exposures appropriately subtracted from the narrow band images allow an even better view of the line emission region around this object. The image shown in Figure 4 also illustrates graphically the potential of this technique as both previously known and unknown bright and faint features throughout the inner nebulosity can be readily discerned and accurately measured down to approximately one arcsecond of the Mira without much trouble. Especially obvious is the famous jet made up of several knots extending in a generally northern direction towards the bottom of the figure but faint wisps, knots, and a counter jet extending to the limits of our image in the southwest are also clearly discernible against the sky background. Direct comparisons of images taken in the light of several emission lines of elements in varying ionization stages show remarkable differences revealing a complex temperature and electron density structure within the nebulosity. These data should prove quite useful in establishing and elucidating the mechanism responsible for the observed activity in this enigmatic system.

More observations of a number of interesting objects with this technique at La Silla are being planned for the near future. The authors welcome suggestions from readers of this publication for improvements, additions to and ideas for new applications of the basic technique described here. If you have a favourite object that might benefit from an investigation with our coronograph, please contact us so that we may explore the feasibility of a joint effort.

Acknowledgements

None of this work would have been even remotely possible without the enthusiastic support of Daniel Hofstadt and his operations group at La Silla, in particular Paul Le Saux, Gerardo Ihle, Michel Maugis, and A. Urquieta. We are especially grateful to Anatoli Evzerov for construction and calibration of the coronograph, to B. G. Taylor, F. Macchetto and H. S. Stockman at ESA and the ST ScI for constant encouragement and financial support, to P. Bély, R. Prangè, R. de Grijp and A. Vidal-Madjar for assistance in many aspect of this programme. We also wish to thank S. di Serego Alighieri for the flat field he kindly supplied and F. Noriel, for expert editorial assistance.

References

1. Burrows, C., F. Paresce, and A. Evzerov, Instrumentation and Data Reduction Techniques for the Detection of Circumstellar Material, *B.A.A.S.*, **18,** 1027, 1986.
2. Paresce, F. and C. Burrows, Wide Band Imaging of the Beta Pictoris Circumstellar Disk, *B.A.A.S.*, **18,** 1027, 1986.
3. Gillett, F.C., "IRAS Observations of Cool Excess around Main Sequence Stars", in *Light on Dark Matter,* ed. F.T. Israel, D. Reidel, **61,** 1986.
4. Solf, J., and H. Ulrich, "The structure of the R Aquarii Nebula", *Astron. Astrophys.*, **148,** 274, 1985.

Search for Supernovae in Distant Clusters of Galaxies

L. HANSEN, Copenhagen University Observatory
H. U. NØRGAARD-NIELSEN, Danish Space Research Institute
H. E. JØRGENSEN, Copenhagen University Observatory

Supernovae and Cosmology

One of the main problems of cosmology today is to determine whether the universe is open or closed, i. e. if it will continue to expand for ever or if it will recollapse in a far future. The classical attempt to settle the question is to observe some kind of standard candle out to large redshifts, z, and measure the positions of the objects in the Hubble diagram (log (z) versus apparent magnitude). The brightest galaxies in rich clusters have for example been used for this purpose, but significant evolution corrections are expected which are hard to determine with the required precision, and no firm conclusion has been reached as yet.

A more promising candidate for a standard candle is the type I supernova (SN I). SN I events show spectra and light curves which are very alike, and the intrinsic scatter in peak brightness is less than 0.3 magnitude. SNe I occur in spirals as well as in elliptical galaxies. Events in elliptical galaxies are not expected to suffer from any significant interstellar extinction in the parent galaxy, which would otherwise be difficult to correct for with the necessary accuracy. SNe I near maximum rival with galaxies in brightness ($M_V = -19.7$ for $H_o = 50\ km\ s^{-1}\ Mpc^{-1}$). At a redshift of $z = 0.5$ the expected peak magnitude in V is about 22.7 depending on K-correction and the cosmological model assumed. For Friedmann models with $q_o = 0.0$ (open) and $q_o = 0.5$ (transition to closed) the difference is 0.28 magnitude. A modest number of SN I events could therefore provide the evidence for an open or closed universe. Notice, that neither H_o nor the absolute peak magnitude need to be known.

