THE AGB NEWSLETTER

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Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra

Figure 1: The Mask Nebula, a planetary nebula in the Southern constellation of Circinus, captured by Don Goldman. See http://astrodonimaging.com/gallery/mask-nebula

Editorial

Dear Colleagues,

It is our pleasure to present you the 227th issue of the AGB Newsletter. It's nice to see Mira itself be the subject of two papers...

Looking for a job? A postdoctoral research post has opened to work on laboratory astrochemistry in lovely Leuven.

Don't forget the continuing Fizeau programme for visits related to optical interferometry.

While the registration deadline was yesterday, asking nicely perhaps might still get you a place on the School on the topic of radio astrophysics.

Thanks to Sakib Rasool for suggesting the cover picture. Please suggest also real new scientific results, not just pictures but spectra or diagrams (or even drawings) will be considered too.

The next issue is planned to be distributed around the 1st of July.

Editorially Yours,
Jacco van Loon, Ambra Nanni and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

What happens when two white dwarves merge, if their total mass is sub-Chandrasekhar?

Reactions to this statement or suggestions for next month's statement can be e-mailed to astro.agbnews@keele.ac.uk (please state whether you wish to remain anonymous)

Refereed Journal Papers

Resolving the extended atmosphere and the inner wind of Mira (o Ceti) with long ALMA baselines

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Context: High angular resolution (sub)millimetre observations of asymptotic giant branch (AGB) stars, now possible with the Atacama Large Millimeter/submillimeter Array (ALMA), allow direct imaging of these objects' photospheres. The physical properties of the molecular material around these regions, which until now has only been studied by imaging of maser emission and spatially unresolved absorption spectroscopy, can be probed with radiative transfer modelling and compared to hydrodynamical model predictions. The prototypical Mira variable, o Cet (Mira), was observed as a Science Verification target in the 2014 ALMA Long Baseline Campaign, offering the first opportunity to study these physical conditions in detail.

Aims: With the longest baseline of 15 km, ALMA produces clearly resolved images of the continuum and molecular line emission/absorption at an angular resolution of ~ 30 mas at 220 GHz. Models are constructed for Mira's extended atmosphere to investigate the physics and molecular abundances therein.

Methods: We imaged the data of ^{28}SiO $v = 0, 2$ $J = 5$–4 and H_2O $v_2 = 1$ $J_{K_a,K_c} = 5_{5,0}$–$6_{4,3}$ transitions and extracted spectra from various lines of sight towards Mira's extended atmosphere. In the course of imaging the emission/absorption, we encountered ambiguities in the resulting images and spectra that appear to be related to the performance of the CLEAN algorithm when applied to a combination of extended emission, and compact emission and absorption. We addressed these issues by a series of tests and simulations. We derived the gas density, kinetic temperature, molecular abundance, and outflow/infall velocities in Mira's extended atmosphere by modelling the SiO and H_2O lines.

Results: We resolve Mira's millimetre continuum emission and our data are consistent with a radio photosphere with a brightness temperature of 2611 ± 51 K. In agreement with recent results obtained with the Very Large Array, we do not confirm the existence of a compact region (< 5 mas) of enhanced brightness. Our modelling shows that SiO gas starts to deplete beyond 4 $R_\star$ and at a kinetic temperature of $\lesssim$600 K. The inner dust shells are probably composed of grain types other than pure silicates. During this ALMA observation, Mira's atmosphere generally exhibited infall motion with a shock front of velocity $\lesssim$12 km s^{-1} outside the radio photosphere. Despite the chaotic nature of Mira's atmosphere, the structures predicted by the hydrodynamical model, CODEX, can reproduce the observed spectra in astonishing detail, while some other models fail when confronted with the new data.

Conclusions: For the first time, millimetre-wavelength molecular absorption against the stellar continuum has been clearly imaged. Combined with radiative transfer modelling, the ALMA data successfully demonstrates the ability to reveal the physical conditions of the extended atmospheres and inner winds of AGB stars in unprecedented detail. Long-term monitoring of oxygen-rich evolved stars will be the key to understanding the unsolved problem of dust condensation and the wind-driving mechanism.

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and from http://www.aanda.org/10.1051/0004-6361/201527867

Chromospheric models and the oxygen abundance in giant stars

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Realistic stellar atmospheric models of two typical metal-poor giant stars in ω Centauri that include a chromosphere

influence the formation of optical lines of Oxygen I: the forbidden lines (630nm, 636nm) and the infrared triplet (777.1–777.5 nm). One-dimensional semi-empirical non-LTE models are constructed based on observed Balmer lines. A full non-LTE formulation is applied in evaluating line strengths of O I including photoionization by the Lyman continuum and photoexcitation by Ly-α and Ly-β. Chromospheric models (CHR) yield forbidden oxygen transitions that are stronger than in radiative/convective equilibrium (RCE) models. The triplet oxygen lines from high levels also appear stronger than produced in an RCE model. The inferred oxygen abundance from realistic CHR models for these two stars is decreased by factors ~ 3 as compared to values derived from RCE models. A lower oxygen abundance suggests that intermediate mass AGB stars contribute to the observed abundance pattern in globular clusters. A change in the oxygen abundance of metal-poor field giants could affect models of deep mixing episodes on the red giant branch. Changes in the oxygen abundance can impact other abundance determinations critical to astrophysics including chemical tagging techniques and galactic chemical evolution.

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An extreme paucity of second population AGB stars in the "normal" globular cluster M 4

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Galactic Globular clusters (GCs) are now known to harbour multiple stellar populations, which are chemically distinct in many light element abundances. It is becoming increasingly clear that asymptotic giant branch (AGB) stars in GCs show different abundance distributions in light elements compared to those in the red giant branch (RGB) and other phases, skewing toward more primordial, field-star-like abundances, which we refer to as subpopulation one (SP1). As part of a larger program targeting giants in GCs, we obtained high-resolution spectra for a sample of 106 RGB and 15 AGB stars in Messier 4 (NGC 6121) using the 2dF+HERMES facility on the AngloAustralian Telescope. In this Letter we report an extreme paucity of AGB stars with [Na/O] > -0.17 in M 4, which contrasts with the RGB that has abundances up to [Na/O] $= 0.55$. The AGB abundance distribution is consistent with all AGB stars being from SP1. This result appears to imply that all subpopulation two stars (SP2; Na-rich, O-poor) avoid the AGB phase. This is an unexpected result given M 4's horizontal branch morphology – it does not have an extended blue horizontal branch. This is the first abundance study to be performed utilising the HERMES spectrograph.

