The Image Photon Counting System and Quasars at La Silla

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August 1978 was a very hectic month on La Silla. Members of the Technical Support Group, under the leadership of Dr. Marius de Jonge, worked around the clock to get everything ready at the 3.6 m Cassegrain focus for two weeks' observations with the Boksenberg Image Photon Counting System. The efforts of the ESO technicians and the visiting astronomers were brilliantly successful and many unique observations were made. Together with other colleagues, Dr. John Danziger (ESO-Geneva) observed a number of faint galaxies and quasars. One of the aims was to study the detailed structure of absorption lines that are seen in many distant quasars and to throw some light on their origin. Are these lines formed in the immediate neighbourhood of the quasar or by intervening matter in intergalactic space?

The Image Photon Counting System

During August and September 1978, the Image Photon Counting System (IPCS) developed at University College London by Dr. A. Boksenberg was installed on the Boller and Chivens spectrograph at the Cassegrain focus of the 3.6 metre telescope. Over a period of more than two weeks, ten different astronomers from Europe and Chile made observations with the system on a variety of different programmes. The IPCS itself was maintained and operated by Dr. Boksenberg and his technical support group consisting of Keith Shortridge and John Fordham. However, the installation of the IPCS on the spectrograph and telescope required considerable extra effort by the Technical Support Group at La Silla. The increased demands for optical, mechanical, and electronic assistance resulted from the introduction of this new instrument to La Silla.

A successful and productive observing period would not have been possible unless members of the Technical Support Group had been prepared to work late into the night preparing equipment and helping to solve unforeseen problems.

It was the greatest support activity ever given to the instrumentation of visiting astronomers. Since the magnetic coil normally used with the IPCS could not be adapted to the Boller and Chivens spectrograph due to the optical and mechanical characteristics of the spectrograph, it was decided that ESO should build a special coil for the experiment. Discussions first began in London in December 1977. ESO provided the mechanical parts of the coil and TV adaptor, and University College did the winding and magnetic field test. After the coil was designed and built in Chile during a three-month period, it was shipped to London for winding at the end of May 1978. Following the necessary work, the wound coil was shipped back to Chile and arrived almost simultaneously with the IPCS electronics which had been shipped from the Hale Observatories in California. It arrived at La Silla some days before the beginning of the observing run. During those few days several last-minute problems had to be solved. Special racks had to be constructed to hold electronic equipment in the Cassegrain cage. An additional machined spacer had to be made to allow correct adaptation of the IPCS module to the camera of the spectrograph. Some temporary rearrangements were required in the control room of the telescope also to provide for convenient observing with the extra control and data-gathering equipment installed there. Figure 1 shows the end result of all of the activity in the Cassegrain cage. One can see the IPCS module attached to the spectrograph on the left, with the control electronic racks in the background.

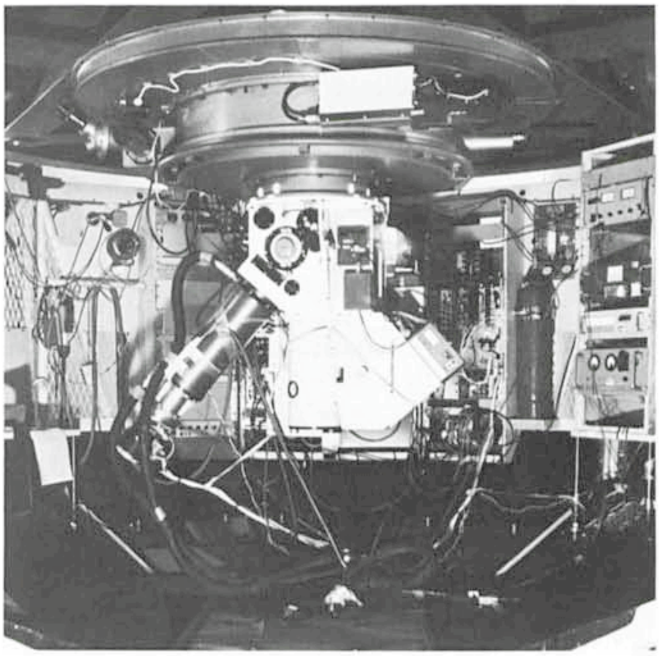

Fig. 1: *A view of the 3.6 m Cassegrain cage with the IPCS equipment installed.*

The IPCS has two important properties that make it extremely useful for working on faint quasars. Individual photons arriving at the detector are recorded as separate events by means of several stages of image-tubes followed by a television camera. In addition, the precise location of each photon event on the photocathode means that when the system is used with a spectrograph, the Boller and Chivens in this case, one can achieve spectral resolutions comparable to those allowed by the optical components of the spectrograph.

