Coordinated Multiband Observations of Stellar Flares

M. Rodonò[1], B. H. Foing[2], J. L. Linsky[3], J. C. Butler[4], B. M. Haisch[5], D. E. Gary[6] and D. M. Gibson[7]

[1] *University of Catania, Italy*
[2] *European Southern Observatory, La Silla, Chile*
[3] *Joint Institute for Laboratory Astrophysics, Boulder, USA.*
[4] *Armagh Observatory, Northern Ireland, U.K.*
[5] *Lockheed Research Laboratory, Palo Alto, USA*
[6] *California Institute of Technology, Pasadena, USA*
[7] *New Mexico Institute of Mining and Technology, Socorro, USA*

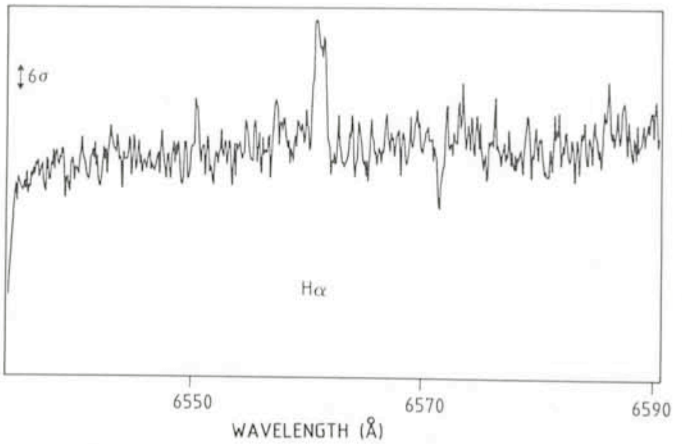

Fig. 1: *High-resolution spectra of the Hα line for Prox Cen taken at the CES, obtained by combination of 8 spectra of exposure 15 min obtained during the monitoring of the star out of any noticeable flare.*

Activity and Flare Stars

Dedicated observations of active stars have suggested a solar-type scenario with activity levels up to several orders of magnitudes higher than the Sun. Activity phenomena have been observed particularly in red dwarfs and subgiants (Byrne and Rodonò 1983): photospheric spots, overlying plages, coronal structures, flaring events, have been inferred from the modelling of the observations, in analogy with solar phenomena. In particular, the U Ceti-type stars (or dwarf M stars presenting the Balmer lines in emission, Fig. 1) show that even at quiescent phases their chromospheres, transition regions and hot coronae, are enhanced in comparison to the Sun. These stars also show evidence of flare events involving variations in the continuum and emission line fluxes over a wide range of wavelengths, from all the levels on the atmosphere, from the photosphere to the corona, and with typical rise and decay times of 10 and 10^3s respectively. Simultaneous photometry and spectroscopy of flares have shown emission line enhancements of different species to take place on different time scales and to last 10–100 times longer than the continuum flash-phase at flare maximum. Line broadening indicating a turbulent motion of 10^2–10^3 km s^{-1} have been inferred from spectroscopic observations. However, many questions remain unanswered about the vertical structure in temperature and pressue of the quiescent, active and flaring chromosphere and corona. The basic physical processes of flares which have been exhaustively studied for the Sun, such as the triggering, the energy budget, the dynamics of the cooling (by radiation, conduction or expansion) have not been elucidated in the stellar case.

Coordinated Multiband International Campaign

To answer these basic questions, a few years ago four groups, at Catania University, JILA (Boulder), Armagh Observatory and Lockheed Research Laboratory (Palo Alto) jointly organized international observation campaigns of flare stars from both satellite and ground-based observatories. Such were the simultaneous IUE and Einstein observations of a major flare of Prox Cen on August 20, 1983 (Haisch et al., 1983). The first time ESO took part in the observation campaign was in October 1983, then in March 1984 and in December 1984, this included simultaneous coverage at IUE, VLA and other ground-based facilities (Rodonò 1983), and in December 1984 concurrent EXOSAT observations were also obtained.

