BIG SCIENCE WITH 2-m CLASS TELESCOPES IN A GLOBAL NETWORK

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НОВЫЕ ГОРИЗОНТЫ ДЛЯ 2-МЕТРОВЫХ ТЕЛЕСКОПОВ В ГЛОБАЛЬНОЙ СЕТИ, Хатцес А. П., Мкртичян Д. Е. – Астросейсмология и поиск внесолнечных планет – это два исследовательских направления, требующих значительных ресурсов наблюдательного времени, которое сложно получить на телескопах с большими апертурами. На малых же телескопах класса 2-метровых предоставляется достаточное количество наблюдательного времени, к тому же с более гибким расписанием. Используя несколько таких телескопов в глобальной сети, можно существенно продвинуться вперед в исследованиях по названным направлениям. В данной статье мы представляем некоторые результаты, полученные на 2-м телескопах по программам высокоточного измерения радиальных скоростей в задачах изучения внесолнечных планет и сейсмологии пульсирующих звезд. Также обсуждается возможный вклад глобальной сети 2-м телескопов в решение этих задач.

Asteroseismology and the search for extrasolar planets are two fields of research which require considerable telescope resources that are difficult to obtain on large aperture telescopes. Small, 2-m class telescopes provide substantial amount of time resources with more flexible scheduling. Using several of these facilities in a global network can make significant contributions to both of these fields. We present some results of precise radial velocity programs on extra-solar planets studies and seismology of pulsating stars obtained on 2-m class telescopes and discuss the scientific impact of a probable Global Network of 2-m class telescopes for these studies.

INTRODUCTION

To date there are about ten telescopes in operation throughout the world with apertures greater than 8 m. Although these facilities are producing exciting results in observational astrophysics, they have not eliminated the need for 2–3-m class telescopes. Scientific programs requiring large amounts of telescope time are best suited for small telescopes as time on the larger facilities is expensive and over-subscribed. Two scientific programs that are ideal for small telescopes are radial velocity searches for extrasolar planets and investigations of pulsating stars. We present here observations of extra-solar planets and pulsating stars taken with high-resolution spectrographs that demonstrate the capabilities of small telescopes. When organized into a global network small telescopes can have a major scientific impact and provide scientific results that are not possible on large telescopes.

2-m TELESCOPES IN A GLOBAL NETWORK

Two-meter class telescopes have a distinct advantages over 8–10 m class telescopes in that they can more easily (and inexpensively) be organized into a global network well distributed in longitude. This can provide continuous coverage of target objects which is important for studies of pulsating stars in order to remove the one day alias present in data from one site. The extended coverage is also essential to resolve the fine splitting of modes necessary to yield information about the stellar structure.

The map in Fig. 1 shows the world-wide distribution of potential 2-m class telescopes equipped with high-resolution ($R \approx 60\,000$) spectrographs that can be used for extended RV studies of pulsating stars. Such a network can also have a major impact in extra-solar planet studies and other fields that require time-resolved or synoptic studies (*e.g.*, Doppler imaging studies of spotted stars).

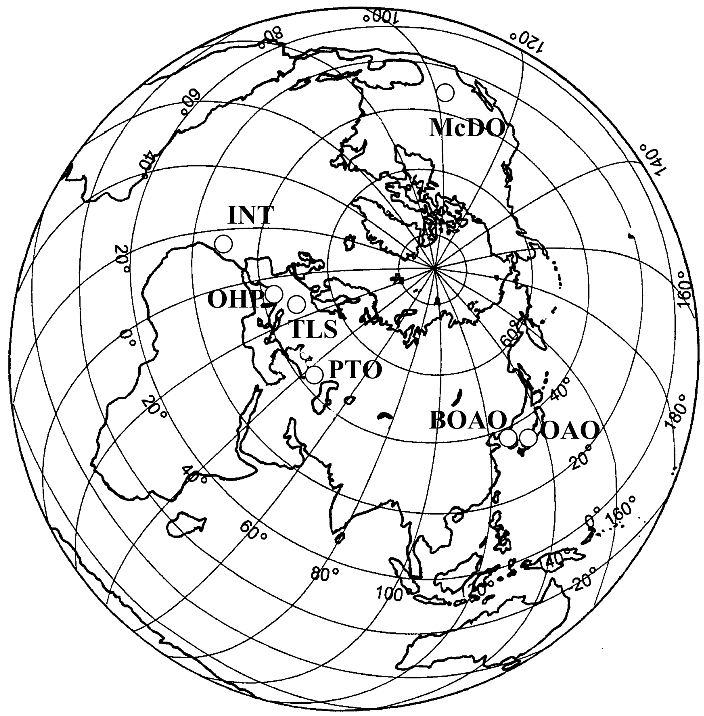

Figure 1. The location of 2-m class telescopes throughout the world that are equipped with high resolution spectrographs that could participate in a global network. McDO: the McDonald Observatory, Texas, USA; INT: the Isaac Newton Group of Telescopes, La Palma; OHP: Observatoir Haut Provence, France; TLS: Thüringer Landessternwarte, Germany; PTO: the Terskol Observatory, Russia; BOAO: the Bohyunsan Optical Astronomy Observatory; OAO: the Okayama Astronomical Observatory, Japan

