ISO's Astronomical Harvest Continues*

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Last autumn, nearly 400 astronomers gathered in Paris for a week-long discussion and review of ISO results, as presented in some 300 papers. This article presents a handful of ISO's many results, selected - mainly from the Proceedings (ESA SP-427) of the Paris meeting - both to show the breadth of the scientific fields being impacted by ISO and to complement results that have previously appeared in the 'In Brief' pages of the Bulletin. ISO has delivered a wealth of new results, spanning long-awaited confirmations of models to unexpected surprises and from our own Solar System out to the most distant extragalactic sources.

Introduction
During its 29-month operational lifetime in orbit, ESA's Infrared Space Observatory (ISO) provided astronomers with a facility of unprecedented sensitivity, wavelength coverage and spectral resolution for exploring the sky at infrared wavelengths. It carried four scientific instruments: two spectrometers each with a medium and a high spectral resolution mode, a camera, and an imaging photo-polarimeter. ISO made nearly 30 000 individual scientific observations of all types of astronomical objects and the data have been re-processed homogeneously and are now available to the entire astronomical community via the World Wide Web.

Solar System
Deuterium-to-hydrogen (D/H) ratio
The abundance of deuterium - the heavy isotope of hydrogen - in the giant planets and in comets is one of the keys to understanding how they formed. Our Solar System is believed to have formed out of a protosolar nebula composed of gas and grains. In Jupiter and Saturn, the lighter elements of the gas such as hydrogen (H) and deuterium (D) constitute the bulk of the planets' mass, with only a small fraction (3% for Jupiter, 10% for Saturn) being made of an icy/rocky core of solid material. It is therefore likely that the deuterium abundances in these two planets represent those of the gaseous part of the protosolar nebula. On the other hand, Uranus and Neptune may have been enriched in deuterium by the mixing of their atmospheres with comparatively much larger cores (more than 50% of their mass) containing deuterium-rich icy grains. Therefore, measuring the D/H ratios in the giant planets and using interior models provides important information on the early history of our Solar System.

ISO provided a coherent and direct determination of the D/H ratio in the four giant planets through the first detections of HD rotational lines (Fig. 1). The results are in agreement with the value obtained by the Galileo probe for Jupiter and are compatible with independent measurements of the protosolar value. On Uranus and Neptune, the D/H ratio is consistent with the current understanding of planetary evolution. The inferred D/H ratio for their icy cores is three times less than that found on comets, implying a different time and/or location for their formation.

Planetary atmosphere composition and structure
ISO observations have enhanced our knowledge of the composition and turbulence of the atmospheres of the giant planets. New hydrocarbons have been detected (CH_3CCH, C_4H_2, C_6H_6 on Saturn; CH_3 on Saturn and Neptune). These components of the planet's stratosphere are produced by photochemistry of methane through complex reaction schemes. Different species have different vertical distributions, so that their relative abundances allow reconstruction of the strength of the vertical transport as a function of altitude. ISO data also show evidence for ammonia clouds on Jupiter, best understood in terms of a two-cloud model, with 10-micron-sized particles in the upper cloud.

Water in planets and comets
A surprise obtained with ISO was the first detection of external water in the stratospheres of all of the giant planets and Titan (Fig. 2). Water is expected to be present deep in their atmospheres, because during their formation they incorporated oxygen, for which H_2O is the main carrier. This water, however, condenses out in the troposphere, as the temperature

* Additional information on ISO, including results galleries and how to retrieve data, can be found by following links from the ISO Home Page (www.iso.vilspa.esa.es); news items are also posted at www.sci.esa.int. Previous ESA Bulletin articles have addressed the data archive (Arviset & Prusti, No. 98, June 1999); the ISO operations (Kessler, Clavel & Faelker, No. 95, August 1998); early ISO results (Kessler, No. 86, May 1996); and pre-launch descriptions of the overall mission (No. 84, November 1995).

