Observations with Adaptive Optics: Getting There

A REPORT ON THE ESO/OSA CONFERENCE, SONTHOFEN, 7-11 SEPTEMBER 1998

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Adaptive Optics on Large Telescopes has opened up the new field of ground-based IR and optical astronomy on scale of less than 0.5″. The resolution routinely achieved is better than 0.15″ – as if the observer had jumped more than 3 times closer to the observed object – a dream! Advances are occurring in all fields, from the solar system to high *z* galaxies.

The first Conference centred on astrophysical results obtained with Adaptive Optics (AO) "Astronomy with Adaptive Optics: Present Results and Future Programs" was organised jointly by ESO and the Optical Society of America and took place 7–11 September 1998, in the Bavarian resort of Sonthofen.

Here, I highlight the points that appeared to me as the most pressing and important of those discussed in and also out of sessions at the Conference.

These points revolve around the central question on how to use AO most effectively and implement the powerful *tools needed to proceed efficiently from raw data to astrophysical papers.*

To make the reading of this report easier, I do not give references to any of the papers presented at the Conference except for the figures. Full versions of the papers can be found in the proceedings, which are now available on the Web and will appear in print in early 1999 (see Section 6 for Web address).

1. How to Make AO Observations Efficient

In astrophysics, the scientific value of the output of any instrument is the combination of the astrophysical questions driving the observing programmes and *the number and technical quality of the published papers.*

Leaving aside for a moment the question of the scientific driver, one can ask the question: What is the most efficient way to obtain astrophysical results with Adaptive Optics now that this technique has been shown to work?

The best way is to have goals that are in line with what the instrument can deliver – a trivial statement when applied to decades-old techniques such as direct imaging and spectrography. It implies, in fact, having a full understanding of the AO data acquisition, calibration and analysis process at the time of the proposal preparation since this process defines the achievable limits of performance.

The AO observations have to be understood as an ensemble formed by the simulations, the planning of the data reduction, the scientific tactical aspects of the optimisation at the telescope, the data acquisition itself, and finally the data processing, analysis and publication. *The proposal preparation must aim at an effective coupling of this entire procedure with sound astrophysical objectives.*

It follows that the observer must become familiar with the various parts of this ensemble and have at his disposal:

– *a powerful system of simulation* where one can choose as input (i) a variety of real or modelled science objects, (ii) different values of the parameters which characterise AO performance i.e. r_0, τ_0, and θ_0 (isoplanicity) relevant to the Observatory, and (iii) different magnitudes and radial distances of the reference star.

– *procedures to calculate the Point Spread Function (PSF)* and its noise from the values in (ii) and (iii) plus the required exposure time needed to achieve a given S/N on the science object.

– *a library of deconvolution algorithms* with illustrative examples of their application.

– *an observatory data bank* with raw and processed data with calibrations and PSF with which the observer can acquire a first-hand knowledge of the potential and limits of the AO instrument.

– *examples of successful* data acquisition and processing.

– *catalogues of artefacts* and spurious effects.

Moreover, at the telescope, the visiting observer should have some possibility to modify a pre-registered observing plan in order to (1) adapt to changing seeing conditions since the performance of AO is so dependent on them (in some conditions, the Strehl ratio depends on the seeing to the sixth power), and (2) immediately repeat or expand observations for which an on-line quick look reveals exciting/unexpected results – it is especially important to have this possibility in a new field such as high angular resolution because the results are often difficult to predict and artefacts can appear. This needs an on-line pipeline for the data reduction. This would result in a more agile observational procedure, enabling the observer to follow through and concentrate on a winning trail.

Finally, it must be recalled that there are different types of AO science to be extracted from the AO observations: photometry, astrometry, mapping of extended objects, mapping around bright sources, detection of faint companions to bright stars, polarisation, and spectra at low and high resolution. They differ rather significantly by the data characteristics which they require, such as angular resolution, Strehl ratio, accuracy in flat-fielding, extent of the corected field, and S/N and, therefore, call for different observing strategies.

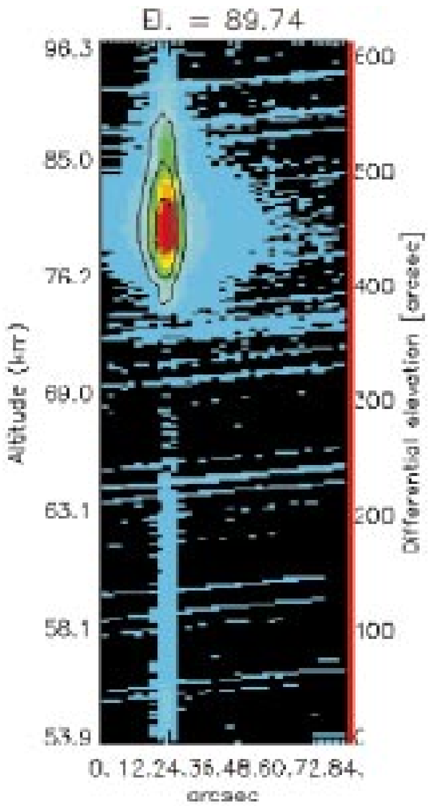

Figure 1: Image of the laser plume in the mesospheric sodium layer and the top of the Rayleigh scattering cone. In this experiment (August 1998) the laser beam emitted by the AO+LGS ALFA system on the 3.5-m telescope at Calar Alto is observed from the side with the 2.2-m telescope located at 343 m from the 3.5-m telescope. The lines across the figure are star trails. Abscisae: apparent width of the beam in arcsec. Ordinates: left altitude in km and right elevation from the bottom of the image in arcsec (F. Delplanque et al.).