SNe I as standard candles are not supposed to be plagued by uncertain corrections, as are other candidates. The K-corrections can be accurately determined from nearby SNe I, and no change of the supernova characteristics with look-back time is expected.

A well-developed theoretical model for SNe I assumes the deflagration of a white dwarf which is pushed to the Chandrasekhar limit by mass accreted from an evolving companion. In this picture virtually the same event happens every time with no variation of mass and chemical composition. This explains the reproducibility of the phenomenon.

It has recently been realized, however, that a subgroup named SNe Ib exists in spiral galaxies. This subgroup is characterized by the absence of the λ 6150 absorption feature in the spectra. SNe 1b will hardly cause any major problem for cosmological applications as they are about $1^{m}.5$ fainter than the majority of SNe I. If they are not discriminated by other means they may be discarded because of gross deviations from the predicted apparent magnitude.

The Search Programme

With the launch of the Hubble Space Telescope (HST) it will become possible to do photometry on distant SNe to magnitudes fainter than 25, and the cosmological goal is then within reach. The first and difficult problem is to find the SNe I. G. A. Tammann (1) estimates that a Coma-like cluster at $z = 0.5$ will show a rate of 0.5 SN I per year within the field of the Wide Field Camera of the HST. However, observing time on the HST is very expensive, and fortunately the job can be performed from the ground. The Danish 1.5-m telescope at La Silla is ideal for the task. The observing time is