The March 1984 campaign involved IUE, VLA and four telescopes at La Silla: the 3.6 m telescope was equipped with the Boller & Chivens spectrograph with the IDS in the 3600–4300 Å range, to allow coverage from the Balmer discontinuity to the Hγ line, with a time resolution of 1 minute and with a spectral resolution that enables measurement of possible shifts and the broadening of emission lines; the CES connected to the 1.4 m CAT telescope provided high spectral resolution of the Hα line with 15-min time resolution; the infrared photometer at the 1 m telescope was operated in fast-speed photometry mode in the K band and, finally, the 50 cm photometer in the U-band and Hα ($\Delta\lambda$ = 20 Å) was used with 10-s time resolution.

The IUE satellite, operated round the clock continuously by European and American collaborators, alternated multiple exposures on the short and long wavelength cameras.

We were fortunate to obtain telescope time at ESO before the IUE observations which permitted us to have a dress rehearsal before the actor/observers went on stage. All the collaborators in the campaign were to follow a schedule for observing the selected active stars. We began with the 50 cm photometer and, as we saw the pen of the strip-chart recorder suddenly rise, we felt the first surge of excitement. "This is a flare", the expert stated.

The excitement increased the following nights as we also recorded simultaneous flare events at the other ESO telescopes. Then the international campaign began. Several flares were observed during the course of our coordinated observations on YZ CMi, Prox Cen and AD Leo.

The 1984, March 28 Flare of AD Leo

On 1984, March 28, we recorded an intense flare on AD Leo at 03^h22^m UT. The observing facilities covered a range from 2000 Å to 20 cm (cf. Fig. 2), including, for the first time, infrared observations at $>1\,\mu$m wavelength. As shown by the U-band, 10-s integration light curve, the flare has a complex structure and a relatively long duration (>30 min). The brightness peak (with magnitude excess $\Delta U = 2.1$) was followed by several secondary peaks. The infrared K-band (2.2 μm) observations gave the first evidence of faint but definite negative events in coincidence with an optical flare. The Hα narrow-band photometry shows an Hα precursor to the flare and a

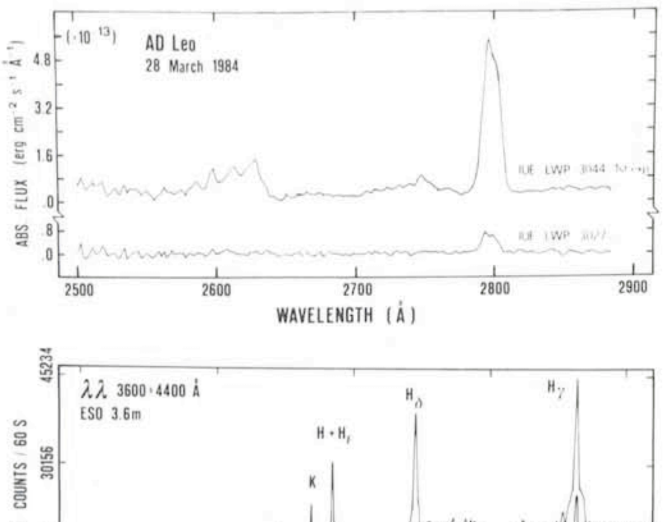

Fig. 2: *The 1984, March 28 flare of AD Leo observed simultaneously with optical and IR photometers (lower panel), optical spectrographs (middle panel) and the IUE. The flare was also detected at 2 cm and 6 cm with the VLA. The IDS spectra S7 and S9 in the middle panel were obtained just before and during the rising phase of the main flare, respectively. In the upper panel, the quiescent IUE spectrum LWP 3027 is also shown for comparison. The IR curve shows the first evidence of a negative event in coincidence with an optical flare.*

longer relaxation of energy release in Hα than in the U-continuum. The comparison between the two selected 60-s exposure uncalibrated IDS spectra, obtained just before and during the flare-rising phase including the flare peak, is striking. They show a strong enhancement in the continuum and line flux, a broadening of Ca II and Balmer emission lines, the appearance of higher members of the H Balmer series and an He I emission line at λ4026 Å. IDS spectra of 60 s were obtained during the whole event and will be presented in a subsequent paper.

