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Abstracts of recently accepted papers

High spatial resolution 'shift-and-add' imaging at UKIRT: multiplicity amongst YSO's

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We present results from near-IR 'shift-and-add' imaging on the UKIRT using the upgraded near-IR imaging camera, IRCAM3, and new control electronics, ALICE. Commissioning data on 12 sources in the Ophiuchus dark cloud complex are described. All but one source have previously been studied using 2D speckle imaging. We compare the results obtained by the two techniques and demonstrate that 'shift-and-add' imaging with IRCAM3 can produce results comparable to those obtained by 2D speckle technique. We additionally discuss both the current imaging quality of the UKIRT and its predicted performance after the planned thermal, dynamical and optical upgrades.

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Preprint at http://www.not.iac.es/~caa/caa_papers.html

The Environment of V633 Cas and V376 Cas: Evidence for Circumstellar Disks

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We present optical direct and polarimetric imaging, optical aperture polarimetry, and infrared direct imaging of the Herbig Ae/Be stars V633 Cas (= LkHα 198) and V376 Cas. Both stars are associated with extended reflection nebulosities.

V633 Cas appears as a single object associated with an extended optical nebula oriented NW-SE with a mean position angle of 128^o. This nebula, having the form of a large "loop", traces the redshifted lobe of a CO outflow. Various features are present within the circumstellar medium of V633 Cas. The position of the star does not change with wavelength within the uncertainties. We suspect its linear polarization to be time-variable. The polarization pattern close to V633 Cas suggests that another source, possibly the infrared source 6$''$ north of V633 Cas, V633 Cas B, is the most probable candidate to drive the large scale outflow.

For V376 Cas, high-resolution images with very good seeing in R and [SII] filters show for the first time two peaks in the isophote contours, about 1$''$ apart. Also, V376 Cas has the largest linear polarization observed so far in a young stellar object, $\approx$ 23% at a position angle of $\approx$ 26^o. This is well explained if an edge-on circumstellar disk is present. Polarization maps of V376 Cas showing a pattern of aligned vectors and two null points support this explanation.

Further support comes from the detection of two intensity peaks which can be explained by the presence of a reflection nebula whose center is hidden by an optically thick disk seen edge-on. A less preferable explanation would be the presence of enhanced line emission regions due to shocks in recollimating flows. We exclude the possibility that V376 Cas is a binary star with a 1″ separation.

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Infrared observations and laboratory simulations of interstellar CH_4 and SO_2

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Interstellar CH_4 may consume a fair amount of the carbon budget in dense molecular clouds, but probably less than CO, CH_3OH, and CO_2. However, it can only be observed at wavelength regions in the infrared that are heavily affected by the earth atmosphere. With new space and airborne missions (e.g. ISO, SOFIA) in mind we have studied the near infrared absorption spectra of solid and gaseous CH_4. We obtained laboratory spectra of the ν_4 deformation mode (1302 cm^{-1}, 7.68 μm) of solid CH_4 in astrophysically relevant mixtures. We found that the peak position and width of this absorption band vary strongly as a function of molecular environment, compared to temperature and particle shape effects. Hence, observations of this feature will provide a powerful probe of the molecular composition of interstellar ices. Also the gas phase CH_4 ro–vibrational spectrum of the same band has been calculated. Using observed physical conditions around the protostar W 33A, we show that unresolved gaseous CH_4 lines are detectable (at the 2–5% level) at a resolution R >1000, when the column density $N \geq 10^{16}$ cm^{-2}.

An astrophysically relevant molecule with a very strong transition in the same wavelength regime, is SO_2. We studied the ν_3 asymmetric stretching mode (1319 cm^{-1}, 7.58 μm) of solid SO_2 in several mixtures, revealing that the peak position, width and detailed profile of this band are very sensitive to the molecular environment. Besides probing the composition of ice mantles, observations of solid SO_2 will provide important information on the sulfur budget locked up in grain mantles, which is currently poorly known.

We compare the laboratory and calculated spectra of CH_4 and SO_2 with previously published ground based spectra and new airborne observations of young stellar objects in the 7–8 μm region. W 33A, NGC 7538 : IRS1 and IRS9 show a feature near 7.68 μm that is consistent with absorption by solid CH_4 or the Q-branch of gaseous CH_4. The column density of solid CH_4 would be 0.3–4% of solid H_2O, indicating that solid CH_4 consumes $0.5 \pm 0.3\%$ of the cosmic carbon abundance. A gaseous origin would imply a column density of at least this amount, being highly dependent on the assumed temperature of the absorbing gas. A second absorption feature is detected toward W 33A and NGC 7538 : IRS1 at 7.58 μm . The peak position and width of this feature are consistent with the ν_3 mode of solid SO_2 in a matrix of solid CH_3OH or pure SO_2. The derived column density is 0.1–1% of solid H_2O, indicating that solid SO_2 locks up 0.6–6% of the cosmic sulfur abundance.

This study shows that 7–8 μm spectroscopy of dense molecular clouds, using new airborne and space–based platforms, will provide valuable information on the composition of icy grain mantles and molecular cloud chemistry.