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A HIFI view on circumstellar H_2O in M-type AGB stars: radiative transfer, velocity profiles, and H_2O line cooling

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Aims: We aim to constrain the temperature and velocity structures, and H_2O abundances in the winds of a sample of M-type Asymptotic Giant Branch (AGB) stars. We further aim to determine the effect of H_2O line cooling on the

energy balance in the inner circumstellar envelope.
Methods: We use two radiative-transfer codes to model molecular emission lines of CO and H_2O towards four M-type AGB stars. We focus on spectrally resolved observations of CO and H_2O from HIFI aboard the *Herschel* Space Observatory. The observations are complemented by ground-based CO observations, and spectrally unresolved CO and H_2O observations with PACS aboard *Herschel*. The observed line profiles constrain the velocity structure throughout the circumstellar envelopes (CSEs), while the CO intensities constrain the temperature structure in the CSEs. The H_2O observations constrain the o-H_2O and p-H_2O abundances relative to H_2. Finally, the radiative-transfer modelling allows to solve the energy balance in the CSE, in principle including also H_2O line cooling.
Results: The fits to the line profiles only set moderate constraints on the velocity profile, indicating shallower acceleration profiles in the winds of M-type AGB stars than predicted by dynamical models, while the CO observations effectively constrain the temperature structure. Including H_2O line cooling in the energy balance was only possible for the low-mass-loss-rate objects in the sample, and required an ad hoc adjustment of the dust velocity profile in order to counteract extreme cooling in the inner CSE. H_2O line cooling was therefore excluded from the models. The constraints set on the temperature profile by the CO lines nevertheless allowed us to derive H_2O abundances. The derived H_2O abundances confirm previous estimates and are consistent with chemical models. However, the uncertainties in the derived abundances are relatively large, in particular for p-H_2O, and consequently the derived o/p-H_2O ratios are not well constrained.

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SU Lyncis, a hard X-ray bright M Giant: Clues point to a large hidden population of symbiotic stars

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Symbiotic star surveys have traditionally relied almost exclusively on low resolution optical spectroscopy. However, we can obtain a more reliable estimate of their total Galactic population by using all available signatures of the symbiotic phenomenon. Here we report the discovery of a hard X-ray source, 4PBC J0642.9+5528, in the *Swift* hard X-ray all-sky survey, and identify it with a poorly studied red giant, SU Lyn, using pointed *Swift* observations and ground-based optical spectroscopy. The X-ray spectrum, the optical to UV spectrum, and the rapid UV variability of SU Lyn are all consistent with our interpretation that it is a symbiotic star containing an accreting white dwarf. The symbiotic nature of SU Lyn went unnoticed until now, because it does not exhibit emission lines strong enough to be obvious in low resolution spectra. We argue that symbiotic stars without shell-burning have weak emission lines, and that the current lists of symbiotic stars are biased in favor of shell-burning systems. We conclude that the true population of symbiotic stars has been underestimated, potentially by a large factor.

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MESA isochrones and stellar tracks (MIST). I: solar-scaled models

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This is the first of a series of papers presenting the Modules for Experiments in Stellar Astrophysics (MESA) Isochrones and Stellar Tracks (MIST) project, a new comprehensive set of stellar evolutionary tracks and isochrones computed using MESA, a state-of-the-art open-source 1D stellar evolution package. In this work, we present models with solar-scaled abundance ratios covering a wide range of ages ($5 \leq \log(\mathrm{Age})$ [yr] ≤ 10.3), masses ($0.1 \leq M/\mathrm{M}_\odot \leq 300$), and metallicities ($-2.0 \leq$ [Z/H] ≤ 0.5). The models are self-consistently and continuously evolved from the pre-main sequence to the end of hydrogen burning, the white dwarf cooling sequence, or the end of carbon burning, depending on the initial mass. We also provide a grid of models evolved from the pre-main sequence to the end of core helium burning for $-4.0 \leq$ [Z/H] < -2.0. We showcase extensive comparisons with observational constraints as well as with some of the most widely used existing models in the literature. The evolutionary tracks and isochrones can be downloaded from the project website at http://waps.cfa.harvard.edu/MIST/.

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All known hot RCB stars are fading fast over the last century

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The R Coronæ Borealis (RCB) stars are cool supergiants that display irregular and deep dips in their light curves, caused by dust formation. There are four known hot RCB stars (DY Cen, MV Sgr, V348 Sgr, and HV 2671), with surface temperatures of 15,000–25,000 K, and prior work has suggested that three of these have secular fading in brightness. I have tested this result by measuring century-long light curves in the Johnson B-band with modern comparison star magnitudes, and I have extended this by measuring many magnitudes over a wide time range as well as for the fourth hot RCB star. In all four cases, the B-band magnitude of the maximum light is now fast fading. The fading rates (in units of magnitudes per century) are 2.5 for DY Cen after 1960, 1.3 for MV Sgr, 1.3 for V348 Sgr, and 0.7 for HV 2671. This secular fading is caused by the expected evolution of the star across the top of the HR diagram at constant luminosity, as the temperature rises and the bolometric correction changes. For DY Cen, the brightness at maximum light is rising from 1906 to 1932, and this is caused by the temperature increase from near 5,800 to 7,500 K. Before 1934 DY Cen had frequent dust dips, while after 1934 there are zero dust dips, so there is some apparent connection between the rising temperature and the formation of the dust. Thus, we have watched DY Cen evolve from an ordinary RCB star up to a hot RCB star and now appearing as an extreme helium star, all in under one century.

