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COMMISSION 30 RADIAL VELOCITIES

VITESSES RADIALES

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COMMISSION 30 WORKING GROUPS

Div. IX / Commission 30 WG	**Radial-Velocity Standard Stars**
Div. IX / Commission 30 WG	**Stellar Radial Velocity Bibliography**
Div. IX / Commission 30 WG	**Catalogue of Orbital Elements of Spectroscopic Binaries**

TRIENNIAL REPORT 2006 - 2009

1. Introduction

This three-year period has seen considerable activity in the Commission, with a wide range of applications of radial velocities as well as a significant push toward higher precision. The latter has been driven in large part by the exciting research on extrasolar planets. This field is now on the verge of detecting Earth-mass bodies around nearby stars, as demonstrated by recent work summarized below, and radial velocities continue to play a central role.

This is not to say that classical applications of RVs have lagged behind. On the contrary, this triennium has seen the release of several very large data sets of stellar radial velocities (Galactic and extragalactic) that are sure to have a significant impact on a number of fields for years to come. The era of mass-producing radial velocities has arrived. Examples include the Geneva-Copenhagen Survey, the Sloan Digital Sky Survey, and RAVE, and are described below.

Due to circumstances beyond our control, the report of Commission 30 for the previous (2003 - 2006) triennium did not appear in the printed version of the IAU Transactions XXVIA, although it did appear in the electronic version. For progress during the previous period, the reader is therefore encouraged to consult the latter, which is also available from the Commission web site.

2. Radial velocities and exoplanets (Guillermo Torres & John A. Johnson)

2.1. *Toward Earth-mass planets*

Detections of Jupiter-mass exoplanets by the radial-velocity method relying on measurements with precisions of a few $\mathrm{m\,s^{-1}}$ are now quite routine. This technique has provided by far the majority of the more than 300 planet discoveries to date. The persistence of astronomers and the increasing precision of their instruments has led to larger and larger numbers of multi-planet systems being found. One example is the interesting case of μ Arae (Pepe *et al.* 2007), with *four* planets, one of which is as small as 10.5 M_{Earth}. The host star also presents the signature of p-mode oscillations seen clearly in the radial velocities.

The record-holder for the most planets is the star 55 Cnc, which is orbited by no less than *five* planets (Fischer *et al.* 2008), of which the smallest has a minimum mass of 10.8 M_{Earth}. Exciting discoveries during this period made possible by the high precision and stability of the HARPS instrument on the ESO 3.6 m telescope at La Silla (Chile) include the system Gls 581 (at only 6.3 pc), attended by at least three planets. In addition to the previously known Neptune-mass body orbiting the star with a period $P = 5.3$ d, two other low mass planets were found by Udry *et al.* (2007) with minimum masses of only 5 M_{Earth} ($P = 12.9$ d) and 7.7 M_{Earth}, the latter being near the outer edge of the habitable zone of the M3V parent star ($P = 83.6$ days). The three-planet orbital solution for this case has an rms residual of only 1.2 m s^{-1}.

Another system with three low-mass planets was announced by Mayor *et al.* (2008) around the nearby (13 pc) metal-poor K2V star HD 40307. The planets weighed in at 4.2, 6.9, and 9.2 M_{Earth}, and the three-planet Keplerian orbital fit gave impressive residuals of just 0.85 m s^{-1}. HARPS has demonstrated that this sort of velocity precision is achievable for 'quiet' stars that present a low level of 'jitter' in their radial velocities due to astrophysical phenomena such as p-mode oscillations, granulation, or chromospheric activity. Indications are that Neptune-mass or smaller planets are more common around solar-type (F-K) stars than previously thought (see, e.g., Mayor & Udry 2008).

