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COMMISSION 35 STELLAR CONSTITUTION

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TRIENNIAL REPORT 2006-2009

1. The activity

The commission home page (http://iau-c35.stsci.edu) is maintained by Claus Leitherer and contains general information on the Commission structure and activities, including links to stellar structure resources that were made available by the owners. The resources contain evolutionary tracks and isochrones from various groups , nuclear reaction , EOS, and opacity data as well as links to main astronomical journals. As a routine activity, the Organizing Committee has commented on and ranked proposals for several IAU sponsored meetings. Our Commission acted as one of the coordinating bodies of a Symposium held at the XXVIth IAU General Assembly in Prague in August 2006 (S239 "Convection in Astrophysics", 21–25 Aug. 2006) and participated in the organization of the following Joint Discussions: JD05 "Calibrating the Top of the Stellar Mass-Luminosity Relation"; JD06 "Neutron Stars and Black Holes in Star Clusters"; JD08 "Solar and Stellar Activity Cycles"; JD11 "Pre-Solar Grains as Astrophysical Tools"; JD14 "Modelling Dense Stellar Systems"; JD17 "Highlights of Recent Progress in the Seismology of the Sun and Sun-like Stars".

Members of Commission 35 were involved in organization of other IAU sponsored meetings: S241 "Stellar Populations as Building Blocks of Galaxies", Dec. 2006; S246 "Dynamical Evolution of Dense Stellar Systems", Sept. 2007; S250 "Massive Stars as Cosmic Engines", Dec. 2007; S251 "Organic Matter in Space", Feb. 2008; S254 "The Galaxy Disk in Cosmological Context", June 2008. Commission 35 has been sponsoring committee for S252 "The Art of Modelling Stars in the 21st Century", Apr. 2008. Many other international meetings, in which members of the commission were involved, were held in these years.

We devote the rest of the report to examine in greater detail the scientific activity in the field of stellar constitution, considering the developments, within the past triennium, in a non exhaustive selection of specific research topics.

2. Supernovae (E. Müller)

According to the Smithsonian/NASA ADS about 5000 publications appeared during the past three years whose title contained the word "supernovae". This immense observational and theoretical activity concerns both thermonuclear (SNe Ia) and core collapse supernovae (see, e.g. Kotake *et al.* 2006; Bruenn *et al.* 2007; Burrows *et al.* 2007b; Janka *et al.* 2007, 2008), as well as the connection between supernovae and gamma-ray bursts (see, e.g. Della Valle, 2008)

There is a consensus that SNe Ia result from the thermonuclear explosion of a carbon-oxygen white dwarf. Substantial progress in supporting this conception has been achieved during the past three years, particularly through the development of 3D SNe Ia models. However, whether the white dwarf is disrupted by a pure deflagration (Röpke *et al.* 2007b; Mazzali *et al.* 2007), a delayed detonation (Bravo & García-Senz 2008; Röpke *et al.* 2007a), or a gravitationally confined detonation (Plewa *et al.* 2004; Jordan *et al.* 2008) is still controversially debated. Besides the mode of propagation, the ignition conditions of the thermonuclear flame have also attracted the attention of model builders (Schmidt & Niemeyer 2006; Röpke *et al.* 2006, 2007a). Moreover, the widely accepted "fact" that the mass of the exploding white dwarf is close to the Chandrasekhar mass, has been questioned by observations of the high-redshift supernova SNLS-03D3bb, which imply a super-Chandrasekhar-mass progenitor (Howell *et al.* 2006). Thus, their use as distance indicators in establishing the acceleration of the universe expansion (see, e.g. Astier *et al.* 2006; Wood-Vasey *et al.*2007; Bronder *et al.* 2008) may be problematic (Howell *et al.* 2006). To this end Sim *et al.* (2007) showed by means of 3D time-dependent radiation transport simulations that observationally significant viewing angle effects are likely to arise and may have important ramifications for the interpretation of the observed diversity of SNe Ia and their use as standard candles. Diagnosing SNe Ia by spectropolarimetry Wang *et al.* (2007) showed that their ejecta typically consist of a smooth, central, iron-rich core and an outer layer with chemical asymmetries. From a systematic spectral analysis of a large sample of well-observed SNe Ia Mazzali *et al.* (2007) conclude that all of them burned similar masses and had progenitors of the same mass. Hence, a single explosion scenario, possibly a delayed detonation, may explain most SNe Ia.