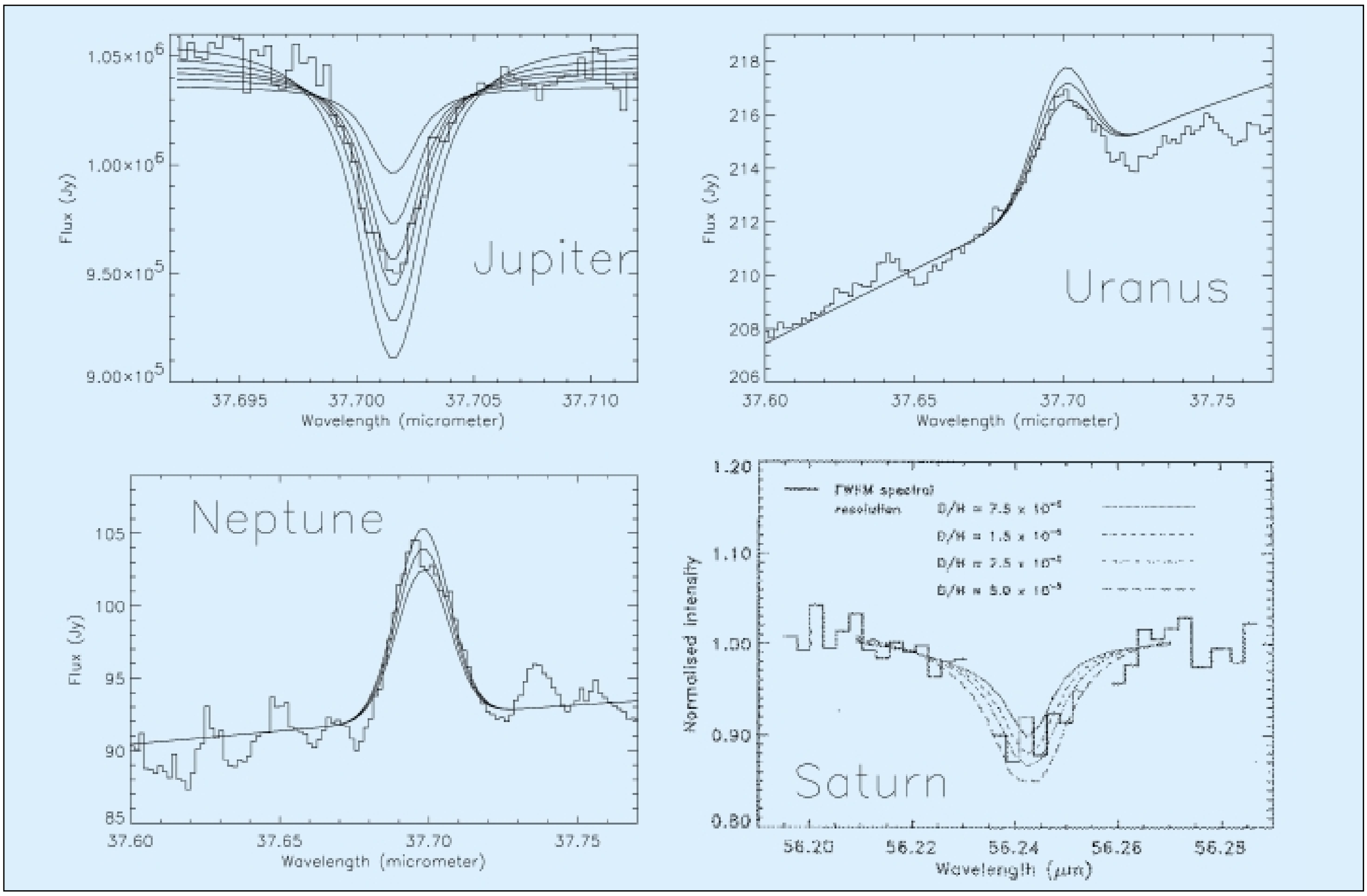


Figure 1. The first detections of HD rotational lines in the four giant planets: HD R(1) detected by LWS/FP in Saturn, HD R(2) detected by SWS/FP in Jupiter and SWS/grating in Uranus and Neptune (after Lellouch, ESA SP-427)

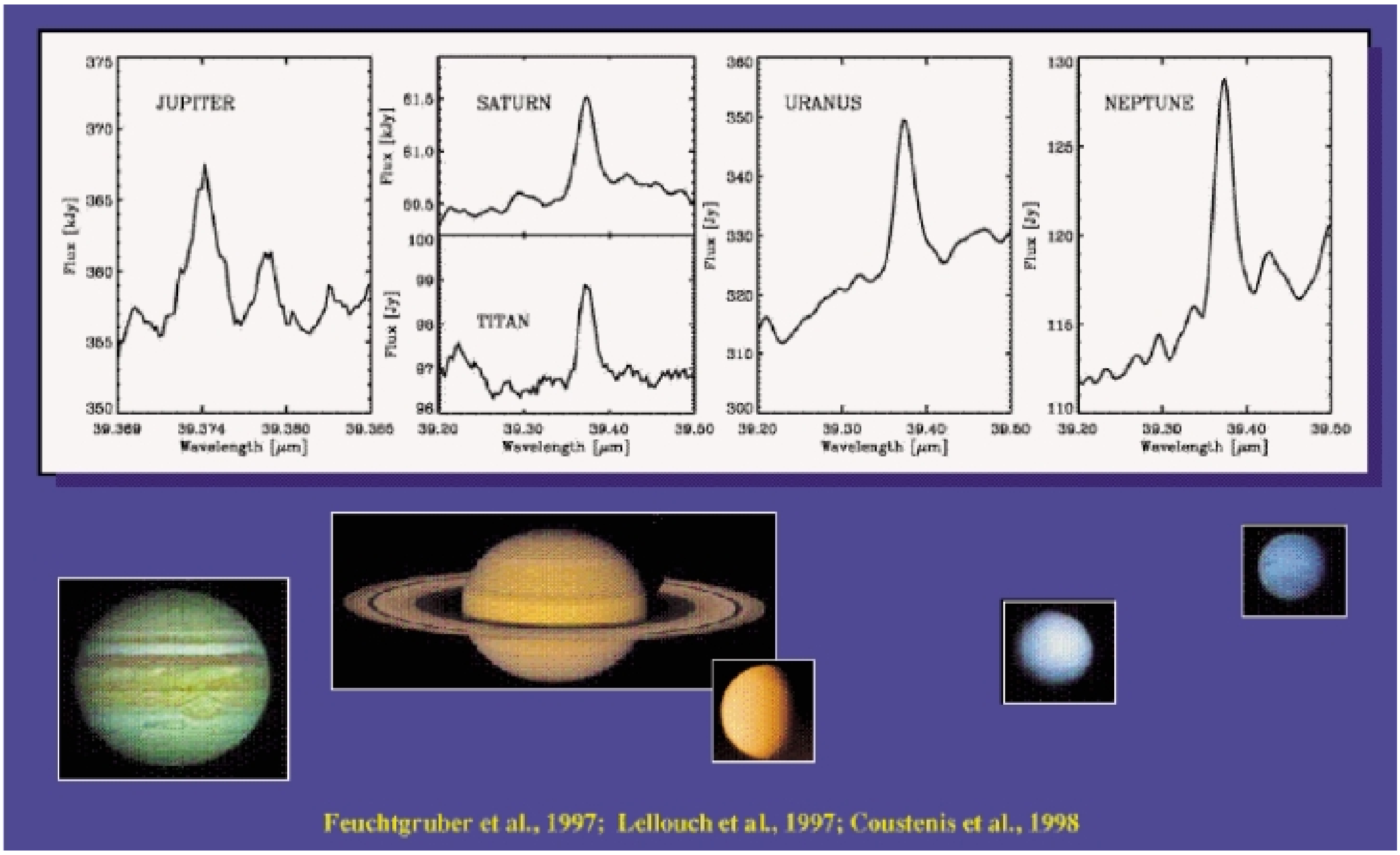


Figure 2. Detections of water lines on all four giant planets and Titan (after Feuchtgruber et al., ESA SP-427)

decreases with altitude. The water vapour detected by ISO comes from the upper tropospheric layers and implies a constant supply of oxygen from an external source. The inferred water input fluxes for the Jovian planets and Titan are similar, thus implying a dominant role for interplanetary dust and comets as the carriers.

Water has been found to be the main constituent of cometary activity, together with CO and CO_2, as observed in comets P/Hartley 2 and Hale-Bopp. On the latter, ISO saw changing production rates for each of those individually, as the comet was approaching the Sun. At 2.9 AU from the Sun, water-ice was detected, and the inferred production rate is consistent with the gaseous water production rate at the same heliocentric distance. This shows that such grains could be an important source of water sublimation, in addition to the nucleus, at such heliocentric distances.

ISO spectra of Mars show an incredibly rich set of water lines. From these, the vertical distribution of water vapour has been determined; the data are consistent with a cloud-forming altitude of 10 km.

Dust

A remarkable result has been the discovery that the cometary dust contains crystalline silicates, both in short-period comets (coming from the Kuiper belt) and in long-period comets (coming from the Oort cloud). Comets are believed to retain the original content of the pre-solar nebula. An interesting link has been the parallel discovery of the same kind of crystalline silicate dust in the circumstellar environment of some young stars, as in the case of the magnesium-rich olivine (fosterite) observed in comet Hale-Bopp and towards the young star HD 100546.

Surfaces of planets and asteroids

ISO is also revealing the nature of the surface of planets and asteroids, as in the case of Pluto and Mars, from the detected rotational modulation of their thermal spectrum. Spectral signatures of SO_2 ice will be used to reconstruct physical parameters of Io's surface. ISO data also suggest the presence of oxides on some asteroids, such as Hygiea and Polyxo, indicative of aqueous alterations on their surfaces early in the history of the Solar System.