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On the relation between the mysterious 21-μm emission feature of post-asymptotic giant branch stars and their mass loss rates

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Over two decades ago, a prominent, mysterious emission band peaking at ~ 20.1 μm was serendipitously detected in

four pre-planetary nebulæ (PPNe; also known as "proto-planetary nebulæ"). So far, this spectral feature, designated as the "21 μm" feature, has been seen in 18 carbon-rich PPNe. The nature of the carriers of this feature remains unknown although many candidate materials have been proposed. The 21-μm sources also exhibit an equally mysterious, unidentified emission feature peaking at 30 μm. While the 21-μm feature is exclusively seen in PPNe, a short-lived evolutionary stage between the end of the asymptotic giant branch (AGB) and planetary nebula (PN) phases, the 30-μm feature is commonly observed in all stages of stellar evolution from the AGB through PPN to PNe phases. We derive the stellar mass loss rates ($M_{\rm loss}$) of these 21-μm sources from their dust infrared (IR) emission, using the 2-DUST radiative transfer code for axisymmetric dusty systems which allows one to distinguish the mass loss rates of the AGB phase ($\dot{M}_{\rm AGB}$) from that of the superwind ($\dot{M}_{\rm SW}$) phase. We examine the correlation between $\dot{M}_{\rm AGB}$ or $\dot{M}_{\rm SW}$ and the fluxes emitted from the 21- and 30-μm features. We find that both features tend to correlate with $\dot{M}_{\rm AGB}$, suggesting that their carriers are probably formed in the AGB phase. The nondetection of the 21-μm feature in AGB stars suggests that, unlike the 30-μm feature, the excitation of the carriers of the 21-μm feature may require ultraviolet photons which are available in PPNe but not in AGB stars.

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Nonlinear pulsations of stars with initial mass 3 $M_\odot$ on the asymptotic giant branch

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Pulsation period changes in Mira type variables are investigated using the stellar evolution and nonlinear stellar pulsation calculations. We considered the evolutionary sequence of stellar models with initial mass $M_{\rm ZAMS} = 3$ $M_\odot$ and population I composition. Pulsations of stars in the early stage of the asymptotic giant branch are shown to be due to instability of the fundamental mode. In the later stage of evolution when the helium shell source becomes thermally unstable the stellar oscillations occur in either the fundamental mode (for the stellar luminosity $L < 5.4 \times 10^3$ $L_\odot$) or the first overtone ($L > 7 \times 10^3$ $L_\odot$). Excitation of pulsations is due to the κ-mechanism in the hydrogen ionization zone. Stars with intermediate luminosities 5.4×10^3 $L_\odot < L < 7 \times 10^3$ $L_\odot$ were found to be stable against radial oscillations. The pulsation period was determined as a function of evolutionary time and period change rates $\dot{\Pi}$ were evaluated for the first ten helium flashes. The period change rate becomes the largest in absolute value ($\dot{\Pi}/\Pi \approx -10^{-2}$ yr^{-1}) between the helium flash and the maximum of he stellar luminosity. Period changes with rate $|\dot{\Pi}/\Pi| \gtrsim 10^{-3}$ yr^{-1} take place during ≈ 500 yr, that is nearly one hundredth of the interval between helium flashes.

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The nucleus of the planetary nebula EGB 6 as a post-Mira binary

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EGB 6 is a faint, large, ancient planetary nebula (PN). Its central star, a hot DAOZ white dwarf (WD), is a prototype of a rare class of PN nuclei associated with dense, compact emission-line knots. The central star also shows excess fluxes in both the near- (NIR) and mid-infrared (MIR). In a 2013 paper, we used *Hubble* Space Telescope (HST)

images to show that the compact nebula is a point-like source, located $0.''16$ (~ 118 au) from the WD. We attributed the NIR excess to an M dwarf companion star, which appeared to coincide with the dense emission knot. We now present new ground-based NIR spectroscopy, showing that the companion is actually a much cooler source with a continuous spectrum, apparently a dust-enshrouded low-luminosity star. New HST images confirm common proper motion of the emission knot and red source with the WD. The I-band, NIR, and MIR fluxes are variable, possibly on timescales as short as days. We can fit the spectral-energy distribution with four blackbodies (the WD, a ~ 1850 K NIR component, and MIR dust at 385 and 175 K). Alternatively, we show that the NIR/MIR SED is very similar to that of Class 0/I young stellar objects. We suggest a scenario in which the EGB 6 nucleus is descended from a wide binary similar to the Mira system, in which a portion of the wind from an AGB star was captured into an accretion disk around a companion star; a remnant of this disk has survived to the present time, and is surrounded by gas photoionized by UV radiation from the WD.

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The Gaia–ESO Survey: Inhibited extra mixing in two giants of the open cluster Trumpler 20?

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We report the discovery of two Li-rich giants, with $A(\mathrm{Li}) \sim 1.50$, in an analysis of a sample of 40 giants of the open cluster Trumpler 20 (with turnoff mass ~ 1.8 $M_{\odot}$). The cluster was observed in the context of the Gaia–ESO Survey. The atmospheric parameters and Li abundances were derived using high-resolution UVES spectra. The Li abundances were corrected for nonlocal thermodynamical equilibrium (non-LTE) effects. Only upper limits of the Li abundance could be determined for the majority of the sample. Two giants with detected Li turned out to be Li rich: star MG 340 has $A(\mathrm{Li})_{\mathrm{non-LTE}} = 1.54 \pm 0.21$ dex and star MG 591 has $A(\mathrm{Li})_{\mathrm{non-LTE}} = 1.60 \pm 0.21$ dex. Star MG 340 is on average ~ 0.30 dex more rich in Li than stars of similar temperature, while for star MG 591 this difference is on average ~ 0.80 dex. Carbon and nitrogen abundances indicate that all stars in the sample have completed the first dredge-up. The Li abundances in this unique sample of 40 giants in one open cluster clearly show that extra mixing is the norm in this mass range. Giants with Li abundances in agreement with the predictions of standard models are the exception. To explain the two Li-rich giants, we suggest that all events of extra mixing have been inhibited. This includes rotation-induced mixing during the main sequence and the extra mixing at the red giant branch luminosity bump. Such inhibition has been suggested in the literature to occur because of fossil magnetic fields in red giants that are descendants of main-sequence Ap-type stars.