Progress in modeling core collapse supernovae was significant during the past three years. Detailed axisymmetric radiation-hydrodynamic simulations with multi-frequency, multi-angle Boltzmann neutrino transport succeeded in producing successful supernova explosions (i) for stars in the range of 8 to 10 solar masses which possess O-Ne-Mg cores at the onset of core collapse (Kitaura *et al.* 2006), and (ii) for stars of 11.2 and 15 solar masses which develop Fe-Ni cores (Janka *et al.* 2007, 2008). This progress was neither due to a sudden unexpected breakthrough nor due to the inclusion of new physical effects, but resulted from a proper treatment of the relevant physics (relativistic gravity, detailed neutrino transport, microphysics), and from performing simulations covering the activity of the standing accretion shock instability (Blondin *et al.* 2003). This generic hydrodynamic instability of the stagnant shock against low-mode non-radial deformation, which aids an explosion by improving the conditions for energy deposition by neutrino heating in the postshock gas, takes several hundreds of milliseconds to make an impact, thus requiring computationally extremely demanding multidimensional radiation-hydrodynamic simulations (Marek & Janka 2007). The controversially discussed excitation of gravity-waves in the surface and core of the nascent neutron star may also have supportive influence on the launch of the explosion (Burrows *et al.* 2006, 2007a; Janka *et al.* 2008; Weinberg & Quataert 2008). Studies employing simpler microphysics and/or neutrino transport, or even no transport at all, focussed on the effects of magnetic fields (see, e.g. Obergaulinger *et al.* 2006; Sawai *et al.* 2008), relativistic gravity (see, e.g. Ott *et al.* 2007; Müller *et al.* 2008), and on the gravitational wave signal produced by core collapse supernovae (see, e.g. Dimmelmeier *et al.* 2007; Kotake *et al.* 2007).

3. Asymtotic Giant Branch (J. Lattanzio & P. Ventura)

Asymptotic Giant Branch (AGB) star research remains a vital and very active area, with their role in nucleosynthesis remaining crucial to many other areas of astrophysics. Recent research has expanded the early work of Marigo (2002) in investigating the consequences of a carbon-rich envelope. The opacities for such mixtures have not been included in the past, but recent work by Cristallo et al. (2007) has begun to address this.

On the other hand, the most massive AGBs are currently thought to provide an essential contribution as polluters of the interstellar medium within Globular Clusters (GC), and many papers have been devoted in this triennum to modelling of the very advanced nucleosynthesis that they achieve at the bottom of their envelope, see in particular the models by Karakas & Lattanzio (2007); Ventura & D'Antona (2008a,b). The latter models produce ejecta whose chemistry is in reasonable agreement with the abundance patterns observed in Globular Cluster stars –although work on the dynamical origin of clusters must still explain the quantitative presence of a fraction of anomalous stars reaching 50% and more. Since massive AGBs are also expected to produce great quantities of helium, the interest of these results is strengthened by the analysis of horizontal branches with an anomalous morphology, that can be naturally explained with the existence of a helium rich population (Caloi & D'Antona 2007, 2008).

The study of Super-AGB stars (those igniting carbon in their cores, but still experiencing thermal pulses, with masses between about 8 and 12 $M_\odot$) has been readdressed in recent years with important papers by Siess (2006, 2007) and Poelarends et al (2008), which investigate the evolution of these stars and emphasise the difficulties of such calculations. The yields from these stars may also be important for the chemical evolution of GCs. In particular, their helium yields reach the values $Y\sim0.37$ necessary to explain the most helium rich populations discovered in the most massive GCs.

A direct quantitative comparison between theoretical AGB models with hot bottom burning and real stars was attempted by McSaveney et al (2007). Although extremely difficult because of shocks and very complicated line profiles, the comparison did verify the basic quantitative predictions of the models, although some uncertainties remain and may be due to uncertainties in the details of the properties of the convective envelope (as always).

We note again the usefulness of population synthesis for trying to understand properties of AGB stars, with recent work including that of Girardi & Marigo (2007), Marigo (2007) and Marigo & Girardi (2007), Bonačić Marinović et al. (2007a, 2007b, 2008) and Izzard et al (2007). An area that continues to both attract and benefit from attention is the very important problem of mass-loss, with increasingly sophisticated hydrodynamical models improving our understanding (e.g. Freytag and Höfner, 2008).