Star formation

Star formation is one of the fundamental astrophysical processes and it impacts many very different research areas. Its consequences are seen at almost all astronomical distance scales. Many galaxies get their brightness from star formation. The spectacular Orion nebula - some 1500 light years away - in the winter sky is visible to us due to star formation. Our planetary system is based on the remnants of the formation process of a star - the Sun. Despite its far-reaching consequences, the details of the star-forming process are still not fully understood.

There are many ways to study star formation, both in general and with ISO. One can examine interstellar clouds, full of gas and dust, which will condense to form stars. It is also possible to study in great detail the youngest known stars, just emerging from their dusty birth clouds. A lot of attention has been paid to studies of young stars with disks around them, with the obvious aim of seeing a link to planetary systems. Instead of trying to summarise all studies in these areas, we will focus here on ISO's impact on our knowledge of a quantity called 'the initial mass function'.

Initial mass function

The initial mass function is, in principle, a very simple quantity. It just tells us how many stars are born and with which masses. The importance of knowing the masses is due to the fact that a star's entire future history depends on its mass at birth, i.e. on the amount of material gathered during its very short accretion phase. One mass-dependent factor is the lifetime of a star. High-mass stars have very short lives. They convert their hydrogen very quickly to heavier elements, which are then spread back into the interstellar medium when the star ends its life as a supernova. It is worth noting that this process provided the elements needed for life on the Earth. On the other hand, low-mass stars evolve very slowly. Their lifetimes are longer than the age of the Universe and therefore the matter in these stars can be considered as lost to any further chemical evolution. If we are able to tell how many low-mass stars are born, then we can estimate the amount of mass locked in these very faint objects.

Observations with ISO are needed to address the question of the number of low-mass stars being born, for several reasons. A newly born low-mass star is much brighter than its older companion of the same mass. At the extreme, this statement is true for brown dwarfs, which are objects below the stellar mass limit. This age-dependence of brightness means that these faint objects are best found when they are young. The requirement of observing stars when they are young forces the observer to look at star-forming regions. This brings problems because the interstellar clouds,

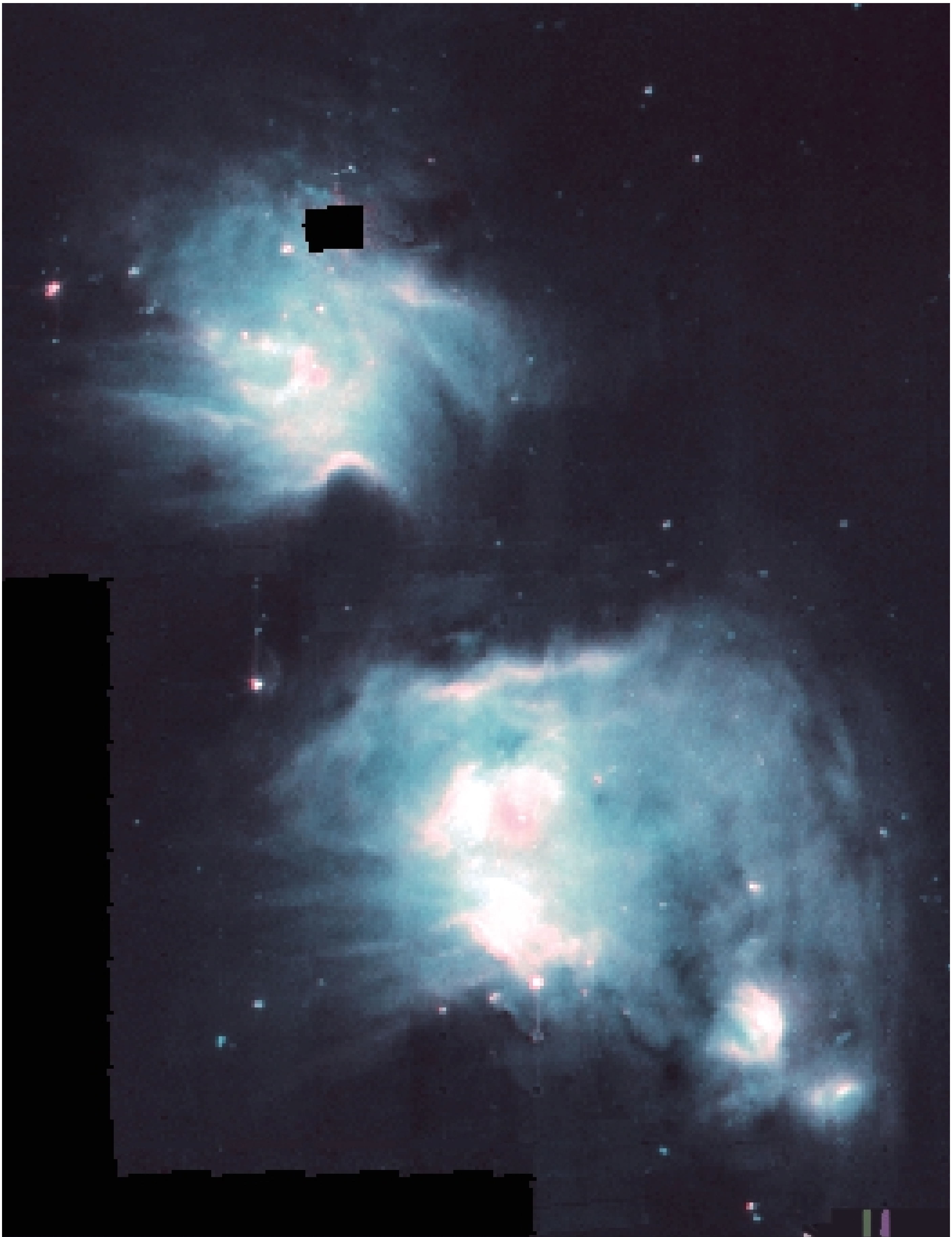
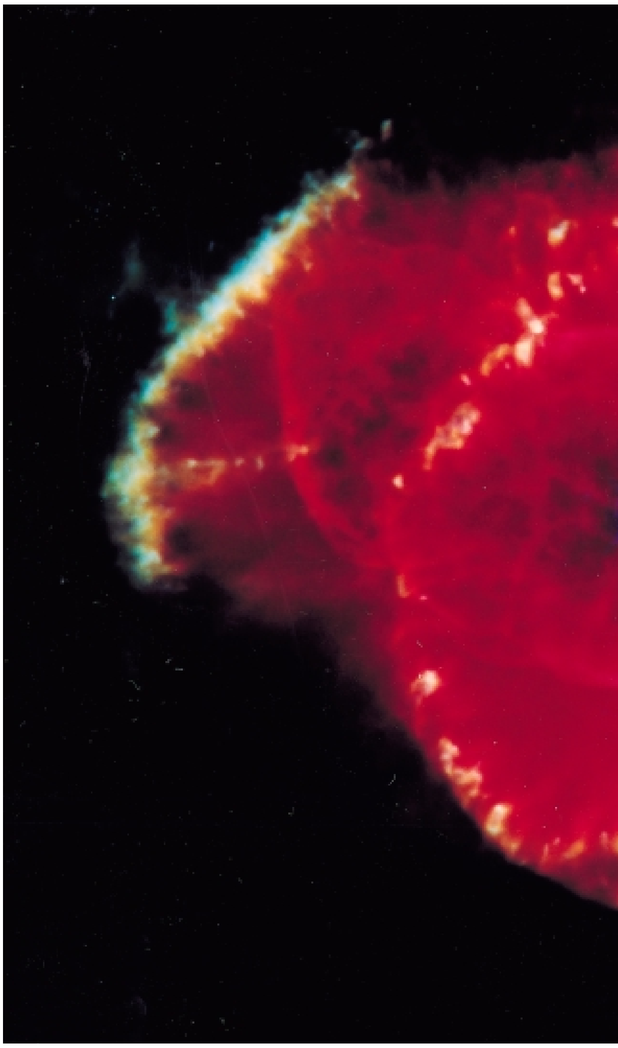


