Binary Stars as Critical Tools & Tests
in Contemporary Astrophysics
Proceedings IAU Symposium No. 240, 2006
W.I. Hartkopf, E.F. Guinan & P. Harmanec, eds.

doi:10.1017/S1743921307004334

Poster Abstracts (Session 6)

(Full Posters are available at http://www.journals.cambridge.org/jid_IAU)

Analytical Binary Modeling and its Role in Dynamics

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Binaries are critical tools that drive stellar systems; which play a major role in galactic dynamics. Internal dynamical evolution of globular clusters (e.g., due to evolution of binaries) can be modulated by external effects (e.g., tidal shocks). This merits a study of the orbital characteristics of binary formation and its applications. We formulate the Hamiltonian treatment of the dynamics of two extended bodies, corresponding to their separation and effective sizes. The internal movement of the constituents of the bodies is taken into account by the hydrodynamic velocities corresponding to their mass distribution and the gravitational potential is considered in the form of a flux. A study of binary motion under spin-orbit synchronization and a condition which favors energy minimization is conducted. Considering binaries to be subsystems in a microcanonical ensemble, we find that for bound binary systems the equipartition distribution of the system parameters favors high eccentricities. Post-collapse evolution of globular clusters are driven by energy output of hard binaries. Our model is of such (hard) type and indicates that most of these eccentric binaries will harden by absorbing energy and lower their eccentricities. Numerical simulation indicate that high eccentricities are maintained for a large timescale; circularization takes place in the adiabatic regimen, but in a very large timescale. In three body encounters the binary is hardened and the single star gains velocity. Thus the core of the cluster is gradually heated; which is a major source of energy input, that drives the post collapse evolution. Preliminary results indicate that this model of hard binaries is likely to stabilize post-collapse oscillations. The model also throws light on the aspects of dynamical evolution of globular clusters that lead to the correlation between their half-mass density and kinetic temperature.

Application of Strong Spin Correlation in Visual Binaries

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Using methods to circumvent selection effects, we find correlation between the projected rotational velocities (spins) in binary systems. In visual binaries this correlation is very strong. Moreover, the degree of correlation is independent of component separation. These results indicate the possibility that spin correlation in binaries is the result of evolutionary history, rather than that of tidal interaction. Studies of spin correlation in binaries could thus be an important tool in understanding the evolution of such systems.

The Binary Evolution of the Subdwarf B Star PG 1336−018

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The formation of subdwarf B (sd B) stars poses several problems for stellar and binary evolution theory. SdB stars are core-helium burning stars ($\sim$0.5 $M_\odot$) with an extremely thin hydrogen envelope ($<$0.02 $M_\odot$). A large fraction of sdB stars are found in binaries. This suggests that Roche lobe overflow can be an effective way to remove almost the entire hydrogen envelope near the tip of the first giant branch.

To test this and other models, a detailed investigation of the sdB interior structure is necessary. Luckily, sdB stars have been observed to pulsate in heat-driven oscillation modes in agreement with theoretical expectations. Thus, asteroseismology provides an excellent tool to test the outcome of sdB formation channels. The work we present here is a first step in this direction and concerns a dedicated study of the range of fundamental parameters of progenitors of the sdB pulsating eclipsing binary PG 1336−018 from a binary evolution code. Our results will constitute a fruitful starting point for our future seismic work on this star which will be based on high-precision VLT photometry and spectroscopy of this target star.

Testing Models of Interacting Binaries Against Observations

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One of the big uncertainties in evolution of binary stars is the efficiency of mass transfer. Can it be described as a conservative process or is a significant amount of mass and angular momentum lost? As the uncertainties in hydrodynamical simulations are still very large, currently the best way to address the problem is to compare observations with stellar evolution models.

Recently Hilditch *et al.* (2005) presented the fundamental parameters of 50 double lined eclipsing binaries in the Small Magellanic Cloud (SMC) with orbital periods between 1 and 5 days. 28 systems are currently transferring mass. This sample is the largest and the most unbiased sample of OB binaries available in any galaxy and therefore suitable to test stellar evolution models of interacting binaries.

