Dear Colleagues,

It is my pleasure to present you the 148th issue of the Magellanic Clouds Newsletter, if with a slight delay. This time, γ-rays and supernova remnants were popular, as were star clusters and their main-sequence turnoffs, as well as the inter-Cloud region seen in variable stars. Plus more!

John Lattanzio’s turning 60 – join the party!

If you have an image, diagram or spectrum you’d like to see featured on the front cover of the newsletter, just send me the file.

The next issue is planned to be distributed on the 1st of October 2017.

Editorially Yours,

Jacco van Loon
We present ALMA and ATCA observations of the luminous blue variable RMC 127. The radio maps show for the first time the core of the nebula and evidence that the nebula is strongly asymmetric with a Z-pattern shape.Hints of this morphology are also visible in the archival HST Hα image, which overall resembles the radio emission. The emission mechanism in the outer nebula is optically thin free–free in the radio. At high frequencies, a component of point-source emission appears at the position of the star, up to the ALMA frequencies. The rising flux density distribution ($S_\nu \sim \nu^{0.78 \pm 0.05}$) of this object suggests thermal emission from the ionized stellar wind and indicates a departure from spherical symmetry with $n_e(r) \propto r^{-2}$. We examine different scenarios to explain this excess of thermal emission from the wind and show that this can arise from a bipolar outflow, supporting the suggestion by other authors that the stellar wind of RMC 127 is aspherical. We fit the data with two collimated ionized wind models and we find that the mass-loss rate can be a factor of two or more smaller than in the spherical case. We also fit the photometry obtained by IR space telescopes and deduce that the mid- to far-IR emission must arise from extended, cool ($\sim 80$ K) dust within the outer ionized nebula. Finally we discuss two possible scenarios for the nebular morphology: the canonical single star expanding shell geometry, and a precessing jet model assuming presence of a companion star.

predominantly by cosmic rays colliding with the interstellar medium through neutral pion ($\pi$) decay. The $\pi$-decay mechanism predicts a unique spectral signature in the $\gamma$-ray spectrum, characterized by a fast rising spectrum and a spectral break below a few hundreds of MeV. We here report the evidence of a spectral break around 500 MeV in the disk emission of Large Magellanic Cloud (LMC), which is found in the analysis of the $\gamma$-ray data extending down to 60 MeV observed by Fermi-Large Area Telescope. The break is well consistent with the $\pi$-decay model for the $\gamma$-ray emission, although leptonic models, such as the electron bremsstrahlung emission, cannot be ruled out completely.

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ALMA observations of N83C in the early stage of star formation in the Small Magellanic Cloud

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We have performed Atacama Large Millimeter/submillimeter Array (ALMA) observations in $^{12}$CO($J = 2–1$), $^{13}$CO($J = 2–1$), C$^{18}$O($J = 2–1$), $^{12}$CO($J = 3–2$), $^{13}$CO($J = 3–2$), and CS($J = 7–6$) lines toward the active star-forming region N83C in the Small Magellanic Cloud (SMC), whose metallicity is $\sim$ 1/5 of the Milky Way (MW). The ALMA observations first reveal sub-pc scale molecular structures in $^{12}$CO($J = 2–1$) and $^{13}$CO($J = 2–1$) emission. We found strong CO peaks associated with young stellar objects (YSOs) identified by the Spitzer Space Telescope, and also found that overall molecular gas is distributed along the edge of the neighboring H ii region. We derived a gas density of $\sim$ 10$^4$ cm$^{-3}$ in molecular clouds associated with YSOs based on the virial mass estimated from $^{12}$CO($J = 2–1$) emission. This high gas density is presumably due to the effect of the H ii region under the low-metallicity (accordingly small-dust content) environment in the SMC; far-UV radiation from the H ii region can easily penetrate and photo-dissociate the outer layer of $^{12}$CO molecules in the molecular clouds, and thus only the innermost parts of the molecular clouds are observed even in $^{12}$CO emission. We obtained the CO-to-H$_2$ conversion factor $X_{\text{CO}}$ of $\sim 8 \times 10^{20}$ cm$^{-2}$ (K km s$^{-1}$)$^{-1}$ in N83C based on virial masses and CO luminosities, which is four times larger than that in the MW, $2 \times 10^{20}$ cm$^{-2}$ (K km s$^{-1}$)$^{-1}$. We also discuss the difference in the nature between two high-mass YSOs, each of which is associated with a molecular clump with a mass of about a few $\times 10^3$ M$_\odot$.