Figure 3. An ISO image of the star-forming region NGC 2068-2071 (after Kaas, Nordh et al., 1999)



A Hubble Space Telescope image of the 'Cat's Eye Nebula' (NGC 6543), one of the most complex and eye-catching planetary nebulae ever seen. It is estimated to be 1000 years old and is a visual 'fossil record' of the late evolution of a dying star

Courtesy of J.P. Harrington & K.J. Borkowski (Univ. of Maryland) and NASA

where stars are born, contain huge quantities of dust, which very effectively block visual light. The remedy is to change the observations from optical to infrared wavelengths. Many star-forming regions had already been studied in the infrared prior to ISO, either with ground-based near-infrared telescopes or with the Infrared Astronomical Satellite (IRAS). However, the key to ISO's success has been the provision of high sensitivity at mid-infrared wavelengths.

The route from observation through data reduction and analysis to initial mass function is long and complex, but also astronomically exciting. Many interesting results have been found. For the star-forming region in the constellation of Serpens, the ISO data reveal a surface density for newly-born stars above 400 per square parsec. To put this number in context, note that the closest star to us is at 1.3 parsec. In the Chameleon star-forming region, the ISO results indicate that there are young stars with big dust disks around them, but at the next step there are stars without any dust disk at all. The intermediate cases are practically absent. This result suggests a very rapid change in the disk. Maybe the dust coagulates at this early stage into planet seeds which are, unfortunately, currently undetectable.

At the end of the data reduction and interpretation, we arrive at the initial mass function. The data indicate that the mass spectrum starts to flatten between 1 and 0.1 solar masses. If we take as a comparison the interval between 10 and 1 solar masses, then there are many more 1 solar mass stars than 10 solar mass stars. The trend continues towards lower masses, but the flattening means that the ratio is less for 0.1 solar mass stars when compared to 1 solar mass objects. The significance of this flattening is that when changing the view from number of stars per mass interval to total mass per mass interval, we are observing a drop: there is no evidence of large quantities of 'hidden' mass in the very lowest mass stars.

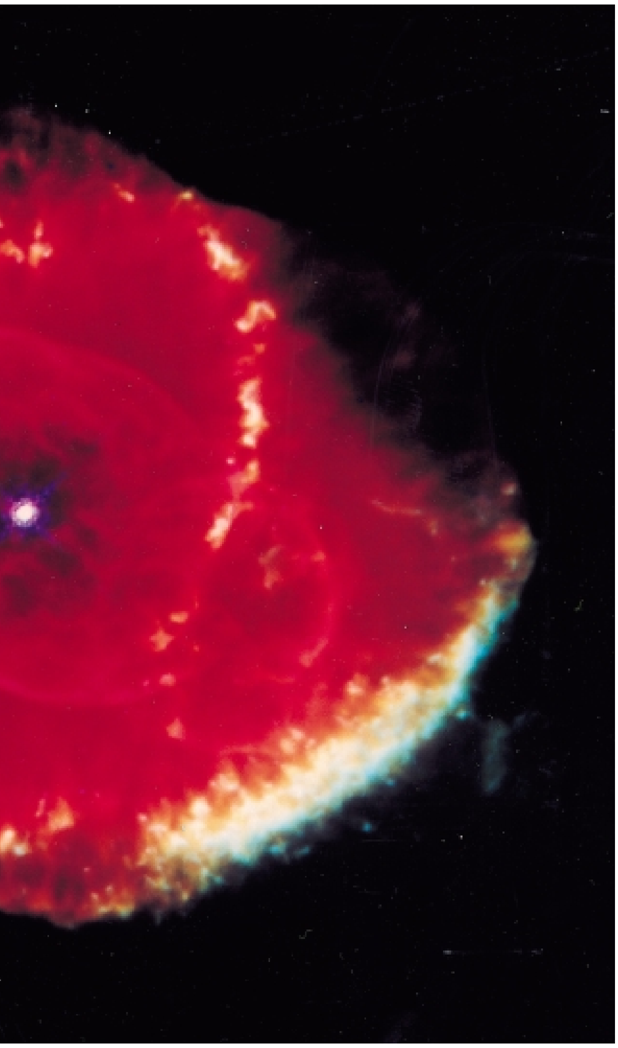
The current state of the art in data reduction indicates that the number of stars in the lowest mass bins continues to rise, but in the similar shallow manner as in the 1 to 0.1 mass interval. On the other hand, studies of brown dwarfs suggest that the number of objects is decreasing towards smaller masses. The challenge of the future ISO work is to examine whether a consistent picture can emerge and whether further flattening and eventual bending down of the initial mass function can be confirmed when entering the brown-dwarf mass domain.

Evolved stars

Oxygen- and carbon-rich stars

Stars are dense gaseous spheres which, for most of their lives, fuse hydrogen to form helium in their interior. For intermediate-mass stars, once their hydrogen supply is exhausted, their interior collapses, heats up and finally ignites fusion of helium to heavier elements. One consequence of this ignition is the expansion of the outer layers of the star - the star becomes very large and cool, a red giant or supergiant. However, this stage also does not last forever. Once the giant star has nearly exhausted its helium supply, the core finally collapses and the star becomes a white dwarf, surrounded by the swept-up circumstellar envelope, a planetary nebula, one of the most beautiful types of object in the sky (e.g. NGC 6543).

