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Abstract of recently accepted papers

Model of Dust Shell of V1853 Cygni

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The spectral energy distribution of the proto-planetary nebula V1853 Cyg from near UV to far IR is fitted using the dust radiative transfer model for a spherically symmetric shell. The characteristics of the central star have been determined by Arkhipova V.P. et al.(Astron. Lett. 2001. V.27. P.719). The luminosity is found to be 6300 $L_{\odot}$, and the effective temperature is equal 20000 K. The model of the dust shell is calculated using the DUSTY (version 2.0) code. For the grain size distribution we adopted the standard MRN model. The dust composition was accepted to be the warm silicate, and the grain number density $n(r) \propto r^{-2}$. The derived parameters of this model are: the optical depth of the dust shell at wavelength 0.55 micron, 0.18; the inner shell radius, 7.6×10^{16} cm; the temperature of the dust at inner radius, 110 K; the distance, 4.1 kpc; the total mass-loss rate, $2.2 \times 10^{-5} \mathrm{M}_{\odot}\,\mathrm{yr}^{-1}$.

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Properties of the close binary and circumbinary torus of the Red Rectangle

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New diffraction-limited speckle images of the Red Rectangle in the wavelength range 2.1–3.3 μm with angular resolutions of 44–68 mas (Tuthill et al. 2002) and previous speckle images at 0.7–2.2 μm (Osterbart et al. 1997, Men'shchikov et al. 1998) revealed well-resolved bright bipolar outflow lobes and long X-shaped spikes originating deep inside the outflow cavities. This set of high-resolution images stimulated us to reanalyze all infrared observations of the Red Rectangle using our two-dimensional radiative transfer code. The high-resolution images imply a geometrically and optically thick torus-like density distribution with bipolar conical cavities and are inconsistent with the flat disk geometry frequently used to visualize bipolar nebulae. The new detailed modeling, together with estimates of the interstellar extinction in the direction of the Red Rectangle enabled

us to more accurately determine one of the key parameters, the distance $D \approx 710\,\mathrm{pc}$ with model uncertainties of 70 pc, which is twice as far as the commonly used estimate of 330 pc. The central binary is surrounded by a compact, massive ($M \approx 1.2\,M_\odot$), very dense dusty torus with hydrogen densities reaching $n_\mathrm{H} \approx 2.5 \times 10^{12}\,\mathrm{cm}^{-3}$ (dust-to-gas mass ratio $\rho_\mathrm{d}/\rho \approx 0.01$). The model implies that most of the dust mass in the dense torus is in very large particles and, on scales of more than an arcsecond, the polar outflow regions are denser than the surrounding medium. The bright component of the spectroscopic binary HD 44179 is a post-AGB star with mass $M_\star \approx 0.57\,M_\odot$, luminosity $L_\star \approx 6000\,L_\odot$, and effective temperature $T_\star \approx 7750\,\mathrm{K}$. Based on the orbital elements of the binary, we identify its invisible component with a helium white dwarf with $M_\mathrm{WD} \approx 0.35\,M_\odot$, $L_\mathrm{WD} \sim 100\,L_\odot$, and $T_\mathrm{WD} \sim 6 \times 10^4\,\mathrm{K}$. The hot white dwarf ionizes the low-density bipolar outflow cavities inside the dense torus, producing a small H II region observed at radio wavelengths. We propose an evolutionary scenario for the formation of the Red Rectangle nebula, in which the binary initially had 2.3 and $1.9\,M_\odot$ components at a separation of $\sim 130\,R_\odot$. The nebula was formed in the ejection of a common envelope after Roche lobe overflow by the present post-AGB star.

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Angular Size Measurements Of Mira Variable Stars At 2.2 μm. II

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We present angular size measurements of 22 oxygen-rich Mira variable stars. These data are part of a long term observational program using the Infrared Optical Telescope Array (IOTA) to characterize the observable behavior of these stars. Complementing the infrared angular size measurements, values for variable star phase, spectral type, bolometric flux and distance were established for stars in the sample; flux and distance led to values for effective temperature (T_{EFF}), and linear radius, respectively. Additionally, values for the $K - [12]$ color excess were established for these stars, which is indicative of dusty mass loss. Stars with higher color excess are shown to be systematically 120 $R_\odot$ larger than their low color excess counterparts, regardless of period. This analysis appears to present a solution to a long-standing question presented by the evidence that some Mira angular diameters are indicative of first overtone pulsation, while other diameters are more consistent with fundamental pulsation. A simple examination of the resultant sizes of these stars in the context of pulsation mode is consistent with at least some of these objects pulsating in the fundamental mode.