The IUE LWP spectrum obtained during the last secondary optical peak shows an enhancement of the continuum, the Mg II doublet and of the Fe II blend (λ2600 Å) that are remarkable. It is compared in Fig. 2 to a quiescent spectrum taken on March 26.

The microwave observations with the VLA show a flux of 32 mJy at 2 cm and 16 mJy at 6 cm, but no detection at 20 cm. The 2-cm event develops faster than the 6-cm one and follows rather close in time the optical light curve shape with a maximum delay of 1–2 minutes. The 6-cm event is rather slow and the two major peaks occur with 2–3 minutes delay relative to the 2-cm event. Also, the flux maximum at 6 cm is reached during the second major peak, which is fainter at all of the other wavelengths (see Rodonò et al. 1984, for more detail).

In March, 1984, several other stellar flares on AD Leo, Prox Cen and YZ CMi were also observed simultaneously from La Silla, IUE and VLA. In December 1984, we had for the first time simultaneous coverage with EXOSAT of several flares detected also in the Balmer lines with the 3.6 m + IDS. The relationship between the X-ray flux and the Balmer or He I lines during the flare will be described in a forthcoming paper.

Conclusion

For the first time, multiband data on stellar flares were obtained over a range from 1200 Å to 20 cm. A quantitative analysis of the flare radiation vs. λ, and of its temporal behaviour in the different spectral bands will allow to test the available flare models and to study the dynamical response of the plasma to the flare impulse from the photosphere to coronal levels. Stellar flares being sporadic and non-recurring phenomena, coordinated simultaneous multiband observations involving both satellite and ground-based facilities are essential for their study. With the present report we intend to demonstrate the importance and feasibility of such programmes.

We would like to thank ESO for letting us schedule this coordinated campaign, the La Silla staff for their efficient technical and scientific assistance, and the observers who participated in the campaign.

References

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Haisch et al., 1983, *Astrophysical Journal* **267,** 280.
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Visiting Astronomers

(April 1 – October 1, 1985)

Observing time has now been allocated for period 35 (April 1 – October 1, 1985). As usual the demand for telescope time was much greater than the time actually available.

The following list gives the names of the visiting astronomers, by telescope and in chronological order. The complete list, with dates, equipment and programme titles, is available from ESO-Garching.

3.6 m Telescope

April: Appenzeller/Östreicher, D'Odorico/Miley, Hunger/Heber/Schönberner/Drilling, Krautter, Pottasch/Bouchet/Dennefeld/Karoji/Belfort, de Jong/Lub/de Grijp, Mouchet/Bonnet-Bidaud/Motch/Schmider, Larsson S./Larsson B., Ilovaisky/Angebault/Chevalier/Motch, Meikle/Graham/Andrews, Courvoisier.

May: Courvoisier, Pottasch/Bouchet/Dennefeld/Karoji/Belfort, Balkowski/Boisson/Durret/Rocca-Volmerange, van der Hucht/Thé, van der Hucht/de Loore/Hoekstra, Schönberner/Hunger, Ulrich/Iye, Finkenzeller/Basri, Kudritzki/Simon/Méndez, Koester/Weidemann, Baade/Danziger, Mathys/Manfroid, Mathys/Stenflo.

June: Mathys/Manfroid, Mathys/Stenflo, Spite, F./François/Spite, M., Gratton/Ortolani, Nesci/Cacciari, Barwig/Schoembs/Kudritzki/Ritter, Moorwood/Cetty-Véron, Azzopardi/Lequeux/Rebeirot, Brahic/Sicardi, Azzopardi/Lequeux/Rebeirot, Oliva/Moorwood.