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Spectral type, temperature and evolutionary stage in cool supergiants

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In recent years, temperature scales in cool supergiants (CSGs) have been disputed, and the possibility that spectral types (SpTs) do not depend primarily on temperature has been raised. We explore the relations between different observed parameters and the capability of deriving accurate intrinsic stellar parameters from them through the analysis of the largest spectroscopic sample of CSGs to date from SMC and LMC. We explore possible correlations between

different observational parameters, also making use of near- and mid-infrared colours and literature on photometric variability. Direct comparison between the behaviour of atomic lines (Fe I, Ti I, and Ca II) in the observed spectra and synthetic atmospheric models provides compelling evidence that effective temperature is the prime underlying variable driving the SpT sequence in CSGs. However, there is a clear correlation between SpT and luminosity, with later ones tending to correspond to more luminous stars with heavier mass loss. The population of CSGs in the SMC is characterised by a higher degree of spectral variability, early spectral types (centred on type K1) and low mass-loss rates (at least as measured by dust-sensitive mid-infrared colours). The population in the LMC displays less spectroscopic variability and later spectral types. The distribution of spectral types is not single-peaked. Instead, the brightest CSGs have a significantly different distribution from less luminous objects, presenting mostly M subtypes (centred on M2), and increasing mass-loss rates for later types. In conclusion, the observed properties of CSGs in the SMC and the LMC cannot be described correctly by standard evolutionary models. The very strong correlation between spectral type and bolometric luminosity, supported by all data from the Milky Way, cannot be reproduced at all by current evolutionary tracks.

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Radiative levitation in carbon-enhanced metal-poor stars with *s*-process enrichment

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A significant fraction of all metal-poor stars are carbon-rich. Most of these carbon-enhanced metal-poor (CEMP) stars also show enhancement in elements produced mainly by the *s*-process (CEMP-*s* stars), and evidence suggests that the origin of these non-standard abundances can be traced to mass transfer from a binary asymptotic giant branch (AGB) companion. Thus, observations of CEMP-*s* stars are commonly used to infer the nucleosynthesis output of low-metallicity AGB stars. A crucial step in this exercise is understanding what happens to the accreted material after mass transfer ceases. Here we present models of the post-mass-transfer evolution of CEMP-*s* stars considering the physics of thermohaline mixing and atomic diffusion, including radiative levitation. We find that stars with typical CEMP-*s* star masses, $M \approx 0.85$ M$_\odot$, have very shallow convective envelopes ($M_{\rm env} \lesssim 10^{-7}$ M$_\odot$). Hence, the surface abundance variations arising from the competition between gravitational settling and radiative levitation should be orders of magnitude larger than observed (e.g., [C/Fe] < -1 or [C/Fe] $> +4$). Lower-mass stars ($M \approx 0.80$ M$_\odot$) retain thicker convective envelopes and thus show variations more in line with observations, but are generally too unevolved ($\log g > 4$) when they reach the age of the Universe. We are therefore unable to reproduce the spread in the observed abundances with these models and conclude that some other physical process must largely suppress atomic diffusion in the outer layers of CEMP-*s* stars. We demonstrate that this could be achieved by some additional (turbulent) mixing process operating at the base of the convective envelope, as found by other authors. Alternatively, mass-loss rates around 10^{-13} M$_\odot$ yr^{-1} could also negate most of the abundance variations by eroding the surface layers and forcing the base of the convective envelope to move inwards in mass. Since atomic diffusion cannot have a substantial effect on the surface abundances of CEMP-*s* stars, the dilution of the accreted material, while variable in degree from one star to the next, is most likely the same for all elements.

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ALMA-resolved salt emission traces the chemical footprint and inner wind morphology of VY CMa

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Context: At the end of their lives, most stars lose a significant amount of mass through a stellar wind. The specific physical and chemical circumstances that lead to the onset of the stellar wind for cool luminous stars are not yet understood. Complex geometrical morphologies in the circumstellar envelopes prove that various dynamical and chemical processes are interlocked and their relative contributions are not easy to disentangle.
Aims: We aim to study the inner-wind structure ($R < 250$ R$_\star$) of the well-known red supergiant VY CMa, the archetype for the class of luminous red supergiant stars suffering high mass loss. Specifically, the objective is to unravel the density structure in the inner envelope and to examine the chemical interaction between some gas and dust species.
Methods: We analyse high spatial resolution ($0\farcs24 \times 0\farcs13$) ALMA Science Verification (SV) data in band 7 in which four thermal emission lines of gaseous sodium chloride (NaCl) are present at high signal-to-noise ratio.
Results: For the first time, the NaCl emission in the inner wind region of VY CMa is spatially resolved. The ALMA observations reveal the contribution of up to four different spatial regions. The NaCl emission pattern is different compared to the dust continuum and TiO_2 emission already analysed from the ALMA SV data. The emission can be reconciled with an axisymmetric geometry, where the lower density polar/rotation axis has a position angle of $\sim 50°$ measured from North to East. However, this picture can not capture the full morphological diversity, and discrete mass ejection events need to be invoked to explain localized higher-density regions. The velocity traced by the gaseous NaCl line profiles is significantly lower than the average wind terminal velocity, and much slower than some of the fastest mass ejections, signalling a wide range of characteristic speeds for the mass loss. Gaseous NaCl is detected far beyond the main dust condensation region. Realising the refractory nature of this metal halide, this hints at a chemical process preventing all NaCl from condensing onto dust grains. We show that in the case of the ratio of the surface binding temperature to the grain temperature being ~ 50, only some 10% of NaCl remains in gaseous form, while for lower values of this ratio thermal desorption efficiently evaporates NaCl. Photodesorption by stellar photons seems not to be a viable explanation for the detection of gaseous NaCl at 220 R$_\star$ from the central star, and instead, we propose shock-induced sputtering driven by localized mass ejection events as alternative.
Conclusions: The analysis of the NaCl lines demonstrate the capabilities of ALMA to decode the geometric morphologies and chemical pathways prevailing in the winds of evolved stars. These early ALMA results prove that the envelopes surrounding evolved stars are far from homogeneous, and that a variety of dynamical and chemical processes dictate the wind structure.