2. Determination of the PSF and Deconvolution

Central to the AO data analysis is the determination of the PSF and the subsequent deconvolution. This question is being vigorously investigated and a number of new developments and results were presented at the Conference. The effort is directed towards the precise mapping of the PSF envelope in radius and azimuth. The method used initially, when there is no star in the field bright enough to provide an accurate PSF, was to observe a nearby bright star before and after the science object observations. This has proven to be unsatisfactory in most cases because of significant changes in the seeing conditions (and thus in the PSF profile) occurring between calibration and science exposures. New approaches are being actively explored alone and in combination:

– The "synchronous PSF" method (developed by J.-P. Véran) makes use of the wavefront sensor, WFS, data to determine the on-axis PSF. The PSF so determined becomes a poorer match with fainter reference stars, increasing distance from the reference star, and, of course, worsening seeing.

The synchronous PSF method can, in principle, be extended to off-centre positions but only if a SCIDAR is on site to measure the dependence on the profile of the turbulence with altitude.

– A method particularly suited to photometry in crowded fields e.g. globular clusters, consists in starting from a given (initially imprecisely known) PSF and using the relatively isolated stars in the field to improve the determination of the PSF. In the myopic deconvolution one can also make use of *a priori* knowledge of the source's shape (point-like, sharp edge, etc...).

– Myopic deconvolution (developed by J. Christou, S. Jefferies and co-workers) makes use of multiple short exposures. The only unchanged pattern common to all exposures is the science object. The method has been applied to resolve images of bright close binaries obtained at 0.85 microns using the 941 actuators AO system on the 3.5-m telescope of the Starfire Optical Range (SOR). The closest resolved separation is 0.067 arcsec for a difference in magnitude of 0.58.

This is a rich and complex topic for which only a schematic overview is given here. Other aspects of post-processing were examined such as various flavours of deconvolution procedures – non-linear deconvolution, Magain, Courbin & Sohy method, Richardson-Lucy method, use of a different PSF at increasing radial distance from the reference star and more.

Other issues were discussed which were related to data-acquisition strategy, flat-field, calibration, tethering, oversampling, non-common path aberration, and how to remove the wings of the star image, which is behind the coronograph.

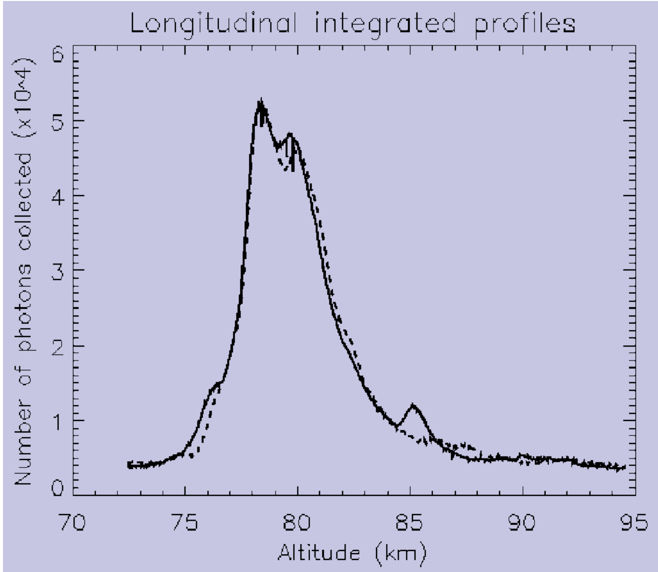

Figure 2: Two longitudinal profiles of the laser plume obtained at 20 minutes interval during the experiment of Fig.1. One can note the changes in the profile near the maximum as well as the appearance of transient layers around 76 and 87 km (F. Delplanque et al.).

Is there a best deconvolution procedure?

Could one procedure be better adapted to a given astrophysical programme than another? In an effort to answer these questions, ESO has proposed to make available a certain number of ADONIS data complete with their PSF(s) and WFS data to several interested groups. Each group will apply its algorithms and procedure to the same data. The results will be compared. Significant differences will have to be understood, and their importance evaluated for different scientific objectives and different hardware implementation of AO. In a first phase, the exercise is applied to photometry in crowded fields. Then, it will be extended to other types of data and astrophysical projects: Fabry-Perot (FP) data, detection of companions, extended emission, spectrography, polarisation, etc... opening a long-range process of continuous improvement of AO data analysis.

Artefacts

Attention was drawn to the danger of artefacts and spurious effects. A startling illustration of this problem was presented in the form of images of the inner region of galaxies harbouring an AGN taken with the Adaptive Optics Bonette (PUEO) of the CFHT. The artefacts for these particular observations take the form of cross pattern structures. These are misleading as they look like the *torus+spiral arms* structure expected, in some models, to be present in the immediate vicinity of AGN. The origin of these cross pattern structures is still unclear but the moral of the story is that extreme care and caution must be exercised in order to avoid this and other pitfalls. More efforts are needed to set up the procedure that will remove these effects.

The Superspeckles and the subtraction of images with identical PSF

There is exciting science, which requires the search, and discovery of very faint companions to bright stars i.e. brown dwarfs and planets. The sensitivity of the search depends on the S/N in the envelope of the AO corrected star image. (The figure of merit here is the magnitude difference, Δm, between the star and the companion.) The speckles produce a correlated noise whose variance dominates the photon noise. To circumvent this difficulty, Racine, Walker and co-workers have devised the method of "Dual Imaging": A beam-splitter produces two images of the field on the detector and a narrow-band filter centred on a spectral band which has a different strength in the companion and the star, is inserted in one of the beams. The two images have identical PSF and differ only by the contrast between the companion and the bright star. By subtracting one image from the other, one obtains an image where the residual correlated speckle noise is reduced by several orders of magnitude correspondingly increasing the S/N of the companion. The performance expected from "Dual Imaging" is to increase Δm by 3 magnitudes and Δm could even reach 22 at 0.5 arcsec! The method of "Dual Imaging" can be used in other projects requiring the subtraction of two images: line/continuum observations, polarisation and speckle imaging.