July: Moorwood/Glass, Le Bertre/Epchtein/Nguyen-Q-Rieu/Sèvre, Habing/Lintel Hekkert/van der Veen, Houziaux/Heck/Manfroid, Grosbøl/Brosch/Greenberg, Azzopardi/Lequeux/Rebeirot, Alcaíno/Liller, Léna/Enard/Lacombe, Zinnecker/Chelli/Perrier, Perrier/Chelli/Léna/de Muizon.

August: Perrier/Chelli/Léna/de Muizon, Preite-Martinez/Persi/Ferrari-T./Pottasch, de Muizon/d'Hendecourt/Perrier, Pietsch/Krautter/Lewin/Pedersen/Sztajno/Trümper/van Paradijs, Danziger/Binette/Matteucci, Jörsäter/Lindblad/Athanassoula, Fosbury/Danziger/Tadhunter, Nelles/Elst, de Grijp/Lub/Miley.

Sept.: Angebault/Chevalier/Hurley/Ilovaisky/Motch/Pedersen, Heckman/Miley, Butcher/Buonanno, Pizzichini/Pedersen, Shaver/Cristiani, Sol, Bergeron, Renzini/D'Odorico/Greggio, Bergeron/D'Odorico, Chmielewski/Jousson.

1.4 m CAT

April: Butcher, Giovannelli/Vittone/Rossi/Bisnovatyi-Kogan/Sheffer/Lamzin, Reimers/Hempe/Toussaint, Ruiz/Melnick/Ortiz, Doazan/Thomas/Boudonneau, Megessier.

May: Megessier, Gredel/Münch, Danks/Lambert, Holweger/Steffen, Wolf/Stahl/Leitherer/Bastian, Spite, M./Spite, F./François.

June: Spite, M./Spite, F./François, Heske/Wendker, Foing/Bonnet/Crivellari/Beckman/Galleguillos/Lemaire/Gouttebroze, Barbuy, Foing/Bonnet/Crivellari/Beckman/Galleguillos/Lemaire/Gouttebroze, Leitherer/Stahl/Wolf/Zickgraf, Baade/Peters/Polidan, Baade/Ferlet.

July: Baade/Ferlet, Ferlet/Vidal-Madjar/Gry/Laurent, Giovannelli/Vittone/Rossi/Bisnovatyi-Kogan/Sheffer/Lamzin, Crane/Mandolesi/Hegyi, Gustafsson/Andersen/Edvardsson/Nissen.

August: Gustafsson/Andersen/Edvardsson/Nissen, Stalio/Porri/Polidan/Smith, Papoular/Catala/Felenbok, Grewing/Baessgen/Barnstedt/Gutekunst/Bianchi.

Sept.: Lührs, Lindgren/Ardeberg/Maurice, Barbieri/Benacchio/Nota.

2.2 m Telescope

April: Pottasch/Bouchet/Dennefeld/Karoji/Belfort, v.d. Hucht/Perryman, Perryman/Jakobsen, Rosa/Benvenuti/Savage, Motch/Courvoisier/Pedersen/Pakull/Ilovaisky, Perryman/Shaver/van Heerde/Macchetto/di Serego Alighieri, Macchetto/Miley/Perryman/Colina/di Serego Alighieri, Miley/Macchetto/di Serego A./Perryman, Bertola/Zeilinger, Ilovaisky/Angebault/Chevalier/Motch, de Waard/Miley/Schilizzi.

May: Colina/Perryman/Kollatschny, Courvoisier, Gratton/Ortolani/Tornambé, van der Kruit/Bottema, Ulrich/Perryman/Collin-Souffrin, Möllenhoff, Krautter/Pietsch, Möllenhoff, Krautter/Frank/Sztajne.

June: Rosa/Mathis, Rosa/Benvenuti/Savage, Véron, Gathier/Atherton/Pottasch/Reay, Dettmar/Wielebinski, Moorwood/Cetty-Véron, Cetty-Véron, MPI.