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Very deep inside the SN 1987A core ejecta: Molecular structures seen in 3D

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Most massive stars end their lives in core-collapse supernova explosions and enrich the interstellar medium with explosively nucleosynthesized elements. Following core collapse, the explosion is subject to instabilities as the shock propagates outwards through the progenitor star. Observations of the composition and structure of the innermost regions of a core-collapse supernova provide a direct probe of the instabilities and nucleosynthetic products. SN 1987A in the Large Magellanic Cloud (LMC) is one of very few supernovae for which the inner ejecta can be spatially resolved but are not yet strongly affected by interaction with the surroundings. Our observations of SN 1987A with the Atacama Large Millimeter/submillimeter Array (ALMA) are of the highest resolution to date and reveal the detailed morphology of cold molecular gas in the innermost regions of the remnant. The 3D distributions of carbon and silicon monoxide (CO and SiO) emission differ, but both have a central deficit, or torus-like distribution, possibly a result of radioactive heating during the first weeks (“nickel heating”). The size scales of the clumpy distribution are compared quantitatively to models, demonstrating how progenitor and explosion physics can be constrained.

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Mass loss rates from mid-IR excesses in LMC and SMC O stars

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We use a combination of \textit{BVJHK} and \textit{Spitzer} [3.6], [5.8] and [8.0] photometry to determine IR excesses for a sample of 58 LMC and 46 SMC O stars. This sample is ideal for determining IR excesses because the very small line of sight reddening minimizes uncertainties due to extinction corrections. We use the core-halo model developed by Lamers &
Waters (1984a) to translate the excesses into mass loss rates and demonstrate that the results of this simple model agree with the more sophisticated cmfgen models to within a factor of 2. Taken at face value, the derived mass loss rates are larger than those predicted by Vink et al. (2001), and the magnitude of the disagreement increases with decreasing luminosity. However, the IR excesses need not imply large mass loss rates. Instead, we argue that they probably indicate that the outer atmospheres of O stars contain complex structures and that their winds are launched with much smaller velocity gradients than normally assumed. If this is the case, it could affect the theoretical and observational interpretations of the “weak wind” problem, where classical mass loss indicators suggest that the mass loss rates of lower luminosity O stars are far less than expected.

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Discovery of extended main sequence turn-offs in four young massive clusters in the Magellanic Clouds

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An increasing number of young massive clusters (YMCs) in the Magellanic Clouds have been found to exhibit bimodal or extended main sequences (MSs) in their color–magnitude diagrams (CMDs). These features are usually interpreted in terms of a coeval stellar population with different stellar rotational rates, where the blue and red MS stars are populated by non- (or slowly) and rapidly rotating stellar populations, respectively. However, some studies have shown that an age spread of several million years is required to reproduce the observed wide turn-off regions in some YMCs. Here we present the ultraviolet–visual CMDs of four Large and Small Magellanic Cloud YMCs, NGC 330, NGC 1805, NGC 1818, and NGC 2164, based on high-precision Hubble Space Telescope photometry. We show that they all exhibit extended main-sequence turn-offs (MSTOs). The importance of age spreads and stellar rotation in reproducing the observations is investigated. The observed extended MSTOs cannot be explained by stellar rotation alone. Adopting an age spread of 35–50 Myr can alleviate this difficulty. We conclude that stars in these clusters are characterized by ranges in both their ages and rotation properties, but the origin of the age spread in these clusters remains unknown.