Astrometry

In star-forming regions, dust absorption strongly modifies the distribution of the visible light as compared to that of the IR light resulting in differences between the maps in the two bands. Exactly aligning the two maps is often problematic (for example, in the absence of foreground stars) and in these cases, the colour and temperature of the sources cannot be measured with confidence. A simple solution is to have the possibility to observe simultaneously in both bands through two cameras, with a dichroic separating the visible and IR beams. For example, on NAOS a visible camera could be installed in the "parallel path".

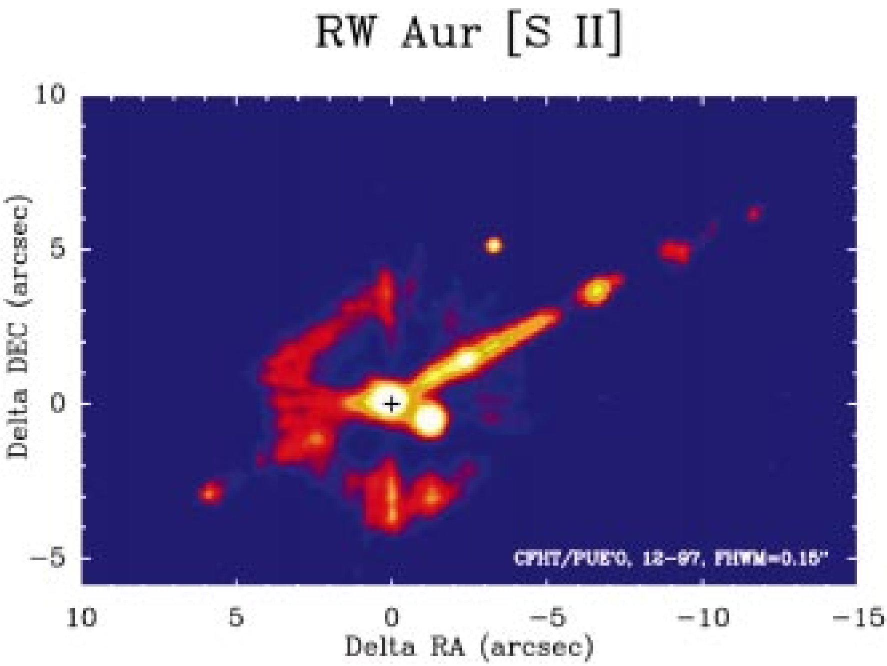

Figure 3: The jet of the pre-main sequence binary RW Aur imaged with PUEO at the CFHT, in the optical emission lines [SII]6717,6734. The jet is associated with component A, marked by a cross. Resolution (FWHM) is 0.15″ and dynamic range 10^5, 3σ (F. Ménard et al.)

3. AO Systems Coming into Operation in the Near Future on Very Large Telescopes

3.1 Systems commissioned next year, 1999, on 6- to 10-m telescopes

– The University of Hawaii AO system Hokupa'a (Curvature sensor and 36 actuators) will be set on the Gemini North 8.2-m telescope.

– Japanese 8.2-m Subaru telescope. (Curvature sensor and 36 actuators).

– Keck 10-m telescope II (Shack-Hartmann sensor with eventually 349 actuators) + laser guide star system, LGS.

– on Mt Hopkins, the "MMT" now retrofitted with a 6.5-m single mirror (Adaptive secondary with 330 actuators).

– It is recalled that the SOR 941 actuators system has started operation on the 3.5-m telescope although not primarily for astronomical observations.

Furthermore, two spectrographs where the entrance slit is in the AO-corrected focal plane have just started operation: the GraF Spectrograph on ADONIS at the ESO 3.6-m telescope and the OASIS integral field spectrograph for PUEO on the CFHT 3.6-m.

3.2 Systems commissioned in 2000+ on 6- to 10-m telescopes

In the year 2000 and shortly after, other very large telescopes will be equipped with AO systems, with LGS system in most cases:

- on the VLT, NAOS+CONICA on UT1, SINFONI on UT1, CRIRES on UT4, MACAO for VLTI.

- on other very large telescopes: Keck I, the 2 LBT-8.4-m telescopes, the 8.2-m telescopes Gemini I and II, and the Magellan 6.5-m.

3.3 Ground-based Adaptive Optics and Space Telescopes

Around the year 2007, when NGST (diameter about 8 m, wavelength range 0.8 to 10 µ) is launched, about ten 6.5-m to 10-m telescopes equipped with AO imaging and/or spectroscopy will have carried out observations for 6–8 years, each with a larger collecting area and higher angular resolution than HST. There is currently an active debate to define HST's uniqueness space in the era of AO systems on 8-m telescopes. The result will be an important input in the definition of HST new instruments and programmes, wide-field deep survey in J for example, and of course UV and optical imaging and spectroscopy. (For more information on this debate one can contact Jim Beletic at jbeletic@eso.org and Bob Fosbury at rfosbury@eso.org.)

Each of the two techniques, space-based observations and ground-based AO observations, has its area of best performance. Complementarity is very fruitful (example in 5.1) – and some overlap is beneficial as a check.

The arguments of the debate in general, and also for the particular case of Ground-based AO versus NICMOS/HST are well known: With equal diameter telescopes and equal integration time, broad-band space observations go deeper than ground-based AO systems in the infrared bands where the sky background dominates. Other advantages of space are stable and uniform PSF, complete sky coverage, continuous wavelength coverage between 1 and 10 microns and beyond and possibility to have the entire telescope cooled. The advantages of ground-based telescopes AO systems are the diversity of instruments (such as narrow-band filters, FP, spectrographs with a variety of resolutions), the easy upgrade of CCD, IR arrays and WFS, and the possibility to carry out large programmes and extensive surveys since a number of large-diameter ground-based telescopes are being equipped with AO systems. Sky coverage is limited to less than 50 per cent, the exact value depending on the Strehl ratio one could accept and on the galactic latitude. In a few years, LGS will bring routinely nearly complete sky coverage and good PSFs.