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or via WWW on http://huey.jpl.nasa.gov/ gerard/postscript

The Modelling of Intermediate Age Stellar Populations: Average Spectra for Upper AGB Stars, and their Use

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The upper AGB is populated with oxygen rich and carbon rich Long Period Variables (LPVs). These stars are essential contributors to the near-IR light of intermediate age stellar populations. Individual observed spectra

of LPVs are so diverse that they cannot be used directly in the synthesis of galaxy spectra. In this paper, the library of individual spectra of Lançon & Wood (2000) is used to construct averages that can be incorporated conveniently in population synthesis work. The connection between such spectra and stellar evolution tracks is discussed.

In order to select a sorting criterion and to define averaging bins for the LPV spectra, correlations between their spectrophotometric properties are reexamined. While optical properties and broad baseline colours such as (I-K) are well correlated, a large dispersion is observed when these indices are plotted against near-IR ones. This is partly due to the intrinsic width of the upper AGB, which is illustrated by locating each of the multiple observations of individual LPVs on the HR diagram. It is argued that broad baseline colour-temperatures are the most sensible sorting criteria. The properties of the resulting sequence of average spectra indeed vary regularly.
We further address: (i) the bolometric corrections and temperature scales needed to associate a spectrum with a given point on a theoretical stellar evolution track (or isochrone), (ii) the simplifying assumptions that will be implicitely made when using the average spectra, (iii) potential biases in the sample of Lançon & Wood and their effects, (iv) the small contribution of LPVs to the interstellar hydrogen emission lines in galaxies. It is emphasized that an a posteriori calibration of the effective temperature scale remains necessary, until consistent models for the evolution, the pulsation and the spectral appearance of LPVs become available.

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FG Sge

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FG Sagittae has evolved from a hot central star of a planetary nebula to an K-type supergiant within approximately the last 100 years. The generally accepted interpretation for this redward evolution is that of a late thermal pulse during the planetary nebula stage, wherein helium burning at the surface of the electron-degenerate carbon-oxygen core is reignited. As the star expands in response to the energy released by helium burning, envelope convection digs deeper and deeper until nuclearly processed material may get dredged-up to the stellar surface. Analysing the spectra as FG Sge is evolving would then give unique information about the temporal development of mixing processes occurring inside the star that are otherwise impossible to obtain. The existing abundance analyses do not give, however, a consistent picture. Especially the question about FG Sge's hydrogen abundance is still unsettled. We present a critical assessment of all the existing data, trying to find a self-consistent picture of the evolution of FG Sge, based on the latest evolutionary models.

Invited Review, IAU Colloqium 187 "Exotic Stars as Challenges to Evolution" (in press) *Preprints can be obtained bycontacting* deschoenberner@aip.de
or via WWW on http://www.aip.de/groups/sternphysik/stp/publications.html

Discovery of the spectral variations of the optical counterpart of IRAS 01005+7910

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We present a study of the high-resolution spectroscopic data for the proto-planetary nebula candidate IRAS 01005+7910. For the first time a careful spectral line identification is carried out, and a significant variability of the optical spectrum is detected. We found absorption lines of C II/III, N II, O II, Al III, Si III, and Mg II (λ4481 Å), as well as emission lines of Si II and [Fe II]. Both absorption and emission components are present in the Balmer lines, Na I resonance $D_{1,2}$ lines, He I, and Fe III lines. The He I line profiles vary from straight to inverse P Cyg-type on a timescale of days to months. The resonance Na I lines show 5 absorption components at a resolution of $R = 3D60000$. Additionally, the Na I D_2 line exhibits a variable emission component with a width, comparable to that of the Balmer line emission components. Using the model atmospheres method within the LTE-approximation, the effective temperature ($T_{eff} \sim 21500$ K), the metallicity $[Fe/H]_{\odot} = 3D - 0.31$, and the ratio $C/O > 1$ was found. Finally, we have suggested that IRAS 01005+7910 is a carbon–rich post–AGB star with a luminosity $\log L/L_{\odot} = 3D3.6$ at a distance about 3 kpc.

