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Editors: Jacco van Loon and Albert Zijlstra

Editorial

Dear Colleagues,

It is our pleasure to present you the 161st issue of the AGB Newsletter.

Just a reminder, that you do not need to wait to be invited to post your abstract in the newsletter – change in policy at the arXiv facility has resulted in two near-misses for one of the editors to be banned from its services, in pursuit of authors of AGB-related articles merely to invite them to post their work in the newsletter.

The next issue is planned to be distributed on the 3rd of January 2011. With the very best wishes for the holidays and New Year,

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

In ten years time, most items in the AGB Newsletter will deal with AGB-related objects outside the Milky Way

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

Refereed Journal Papers

From pre- to young Planetary Nebulae: radio continuum variability

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Searching for variability, we have observed a sample of hot post-AGB stars and young Planetary Nebulae candidates with the Very Large Array at 4.8, 8.4, and 22.4 GHz. The sources had been previously detected in the radio continuum, which is a proof that the central stars have started ionising their circumstellar envelopes and an increase in radio flux with time can be expected as a result of the progression of the ionisation front. Such a behaviour has been found in IRAS 18062+2410, whose radio modelling has allowed us to determine that its ionised mass has increased from 10^{-4} to $3.3{\times}10^{-4}$ $M_{\odot}$ in 8 years and its envelope has become optically thin at lower frequencies.

Different temporal behaviours have been found for three other sources. IRAS 17423−1755 has shown a possibly periodic pattern and an inversion of its radio spectral index, as expected from a varying stellar wind. We estimate that the radio flux arises from a very compact region around the central star ($\sim 10^{15}$ cm) with an electron density of 2×10^6 cm^{-3}. IRAS 22568+6141 and 17516−2525 have decreased their radio flux densities of about 10% per year over 4 years.

While a linear increase of the flux density with time points out to the progression of the ionisation front in the envelope, decreases as well as quasi-periodic patterns may indicate the presence of unstable stellar winds/jets or thick dusty envelopes absorbing ionising photons.

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Available from arXiv:1011.0685

Rotation and multiple stellar population in globular clusters

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We investigate structure and kinematics of the second generation of stars (SG) formed from gaseous ejecta of the first generation of stars (FG) in forming globular clusters (GCs). We consider that SG can be formed from gaseous ejecta from AGB stars of FG with the initial total mass of 10^6–10^8 $M_{\odot}$ to explain the present masses of the Galactic GCs. Our 3D hydrodynamical simulations with star formation show that SG formed in the central regions of FG can have a significant amount of rotation ($V/\sigma \sim 0.8$–2.5). The rotational amplitude of SG can depend strongly on the initial kinematics of FG. We thus propose that some GCs composed of FG and SG had a significant amount of rotation when they were formed. We also suggest that although later long-term (~ 10 Gyr) dynamical evolution of stars can smooth out the initial structural and kinematical differences between FG and SG to a large extent, initial flattened structures and rotational kinematics of SG can be imprinted on shapes and internal rotation of the present GCs. We discuss these results in terms of internal rotation observed in the Galactic GCs.

Published in ApJL
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Asteroseismology of red giants from the first four months of Kepler data: Fundamental parameters

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Clear power excess in a frequency range typical for solar-type oscillations in red giants has been detected in more than 1000 stars, which have been observed during the first 138 days of the science operation of the NASA Kepler satellite. This sample includes stars in a wide mass and radius range with spectral types G and K, extending in luminosity from the bottom of the giant branch up to high-luminous red giants. The high-precision asteroseismic observations with Kepler provide a perfect source for testing stellar structure and evolutionary models, as well as investigating the stellar population in our Galaxy. We fit a global model to the observed frequency spectra, which allows us to accurately estimate the granulation background signal and the global oscillation parameters, such as the frequency of maximum oscillation power. We find regular patterns of radial and non-radial oscillation modes and use a new technique to automatically identify the mode degree and the characteristic frequency separations between consecutive modes of the same spherical degree. In most cases, we can also measure the small separation. The seismic parameters are used to estimate stellar masses and radii and to place the stars in an H–R diagram by using an extensive grid of stellar models that covers a wide parameter range. Using Bayesian techniques throughout our analysis allows us to determine reliable uncertainties for all parameters. We provide accurate seismic parameters and their uncertainties for a large sample of red giants and determine their asteroseismic fundamental parameters. We investigate the influence of the stars' metallicities on their positions in the H–R diagram. We study the red-giant populations in the red clump and bump and compare them to a synthetic population and find a mass and metallicity gradient in the red clump and clear evidence of a secondary-clump population.

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Strong [O III] and [N II] emission lines in globular clusters from photoionized R Corona Borealis star winds

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The globular cluster X-ray source CXO J033831.8−352604 in NGC 1399 has recently been found to show strong emission lines of [O III] and [N II] in its optical spectrum in addition to ultraluminous X-ray emission with a soft X-ray spectrum. It was further suggested that this system contained an intermediate mass black hole which had tidally disrupted a white dwarf, producing the strong emission lines without detectable hydrogen emission. We show that an alternative exists which can explain the data more naturally in which the oxygen and nitrogen rich material is ejecta from a RCB star, or a tidal disruption of an RCB star or a hydrogen-deficient carbon star. The scenario we propose here does not require an intermediate mass black hole as the accretor, but also does not exclude the possibility.