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The ^{12}C/^{13}C Isotopic Ratio in Photodissociated Gas in M42

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We have observed the 158 μm $^2P_{\frac{3}{2}} \leftarrow ^2P_{\frac{1}{2}}$ fine-structure line of ^{12}C II simultaneously with the $F = 2 \leftarrow 1$ and $F = 1 \leftarrow 0$ hyperfine components of this transition in ^{13}C II in the Orion photodissociation region near θ^1C. The line profiles were fully resolved using a heterodyne spectrometer with 0.5 km s^{-1} resolution. The relative intensities of these lines give

a $^{12}C/^{13}C$ isotopic ratio of $R = 58$ ($^{+6}_{-5}$) for the most probable ^{12}C II peak optical depth $\tau = 1.3$. The constrained range of $\tau(^{12}\text{C II})$ between 1.0 and 1.4 corresponds to a range of $^{12}C/^{13}C$ between 52 and 61. The most probable value of 58 agrees very well with that obtained from a relationship between the isotopic ratio and galactocentric distance derived from CO measurements, but is lower than the specific value of 67±3 obtained for Orion from CO data. An isotopic ratio as low as 43, as previously suggested based on optical absorption measurements of the local interstellar medium, is excluded by the C II data at about the 2σ level.

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Interstellar Polarization from CO and XCN Mantled Grains : A Severe Test for Grain Alignment Mechanisms

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We present spectropolarimetry in the wavelength range 4.5 - 4.8μm of the embedded infrared source W33A. Our observations show for the first time the presence of polarization associated with the CO and XCN ice features, demonstrating that the absorbers reside in or on aligned grains. Both narrow and broad components of the solid CO feature near 4.67μm are polarized. The detection of polarization associated with the narrow CO component is particularly significant, as the ices responsible are thought to exist only in dense, cold regions of molecular clouds, where gas and grain temperatures are expected to be closely coupled and traditional grain alignment mechanisms should become ineffective. We discuss the significance of this result with regard to current grain alignment theories. Mechanisms in which grain rotational energy is enhanced by interaction with cosmic rays merit further investigation.

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Scale Free Fragmentation Models for Binary Star Formation: Observational Implications

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We set out the statistical properties of binaries formed through a scale free fragmentation scenario, in which binaries result from the splitting into two of non-interacting Jeans unstable clumps with a range of masses. The predictions of such a scenario are contrasted with those of 'capture' models, in which dynamical interactions involving more than two stars are important in binary formation. It is found that the binary pairing statistics for a range of primary masses should provide clear diagnostics of the mode of binary formation involved. The particular predictions of scale free fragmentation models are that both the mass ratio distribution and the total binary fraction are only weakly dependent on primary mass. 'Capture' models, by contrast, predict a companion mass distribution that is invariant with primary mass, and a binary fraction increasing strongly with primary mass. It is also shown that scale free fragmentation models can give rise to apparent random pairing only if the IMF is a power law.

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Star formation in the S235 A-B complex

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We present near infrared broad band (J,H and K) and narrow band (H_2 S(1) 1 $\rightarrow$ 0 and Brγ) images, and high resolution molecular observations ($C^{34}S$(2-1), (3-2), (5-4) and ^{13}CO(2-1)) around the highly variable H_2O maser located between the S235 A and B optical nebulosities. These observations are part of an on-going search for the sources of excitation of H_2O masers in regions of star formation or, alternatively, for the earlieast evolutionary phases of massive stars.

We confirm the presence of a highly obscured stellar cluster between S235 A and B and, from the colour-colour analysis, we show that the cluster contains many sources with infrared excess, which are believed to be Young Stellar Objects (YSOs) in an early evolutionary stage.

Diffuse Brγ emission is found mainly in the vicinity of S235 A, and unresolved Brγ emission is found coincident with S235 B. Hot molecular hydrogen emission is distributed around the S235 A nebula, especially in a belt-like region to the south of S235 A, at the edge of the HII region.

The driving source of the H_2O maser does not appear to be either the YSO inside S235 A or S235 B, but is identified with a faint near infrared member of the cluster, with a large (H–K) colour excess, located near the position of the maser. A hot dust envelope around an early type star may be the source of the near IR emission. This identification is supported by the coincidence of the maser and the near IR source with the center of a high density and compact molecular core observed in $C^{34}S$ and ^{13}CO. The lack of radio continuum emission from the area around the maser suggests that the star powering the maser and responsible for the near IR emission must be in a very early evolutionary stage, highly obscured even at K band and surrounded by an envelope with such a high density that any radio continuum emission is stronglyself-absorbed. In any case the evolutionary status of such a star is much earlier than those of the exciting stars of S235 A and S235 B. Strong variability of the maser emission and large velocity differences of the maser features with respect to the molecular cloud velocity imply the presence of highly collimated, energetic and short duration jet activity in this YSO. The more evolved members of the cluster S235 A and S235 B lie on the sides of the molecular core, suggesting that star formation in the cluster is not coeval but proceeds from the outside towards the core of the molecular cloud.

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Hubble Space Telescope Observations of the HH47 Jet: Narrow Band Images

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We present high-resolution emission-line images of the remarkable Herbig-Haro jet HH 46/47 obtained with the Wide Field and Planetary Camera 2 (WFPC2) aboard the *Hubble Space Telescope*. Two narrowband filters were used, F673N which isolates the [S II]$\lambda\lambda 6716, 6731$ doublet, and F656N which transmits Hα. The exposures through each filter had a total integration time of 11,900s. The $0.1''$ spatial resolution of the WFPC2 images (corresponding to 45 AU at the distance of HH 46/47), coupled with the high signal-to-noise of these images, allows us to study this collimated outflow, driven by a young star, in unprecedented detail. In particular, we are able to resolve the sizes of emission knots and filaments, and determine the structure and scale of the cooling zone behind the shock waves in the flow. We discuss the observed structures in terms of radiative shock models. Both in the major working surfaces and along the body of the jet we identify many shocks in which the Balmer emission arises predominantly from collisional excitation in the thin heating zone at the shock front.