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Re-evaluation of the $^{16}O(n,\gamma)^{17}O$ cross section at astrophysical energies and its role as neutron poison in the *s* process

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The doubly-magic nucleus ^{16}O has a small neutron capture cross section of just a few tens of microbarn in the astrophysical energy region. Despite of this, ^{16}O plays an important role as neutron poison in the astrophysical slow neutron capture (s) process due to its high abundance. We present in this paper a re-evaluation of the available experimental data for $^{16}O(n,\gamma)^{17}O$ and derive a new recommendation for the Maxwellian-averaged cross sections (MACS) between kT = 5–100 keV. Our new recommendations are lower up to kT = 60 keV compared to the previously recommended values but up to 14% higher at kT = 100 keV. We explore the impact of this different energy dependence on the weak s-process during core helium- (kT = 26 keV) and shell carbon burning (kT = 90 keV) in massive stars where ^{16}O is the most abundant isotope.

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Pulsation-triggered mass loss from AGB stars: the 60-day critical period

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Low- and intermediate-mass stars eject much of their mass during the late, red giant branch (RGB) phase of evolution. The physics of their strong stellar winds is still poorly understood. In the standard model, stellar pulsations extend the atmosphere, allowing a wind to be driven through radiation pressure on condensing dust particles. Here we investigate the onset of the wind, using nearby RGB stars drawn from the *Hipparcos* catalogue. We find a sharp onset of dust production when the star first reaches a pulsation period of 60 days. This approximately co-incides with the point where the star transitions to the first overtone pulsation mode. Models of the spectral energy distributions show stellar mass-loss rate suddenly increases at this point, by a factor of ~ 10 over the existing (chromospherically driven) wind. The dust emission is strongly correlated with both pulsation period and amplitude, indicating stellar pulsation is the main trigger for the strong mass loss, and determines the mass-loss rate. Dust emission does not strongly correlate with stellar luminosity, indicating radiation pressure on dust has little effect on the mass-loss rate. RGB stars do not normally appear to produce dust, whereas dust production by asymptotic giant branch stars appears commonplace, and is probably ubiquitous above the RGB-tip luminosity. We conclude that the strong wind begins with a step change in mass-loss rate, and is triggered by stellar pulsations. A second rapid mass-loss-rate enhancement is suggested when the star transitions to the fundamental pulsation mode, at a period of ~ 300 days.

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Study of the inner dust envelope and stellar photosphere of the AGB star R Doradus using SPHERE/ZIMPOL

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We use high-angular-resolution images obtained with SPHERE/ZIMPOL to study the photosphere, the warm molecular layer, and the inner wind of the close-by oxygen-rich AGB star R Doradus. We present observations in filters V, cntHα, and cnt820 and investigate the surface brightness distribution of the star and of the polarised light produced in the inner envelope. Thanks to second-epoch observations in cntHα, we are able to see variability of the stellar photosphere. We find that in the first epoch the surface brightness of R Dor is asymmetric in V and cntHα, the filters where molecular opacity is stronger, while in cnt820 the surface brightness is closer to being axisymmetric. The second-epoch observations in cntHα show that the morphology of R Dor changes completely in a timespan of 48 days to a more axisymmetric and compact configuration. The polarised intensity is asymmetric in all epochs and varies by between a factor of 2.3 and 3.7 with azimuth for a given image. The changes seen in polarised light between the two epochs are less pronounced than those seen in unpolarised light. We fit the radial profile of the polarised intensity using a spherically symmetric model and a parametric description of the dust density profile, $\rho(r) = \rho_\circ r^{-n}$. On average, we find exponents of -4.5 ± 0.5 that correspond to a much steeper density profile than that of a wind expanding at constant velocity. The dust densities we derive imply an upper limit for the dust-to-gas ratio of $\sim 2 \times 10^{-4}$ at 5.0 $R_\star$. Given the uncertainties in observations and models, this value is consistent with the minimum values required by wind-driving models for the onset of a wind, of $\sim 3.3 \times 10^{-4}$. However, if the steep density profile we find extends to larger distances from the star, the dust-to-gas ratio will quickly become too small for the wind of R Dor to be driven by the grains that produce the scattered light we see.

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The abundance discrepancy factor and t^2 in nebulæ: are non-thermal electrons the culprits?

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Photoionization produces supra-thermal electrons, electrons with much more energy than is found in a thermalized gas at electron temperatures characteristic of nebulæ. The presence of these high energy electrons may solve the

long-standing t^2/ADF puzzle, the observations that abundances obtained from recombination and collisionally excited lines do not agree, and that different temperature indicators give different results, if they survive long enough to affect diagnostic emission lines. The presence of these non-Maxwellian distribution electrons are usually designated by the term κ. Here we use well established methods to show that the distance over which heating rates change are much longer than the distance supra thermal electrons can travel, and that the timescale to thermalize these electrons are much shorter than the heating or cooling timescales. These estimates establish that supra thermal electrons will have disappeared into the Maxwellian velocity distribution long before they affect the collisionally excited forbidden and recombination lines that are used for deriving abundances relative to hydrogen. The electron velocity distribution in nebulae should be closely thermal.

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Many new variable stars discovered in the core of the globular cluster NGC 6715 (M 54) with EMCCD observations

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We show the benefits of using Electron-Multiplying CCDs and the shift-and-add technique as a tool to minimise the effects of the atmospheric turbulence such as blending between stars in crowded fields and to avoid saturated stars in the fields observed. We intend to complete, or improve, the census of the variable star population in globular cluster NGC 6715.

Our aim is to obtain high-precision time-series photometry of the very crowded central region of this stellar system via the collection of better angular resolution images than has been previously achieved with conventional CCDs on ground-based telescopes.

Observations were carried out using the Danish 1.54-m Telescope at the ESO La Silla observatory in Chile. The telescope is equipped with an Electron Multiplying CCD that allowed to obtain short-exposure-time images (ten images per second) that were stacked using the shift-and-add technique to produce the normal-exposure-time images (minutes). The high precision photometry was performed via difference image analysis employing the DanDIA pipeline. We attempted automatic detection of variable stars in the field.