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The *Spitzer* Atlas of Stellar Spectra (SASS)

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We present the *Spitzer* Atlas of Stellar Spectra (SASS), which includes 159 stellar spectra (5 to 32 μm; $R \sim 100$) taken with the Infrared Spectrograph on the *Spitzer* Space Telescope. This Atlas gathers representative spectra of a broad section of the Hertzsprung–Russell diagram, intended to serve as a general stellar spectral reference in the mid-infrared. It includes stars from all luminosity classes, as well as Wolf–Rayet (WR) objects. Furthermore, it includes some objects of intrinsic interest, like blue stragglers and certain pulsating variables. All the spectra have been uniformly reduced, and all are available online. For dwarfs and giants, the spectra of early-type objects are relatively featureless, dominated by Hydrogen lines around A spectral types. Besides these, the most noticeable photospheric features correspond to water vapor and silicon monoxide in late-type objects and methane and ammonia features at the latest spectral types. Most supergiant spectra in the Atlas present evidence of circumstellar gas. The sample includes five M supergiant spectra, which show strong dust excesses and in some cases PAH features. Sequences of WR stars present the well-known pattern of lines of He I and He II, as well as forbidden lines of ionized metals. The characteristic flat-top shape of the [Ne III] line is evident even at these low spectral resolutions. Several Luminous Blue Variables and other transition stars are present in the Atlas and show very diverse spectra, dominated by circumstellar gas and dust features. We show that the [8]–[24] *Spitzer* colors (IRAC and MIPS) are poor predictors of spectral type for most luminosity classes.

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and from http://web.ipac.caltech.edu/staff/ardila/Atlas/index.html

The Stellar Abundances for Galactic Archaeology (SAGA) Database II — Implications for mixing and nucleosynthesis in extremely metal-poor stars and chemical enrichment of the Galaxy

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We discuss the characteristics of known extremely metal-poor (EMP) stars in the Galaxy using the Stellar Abundances for Galactic Archaeology (SAGA) database (Suda et al. 2008, PASJ, 60, 1159). The analyses of carbon-enhanced stars in our sample suggest that the nucleosynthesis in AGB stars can contribute to the carbon enrichment in a different way depending on whether the metallicity is above or below [Fe/H] ~ -2.5, which is consistent with the current models of stellar evolution at low metallicity. We find the transition of the initial mass function at [Fe/H] ~ -2 in the viewpoint of the distribution of carbon abundance and the frequency of carbon-enhanced stars. For observed EMP stars, we confirmed that some, not all, of observed stars might have undergone at least two types of extra mixing to change their surface abundances. One is to deplete the lithium abundance during the early phase of red giant branch. Another is to decrease the C/N ratio by one order of magnitude during the red giant branch phase. Observed

small scatters of abundances for α-elements and iron-group elements suggest that the chemical enrichment of our Galaxy takes place in a well-mixed interstellar medium. We find that the abundance trends of α-elements are highly correlated with each other, while the abundances of iron-group elements are subject to different slopes relative to the iron abundance. This implies that the supernova yields of α-elements are almost independent of mass and metallicity, while those of iron-group elements have a metallicity dependence or mass dependence with the variable initial mass function. The occurrence of the hot bottom burning in the mass range of $5 \lesssim M/\mathrm{M}_{\odot} \lesssim 6$ is consistent with the initial mass function of the Galaxy peaked at $\sim$ 10–12 $\mathrm{M}_{\odot}$ to be compatible with the statistics of carbon enhanced stars with and without s-process element enhancement, and of nitrogen enhanced stars. For s-process elements, we find not only the positive correlation between carbon and s-process element abundances, but the increasing slopes of the abundance ratio between them with increasing mass number of s-process elements. The dominant site of the s-process is still an open question because none of the known mechanisms of the s-process is able to account for this observed correlations. In spite of the evidence of AGB evolution in observed abundances of EMP stars, we cannot find any evidence of binary mass transfer through the effect of dilution in the convective envelope. We found the dependence of sulphur and vanadium abundances on the effective temperatures in addition to the previously reported trends for silicon, scandium, titanium, chromium, and cobalt.

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The connection between missing AGB stars and extended horizontal branches

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Recent surveys confirm early results about a deficiency or even absence of CN-strong stars on the asymptotic giant branch (AGB) of globular clusters (GCs), although with quite large cluster-to-cluster variations. In general, this is at odds with the distribution of CN band strengths among first ascent red giant branch (RGB) stars. Norris et al. proposed that the lack of CN-strong stars in some clusters is a consequence of a smaller mass of these stars that cannot evolve through the full AGB phase. In this short paper we found that the relative frequency of AGB stars can change by a factor of two between different clusters. We also find a very good correlation between the minimum mass of stars along the horizontal branch (Gratton et al. 2010) and the relative frequency of AGB stars, with a further dependence on metallicity. We conclude that indeed the stars with the smallest mass on the HB cannot evolve through the full AGB phase, being AGB-manqué. These stars likely had large He and N content, and large O-depletion. We then argue that there should not be AGB stars with extreme O depletion, and few of them with a moderate one.