The body of the jet is seen primarily in [S II] emission. The jet has a complicated structure consisting of a sinuous chain of emission knots and strands. The [S II] emission in the jet appears to arise where shocks are excited in the jet material by its interaction with the surrounding gas and by collisions between faster and slower moving segments of the flow. A combination of time variability in the velocity and direction of ejection may explain the jets sinuous structure.

In Hα we see with absolute clarity the delicate wisps and filaments bordering the jet that were only barely visible in the best ground-based images. We identify these wisps as Balmer-line emitting shock fronts marking where shock waves are driven into the (apparently) neutral gas surrounding the jet. These Balmer-line filaments are only $0.2'' - 0.3''$ wide but can be up to $2''$ long. Each is associated with a [S II]-bright knot in the jet. These wisps have an arcuate morphology, with trailing wings which sweep back at an oblique angle to the direction of the flow. They thus resemble one-sided bow shocks that extend into and accelerate the ambient gas. All the knots in the jet may excite similar shock waves, however, these are only detected as an Hα filament where the shock front lies almost tangent to the line of sight.

The fact that we see strong Balmer emission from the shock fronts, and that high excitation lines such as [O III] are not detected in ground-based spectra, implies that the shocks driven into the ambient medium are weak ($V_{sh} \ll 100$ km s^{-1}. However, proper motion measurements show that these shock systems propagate along the jet at ~ 300 km s^{-1}. Hence material alongside the jet flows away from the source at an appreciable fraction of the jet's velocity. We believe that the dominant process that accelerates the gas surrounding the jet is *prompt entrainment*, where the major bow shocks HH 47D and HH 47A, aided by the lesser but more frequent Balmer-arc-shocks, push material ahead and away from the axis of the jet. The very extended wings of HH 47D and HH 47A suggest that their influence may be felt far from the jet's axis. Prompt entrainment by these bow shocks might drive the weak, approaching lobe of the molecular flow associated with the HH 47 complex. The long term meandering of the jet, evident from the misalignment between the bow shocks and the jet, may further widen the flow channel. As the jet changes direction, the newly ejected gas will entrain material from the cloud, and this could produce the observed filaments in the reflection nebula that extend roughly parallel to the northern boundary of the jet. Our high resolution images show no clear evidence for a turbulent mixing layer at the interface between the jet and its surroundings.

In the HH 47A working surface at the terminus of the jet we resolve the double shock structure expected from theory. Both the forward (or bow) shock and reverse shock (or Mach disk) have collisionally excited Hα components that delineate the positions of the respective shock fronts. Sandwiched between these two shock waves is a region, luminous in [S II], where the shock-heated gas cools. The turbulent structure seen in [S II] suggests that instabilities fragment the cooling, compressed material into clumps, as seen in some hydrodynamical simulations of jets. Our realization that the Hα luminosity of the Mach disk arises from collisional excitation at the shock front, and our discovery of a similar Hα-bright leading shock, leads us to reassess the relative strengths of the two shocks. We conclude that they are of comparable strength, and hence that the jet is of similar density to its surroundings. This is contrary to the earlier findings that the HH 47 jet was a rare example of a "light" stellar jet.

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A Near-Infrared Survey of the Taurus Molecular Cloud: Near-Infrared Luminosity Function

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We have carried out a near-infrared survey of the central 1° x 1° region of Heiles Cloud 2 (HC2), one of the densest regions of the Taurus molecular cloud. The limiting magnitude of this survey was 13.4 mag, and we have detected 831 sources at K. Based on the color-color diagram, 47 sources were classified as class II objects, and three as class I objects. The differential luminosity function of the class II objects in HC2 does not appear to have any cut-off, in agreement with the result by Comeron et al. for the ρ Ophiuchi cloud. The majority of the sources are low-luminosity class II objects. Either these are very low mass class II objects with about 1/10 solar mass or the dissipation timescale of the circumstellar disk is longer than that of typical visible class II objects.

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Imaging of the Compact Dust Disk around DG Tauri with One arcsec Resolution

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We have made aperture synthesis observations of 147 GHz continuum emission from the dust around a young star DG Tau with the Nobeyama Millimeter Array. Using the sparsest AB configuration of the array, we attained a small synthesized beam of $1''.48 \times 1''.08$ with P.A. = 117°. As a result, a disklike structure of the dust has been successfully resolved. The size of the dust disk is estimated to be $1''.56 \times 0''.54$ (218 AU × 76 AU) with P.A. = 99°, which is corrected for the synthesized beam pattern and atmospheric seeing. The disk size of the seeing was estimated to be $0''.42$ from observations of a pointlike calibrator. Assuming a geometrically thin disk, the radius and inclination angle of the dust disk are calculated to be 109 ± 22 AU and 70° ± 10°, respectively. The total flux density emitted from the dust disk is 186 ± 17 mJy, and the disk mass is calculated to be 0.01–0.06 $M_\odot$, using the dust opacity coefficient κ_ν = 0.05–0.02 cm^{2}g^{-1}. The resolved dust disk is quite consistent with the spectral energy distribution of DG Tau, although the disk radius of 109 AU is slightly larger than the radius of 75 AU derived by Adams, Emerson, & Fuller. Our results, however, do not agree with the infalling envelope model proposed by Calvet and coworkers, where the major part of the flux density in the millimeter to mid-infrared range comes from the large envelope.