Another consequence of the expansion is that the star starts to lose material from its outermost layers, and slowly builds up a 'circumstellar envelope'. These circumstellar envelopes contain various constituents: warm gas, simple and complex molecules, ices and dust grains. Depending on the evolutionary state of the star, its composition may be richer



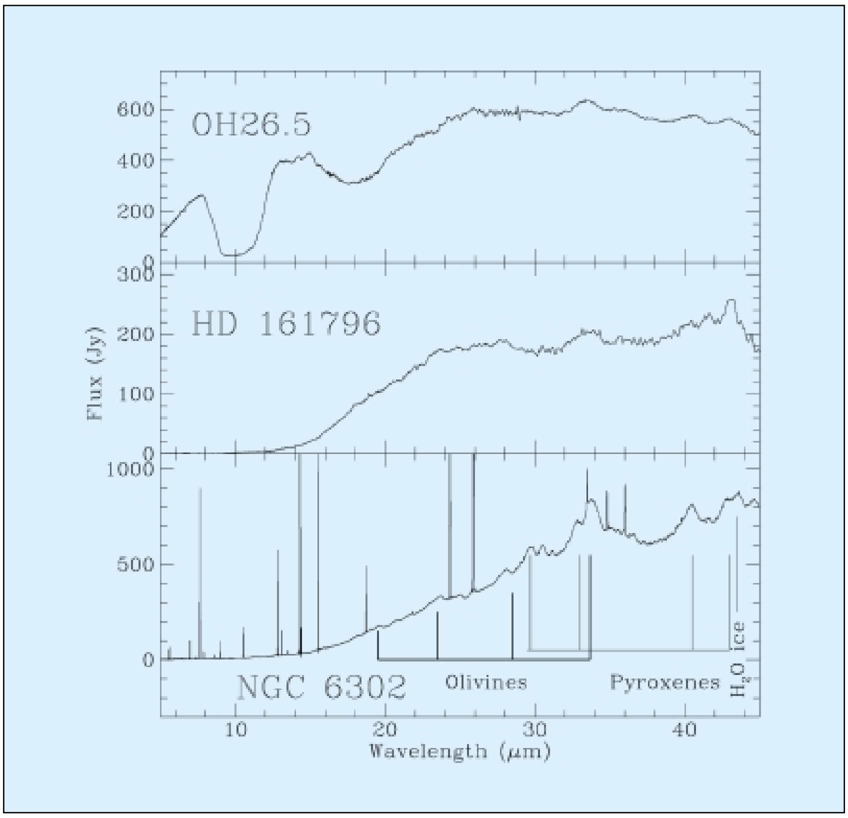


Figure 4. Crystalline silicates in ISO spectra of oxygen-rich evolved stars: OH 26.5, a star with heavy mass loss; HD161796, a star in transition to a planetary nebula; and NGC 6302, a bipolar planetary nebula. The strong narrow peaks in NGC 6302 are fine-structure lines from the ionised gas (after Waters et al., ESA SP-427)

in oxygen or richer in carbon, giving rise to either oxygen-rich or carbon-rich signatures in the infrared spectrum. At least, prior to ISO, that was the popular thinking about chemical evolution.

ISO observations of a variety of evolved stars have revealed, however, that the co-existence of oxygen-rich and carbon-rich circumstellar material is much more common than was previously believed.

One of the surprises of the ISO results has been the detection of crystalline silicates (such as olivines, pyroxenes and fosterites) in red giants and planetary nebulae. As discussed earlier, ISO has also found such materials in the Solar System and around young stars. These spectral signatures, only detectable at infrared wavelengths, get stronger with increasing evolutionary state, and were detected to be strongest in planetary nebulae (Fig. 4). It is still an open question whether these solid-state silicates reside in a circumstellar disc, thus being indicators for such a disc, or whether they are formed in the outflow of the expanding circumstellar envelope.

The mammoth wavelength coverage and resolution of the ISO spectrometers is proving crucial in accurately modelling the chemical composition and temperature regime of the lower layers of the circumstellar envelope. As an example, Figure 5 shows the richness of the lines detectable in the spectrum of the brightest carbon-rich evolved star CW Leo (also known as IRC+10216).

OH masers and megamasers

A large number of red giant and supergiant stars exhibit prominent hydroxyl (OH) maser lines at radio wavelengths. For more than a decade, radio astronomers have also been studying intense OH emission - dubbed 'OH megamasers' - from infrared luminous galaxies. It was a long-standing suggestion that the inversion mechanism for this maser emission was radiative pumping. The pumping cycle consists essentially of the OH radical absorbing stellar light in the mid-infrared and a subsequent cascading to lower energy levels - seen as emission lines - resulting in an overpopulation of the levels from which the maser arises. Before ISO, however, this model could not be confirmed, since the absorption and emission lines involved in the pumping cycle are not observable from the ground.

ISO spectra of a prominent evolved star IRC+10420, an extreme supergiant with strong OH maser emission, and of Arp220, the prototypical ultra-luminous infrared galaxy, have revealed all the lines relevant for the pumping

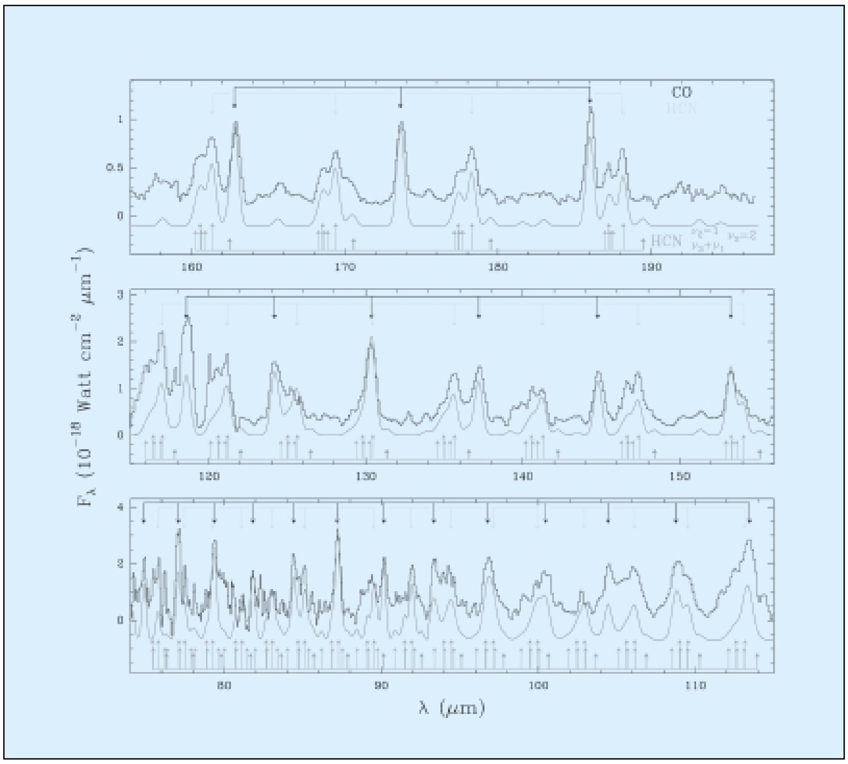


Figure 5. ISO spectrum of the carbon-rich evolved star IRC+10216 (CW Leo), with a wealth of emission lines from highly excited CO and from HCN (from Cernicharo et al., 1996), in Waters et al., ESA SP-427)

cycle. This provides direct proof of the model and confirms that we now understand the processes at work.