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Modeling IR spectra of OH/IR stars at different phases

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We investigate the spectral energy distributions (SEDs) of OH/IR stars (OH127.8+0.0 and OH26.5+0.6) having thick dust envelopes at different pulsation phases. Using new infrared observational data including the Infrared Space Observatory (ISO) data, we determine the new pulsation parameters. The deep silicate absorption features show significant variations depending on the pulsation phase. The variations are mainly due to changes in the properties of dust envelopes around the OH/IR stars. Comparing the results of detailed radiative model calculations with observations, we explore the changes of the relevant parameters of the envelopes and central stars depending on the pulsation phase. We find that when the central luminosity increases from the minimum to maximum phase, the inner radius of the dust shell increases with velocity faster than the outer shell expansion velocity and the dust shell optical depth decreases. During the phase change from the minimum to maximum, we find that dust formation ceases and about a half of the dust grains in the volume difference should be evaporated. During the phase change from the maximum to minimum, we find that the dust formation should be enhanced because the inner radius is decreasing. In the outer radii of the dust shell, the constant dust winds are easily maintained. We expect that the dust evaporation process driven by pulsation could be a mechanism for crystallizing the dust grains in inner regions of the dust shells around OH/IR stars.

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The Origin of Subdwarf B Stars (I): the Formation Channels.

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Subdwarf B (sdB) stars (and related sdO/sdOB stars) are believed to be helium core-burning objects with very thin hydrogen-rich envelopes. In recent years it has become increasingly clear from observational surveys that a large fraction of these objects are members of binary systems. To better understand their formation, we here present the results of a detailed investigation of the three main binary evolution channels that can lead to the formation of sdB stars: the common envelope (CE) ejection channel, the stable Roche lobe overflow (RLOF) channel and the double helium white dwarfs (WDs) merger channel. The CE ejection channel leads to the formation of sdB stars in short-period binaries with typical orbital periods between 0.1 and 10 d, very thin hydrogen-rich envelopes and a mass distribution sharply peaked around $\sim 0.46 M_{\odot}$. On the other hand, under the assumption that all mass transferred is soon lost, the stable RLOF channel produces sdB stars with similar masses but long orbital periods (400 – 1500 d) and with rather thick hydrogen-rich envelopes. The merger channel gives rise to single sdB stars whose hydrogen-rich envelopes are extremely thin but which have a fairly wide distribution of masses ($0.4 - 0.65\,M_{\odot}$). We obtained the conditions for the formation of sdB stars from each of these channels using detailed stellar and binary evolution calculations where we modelled the detailed evolution of sdB stars and carried out simplified binary population synthesis simulations. The observed period distribution of sdB stars in compact binaries strongly constrains the CE ejection parameters. The best fits to the observations are obtained for very efficient CE ejection where the envelope ionization energy is included, consistent with previous results. We also present the distribution of sdB stars in the $T_{\rm eff}$ - $\log g$ diagram, the Hertzsprung-Russell diagram and the distribution of mass functions.

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or via WWW on http://www.ast.cam.ac.uk/ zhanwen (the 1st paper in the publication section.
Also available from the URL http://asXiv.org/abs/astro-ph/0206130

High Resolution CO and H_2 Molecular Line Imaging of a Cometary Globule in the Helix Nebula

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We report high resolution imaging of a prominent cometary globule in the Helix nebula in the CO $J = 3D1 - 0$ (2.6 mm) and H_2 $v = 3D1 - 0$ $S(1)$ (2.12 μm) lines. The observations confirm that globules consist of dense condensations of molecular gas embedded in the ionized nebula. The head of the globule is seen as a peak in the CO emission with an extremely narrow line width (0.5 km s^{-1}) and is outlined by a limb-brightened surface of H_2 emission facing the central star and lying within the photo-ionized halo. The emission from both molecular species extends into the tail region. The presence of this extended molecular emission provides new constraints on the structure of the tails, and on the origin and evolution of the globules.

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The rich 6 to 9 μm spectrum of interstellar PAHs

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IR spectroscopy provides a valuable tool for the characterisation and identification of interstellar molecular species. Here, we present 6–9 μm spectra of a sample of reflection nebulae, HII regions, YSOs, evolved stars and galaxies that show strong unidentified infrared bands, obtained with the SWS spectrograph on board ISO. The IR emission features in this wavelength region show pronounced variations. 1) The 6.2 μm feature shifts from 6.22 to 6.3 μm and clearly shows profile variations. 2) The 7.7 μm complex is comprised of at least two subpeaks peaking at 7.6 and one longwards of 7.7 μm. In some cases the main peak can apparently shift up to 8 μm. Two sources do not exhibit a 7.7 μm complex but instead show a broad emission feature at 8.22 μm. 3) The 8.6 μm feature has a symmetric profile in all sources and some sources exhibit this band at slightly longer wavelengths. For the 6.2, 7.7 and 8.6 μm features, the sources have been classified independently based on their profile and peak position. The classes derived for these features are directly linked with each other. Sources with a 6.2 μm feature peaking at $\sim$ 6.22 μm exhibit a 7.7 μm complex dominated by the 7.6 μm component. In contrast, sources with a 6.2 μm profile peaking longwards of 6.24 μm show a 7.7 μm complex with a dominant peak longwards of 7.7 μm and a 8.6 μm feature shifted toward the red. Furthermore, the observed 6–9 μm spectrum depends on the type of object. All ISM-like sources and a few PNe and Post-AGB stars belong to the first group while isolated Herbig AeBe stars, a few Post-AGB stars and most PNe belong to the second group. We summarise existing laboratory data and theoretical quantum chemical calculations of the modes emitting in this wavelength region of PAH molecules. We discuss the variations in peak position and profile in view of the exact nature of the carrier. We attribute the observed 6.2 μm profile and peak position to the combined effect of a PAH family and anharmonicity with pure PAHs representing the 6.3 μm component and substituted/complexed PAHs representing the 6.2 μm component. The 7.6 μm component is well reproduced by both pure and substituted/complexed PAHs but the 7.8 μm component remains an enigma. In addition, the exact identification of the 8.22 μm feature remains unknown. The observed variations in the characteristics of the IR emission bands are linked to the local physical conditions. Possible formation and evolution processes that may influence the interstellar PAH class are highlighted.