Ground-based telescopes in the 2-m diameter range could also be equipped with AO systems getting close to the diffraction limit in the visible. The large number of medium-size telescopes will make it possible to carry out large scale programmes and surveys.

4. Other Important Issues

4.1 Technologies – Laser Guide Star Systems

A number of technological advances and experimental results were presented on deformable mirrors, adaptive secondaries and laser guide-star systems (LGS). The first astrophysical results ever obtained in Europe with an AO+LGS system were presented (Section 5.2). Monitoring of the column density and effective altitude of the sodium mesospheric layer is planned or under way at all observatories building a LGS system and first results were presented. A large part of the LGS studies in Europe are coordinated through a network funded by the European Union within its "Training and Mobility for Researchers" (TMR) Programme. An example of such study is the observation of the laser beam of the ALFA system at Calar Alto. In this experiment, the beam is launched from the 3.5-m telescope towards the zenith and is observed from the side with the 2.2-m telescope located 343 m from the 3.5-m. The beam excites the mesospheric sodium layer of about 10 km thickness located at an average altitude of 80 km. From the side the excited region is seen as a bright "plume". The properties of this plume and their time variability are the object of the study. Some of the results obtained in August 1998 can be seen in Figures 1 and 2 (F. Delplanque et al.). The 5-min. exposure on Figure 1 shows the plume, and below and above it the trail caused by Rayleigh scattering, the intensity of the trail reaching 1% of the maximum intensity of the plume at 7 arcmin below the plume centroid. The two curves on Figure 2 are the longitudinal (i.e. along the laser beam direction) profiles of the plume measured 20 minutes apart. In this time interval, there are already noticeable variations of the longitudinal profile and, moreover, one can note the appearance of transient layers below and above the maximum intensity of the plume, here at 76 and 85 km. These changes in shape

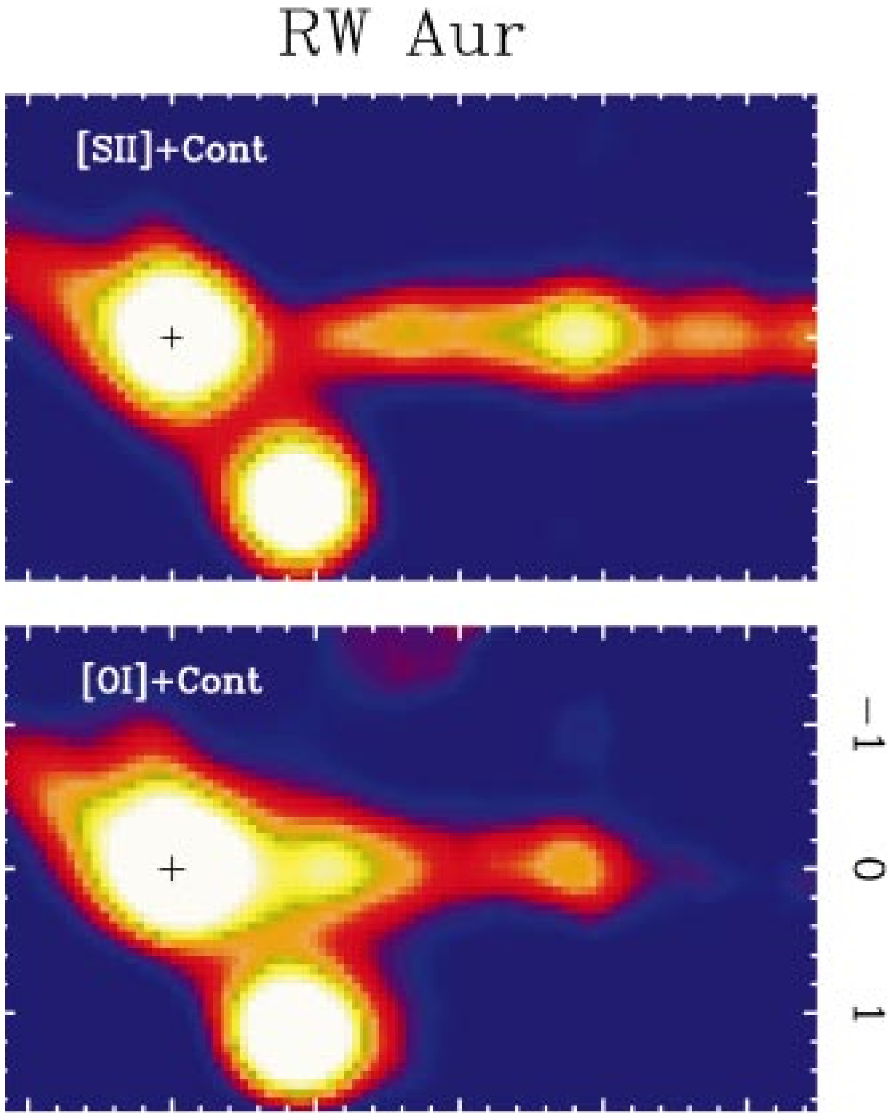

Figure 4: Comparison of the structure of the RW Aur A jet in the [SII] line and the [OI]6300 line. The line intensity ratio varies along the jet; the [OI] emission decreases very rapidly along the jet and the first [OI] knot has no counterpart in [SII] (C. Dougados et al. quoted in Ménard et al.).

and in effective altitude have consequences on the wave-front sensor operation. The shape modification increases the noise on the centroid measurements in a different way on each sub-aperture and requires an adapted modal control. The altitude variations require that a continuous measurement of the sodium spot effective altitude be made in order to correct for the induced defocus. Happily, these effects change relatively slowly allowing for efficient correction. The hindering effects of the light pollution for the other telescopes on the site, and possible solutions are also investigated.