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Dust emission from star-forming regions. IV. Dense cores in the Orion B molecular cloud

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In a search for isothermal pre-stellar cores and protostars we surveyed 14 fields in the Orion B Molecular Cloud (L 1630) for its λ 1.3 mm dust emission using the SEST. The CS(2–1) survey by Lada *et al.* (1991, LBS) was used as a search list. Our survey covers a total area of ≈800 armin^2 which contains 25 LBS CS cores. With an effective FWHP of 22–30$''$ and a 3σ detection limit of 2 m$_\odot$/beam (380 mJy), we found dust continuum sources in 11 of the CS cores. For nine of these dust cores, we obtained maps of higher SNR and angular resolution ($\sim 12''$) using the IRAM 30-m MRT. In addition, we observed the detected mm dust emission cores in the NIR to determine the presence or absence of young stellar objects. From the dust emission maps, we determine the morphology of the detected cloud cores. About one half of these cores have a compact core surrounded by an extended envelope. The λ 1.3 mm dust emission maps were compared with NIR (2.13 μm) and FIR (IRAS) maps to discriminate between isothermal and self-luminous cores. Four of the cores were classified as isothermal (containing no internal heating source). Four other cores are self-luminous protostars. Apart from NGC 2024 and NGC 2071, we find no other dense core which would contain enough mass to be involved in present-day high-mass star formation. A comparison of virial masses derived from CS line widths (LBS paper) with gas masses derived from λ 1.3 mm dust emission shows that virial masses are on average by a factor of 20 . . . 30 larger. Due to both different angular resolution and opacity effects in the line emision the LBS line survey and our λ 1.3 mm dust emission survey trace different components of the cloud cores. From our survey we draw the conlusion that apart of the four major star-forming regions NGC 2023, NGC 2024, NGC 2068, and NGC 2071, only single stars or small groups of low- to intermediate-mass stars currently form in the Orion B Molecular cloud.

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The Cold, Massive Molecular Cloud G216-2.5: III. Infrared Properties

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We present results concerning the star forming activities and dust properties of the unusual giant molecular cloud G216-2.5. As suggested by earlier CO observations, we confirm that this cloud is unusually cold for a GMC and shows no evidence for massive star formation. The average temperature of the dust based on the extended emission at 60 and 100 μm is 22-26 K. We attribute this low value to the lack of substantial internal heating sources. Dust heating in the cloud is probably dominated by the interstellar radiation field.

Near-infrared imaging of the IRAS point sources seen toward G216-2.5 reveal at least four sites of low-luminosity, and presumably low-mass, star formation within the cloud. All four sites lie preferentially toward the edge of the cloud. Two small groupings of stars are identified as the near-infrared counterparts to two of the IRAS point sources, and the group members may be similar to T Tauri stars. Somewhat more luminous and massive stars appear to be associated with two other IRAS point sources. Even the most luminous star formation site in G216-2.5 has a far-infrared luminosity of only 300 $L_\odot$.

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Radiation transfer in circumstellar disks

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We describe a new approach to the solution of the frequency-dependent stationary radiative transfer equation for axially-symmetric circumstellar dust disks. We apply our method to flared disks which are considered here as spheres with the polar cones removed. We have simplified the problem by computing the moments of the specific intensity only for the midplane and the surface of the flared disk. At the same time, we solve the radiative transfer equation exactly for an "equivalent" spherical envelope. The basic assumption is that density distribution in the disk depends only on the radial distance from the central star. This results in significantly faster calculations, reduces necessary computer memory, and allows incorporation of the algorithm into a hydrodynamical code.

Extensive calculations have been performed, to test the method and to compute the radiation field between the limits of small and large opening angle for the flared disk ($0.001^\circ \leq \psi \leq 180^\circ$), as well as between the limits of small and large optical depth ($0.01 \leq \tau_V \leq 2150$). We demonstrate that significant differences in spectral appearance can be attributed to the optical depths, geometry, and viewing angles. Quantitative comparisons with results obtained with another method applied to the same geometry show very good agreement, in terms of the spectral energy distributions (SEDs), intensity maps, and temperature profiles. Since our method is much faster than a general two-dimensional (2D) program, it enables calculations with high radial and angular resolutions.

We apply our 2D radiative transfer code to a detailed modeling of the deeply embedded young stellar object (YSO) L1551 IRS 5. The thick flared disk model fits perfectly the broad-band photometry in the whole spectral range from visual to millimeter wavelengths. Intensity maps are in a very good agreement with available linear scans and maps at 50 μm, 100 μm, 1.25 mm, and 1.3 mm. Model visibilities fit very well the interferometry measurements at submm/mm wavelengths (870 μm, 2.73 mm) and confirm the presence of a compact and very dense core (radius $\approx$ 50 AU, $n_{H_2} \approx 2 \cdot 10^9\, cm^{-3}$) at the center of IRS 5. Model polarization maps at 1 μm predicting both the polarization degree and overall pattern are in agreement with the observed ones. The thick flared disk model of IRS 5 with the opening angle $\psi = 90^\circ$ between the upper and lower conical surfaces can naturally account for the cross-shaped pattern

recently observed at 730 μm. While the model of L1551 IRS 5 agrees well with all the observations, it implies a massive envelope (8 $M_\odot$) and a low luminosity of the central object (16 $L_\odot$), in contrast to previous models.