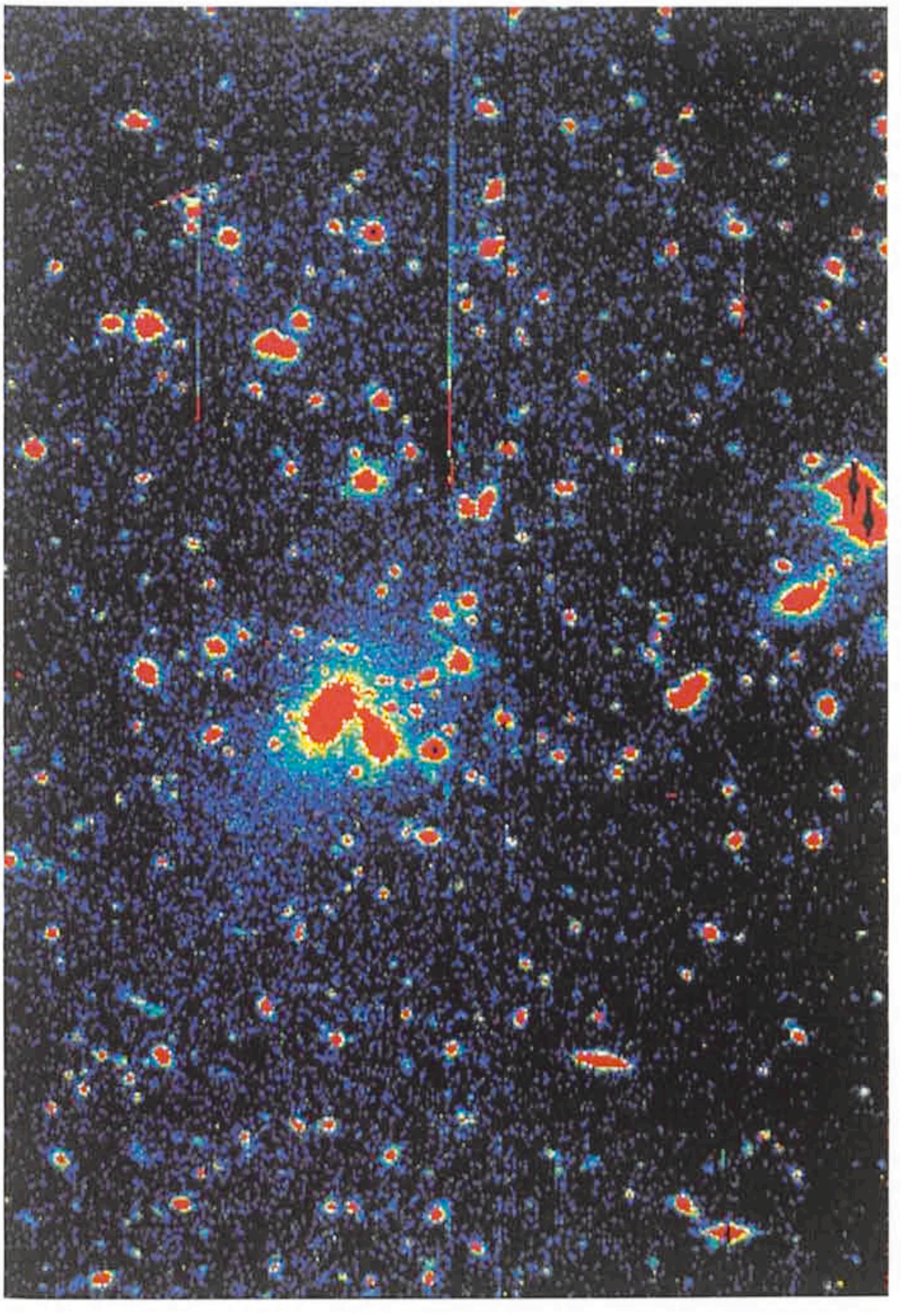

Figure 1: *A 1-hour CCD exposure in the V-band of the cluster AC 114 (z = 0.31) obtained with the Danish 1.5-m telescope. The seeing was 0".9 (FWHM). The field is 2'.5 × 4'. Most of the objects seen are galaxies.*

relatively cheap, the field of view somewhat larger than for the Wide Field Camera, it has a large number of nights with good seeing, and it is known for its high image quality. Photometry on stars of 24^m can be made with a CCD camera from 30-minute exposures (2). As explained in the text of Figure 2 we have performed realistic simulations of a supernova event and demonstrated the feasibility of our methods. We have, therefore, initiated a major campaign in September 1986 with the aim to find distant SNe I in elliptical galaxies.

Our plan is to observe rich clusters of galaxies with redshifts from 0.2 to 0.6 if possible each month from September through April with the Danish 1.5-m telescope. A SN I remains within 1 magnitude of its maximum brightness for about 25 days, but because of relativistic effects (time dilation) time intervals are stretched by a factor $1 + z$ when observed at the redshift z. This means that for $z = 0.5$ and less a SN I remains above our detection limit of approximately 24^m for more than a month, and it cannot avoid discovery if it occurs within the half year period of our watch. If, say, 20 clusters are searched every month we expect 5 SNe I per year to be found.

The Procedure

During the last part of 1986 we observed using the old ESO CCD camera with a pixel size corresponding to 0".47. The old CCD has many defects and a rather large read-out noise. From 1987 we will use a new one with twice as much spatial resolution, few defects and reduced noise. Of great importance is also the availability of the ESO image processing system, IHAP.

Our exposure time is 45 minutes to 1 hour, and generally we use the V-band, although some exposures have been obtained in Gunn R. However, interference fringes from night sky emission lines are very prominent in the R-band and hard to correct for in a satisfactory way.

As soon as a new exposure has been started, the previous exposure is reduced. This is only a matter of a few minutes. We then start a large BATCH procedure that compares the new images with a standard exposure of the field. A number of common objects are identified, and the new image is rotated to coincide with the standard within 0.05 pixel. The seeing is determined, and the image of best seeing is Gauss-smoothed in order to match the seeing of the other. After scaling the intensity of the objects to the same level in the two images the standard is subtracted from the new, and a difference image is obtained.