Beyond our galaxy

Beyond our own galaxy, apart from the few nearest galaxies, we enter a regime in which observation and its interpretation become intimately entangled with the evolution and history of the Universe as a whole.

Light arriving from objects at intergalactic and cosmological distances takes millions to billions of years to reach us. The objects from which it originates are diverse, including giant old elliptical galaxies, dusty spiral galaxies exhibiting various degrees of star formation, galaxies in violent collision - obscured by dust and massively star-forming. At the extremes of energy production are found the enormously powerful Active Galactic Nuclei (AGNs). These are believed to be powered by enormous black holes at their centres, consuming gas and dust, entire stars and stellar systems.

All of these objects are seen by us at various stages of their ‘life-cycles’, literally scattered through time by the many different ‘light-travel times’ which separate them from us. The aim of much of modern cosmology is to understand how the Universe has developed from its formation (the Big Bang), through the formation of the first stars and galaxies, through the aggregation of galaxies into the diverse forms seen in the observational record, and on to the emergence of the structures (like our own Milky Way galaxy) found in our ‘locality’ today.

Prior to the launch of ISO, certain fundamental questions concerning the relationships among the different types of galaxies seen, remained open or poorly resolved. For example, of the most luminous galaxies - the Ultra-Luminous Infra-Red Galaxies (ULIRGs) which emit as much energy as a million million Suns - what fraction of their number is dominated by active nuclei powered by massive black holes (Active Galactic Nuclei, AGNs), and what fraction derive their energy from huge star-formation events? What happens in detail when galaxies collide? At which epoch or epochs in the history of the Universe did stars form in greatest abundance? How much of the history of star formation is obscured from our view in visible and ultraviolet observations by intervening dust? ISO has been able to advance the study of these important questions very significantly.

Ultra-luminous infrared galaxies

Pre-ISO models for the evolution of ULIRGs envisaged their formation in the collision and merging of galaxies, triggering a starburst, which then faded giving way to a black-hole-powered AGN fed by interstellar material falling inwards to the central black hole. ULIRGS should therefore progress through degrees of interaction and end up as fully merged systems with AGNs. Pre-ISO observations produced no clear conclusions as to the energy source in ULIRGs, optical and radio observations giving conflicting impressions of AGN and starburst activity, respectively.

Indeed, while both mechanisms are present to some degree, ISO spectroscopy in the mid- and far-infrared has provided a powerful technique for discriminating starburst and AGN energy sources. Because of its ability to make observations through dust layers opaque to visible and ultraviolet light, ISO has been able to study the normally obscured inner, energetic regions of ULIRGs.

A crucial factor discriminating between AGN activity and star-formation activity is the ‘hardness’ and ‘intensity’ of the ultraviolet radiation field. The hardness refers to the energy of the individual photons, while the intensity refers to their abundance. ISO could measure the energetics of the ultraviolet photons by studying their ability to ionise the gas in the target galaxies. A high ratio of, for example, energetic highly-ionised oxygen (OIV) species relative to low-energy ionised neon (Ne II) species signifies a hard radiation field. At the same time, the intensity of the ultraviolet radiation could be measured by determining its ability to destroy the layers of organic compounds that form on dust grains in the interstellar medium of target galaxies.

The earlier infrared survey mission IRAS showed that mid-infrared spectral features, normally attributed to carbon-rich molecules accumulated on small dust grains, were common throughout the galaxy and in other galaxies. ISO has confirmed the ubiquity of these substances - usually referred to as Polycyclic Aromatic Hydrocarbons (PAHs) or for the more cautious as the Unidentified Infrared Bands. These substances, however, are believed to be destroyed, and their spectral signatures consequently erased, in regions with intense ultraviolet radiation fields. At the same time, the dust grains that carry the PAHs are heated by the ultraviolet and emit stronger thermal continuum radiation.

It follows that a search with ISO's various spectrometers allows both the O IV/Ne II line ratio (ultraviolet hardness) and the presence or absence of PAHs relative to hot-dust emission (ultraviolet intensity), to be explored for a range of targets. It was found that high values of the line ratio ('hard' photons) coupled with low ratios of the PAH features to dust emission (lots of photons), correlate well with AGN energy sources, while low values of the line ratio ('soft' photons) and higher values of PAH signature (fewer photons) correlate with starbursts.

By comparing the properties of a sample of ULIRGs with the above criterion, it has been established that most ULIRGs derive the bulk of their energy from enormous bursts of star formation, while only a fraction, and mainly the most luminous ones, are powered by massive black holes in AGNs. Also, there is no evidence for the model-predicted trend of moving from starburst power to AGN power with the progression of the galaxy merger. In fact, no simple evolutionary trend from starburst to AGN mechanisms is seen in ISO observations of ULIRGs, but the discrimination of the two mechanisms has become possible.

Galaxies in collision

A number of results with ISO have revealed fascinating and hitherto unseen details of galactic interactions. One example is the case of the merging pair of galaxies called the Antennae (NGC 4038/4039) – so-called because of the diffuse tails of material (dust, gas and stars) seen in optical images and cast off from the galaxies through their gravitational tidal interaction. In the Antennae, spectroscopic imaging with ISO's camera revealed that by far the brightest source in the infrared is neither of the merging galaxies' nuclei, but instead a region at the location of 'collision' of the two systems. Completely hidden by dust in visible light, it is revealed as a strong star-forming event in ISO's infrared images.