July: MPI, Lacombe/Léna/Chelli/Rouan.

August: Lacombe/Léna/Chelli/Rouan, Fricke/Kollatschny/Hellwig, Pietsch/Krautter/Lewin/Pedersen/Sztajno/Trümper/van Paradijs, Jörsäter/Lindblad/Athanassoula, Fosbury/Danziger/Tadhunter, Danziger/Binette/Matteucci, Pizzichini/Pedersen, Nelles/Elst, de Grijp/Lub/Miley, Häfner/Metz/Pietsch/Voges.

Sept.: Rafanelli/Schulz/di Serego Alighieri, Macchetto/Miley/Barthel, Courvoisier, Jørgensen/Hansen/Norgaard-Nielsen, Vauclair/Macchetto/Fort/Nieto/Prugniel/Lelièvre/Perryman/di Serego Alighieri, Macchetto/Miley/Barthel, Rafanelli/Schulz/di Serego Alighieri, Jørgensen/Hansen/Nørgaard-Nielsen, Sommer Larsen/Christensen, Buser/Cayrel.

1.5 m Spectrographic Telescope

April: Kroll/Schneider/Voigt, Giovanelli/Vittone/Rossi/Bisnovatyi-Kogan/Sheffer/Lamzin, Gry/Vauclair, Chincarini/de-Souza/Manousoyannaki/Kotanyi, Chincarini, de Souza, Bues/Rupprecht, Fischerström/Liseau.

May: Fischerström/Liseau, Lebertre/Epchtein/Nguyen-Q-Rieu/Sèvre, Wamsteker/Danks/Fricke, Bica/Alloin, Finkenzeller/Basri, Lindgren/Ardeberg/Maurice/Prévot, Pauls/Kohoutek, Molaro/Franco/Morossi/Ramella.

June: Molaro/Franco/Morossi/Ramella, Gerbaldi/Morguleff/Pasinetti/Fracassini/Pastori/Antonello, Bouvier/Bertout, Maciel/Barbuy/Aldrovandi/Faundez, Leitherer/Stahl/Wolf/Zickgraf, Strupat/Drechsel/Haug/Böhnhardt/Rahe.

July: Strupat/Drechsel/Haug/Böhnhardt/Rahe, Giovannelli/Vittone/Rossi/Bisnovatyi-Kogan/Sheffer/Lamzin, Houziaux/Heck/Manfroid, Acker/Stenholm/Lundström, Thé/Westerlund, Acker/Stenholm/Lundström.

August: Acker/Stenholm, Lundström, Lindgren/Ardeberg/Maurice/Prévot, Fricke/Colina, Häfner/Metz/Pietsch/Voges.

Sept.: Richtler/Seggewiss, Heydari-Malayeri/Testor/Lortet, Hahn/Lagerkvist/Rickman.

1 m Photometric Telescope

April: Leene/Goss/Beichmann, Giovannelli/Vittone/Rossi, Bisnovatyi-Kogan/Sheffer/Lamzin, Liller/Alcaíno, Bues/Rupprecht, Westerlund/Jörgensen (UG), Fischerström/Liseau.

May: Fischerström/Liseau, van der Hucht/Thé, Stanga/Natta/Lenzuni, Kollatschny/Loose, Heske/Wendker, Lebertre/Epchtein/Nguyen-Q-Rieu.

June: Lebertre/Epchtein/Nguyen-Q-Rieu, Terzan, Barwig/Schoembs/Kudritzki/Ritter, Brahic/Sicardy, Haug/Drechsel/Strupat/Rahe, Habing/Lintel Hekkert/van der Veen.

July: Habing/Lintel Hekkert/van der Veen, Epchtein/Braz, Giovannelli/Vittone/Rossi/Bisnovatyi-Kogan/Sheffer/Lamzin, Grosbøl/Brosch/Greenberg, Lebertre/Epchtein/Nguyen-Q-Rieu/Sèvre, Heck/Manfroid, Thé/Westerlund.