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Linking $\gamma$-ray spectra of supernova remnants to the cosmic ray injection properties in the aftermath of supernovæ

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The acceleration times of the highest-energy particles which emit $\gamma$-rays in young and middle-age SNRs are comparable
with SNR age. If the number of particles starting acceleration was varying during early times after the supernova explosion then this variation should be reflected in the shape of the γ-ray spectrum. We use the solution of the non-stationary equation for particle acceleration in order to analyze this effect. As a test case, we apply our method to describe γ-rays from IC 443. As a proxy of the IC 443 parent supernova we consider SN 1987A. First, we infer the time dependence of injection efficiency from evolution of the radio spectral index in SN 1987A. Then, we use the inferred injection behavior to fit the γ-ray spectrum of IC 443. We show that the break in the proton spectrum needed to explain the γ-ray emission is a natural consequence of the early variation of the cosmic ray injection, and that the very-high energy γ-rays originate from particles which began acceleration during the first months after the supernova explosion. We conclude that the shape of the γ-ray spectrum observed today in SNRs critically depends on the time variation of the cosmic ray injection process in the immediate post explosion phases. With the same model, we estimate also the possibility in the future to detect γ-rays from SN 1987A.

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OGLE-ing the Magellanic System: three-dimensional structure of the Clouds and the Bridge using RR Lyræ stars

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We present a three-dimensional analysis of a sample of 22 859 type ab RR Lyrae stars in the Magellanic System from the OGLE-IV Collection of RR Lyrae stars. The distance to each object was calculated based on its photometric metallicity and a theoretical relation between color, absolute magnitude and metallicity. The LMC RR Lyrae distribution is very regular and does not show any substructures. We demonstrate that the bar found in previous studies may be an overdensity caused by blending and crowding effects. The halo is asymmetrical with a higher stellar density in its north-eastern area, which is also located closer to us. Triaxial ellipsoids were fitted to surfaces of a constant number density. Ellipsoids farther from the LMC center are less elongated and slightly rotated toward the SMC. The inclination and position angle change significantly with the a axis size. The median axis ratio is 1:1.23:1.45.

The RR Lyrae distribution in the SMC has a very regular, ellipsoidal shape and does not show any substructures or asymmetries. All triaxial ellipsoids fitted to surfaces of a constant number density have virtually the same shape (axis ratio) and are elongated along the line of sight. The median axis ratio is 1:1.10:2.13. The inclination angle is very small and thus the position angle is not well defined.

We present the distribution of RR Lyrae stars in the Magellanic Bridge area, showing that the Magellanic Clouds’ halos overlap.

A comparison of the distributions of RR Lyrae stars and Classical Cepheids shows that the former are significantly more spread and distributed regularly, while the latter are very clumped and form several distinct substructures.

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and from http://adsabs.harvard.edu/abs/2017AcA....67....1J
Concluding Henrietta Leavitt’s work on Classical Cepheids in the Magellanic System and other updates of the OGLE collection of variable stars

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More than a century ago, Henrietta Leavitt discovered the first Cepheids in the Magellanic Clouds together with the famous period–luminosity relationship revealed by these stars, which soon after revolutionized our view of the Universe. Over the years, the number of known Cepheids in these galaxies has steadily increased with the breakthrough in the last two decades thanks to the new generation of large-scale long-term sky variability surveys.

Here we present the final upgrade of the OGLE Collection of Cepheids in the Magellanic System which already contained the vast majority of known Cepheids. The updated collection now comprises 9649 classical and 262 anomalous Cepheids. Type-II Cepheids will be updated shortly. Thanks to high completeness of the OGLE survey the sample of classical Cepheids includes virtually all stars of this type in the Magellanic Clouds. Thus, the OGLE survey concludes the work started by Henrietta Leavitt.