4. Transport processes in stars (C.Charbonnel)

One of the main conclusions of the IAU Symposium 252 (April 2008, Sanya, China) was that "The Art of Modelling Stars in the 21st Century" would strongly rely on our ability to model transport processes in stellar interiors. It is clear now that non-standard transport processes of chemicals and angular momentum have to be included in modern stellar models in order to reproduce detailed data in several parts of the HR diagram.

This is a major issue in view of the wealth of new and unprecedented data expected from current and future asterosismologic instruments. Rotation appears to be a key ingredient, together with internal gravity waves and magnetic fields.

Rotation has been shown to play a determinant role at very low metallicity, bringing heavy mass loss where almost none was expected, and thus modifying drastically the evolution of the very-low metallicity stars (Meynet et al. 2006). If the stars start their evolution with a sufficiently high equatorial velocity, they reach a critical limit above which mass is lost, probably through a decretion disk (Owocki 2005). In this context, Decressin et al.(2007a) have shown that the material ejected in this slow mechanical wind is enriched in H-burning products and presents abundance patterns similar to the chemical anomalies observed in globular cluster stars. These authors (see also Prantzos et al. 2007, and Decressin et al. 2007b) have thus proposed the so-called “wind of fast rotating star” scenario to explain the origin of the abundance patterns in globular clusters.

Ekstrom et al. (2008) have studied the effects of rotation on the evolution of primordial (i.e., Pop III) stars. They find that Z=0 models rotate with an internal profile $\Omega(r)$ close to local angular momentum conservation, due to a weak envelope-core coupling. Rotation boosts ^{14}N production that can be as much as 6 orders of magnitude higher than in the Z=0 non-rotating models. In addition, the high rotation rate at death is expected to lead to much stronger explosion than previously thought, changing the fate of the models.

The competition between atomic diffusion and rotation-induced mixing has been studied both from the theoretical and observational point of view. Fossati et al. (2008) observed a large sample of late B-, A-, and early-F type stars belonging to open clusters of different ages, in order to study how surface chemical abundances of these objects evolve with time and correlate with stellar parameters. They found a strong correlation between the peculiarity of Am stars and vsin i. This nicely confirms the predictions by Talon et al. (2006) using state-of-the art treatment for rotation-induced mixing.

The long quest for the mechanism that strongly modifies the surface abundances of $\sim$ 95% of low-mass stars when they reach the bump on the RGB has finally been successful. Based on 3D simulations of a tip RGB star (Dearborn et al. 2006), Eggleton et al. (2006) suggested a possible cause, namely the molecular weight inversion created by the 3He(3He,2p)4He reaction in the upper part of the hydrogen-burning shell. They claimed that this mixing was due to the well-known Rayleigh-Taylor instability, which occurs in incompressible fluids when there is a density inversion. In stellar interiors, which are stratified due to their compressibility, a similar dynamical instability occurs when the Ledoux criterion for convection is satisfied, but it acts to render the temperature gradient adiabatic rather than to suppress the density inversion. Presumably it is that instability Eggleton and colleagues have observed with their 3D code, as attested by the high velocities they quote. In reality, the first instability to occur in a star, as the inverse μ–gradient gradually builds up, is the thermohaline instability, as was pointed out by Charbonnel & Zahn (2007a). This double-diffusive instability is observed in salted water in the form of elongated fingers, when the temperature is stably stratified, but salt is not, with fresh water at the bottom and salted at the top, the overall stratification being dynamically stable (Stern 1960). On Earth, this phenomenon leads to the well-known thermohaline circulation, which is the global density-driven circulation of the oceans. It was Ulrich (1972) who first noticed that the 3He(3He,2p)4He reaction would cause a μ-inversion, and he was the first to derive a prescription for the turbulent diffusivity produced by the thermohaline instability in stellar radiation zones. This prescription is based on a linear analysis, and it is certainly very crude, but it has the merit to exist. When it is applied to the μ-inversion layer in RGB stars, with the shape factor recommended by Ulrich, it yields a surface composition that reproduces the observed behaviour of the carbon isotopic ratio as well as that of lithium, carbon and nitrogen in RGB stars; it simultaneously leads to the destruction of most of the 3He produced during the star's lifetime (Charbonnel & Zahn 2007a). Charbonnel & Zahn (2007b) then focussed on observations that disagree with that general scheme: a couple of evolved stars, NGC 3242 and J320, appear indeed to have eluded the thermohaline mixing because they show a high 3He abundance (Balser et al. 2007). Charbonnel & Zahn suggest that a fossil magnetic field suppresses the thermohaline mixing in the descendants of Ap stars, including NGC 3242 and J320. The relative number of such stars with respect to non-magnetic objects that undergo thermohaline mixing is consistent with the statistical constraint coming from observations of the carbon isotopic ratio in red giant stars. It also satisfies the Galactic requirements for the evolution of the 3He abundance.