August: Thé/Westerlund, de Muizon/d'Hendecourt/Perrier, Wargau/Wolterbeek, Olofsson/Bergvall, Clementini/Cacciari/Prévot/Lub/de Bruyn/Lindgren, Arlot/Thuillot/Morando/Lecacheux/Bouchet, di Martino/Zappala/Farinella/Paolicchi/Cacciatori/Barucci.

Sept.: di Martino/Zappala/Farinella/Paolicchi/Cacciatori/Barucci, Poulain, Arlot/Thuillot/Morando/Lecacheux/Bouchet, Poulain, Richtler/Seggewiss, Arlot/Thuillot/Morando/Lecacheux/Bouchet, Hahn/Lagerkvist/Rickman.

50 cm ESO Photometric Telescope

April: Schneider/Pavlovski/Maitzen, Carrasco/Loyola, Scaltriti/Busso/Cellino, Westerlund/Jörgensen (UG).

May: Westerlund/Jörgensen (UG), Lodén LO/Engberg, Schönberner/Hunger, Lodén K., Arlot/Thuillot/Morando/Lecacheux/Bouchet, Lodén K.

June: Lodén K./Arlot/Thuillot/Morando/Lecacheux/Bouchet, Antonello/Conconi/Mantegazza, Arlot/Thuillot/Morando/

Lecacheux/Bouchet, Antonello/Conconi/Mantegazza, Carrasco/Loyola, Haug/Drechsel/Strupat/Rahe.

July: Haug/Drechsel/Strupat/Rahe, Arlot/Thuillot/Morando/Lecacheux/Bouchet, Thé/Westerlund, Arlot/Thuillot/Morando/Lecacheux/Bouchet.

August: Arlot/Thuillot/Morando/Lecacheux/Bouchet, Carrasco/Loyola, Schober/Surdej A. and J./Michalowski, Häfner/Metz, Pietsch/Voges.

Sept.: Häfner/Metz, Pietsch/Voges, di Martino/Zappala/Farinella/Paolicchi/Cacciatori/Barucci, Arlot/Thuillot/Morando/Lecacheux/Bouchet, di Martino/Zappala/Farinella/Paolicchi/Cacciatori/Barucci, Hahn/Lagerkvist/Rickman, Arlot/Thuillot/Morando, Lecacheux/Bouchet, Debehogne/Zappala/de Sanctis.

GPO 40 cm Astrograph

April: Goossens/Waelkens.

May: Bässgen/Grewing/Kappelmann/Krämer, Goossens/Waelkens.

June: Goossens/Waelkens.

July: Goossens/Waelkens.

Sept.: Debehogne/Machado/Caldeira/Viera/Netto/Zappala/de Sanctis/Lagerkvist/Mourao/Tavares/Nunes, Protitch-B./Bezerra.

1.5 m Danish Telescope

April: Alcaíno/Liller, de Jong/Lub/de Grijp, Motch/Ilovaisky/Chevalier/Pedersen/Pakull/Beuermann, Mouchet/Bonnet-Bidaud/Motch/Schmider, Larsson S./Larsson B., de Souza/Chincarini, Boisson/Reid.

May: Reiz, Teuber/Nielsen/Johansen, Schuster/Nissen.

June: Pedersen, Fusi Pecci/Battistini/Bonoli/Federici, Ortolani/Gratton, Lebertre/Epchtein/Nguyen-Q-Rieu/Sèvre, Rosino/Ortolani, Leitherer/Stahl/Wolf/Zickgraf, Pedersen.

July: Pedersen, Veillet, Acker/Maurice/Prévot, Lindgren/Ardeberg/Maurice/Prévot.

August: Lindgren/Ardeberg/Maurice/Prévot, Andersen/Nordström/Olsen, Mayor/Mermilliod, Clementini/Cacciari/Prévot/Lub/de Bruyn/Lindgren, Andersen/Nordström.