Additionally, the OGLE sample of RR Lyr stars in the Magellanic System has been updated. It now counts 46 443 variables. A collection of seven anomalous Cepheids in the halo of our Galaxy detected in front of the Magellanic Clouds is also presented.

OGLE photometric data are available to the astronomical community from the OGLE Internet Archive. The time-series photometry of all pulsating stars in the OGLE Collection has been supplemented with new observations.

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A novel method to automatically detect and measure the ages of star clusters in nearby galaxies: Application to the Large Magellanic Cloud

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We present our new, fully-automated method to detect and measure the ages of star clusters in nearby galaxies, where individual stars can be resolved. The method relies purely on statistical analysis of observations and Monte-Carlo simulations to define stellar overdensities in the data. It decontaminates the cluster color–magnitude diagrams and, using a revised version of the Bayesian isochrone fitting code of Ramírez-Siordia et al., estimates the ages of the clusters. Comparisons of our estimates with those from other surveys show the superiority of our method to extract and measure the ages of star clusters, even in the most crowded fields. An application of our method is shown for the high-resolution, multi-band imaging of the Large Magellanic Cloud. We detect 4850 clusters in the 7 deg2 we surveyed, 3451 of which have not been reported before. Our findings suggest multiple epochs of star cluster formation, with the most probable occurring ∼ 310 Myr ago. Several of these events are consistent with the epochs of the interactions among the Large and Small Magellanic Clouds, and the Galaxy, as predicted by N-body numerical simulations. Finally, the spatially resolved star cluster formation history may suggest an inside-out cluster formation scenario throughout the LMC, for the past 1 Gyr.

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Extended main sequence turnoffs in intermediate-age star clusters: stellar rotation diminishes, but does not eliminate, age spreads

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Extended main sequence turn-off (eMSTO) regions are a common feature in color–magnitude diagrams of young and intermediate-age star clusters in the Magellanic Clouds. The nature of eMSTOs remains debated in the literature. The currently most popular scenarios are extended star formation activity and ranges of stellar rotation rates. Here we study details of differences in MSTO morphology expected from spreads in age versus spreads in rotation rates, using Monte Carlo simulations with the Geneva syclist isochrone models that include the effects of stellar rotation. We confirm a recent finding of Niederhofer et al. that a distribution of stellar rotation velocities yields an MSTO extent that is proportional to the cluster age, as observed. However, we find that stellar rotation yields MSTO crosscut widths that are generally smaller than observed ones at a given age. We compare the simulations with high-quality Hubble Space Telescope data of NGC 1987 and NGC 2249, the two only relatively massive star clusters with an age of ~1 Gyr for which such data is available. We find that the distribution of stars across the eMSTOs of these clusters cannot be explained solely by a distribution of stellar rotation velocities, unless the orientations of rapidly rotating stars are heavily biased towards an equator-on configuration. Under the assumption of random viewing angles, stellar rotation can account for ~60% and ~40% of the observed FWHM widths of the eMSTOs of NGC 1987 and NGC 2249, respectively. In contrast, a combination of distributions of stellar rotation velocities and stellar ages fits the observed eMSTO morphologies very well.

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Spatial variations of turbulent properties of neutral hydrogen gas in the Small Magellanic Cloud using structure function analysis

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We investigate spatial variations of turbulent properties in the Small Magellanic Cloud (SMC) by using neutral hydrogen (H i) observations. With the goal of testing the importance of stellar feedback on H i turbulence, we define central and outer SMC regions based on the star formation rate (SFR) surface density, as well as the H i integrated intensity. We use the structure function and the Velocity Channel Analysis (VCA) to calculate the power-law index (γ) for both underlying density and velocity fields in these regions. In all cases, our results show essentially no difference in γ between the central and outer regions. This suggests that H i turbulent properties are surprisingly homogeneous across the SMC when probed at a resolution of 30 pc. Contrary to recent suggestions from numerical simulations, we do not find a significant change in γ due to stellar feedback as traced by the SFR surface density. This could be due to the stellar feedback being widespread over the whole of the SMC, but more likely due to a large-scale gravitational driving of turbulence. We show that the lack of difference between central and outer SMC regions can not be explained by the high optical depth H i.