These are the properties of a spectrograph-detector system that one requires in order to study narrow absorption lines in distant quasars. During the observing run on the 3.6 metre telescope most programmes were involved with extragalactic astronomy, and some of the results for galaxies will undoubtedly be described at a later time in the *Messenger.* For the moment, we want to explain what was attempted with the observations of quasars, programmes of interest mainly to Boksenberg, Danziger, Fosbury and Goss.

Quasar Absorption Lines, "Intrinsic" or "Cosmological"?

During the past decade there have been known to exist many narrow absorption lines in the spectra of quasars. Due to more intensive studies in recent years it is known that these lines, which occur more frequently in the distant quasars, are much more prodigious in number at wavelengths shortward of Lymann α than at longer wavelengths. Only because one observes distant quasars with large redshifts (probably due to the cosmological expansion of the universe) can one see Lyman α redshifted from a rest wavelength of 1215 Å into the optical wavelength region near 4500 Å.

The origin of these absorption lines, i.e. the region in space where they are formed, and the physics of their origin has been a debating point in astronomy during the past decade. There are two main competing schools of thought which we shall call the "intrinsic" and the "cosmological". One school believes that the lines are formed in material that is physically related to the quasar in whose spectra the lines are observed. This material, while being close to the quasars, is hypothesized as matter ejected or expelled from the quasar. The other school of thought believes that they are mostly Lyman α lines formed in intergalactic gas clouds possibly associated with galaxies at large distances, i.e. cosmological distances, from the quasar, but lying in the line-of-sight to the quasar.

Why is it important to clarify which of these ideas is correct? If the first point of view is correct then the study of these absorption lines provides a means of probing the immediate or even partially internal environment of quasars; if the second is correct one has a means, however limited, for studying intergalactic gas, the amount of it, and possibly its chemical composition, both important parameters in the study of cosmology. In principle one ought not to allow preconceived preferences to obscure one's perception of reality. At the risk of seeming to contravene this dictum before discussing further evidence, one could say that the second hypothesis might in the long run be more interesting if true, because at last, one might have a means of probing what hitherto has been observationally a very elusive intergalactic medium. But in addition one will be able to probe intergalactic gas clouds and galactic halos at distances (and therefore ages) that are in cosmological terms significantly different (and younger) than the nearby galaxies.

Since week-long meetings are given to discussing this subject, one can give here only the briefest of summaries concerning the evidence for and against the two theories.

1. It is difficult to understand empirically in the "intrinsic" hypothesis how the absorption lines can have such small velocity dispersions when the indicated velocity of ejection from the quasar is in some cases relativistic. This poses no special problem for the "cosmological" theory since narrow absorption lines have already been found in halos of galaxies.

2. It is claimed that there is a non-random distribution of the absorption line velocities seen in quasars. While the reasons are not explained physically in detail in the "intrinsic" theory, such a phenomenon is difficult to understand in the "cosmological" case. There is not, however, agreement about the reality of this non-randomness, and the debate continues with strong counter-claims of evidence for randomness.

3. There is also a claim for the frequent occurrence of an absorption (and emission) line redshift system at $Z = 1.95$. If it is real it is difficult to understand within the "cosmological" framework.