2.2. *Retired A-type stars and their planets*

Most Doppler searches for planets have concentrated on main sequence stars of spectral types F or later, because the velocity precision for earlier type stars is seriously compromised by line broadening induced by rapid rotation, as well as the overall fewer number of spectral lines available. This difficulty in studying higher-mass stars introduces a bias in our understanding of planets, but it can be overcome by looking at such stars after they have left the main sequence. This is precisely the approach of an ongoing project to investigate the relationship between stellar mass and planet formation by using the HIRES instrument on the Keck 10 m telescope to search for planets in a sample of 240 intermediate-mass subgiants ($1.3 < M_*/M_\odot < 2.2$). Subgiants have lower surface temperatures and rotational velocities than their main-sequence progenitors, making them ideal proxies for A- and F-type stars in Doppler studies. From a smaller sample of subgiants observed previously by Johnson *et al.* (2007a) at Lick Observatory for 4 years with a typical velocity precision of 4 m s^{-1}, a strong correlation was detected between stellar mass and planet occurrence, with a detection rate of 9% within 2.5 AU among the high-mass sample, compared to 4.5% for Sun-like stars and less than 2% for M dwarfs. A paucity of planets within 1 AU of stars with masses greater than 1.5 $M_\odot$ was found, indicating that stellar mass also plays a key role in planet migration (Johnson *et al.* 2007b, Johnson *et al.* 2008). The goal of the expanded Keck survey (with an increased velocity precision of about 2 m s^{-1}) is to map out the relationships between stellar mass and exoplanet properties in greater detail by examining the distribution of planetary minimum masses, eccentricities, semimajor axes, and the rate of multiplicity around evolved A stars. If the 9% occurrence rate is confirmed, some 20 to 30 new planets should be found in the sample orbiting some of the most massive stars so far examined by the Doppler technique.

2.3. *Current status and prospects*

In May of 2008 NASA convened the Exoplanet Forum 2008, a meeting of experts from the US and other countries in eight different observational techniques related to exoplanet research. The purpose was to discuss paths forward for exploring and characterizing planets around other stars, and to provide specific suggestions for space missions, technology development, and observing programmes that could fulfill the recommendations of a previously held meeting of the Exoplanet Task Force (<www.nsf.gov/mps/ast/exoptf.jsp>). The reports resulting from these meetings are intended to provide input for consideration by various advisory committees in the USA, and in particular by the *Astronomy and Astrophysics Decadal Survey* that is currently underway.

Radial velocities was one of the eight techniques considered by the Exoplanet Forum 2008. The corresponding chapter of the report, available at <exep.jpl.nasa.gov/exep_exfCommunityReport.cfm>, summarized the progress in the field over the last few years, which is illustrated by a velocity precision of 1 $\mathrm{m\,s^{-1}}$ or slightly better achieved so far, led by the Swiss team using the HARPS instrument on the ESO 3.6 m telescope, and the California-Carnegie team using the HIRES instrument on the Keck 10 m telescope. The factors currently limiting the precision were discussed briefly and have been described in detail by Pepe & Lovis (2007). They include various sources of astrophysical noise (stellar oscillations, granulation, magnetic cycles, collectively known as 'stellar jitter'), guiding, the illumination of the spectrograph, and the wavelength reference. Good progress has been made in each of these areas. For example, it appears that jitter can be substantially reduced through longer exposures or binning, to the level of perhaps 10 $\mathrm{cm\,s^{-1}}$ or less. A new thorium-argon line list was developed by Lovis & Pepe (2007) that significantly improves the velocity precision when using this source as the wavelength reference. Further improvements in the velocity precision perhaps reaching a few $\mathrm{cm\,s^{-1}}$ appear possible using a dense spectrum of lines generated by a femtosecond-pulsed laser ('laser comb'), described in more detail below. The next few years will tell whether this promise can be realized in practice.

The report of the Exoplanet Forum also described recent progress in techniques to measure precise velocities in the near infrared (see, e.g., Ramsey *et al.* 2008), which are now approaching the 10 $\mathrm{m\,s^{-1}}$ level in initial tests. Longer wavelengths potentially provide a significant advantage for the Doppler detection of very small (even Earth-mass) planets, since these objects produce a larger signal when orbiting less massive stars, which emit most of their flux in the near infrared.