We statistically analysed the light curves of 1405 stars in the crowded central region of NGC 6715 to automatically identify the variable stars present in this cluster. We found light curves for 17 previously known variable stars near the edges of our reference image (16 RR Lyræ and 1 semi-regular) and we discovered 67 new variables (30 RR Lyræ, 21 long-period irregular, 3 semi-regular, 1 W Virginis, 1 eclipsing binary, and 11 unclassified). Photometric measurements for these stars are available in electronic form through the Strasbourg Astronomical Data Centre.

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An observational study of dust nucleation in Mira (o Ceti): I. Variable features of AlO and other Al-bearing species

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Context: Dust is efficiently produced by cool giant stars, but the condensation of inorganic dust is poorly understood. Observations of key aluminum bearing molecules around evolved stars has allowed us to investigate the nucleation of alumina (Al_2O_3) dust in the gas.
Aims: Identify and characterize aluminum bearing species in the circumstellar gas of Mira (o Ceti) in order to elucidate their role in the production of Al_2O_3 dust.
Methods: Multiepoch spectral line observations at (sub-)millimeter, far-infrared, and optical wavelengths including: maps with ALMA which probe the gas distribution in the immediate vicinity of the star at ~ 30 mas; observations with ALMA, APEX, and *Herschel* in 2013–2015 for studying cycle and inter-cycle variability of the rotational lines of Al bearing molecules; optical records as far back as 1965 to examine variations in electronic transitions over time spans of days to decades; and velocity measurements and excitation analysis of the spectral features which constrain the physical parameters of the gas.
Results: Three diatomic molecules AlO, AlOH, and AlH, and atomic Al I are the main observable aluminum species in Mira, although a significant fraction of aluminum might reside in other species that have not yet been identified. Strong irregular variability in the (sub-)millimeter and optical features of AlO (possibly the direct precursor of Al_2O_3) indicates substantial changes in the excitation conditions, or varying abundance that is likely related to shocks in the star. The inhomogeneous distribution of AlO might influence the spatial and temporal characteristics of dust production.
Conclusions: We are unable to quantitatively trace aluminum depletion from the gas, but the rich observational material constrains time dependent chemical networks. Future improvements should include spectroscopic characterization of higher aluminum oxides, coordinated observations of dust and gas species at different variability phases, and tools to derive abundances in shock excited gas.

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Evolved stars in the Local Group galaxies. I. AGB evolution and dust production in IC 1613

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We used models of thermally-pulsing asymptotic giant branch (AGB) stars, that also describe the dust-formation process in the wind, to interpret the combination of near- and mid-infrared photometric data of the dwarf galaxy IC 1613. This is the first time that this approach is extended to an environment different from the Milky Way and the Magellanic Clouds (MCs). Our analysis, based on synthetic population techniques, shows a nice agreement between the observations and the expected distribution of stars in the colour–magnitude diagrams obtained with JHK and *Spitzer* bands. This allows a characterization of the individual stars in the AGB sample in terms of mass, chemical composition, and formation epoch of the progenitors. We identify the stars exhibiting the largest degree of obscuration as carbon stars evolving through the final AGB phases, descending from 1–1.25 $M_\odot$ objects of metallicity $Z = 10^{-3}$ and from 1.5–2.5 $M_\odot$ stars with $Z = 2 \times 10^{-3}$. Oxygen–rich stars constitute the majority of the sample ($\sim 65\%$), mainly low mass stars (< 2 $M_\odot$) that produce a negligible amount of dust ($\leq 10^{-7}$ $M_\odot$ yr^{-1}). We predict the overall dust-production rate from IC 1613, mostly determined by carbon stars, to be $\sim 6 \times 10^{-7}$ $M_\odot$ yr^{-1} with an uncertainty of 30%. The capability of the current generation of models to interpret the AGB population in an environment different from the MCs opens the possibility to extend this kind of analysis to other Local Group galaxies.

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Habitable zones of post-main sequence stars

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Once a star leaves the main sequence and becomes a red giant, its Habitable Zone (HZ) moves outward, promoting detectable habitable conditions at larger orbital distances. We use a one-dimensional radiative-convective climate and stellar evolutionary models to calculate post-MS HZ distances for a grid of stars from 3,700 K to 10,000 K (~M1 to A5 stellar types) for different stellar metallicities. The post-MS HZ limits are comparable to the distances of known directly imaged planets. We model the stellar as well as planetary atmospheric mass loss during the Red Giant Branch (RGB) and Asymptotic Giant Branch (AGB) phases for super-Moons to super-Earths. A planet can stay between 200 million years up to 9 Gyr in the post-MS HZ for our hottest and coldest grid stars, respectively, assuming solar metallicity. These numbers increase for increased stellar metallicity. Total atmospheric erosion only occurs for planets in close-in orbits. The post-MS HZ orbital distances are within detection capabilities of direct imaging techniques.

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Application of a theory and simulation based convective boundary mixing model for AGB star evolution and nucleosynthesis

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The *s*-process nucleosynthesis in Asymptotic Giant Branch (AGB) stars depends on the modeling of convective boundaries. We present models and *s*-process simulations that adopt a treatment of convective boundaries based on the results of hydrodynamic simulations and on the theory of mixing due to gravity waves in the vicinity of convective boundaries. Hydrodynamics simulations suggest the presence of convective boundary mixing (CBM) at the bottom of the thermal pulse-driven convective zone. Similarly, convection-induced mixing processes are proposed for the mixing below the convective envelope during third dredge-up where the ^{13}C pocket for the s process in AGB stars forms. In this work we apply a CBM model motivated by simulations and theory to models with initial mass $M = 2$ and $M = 3$ $M_\odot$, and with initial metal content $Z = 0.01$ and $Z = 0.02$. As reported previously, the He-intershell abundance of ^{12}C and ^{16}O are increased by CBM at the bottom of pulse-driven convection zone. This mixing is affecting the ^{22}Ne(α,n)^{25}Mg activation and the s-process efficiency in the ^{13}C-pocket. In our model CBM at the bottom of the convective envelope during the third dredge-up represents gravity wave mixing. We take further into account that hydrodynamic simulations indicate a declining mixing efficiency already about a pressure scale height from the convective boundaries, compared to mixing-length theory. We obtain the formation of the ^{13}C-pocket with a mass of $\approx 10^{-4}$ $M_\odot$. The final s-process abundances are characterized by $0.36 < [s/\mathrm{Fe}] < 0.78$ and the heavy-to-light s-process ratio is $0.23 < [hs/ls] < 0.45$. Finally, we compare our results with stellar observations, pre-solar grain measurements and previous work.