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Discovery of an edge-on dust disk around the [WC10] central star CPD–56°8032

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We present Hubble Space Telescope ultraviolet and optical STIS spectroscopy of the [WCL] planetary nebula central star CPD–56°8032, obtained during its latest lightcurve minimum. The UV spectrum shows the central star's continuum light distribution to be split into two bright peaks separated by 0.10 arcsec. We interpret this finding as due to an edge-on disk or torus structure that obscures direct light from the star, which is

seen primarily via its light scattered from the disk's rims or lobes. CPD–56°8032 is an archetype of dual dust chemistry [WCL] planetary nebulae, which exhibit strong infrared emission features from both carbon-rich and oxygen-rich materials, and for which the presence of a disk harboring the O-rich grains had been suggested. Our direct observation of an edge-on occulting dust structure around CPD–56°8032 provides strong support for such a model and for binary interactions being responsible for the correlation between the dual dust chemistry phenomenon in planetary nebulae and the presence of a hydrogen-deficient [WCL] Wolf-Rayet central star.

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Physical structure of the protoplanetary nebula CRL618. I. Optical long-slit spectroscopy and imaging

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In this paper (paper I) we present optical long-slit spectroscopy and imaging of the protoplanetary nebula CRL618. The optical lobes of CRL618 consist of shock-excited gas, which emits many recombination and forbidden lines, and dust, which scatters light from the innermost regions. From the analysis of the scattered Hα emission, we derive a nebular inclination of i=3D24°$\pm$6°. The spectrum of the innermost part of the east lobe (visible as a bright, compact nebulosity close to the star in the Hα *HST* image) is remarkably different from that of the shocked lobes but similar to that of the inner HII region, suggesting that this region represents the outermost parts of the latter. We find a non-linear radial variation of the gas velocity along the lobes. The largest projected LSR velocities ($\sim$80 km s^{-1}) are measured at the tips of the lobes, where the direct images show the presence of compact bow-shaped structures. The velocity of the shocks in CRL618 is in the range $\sim$75-200 km s^{-1}, as derived from diagnostic line ratios and line profiles. We report a brightening (weakening) of [OIII]λ5007Å ([OI]λ6300Å) over the last $\sim$ 10 years that may indicate a recent increase in the speed of the exciting shocks. From the analysis of the spatial variation of the nebular extinction, we find a large density contrast between the material inside the lobes and beyond them: the optical lobes seem to be 'cavities' excavated in the AGB envelope by interaction with a more tenuous post-AGB wind. The electron density, with a mean value $n_{\rm e}\sim5\times10^3$-10^4 cm^{-3}, shows significant fluctuations but no systematic decrease along the lobes, in agreement with most line emission arising in a thin shell of shocked material (the lobe walls) rather than in the post-AGB wind filling the interior of the lobes. The masses of atomic and ionized gas, respectively, in the east (west) lobe are $>1.3\times10^{-4}\,M_\odot$ ($>7\times10^{-5}\,M_\odot$) and $\sim6\times10^{-5}\,M_\odot$ ($\sim4\times10^{-5}\,M_\odot$). The shocks in CRL618 are in a radiative regime and may lead in the future to the evolution of the optically-emitting lobes into a fast, bipolar molecular outflow. The time required by the dense, shocked gas to cool down significantly is ¡ 2 yr, which is substantially lower than the kinematical age of the lobes (¡ 180 yr). This result suggests that a fast wind is currently active in CRL618 and keeps shocking the circumstellar material.