No applicable models are currently available for the metallicity of the SMC. Therefore we present a large grid of conservative and non-conservative binary evolution tracks computed with using the fast detailed stellar evolution code STARS (based on Eggleton, 1971). We compare observations and models by fitting evolution tracks to each individual system and by comparing the whole sample at once to a synthetic population. In the near future we plan to present detailed binary evolution models for a larger range of metallicities and orbital periods.

https://doi.org/10.1017/S1743921307004334 Published online by Cambridge University Press

Calibration of the Pre-Main Sequence Binary System RS Cha: Impact of the Initial Chemical Mixture

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Accurate observational data are available for the eclipsing double-lined spectroscopic binary system RS Cha, composed of two stars in the pre-main sequence stage of evolution: masses, radii, luminosities and effective temperatures of each component and metallicity of the system. This allows to build pre-main sequence models representing the components of RS Cha and to constrain them in terms of the physical ingredients, initial chemical composition and age.

We present stellar models we have calculated with the CESAM code for different sets of physical inputs (opacities, nuclear reaction rates...) and different initial parameters (global metallicity, helium abundance, individual abundances of heavy elements). We discuss their ability to reproduce the observational constraints simultaneously for the two components. We focus on the impact on the models of the chemical mixture adopted and we propose a calibration for the RS Cha system providing an estimate of its age and initial helium abundance.

Confronting Stellar Evolution Models for Active and Inactive Solar-Type Stars: the Triple System V1061 Cygni

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We present spectroscopic and photometric observations of the chromospherically active (X-ray strong) eclipsing binary V1061 Cyg ($P = 2.35$ days) showing that it is in reality a hierarchical triple system. We combine these observations with *Hipparcos* intermediate data (abscissa residuals) to derive the outer orbit with a period of 15.8 yr. We determine accurate values for the masses, radii, and effective temperatures of the eclipsing binary components, as well as for the mass and temperature of the third star. For the primary we obtain $M = 1.282 \pm 0.015$ M$_\odot$, $R = 1.615 \pm 0.017$ R$_\odot$, $T = 6180 \pm 100$ K, for the secondary $M = 0.9315 \pm 0.0068$ M$_\odot$, $R = 0.974 \pm 0.020$ R$_\odot$, $T = 5300 \pm 150$ K, and for the tertiary $M = 0.925 \pm 0.036$ M$_\odot$ and $T = 5670 \pm 100$ K. Current stellar evolution models agree well with the properties of the primary star, but show a large discrepancy in the radius of the secondary in the sense that the observed value is about 10% larger than predicted (a 5σ effect). We also find the secondary temperature to be $\sim$200 K cooler than indicated by the models. These discrepancies are quite remarkable considering that the secondary is only 7% less massive than the Sun, which is the calibration point of all stellar models. Similar differences with theory have been seen before for lower mass stars. We identify chromospheric acivity as the likely cause of the effect. Inactive stars agree very well with the models, while active ones such as the secondary of V1061 Cyg appear systematically too large and too cool. Both of these differences are understood in terms of the effects of magnetic fields commonly associated with chromospheric activity.

https://doi.org/10.1017/S1743921307004334 Published online by Cambridge University Press

Early Evolution of the 2006 Eruption of the Recurrent Nova RS Oph

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Classical novae occur frequently, but repeated outbursts of a KNOWN nova occur rarely. These observed repeated outbursts render recurrent novae (RN) unique amongst all novae, and important astrophysical laboratories in which to study the outburst physics and chemical processing that occurs in novae (or at least this subclass). The primaries of RN are thought to be massive white dwarfs (1.3–1.4 $M_\odot$, close to the Chandrasekhar limit). Consequently, their outbursts are quite brief, returning back to their quiescent state within just a few months. If the white dwarf (WD) retains a net gain in mass after each accretion-eruption cycle, this could eventually result in a Type Ia supernovae explosion. RS Oph is one of only a few known recurrent novae, itself having been observed to erupt in 1898, 1933, 1958, 1967, and 1985; roughly once a generation! RS Oph is further unique in that the secondary is a late-type $\sim$M2III giant star in a long-period orbit of $\sim$460 days. Thus, the hot WD is enshrouded within the extended wind of the giant companion. On 2006 February 12, RS Oph experienced yet another eruption, rising by about 6 mags to $V\sim5$. A high-dispersion spectroscopic campaign was initiated on RS Oph using the APO 3.5-m telescope using the echelle spectrograph (R$\sim$37,500, continuous coverage from 0.35nm to 0.98nm, $\sim$25 nights) complimented by lower-dispersion spectra obtained on the SMARTS 1.5-m telescope at CTIO, and coordinated with various campaigns conducted with space observatories. We report initial results from the spectroscopic ground-based campaign, and compare with results found during previous eruptions. Though the 2006 eruption behaved qualitatively similar to the 1985 outburst, important differences are observed. For example, the 2006 eruption proceeded more rapidly than the 1985 outburst, likely a result of a larger envelope mass accreted before the thermonuclear runaway ensured. Broad hydrogen lines narrowed as the eruption evolved, while He I lines disappeared, replaced by He II lines as the ejecta became shock heated. Details of the evolving ionization state, kinematics, and equivalent widths will be discussed.