4.2 Flexible Scheduling

The performance of an AO system, the Strehl ratio in particular, improves

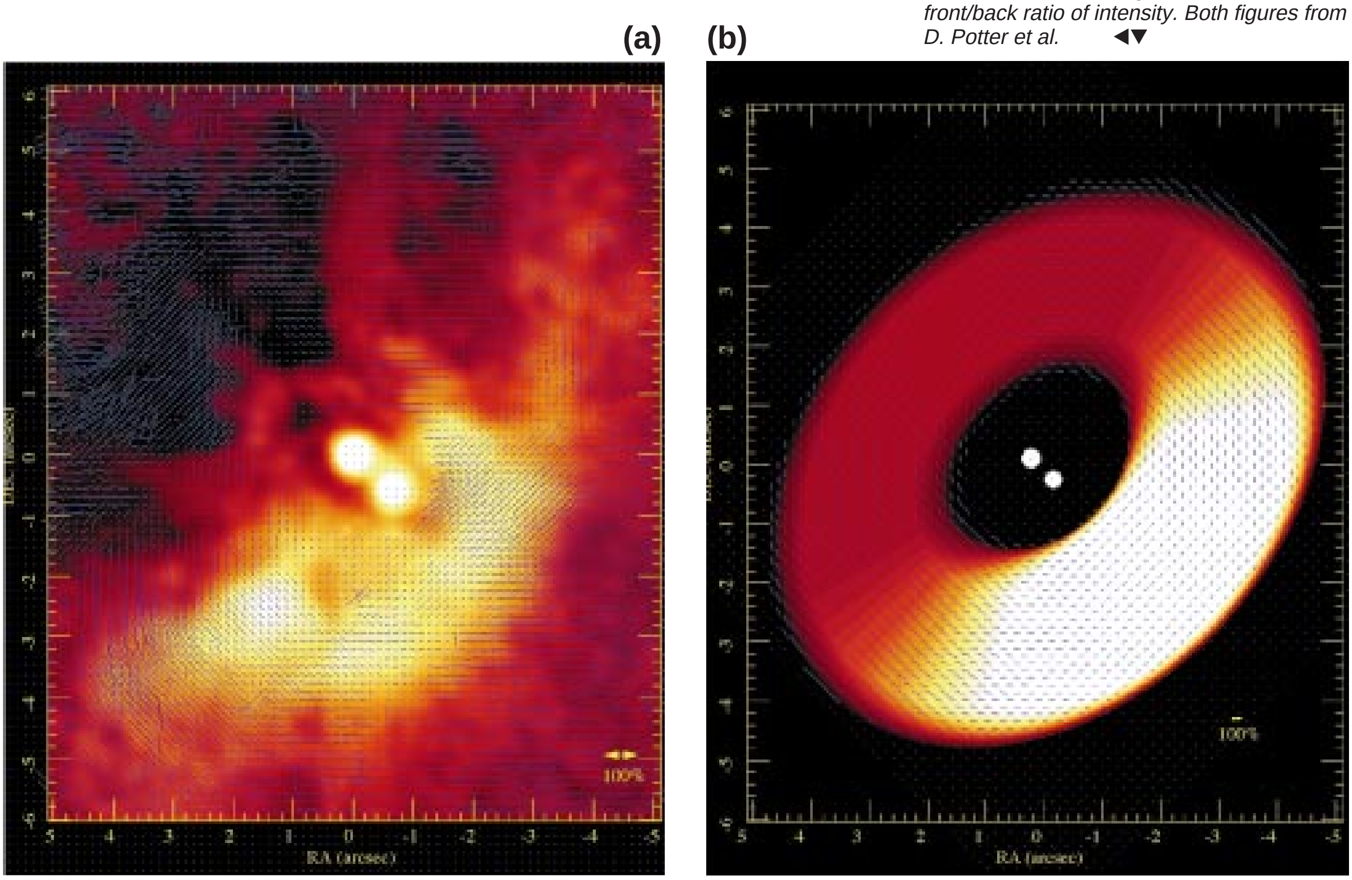

Figure 5: (a) The polarisation vectors of the envelope surrounding the double T Tauri system UY Aur superposed on an image in J (Hokupa'a on the CFHT 3.6-m, November 1997). Note the maximum in polarisation at PA 130 and –40 degrees, the centrosymmetric pattern in polarisation angle and the high front/back contrast of the background image in J.
(b) For comparison, a Mie scattering model of a flattened dust disk with a power law (–4.7) size distribution of dust grain which best fits the front/back ratio of intensity. Both figures from D. Potter et al.