In addition to velocity precision, the report pointed out what is currently considered by the community to be the greatest challenge for making progress in the detection of exoplanets by the Doppler technique: the limited access to telescope time. This has a direct impact not only on the size of the samples of solar-type stars that can be studied, but also severely restricts the number of late-type (faint) stars that can be targeted to search for Earth-mass planets. The need for exposure times longer than dictated by Poisson statistics to reduce stellar jitter, as mentioned above, is a further strain on the limited resources currently available on telescopes equipped with high-precision spectrographs.

3. **Toward higher radial velocity precision** (Guillermo Torres)

During this period agreement has been reached for the construction of an improved copy of the very successful HARPS spectrograph, currently in operation at the ESO 3.6 m telescope at La Silla, for the northern hemisphere (HARPS-NEF). This is a high-resolution ($R \simeq 120\,000$) fibre-fed optical spectrograph with broad wavelength coverage

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(3780 - 6910 Å) designed for high radial velocity precision. HARPS-NEF is a collaboration between the New Earths Facility (NEF) scientists of the Harvard Origins of Life Initiative and the HARPS team at the Geneva Observatory. It is expected to be the workhorse for follow-up of transiting planet candidates for NASA's *Kepler* mission, and should be operational perhaps in late 2010.

HARPS-NEF is a cross-dispersed echelle spectrograph that will benefit not only from updates and improvements over the original HARPS instrument, but in addition it will be installed on a larger telescope aperture in the northern hemisphere (the 4.2 m William Herschel Telescope on La Palma, Canary Islands). It is designed for ultra-high stability (10-20 cm s^{-1}), and like HARPS it will be placed in a vacuum chamber with careful temperature control.

One of the key factors that determine the precision of the RVs is the wavelength reference. Existing technologies in the optical (such as the Th-Ar technique and iodine gas absorption cell) have already reached sub-m s^{-1} precision in some cases, but further improvements are needed if the Doppler method is to reach cm s^{-1}, as is needed to detect terrestrial-mass planets. A new technology that has emerged in the last few years and that holds great promise for providing a very stable reference is that of laser 'frequency combs'. As the name suggests, a frequency comb generated from mode-locked femtosecond-pulsed lasers provides a spectrum of very narrow emission lines with a constant frequency separation given by the pulse repetition frequency, typically 1 GHz for this application. This frequency can be synchronized with an extremely precise reference such as an atomic clock. For example, using the generally available Global Positioning System (GPS), the frequencies of comb lines have long-term fractional stability and accuracy of better than 10^{-12}.

This is more than enough to measure velocity variations at a photon-limited precision level of 1 cm s^{-1} in astronomical objects (see, e.g., Murphy *et al.* 2007). This direct link with GPS as the reference allows the comparison of measurements not only between different instruments, but potentially also over long periods of time. To provide lines with separations that are well matched to the resolving powers of commonly used echelle spectrographs, a recent improvement incorporates a Fabry-Pérot filtering cavity that increases the comb line spacing to $\sim$40 GHz over a range greater than 1000 Å (Li *et al.* 2008). Prototypes using a titanium-doped sapphire solid-state laser have been built that provide a reference centered around 8500 Å. In practice, of course, Doppler measurements are also affected by other instrumental problems, so that the value of this new technology for highly precise RV measurements is still to be demonstrated. Tests have been initiated during this triennium.

Plans call also for the installation of a laser comb on the HARPS-NEF spectrograph described above. Applications of this technique are not limited to stars. For example, a direct measurement of the expansion of the Universe could be made by observing *in real time* the evolution of the cosmological redshift of distant objects such as quasars. Such a measurement would require a precision in determining Doppler drifts of $\sim$1 cm s^{-1}/yr (see, e.g., Steinmetz *et al.* 2008), which a laser comb can in principle deliver.