https://doi.org/10.1017/S1743921307004334 Published online by Cambridge University Press

Eta Carinae and the Homunculus: an Astrophysical Laboratory

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High spatial resolution spectroscopy with HST/STIS between 1998.0 and 2004.2 has provided much exciting information about the central binary system and the physics of its N-rich, C,O-poor ejecta.

Stellar He I profiles, noticeably blue-shifted relative to P Cygni H and Fe II line profiles, originate from the ionized wind region between two massive companions. Changes in profiles of He I singlet and triplet lines provide clues to the excitation mechanisms involved as the hot, UV companion moves in its highly eccentric orbit.

For 90% of the 5.54-year period, the spectra of nearby Weigelt blobs and the Little Homunculus include highly excited emission lines of Ar, Ne, and Fe. During the few month-long spectroscopic minimum, these systems are deprived of Lyman continuum. Recombination, plus cooling, occurs. In the skirt region between the bipolar Homunculus, a neutral emission region, devoid of hydrogen emission, glows in Ti II, Fe I, Sr II, Sc II, etc. We find the ejecta to have Ti/Ni abundances nearly 100 times solar, not due to nuclear processing, but due to lack of oxygen. Many metals normally tied up in interstellar dust remain in gaseous phase.

Much information is being obtained on the physical processes in these warm N-rich gases, whose excitation varies with time in a predictable pattern. Indeed recent GRB high dispersion spectra include signatures of circum-GRB warm gases. This indicates that the early, primordial massive stars have warm massive ejecta reminiscent to that around η Carinae.

The Eclipsing Model for the Symbiotic Binary YY Her

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Extensive long-term CCD and photoelectric photometric observations of the classical symbiotic star YY Her, covering the period of its post-outburst activity (JD 2 451 823 – 2 453 880), are presented. We explain the periodic variations of the brightness of YY Her by the eclipses of the components in the symbiotic system. The model with a deformed (non-homogeneous) envelope, surrounding the white dwarf is discussed. In addition, we observed a flare in about JD 2 452 440, during the primary minimum, that was later followed by an energetic outburst in JD 2 452 700. The next outburst activity is well detected on the light curve.

https://doi.org/10.1017/S1743921307004334 Published online by Cambridge University Press

Finding the Primordial Binary Population in Sco OB2: on the Interpretation of Binary Star Observations

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The majority of stars form in of a binary or multiple systems. Detailed knowledge of the properties of binary systems thus provides important information about the process of star formation. It is difficult to study the binary population during star formation due to the large interstellar extinction. However, after the first massive stars have formed, the interstellar gas is quickly removed by stellar winds, and a freshly exposed population, the “primordial binary population” (PBP), is born. OB associations are the prime targets for finding the PBP. Due to their youth and low stellar density, the binary population has only modestly changed since formation. We targeted Sco OB2 for our study, as this is the nearest young OB association.

Finding the PBP in Sco OB2 involves three steps: (1) performing observations and a literature study to obtain as much information on binarity as possible, (2) finding the true binary population by removing the selection effects from the binarity dataset, and (3) going back in time, to the PBP, by correcting for the effects of stellar and dynamical evolution that have changed the binary population over time.

We present the results of our study. We have performed two binarity surveys with the adaptive optics instruments ADONIS and NACO (in order to fill up the gap between the close spectroscopic and wide visual binaries), and combine our results with literature data. We simulate associations and study the selection effects using “synthetic observations” of visual, spectroscopic, and astrometric binaries in our simulated association. By varying the association properties and performing synthetic observations, we find which properties of the binary population correspond best to the true observations, and find the true binary population. We present the results of detailed N-body simulations (including stellar and binary evolution), which we use to derive the primordial binary population in Sco OB2.