Sept.: Andersen/Nordström, Jørgensen/Hansen/Nørgaard-Nielsen, Imbert/Andersen/Nordström/Ardeberg/Lindgren/Mayor/Maurice/Prévot.

50 cm Danish Telescope

April: Schuster/Nissen

May: Lindgren/Ardeberg/Maurice/Prévot, Foing/Bonnet/Crivellari/Beckman/Galleguillos/Lemaire/Gouttebroze.

June: Foing/Bonnet/Crivellari/Beckman/Galleguillos/Lemaire/Gouttebroze, Baade/Ferlet.

July: Baade/Ferlet.

August: Lindgren/Ardeberg/Maurice/Prévot, Group for Long Term Photometry of Variables.

Sept.: Group for Long Term Photometry of Variables, Grenon/Hög/Petersen.

90 cm Dutch Telescope

April: van Roermund, de Loore/Monderen, Pakull/Beuermann/Weißsieker/Reinsch.

May: Pakull/Beuermann/Weißsieker, Reinsch, Roobeek.

June: Roobeek, Trefzger/Pel/Blaauw, Gathier/Atherton/Pottasch/Reay, de Zeeuw/Lub/de Geus/Blaauw.

July: de Zeeuw/Lub/de Geus/Blaauw, de Geus, van Amerongen.

August: Thé/Westerlund, v. Amerongen/v. Paradijs, Courvoisier.

61 cm Bochum Telescope

April: Hanuschik.

May: Hanuschik, Kohoutek, Group for Long Term Photometry of Variables.

June: Group for Long Term Photometry of Variables.

July: Group for Long Term Photometry of Variables.

August: Group for Long Term Photometry of Variables, Grewing/Bässgen/Barnstedt/Bianchi/Gutekunst.

Sept.: Grewing/Bässgen/Barnstedt/Bianchi/Gutekunst, Kiehling.

Serendipitous Discovery of a High Redshift Quasar

M. Azzopardi, ESO

Within the framework of our survey of carbon stars (C stars) in dwarf spheroidal galaxies (Azzopardi and Westerlund, 1984, *The Messenger* **36,** 12), the Carina galaxy was observed on November 2, 1983 at La Silla. A very good quality 2-hour-exposure plate was obtained at the prime focus of the 3.6 m telescope, using the triplet corrector, the Hoag Grism R35 and a GG435 filter (see Breysacher and Lequeux, 1983, *The Messenger* **33,** 21). The GG435 filter, in combination with the IIIa-J emulsion in order to reduce the instrumental spectral domain to the useful range 4350–5300 Å, allows one to reduce the crowding. The plate was searched systematically using a binocular microscope with small magnification. This allowed us to identify 6 out of the 7 C stars listed by Mould et al. (1982, *Astrophysical Journal* **254,** 500) plus 4 new candidates and one dubious (Azzopardi, Lequeux and Westerlund, 1984, ESO preprint No. 345).

These five newly discovered C star candidates were observed with the Cassegrain Boller and Chivens spectrograph and a CCD camera (CID 53612) at the ESO 3.6 m telescope during the nights of November 23–24, 1984 and January 19–21, 1985. A 400 line/mm grating, blazed at 5400 Å, was used in the first order (171 Å mm^{-1}). The slit aperture measured 2 arcseconds, giving a final resolution of 8 Å (FWHM). The observations allowed us to confirm as C stars the candidates Nos. ALW 1, 2 and 3 and to classify as a late M dwarf the dubious candidate ALW 5 according to the library of stellar spectra by Jacoby et al. (1984, *Astrophysical Journal Suppl.* **56,** 257.

Surprisingly, the object ALW 11, which was somewhat far from the central regions of Carina, turned out to be a quasar. Fig. 1 gives the identification chart. Its 1950.0 position is $\alpha = 6^h42^m13^s\!.40$, $\delta = -50°38'07''\!.1$ and a rough estimate of its