The next step is the exciting evaluation of the difference image. The standard frame is displayed in the first quadrant of the colour screen, while the three other quadrants show 1/15 of the field in the new, the standard, and the difference image. With the special colour scale we use, the noisy difference image will look greenish. Pixel-values deviating more than about 2.5 σ will appear either black or red. A stellar image of 24^m and average seeing 1".5 covers some 10 pixels (old chip). If such a star appears between two exposures it will stand out very prominently in the difference as black or red.

When we examine the field in 15 steps we notice a number of black or red features from well-known bad pixels and columns of the CCD. Often we find that a few stars are too bright to cancel when the difference between two large count-numbers are taken. These stars are then checked for variability by one or more procedures for magnitude determination. We will also find a number of cosmic (radioactive) events in the CCD chip. This is a problem which worries our sceptic colleagues more than it worries us. Cosmics have a very narrow energy distribution, and the large majoritiy of events are easily distinguished

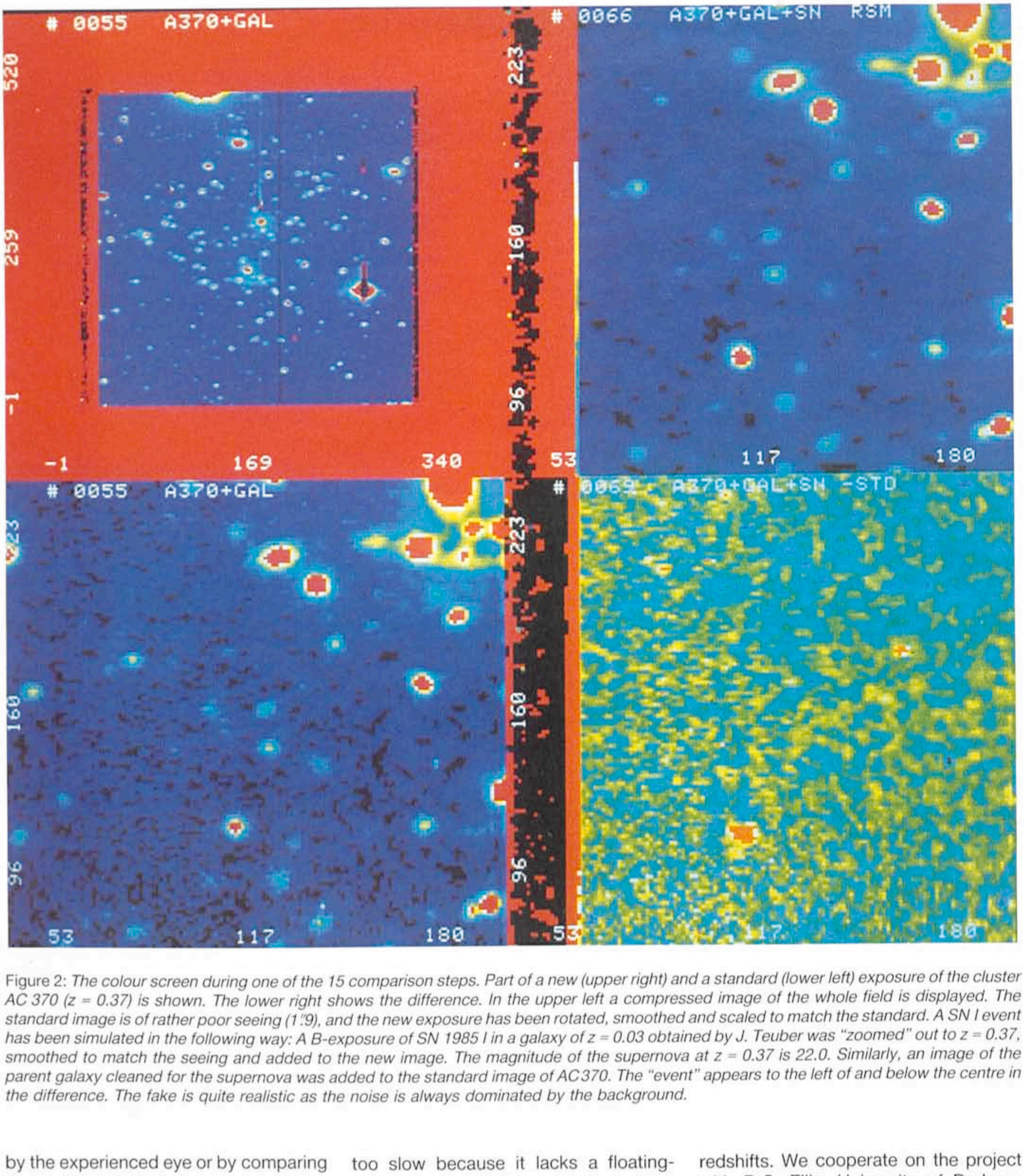

Figure 2: *The colour screen during one of the 15 comparison steps. Part of a new (upper right) and a standard (lower left) exposure of the cluster AC 370 (z = 0.37) is shown. The lower right shows the difference. In the upper left a compressed image of the whole field is displayed. The standard image is of rather poor seeing (1."9), and the new exposure has been rotated, smoothed and scaled to match the standard. A SN I event has been simulated in the following way: A B-exposure of SN 1985 I in a galaxy of z = 0.03 obtained by J. Teuber was "zoomed" out to z = 0.37, smoothed to match the seeing and added to the new image. The magnitude of the supernova at z = 0.37 is 22.0. Similarly, an image of the parent galaxy cleaned for the supernova was added to the standard image of AC370. The "event" appears to the left of and below the centre in the difference. The fake is quite realistic as the noise is always dominated by the background.*

by the experienced eye or by comparing the profile with that of a star.