Our modeling demonstrates the danger of deriving source parameters by fitting only spectral energy distributions. Depending on the *unknown* geometry, density structure, dust properties, optical depths, and viewing angle, derived luminosities and masses of the sources can be in error *by a factor of* $\sim$ *30* or even more. An intrinsic ambiguity of a solution of the inverse problem by fitting only a featureless continuum makes this standard method useless or at least implies *huge error bars* in derived parameters. The only way to estimate reliable parameters of embedded objects is to use *all of the spatial information* coded in observations *and to fit many different data sets*, in the frame of a self-consistent model. We emphasize that photometry made with different beam sizes is a readily available (but often ignored) source of spatial information which can help to test model predictions and constrain source parameters, and which is especially important for a large number of objects with no high-resolution observations.

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The Spatial Intensity Distribution of the UV light in HH objects Revisited.

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Simple kinematical bow shock models have successfully explained many of the observed features in Herbig-Haro objects. It is shown that similar models can be applied to the spatial intensity distribution of the UV lines observed by IUE. Archival IUE spectra have been used for the HH 1, HH 2(H+A′), HH 2(G+B), HH 24A, HH 32A, HH 43(A+B+C) and HH 47A objects, where the brightest UV lines (C IV λ1549, Si III] λ1891, C III] λ1909, C II] λ2326, Mg II λ2799) were studied, as well as the UV continuum (modeled by the Hydrogen two-photon continuum). The quality of the IUE data is rather limited due to the broad point spread function and the low signal-to-noise, and therefore the models were degraded to make them comparable to the observations. The physical parameters used in the models were obtained from previous optical studies and varied accordingly to match the observations, but within the known uncertainties. The objects were modeled by a single bow shock (i.e. HH 1, HH 24A, HH 32A & HH 47A) or the superposition of two (i.e. HH 2(H+A′) & HH 2(G+B) or more (i.e. HH 43(A+B+C)) bow shock models. The idea was to take into account the complexity of the morphology of these objects, and the contribution to the UV light from different condensations within the IUE aperture. The models provide a reasonable description of the available IUE observations of the HH objects spatial intensity distribution, and a method to understand future UV higher spatial resolution observations.

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High resolution CH_3CN observations towards hot cores

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The main goal of this paper is to study the spatial distribution and the temperature, density, and velocity gradients of the hot molecular gas in regions of massive star formation, on scales ranging from $\sim 10''$ to $\sim 1''$. To this purpose, we have used the IRAM Plateau de Bure Interferometer (PdBI) to make high angular resolution ($\sim 2''$) maps in several CH_3CN lines of the molecular clumps associated with the two ultracompact HII regions G10.47+0.03 and G31.41+0.31. Part of the results for G31.41 have already been published (Cesaroni et al. 1994): here we present the observations of G10.47 and discuss them in relationship to the results obtained for G31.41.

We have produced PdBI maps of both sources in the ground state CH_3CN(6–5), $CH_3{}^{13}CN$(6–5) and vibrationally excited (v_8=1) CH_3CN(6–5) transitions, and in the 2.7 mm continuum emission and ^{13}CO(1–0) line. We also obtained hybrid maps in the CH_3CN(6–5) lines, by merging the interferometer data with the IRAM 30-m telescope maps of Olmi et al. (1996). We derive estimates of the size and mass of the hot molecular cores known from earlier ammonia and methyl cyanide observations. The conclusions drawn by Cesaroni et al. (1994) for G31.41 are rediscussed here in view of new results obtained in the ^{13}CO(1–0) line and we show that the disk interpretation for the observed velocity gradient in CH_3CN is to be favoured against the outflow hypothesis; such an outflow is detected in the ^{13}CO(1–0) transition. As in the case of G31.41, we demonstrate that most of the continuum emission at 2.7 mm seen towards G10.47 is due to dust and derive a clump mass of $\sim$ 2000 $M_\odot$. We study the velocity field in G10.47 and detect two trends: an east–west velocity shift is observed in CH_3CN, while in ^{13}CO the velocity increases steadily from south to north. We discuss the possibility that towards G10.47, we observe a disk (in CH_3CN) *and* an outflow (in ^{13}CO).

We conclude that in both sources we are observing low mass halos surrounding massive cores; such cores seem to be flattened rotating structures, which lie at the centre of bipolar outflows.

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Simultaneous optical speckle masking and NIR adaptive optics imaging of the 126 mas Herbig Ae/Be binary star NX Puppis

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We present simultaneous optical and near-infrared high angular resolution observations of the close Herbig Ae/Be binary star NX Pup which is associated with cometary globule 1. The reconstructed images have a diffraction–limited resolution of 62 mas in V, 75 mas in R (speckle masking reconstruction), and 115 mas in H, 156 mas in K (adaptive optics + post–processing). Compared to previous results we were able to derive better estimates on spectral type and luminosity and hence put better constraints on the evolutionary status (mass & age) of NX Pup A and B: with NX Pup A of spectral type F0-F2 we estimate the spectral type of NX Pup B in the range F7-G4, masses of 2 $M_\odot$ and 1.6–1.9 $M_\odot$, respectively, and an age of 3–5 Myr for both stars.

We discuss the implication of the new age determination on the physical relation between NX Pup and the cometary globule. The dynamical lifetime of $\approx 10^6$ yr for cometary globule 1 suggests that cometary globule 1 and the nearby cometary globule 2 represent transient phenomena and are left overs of a larger molecular cloud which in turn was the parental cloud of NX Pup A and B and finally got dispersed by photoevaporation.