PRECISE RADIAL VELOCITIES WITH AN IODINE GAS CELL

Many programs require the precise measurements of relative stellar radial velocities (RV). An iodine gas absorption cell is a convenient and inexpensive means of converting any high resolution spectrograph into precise radial velocity instrument. The cell when placed in the optical light path produces a set of iodine absorption lines that are superimposed on the stellar spectrum (see Fig. 2). The velocity shifts of the star are measured with respect to the fixed pattern of the iodine spectrum which minimizes instrumental shifts. This technique is capable of achieving an RV precision of 3 m/s, *even for spectrographs that were not designed to achieve such RV precision.*

SEARCHES FOR EXTRA-SOLAR PLANETS

The existence of giant planets in orbit around other stars is undoubtedly one of the more important astronomical discoveries of the past decade. Most of these discoveries were made with 2–3-m class telescopes (see review by Marcy & Butler [4]). Fig. 3 shows radial velocity measurements for two known extrasolar planets made with the TLS 2-m telescope + echelle spectrograph ($R = 67\,000$). The TLS echelle spectrograph+iodine cell can achieve an RV precision of 2–3 m/s. When the spectrograph was constructed it was not envisioned that such high precision RV measurements would be made with it. The fact that it is capable of making state-of-the-art RV measurements is a testament to the wavelength stability provided by the iodine absorption cell.

PULSATING K GIANT STARS

The K giant stars are a new class of multi-periodic variable stars that vary on timescales of days to hundreds of days [1, 2]. The long period variations are due either to surface features, pulsations, or planetary companions, although recent RV studies suggest that planetary companions may indeed be the cause of some long period variations found in these stars [6].

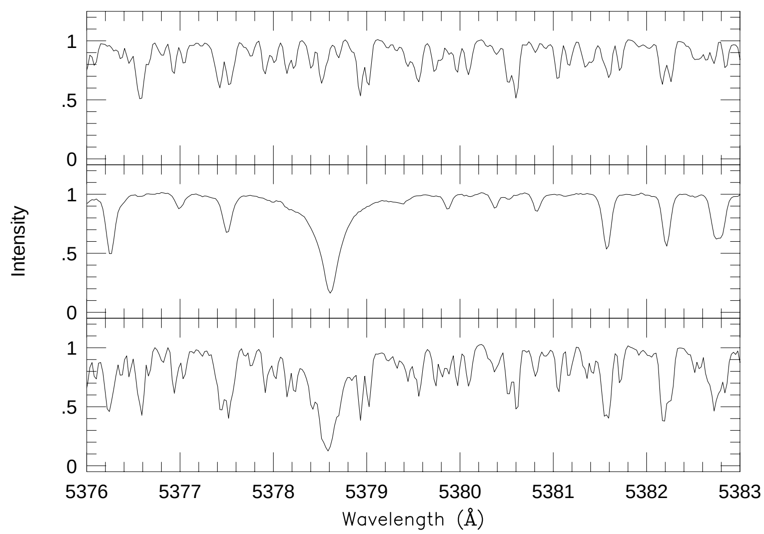

Figure 2. Spectrum of iodine gas (upper panel), spectrum of star (middle panel), spectrum of star through iodine gas (bottom panel)

