SUMMARY AND OUTLOOK

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This has been an exciting meeting in which we saw all the different instruments on ISO revealing strikingly novel results that challenged conventional perceptions with unexpected findings or confirmed long-held astrophysical views which previously had to be taken on faith.

Alan Moorwood told us about an important confirmation of how OH megamasers work. For many years, the pumping mechanism of these masers, prominent in many active galaxies, has been thought to involve far-infrared absorption. A doublet at 34.629 and 34.603 μm excites a transition in the OH radical directly from the F_1 ($^2\Pi_{3/2}$) ground state to the F_2 ($^2\Pi_{1/2}$) J = 5/2 state. From there the radical transits back down to a metastable hyperfine level of the ground state, sometimes by an alternative return path that re-emits no 34μm photons. Because of this, the source spectrum is expected to display an absorption feature at this wavelength.

Moorwood now showed that this explanation appears correct for the OH megamaser in Arp 220. Using the short-wavelength spectrometer on ISO he and his colleagues observed a strong 35μm absorption feature in this ultraluminous galaxy. The number of infrared photons absorbed in this one spectral line alone is of the correct magnitude to explain the entire observed OH maser flux. Roughly 150 photons at 35μm are absorbed for each maser photon produced. Theoretical models suggest a pumping efficiency of 1%, in rough agreement with observations. The maser and infrared absorption line widths are also in good agreement as would be expected. With this observation we move one step closer to understanding the workings of these highly luminous masers (C. J. Skinner *et al*, 1997).

The past decade has seen a revolution in X-ray astronomy. Prominent among the new findings is the existence of enormous quantities of extremely hot iron-rich intracluster gas. Dietrich Lemke showed us that this medium is also dusty. ISO photometer scans through the central portions of the Coma cluster at 120 and 180 μm demonstrate a clear rise in 120 μm emission over and above a baseline flux at 180 μm. Two such scans traversing the cluster at roughly 45° to each other exhibit emission over a span of 10 to 15 arc minutes. This is substantially wider than the instrumental field of view. It is, therefore, not due to individual galaxies, whose profiles would have been narrower.

The total mass of dust inferred from these measurements is quite uncertain, but estimates lie in the range of 10^8 to $10^{10}\,M_\odot$. The infrared emission has been predicted to arise through grain heating by the hot intracluster gas. With a ROSAT-derived intracluster gas mass of $\sim 10^{13}\,M_\odot$, the dust seems to be depleted by one to three orders of magnitude compared to its interstellar abundance. This may not be surprising, since the X-rays that heat the dust are expected to also destroy it in $\sim 10^8$ yr. The observed dust needs to be replenished either by continuing explosive ejection of galactic supernova remnants or through gas stripped from colliding galaxies (Stickel *et al*, 1997).

Peter Clegg spoke about a striking new finding with the ISO long-wavelength spectrometer. D. Neufeld *et al* (1997) have reported the detection of interstellar hydrogen fluoride, HF, in absorption toward the Galactic center source Sgr B2. Using the Fabry-Perot mode of the long-wavelength spectrometer on ISO, they detected the 121.6973 μm J = 2 to 1 line of HF. They derive an HF abundance relative to H_2 of $\sim 3 \times 10^{-10}$ for Sgr B2. This is only 2% of the total number of fluorine nuclei if the abundance of elements is solar. Much of this element, therefore, is likely to be depleted on dust.

The astrophysical importance of this study is that the formation mechanism of HF is so different from other interstellar hydrides. HF forms directly through exothermic reactions with both H_2 and H_2O in the gas phase. Unlike other hydrides it is not formed on the surface of grains and does not

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require the existence of dust. Because of its great bond strength it is also appreciably more stable than any other fluorine-containing molecule and should account for more than 99% of all gas phase fluorine. Hydrogen fluoride can therefore serve as an important analytic probe of interstellar gas and gas-grain interactions.

Catherine Cesarsky reported on 6.7 μm ISOCAM studies of embedded objects in the Chameleon 1 star-forming region. A strong correlation is found between the 6.7μm emission and the stars' bolometric luminosity. The distribution of source luminosities in this cloud, and the assumption that their ages are identical, permits a derivation of masses and an initial mass function. Surprisingly, masses below $0.03M_\odot$ appear to be quite common, indicating the emergence of abundant numbers of brown dwarfs. This is surprising because so little is know about isolated brown dwarfs. To date only one or two genuine candidates are known.

Jean-Loup Puget told us about unidentified interstellar emission observed from regions illuminated by ultraviolet and optical radiation fields of vastly different strengths. Theoretical models have long suggested that the unidentified emission bands are due to interstellar macromolecules containing perhaps a few hundred atoms. The molecules absorb individual optical or UV photons, rapidly thermalize the energy, and then re-emit it through characteristic vibrational and torsional transitions. The models predict that the emission spectrum should be unaffected by the photon number-density in the irradiating field, since the infrared emission is rapid and takes place before the macromolecule absorbs a further photon. Puget reported that these predictions are borne out. The infrared emission spectrum remains unaltered from region to region, even when the irradiating fields vary by factors of 500 in photon number-densities. This is an important observational confirmation for a theoretical model we had long accepted on faith.

Looking to the future, we should heed the introductory presentation of Martin Kessler, who showed how striking new results are obtained when all four instruments on ISO jointly study a region of interest. In this age of smaller-faster-cheaper missions that concentrate on single instruments, we may lose much of this ability to study rare phenomena with correlated techniques. We gain the greatest insight on comets, rapidly variable active galaxies, or nearby supernova explosions when we can examine the phenomenon at many different wavelengths and with many different techniques. ISO is showing us the uses of an observatory with wide-ranging abilities to study interesting phenomena through one telescope with known characteristics. This may be the most important single lesson to take away from this symposium. Observatory class instruments may be expensive, but the astrophysical insights they offer pay back the investment with interest.

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References

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