The IR excess of NX Pup A can be modeled by a viscous accretion disk, which is cut off at $\approx$ 20 AU from the star. NX Pup B has a smaller IR excess which indicates that there is less circumstellar material present than around the primary.

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http://www.astro.uni-wuerzburg.de/supplements.html

Measurement of T Tauri Binaries using the Hubble Space Telescope Fine Guidance Sensors

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We report measurements of young star multiples in the Taurus star forming region using the Fine Guidance Sensors

(FGS) of the *HST*. Of the 8 confirmed IR-discovered multiples, the FGS detected 6 in visible light: DF Tau, ZZ Tau, V928 Tau, Elias 12, HV Tau, and GN Tau. The V band magnitudes of the components range from 12.1 to 16.4 mag, and the observed separations range from 0.042″ to 0.34″. Component separations in DF Tau, ZZ Tau, HV Tau, and Elias 12 are sufficiently small that their binary orbital parameters could be determined in a few years. Our targets are quite red and the FGS observations confirm the predicted sensitivity of the FGS in transfer function mode to extreme color indices.

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ASCA Observations of HD104237 (A4e) and the Origin of X-ray Emission from Herbig Ae Stars

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ASCA observed the bright Herbig star HD104237 (A4e) for 30 ksec in April 1995, providing the best X-ray spectrum yet obtained of an intermediate mass pre-main-sequence star. The objective was to identify the physical mechanism responsible for the X-ray emission, with emphasis on discriminating between the softer emission that is characteristic of shocks and the harder emission ($\geq$1 keV) that is normally associated with magnetic activity. Spectral fits using optically thin plasma models show that most of the emission comes from a cool component at 0.2 - 0.4 keV ($\sim$2 - 4 MK) and a hotter component whose temperature is not tightly constrained but is above 1.6 keV ($\sim$18 MK). We consider several possible emission mechanisms including wind shocks, accretion shocks, a wind-fed magnetosphere, and a corona. Our main conclusion is that the X-ray emission most likely arises in a corona. However, coronal X-ray emission is unanticipated since Herbig stars are thought to lack the convection zones needed to sustain magnetic activity via a solar-like dynamo. We examine two possible solutions to this apparent paradox, namely (i) a corona around the Herbig star itself, sustained by a *nonsolar* shear-induced dynamo (Tout and Pringle 1995), and (ii) a corona around a faint late-type companion whose presence is suspected on the basis of recent infrared observations.

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The Smoothness of Line Profiles: a Useful Diagnostic of Clump Properties

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If a cloud is clumpy, and if individual clumps emit lines which are narrower than those emitted by their ensemble (the cloud), they must leave an imprint as velocity structure superimposed on ensemble profiles. Thus, a possible route to explore clumpiness is to observe emission lines with very high signal-to-noise ratios and very high velocity resolution, analyze the fluctuations in brightness temperature present on the line shape, and infer from them the properties of the clumps present in the beam. This technique was developed recently and applied to the case of Orion (Tauber, Goldsmith and Dickman 1991), using CO and ^{13}CO lines as tracers. However, in that paper the clumps were assumed to be "black disks", and the beam area filling factor was assumed to be small. We have now generalized the technique to include clumps with an arbitrary central opacity and radial distribution, using as a framework the clumpy cloud model of Martin, Sanders and Hills (1984). We show how with this model, the smoothness of the observed profiles can be used to constrain the parameter space of the unresolved clumps. We also analyze the effect of an interclump medium on the profiles emerging from the clumpy cloud. We apply this technique to the case of two star forming regions, M17SW and Orion A, and find surprisingly different results.

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Postscript version available at: http://astro.estec.esa.nl/SA-general/Research/ISM/smo.html

The H II/Molecular Cloud Complex W3 revisited: imaging the radio continuum sources using multi-configuration, multi-frequency observations with the VLA

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The H II/molecular cloud complex W3 has been imaged at 4.9 GHz, 14.9 GHz and 22.5 GHz in the radio continuum and the H66α radio recombination line with subarcsecond angular resolution using combined multiple VLA configurations. Several hypercompact continuum sources with diameters $\leq$ 1000 AU have been detected toward IRS 4 and IRS 5, reminiscent of the "Orion Radio Zoo". They have been imaged with a maximum angular resolution of 0.″1. From the flux densities at 1.3 cm, 2 cm and 6 cm we determine their spectral indices. The compact and ultracompact H II regions with diameters $< 20,000$ AU exhibit spectral indices α in the range -0.1 to < 1.5. The gradients in spectral indices across these regions correspond to asymmetries in their radio continuum intensities as well as gradients in the densities of the surrounding molecular gas. This indicates gradients in the electron density.

From a direct comparison of the continuum emission of the ionized hydrogen gas with the emission of the dense molecular gas and dust continuum, we refine the analyses of the interaction of the radio components with the molecular gas. From our H66α recombination line data we compare the radial velocities of the H II regions with those found for the molecular gas toward W3. We find linewidth and velocity gradients in the ionized gas which are indicative of expansion and turbulent flows caused by pressure gradients in the ambient neutral gas. We propose that the observed morphologies of compact and ultracompact H II regions are determined by turbulent expansion of the ionized gas into highly anisotropic and clumpy molecular gas. Thus, we believe there can be no definite prediction for the morphologies observed in H II regions with current kinematic models without considering these inhomogeneities. Furthermore, we propose that the spatial and kinematic relation of the compact, ultracompact and hypercompact radio continuum regions toward W3 is indicative of sequentially triggered star formation caused by the pressure of the expanding H II regions and the subsequent compression of the molecular gas.