An opposite assumption was made by Busso et al. (2007) who suggest that extra-mixing on the RGB originates in a stellar dynamo operated by the differential rotation below the envelope, maintaining toroidal magnetic fields near the hydrogen-burning shell. They use a phenomenological approach to the buoyancy of magnetic flux tubes, assuming that they induce matter circulation as needed by the so-called "cool bottom processing" models. The distinction between the two opposite explanations should be made possible in the near future, thanks to the search for magnetic fields in evolved stars with spectropolarimeters.

The prediction of the spins of the compact remnants is a fundamental goal of the theory of stellar evolution. Suijs et al. (2008) confronted the predictions for white dwarf spins from evolutionary models including rotation with observational constraints. They calculate two sets of model sequences, with and without inclusion of magnetic fields. From the final computed models of each sequence, they deduce the angular momenta and rotational velocities of the emerging white dwarfs. They found that while models including magnetic torques predict white dwarf rotational velocities between 2 and 10 km s^{-1}, those from the nonmagnetic sequences are found to be one to two orders of magnitude larger, well above empirical upper limits. They find the situation analogous to that in the neutron star progenitor mass range, and conclude that magnetic torques may be required to understand the slow rotation of compact stellar remnants in general.

Some progress has also been made on the impact of internal gravity waves (IGW) in stellar interiors. Talon & Charbonnel (2008) showed that angular momentum transport by IGWs emited by the convective envelope could be quite important in intermediate-mass stars on the pre-main sequence, at the end of the sub- giant branch, and during the early-AGB phase. This implies that possible dierential rotation, which could be a relic of the stars main sequence history and subsequent contraction, could be strongly reduced when the star reaches the AGB-phase. This could have profound impact on the subsequent evolution. In particular, this could help explaining the observed white dwarf spins (Suijs et al. 2008).

5. Helio– and asteroseismology (J. Montalbán and A. Noels)

Helioseismology has proven during the last decade, with SOHO especially, that probing the internal structure of the Sun was indeed within our reach. As a result, researchers have made tremendous efforts in obtaining light curves for stars covering the whole HR diagram. Ground-based observations are now reaching high levels of accuracy. Space missions have been designed to even more increase the signal to noise ratios for variable stars observed during long periods of time. After the successful MOST mission (still running), the CoRoT satellite was launched on December 26, 2007. It has already achieved an initial run of ∼60 days, short runs of ∼30 days and long runs of ∼150 days. The light curves of an exceptional quality are now in the process of being analysed and frequencies have already been obtained for various types of variable stars, from solar-like to γ Dor, δ Scu, SPB, ρ Cep, and red giants. KEPLER and BRITE will soon follow while PLATO is waiting for a final selection.

On the other hand, "HELAS", the European Helio- and Asteroseismology Network is funded by the European Commission since April 1st, 2006, as a "Co-ordination Action" under its Sixth Framework Programme (FP6). The role of HELAS is to coordinate the activities of researchers active in the helio- and asteroseismology fields. These coordinating activities are certainly creating a dynamism among researchers mostly through colloquia and workshops (see http://www.helas-eu.org/ for a list of HELAS meetings) and are helping to promote this new approach of the understanding of stellar interiors.

The Sun has indeed "suffered" from the new solar abundances (Asplund et al. 2005). These abundances, of the order of 30% smaller for C,N,O, decrease the opacity near the internal border of the convective envelope, which destroys the good agreement between the standard solar models and helioseismology found with Grevesse & Noels (1993) abundances. A thorough discussion of all the effects of these new low abundances on the internal structure of the Sun and of the possible solutions has been made by Basu & Antia (2008). An increase of opacity in the upper radiative zone seems to be needed to reconcile the theoretical new Sun with helioseismic observations. A possible solution was proposed by Drake & Testa (2005) suggesting an increase in the Ne abundance by a factor 2.5 based on X-ray measurements. This is now totally contradicted by new observations (Robrade et al. 2008), which confirm the low Ne value recommended by Asplund et al. (2005). The "solar problem" is still pending.