4. **Radial velocities and asteroseismology** (Guillermo Torres)

The significant increase in the precision of velocity measurements over the past few years, driven by exoplanet searches, has enabled important studies of the internal constitution of stars through the technique of asteroseismology. A number of spectrographs now reach the precision needed for this type of investigation. During this period Bedding

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et al. (2006) observed the metal-poor subgiant star ν Ind with the UCLES instrument on the 3.9 m Anglo-Australian Telescope, and with the CORALIE spectrograph on the 1.2 m Swiss telescope at ESO. The precision of those measurements ranged from 5.9 to 9.5 m s^{-1}, and allowed the authors to place constraints on the stellar parameters confirming that the star has a low mass and an old age. This was the first application of asteroseismology to a metal-poor star. α Cen A was observed by Bazot *et al.* (2007) with the HARPS spectrometer on the ESO 3.6 m telescope, and 34 p-modes were identified in the acoustic oscillation spectrum of the star. Individual observations had errors well under 1 m s^{-1}. A similar study by Mosser *et al.* (2008a) was conducted on Procyon (α CMi) using the SOPHIE spectrograph on the 1.9 m telescope at the Haute-Provence Observatory, yielding a precision of about 2 m s^{-1}. The HARPS instrument was used again by Mosser *et al.* (2008b) to study the old Galactic disk, low-metallicity star HD 203608. A total of 15 oscillation modes were identified, and the age of the star was determined to be 7.25 ± 0.07 Gyr.

5. Radial velocities in Galactic and extragalactic clusters (Elena V. Glushkova, Hugo Levato and Guillermo Torres)

Searches for spectroscopic binaries in southern open clusters have continued during this period (e.g., González & Levato 2006). These authors have reported results for the open cluster Blanco 1. Forty four stars previously mentioned in the literature as cluster candidates, plus an additional 25 stars in a wider region around the cluster were observed repeatedly during five years. Six new spectroscopic binaries have been detected and their orbits determined. All of them are single-lined spectroscopic systems with periods ranging from 1.9 to 1572 d. When considering also all suspected binaries, the spectroscopic binary frequency in this cluster amounts to 34%. Additional velocities were measured in this cluster by Mermilliod *et al.* (2008a), who obtained a rather similar binary frequency.

Results from long term radial velocity studies based on the CORAVEL spectrometers have been presented during this period for the open clusters NGC 6192, NGC 6208, and NGC 6268 (Clariá *et al.* 2006), as well as for NGC 2112, NGC 2204, NGC 2243, NGC 2420, NGC 2506, and NGC 2682 (Mermilliod & Mayor 2007). These studies were complemented with photometric observations in a variety of systems, and included membership determination and binary studies. A number of new spectroscopic binaries were discovered, and their orbital elements were determined.

Other individual cluster studies in the Milky Way, which we merely reference here without giving the details due to space limitations, include: IC 2361 (Platais *et al.* 2007), NGC 2489 (Piatti *et al.* 2007), α Per (Mermilliod *et al.* 2008b), the five distant open clusters Ru 4, Ru 7, Be 25, B 73 and Be 75 (Carraro *et al.* 2007), Tombaugh 2 (Frinchaboy *et al.* 2008), the Orion Nebula cluster (Fürész *et al.* 2008), the most massive Milky way open cluster Westerlund 1 (Mengel & Tacconi-Garman 2008), the Galactic center star cluster (Trippe *et al.* 2008), and the globular clusters M 4 (Sommariva *et al.* 2008) and ω Cen (Da Costa & Matthew 2008).

This triennium saw the publication of the final results of the 20 year efforts of J.-C. Mermilliod and colleagues to measure the radial velocities of giant stars in open clusters for a variety of studies related to their kinematics, membership, and photometric and spectroscopic properties. A catalogue of spectroscopic orbits for 156 binaries based on more than 4000 individual velocities was published by Mermilliod *et al.* (2007), based on measurements from CORAVEL and the CfA Digital Speedometers. Orbital periods range from 41 d to more than 40 yr, and eccentricities are as high as $e = 0.81$. Another 133 spectroscopic binaries were discovered but do not have sufficient observations and/or time coverage to determine orbital elements. This material provides a dramatic increase in the body of homogeneous orbital data available for red-giant spectroscopic binaries in open clusters, and should form the basis for a comprehensive discussion of membership, kinematics, and stellar and tidal evolution in the parent clusters. A companion catalogue (Mermilliod *et al.* 2008c) reports mean radial velocities for 1309 red giants in clusters based on 10 517 individual measurements, and mean radial velocities for 166 open clusters among which 57 are new. This information, combined with recent absolute proper motions, will permit a number of investigations of the galactic distribution and space motions of a large sample of open clusters.