The Eclipsing Binary System V2154 Cyg: Observations and Models

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V2154 Cyg is one of the nearest eclipsing binary systems, located at 88 pc and discovered by the HIPPARCOS mission. Based on photometric and spectroscopic observations carried out respectively at the Nevada Observatory, Spain (*uvby* photometry) and by CORAVEL-ELODIE, at the Haute-Provence Observatory, we determine the masses, effective temperature and radius for both components of the eclipsin system. On the other hand we analyse the HR Diagram position of V2154 Cyg A and B by means of the theoretical models. This system is very interesting thanks to the fact that, being composed of coeval stars, the different masses the eclipsing binary components ($1.27 M_\odot$ + $0.76 M_\odot$) allow a comparison between two stars with clearly different internal structures and evolutionary regimes, mainly on convection processes. We present preliminary results on the determination of the age and helium of the system.

https://doi.org/10.1017/S1743921307004334 Published online by Cambridge University Press

How to Measure Gravitational Aberration?

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In 1905, Henri Poincaré predicted the existence of gravitational waves and assumed that their speed c_g would be that of the speed of light c. If the gravitational aberration would also have the same magnitude as the aberration of light, we would observe several paradoxical phenomena. For instance, the orbit of two bodies of equal mass would be unstable, since two attractive forces arise that are not in line and hence form a couple. This tends to increase the angular momentum, period, and total energy of the system. This can be modelled by a system of ordinary differential equations with delay. A big advantage of computer simulation is that we can easily perform many test for various possible values of the speed of gravity [1].

In [2], Carlip showed that gravitational aberration in general relativity is almost cancelled out by velocity-dependent interactions. This means that rays of sunlight are not parallel to the attractive gravitational force of the Sun, i.e., we do not see the Sun in the direction of its attractive force, but slightly shifted about an angle less than $20''$. We show how the actual value of the gravitational aberration can be obtained by measurement of a single angle at a suitable time instant T corresponding to the perihelion of an elliptic orbit. We also derive an *a priori* error estimate that expresses how acurately T has to be determined to attain the gravitational aberration to a prescribed tolerance.

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On the Evolutionary History of EHB Objects in Binary Systems with Hot Subdwarf Companions

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It has been shown quite recently (Morales-Rueda *et al.* 2003) that dB stars, extreme horisontal branch (EHB) objects in high probability all belong to binary systems. We study in detail the mass and angular momentum loss from the giant progenitors of sdB stars in an attempt to clarify why binarity must be a crucial factor in producing EHB objects. Assuming that the progenitors of EHB objects belong to the binaries with initial separations of a roughly a hundred solar radii and fill in their critical Roche lobes when being close to the tip of red giant branch, we have found that considerable shrinkage of the orbit can be achieved due to a combined effect of angular momentum loss from the red giant and appreciable accretion on its low mass companion on the hydrodynamical time scale of the donor, resulting in formation of helium WD with masses roughly equal to a half solar mass and thus evading the common envelope stage.

Near-Contact Binaries (NCB): Close Binary Systems in a Key Evolutionary Stage

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Short-period eclipsing binary systems with EB-type light variations are interesting objects for understanding the evolutionary changes undergone by close binaries. As investigated by many authors (J. Kalužny, A. Yamasaki, D.S. Zhai, X.B. Zhang, R.W. Hilditch, T.M. McFarlane, D.J. King, J.S. Shaw, R.G. Samec, P.G. Niarchos, Kyu-Dong Oh, etc.), a majority of them belong to an important subclass of close binaries called near-contact binaries (NCBs). According to the geometric definition of this subclass, NCBs actually comprise semi-detached, marginal-contact, and marginal-detached systems. They can be in the intermediate stage between detached or semi-detached state and contact state. Therefore, NCBs are the important observational targets which may be lying in key evolutionary states.

In this paper, we observed and investigated several NCBs (BL And, GW Tau, RU UMi, GSC 3658−0076, UU Lyn, AS Ser, IR Cas, EP Aur). Our results show that the orbital periods of BL And, GW Tau, RU UMi and UU Lyn are decreasing, while that of IR Cas is decreasing and oscillating. The mechanisms that could explain the period variations are discussed. Combining the photometric solutions with period variations of these systems, we divide them into four types: BL And is a semi-detached system with a lobe-filling primary; RU UMi and EP Aur are semi-detached systems with lobe-filling secondaries; GW Tau, UU Lyn and AS Ser are marginal contact systems; and GSC 3658-0076 is a marginal detached system. Finally, the evolutionary stage of each system is discussed and some statistical relations of NCBs are presented.