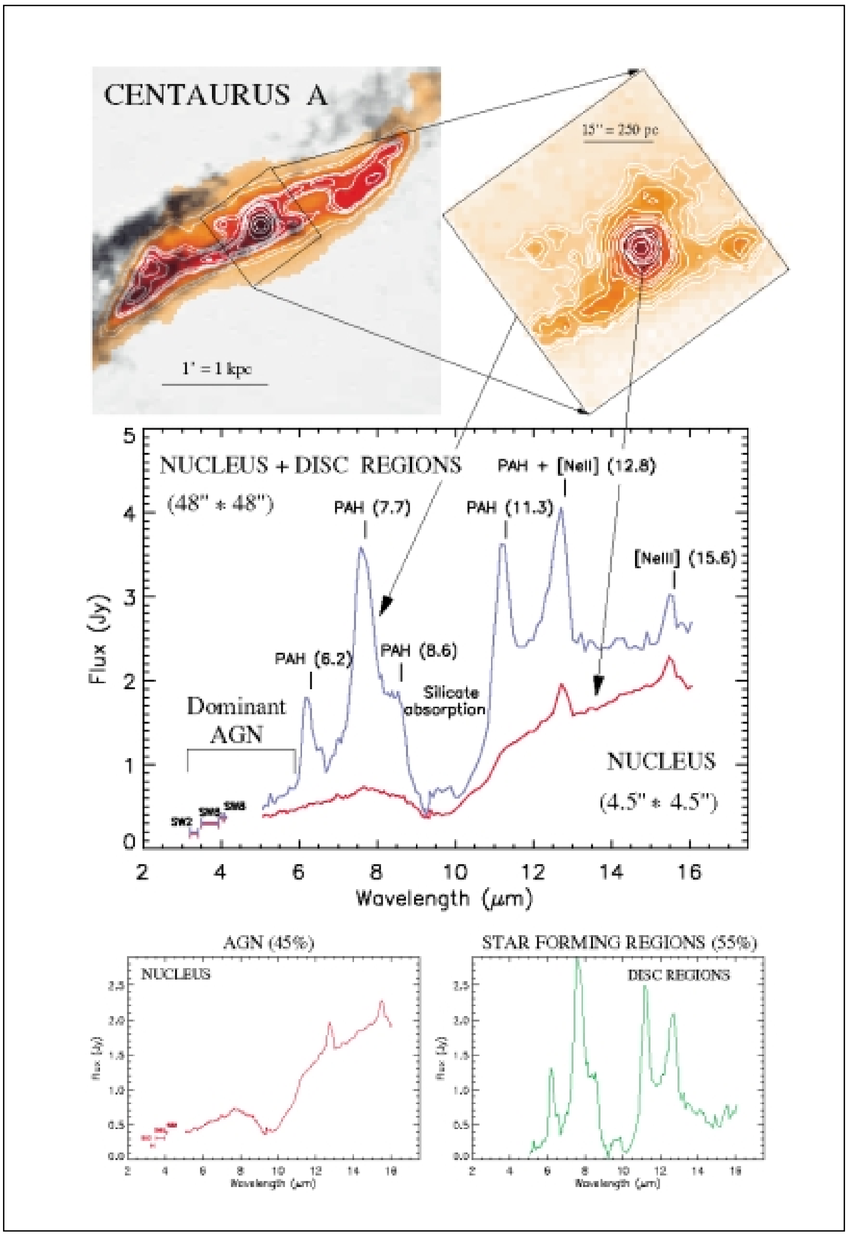


Figure 6. Centaurus A. Upper left panel: Distribution of dust in the inner region observed at 7 microns (contours) with optical dark lanes superimposed. Upper right panel: Map at 8 microns of the nuclear region in spectro-imaging mode where we observe the nucleus as well as a part of the disc structure. Middle panel: The lower curve represents the mid-IR spectrum covering the nuclear region, whereas the upper curve shows the spectrum integrated over a larger region including both disc structures and the nucleus. Bottom panel: The AGN spectrum (left) represents 45% of the energy between 5 and 16 microns and is highly dominant at short wavelengths between 3 and 6 microns. The emission associated with star-formation regions (right) is not detected with the three narrow-band filters at 3-4 microns. The absence of PAH bands is clearly observed in a region of 50 pc in radius containing the AGN, whereas PAH bands dominate the emission outside the nucleus. In addition, the high [Ne III]/[Ne II] ratio detected in the AGN reveals the presence of a hard radiation field (after Laurent et al., ESA SP-427)

Another beautiful example of the detailed events within a galaxy merger is found in the spectroscopic imaging of the giant elliptical galaxy Centaurus A. This galaxy contains the closest Active Galactic Nucleus (AGN) to Earth. The camera data, shown in Figure 7, reveal the presence of a spiral galaxy, captured in a merger, and now residing inside the giant-elliptical galaxy. These data raise the question

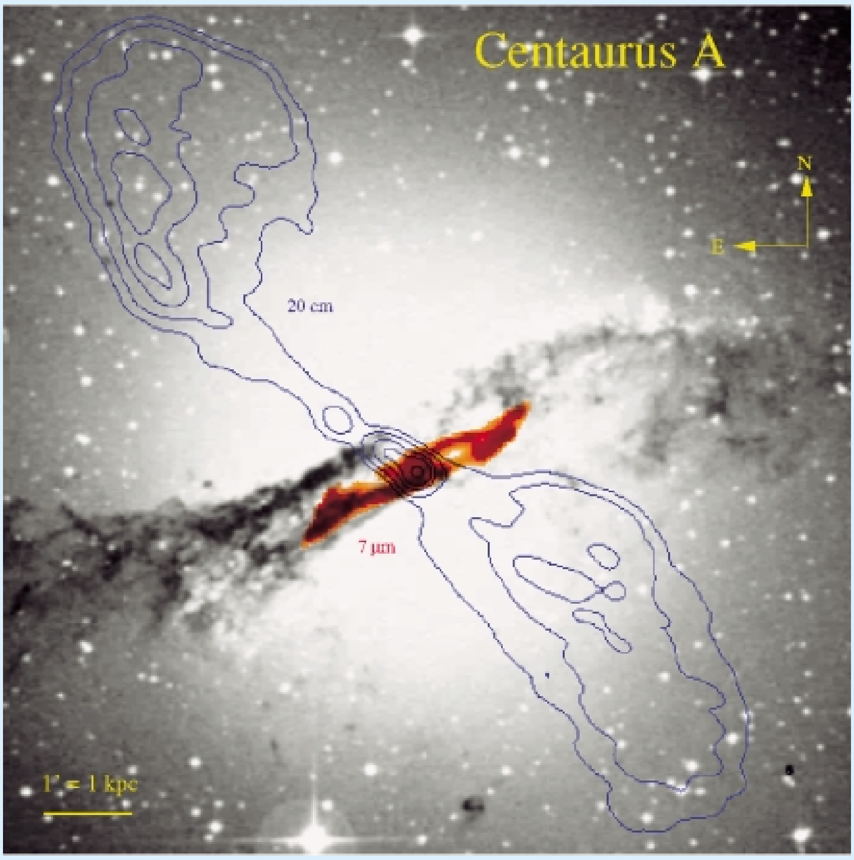


Figure 7. ISO image of Centaurus A (red) superposed on an optical image. Also shown are the radio-continuum (50 cm) contours (from Mirabel et al. (1998), in Vigroux et al., ESA SP-427)

as to whether giant radio galaxies like Centaurus A are composed of a barred spiral inside an elliptical, where the bar serves to funnel gas towards the central AGN black hole - a picture which resonates with the discussion of the nature of ultra-luminous infrared galaxies above.

Other ISO observations of interacting galaxy systems include observations of ring-shaped galaxies, which result when a small galaxy passes through the centre of a larger one causing a star-forming density wave to propagate outwards through the target galaxy (Fig. 8). In one particularly difficult observation, ISO imaged a very distant (redshift = 1) ring galaxy through a foreground cluster of galaxies whose gravity bent the light from the background object and magnified its image and brightness. Gravitational-lensing theory allowed the intrinsic visual form of the ring galaxy to be reconstructed and correlated with the ISO measurements, leading to the recognition of an interaction-generated starburst in the ring. Further, based upon the ISO mid-infrared fluxes, it was inferred that the nucleus of this particular very distant ring galaxy harbours an AGN.