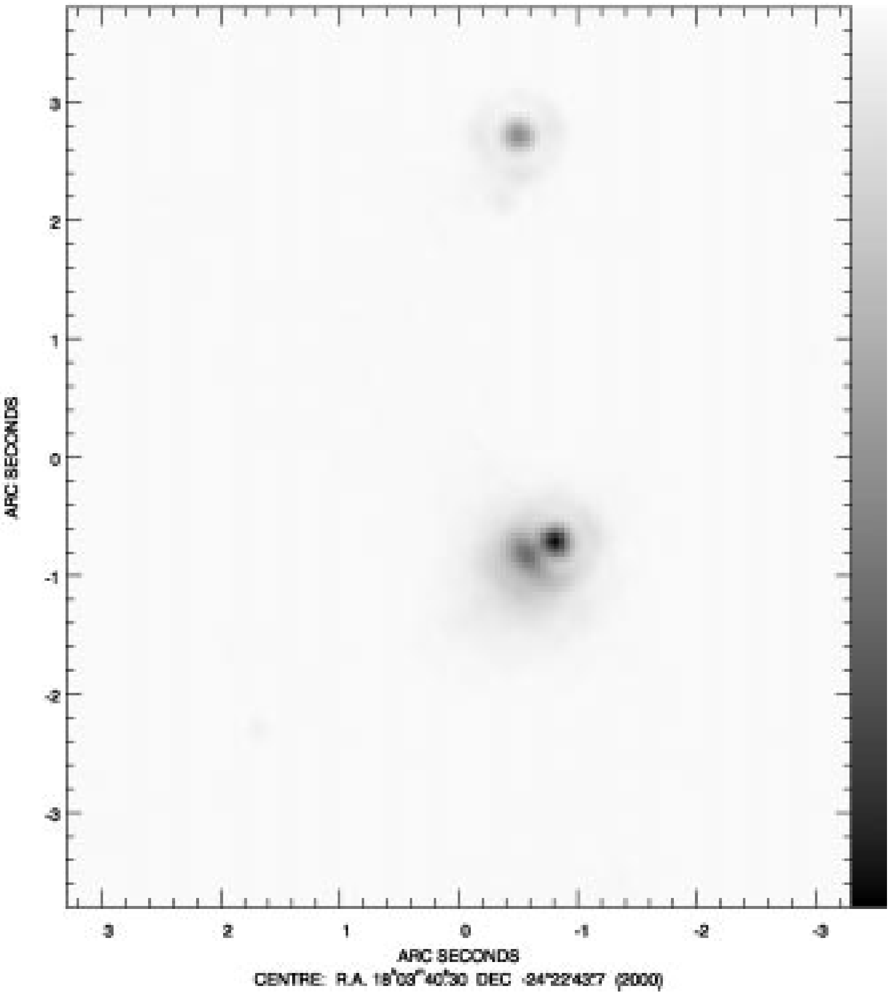

Figure 6: The young massive star Her 36 and the mysterious intense infrared source form the double object in the lower half of the image. The IR source is at 0.3", or 500 AU in projection, from Her 36; its nature is still unknown. Observations with ADONIS in L (B. Stecklum et al.).

strongly with improving seeing. *For best return of money and time* spent on building the AO system and the telescope, the AO system should be used in excellent atmospheric conditions. Flexible Scheduling and Queue Scheduling aim at assigning the best conditions to the instruments and programmes that need them the most. This is a complicated process, and requires to have on hand the statistical properties of the atmosphere (r_0, τ_0, θ_0) at the site on time scales ranging from hours to months. The advantage of splitting nights with other instruments will have to be clearly demonstrated, taking into account calibration time and overhead time to pass from the AO instrument to another and vice-versa. A recommended approach for early use of the next generation of AO instruments is to use it through entire (selected) nights, and execute the best AO programmes suited to the current conditions.

5. Astrophysical Results of AO Observations

10 papers on Circumstellar disks and jets, 8 on binaries and stars with faint companions, 7 on galaxies and quasars, and 2 on the Solar System were presented at the Conference.

5.1 Circumstellar disks, Jets, and Stars

Star formation and Planet formation

AO observing in the near IR is particularly well suited to this phenomenon which occurs in dust rich regions. The final mass of a star results from the combined effects of accretion through the disk and mass loss through jets and outflows. Detailed maps, polarisation and spectroscopy provide clues to the fundamental processes of star formation and early evolution, and disk and jet formation and evolution. The best laboratories in which to observe these phenomena are the Classical T Tauri stars because, in these systems, part of the dust has been cleared out making the base of the jets (and the disk) directly observable. Classical T Tauri are thus favourite targets to investigate jet formation. As an example, Figures 3 and 4 show the jet associated with component A of the binary Classical T Tauri star RW Aur, mapped in the optical range with PUEO at the CFHT (F. Ménard et al.). The fact that the jet is very straight is an important finding about the location of the jet formation. Tidal torques being expected to disrupt or warp the disk, the jet's straightness suggests that the jet originates from the very central part of the disk which remains unperturbed by the companion star.

Only a handful of circumstellar disks around T Tauri stars have been resolved in their scattered light. There is very limited information on the composition and size distribution of the dust grains in these disks and on density inhomogeneities. This information, however, is crucial to the understanding of how planets form. The combination of infrared imaging and polarisation is a powerful tool to gather this information as is illustrated in the images of the circumbinary disk around UY Aurigae (Figure 5a, b from D. Potter et al.) obtained with Hokupa'a on the 3.6-m CFHT in November 1997. Figure 5a shows the high-contrast, high-resolution polarimetry map with the polarisation vectors overlaid on the deconvolved grey-scale image in J. The polarisation vectors show a centrosymmetric pattern in angle and intensity with peaks in polarisation intensity at position angle of 130 and –40 degrees. This pattern is entirely consistent (Figure 5b) with the extended IR surface brightness observed around UY Aur being a flattened dust disk with a large number of small grains. The front/back ratio of intensity constrains the power law size distribution of the grains. The alternative model of a spherical envelope of dust appears unlikely.

Results obtained on the young massive star Her 36 also illustrate the power of AO observations and give an example of the complementarily of AO, HST and radio observations (Figures 6 and 7 from B. Stecklum et al.). Her 36, spectral type O7V, is responsible for the ionisation of the "Hourglass" Nebula. Early photometric and polarimetric investigations yielded clear evidence that it showed unexpected peculiarities in polarisation and a strong infrared excess. High angular resolution in the IR, first by lunar occultation, then with ADONIS, revealed the intense IR source to be not Her 36 itself but a separate object located 0.3″, or 500 AU from Her 36 in projection (Figure 6). This clarifies the nature of Her 36 as a normal young massive star, but the nature of the intense IR source remains a mystery. HST detected the source in Hα and the VLA detected it as a weak point source at 2 cm (Figure 7). The search and non-detection in maser emission makes it unlikely that the IR source is a deeply embedded massive young stellar system. Could it be disk debris left from the formation of Her 36, or a proplyd object, or an evaporating gaseous globule?