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AGB stars in Leo I

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The first results of a study of the dwarf spheroidal galaxy, Leo I, using the new Nagoya-South African Infrared Survey Facility (IRSF) are presented. J, H, K_s observations show that most, if not all, of at least the top magnitude of the AGB in K_s is populated by carbon stars. In addition there are five very red objects which are believed to be dust enshrouded AGB stars. One of these is, remarkably, well outside the main body of the galaxy. Three of these obscured stars and five known carbon stars show variability in observations 11 months apart. One of the obscured stars has $\Delta K_s = 3D0.87$ making it highly likely that it, at least, is a Mira variable. The tip of the AGB is at $M_{bol} \sim -5.1$, but further variability studies are necessary to obtain a definitive value. Comparison with carbon stars, both Miras and non-Miras, in Magellanic Cloud clusters and taking into account other evidence on the ages and metallicities of Leo I populations suggests that these obscured stars belong to the youngest significant population of Leo I and have ages of ~ 2 Gyr.

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Proper motions in the knotty, bipolar jet in Hen 2-90

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Using second-epoch *HST* imaging of the unusual, bipolar jet source Hen 2-90, we have discovered proper motions of 0.03 arcsec yr^{-1} in the jet knots. Combining the proper motion with the knots' radial velocity measured from ground-based long-slit data, we find that the jet speed is roughly 150-360 km s$-$1, the source distance is 1-2.5 kpc, and the inclination (to the sky-plane) of the jet axis is $\theta = 3D10^\circ - 4^\circ$, although smaller values of θ and larger values of the jet speed and distance are not ruled out. A comparison of the [OIII] and [NII] images shows the central obscuring disk structure directly. The disk, seen nearly edge-on, is embedded within a low-excitation circumstellar region extending from the equator up to a latitudinal angle of about $\pm 62^\circ$, with the remaining latitudinal angular space being occupied by a biconical high-excitation region whose symmetry axis is aligned along the jet. The jet is at least 1400 yr old; the knots are being ejected at the rate of one pair roughly every 35-45 years (independent of the tilt angle and distance to Hen 2-90), and accretion is still occurring since the youngest jet material is only $\sim$10 yr old. The jet can be plausibly driven by an accretion disk around a low-mass companion in an eccentric orbit with a period of $\sim$40 yr, with increased accretion during periastron passage producing the jet knots.

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Multi-polar structures in Young Planetary and Protoplanetary Nebulae

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The imaging of young planetary and proto-planetary nebulae (PNe and PPNe) with unprecedented high angular resolution and dynamic range, using the Hubble Space Telescope, has led to the realisation that almost all of these objects are highly aspherical, with complex *multipolar* morphologies. The complexity, organization and symmetry of the morphological structures we find is forcing radical changes in, and inspiring fresh theoretical efforts to advance, our understanding of the mass-loss processes during late stellar evolution. In this paper, we review the HST data, and show some of the highlights of our imaging studies. Although the origins

of many of the morphological features remains puzzling, we find that the general presence of multipolar structures support a model for PN formation in which the primary agent for shaping PNe are high-speed collimated outflows or jets which operate during the late AGB and/or early post-AGB evolutionary phase, and undergo episodic changes in their orientation (or collimated outflows operate quasi-simultaneously with different orientations).

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Chemical Evolution of the Circumstellar Envelopes of Carbon-rich Post-AGB objects

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We have observed with the 30-m IRAM telescope, the CSO telescope and the ISO[4] satellite (*Infrared Space Observatory*) the rotational lines of CO at millimeter, submillimeter and far infrared wavelengths in the direction of C-rich stellar objects at different stages of evolution : CRL 2688 (a very young Proto-Planetary Nebula), CRL 618 (a Proto-Planetary Nebula), and NGC 7027 (a young Planetary Nebula). Several changes in the longwave emission of CO and other molecules are discussed here in relation with the degree of evolution of the objects. In the early stages, represented by CRL 2688, the longwave emission is dominated by CO lines. In the intermediate stage, CRL 618, very fast outflows are present which, together with the strong UV field from the central star, dissociate CO. The released atomic oxygen is seen via its atomic lines, and allows the formation of new O-bearing species, such as H_2O and OH. The abundance of HNC is enhanced with respect to HCN as a result of the chemical processes occurring in the photo-dissociation region (PDR). At this stage, CO lines and [O*I*] lines are the dominant coolants, while the cooling effect of [C*II*] is rising. At the Planetary Nebula stage, NGC 7027, large parts of the *old* CO AGB material have been reprocessed. The spectrum is then dominated by atomic and ionic lines. New species such as CH^+ appear. Water has probably been reprocessed in OH.

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