In general, as in the case of the ULIRG study described earlier, ISO observations show that interacting galaxies are not always associated with active nuclei (well-fed central black holes). Indeed, interactions are observed whose infrared properties place them comfortably into the ranges of star formation occupied by more typical 'normal' galaxies.

Epochs of star formation

Apart from the detailed studies of the properties of galaxies and galaxy types, ISO has been used to perform a number of deep surveys in the mid- and far-infrared using the camera and photometer. Collectively, these surveys have led to the recognition of major global star-forming events in the Universe, previously undetected due to dust obscuration. These account, in the emission of discrete sources, for much of what was previously attributable only as a mysterious diffuse infrared background. A significant population of infrared bright, and presumably star-forming, galaxies has been found in camera surveys at redshifts between 0.6 and 1, and the fall-off beyond a redshift of 1 may be partly due to important mid-infrared spectroscopic features (Polycyclic Aromatic Hydrocarbons, PAHs) being red-shifted out of the range of the camera filters for redshifts larger than 1.4. However, for the higher redshifts, the far-infrared capability of the photometer takes over in 175-micron survey work. The latter has extended ISO's detection of global star-formation out to red-shifts beyond 2. ISO's resolving of much of the

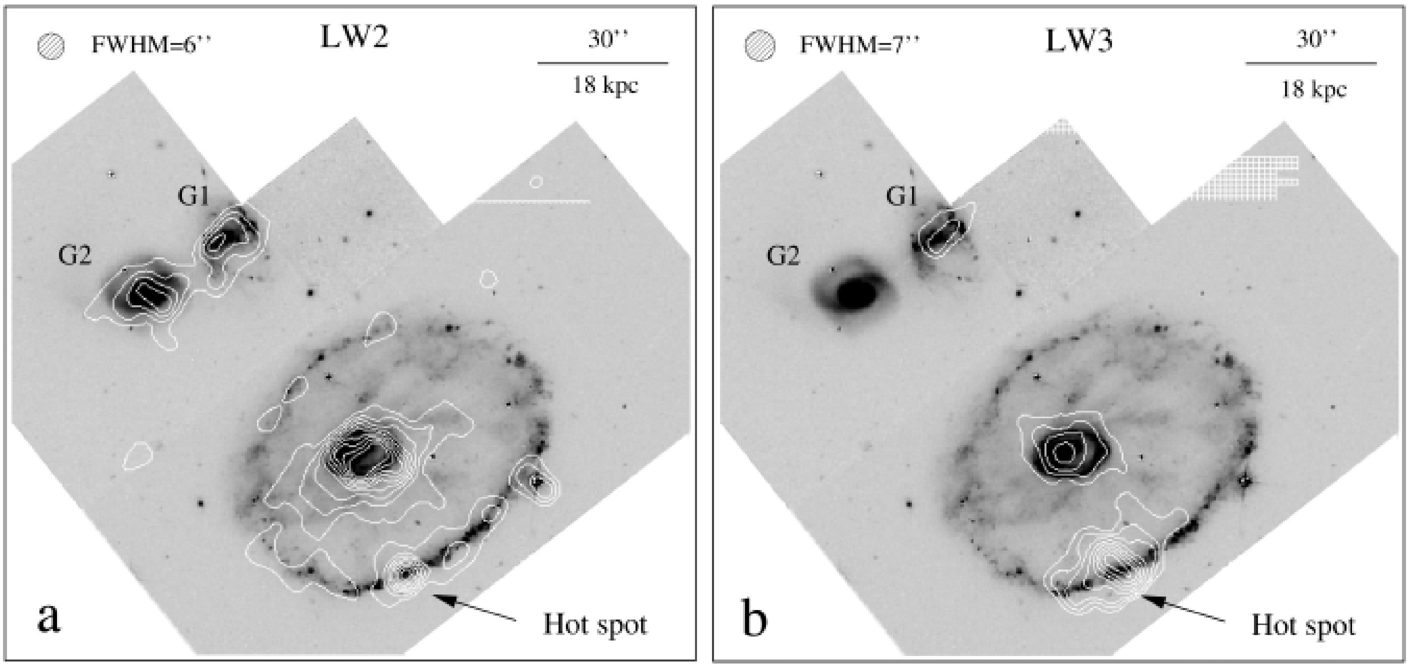


Figure 8. The Cartwheel Galaxy: ISO images at wavelengths of 7 microns (left panel) and 15 microns (right panel) overlaid on an HST image (after Charmandaris et al., ESA SP-427)

universal infrared background into discrete sources is a major cosmological result, helping us to recognise when and where the stars formed, and strongly emphasising the caution needed when interpreting star-formation rates from optical or ultraviolet measurements alone – which cannot see through obscuring dust to recognise the events seen by ISO. Its implications will trigger follow-up work for some time to come.

Conclusion

Across the full range of astronomical objects and spanning the history of the Universe, ISO's sensitivity, broad wavelength coverage and diverse instrument complement have permitted it to study crucial physical processes related to planet, star and galaxy formation and evolution. It has revealed hidden events of major importance and given clear views into the details of key evolutionary processes, previously completely unobtainable. The broad spectral coverage and instrumental diversity of ISO have allowed physical mechanisms to be constrained simultaneously in several energy ranges and on several spatial scales. The capacity of ISO's results to draw unifying threads through diverse areas of astrophysics can be glimpsed in the examples discussed above.

Major themes and puzzles of modern astrophysics and cosmology, including Solar System studies, the star-formation process, stellar evolution, the energy sources of ultra-luminous galaxies, the relative importance of star formation versus active galactic nuclei driven by black holes, the properties of colliding and interacting galaxies, and the global history of star formation, have been addressed by ISO and are being drawn together.

The ISO data have been only partly exploited so far, but already the emergence of vital new perspectives on fundamental puzzles has become evident. With the availability of its entire data set to the world-wide astronomical community, the harvest of new and exciting results from ISO will continue for some time yet.

Acknowledgements

The results described above are the work of a large number of astronomers, who for reasons of readability have not been individually credited throughout the article. Details of their work, and full references, can be found in *'The Universe as Seen by ISO',* ESA SP-427, March 1999, edited by P. Cox and M.F. Kessler. As starting points for each of the sections of this article, the reader is referred to the following papers in those Proceedings: *Solar System*, review by E. Lellouch and references therein, J. Crovisier et al., H. Feuchtgruber et al., and many of the Poster Papers; *Initial Mass Function*, review by T. Prusti and references therein, review by G. Olofsson et al. and references therein; *Evolved Stars*, review by L. Waters and references therein, J. Cernicharo et al., conference summaries by M. Harwit and R. Genzel; *Extragalactic*, reviews by A. Moorwood and by G. Helou, conference summary by R. Genzel, and many of the poster papers, including Charmandaris et al., Dole et al., Elbaz et al., Laurent et al., Metcalfe et al., Rigopoulou et al. and Vigroux et al.

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