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Asteroseismology of red giants from the first four months of *Kepler* data: Global oscillation parameters for 800 stars

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We have studied solar-like oscillations in $\sim$ 800 red-giant stars using *Kepler* long-cadence photometry. The sample includes stars ranging in evolution from the lower part of the red-giant branch to the Helium main sequence. We investigate the relation between the large frequency separation ($\Delta\nu$) and the frequency of maximum power ($\nu_{\rm max}$) and show that it is different for red giants than for main-sequence stars, which is consistent with evolutionary models and scaling relations. The distributions of $\nu_{\rm max}$ and $\Delta\nu$ are in qualitative agreement with a simple stellar population model of the Kepler field, including the first evidence for a secondary clump population characterized by $M \gtrsim 2$ M$_\odot$ and $\nu_{\rm max} \sim$ 40–110 μHz. We measured the small frequency separations $\delta\nu_{02}$ and $\delta\nu_{01}$ in over 400 stars and $\delta\nu_{03}$ in over 40. We present C–D diagrams for l = 1, 2 and 3 and show that the frequency separation ratios $\delta\nu_{02}/\Delta\nu$ and $\delta\nu_{01}/\Delta\nu$ have opposite trends as a function of $\Delta\nu$. The data show a narrowing of the l = 1 ridge towards lower $\nu_{\rm max}$, in agreement with models predicting more efficient mode trapping in stars with higher luminosity. We investigate the offset ϵ in the asymptotic relation and find a clear correlation with $\Delta\nu$, demonstrating that it is related to fundamental stellar parameters. Finally, we present the first amplitude-$\nu_{\rm max}$ relation for *Kepler* red giants. We observe a lack of low-amplitude stars for $\nu_{\rm max} \gtrsim 110$ μHz and find that, for a given $\nu_{\rm max}$ between 40–110 μHz, stars with lower $\Delta\nu$ (and consequently higher mass) tend to show lower amplitudes than stars with higher $\Delta\nu$.

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Investigation for the enrichment pattern of the element abundances in r+s star HE 0338−3945: a special r-II star?

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The very metal-poor star HE 0338−3945 shows a double-enhanced pattern of the neutron-capture elements.The study of this sample could help people gain a better understanding of s- and r-process nucleosynthesis at low metallicity. Using a parametric model, we find that the abundance pattern of the neutron-capture elements could be best explained by a binary system formed in a molecular cloud that had been polluted by r-process material. The observed abundance pattern of C and N can be explained by an asymptotic giant branch (AGB) model. Combined with the parameters obtained from Cui & Zhang, we suggest that the initial mass of the AGB companion is most likely to be about 2.5 M$_\odot$, which excludes the possibility of forming a Type 1.5 supernova. By comparing with the observational abundance pattern of CS 22892−052, we find that the dominant production of O should accompany the production of the heavy

r-process elements of r+s stars. Similar to r-II stars, the heavy r-process elements are not produced in conjunction with all the light elements from the Na to Fe group. The abundance pattern of the light and r-process elements for HE 0338−3945 is very close to the pattern of the r-II star CS 22892−052. Therefore, we suggest that HE 0338−3945 should be a special r-II star.

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The 2010 nova outburst of the symbiotic Mira V407 Cyg

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The nova outburst experienced in 2010 by the symbiotic binary Mira V407 Cyg has been extensively studied at optical and infrared wavelengths with both photometric and spectroscopic observations. This outburst, reminiscent of similar events displayed by RS Oph, can be described as a very fast He/N nova erupting while being deeply embedded in the dense wind of its cool giant companion. The hard radiation from the initial thermonuclear flash ionizes and excites the wind of the Mira over great distances (recombination is observed on a time scale of 4 days). The nova ejecta is found to progressively decelerate with time as it expands into the Mira wind. This is deduced from line widths which change from a FWHM of 2760 km s^{-1} on day +2.3 to 200 km s^{-1} on day +196. The wind of the Mira is massive and extended enough for an outer neutral and unperturbed region to survive at all outburst phases.

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Reaction networks for interstellar chemical modelling: improvements and challenges

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We survey the current situation regarding chemical modelling of the synthesis of molecules in the interstellar medium. The present state of knowledge concerning the rate coefficients and their uncertainties for the major gas-phase processes

– ion-neutral reactions, neutral-neutral reactions, radiative association, and dissociative recombination – is reviewed. Emphasis is placed on those key reactions that have been identified, by sensitivity analyses, as 'crucial' in determining the predicted abundances of the species observed in the interstellar medium. These sensitivity analyses have been carried out for gas-phase models of three representative, molecule-rich, astronomical sources: the cold dense molecular clouds TMC-1 and L134N, and the expanding circumstellar envelope IRC +10 216. Our review has led to the proposal of new values and uncertainties for the rate coefficients of many of the key reactions. The impact of these new data on the predicted abundances in TMC-1 and L134N is reported. Interstellar dust particles also influence the observed abundances of molecules in the interstellar medium. Their role is included in gas-grain, as distinct from gas-phase only, models. We review the methods for incorporating both accretion onto, and reactions on, the surfaces of grains in such models, as well as describing some recent experimental efforts to simulate and examine relevant processes in the laboratory. These efforts include experiments on the surface-catalysed recombination of hydrogen atoms, on chemical processing on and in the ices that are known to exist on the surface of interstellar grains, and on desorption processes, which may enable species formed on grains to return to the gas-phase.

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The universal red-giant oscillation pattern; an automated determination with CoRoT data

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The CoRoT and *Kepler* satellites have provided thousands of red-giant oscillation spectra. The analysis of these spectra requires efficient methods of identifying all eigenmode parameters. The assumption of new scaling laws allowed us to construct a theoretical oscillation pattern. We then obtained a highly precise determination of the large separation by correlating the observed patterns with this reference. We demonstrate that this pattern is universal and are able to unambiguously assign the eigenmode radial orders and angular degrees. This solves one of the remaining problems of asteroseismology, hence allowing precise theoretical investigation of red-giant interiors.