In rare cases cosmics may simulate a SN event, e.g. by falling on top of an object in the image. Therefore, a promising SN candidate must be confirmed. We planned that the whole comparison procedure should take less than 30 minutes. A candidate can then be confirmed by a second observation the very same night. This is important for the follow-up. In practice it is no problem to do the comparison within 30 minutes – at the computer centre! The computer on the Danish 1.5-m turned out to be too slow because it lacks a floating-point processor. At present we must accept a delay of one day, which may have sad consequences if a candidate appears on the last night of observing.

Preliminary Results

Until now we have had 5 runs on the Danish 1.5-m. We have paid most attention to the clusters in the range $0.2 < z < 0.4$ because (a) HST is not yet in orbit, (b) we want to be sure of our methods, and (c) ground-based spectroscopy can be made for SNe I at these redshifts. We cooperate on the project with R.S. Ellis, University of Durham, and W. Couch, Anglo-Australian Observatory. They have supplied us with a number of distant clusters, and they have obtained over-head time on the anglo-Australian 3.9-m telescope and the Isaac Newton 2.5-m telescope with the possibility to do spectroscopy with short notice of events down to about $V = 22^m$.

Our survey supplies us with a steadily increasing list of faint blue variable objects. One of the objects for example is apparently an active galaxy possibly at the cluster redshift ($z = 0.3$). Most likely the majority of the variables are faint QSO's roughly in agreement with statistics of QSO's around 22^m (3) predicting approximately 1/3 object per CCD-frame.

After the first 5 runs we have been able to do 48 comparisons of fields. The expected number of SN I events in 2 according to the supernova-rate given above, but we have found non until now. Why? Part of the answer may be that although many of the clusters are really impressive some are less rich than Coma. One should also notice that the local supernova-rate is uncertain with a factor of 2 according to Tammann (private communication). Further, there is at present no evidence of the rate at earlier epochs of the universe.

This campaign will at the very least put important limits on the supernova rate at cosmological distances. A valuable spin-off will also be the nice selection of high quality cluster images, because sub-arcsecond seeing is not an unusual event at the Danish 1.5-m. However, the primary purpose is to discover SNe. The first season has convinced us that our technique works. If a supernova appears we will find it!