Frinchaboy & Majewski (2008) reported on a survey of the chemical and dynamical properties of the Milky Way disk as traced by open star clusters. They used medium-resolution spectroscopy ($R \approx 15\,000$) with the Hydra multi-object spectrographs on the Cerro Tololo Inter-American Observatory 4 m and WIYN 3.5 m telescopes to derive moderately high-precision RVs ($\sigma < 3\,\mathrm{km\,s^{-1}}$) for 3436 stars in the fields of 71 open clusters within 3 kpc of the Sun. Along with the work described in the preceding paragraph, these represent the largest samples of clusters assembled thus far having uniformly determined, high-precision radial velocities.

A good deal of activity focused on kinematic analyses of globular cluster (GC) systems in other galaxies. Lee *et al.* (2008a) measured radial velocities for 748 GC candidates in M31, and Lee *et al.* (2008b) obtained radial velocities of 111 objects in the field of M60. Konstantopoulos *et al.* (2008) obtained new spectroscopic observations of the stellar cluster population of region B in the prototype starburst galaxy M 82. Schuberth *et al.* (2006) presented the first dynamical study of the GC system of NGC 4636 based on radial velocities for 174 clusters. Bridges *et al.* (2006) measured radial velocities of 38 GCs in the Virgo elliptical galaxy M 60, and Bridges *et al.* (2007) obtained new velocities for 62 GCs in M 104.

An interesting problem was discussed by Abt (2008), pointing to a possible bias in the RVs of many B-type stars. The author looked at 10 open clusters younger than about 30 million years with sufficient numbers of measured radial velocities, many of them being measured with CORAVEL, and found that in each case, the main-sequence B0–B3 stars have larger velocities than earlier- or later-type stars.

6. Radial velocities for field giants (Guillermo Torres)

A programme to measure precise radial velocities for 179 giant stars has been ongoing at the Lick Observatory, with individual errors of 5-8 $\mathrm{m\,s^{-1}}$ per measurement (Hekker *et al.* 2006). This study presented a list of 34 stable K-type giants (with RV standard deviations under 10 $\mathrm{m\,s^{-1}}$) suitable to serve as reference stars for NASA's Space Interferometry Mission. A follow-up paper (Hekker *et al.* 2008) reported that 80% of the stars monitored show velocity variations at a level greater than 20 $\mathrm{m\,s^{-1}}$, of which 43 exhibit significant periodicities. One of the goals was to investigate possible mechanisms that cause these variations. A complex correlation was found between the amplitude of the changes and the surface gravity of the star, in which part of the variation is periodic and uncorrelated with $\log g$, and another component is random and does correlate with surface gravity.

Massarotti *et al.* (2008) reported radial velocities made with the CfA Digital Speedometers for a sample of 761 giant stars, selected from the *Hipparcos* Catalogue to lie within 100 pc. Rotational velocities and other spectroscopic parameters were determined as well. Orbital elements were presented for 35 single-lined spectroscopic binaries and 12 double-lined binaries. These systems were used to investigate stellar rotation in field giants to

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look for evidence of excess rotation that could be attributed to planets that were engulfed as the parent stars expanded.