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The origin of dust in the early universe: probing the star formation history of galaxies by their dust content

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Two distinct scenarios for the origin of the $\sim 4 \times 10^8$ $M_\odot$ of dust observed in the high-redshift ($z = 6.4$) quasar J1148+5251 have been proposed. The first assumes that this galaxy is much younger than the age of the universe at

that epoch so that only supernovae (SNe) could have produced this dust. The second scenario assumes a significantly older galactic age, so that the dust could have formed in lower-mass asymptotic giant branch (AGB) stars. Presenting new integral solutions for the chemical evolution of metals and dust in galaxies, we offer a critical evaluation of these two scenarios, and observational consequences that can discriminate between the two. We show that AGB stars can produce the inferred mass of dust in this object, however, the final mass of surviving dust depends on the galaxy's star formation history (SFH). In general supernovae cannot produce the observed amount of dust unless the average SN event creates over ~ 2 $M_\odot$ of dust in its ejecta. However, special SFHs can be constructed in which SNe can produce the inferred dust mass with a reasonable average dust yield of ~ 0.15 $M_\odot$. The two scenarios propose different origins for the galaxy's spectral energy distribution, different star formation efficiencies and stellar masses, and consequently different comoving number densities of J1148+5251-type hyperluminous infrared (IR) objects. The detection of diagnostic mid-IR fine structure lines, and more complete surveys determining the comoving number density of these objects can discriminate between the two scenarios.

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Genesis and evolution of dust in galaxies in the early Universe I. Modeling dust evolution in starburst galaxies

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The aim is to elucidate the astrophysical conditions required for generating large amounts of dust in massive starburst galaxies at high redshift. We have developed a numerical galactic chemical evolution model. The model is constructed such that the effect of a wide range of parameters can be investigated. It takes into account results from stellar evolution models, a differentiation between diverse types of core collapse SNe and the contribution of AGB stars in the mass range 3–8 $M_\odot$. We consider the lifetime-dependent yield injection into the ISM by all sources as well as dust destruction due to SN shocks in the ISM. We ascertain the temporal progression of the dust mass, the dust-to-gas and dust-to-metal mass ratios as well as other physical properties of a galaxy and study their dependence on the mass of the galaxy, the IMF, dust production efficiencies and dust destruction in the ISM. The amount of dust and the physical properties of a galaxy strongly depend on the initial gas mass available. Overall, while the total amount of dust produced increases with galaxy mass, the detailed outcome depends on the SN dust production efficiency, the IMF and the strength of dust destruction in the ISM. Dust masses are higher for IMFs biased towards higher stellar masses, despite the fact that these IMFs are more strongly affected by dust destruction in the ISM. The sensitivity to the IMF increases as the mass of the galaxy decreases. SNe are primarily responsible for a significant enrichment with dust at early epochs (< 200 Myr). Dust production with a dominant contribution by AGB stars is found to be insufficient to account for dust masses in excess of 10^8 $M_\odot$ within 400 Myr after starburst. We find that galaxies with initial gas masses between 1–5 $\times$ 10^{11} $M_\odot$ are sufficiently massive to enable production of dust masses $> 10^8$ $M_\odot$. Our preferred scenario is dominated by SN dust production in combination with top-heavy IMFs and moderate dust destruction in the ISM.

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Shaken, not stirred: The disrupted disk of the starburst galaxy NGC 253

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Near-infrared images obtained with the CFHT WIRCam are used to investigate the recent history of the nearby Sculptor Group spiral NGC 253. The distribution of stars in the disk is lop-sided, in the sense that the projected density of AGB stars in the north east portion of the disk between 10 and 20 kpc from the galaxy center is ~ 0.5

dex higher than on the opposite side of the galaxy. With the exception of the central 2 kpc, the north east portion of the disk appears to have been the site of the highest levels of star-forming activity in the galaxy during the past ~ 0.1 Gyr. Diffuse stellar structures are found in the periphery of the disk, and the most prominent of these is to the south and east of the galaxy. Bright AGB stars are detected out to 15 kpc above the disk plane, and these are part of a diffusely distributed, flattened extraplanar component. Comparisons between observed and model luminosity functions suggest that the extraplanar regions contain stars that formed throughout much of the age of the Universe. It is suggested that the disk of NGC 253 was disrupted by a tidal encounter with a now defunct companion. The ages of the youngest extraplanar stars suggests that the event that produced the extraplanar population, and presumably induced the starburst, occured within the past ~ 0.2 Gyr.

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Warm water vapour in the sooty outflow from a luminous carbon star

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The detection of circumstellar water vapour around the ageing carbon star IRC +10 216 challenged the current understanding of chemistry in old stars, as water was predicted to be almost absent in carbon-rich stars. Several explanations for the water were postulated, including the vaporization of icy bodies (comets or dwarf planets) in orbit around the star, grain surface reactions, and photochemistry in the outer circumstellar envelope. With a single water line detected from this one carbon-rich evolved star, it is difficult to discriminate between the different mechanisms proposed. Here we report the detection of dozens of water vapour lines in the far-infrared and sub-millimetre spectrum of IRC +10 216 using the Herschel satellite. This includes some highexcitation lines with energies corresponding to 1,000 K, which can be explained only if water is present in the warm inner sooty region of the envelope. A plausible explanation for the warm water appears to be the penetration of ultraviolet photons deep into a clumpy circumstellar envelope. This mechanism also triggers the formation of other molecules, such as ammonia, whose observed abundances are much higher than hitherto predicted.

