Gage (NOAA) have extended their work[10] on the annual variation of the height of the tropical tropopause to model an 11 yr variation, with change in solar 'constant' as a key factor. They showed that there is considerable sensitivity of that height to mean sea surface temperatures, via absolute humidity and deep cumulus convention. To establish agreement with observations, an increase in the solar 'constant' on the 11 yr basis is required. Reid reminded listeners that the decreases so far observed, of a few tenths of 1 per cent, are for shorter periods, and that the change in solar irradiance over the 11 yr cycle is not yet established.

The symposium heard substantial papers on the variations of solar input to the atmosphere, induced effects in the upper atmosphere, responses of climate models to solar perturbations and also many papers on short-term effects and favoured mechanisms. These will appear in the proceedings. Special mention may be made of a survey by M. Nicolet (Pennsylvania State University) of photochemical responses affecting ozone: this comprehensive study will be a valuable reference source. □

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A new type of pulsating star

from John P. Cox

A NEW type of pulsating star has been found by astronomers at the McDonald Observatory in Texas. The newly discovered variable star, known as GD358, is unique in that it is the first variable star to have been predicted as variable before its discovery[1,2].

The discovery, made by D.E. Winget, E.L. Robinson, R.E. Nather and G. Fontaine, was announced at the recent conference on 'Pulsations in Classical and Cataclysmic Variable Stars' held in Boulder, Colorado[3]. A more detailed account will be published soon in the *Astrophysical Journal.*

The new variable star is a kind of white dwarf — a DB white dwarf — whose outermost layers are composed of nearly pure helium. The surface temperature of GD358 is probably close to 30,000K. Several periods have been observed in GD358, ranging from a little more than 2 minutes up to about 16 minutes.

White dwarfs are extremely dense stars, with a mass equal to about that of the Sun and a radius comparable with the Earth's. Hence their densities are quite large — some 10^6 times the density of water — and their surface gravities approximately 10^5 times that of the Earth. White dwarfs are thought to represent the end stages in the evolution of at least certain kinds of stars. Consequently, the interiors of the white dwarfs are likely to be devoid of hydrogen and, in most cases, of helium also. The hydrogen and helium often observed on the surfaces of white dwarfs is thought to be present only in thin 'films' formed when these lighter elements float to the surface under the influence of the strong gravitational field. In contrast, in most ordinary stars, the hydrogen and helium is believed to be distributed fairly uniformly throughout the interior.

The DB white dwarfs comprise only a small fraction, some 10 per cent, of all white dwarfs. Most, perhaps 80 per cent, have predominantly hydrogen in their outermost layers, and are called DA white dwarfs.

In the past decade or so, a number of variable DA white dwarfs have been found[4]. All have surface temperatures in the range 10,000–12,000K and are called 'ZZ Ceti' stars. Their periods range from about 2 to 20 minutes. The pulsations are thought to be nonradial, with different parts of the stellar surface moving out of phase with each other. The variable DA white dwarfs are thought to be ordinary DA white dwarfs which have slowly evolved into a condition where they pulsate for a time, perhaps a few million years — like temporary 'sickness' — and then become ordinary, nonvariable DA white dwarfs again.

Although less than 20 ZZ Ceti stars are known, they are probably by far the most numerous kind of variable star in the Galaxy, in large part because white dwarfs themselves are so numerous (perhaps 10 per cent of all stars in the Galaxy). The variable DB white dwarfs may turn out to be the second most numerous kind of variable star in the Galaxy.

The new discovery is particularly significant because it confirms many of our ideas regarding stellar pulsation and its causes in general, and variable white dwarfs in particular. By applying pulsation theory to certain details of the observed period structures, it is possible to infer, for example, the rotation periods of the white dwarfs of interest, something that has been difficult to do by other methods. This has now been done for several variable white dwarfs. For the GD358 the method yields a rotation period of about 1.5 hours, which is quite representative of periods for white dwarfs whose rotations have been studied.

By applying pulsation theory to other aspects of variable white dwarfs, it is possible to study their internal structure in much the same way geophysicists use seismic waves to study the interior of the Earth. For example, that only certain periods are present in the variable white dwarfs strongly suggests that the outer regions have a layered structure — the thin hydrogen and/or helium layers can 'trap' certain pulsation modes[5]. The layered structure had previously been inferred on the basis of other elements of stellar evolution theory[6]. Since nearly all DA white dwarfs are expected to go through a variable phase sometime in their evolution, the layered structure is probably found in white dwarfs in general.

Similarly, it should be possible in the future to use the pulsations of GD358 to infer something about the interiors of the DB white dwarfs. It is interesting that the 'driving agent' for the pulsations of the DB white dwarfs is second helium ionization, as is thought to be mainly responsible for pulsations in the classical Cepheids. On the other hand, the same theory that led to the prediction that GD358 should be variable has identified the main physical cause of the pulsations of the ZZ Ceti stars as hydrogen ionization[1-3,7,8]. This is the same physical agent that is believed to be mainly (or at least largely) responsible for the pulsations of the Mira variables[9], among the largest stars known. □

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