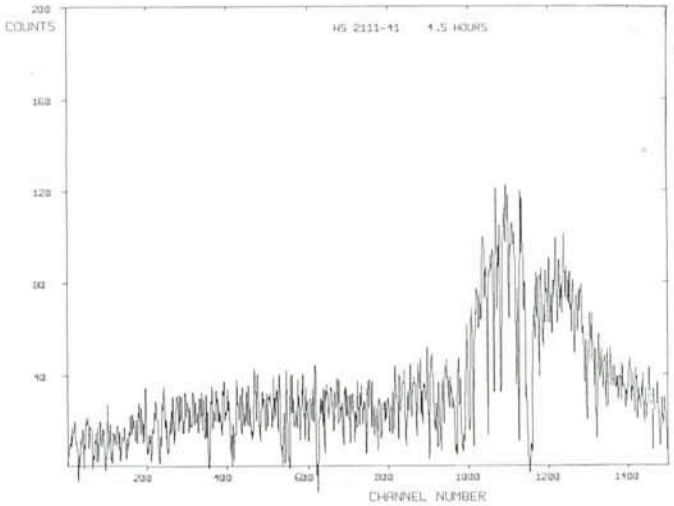

Fig. 2: *A tracing of the spectrum of H-S 2111-41, resulting from $4^{1}/_{2}$ hours observing, with the sky light subtracted. Redshifted Lyman α is the broad emission feature to the right. Narrow absorption lines are seen over most of the spectrum.*

4. Claims for the occurrence of other special wavelength ratios have been interpreted in the "intrinsic" theory as evidence for "line-locking". In principle "line-locking" requires that the expelled gas have absorption line features which, when Doppler-shifted relative to the velocity system of the parent quasar, correspond in wavelength to that of an emission feature, possibly an absorption feature or absorption edge.

While there is no reason to expect this phenomenon in the "cosmological" theory because of the very diffuse radiation fields in intergalactic clouds, it is also theoretically difficult to understand whether there would be sufficient energy to make this a viable mechanism in the "intrinsic" theory. In any case the reality of these special wavelength ratios has been challenged at various times.

5. The absence of absorption lines formed from fine structure levels in ions represents a major problem for the "intrinsic" theory. One might have expected that in the higher radiation fields and/or higher density regions near quasars such fine structure levels would be populated. Their absence poses no problems for the "cosmological" theory since in remote clouds the radiation density and particle density would be low. Indeed even their possible presence in galactic halos would not invalidate the "cosmological" theory, since denser clouds in our own galaxy produce such lines.

6. The presence of H and K Ca II absorption lines seen in the spectrum of the quasar 3C 232, but having the velocity of the bright galaxy NGC 3067 behind whose halo 3C 232 is situated, makes a strong case for the "cosmological" theory. These observations of Boksenberg and Sargent (*Ap.J.* **220,** 42, 1978) and the 21 cm radio line observations in the same region and in other extended galaxies demonstrate that sufficient material exists in the extended halos of normal galaxies to give rise to absorption lines of the type seen in distant quasars.

This does not exhaust all of the evidence and ideas used in the debate on narrow absorption lines in quasars, but it provides a basis and rationale for the IPCS observations made with the 3.6 metre telescope at La Silla.

High-resolution Observations of Faint Quasars

Figure 2 shows a spectrum of the distant quasar Hoag-Smith 2111-41 resulting from 4½ hours of integration at a spectral dispersion of 30 Å/mm obtained at La Silla. The ordinate shows real photon counts for each picture element accumulated over the total integration time. Therefore the detected photon arrival rate is on average approximately 10 per picture-element per hour. Having a visual magnitude of 20 this is the faintest quasar ever observed at such a high dispersion.

One can see on the right the broad emission feature of Lyman α redshifted ($Z = 2.64$) to 4420 Å. Most of the sharp absorption lines will be the narrow Lyman α lines discussed above. Note that many of the lines have zero intensity at their centres, indicative of considerable absorbing material in the clouds. The lines in many cases are not resolved which will help put a significant upper limit on their widths.

Spectroscopic material of this quality is relevant to and exemplifies the discussion of items 1, 2, 4 and 5 above. In particular H-S 2111-41 is faint for its redshift, and was chosen because of that. If the "intrinsic" hypothesis is correct, one ought to see differences in the nature of the absorption-line spectrum (velocity distribution and strength of the lines) compared to the spectrum of a quasar with similar redshift but of greater luminosity. There is accumulating evidence that no significant differences exist in such comparisons, and hence the evidence goes against the "intrinsic" idea.

Another important observation at La Silla relevant to item 6 above was the observation of the $17^{\mathrm{m}}.5$ quasar PKS 2020-37. It falls near but outside of a foreground galaxy of uncertain (spiral?) type. PKS 2020-37 (redshift $Z = 1.1$) was observed for 5 hours with the IPCS at a spectral dispersion of 30 Å/mm. The H and K Ca II absorption lines which are reasonably narrow, have been detected in the spectrum of the quasar but with the redshift of the nearby galaxy which was determined during the same period.