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Water content and wind acceleration in the envelope around the oxygen-rich AGB star IK Tauri as seen by *Herschel*/HIFI

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During their asymptotic giant branch evolution, low-mass stars lose a significant fraction of their mass through an intense wind, enriching the interstellar medium with products of nucleosynthesis. We observed the nearby oxygen-rich asymptotic giant branch star IK Tau using the high-resolution HIFI spectrometer onboard *Herschel*. We report on the first detection of $H_2{}^{16}O$ and the rarer isotopologues $H_2{}^{17}O$ and $H_2{}^{18}O$ in both the ortho and para states. We deduce a total water content (relative to molecular hydrogen) of 6.6×10^{-5}, and an ortho-to-para ratio of 3:1. These results

are consistent with the formation of H_2O in thermodynamical chemical equilibrium at photospheric temperatures, and does not require pulsationally induced non-equilibrium chemistry, vaporization of icy bodies or grain surface reactions. High-excitation lines of ^{12}CO, ^{13}CO, ^{28}SiO, ^{29}SiO, ^{30}SiO, HCN, and SO have also been detected. From the observed line widths, the acceleration region in the inner wind zone can be characterized, and we show that the wind acceleration is slower than hitherto anticipated.

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Silicon in the dust formation zone of IRC +10 216

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The interstellar medium is enriched primarily by matter ejected from evolved low and intermediate mass stars. The outflows from these stars create a circumstellar envelope in which a rich gas-phase and dust-nucleation chemistry takes place. We observed the nearest carbon-rich evolved star, IRC +10 216, using the PACS (55–210 μm) and SPIRE (194–672 μm) spectrometers on board *Herschel*. We find several tens of lines from SiS and SiO, including lines from the $v = 1$ vibrational level. For SiS these transitions range up to $J = 124$–123, corresponding to energies around 6700 K, while the highest detectable transition is $J = 90$–89 for SiO, which corresponds to an energy around 8400 K. Both species trace the dust formation zone of IRC +10 216, and the broad energy ranges involved in their detected transitions permit us to derive the physical properties of the gas and the particular zone in which each species has been formed. This allows us to check the accuracy of chemical thermodynamical equilibrium models and the suggested depletion of SiS and SiO due to accretion onto dust grains.

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The discovery of infrared rings in the planetary nebula NGC 1514 during the WISE all-sky survey

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We report the discovery of a pair of infrared, axisymmetric rings in the planetary nebula NGC 1514 during the course of the WISE all-sky mid-infrared survey. Similar structures are seen at visible wavelengths in objects such as the "Engraved Hourglass Nebula" (MyCn 18) and the "Southern Crab Nebula" (Hen 2-104). However, in NGC 1514 we see only a single pair of rings and they are easily observed only in the mid-infrared. These rings are roughly 0.2 pc in diameter, are separated by 0.05 pc, and are dominated by dust emission with a characteristic temperature of 160 K. We compare the morphology and color of the rings to the other nebular structures seen at visible, far-infrared, and radio wavelengths, and close with a discussion of a physical model and formation scenario for NGC 1514.

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Deep mixing in evolved stars: I. The effect of reaction rate revisions from C to Al

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We present computations of nucleosynthesis in low-mass red-giant-branch and asymptotic-giant-branch stars of Population I experiencing extended mixing. We adopt the updated version of the FRANEC evolutionary model, a new post- process code for non-convective mixing and the most recent revisions for solar abundances. In this framework, we discuss the effects of recent improvements in relevant reaction rates for proton captures on intermediate-mass nuclei (from carbon to aluminum). For each nucleus we briefly discuss the new choices and their motivations. The calculations are then performed on the basis of a parameterized circulation, where the effects of the new nuclear inputs are best compared to previous works. We find that the new rates (and notably the one for the ^{14}N(p,α)^{15}O reaction) imply considerable modifications in the composition of post-main sequence stars. In particular, the slight temperature changes due to the reduced eciency of proton captures on ^{14}N induce abundance variations at the first dredge up (especially for ^{17}O, whose equilibrium ratio to ^{16}O is very sensitive to the temperature). In this new scenario presolar oxide grains of AGB origin turn out to be produced almost exclusively by verylow mass stars ($M \leq 1.5$–1.7 M$_\odot$), never becoming C-rich. The whole population of grains with ^{18}O/^{16}O below 0.0015 (the limit permitted by first dredge up) is now explained. Also, there is now no forbidden area for very low values of ^{17}O/^{16}O (below 0.0005), contrary to previous findings. A rather shallow type of transport seems to be sucient for the CNO changes in RGB stages. Both thermohaline diffusion and magnetic-buoyancy-induced mixing might provide a suitable physical mechanism for this (and we shall briefly comment in section 7 on recent results from 2D calculations that offer some interesting clues for constructing a realistic model). Thermohaline mixing is in any case certainly inadequate to account for the production of ^{26}Al on the AGB. Other transport mechanisms must therefore be at play. In general, observational constraints from RGB and AGB stars, as well as from presolar grains, are well reproduced by our approach. An exception remains the nitrogen isotopic ratio in mainstream SiC grains. For the low values measured in them (i.e. for ^{14}N/^{15}N < 2000) we have no explanation. Actually, for the several grains with subsolar nitrogen isotopic ratios no known stellar process acting in low mass stars can provide a clue. This might be an evidence that some form of contamination from cosmic ray spallation occurs in the interstellar medium, adding fresh ^{15}N to the grains.