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Evidence for protostellar infall in NGC 1333–IRAS2

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Observations are presented of HCO^+ (J=4→3) emission towards the Class 0 protostar NGC 1333–IRAS2, showing a self-absorbed, asymmetric, double-peaked spectral line profile, with the blue peak more intense than the red. Such a profile is expected in the infalling envelopes of protostars. A non-local, spherically symmetric, exact Λ-iteration radiative transfer code is used to generate a model HCO^+ spectrum for an infalling envelope, which is found to be in good agreement with the observations, supporting the protostellar infall interpretation. The total mass and luminosity of the protostar required by the model fit to the spectral line data are consistent with those previously derived, although the exact radial dependence of parameters such as density and velocity are not well constrained. This source therefore becomes one of only a small number of protostars in which infall has been directly observed.

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Diffraction-Limited 3.8 Micron Imaging of Protostellar Outflow Sources

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We used the new high spatial resolution observing mode of the Kitt Peak near-IR Cryogenic Optical Bench on the 4-m telescope to detect and determine the locations of the powering sources of three protostellar outflows. Diffraction limited images at 3.8 μm of the cores of AFGL 437, L1287, and NGC 7129 demonstrate that, in each case, a young stellar object — WK 34, IRAS 00338+6312, and NGC 7129 PS 1, respectively — lies at the position predicted for the outflow source on the basis of near-IR polarimetric imaging at 2.2 μm. WK 34 and the NGC 7129 PS 1 display nebulosity at 3.8 μm, confirming that each illuminates an outflow cavity. These data support the hypotheses that protostellar outflows are almost always associated with very young, heavily extincted sources, that associations of outflows with pre-main sequence stars are likely to be incorrect, and that infrared polarimetric imaging is a dependable tool for probing reflection nebulae to locate embedded young stellar objects.

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Pre-main sequence candidates in the very young open cluster NGC 6611

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For the search of Herbig Ae/Be objects in the extremely young open cluster NGC 6611 we have selected a sample of 52 pre-main sequence candidates, discovered by Walker (1961), Sagar & Joshi (1979), Chini & Wargau (1990) and Thé et al. (1990). We continue the approach of the last paper by studying each star individually with new and unpublished Walraven $WULBV$, Johnson/Cousins $UBV(RI)_C$ and Johnson $JHKLM$ photometric data as well as low resolution spectroscopy.

Each object is shown to have its own extinction law, which is investigated using their spectral energy distribution (SED). There does not seem to be a clear relationship between the location of a star and the extinction law. This means that the extinction is generated locally and its correction must be taken individually. For each object accurate astrophysical parameters are then derived. Plotting the objects in an HR-diagram, together with the values for the $E(B-V)$, the probability of membership value P and the extinction characteristics, helps to discriminate between cluster members and non-cluster members.

Most foreground stars are of late spectral type and are labeled as *Group III* objects. *Group I*, to which most members of this cluster belong, contains objects of early spectral type, Part of them seem to be in their post-ZAMS phase and the other part in their pre-ZAMS stage. By comparing the evolutionary tracks of Palla & Stahler (1993) for pre-MS objects and of Maeder & Meyenet (1988) for post-MS stars we have concluded that the cluster contains objects of a few 0.1 Myr as well as objects of about 6 Myr. As most of the *Group I* objects do not show well-known Herbig Ae/Be characteristics, the time scale of clearing the disk material must be typically less than about 0.1 Myr for the more massive objects. Objects that show an IR-excess are found among the less luminous ones. They could still be in their pre-ZAMS phase, having an age of about 1 Myr. Such an age is appropriate for the *Group II* objects, which are of intermediate spectral type. As they are located close to the stellar birthline they should have been formed recently. It seems that an efficient clearing mechanism must have taken place, because not many of these objects are embedded and show only some IR-anomalies. This could be the reason that we have found no more than four typical Herbig Ae/Be candidates.

We support the hypothesis of Hillenbrand et al. (1993) that there is an age spread in NGC 6611. The stars with the highest A_V values are located in the centre of the cluster, somewhat to the northwest. This coincides with the

location of many embedded sources more towards the northwest, a region in which star-formation is probably still taking place. The age of the most evolved objects is about 6 Myr.

It would be interesting to study these regions and the *Group II* objects since investigating the youngest objects which are still partly embedded may help us to understand the first phases of star formation and the rapid cleaning of the circumstellar material. Young "naked" stars can also be formed by evaporating gaseous globules (EGGs) as was recently discovered in dark regions of this cluster (Hester & Scowen 1995). The lack of angular momentum of such objects could explain the paucity of HAeBe candidates.