Main Sequence Stars

Circumstellar disks are also observed around MS stars. The best known ex-

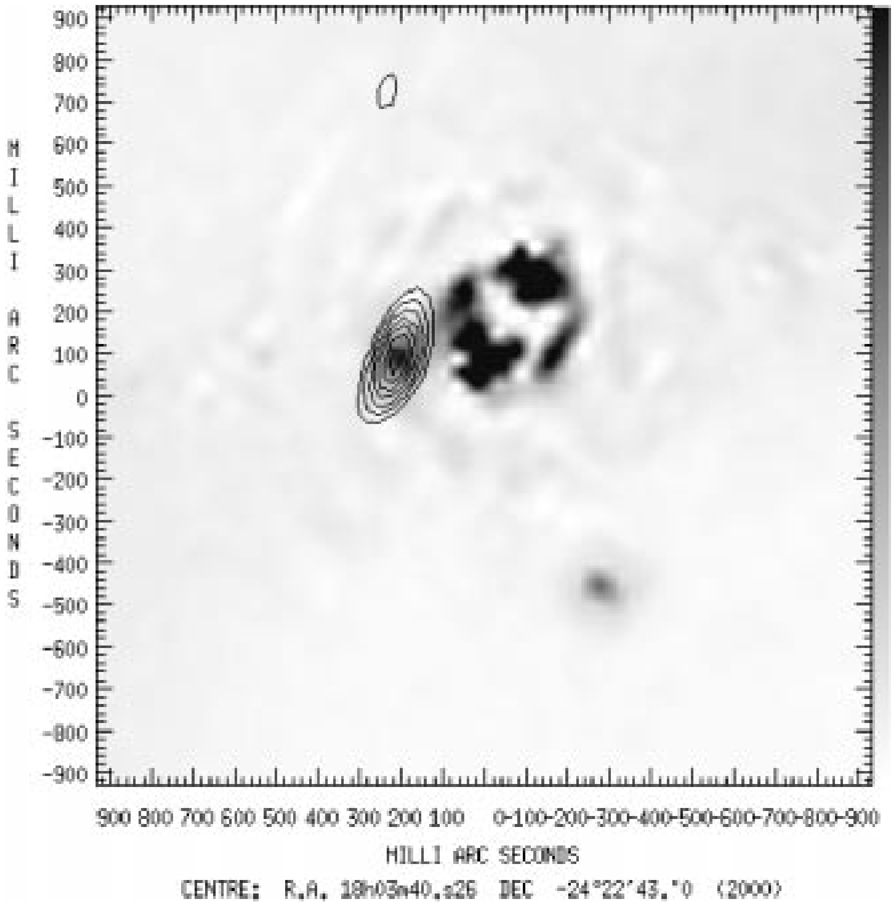

Figure 7: HST/WFPC2 Hα image of Her 36 after PSF subtraction. The intense IR source is detected as a weak point-like source at 2 cm with the VLA (contour lines) but is not detected in maser emission making it unlikely that it is a deeply embedded young stellar object (B. Stecklum et al.).

ample is β Pictoris. By coronography with ADONIS, the disk has been mapped to within 20 AU from the star, that is inside the planet orbits in our Solar System!

Several papers were also given on the frequency of occurrence of binary stars and its dependence on environment and age, and on the search for brown dwarfs and planetary companions. The image analysis strategy can take advantage of the *a priori* information that the sources in the field are point-like. This is valid also for that uniquely important target, the Galactic Centre.

5.2 Extragalactic Studies

Results have been reported on gravitational lenses, intervening galaxies, and quasar companions. Attempts have been made at finding signs of accretion in the vicinity of AGN or at identifying structures which could be the molecular torus expected to be present around AGNs. Maps of luminous IR galaxies with unprecedented resolutions were presented. The compactness of the IR central source helps to distinguish between the presence of a dust embedded quasar or of a compact bright star-forming region.

At the Conference were presented the first images of galaxies ever obtained in Europe with an AO+LGS system (R. Davies et al.). They are part of a programme to observe the light distribution in the core of galaxies in clusters. In the clusters studied, there appears to be a correlation between the size of the core at the galaxies' centre *with* the radial distance of the galaxies from the cluster's centre and their HI content – the core being more compact in more centrally located galaxies. Davies et al. suggest that the crossing of the central part of the cluster by a galaxy depletes the galaxy of its HI (a long-known effect) and stimulates star formation in the gas left in the galaxy core, gas which is likely to be subjected to strong tidal effects.

5.3 Solar System

In the age of space probes, there remain important Solar System observations, which are most successfully carried out with AO on large telescopes. AO can detect and monitor faint, variable or transient objects/structures on the planetary surfaces, rings, and satellites. Furthermore, AO yields the most detailed maps of solar-system objects not targeted by the space probes. One of the impressive planetary observations presented in Sonthofen is shown in Figure 8 (F. Roddier et al.). The three images of Neptune were taken 45 min apart on July 6, 1998. They were taken through a narrow-band filter centred inside a methane absorption band at 1.72 μ, with Hokupa'a on the CFHT. The angular diameter of Neptune was 2.36″. High-altitude clouds are seen here against a dark methane band atmospheric absorption and appear bright. During the Voyager encounter, most of Neptune's cloud activity was in the South