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The deepest HST color–magnitude diagram of M 32: Evidence for intermediate-age populations

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We present the deepest optical color–magnitude diagram (CMD) to date of the local elliptical galaxy M 32. We have obtained F435W and F555W photometry based on Hubble Space Telescope ACS/HRC images for a region 110″ from the center of M 32 (F1) and a background field (F2) about 320″ away from M 32 center. Due to the high resolution of our Nyquist-sampled images, the small photometric errors, and the depth of our data we obtain the most detailed resolved photometric study of M 32 yet. Deconvolution of HST images proves to be superior than other standard methods to derive stellar photometry on extremely crowded HST images. The location of the strong red clump in the

CMD suggests a mean age between 8 and 10 Gyr for [Fe/H] = −0.2 dex in M 32. We detect for the first time a red giant branch bump and an asymptotic giant branch bump in M 32 which, together with the red clump, allow us to constrain the age and metallicity of the dominant population in this region of M 32. These features indicate that the mean age of M 32's population at 2′ from its center is between 5 and 10 Gyr. We see evidence of an intermediate-age population in M 32 mainly due to the presence of asymptotic giant branch stars rising to $M_{\rm F555W} \sim -2.0$. Our detection of a blue component of stars(blue plume) may indicate for the first time the presence of a young stellar population, with ages of the order of 0.5 Gyr, in our M 32 field. However, it is likely that the brighter stars of this blue plume belong to the disk of M 31 rather than to M 32. The fainter stars populating the blue plume indicate the presence of stars not younger than 1 Gyr and/or blue straggler stars in M 32. The CMD of M 32 displays a wide color distribution of red giant branch stars indicating an intrinsic spread in metallicity with a peak at [Fe/H] ~ -0.2. There is not a noticeable presence of blue horizontal branch stars, suggesting that an ancient population with [Fe/H] < -1.3 does not significantly contribute to the light or mass of M 32 in our observed fields. M 32's dominant population of 8–10 Gyr implies a formation redshift of $1 < z_{\rm f} < 2$, precisely when observations of the specific star formation rates and models of "downsizing" imply galaxies of M 32's mass ought to be forming their stars. Our CMD therefore provides a "ground-truth" of downsizing scenarios at $z = 0$. Our background field data represent the deepest optical observations yet of the inner disk and bulge of M 31. Its CMD exhibits a broad color spread of red giant stars indicative of its metallicity range with a peak at [Fe/H] ~ -0.4 dex, slightly more metal-poor than M 32 in our fields. The observed blue plume consists of stars as young as 0.3 Gyr, in agreement with previous works on the disk of M 31. The detection of bright AGB stars reveals the presence of intermediate-age population in M 31, which is however less significant than that in M 32 at our field's location.

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A disk inside the bipolar planetary nebula M 2-9

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Bipolarity in proto-planetary and planetary nebulae is associated with events occurring in or around their cores. Past infrared observations have revealed the presence of dusty structures around the cores, many in the form of disks. Characterising those dusty disks provides invaluable constraints on the physical processes that govern the final mass expulsion of intermediate-mass stars. We focus this study on the famous M 2-9 bipolar nebula, where the moving lighthouse beam pattern indicates the presence of a wide binary. The compact and dense dusty core in the center of the nebula can be studied by means of optical interferometry. M 2-9 was observed with VLTI/MIDI at 39–47 m baselines with the UT2–UT3 and UT3–UT4 baseline configurations. These observations are interpreted using a dust radiative transfer Monte Carlo code. A disk-like structure is detected perpendicular to the lobes and a good fit is found with a stratified disk model composed of amorphous silicates. The disk is compact, 25×35 mas at 8 μm, and 37×46 mas at 13 μm. For the adopted distance of 1.2 kpc, the inner rim of the disk is ~ 15 AU. The mass represents a few percent of the mass found in the lobes. The compactness of the disk puts strong constraints on the binary content of the system, given an estimated orbital period 90–120 yr. We derive masses of the binary components between 0.6–1.0 $M_\odot$ for a white dwarf and 0.6–1.4 $M_\odot$ for an evolved star. We present different scenarios on the geometric structure of the disk accounting for the interactions of the binary system, which includes an accretion disk as well.

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The abundances of polyacetylenes towards CRL 618

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We present a mid-infrared high spectral resolution spectrum of CRL 618 in the frequency ranges 778–784 and 1227–1249 cm^{-1} (8.01–8.15 and 12.75–12.85 μm) taken with the Texas Echelon-cross-Échelle Spectrograph (TEXES) and the Infrared Telescope Facility (IRTF). We have identified more than 170 ro-vibrational lines arising from C_2H_2, HCN, C_4H_2, and C_6H_2. We have found no unmistakable trace of C_8H_2. The line profiles display a complex structure suggesting the presence of polyacetylenes in several components of the circumstellar envelope (CSE). We derive total column densities of 2.5×10^{17}, 3.1×10^{17}, 2.1×10^{17}, 9.3×10^{16} cm^{-2}, and $< 5 \times 10^{16}$ cm^{-2} for HCN, C_2H_2, C_4H_2, C_6H_2, and C_8H_2, respectively. The observations indicate that both the rotational and vibrational temperatures in the innermost CSE depend on the molecule, varying from 100 to 350 K for the rotational temperatures and 100 to 500 K for the vibrational temperatures. Our results support a chemistry in the innermost CSE based on radical-neutral reactions triggered by the intense UV radiation field.

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Conference Papers

Dynamics of extended AGB star envelopes

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The dust formed in extended circumstellar envelopes of long-period variables and Miras has a strong influence on the envelope dynamics. A radiatively driven instability caused by the formation of dust leads to the development of an autonomous dynamics characterised by a set of distinct frequencies. We study the interplay between the envelope's internal dynamics and an external excitation by a pulsating star.