Stars are now entering the game with full force. Important questions are on the verge of being answered or put into perspective:

- What are the consequences of the new solar abundances (Asplund et al. 2005) on other types of stars? The lower abundances of C,N,O are due to combined NLTE effects and 3D modelling of the atmospheric layers. They should affect hot stars as well. New abundances determinations (Morel et al. 2006) are in favour of such a decrease in C,N,O and of a low metallicity of about Z=0.01 in B stars.
- Different abundance mixtures but also different opacities (OPAL versus OP) have been tested in SPB and β Cep stars modelling (Pamyatnykh 2007; Miglio et al. 2007; Dziembowski and Pamyatnykh 2008). Although the situation is improving with the new solar abundances and OP opacities, there still remain some problems with the excitation of the observed modes. There seems to be a need for an upward revision of opacities, especially in the temperature domain of the iron opacity bump, an alternative solution being an accumulation of iron due to radiative forces. Such an increase in opacity is necessary to explain the presence of pulsations in some β Cep, especially in a low Z environment such as the SMC (Diago et al. 2008).
- An iron enhancement in the iron opacity bump is also necessary to explain the excitation in sdB stars (Jeffery & Saio, 2006; Charpinet et al. 2007). Binarity seems to be rather common in sdBs (van Grootel et al. 2008) and the question of the origin (single or binary) of such stars is now a matter of debate.
- Modelling convection and the interaction between convection and pulsation plays a key role in establishing the red limits of the instability strips, not only for δ Scu stars but also for γ Dor stars (Dupret et al. 2007).
- Although progress has been made in the understanding of roAps pulsations (Théado et al. 2005; Théado and Cunha 2006), the coolest roAp stars are still to be explained (Théado et al. 2008). The presence of a magnetic field is a necessary condition to explain the lack of δ Scu–like pulsations in roAp stars. The blue to red feature in the line-profile

variation can be explained by shock waves propagating through the atmospheric layers, in accordance with the oblique pulsator model (Shibahashi et al. 2008).

- Stochastic excitation of non radial modes in solar-like stars is the result of the presence of an outer convective zone (Belkacem et al. 2008). Since convective zone can also be found in hot stars due to the iron peak, solar-like oscillations could indeed be expected in B stars.
- New types of variables have been discovered: B-type supergiants (Lefever et al. 2006), SPBsg (Saio et al. 2006), SPBe (Cameron et al. 2008), hot DQV (their progenitors could be roAps), sdO (Woudt et al. 2006), WR (Moffat et al. 2008), ... and many more are to come.

6. Evolution of binary stars

In the field of formation of binaries, modelling of fragmentation and binary formation processes in 3D has shown that the latter is mainly controlled by the initial ratio of the rotational to the magnetic energy, regardless of the initial thermal energy and amplitude of the nonaxisymmetric perturbations. As the ratio of these energies decreases, formation of clouds results in formation of wide [$a \simeq (3-300)$ A.U.] binaries or close ones [$a \lesssim 0.3$ A.U.]. Thus, one may expect to observe a bimodal distribution of separations for young stars. Strong magnetic field suppresses fragmentation and formation of single stars is then expected (Machida et al. 2008).

A significant attention was devoted to binaries with degenerate donors. It appeared that a larger fraction of detached double WD survive the onset of mass transfer than has been hitherto assumed, even if mass transfer is initially unstable and rises to super-Eddington levels or direct impact occurs (Gokhale et al. 2007; Motl et al. 2007). Deloye & Taam (2006), found that during the early contact phase, while $\dot{M}$ is increasing, gravity wave emission continues to drive the binary to shorter $P_{\rm orb}$ for $10^3 - 10^6$ yr. This may explain $\dot{P}_{\rm orb} < 0$ of RX J0806+1527 and RX J914+2456, the binaries with shortest known $P_{\rm orb}$. D'Antona et al. (2006) have shown that $\dot{P}_{\rm orb} < 0$ on a time scale consistent with the $P_{\rm orb}$ decrease in RX J0806+1527 is possible in a very plausible situation when the donor retained some hydrogen in the envelope and mass-transfer occurs from a not fully-degenerate envelope. The full stellar evolution of arbitrarily degenerate He-dwarf donors in AM CVn systems for the first time was computed by Deloye et al. (2007). Bildsten et al. (2007) noticed that, as the orbit if an AM CVn system widens and $\dot{M}$ drops, the mass required for the unstable ignition of accreted He increases, leading to progressively more violent flashes up to a final flash with helium shell mass 0.02-0.1 $M_\odot$, which may power a faint (M_V = -15 to -18) and rapidly rising (few days) thermonuclear supernova nicknamed "SN .Ia" (one-tenth as bright for one-tenth the time as a SN Ia). On the other hand, Yoon & Langer (2005) have shown that rapid rotation imposed by accretion may stabilise burning in helium shells thus facilitating the growth of WD to Chandrasekhar mass.