7. Galactic structure – large surveys (Birgitta Nordström and Guillermo Torres)

7.1. *The Geneva-Copenhagen Survey*

During the previous 3-year period one of the mayor surveys completed and published is the *Geneva-Copenhagen Survey of the Solar Neighbourhood* (Nordström *et al.* 2004). Unfortunately, the full description of this project and the important new science results that came out of it did not make it into the printed version of the IAU Transactions XXVIA for the triennium 2003 - 2006, so we summarize and update that information here for its significant impact for the study of Galactic structure. This survey provided accurate, multi-epoch radial velocities for a magnitude-complete, all-sky sample of 14 000 F- and G-type dwarfs down to a brightness limit of $V = 8.5$, and is volume complete to about 40 pc. The catalogue includes new mean radial velocities for 13 464 stars with typical mean errors of 0.25 km s^{-1}, based on 63 000 individual observations made mostly with the CORAVEL photoelectric cross-correlation spectrometers covering both hemispheres. Studies of this rich data set have found evidence for dynamical substructures that are probably due to dynamical perturbations induced by spiral arms and perhaps the Galactic bar. These 'dynamical streams' (Famaey *et al.* 2005) contain stars of different ages and metallicities which do not seem to have a common origin. These features, which dominate the observed UVW diagrams, make the conventional two-Gaussian decomposition of nearby stars into thin and thick disk members a highly dubious procedure. An analysis by Helmi *et al.* (2006) suggests that tidal debris from merged satellite galaxies may be found even in the solar neighbourhood.

A new release of this large catalogue with updated calibrations as well as new age and metallicity determinations was published during the present triennium by Holmberg *et al.* (2007), and is available from the CDS at `<cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/475/51>`. A follow-up paper and catalogue are expected to be available shortly, containing new kinematic data (UVW velocities) resulting from a re-analysis using the revised *Hipparcos* parallaxes (van Leeuwen 2007), and on-line updates.

7.2. *Sloan Digital Sky Survey*

This triennium saw the sixth data release of the Sloan Digital Sky Survey (Adelman-McCarthy *et al.* 2008), which now covers an area of 9583 square degrees on the sky. This release includes nearly 1.1 million spectra of galaxies, quasars, and stars with sufficient signal to be usable, along with redshift determinations, as well as effective temperature, surface gravity, and metallicity determinations for many stars. The spectra cover the wavelength region 3800–9200 Å at a resolving power R ranging from 1850 to 2200. Velocity precisions range from about 9 km s^{-1} for A- and F-type stars to about 5 km s^{-1} for K-type stars. The zero point of the velocities is in the process of being calibrated using spectra from the ELODIE spectrograph. These data are a valuable resource for a variety of investigations related to Galactic structure and the evolution and history of the Milky Way.

7.3. *RAVE*

The second data release of the Radial Velocity Experiment (RAVE) was published during this triennium (Zwitter *et al.* 2008). This is an ambitious spectroscopic survey to measure radial velocities as well as stellar atmosphere parameters (effective temperature,

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metallicity, surface gravity, rotational velocity) of up to one million stars using the 6dF multi-object spectrograph on the 1.2 m UK Schmidt telescope of the Anglo-Australian Observatory. The RAVE programme started in 2003, obtaining medium resolution spectra (median $R = 7500$) in the Ca II triplet region (8410 - 8795 Å) for southern hemisphere stars drawn from the Tycho-2 and SuperCOSMOS catalogues, in the magnitude range $9 < I < 12$. Following the first data release, the current release doubles the sample of published radial velocities, now reaching 51 829 measurements for 49 327 individual stars observed between 2003 and 2005. Comparison with external data sets indicates that the new data collected since April 2004 show a standard deviation of 1.3 km s^{-1}, about twice as good as for the first data release. For the first time, this data release contains values of stellar parameters from 22 407 spectra of 21 121 individual stars. The data release includes proper motions from the STARNET 2.0, Tycho-2, and UCAC2 catalogues, and photometric measurements from Tycho-2, USNO-B, DENIS, and 2MASS. The data can be accessed via the RAVE web site at <www.rave-survey.org>. Scientific uses of these data include the identification and study of the current structure of the Galaxy and of remnants of its formation, recent accretion events, as well as the discovery of individual peculiar objects and spectroscopic binary stars. For example, kinematic information derived from the RAVE data set has been used by Smith *et al.* (2007) to constrain the Galactic escape velocity at the solar radius to $V_{\rm esc} = 536^{+58}_{-44}$ km s^{-1} (90% confidence).