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The real population of star clusters in the bar of the Large Magellanic Cloud

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We report results on star clusters located in the South–Eastern half of the Large Magellanic (LMC) bar from Washington CT measured photometry. Using appropriate kernel density estimators we detected 73 star cluster candidates, three of which do not show any detectable trace of star cluster sequences in their colour–magnitude diagrams (CMDs). We did not detect other 38 previously catalogued clusters, which could not be recognized when visually inspecting the C and T images either; the distribution of stars in their respective fields do not resemble that of an stellar aggregate. They represent ∼ 33 per cent of all catalogued objects located within the analysed LMC bar field. From matching theoretical isochrones to the cluster CMDs cleaned from field star contamination, we derived ages in the range $7.2 < \log(t \text{ yr}^{-1}) < 10.1$. As far as we are aware, this is the first time homogeneous age estimates based on resolved stellar photometry are obtained for most of the studied clusters. We built the cluster frequency (CF) for the surveyed area, and found that the major star cluster formation activity has taken place during the period $\log(t \text{ yr}^{-1}) \sim 8.0–9.0$. Since ∼ 100 Myr ago, clusters have been formed during few bursting formation episodes. When comparing the observed CF to that recovered from the star formation rate we found noticeable differences, which suggests that field star and star cluster formation histories could have been significantly different.

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The 2016 super-Eddington outburst of SMC X-3: X-ray and optical properties and system parameters


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On 2016 July 30 (MJD 57599), observations of the Small Magellanic Cloud by Swift/XRT found an increase in X-ray counts coming from a position consistent with the Be/X-ray binary pulsar SMC X-3. Follow-up observations on 2016 August 3 (MJD 57603) and 2016 August 10 (MJD 57610) revealed a rapidly increasing count rate and confirmed the onset of a new X-ray outburst from the system. Further monitoring by Swift began to uncover the enormity of the outburst, which peaked at $1.2 \times 10^{39}$ erg s$^{-1}$ on 2016 August 25 (MJD 57625). The system then began a gradual decline in flux that was still continuing over 5 months after the initial detection. We explore the X-ray and optical behaviour of SMC X-3 between 2016 July 30 and 2016 December 18 during this super-Eddington outburst. We apply a binary model to the spin-period evolution that takes into account the complex accretion changes over the outburst, to solve for the orbital parameters. Our results show SMCX-3 to be a system with a moderately low eccentricity amongst the Be/X-ray binary systems and to have a dynamically determined orbital period statistically consistent with the prominent period measured in the OGLE optical light curve. Our optical and X-ray derived ephemerides show that the peak in optical flux occurs roughly 6 days after periastron. The measured increase in I-band flux from the counterpart during the outburst is reflected in the measured equivalent width of the H$\alpha$ line emission, though the H$\alpha$ emission itself seems variable on sub-day time-scales, possibly due to the NS interacting with an inhomogeneous disc.

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The Magellanic Inter-Cloud Project (MAGIC) III: First spectroscopic evidence of a dwarf stripping a dwarf

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The Magellanic Bridge (MB) is a gaseous stream that links the Large (LMC) and Small (SMC) Magellanic Clouds. Current simulations suggest that the MB forms from a recent interaction between the Clouds. In this scenario, the MB should also have an associated stellar bridge formed by stars tidally stripped from the SMC by the LMC. There are several observational evidences for these stripped stars, from the presence of intermediate age populations in the MB and carbon stars, to the recent observation of an over-density of RR\,Lyrae stars offset from the MB. However, spectroscopic confirmation of stripped stars in the MB remains lacking. In this paper, we use medium resolution spectra to derive the radial velocities and metallicities of stars in two fields along the MB. We show from both their chemistry and kinematics that the bulk of these stars must have been tidally stripped from the SMC. This is the first spectroscopic evidence for a dwarf galaxy being tidally stripped by a larger dwarf.