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The AGB population of NGC 6822

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The metallicity gradient and the stellar distribution within the Local Group dwarf galaxy NGC 6822 has been studied photometrically using asymptotic branch stars (AGB). In order to study the stellar and metallicity distribution, the carbon- and oxygen-rich AGB stars have been isolated using deep high-quality near-infrared UKIRT photometry. The

ratio between them, the C/M ratio, has been used to derive the [Fe/H] abundance within the galaxy. The [Fe/H] abundance and stellar distribution were analysed as a function of galactic radius. A mean C/M ratio of 0.288 ± 0.014 has been found which corresponds to an iron abundance of [Fe/H] $= -1.14 \pm 0.08$ dex, with variations in the north and south, as well as at larger galactocentric distances. Variations in the magnitude of the tip of the red giant branch have also been detected.

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Evidence for terrestrial planetary system remnants at white dwarfs

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The last several years have brought about a dynamic shift in the view of exoplanetary systems in the post-main sequence, perhaps epitomized by the evidence for surviving rocky planetary bodies at white dwarfs. Coinciding with the launch of the *Spitzer* Space Telescope, both space- and ground-based data have supported a picture whereby asteroid analogs persist at a significant fraction of cool white dwarfs, and are prone to tidal disruption when passing close to the compact stellar remnant. The ensuing debris can produce a detectable infrared excess, and the material gradually falls onto the star, polluting the atmosphere with heavy elements that can be used to determine the bulk composition of the destroyed planetary body. Based on the observations to date, the parent bodies inferred at white dwarfs are best described as asteroids, and have a distinctly rocky composition similar to material found in the inner Solar System. Their minimum masses are typical of large asteroids, and can approach or exceed the mass of Vesta and Ceres, the two largest asteroids in the Solar System. From the number of stars surveyed in various studies, the fraction of white dwarfs that host terrestrial planetary system remnants is at least a few percent, but likely to be in the range 20% to 30%. Therefore, A- and F-type stars form terrestrial planets efficiently, with a frequency at least as high as the remnants detected at their white dwarf descendants.

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Asymmetric line profiles in spectra of gaseous metal disks around single white dwarfs

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Around several single DAZ and DBZ white dwarfs metal-rich disks have been observed, which are mostly believed to originate from disruption of smaller rocky planetesimals. In some cases the material does not (only) form a dusty but gaseous disk. In the case of SDSS J122859.93+104032.9 the double peaked infrared Ca II triplet at about 8500 Å, one of only two emission features of the spectra, exhibits a strong red/violet asymmetry. Assuming a composition similar to a chondrite-like asteroid, being the most prominent type in our own solar system, we calculated the spectrum and vertical structure of the disk using the Tübingen NLTE accretion disk code "AcDc". Modified to simulate different non axis-symmetrical disk geometries, the first preliminary results are in good agreement with the observed asymmetric line profile.

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Determining the forsterite abundance of the dust around AGB stars

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We present a diagnostic tool to determine the forsterite abundance of the dust ejected by AGB stars. Our method is based on a comparison between the observed strength of spectral bands of forsterite and model calculations. We show that the 11.3 μm forsterite band is a robust indicator of the forsterite abundance of the current mass- loss period for AGB stars with an optically thick dust shell. The 33.6 μm band of forsterite is sensitive to changes in the density and the geometry of the emitting dust shell, and so a less robust indicator. We apply this method to six high mass-loss rate AGB stars, showing that AGB stars can have forsterite abundances of 12% by mass and higher, which is more than the previously found maximum abundance of 5%.

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Detection of the 69 μm band of crystalline forsterite in the *Herschel* MESS-program

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In this article we present the detection of the 69 μm band of the crystalline olivine forsterite within the MESS key program of *Herschel*. We determine the temperature of the forsterite grains by fitting the 69 μm band.

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Abundance patterns in S-type AGB stars: Setting constraints on nucleosynthesis and stellar evolution models

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During the evolution on the AGB, S-type stars are the first objects to experience s-process nucleosynthesis and third dredge-ups, and therefore to exhibit s-process signatures in their atmospheres. Their significant mass-loss rates (10^{-7} to 10^{-6} $M_\odot$ yr^{-1}) make them major contributors to the AGB nucleosynthesis yields at solar metallicity. Precise

abundance determinations in S stars are of the utmost importance for constraining, e.g., the third dredge-up luminosity and efficiency (which has been only crudely parameterized in all current nucleosynthetic models so far). Here, dedicated S-star model atmospheres are used to determine precise abundances of key s-process elements, and to set constraints on nucleosynthesis and stellar evolution models. A special interest is paid to technetium, an element with no stable isotopes (^{99}Tc, the only isotope produced by the s-process in AGB stars, has a half-life of 2.1×10^5 years). Its detection is considered as the best signature that the star effectively populates the thermally-pulsing AGB phase of evolution. The derived Tc/Zr abundances are compared, as a function of the derived [Zr/Fe] overabundances, with AGB stellar model predictions. The [Zr/Fe] overabundances are in good agreement with the model predictions, while the Tc/Zr abundances are slightly overpredicted. This discrepancy can help to set better constraints on nucleosynthesis and stellar evolution models of AGB stars.

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Extended atmospheres of AGB stars: modeling and measurement

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Encoded in the time- and wavelength dependent properties of pulsating AGB stars are the underlying fundamental parameters of mass, composition and evolutionary state. However, the standard technique of placing stars on a HR diagram, even with the aid of pulsation periods, can not be done easily for extended AGB stars, because of the difficulty of defining a radius or temperature. The atmospheres of Mira variables are so extended that the optical depth unity radius can vary by a factor of ~ 3 over the energetically important region of the spectrum. Many important constituents in the radiative transfer are far from local thermodynamic equilibrium, and for the coolest stars, the process of dust formation and destruction requires a time-dependent model of grain growth. I will describe the challenges and some of the solutions to modeling these atmospheres, and describe the utility of different kinds of observations in helping understand both fundamental parameters and chaotic processes in complex AGB atmospheres.

