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Conclusions and future work

The field of exoplanet research is evolving at astonishing velocities since the first discovery of an exoplanet around a solar-like star, 51 Peg (Mayor & Queloz 1995). Among the different detection techniques, the transit method provides the strongest tool to date to measure physical parameters of these intriguing Hot Jupiters. Combined with the measurement of the radial velocity of the host star, it can yield the planetary density, which can provide clues about its formation history. The discovery of new transiting planets by ground and space projects in the next few years will certainly increase our knowledge of these objects. We are beginning to be able to perform comparative planetology, and new insights on the *real* mass distribution of these objects will be provided in the near future. The current situation has been compared by some authors to the state of the stellar evolution knowledge just before the first H-R diagram was built. With more than 150 exoplanets discovered to date, we are approaching the status in which the statistical studies on these objects begin to be meaningful.

7.1 Conclusions on exoplanet research

The conclusions of this work are summarized in the following points:

- We have discovered the first transiting planet detected by a wide-field telescope (STARE), TrES-1. It is orbiting a moderately active K0V star that shows no Lithium down to the detectable levels. The measured mass of 0.76±0.05 M_J and radius of $1.04^{+0.08}_{-0.05}$ R_J make this planet the second best known in terms of precision of its physical parameters. Contrary to the currently best studied exoplanet, HD 209458b, the radius of TrES-1 is well matched by models of planetary evolution under intense radiation of the host star. There is no need for an extra source of internal energy in the planet. Further work (Charbonneau et al. 2005) has allowed the detection of the secondary eclipse, which constitutes the first detection of thermal emission at 4.5 and 8 μm from an exoplanet. With this detection, the effective temperature of the planet is estimated in T_{eff}=1060±50 K, and the eccentricity is strongly constrained to a circular orbit ($e \cos w$=0.0030±0.0019).

- A detailed analysis of the different follow-up techniques needed to confirm or reject a planetary transit candidate has been performed, and a tentative chain of tests, ranging from the cheapest ones to the most expensive, in terms of telescope needs and effort, has been proposed. This consists of:
  - Careful interpretation of the light curve: search for out-of-eclipse modulation and transit shape fitting.
  - Low signal to noise radial velocity, to detect eclipsing stellar systems.
  - Multicolor transit photometry, aimed to the detection of triple systems.
  - Imaging with very high resolution, to resolve triple stellar systems (hierarchical or unbound).
  - High signal to noise radial velocities and bisector analysis, to finally measure the orbital reflex motion of the parent star, and thus the mass of the planet.

- A sample field of the TrES network in the constellation Lyra has been analyzed in detail, paying special attention to the follow-up observations of the 16 objects identified as transiting planet candidates. These resulted in the detection of 6 binary systems, 7 blended triple systems, 2 unsolved cases and the transiting planet TrES-1.

- The 2004 Venus transit has permitted the first detection of $^{12}CO_2$ and $^{13}CO_2$ traces in the atmosphere of the planet by the use of the *transit spectroscopy* technique. Further work will be devoted to interpret the obtained transmission spectra, and the preliminary measured dependance of the depths of the features as a function of the sampled Venusian latitude.

7.2 Conclusions on stellar variability

Several studies have been performed with the STARE data in the field of stellar variability; these are summarized in the next two appendixes. The main conclusions that follow from these studies are:

- The STARE (or any of the TrES) light curves achieve enough precision as to perform serious studies of stellar variability.

- The STARE light curve of the δ Sct V1821 Cygni has been studied in detail, detecting 4 clear pulsation frequencies on this star. One frequency had not been detected in previous observations of the star. Another 3 frequencies close to the noise level might serve to explain the apparent amplitude variability of the main frequency f_1. However, it is not possible to reject the possibility that f_1 is intrinsically variable, and the 3 close frequencies are an artifact of the frequency analysis tool used.

- Frequencies, amplitudes and phases of 5 newly discovered pulsators in the constellation Cygnus have been provided as a by-product of the investigation on V1821 Cygni.

- As a result of a collaboration for the COROT space mission, a total of 38 variable stars have been discovered with STARE in the potential fields accessible to the spacecraft. Some of them are either too faint to be observed with the COROT seismology CCDs or too far from the main COROT targets, but 18 stars have been identified as potential secondary targets in the COROT seismology CCDs. These are mostly δ Sct stars, but also γ Dor pulsators and eclipsing binaries have been discovered.

7.3 Future work

Preliminary analysis of observations of TrES-1 using HST/ACS results in a determination of the planet parameters that is within the error bars of the parameters stated in this work, and in the probable detection of a large star spot that was occulted by the planet during one of the HST visits. The detailed shape of the ingress-egress phases in these data will serve to search for planetary rings on the planet. The precise eclipse timing and the study of the residuals of the transit fitting will be used to search for TrES-1 satellites.

Further work is needed to interpret the observations carried on the 2004 Venus transit, specially to establish the origin of the observed latitudinal dependance of the spectral features. In particular, a measurement of the ratio of equivalent widths between two clear $^{12}CO_2/^{13}CO_2$ lines can provide insights on the temperatures at the altitudes in which those lines become opaque to the tangential solar rays.

While many of the TrES transiting planet candidates are rejected as eclipsing binary (or triple) systems, there is valuable information on the sizes of eclipsing M stars within these candidates. Some of the TrES team members are working on obtaining the orbital and physical parameters of these binary systems (some of which were detected in the field of the constellation Lyra that was discussed in this Thesis). As a first result, the up-to-now fourth known eclipsing binary with two M star components has been detected in one field of the constellation Hercules (Creevey et al. 2005).

And, finally, the TrES network will be working for at least three more years, surveying the night sky in search for new TrES exoplanets.

When a significant number of transiting planet candidates are detected, it will be worthwhile to perform a detailed analysis of the rate of detections of false positives, and on the nature of each of those. This might serve to establish if the rate of occurrence of transiting planets is in good agreement with the rate of occurrence of planets detected so far by the radial velocity technique.