References

(1) Tammann, G.A.: 1979, in *Astronomical Uses of the Space Telescope,* proceedings from the ESA/ESO workshop, ed. Macchetto et al.

(2) Stobie, R.S., Sagar, R., and Gilmore, G.: 1985, *Astron. Astrophys. Suppl.* **60,** 503.

(3) Koo, D.C., Kron, R.G., and Cudworth, K.M.: 1986, *Publ. Astron. Soc. Pacific* **98,** 285.

NEWS ON ESO INSTRUMENTATION

On the Rates of Radiation Events in ESO CCDs

Radiation events (cosmic rays and local radiation) stand out in exposures taken with thinned CCD devices as spikes covering 1–4 pixels. Their intensities vary from about one hundredth electrons (the lower detection limit) above the background to a few thousand for the most energetic events. In front-illuminated, thick CCDs energetic particles can produce a short track of electrons as they cut diagonally through the silicon layer.

The number of radiation events per unit time is such that they contribute in a significant way to the noise in the astronomical data extracted from the CCD frames. In direct imaging they can be distinguished from stars on the basis of the point spread function. The problem is more serious for spectroscopic observations. In long-slit spectra where the dispersion direction is aligned with the rows or the columns of the CCD, the area where the sky is sampled can be efficiently cleaned with a median filter running in a window which moves perpendicular to the dispersion (RBLEMISH command in the ESO IHAP data reduction system). For spectra in the echelle format, the only effective way to identify the radiation events is by comparison of two, or possibly more, spectra taken with an identical configuration. Pixels affected by a cosmic ray in a single exposure can be sorted out and rejected when their signal value is compared with that measured on the average frame. Routines operating on this basis exist in both the MIDAS and IHAP data analysis systems. To achieve good cleaning without degradation of the astronomical data, it is necessary that parameters like sky transparency, seeing and sky emission line intensities do not vary too much during the sequence of exposures.

Billions of radiation events have been duly recorded by CCDs used for astronomy in the last 10 years, but being considered essentially a nuisance, little has been published on their rate or energy distribution. As a step towards a better understanding of this phenomenon, we have counted radiation events in a number of long (typically one hour) dark exposures obtained in the last four years with ESO CCDs both in the Garching lab and at different instruments at La Silla. We list in Table 1 the event rates derived from these exposures. Typical values for some of the ESO CCDs have been reported occasionally in the Operating Manuals of the instruments (CASPEC, EFOSC). The data collected here are more systematic and give the possibility to draw a few simple conclusions. A batch programme based on a filtering technique was used to identify the events with intensities larger then about 5 σ of the background noise. The rates are not very sensitive to the value of this lower cut, most of the events being of sufficient energy to be detected. No systematic difference is found between measurements at Garching and La Silla, with variations being observed in both directions at the 10–20 % level. The rates do not seem to correlate with the telescope or the instrument type. It is worth noting that

Table 1: *Radiation event frequency in CCDs*

ESO CCD Number	Type	Telescope	Instrument	Number cm^{-2} min^{-1}	No. Exposures
3	RCA SID 501 EX (thinned)	3.6 m	CASPEC	5.8	3
3	RCA SID 501 EX (thinned)	3.6 m	EFOSC	5.2	5
3	RCA SID 501 EX (thinned)	2.2 m	B & C	5.7	3
5	RCA SID 501 EX (thinned)	3.6 m	CASPEC	6.6	4
5	RCA SID 501 EX (thinned)	2.2 m	Imaging	6.1	3
6	GEC 8603⁺	2.2 m	B & C	1.2	2
7	GEC 8603⁺	2.2 m	B & C	2.1°	3
7	GEC 8603⁺	3.6 m	CASPEC	2.3°	2
8	RCA* SID 006 ES	3.6 m	EFOSC	5.2	2
12	TEK 512 M –11⁺	3.6 m	CASPEC	1.4	3

* 15 μm pixels ⁺ Coated to improve UV-blue sensitivity
° Possibly contaminated by electronic noise