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AGB stars in WLM

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We investigate the star formation history and metallicity of the Local Group irregular dwarf galaxy WLM using wide-field JHK near-infrared imaging, spanning a region of approximately 1 sq. degree, obtained with WFCAM on UKIRT. JHK photometry clearly reveals the tip of the red giant branch, allowing a new estimate of the distance, and allows ready identification of C-type and M-type AGB stars. The C/M ratio was used to produce a surface map of the metallicity distribution which is compared to previous studies. Multi-wavelength spectral energy distributions (SEDs) were constructed for some AGB stars.

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Asymptotic Giant Branch variables in NGC 6822

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Using multi-epoch JHK photometry obtained with the 1.4-m Japanese–South African Infrared Survey Facility at Sutherland we have identified large numbers of AGB variables in NGC 6822. This paper uses 30 large amplitude variables, with periods ranging from about 200 to 900 days, to provide a new calibration of the period–luminosity relation.

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A grid of MARCS model atmospheres for S stars

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S-type stars are late-type giants whose atmosphere is enriched in carbon and s-process elements because of either extrinsic pollution by a binary companion or intrinsic nucleosynthesis and dredge-up on the thermally-pulsing AGB. A large grid of S-star model atmospheres has been computed covering the range $2700 \leq T_{\rm eff}({\rm K}) \leq 4000$ with $0.5 \leq {\rm C/O} \leq 0.99$. ZrO and TiO band strength indices as well as VJHKL photometry are needed to disentangle $T_{\rm eff}$, C/O and [s/Fe]. A "best-model finding tool" was developed using a set of well-chosen indices and checked against photometry as well as low- and high-resolution spectroscopy. It is found that applying M-star model atmospheres (i.e., with a solar C/O ratio) to S stars can lead to errors on $T_{\rm eff}$ up to 400 K. We constrain the parameter space occupied by S stars of the vast sample of Henize stars in terms of $T_{\rm eff}$, [C/O] and [s/Fe].

Oral contribution, published in "Why Galaxies Care About AGB Stars II", Vienna Aug. 2010, ASP Conference Series
Available from arXiv:1011.2092

Job Advert

2(+1)yr postdoctoral position

Radiative transfer and chemical models for the stellar winds of evolved stars

The Instituut voor Sterrenkunde (IvS) of Leuven University is a young and active research group of some 50 scientists, engineers and administrative staff (http://www.ster.kuleuven.be). The institute is involved in several international networks and research projects, involving telescopes at international observatories and space missions. The institute is also responsible for the organisation of the Master in Astronomy & Astrophysics of the Faculty of Science at Leuven University.

With this vacancy, we are searching a motivated postdoc to join the team on evolved stars of IvS, which presently consists of 3 staff members, 7 PhD students, 7 postdocs and 2 engineers.

The project

The project is embedded in a larger theoretical and observational effort at the IvS to study in detail the late stages of evolution of low and intermediate mass stars.

Evolved stars are important sources for the enrichment of the interstellar medium due to their dense outflows. These outflows are variable on many timescales and their physics and chemistry are not well understood. Presently, the IvS is in the unique position to use guaranteed time observations of both the HIFI and PACS instrument onboard the *Herschel* Space Observatory (launched in May 2009) to study with unprecedented detail the role of different molecules in the stellar winds of evolved Asymptotic Giant Branch (AGB) stars. As proven by the publications in Nature and Astronomy & Astrophysics, many exciting results were already obtained last year. These data can, however, only be exploited in full detailed when being confronted with state-of-the-art theoretical models coupling hydrodynamical, chemical and radiative transfer processes.

A post-doctoral position is offered at the IvS to further develop the in-house developed radiative transfer tools to analyse the new observations. The main goal is to couple radiative transfer and chemistry in a multi-dimensional geometry. Expertise in radiative transfer modelling or chemistry is hence an asset. The applicant will be given the possibility to confront the new theoretical models with *Herschel* and ground-based observations, or with the own observations (already) gathered by the applicant. While the IvS has a strong expertise in the field of evolved stars, interested candidates with expertise in other research fields are also welcomed.

The position

The candidate will work under supervision of Prof. Leen Decin and will collaborate with the other team members at the IvS. As is common at the Leuven University, the postdoc shall take up a teaching assistance task of maximum 4 hours per week in the Bachelor of Physics (Dutch) or in the Master of Astronomy & Astrophysics (English). The postdoc shall perform at least one observing run of 10 nights per year for the pooled IvS programmes at the observatories of La Palma or La Silla.

Contract

The initial contract runs over 2 years. Depending on the seniority of the candidate, it could be prolonged with another year after positive evaluation. The salary will be commensurate to the standard scale for post-doctoral researchers at the Leuven University. The preferred starting date is between 1 March 2011 and 15 April 2011, but will be adapted to the selected candidate's availability. Candidates are thus requested to indicate their preferred starting date in the application.

Interested?

The successful candidate must have a PhD degree in astrophysics or chemistry. Applications should be sent to Leen Decin (Leen.Decin@ster.kuleuven.be) and must include a CV and statement of research interests; please also arrange for three letters of reference (to be sent directly). Applications must arrive before January 31, 2011 or until the position is filled. For more information please contact Leen Decin (Leen.Decin@ster.kuleuven.be).

See also http://www.ster.kuleuven.be/vacancies/2010_2/