In the field of "traditional" H-rich cataclysmic variables, Nomoto et al. (2007) addressed the physics of stable burning of accreted hydrogen by WD and confirmed that it is possible only within a narrow range of $\dot{M}$ close to Eddington limit, while Shen & Bildsten (2007) have shown that this is due to radiation pressure stabilization of burning layer. Norton et al. (2008) carried out numerical simulations of accretion flows in magnetic cataclysmic variables: disks, streams, rings, and propellers and have shown that fundamental observable determining the accretion flow, for a given mass ratio, is the spin-to-orbital-period ratio of the system. A 3D hydrodynamic simulation of the quiescent accretion with the subsequent explosive phase, showing that accumulation of mass is possible was carried out by Walder et al. (2008). Viallet & Hameury (2007) addressed numerically the problem of irradiation of secondaries during outbursts and have shown that the resulting increase in the mass transfer rate is moderate, so unlikely to be able to account for the duration of long outbursts. Matthews et al. (2006) demonstrated that combination of a weak magnetic propeller and accretion disc resonances can effectively halt accretion in short-period CVs. Epelstain et al. (2007) studied a multi-cycle nova evolution and have shown that for a low-mass WD ($0.65 M_\odot$) characteristics of the outbursts remain permanent while for more massive WD ($1 M_\odot$) they change from fast to moderate fast and then attain steady state.

One of the most popular topics remained mergers of relativistic objects, which are deemed to be associated with gamma-ray, gravity wave outbursts, chemical evolution of the galaxies. Different aspects of mergers were studied by Rantsiou et al. (2008, black holes plus neutron stars in 3D), Surman et al. (2008, nucleosynthesis in black hole plus neutron stars mergers), Anderson et al. (2008, GWR from mergers of magnetized neutron stars), Shibata & Taniguchi (2008, fully general relativistic simulation of the black hole plus neutron star binaries), Oechslin & Janka (2007, GWR signal from merging neutron stars as function of EOS and system parameters), Setiawan et al. (2006, 3D-simulations of accretion by remnant black holes of compact object mergers aiming at possibility of production short GRB), Podsiadlowski (2007, stability of mass transfer in black hole – neutron star mergers and conditions for formation of a hot disk around a black hole — progenitor of a short-hard GRB). The role of binarity in producing rapidly spinning Wolf-Rayet stars — progenitors of collapsars associated with long GRB — was studied by Cantiello et al. (2007); Tutukov & Fedorova (2007). Significant efforts were invested in the studies of stellar mergers. Yoon et al. (2007) studied dynamical process of the merger of CO WD, followed by 3D SPH and found conditions in which central object becomes a CO star and a a SN Ia progenitor. Martin et al. (2006) found that if initial masses of accreting CO WD is $1.1\ M_\odot$, mild carbon flashes propagating inward and converting WD into an ONe with subsequent accretion-induced collapse may be avoided, if accretion rate may be limited to ~ 0.46 Eddington. Hicken et al. (2007), based on the enormous amount of ejected ^{56}Ni – $1.2 M_\odot$, suggested that the luminous and carbon-rich SN 2006gz might have a super-Chandrasekhar progenitor and descends from a double-degenerate. Gourgouliatos & Jeffery (2006) showed that it is necessary to lose about 50% of initial angular momentum for for formation of helium-rich giants by CO+He WD mergers.

Madhusudhan et al. (2006); Patruno et al. (2006) computed the models of ULX sources assuming a range of masses for accretors (presumably, intermediate mass black holes) and donors, while Rappaport et al. (2005) have shown that most of ULX may be reproduced assuming stellar mass black holes as accretors.

Bonačić Marinović et al. (2008) suggested a mechanism of a tidally enhanced mass loss from AGB stars, that efficiently works against the tidal circularisation of the orbit in binary systems containing a white dwarf and a less evolved companion, thus allowing to solve a long-standing problem of eccentricities of orbits of systems like Sirius and barium stars.

Francesca D'Antona
president of the Commission 35

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