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Planetary nebulæ in the Small Magellanic Cloud

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We analyse the planetary nebulæ (PNe) population of the Small Magellanic Cloud (SMC), based on evolutionary models of stars with metallicities in the range $10^{-3} \leq Z \leq 4 \times 10^{-3}$ and mass 0.9 $M_\odot < M < 8$ $M_\odot$, evolved through the asymptotic giant branch (AGB) phase. The models used account for dust formation in the circumstellar envelope. To characterise the PNe sample of the SMC, we compare the observed abundances of the various species with the final chemical composition of the AGB models: this study allows us to identify the progenitors of the PNe observed, in terms of mass and chemical composition. According to our interpretation, most of the PNe descend from low-mass ($M < 2$ $M_\odot$) stars, which become carbon rich, after experiencing repeated third dredge-up episodes, during the AGB phase. A fraction of the PNe showing the signature of advanced CNO processing are interpreted as the progeny of massive AGB stars, with mass above ~ 6 $M_\odot$, undergoing strong hot bottom burning. The differences with the chemical composition of the PNe population of the Large Magellanic Cloud (LMC) is explained on the basis of the diverse star formation history and age–metallicity relation of the two galaxies. The implications of the present study for some still highly debated points regarding the AGB evolution are also commented.

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Conference Papers

3-D structures of planetary nebulæ

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Recent advances in the 3-D reconstruction of planetary nebulæ are reviewed. We include not only results for 3-D

reconstructions, but also the current techniques in terms of general methods and software. In order to obtain more accurate reconstructions, we suggest to extend the widely used assumption of homologous nebula expansion to map spectroscopically measured velocity to position along the line of sight.

Oral contribution, published in "11$^{\rm th}$ Pacific Rim Conference", held in Hong Kong in December 2015, Sun Kwok (editor)
Available from arXiv:1605.03082

Chemistry in AGB stars: successes and challenges

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Emission and absorption line observations of molecules in late-type stars are a vital component in our understanding of stellar evolution, dust formation and mass loss in these objects. The molecular composition of the gas in the circumstellar envelopes of AGB stars reflects chemical processes in gas whose properties are strong functions of radius with density and temperature varying by more than ten and two orders of magnitude, respectively. In addition, the interstellar UV field plays a critical role in determining not only molecular abundances but also their radial distributions. In this article, I shall briefly review some recent successful approaches to describing chemistry in both the inner and outer envelopes and outline areas of challenge for the future.

Oral contribution, published in "11$^{\rm th}$ Pacific Rim Conference on Stellar Astrophysics", Hong Kong, Dec. 14–17, 2015, Sun Kwok (ed.)
Available from arXiv:1605.03365

Review Paper

The jet feedback mechanism (JFM) in stars, galaxies and clusters (a review)

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I review the influence jets and the bubbles they inflate might have on their ambient gas as they operate through a negative jet feedback mechanism (JFM). I discuss astrophysical systems where jets are observed to influence the ambient gas, in many cases by inflating large, hot, and low-density bubbles, and systems where the operation of the JFM is still a theoretical suggestion. The first group includes cooling flows in galaxies and clusters of galaxies, star-forming galaxies, young stellar objects, and bipolar planetary nebulæ. The second group includes core collapse supernovæ, the common envelope evolution, the grazing envelope evolution, and intermediate luminosity optical transients. The suggestion that the JFM operates in these four types of systems is based on the assumption that jets are much more common than what is inferred from objects where they are directly observed. Common to all eight types of systems reviewed here is the presence of a compact object inside an extended ambient gas. The ambient gas serves as a potential reservoir of mass to be accreted on to the compact object. If the compact object launches jets as it accretes mass, the jets might reduce the accretion rate as they deposit energy to the ambient gas, or even remove the entire ambient gas, hence closing a negative feedback cycle.

Published in New Astronomy Reviews (submitted)
Available from arXiv:1605.02672

Job Advert

Institute of Astronomy, Leuven University, Belgium
Vacancy for a post-doctoral position in the field of laboratory experiments for astrochemical research

The project and the position

At the Leuven University (Belgium), we seek an excellent candidate for a post-doctoral research position ready to play a key role in the interdisciplinary ERC Consolidator Grant AEROSOL (2016–2020, PI. Prof. Leen Decin). The aim of the project is to boost our understanding of the physics and chemistry characterizing the stellar winds around evolved stars. The project builds upon novel observations (including ALMA, *Herschel*, etc.), detailed theoretical wind models, and targeted laboratory experiments (see http://fys.kuleuven.be/ster/Projects/aerosol/aerosol). The candidate will interact closely with a team consisting of astrophysicists, chemists, and computational mathematicians.

Specifically, we seek a post-doctoral researcher with expertise in gas-phase reaction kinetics. The experimental research concerns the determination of rate coefficients and product distributions of elementary gas-phase reactions involving key reactive species (Si- and S-bearing species and HCCO radicals) in stellar winds for which data is currently lacking. Specifically, several advanced laser-spectroscopic and chemiluminescence techniques will be employed to follow photolytically-generated reactive species in real time in a novel temperature-graded reaction vessel (200–900 K) coupled with cavity-ringdown/Fourier-transform infrared spectroscopy to elucidate reaction product channels. In addition, we will concentrate on the construction and exploitation of a novel low-temperature Laval-nozzle apparatus with the aim to obtain the rates of the same gas-phase reactions at temperatures below 200 K.

Candidates should have an interest in physical chemistry, high-resolution laser spectroscopy, and technical experimentation. The post-doctoral researcher will collaborate with Prof. S. Carl from the Department of Chemistry, division of Quantum and Physical chemistry. The experimental work will be carried out in the modern and fully-equipped new research laboratories of the Department of Chemistry. The group currently enjoys and encourages further close collaboration with researches in the department employing high-level quantum chemical calculations on species related to this project.