This supports the results and conclusions discussed as item 6 above, and reinforces the notion that galaxies have extended halos and can contribute to the narrow absorption lines seen in distant quasars. Figure 3 shows a tracing made at the telescope revealing the broad H and K lines in the spectrum of the galaxy and a tracing revealing the narrow lines in the spectrum of the quasar at almost the same wavelength.

Thus, the two observations discussed above serve to exemplify classes of almost limiting astronomical problems that are accessible to European astronomers using the 3.6 metre telescope equipped with a modern detector.

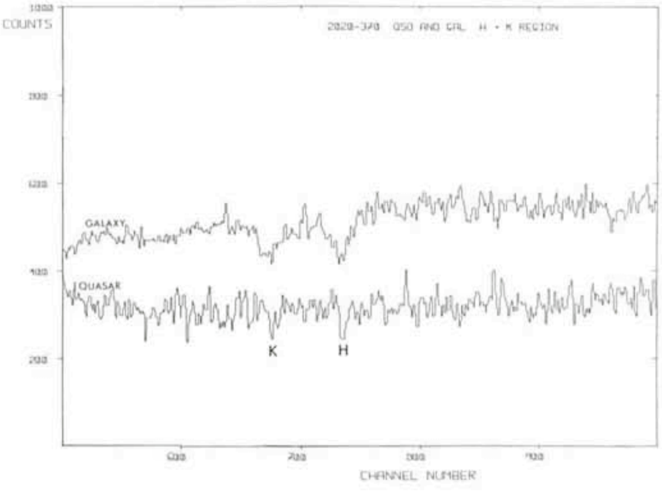

Fig. 3: *The upper tracing is that of the foreground galaxy discussed in the text. One sees stellar (and possibly interstellar) Ca II H and K. The lower tracing is the spectrum of PKS 2020-37 showing interstellar H and K at the same wavelength (or velocity) as the H and K in the galaxy.*

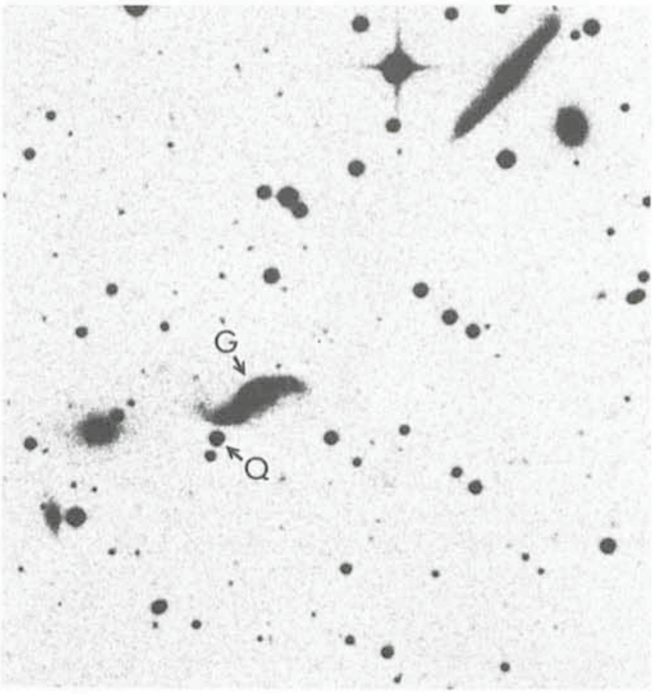

Fig. 4: *A direct photograph of the field of PKS 2020-37 reproduced from a IIIa-J SRC Schmidt survey plate. Arrows indicate the quasar PKS 2020-37 and the nearby galaxy.*

INFORMATION FOR VISITING ASTRONOMERS

Photographic Plate Service on La Silla

Recent analysis covering a period of 18 months has shown that various of the photographic emulsions offered to the visiting astronomers are never requested.

Since offering a photographic emulsion implies regular quality control, renewal of stock, etc., a considerable economy can be realized if emulsions that are never requested and used are suppressed.

As a consequence, only the emulsions listed below will be offered to the visiting astronomers as from January 1, 1979.

IIa-O, IIa-D, IIIa-J, IIIa-F, 103a-D, 098-02, IV-N.

Only for these emulsions will quality control tests be performed and the stock renewed regularly.

The emulsions 103a-E, 103a-F, 103a-G, 103a-O and I-N will only be available as long as the present stock lasts. Quality control tests will not be made any longer for these emulsions.

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