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Conference Papers

Observed properties of red supergiant and massive AGB star populations

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This brief review describes some of the observed properties of the populations of massive asymptotic giant branch (AGB) stars and red supergiants (RSGs) found in nearby galaxies, with a focus on their luminosity functions, mass-loss rates and dust production. I do this within the context of their role as potential supernova (SN) progenitors, and the evolution of SNe and their remnants. The paper ends with an outlook to the near future, in which new facilities such as the James Webb Space Telescope offer a step change in our understanding of the evolution and fate of the coolest massive stars in the Universe.

The evolution of massive stars: bridging the gap in the Local Group

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The nearby galaxies of the Local Group can act as our laboratories in helping to bridge the gap between theory and observations. In this review we will describe the complications of identifying samples of OB stars, yellow and red supergiants, and Wolf–Rayet stars, and what we have so far learned from these studies.

Oral contribution, published in “Bridging the gap: from massive stars to supernovæ”, Philosophical Transactions A

Properties of O dwarf stars in 30 Doradus

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We perform a quantitative spectroscopic analysis of 105 presumably single O dwarf stars in 30 Doradus, located within the Large Magellanic Cloud. We use mid-to-high resolution multi-epoch optical spectroscopic data obtained within the VLT-FLAMES Tarantula Survey. Stellar and wind parameters are derived by means of the automatic tool \texttt{iacob-gbat}, which is based on a large grid of \texttt{fastwind} models. We also benefit from the Bayesian tool \texttt{bonnsai} to estimate evolutionary masses. We provide a spectral calibration for the effective temperature of O dwarf stars in the LMC, deal with the mass discrepancy problem and investigate the wind properties of the sample.

Oral contribution, published in IAU Symposium No. 329, ”The lives and death-throes of massive stars”

Announcement

Conference to celebrate the 60\textsuperscript{th} birthday of John Lattanzio

You are invited to participate in in a workshop to celebrate John Lattanzio’s 60\textsuperscript{th} birthday.

\textit{One Hand Waving Free}

A workshop to celebrate the first 60 years of John Lattanzio

Port Douglas, Queensland

29\textsuperscript{th} October to 4\textsuperscript{th} November 2017

This meeting celebrates the life and achievements of Prof. John C. Lattanzio. John has made a succession of important contributions to the theory of stellar evolution over a sustained career that has seen him move to Canada, the USA and the United Kingdom before returning to his Australian roots. He remains instantly recognisable on the international stage where he is a speaker of choice on many aspects of stellar evolution and nucleosynthesis. Lattanzio’s contributions to research training at all levels are numerous. His undergraduate lectures are delivered with an enthusiasm that has ignited many a career in astrophysics and he has trained a number of excellent graduate students and postdoctoral researchers who have gone on to hold positions worldwide. John is the active president of
the International Astronomical Union’s Commission G3 on stellar evolution.

The workshop will cover the topics on which John has had such an impact through his varied and distinguished career. Scientific sessions will focus on topics on which John has worked and will include stellar evolution of low- and intermediate-mass stars, SAGB stars, nucleosynthesis, grains, galactic archaeology and hydrodynamics of star formation and evolution as well as outreach sessions for the public and for undergraduates.

Please address any questions to

lattanzio60th@gmail.com

We look forward to hearing from you soon and indeed seeing you in Port Douglas.

Spaces are limited but there is plenty of room for now. Registration is open with a deadline of 28th August.

Many thanks and best wishes,
Christopher Tout, John Lattanzio, Richard Stancliffe, Amanda Karakas and Ghina Halabi

See also [http://www.ast.cam.ac.uk/~gmh/JL60th/](http://www.ast.cam.ac.uk/~gmh/JL60th/)