Subdwarf B Stars: Tracers of Binary Evolution

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Subdwarf B stars are a superb stellar population to study binary evolution. In 2001, Maxted *et al.* (MNRAS, 326, 1391) found that 21 out of the 36 subdwarf B stars they studied were in short-period binaries. These observations inspired new theoretical work that suggests that up to 90% of subdwarf B stars are in binary systems with the remaining apparently single stars being the product of merging pairs. This high binary fraction added to the fact that they are detached binaries that have not changed significantly since they came out of the common envelope, make subdwarf B stars a perfect population to study binary evolution. By comparing the observed orbital period distribution of subdwarf B stars with that obtained from population synthesis calculations we can determine fundamental parameters of binary evolution such as the common envelope ejection efficiency. Here we give an overview of the fraction of short period binaries found from different surveys as well as the most up to date orbital period distribution determined observationally. We also present results from a recent search for subdwarf B stars in long period binaries.

https://doi.org/10.1017/S1743921307004334 Published online by Cambridge University Press

Orbits of Post-AGB Binaries with Dusty Discs

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Introduction: Post-AGB stars with RV Tauri-like spectral energy distributions have been studied to establish a connection between binarity and this type of SED.

Methods: Stars were selected from those with the appropriate IRAS colours by their F-type optical spectra and the existence of an infrared excess at K and L. These stars are hotter than classical RV Tauri stars and have pulsations of smaller amplitude, making it simpler to disentangle orbital from pulsational radial velocity variations. Radial velocity measurements were made with CORALIE on the Swiss telescope on La Silla, and spectroscopic orbits were obtained for all six stars. Optical photometry from SAAO, the Flemish Mercator Telescope and the ASAS-3 data bank enabled the determination of pulsation periods for these stars.

Results: These six stars have orbits with periods of several hundred days; several have significantly non-zero eccentricities. The dust may be contained in a circum-binary disc, which in the past has acted as the site where refractory elements have been sequestered in dust grains, leaving depleted gas, which has been returned to the star and has modified the elemental abundances in the photosphere.

Discussion: These observations confirm the close relation between binarity and the presence of a Keplerian dusty disc. The mode of formation of the disc is still poorly understood: dust is commonly observed in the form of an expanding shell about AGB stars, but the presence of a companion provides the possibility of it forming a disk.

The non-zero eccentricities of several of the orbits are surprising, as circularising interactions might have been expected when the primary star was on the AGB and may have filled its Roche lobe.

Binary Stars as a Probe for Massive Star Evolution: the Case of Delta Ori

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Variability of line profiles in spectra of the triple system δ Ori A with massive components Aa1, Aa2 and Ab is studied. A variability amplitude on the level of 0.5-1% in the continuum units is revealed. The detected variability is probably cyclical with a period about of $4^{\rm h}$. In dynamical wavelet spectra of these line variations we have detected large-scale (25-50 km/s) components moving in a band from $-V\sin i$ to $+V\sin i$ for the main star Aa1. A crossing time of the band is 4-$5^{\rm h}$. However, some variable components are found outside this band, what could be related to non-radial pulsations of the fainter component Ab. The nature of this component is investigated. Evidence that it is a binary star with massive components is found.

This work has been supported by RFBR grant 05-02-16995-a.

Probing the Low-Luminosity X-ray LF of LMXBs in Normal Elliptical Galaxies

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We present the first low luminosity ($L_X > 5$–10×10^{36} erg s^{-1}) X-ray luminosity functions (XLFs) of low-mass X-ray binaries (LMXBs) determined for two typical old elliptical galaxies, NGC 3379 and NGC 4278. Because both galaxies contain little diffuse emission from hot ISM and no recent significant star formation (hence no high-mass X-ray binary contamination), they provide two of the best homogeneous sample of LMXBs. With 110 and 140 ks *Chandra* ACIS S3 exposures, we detect 59 and 112 LMXBs within the D_{25} ellipse of NGC 3379 and NGC 4278, respectively. The resulting XLFs are well represented by a single power-law with a slope (in a differential form) of 1.9 ± 0.1. In NGC 4278, we can exclude the break at $L_X \sim 5 \times 10^{37}$ erg s^{-1} that was recently suggested to be a general feature of LMXB XLFs. In NGC 3379 instead we find a localized excess over the power law XLF at $\sim 4 \times 10^{37}$ erg s^{-1}, but with a marginal significance of $\sim 1.6\sigma$. Because of the small number of luminous sources, we cannot constrain the high luminosity break (at 5×10^{38} erg s^{-1}) found in a large sample of early type galaxies. While the optical luminosities of the two galaxies are similar, their integrated LMXB X-ray luminosities differ by a factor of 4, consistent with the relation between the X-ray to optical luminosity ratio and the globular cluster specific frequency.

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