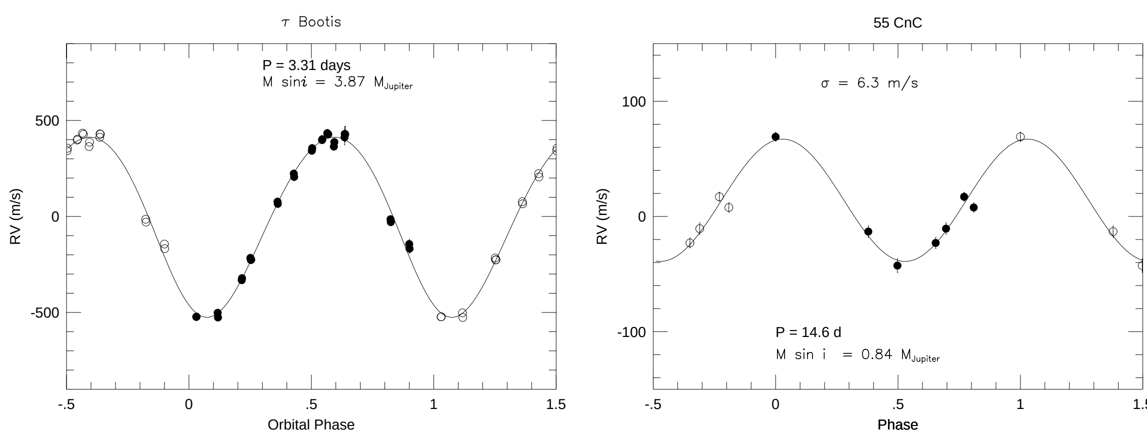

Figure 3. (Left) The radial velocity variations of τ Boo due to a 3.9 $M_{Jupiter}$ companion in a 3.3 day orbit. Open circles represent points that are replotted for another orbital cycle. (Right) The radial velocity variations of 55 Cnc due to a 0.84 $M_{Jupiter}$ companion in a 14.6 day orbit. The scatter about the orbital solution of these measurements taken with the TLS 2-m telescope is 6.3 m^{-1}

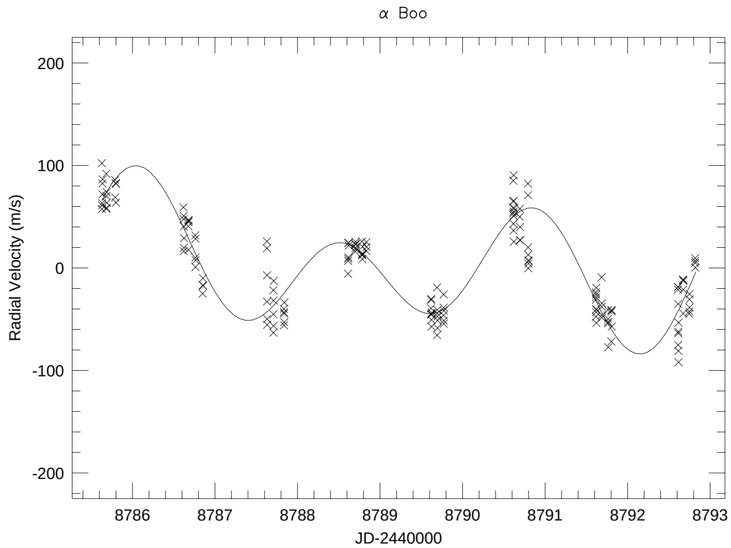

Figure 4. The multi-mode pulsations in Arcturus over eight consecutive nights based on data taken with the McDonald Observatory 2.1-m telescope. Crosses represent the data and the solid line represents a fit which is a sum of three periods: 2.46, 4.03, and 8.5 days

Fig. 4 shows short period variations of Arcturus (α Boo) taken over eight consecutive nights using the McDonald Observatory 2.1-m telescope and an iodine gas cell. The solid line represents a fit of three periods of 2.46, 4.03, and 8.5 days. So far 10 modes showing the equi-spaced frequency of p-modes have been found in this star [2, 5]. The solid lines in Fig. 5 represent modes found at the McDonald Observatory in several 7-night observing runs. In spite of these many nights of observations not all modes were detected. The dashed lines modes found by Merline [5] are based on many more nights of data. The multi-modes that are present in K-giants are ideal for asteroseismic studies, but the long periods and rich spectrum of modes requires large amounts of observing time with continuous monitoring. For instance the McDonald data detected different modes on each observing run. The study of oscillations in K giants, many of which are bright objects, is ideally suited to 2-m class telescopes equipped with high resolution spectrographs that can devote the many consecutive nights needed to find all modes.

RAPIDLY OSCILLATING Ap STARS

The rapidly-oscillating Ap (roAp) stars are a class of stars pulsating in p-modes with periods of 6–12 minutes. Spectral studies show that the RV behavior of these stars can be quite complex with individual spectral lines showing RV pulsational amplitudes that are factors of 10–100 times higher than most spectral lines [3]. Figure 6 shows the Fourier transform of RV measurements of the roAp star HD 134214 in seven spectral regions taken with the 2.1-m telescope at the McDonald Observatory + Sandiford Echelle spectrograph ($R = 50\,000$)+iodine cell. The dashed line denotes the position of the known pulsation period. The pulsation RV amplitude strongly varies with the spectral region.

These kinds of measurements are yielding valuable clues about the vertical structure to the pulsations in roAp stars. Figure 7 shows the RV variations for Nd II and Nd III lines in the roAp star 33 Lib taken with 2.7-m telescope at the McDonald Observatory. The two species oscillate out-of-phase with each other. Since Nd III is formed higher in the stellar atmosphere these data are evidence for a radial node in a standing acoustic wave in the stellar atmosphere.