Institute of Astronomy

The Institute of Astronomy (IoA) of the Leuven University in Belgium is a young and vibrant research group of some 50 scientists, engineers and administrative staff (fys.kuleuven.be/ster), including 6 full-time and 3 part-time professors. The institute is an expertise centre in stellar physics and is active in several international consortia and collaborations, involving telescopes at observatories worldwide and in space. Members of IoA have access to parallel computing facilities at Leuven University. The IoA is responsible for the organisation of the 2-year Master in Astronomy & Astrophysics of the Faculty of Science and owns the 1.2m Mercator telescope at Roque de los Muchachos, La Palma Observatory, Canary Islands. The institute has a long tradition in instrumental, observational, and theoretical studies of the late stages of evolution of low and intermediate mass stars.

Contract

The successful applicant will perform research in the context of AEROSOL and will take up project teaching tasks in the Bachelor of Physics or Chemistry and/or Master in Astronomy & Astrophysics programmes (for a maximum of 4 hours/week). Postdoctoral researchers at Leuven University are allowed to act as master thesis supervisor, as well as take up co-supervision of Ph.D. students. The postdoc will also be able to take up personal training in science and people management, science communication, and grant application writing with the aim to develop a personal independent career track. The selected candidate will be offered a 2-year contract, once renewable with 1 or 2 more years depending on performance. The salary will be commensurate to the standard scale for postdoctoral researchers in Flanders; it includes social and medical insurance as well as pension rights. The starting date shall be between 1 September and 1 December 2016. In their application, candidates are requested to indicate their preferred starting date.

Requirements and instructions to apply

Applicants must hold a Ph.D. degree in astrophysics or chemistry or own an equivalent diploma; the degree must be dated at the latest one month before the position can be taken up. High proficiency in English is assumed. The application package should be sent as a single PDF containing a complete curriculum vitæ with a full publication list and a statement of interest of maximally two pages. Applicants must also provide the names and contact details of three experts in the field who would be prepared to send confidential recommendation letters should they be requested to do so. The selection committee will send out requests for such letters for those applicants on the short-list after an initial ranking. The short-listed applicants will be invited for an interview (live or via skype).

The application material should be sent by e-mail to katrijn.clemer@ster.kuleuven.be at the latest by 15 July 2016. Only complete applications received by that date will be considered.

More information can be obtained by contacting

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See also http://fys.kuleuven.be/ster/vacancies

Announcements

École Evry Schatzman 2016 school: The HR diagram in radio – stellar physics at long wavelengths

The "Programme National de Physique Stellaire" organizes the 2016 Evry Schatzman School in stellar physics entitled: "The HR diagram in radio – stellar physics at long wavelengths", which also includes circumstellar radio emission (jets, disks, AGB winds and envelopes) in the framework of the modern ground observatories NOEMA, ALMA and SKA.

The School is supported by PNPS, PCMI, ASA and AS-SKA.

The School will take place in the Teich Bird Reserve (near Arcachon, France), from 26 to 30 September 2016.

Registration is open up to 31 May 2016, on the dedicated Web site where all scientific and practical information are given. http://ees2016.sciencesconf.org/

All lectures will be given in English.

Here follows the programme:

Lectures:

- the HR diagram in radio: observational techniques and emission processes: 2×1^h30 (Eric Josselin)
- activity, binarity, and magnetism as seen in the radio: 2×1^h30 (Daniel Tafoya)
- Solar type stars: chromospheric and coronal radio emission, magnetospheres: 2×1^h30 (Sven Wedemeyer)
- Star formation and protostars in the radio range:

  Disks: 2^h (Anne Dutrey)
  Jets: 2^h (Frédéric Gueth)

- Winds and mass-loss in the radio range:

  Hot stars: 2^h (Jean-Claude Bouret)
  Cold stars: 2^h (Sofia Ramstedt)

Seminars and tutorials:

- presentation of ALMA and NOEMA: 1^h30 (Sébastien Maret)
- presentation of SKA: 1^h30 (Stéphane Corbel)
- Preparation and reduction of radio observations: 2×2^h (Fabrice Herpin & Stéphane Guilloteau)

Should you have any question, please contact Eric Josselin (eric.josselin@umontpellier.fr) or Yveline Lebreton (Yveline.Lebreton@obspm.fr).

The SOC (E. Josselin, Y. Lebreton, F. Herpin, S. Cabrit)

N.B. Lodging and travel expenses:

No registration fees.

Lodging expenses (hotel and food) are waived for CNRS employees, thanks to the support of the Formation Permanente of CNRS.

In addition and thanks to the financial support of PNPS, PCMI, ASA and AS-SKA, lodging expenses (300 euros) can also be waived for some other researchers and PhD students. If you would like to apply for such a financial support, please indicate it when you pre-register.

Note that we do not offer travel support. CNRS employees must contact their "Délégation Régionale" for travel expenses, and other participants should ask support to their host institution. PhD students should ask their École Doctorale for support.

It will possible to present e-posters which will be communicated to participants on an USB key. Posters will be discussed during the school.

See also http://ees2016.sciencesconf.org/

Fizeau exchange visitors program in optical interferometry supplemental call for applications

Dear colleagues!

The Fizeau exchange visitors program in optical interferometry funds (travel and accommodation) visits of researchers to an institute of his/her choice (within the European Community) to perform collaborative work and training on one of the active topics of the European Interferometry Initiative. The visits will typically last for one month, and strengthen the network of astronomers engaged in technical, scientific and training work on optical/infrared interferometry. The program is open for all levels of astronomers (Ph.D. students to tenured staff), non-EU based missions will only be funded if considered essential by the Fizeau Committee. Applicants are strongly encouraged to seek also partial support from their home or host institutions.

The deadline for applications is June 15. Fellowships can be awarded for missions carried out until the end of 2016! For missions in 2017 please wait for further announcements!

Further informations and application forms can be found at www.european-interferometry.eu

The program is funded by OPTICON/FP7.

Please distribute this message also to potentially interested colleagues outside of your community!

Looking forward to your applications,
Josef Hron & László Mosoni
(for the European Interferometry Initiative)

See also www.european-interferometry.eu