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A preprint of this paper will be available soon via the WWW at http://www.astro.uva.nl/preprints/preprints.html

IRAS Sources beyond the Solar Circle. VII. The ^{12}C/^{13}C Ratio in the Far Outer Galaxy

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We have investigated the ^{12}C/^{13}C abundance ratio in the far-outer Galaxy.
We have used the IRAM 30-m telescope to obtain the ^{12}CO and ^{13}CO(1–0) and (2–1) distributions towards five IRAS sources at about 16-17 kpc from the galactic center. C^{18}O(1–0) and (2–1) were observed towards the ^{13}CO peak positions in those clouds. The source with the strongest C^{18}O emission, WB89-437, was subsequently observed in ^{13}C^{18}O(1–0) and (2–1) and in $H_2CS(3_{1,2}–2_{1,1})$ and $(6_{1,5}–5_{1,4})$. To be able to compare our results with published data, we observed the same transitions towards the inner Galaxy source W33, and towards W3OH.
The ratio of the ^{13}CO and C^{18}O column densities is about 14, slightly larger than what was found in local GMCs. This ratio is dominated by excitation and beam filling effects, and is therefore not indicative of the abundance ratios.
The ratio C^{18}O(1–0)/^{13}C^{18}O(1–0) directly yields the ^{12}C/^{13}C abundance ratio however, for which towards WB89-437 we find a 3σ lower limit of 201±15, which means that the ^{12}C/^{13}C gradient found in the inner Galaxy continues further out. Our results for W33 and W3OH are consistent with earlier observations and give abundance ratios of 43.0±4.3 and 85±15, respectively.
These J=1–0 measurements are however in contrast to results obtained from the corresponding J=2–1 transitions: we obtain abundance ratios of 104±60 (WB89-437), 31±2 (W33), and 24±2 (W3OH). These differences may be due to the emission of the two transitions originating in different parts of the cloud with different excitation conditions.
The ^{12}CO emission towards WB89-437 shows strong outflow emission, and that of WB89-380 is dominated by self-absorption. The sizes of the ^{13}CO clumps are 1-2 pc and they have peak positions located within 10$''$ (0.5 pc) from the IRAS position. Their (virial) masses are typically several 1000 $M_\odot$.

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Application of high angular resolution techniques to the study of the circumstellar environment of highly polarised young stellar objects.

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Ph.D degree awarded: Dec. 1995

In generally accepted scenario of star formation, stars form in an inside-out collapse of the parent molecular cloud and grow up in this dusty environment. Undoubtedly the interaction of the central object with its immediate surroundings is of prime importance to determine the final physical properties of the star. Therefore the study of the star formation process would not be complete without the study of the circumstellar environment from a few stellar radii (inner accretion disk, boundary layer) up to hundreds (if not thousands) of AU (observations of mm-radiation and polarised light from disks, infalling dust envelope).

The study of the close circumstellar environment few tens of AU implies the use of HAR techniques. Therefore we used the MPE near-infrared speckle camera SHARP (System for High Angular Resolution Pictures) at the ESO NTT (New Technology Telescope of 3.5m equiped with active optics). This camera has been designed to give diffraction limited images at 2.2μm (K band), when used at this telescope.

Therewith we studied the circumstellar environment of YSOs in search of extended matter or disks. The sources were selected to be highly polarised at optical wavelength, which is interpreted in the frame of scattering (Mie theory) by the presence of asymmetrically distributed matter in the near environment of the source.

Over 28 YSOs observed, we found 9 binaries, 3 multiple systems and 4 extended sources from which one is a binary. Some of the results were known but not at our resolution (in average 0.2”). The purpose of the observations was to find an explanation for the high degree of polarisation. Individual results for each multiple source are analysed as well as the relative importance of the different physical polarization mechanism (synchrotron effect, scattering by small dust grains or the so called 'Davis-Greenstein' mechanism).

As for most sources the degree of polarisation at NIR wavelength is not known and in order to complete the study of these objects, we made two-dimensional speckle polarimetry measurements. The set-up used and the observational mode are largely presented. This experiment gives polarisation with an up to now never achieved resolution (diffraction limit in K). Some results, among others on the infrared nebula of Chamaeleon, are discussed.

To get high quality results, good data are not enough: the reconstruction of the image is extremly important. To avoid the known problem of phase wrapping, we developped a new method based on the integration of the phasors. This method is presented with its tests and results on real data.

Two new methods are resulting from this work: an observational one (two-dimensional speckle polarimetry) and an image reconstruction one (reconstruction of the phasors). The first one is still requiring some work and tests to be pushed to its limits.

From the observational point of view, the disparity of the sample do not allow to draw general conclusions. However some new exciting results on some of the sources point out and require further observations (detailed information also given in this work) to be completed.

IAU Symposium No. 182

Herbig-Haro Flows and the Birth of Low Mass Stars

20-24 January 1997, Chamonix, France

The symposium will take place at the congress center *Le Majestic* in Chamonix, France, starting on monday 20 January 1997 at 9:00 AM, and finishing on friday 24 January in the evening.

Objectives:

When Herbig-Haro objects were discovered 50 years ago, they were enigmatic emission nebulae found in star forming dark clouds and recognized as somehow related to the star formation process. In the intervening half century major observational and theoretical efforts have been made in this field, and it is now well established that Herbig-Haro objects are tracing highly collimated outflows from newborn stars. As such, they have emerged as fascinating astrophysical laboratories involving shock physics and chemistry, hydrodynamics and radiation processes. More importantly, however, when coupled with the explosive growth in our understanding of how stars form, it has been realized that Herbig-Haro jets are Rosetta stones for our attempts to unravel the phenomena that govern the earliest stellar evolutionary phases. Recently, in addition to Herbig-Haro flows, a wide range of observational phenomena such as molecular outflows, embedded shocks detected in molecular hydrogen, radio continuum and SiO jets, and winds from T Tauri stars, are gradually being related to infall indicators to reveal how accretion and mass loss occur simultaneously in the global process of star birth. The symposium will review the status of this field, and provide a forum for presenting the latest new results and discussion of the many still outstanding issues.

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Starting on **1 July** you can connect to the symposium homepage at `http://gag.observ-gr.fr/meetings/iau182` to get further information. To register, click on the Registration link and fill out the relevant windows.

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