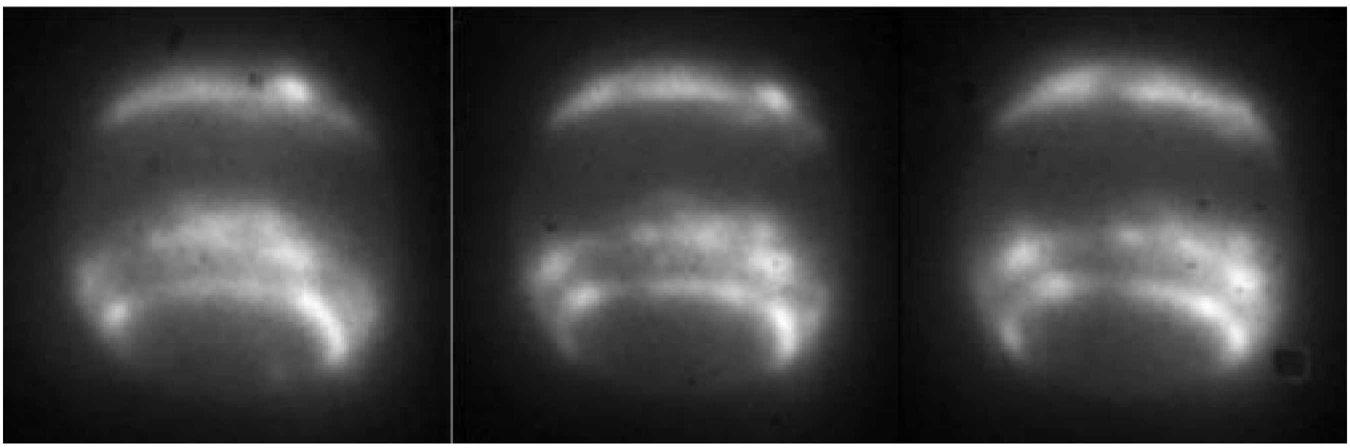

Figure 8: Cloud activity on Neptune. Images taken 45 min apart with Hokupa'a on the CFHT on July 6, 1998. High-altitude clouds appear bright against a dark methane band atmospheric absorption. Note the rapid planet rotation. The angular diameter of Neptune was 2.36″ (F. Roddier et al.).

hemisphere. It then moved to the north where it peaked around 1994. In July 1998, as can be seen on the Figure, the cloud activity had grown again in the south. The causes of these changes are unknown.

6. Conclusions

This first Conference centred on Astrophysics with AO was a success, and the common wish at the end was to have such a Conference on "Astronomy with Adaptive Optics" every 1.5 years.

The Adaptive Optics systems expected to be routinely operating in the near future are growing in number. The observers are getting more and more familiar and proficient with their "new tool" and define new strategies to observe efficiently. We can expect a large growth of striking results in the coming years as well as a continuation of the technology maturation process. This continues to motivate ESO's effort to equip the VLT with several AO systems in the near future. Moreover, these efforts pave the way to the road to the Giant Optical Telescopes of the next century.

The paper version of the Proceedings can be obtained by writing to Christina Stoffer at ESO, cstoffer@eso.org. On-line version of the papers is available at http://www.eso.org/gen-fac/meetings/eso-osa98

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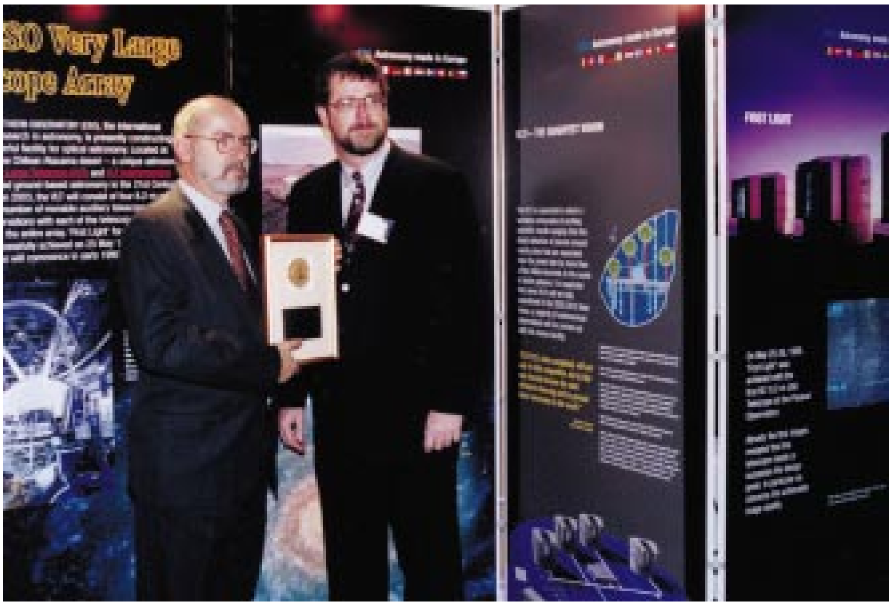
Award for the ESO VLT Project

Naturally, 'First Light' for the first of the VLT Unit Telescopes has not gone unnoticed by the astronomical community. However, also newspapers, magazines, radio and TV have reported widely about this new facility and about the first, fascinating pictures that were obtained with UT1. Another sign of the world-wide attention that the VLT has caught was the fact that the well-known US magazine Popular Science chose the project for one of the coveted "The Best of What's New Awards" for 1998, given to the 100 most important technology developments in the course of the year. The construction of the VLT was recognised as an "outstanding achievement" within the "Aviation and Space" category.

The Award was formally handed over to ESO, represented by Prof. Massimo Tarenghi, during a luncheon at the Tavern on the Green in New York on November 13. On the same occasion, about 500 invited guests from industry, the media and government agencies had the opportunity to inform themselves about the individual prize winners through project and product presentations by means of small exhibitions. Here, ESO found itself in the company of a great variety of organisations and enterprises working in different high-tech areas, ranging from NASA (International Space Station and the Mars rover "Sojourner"), Airbus Industrie (A-340-500) and various experimental aircraft manufacturers, through IBM (copper-based computer chips), Apple Computer (iMac), and Iridium Satellite telephones to the latest products in medicine and medical research.



M. Tarenghi, posing for the official photo at the ESO Stand.

Popular Science editor Cecilia Wessner speaking at the award ceremony.

Given the audience and the extremely high technological level of the projects and innovations presented, this was undoubtedly a good occasion for ESO to inform US media and the technologically interested public about the VLT as major European science project.

C. MADSEN