The study of the vertical structure of pulsations in roAp stars requires the accurate determination of the phase and amplitude of individual spectral lines. These require a very long time sequence of observations. Furthermore, to remove the one day alias of one observing site that is needed to detect additional modes can only be done in a global network.

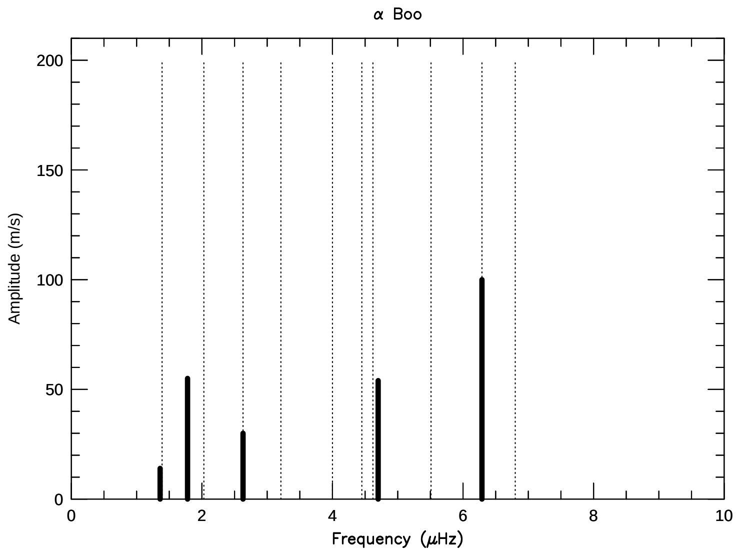

Figure 5. The schematic of pulsation frequency spectrum of Arcturus. Solid lines represents modes found at the McDonald Observatory (height indicates amplitude), dashed lines indicate the frequency (and not amplitude) of modes found by Merline [5]

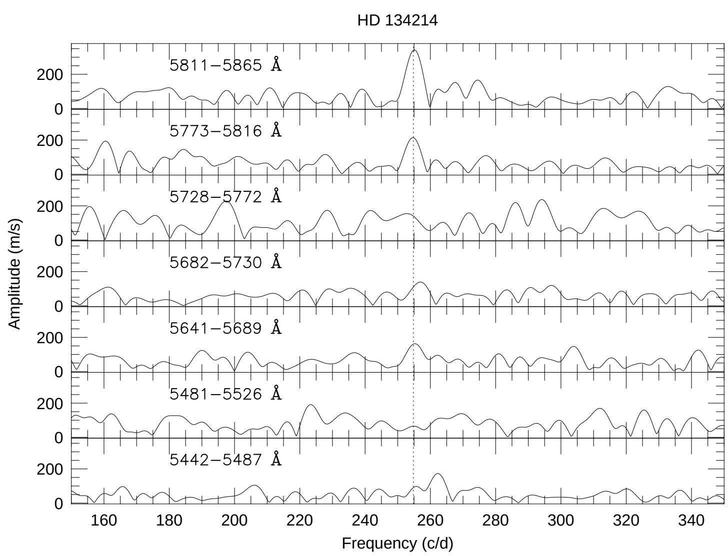

Figure 6. The DFT spectrum of RVs in HD 134214 in seven spectral regions. The dashed line marks the location of the photometric frequency. Note the different pulsational amplitude in each spectral region

CONCLUSION

The precise radial velocity measurements with a global network of 2-m class telescopes will have a great scientific impact on studies of extra-solar planets and seismology of different types of variable stars. For many of these programs the stars are bright, so a study with large telescopes is not justified. Furthermore, to make significant progress in these fields, particularly in asteroseismology, many tens of consecutive nights, often in coordinated multi-site campaigns are needed. This is simply not possible on the larger telescopes. The RV precision of few m/s needed to make the breakthroughs

Figure 7. The radial velocities of Nd II and Nd III lines in 33 Lib phased to the pulsational period. The two species are formed in different heights in the stellar atmosphere and indicate the presence of a radial node to the pulsations

in these exciting fields is made possible by the iodine cell technique. Any telescope equipped with a high resolution spectrograph can join in a multi-site campaign. In the near future there are several important space missions for the photometric study of extrasolar planets and pulsations (*e.g.*, MOST, COROT, Eddington, Kepler). A global network of 2-m telescopes for simultaneous ground-based spectroscopic studies can provide essential data for the interpretation of the results from these space missions.

The 2-m telescope of the Terskol Observatory of ICAMER which is located at the intermediate geographic longitude in the continent Eurasia is well suitable for participation in a global multi-site high-resolution spectroscopic campaign to provide data in a key longitude gap. We intend to install an iodine-cell in the coude-room of this telescope and to test it for typical RV accuracies during 2002/2003 season.

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