8. Working groups

Below are the progress reports of the three active working groups of Commission 30. Their efforts are focused on providing a service to the astronomical community at large through the compilation of a variety of information related to radial velocities.

8.1. *WG on radial velocity standard stars* (Stephane Udry)

Large radial-velocity surveys are being conducted to search for extrasolar planets around different types of stars, including A- to M-type dwarfs, and G- to K-type giants (e.g., Udry & Santos 2007). Although not aiming at establishing a set of radial-velocity standard stars, the non-variable stars in these programmes, followed over a long period of time, provide ideal candidates for our list of standards. They will moreover broaden the domain of stellar properties covered (brightness and spectral type). At this point, the results of most of those programmes are still not publicly available and we must still wait a bit in order to fine-tune and enlarge the list presently available at <obswww.unige.ch/∼udry/std/std.html>. In addition to the by-product aspect of planet search programmes, a targeted observational effort, dedicated to the definition of a large sample of RV standards for *Gaia*, is being pursued with several instruments (CORALIE, SOPHIE, etc). It will provide in a few years a list of several thousand suitable standards spread over the entire sky (Crifo *et al.* 2007).

For all of the efforts above, work remains to be done to combine the data from the different instruments into a common RV system, for example through the observation of minor planets in the solar system (Zwitter *et al.* 2007). This has still to be done for most of the planet search programmes, but is already included in the *Gaia* effort.

8.2. *WG on stellar radial velocity bibliography* (Hugo Levato)

During the 2006 - 2009 triennium, the WG searched for the papers with measurements of radial velocities of stars in 33 journals. As of December 2007 113 658 entries have been catalogued. We expect to finish 2008 with more than 150,000. It is worth mentioning that at the end of 1996 there were 23 358 entries recorded, so that in 10 years the number of

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entries in the catalogue has expanded by a factor of five. During the triennium we have improved the search engine to search by different parameters. In the main body of the catalogue we have included information about the technical characteristics of the instrumentation used for radial velocity measurements, and comments about the nature of the objects. The catalogue can be accessed at `<www.casleo.gov.ar/catalogue/catalogue.html>`.

8.3. *WG on the catalogue of orbital elements of spectroscopic binaries (SB9)* (Dimitri Pourbaix)

In Manchester, a WG was set up to work on the implementation of the 9th catalogue of orbits of spectroscopic binaries (SB9), superseding the 8th release of Batten *et al.* (1989) (SB8). SB9 exists in electronic format only. The web site `<sb9.astro.ulb.ac.be>` was officially released during the summer of 2001. This site is directly accessible from the Commission 26 web site, from BDB (in Besançon), and from the CDS, among others.

Since the last report, substantial progress has been accomplished, in particular in the way complex systems can be uploaded together with their radial velocities. That is the case, for instance, for triple stars with the light time effect accounted for and systems with a pulsating primary.

At the time of this writing SB9 contains 2802 systems (SB8 had 1469) and 3340 orbits (1469 in SB8). A total of 563 papers were added since August 2000, although most of them come from *outside* the WG. Many papers with orbits still await uploading into the catalogue. According to ADS, the release paper (Pourbaix *et al.* 2004) has been cited a total of 58 times since 2005. This is twice as many as the old Batten *et al.* catalogue over the same period.

Even though this work has been very well received by the community and a number of tools have been designed and implemented to make the job of entering new orbits easier (input file checker, plot generator, etc.), the WG still suffers from a serious lack of manpower. Few colleagues outside the WG spontaneously send their orbits (but they are usually pleased to send their data when we ask for them). Any help (from authors, journal editors, and others) is therefore very welcome. Uploading an orbit into SB9 also involves checking for typos. In this way we have found several mistakes in published solutions, which we have corrected. Sending orbits to SB9 prior to publication (e.g., at the proof stage) would therefore be a way to prevent some mistakes from making it into the literature.

Guillermo Torres
vice-president of the Commission

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