The Metallicity of the Young SMC Cluster NGC330 and its Environment Derived from CCD Strömgren Photometry

The distinct metal deficiency of the young globular cluster NGC 330 in the Small Magellanic Cloud, although independently found in several spectroscopic analyses (e.g. Spite and Spite, 1991) is nevertheless surprising. NGC330 belongs to the youngest population in the SMC. The metal abundances of young SMC field stars turned out to be about −0.6 dex (e.g. Spite and Spite, 1991), and not −1 dex or even lower as it was found for NGC330.

In an attempt to measure directly a possible metallicity difference between NGC330 and the surrounding field, we performed CCD Strömgren photometry in this region with the 2.2-m telescope on La Silla.

Our results are displayed in Figure 1. The filled circles are red supergiants which are radial-velocity members of NGC330, while the open symbols represent stars which are located at distances of more than 100″ from the cluster centre and which we consider to be field stars. Indicated are three loci of equal metallicities according to a calibration using published spectroscopic abundances and Strömgren colours of galactic stars of luminosity class III or brighter. We derive a mean abundance of the SMC field stars of −0.8 dex, while the cluster stars give −1.2 dex (a reddening of $E_{B-V}=0^m.03$ is assumed).

Here, we prefer not to put too much emphasis on the absolute values, although they are in reasonable agreement with the spectroscopic analyses. The important point is that cluster stars and stars in the neighbouring field show a differential offset in their metallicity as derived from photometry, a difference which agrees excellently with that predicted by spectroscopy. This questions the role of globular clusters as tracers of chemical evolution!

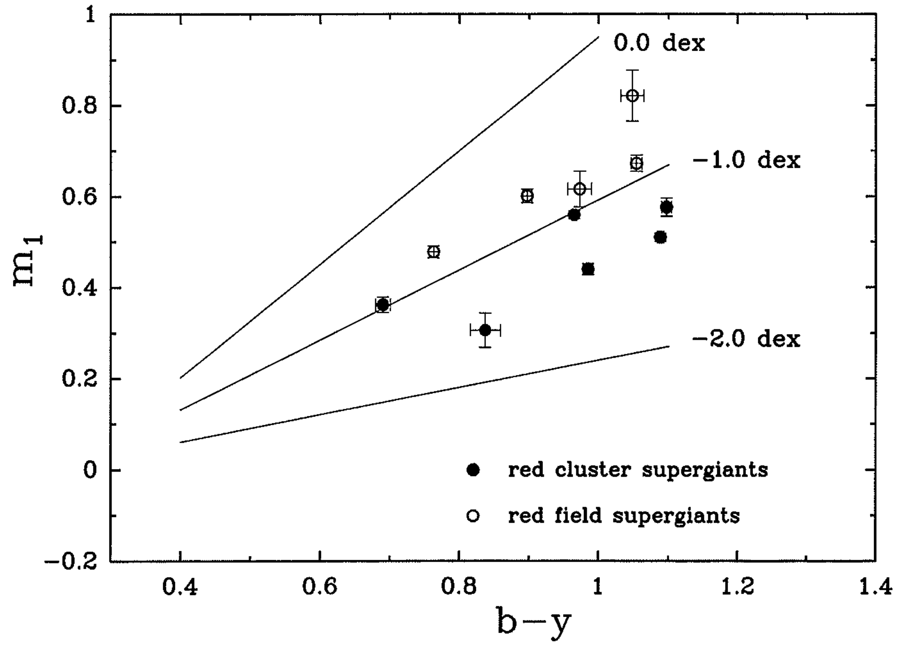

Figure 1: *This (b-y)-m_1 diagram shows the location of supergiants in NGC330 (filled circles) and in the surrounding field (open circles). A reddening of $E_{B-V}=0^m.03$ has been adopted. Indicated are three lines of equal metallicities. The cluster stars are clearly separated from the field stars, which is interpreted as an offset in metallicity of about 0.4 dex.*

The interpretation of this finding is beyond the scope of this short communication. However, a possible role of metal deficiency in a scenario of globular cluster formation has been suggested by several authors (e.g. Fall and Rees, 1985, Richtler and Seggewiss, 1989).

Our results show that CCD Strömgren photometry is a very promising tool for investigating the pattern of the distribution of stellar metallicities in the Magellanic Clouds.

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IC 4296: Observations of an Elliptical Galaxy Core

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Introduction

The cores of elliptical galaxies can provide very important clues to the formation and dynamical evolution of the parent galaxies, e.g. recent episodes of star formation, merging and cannibalism, possible presence of central black holes. Cores kinematically decoupled from the main body of the galaxy are known to exist in many ellipticals and are widely interpreted as evidence for galactic cannibalism. Different signatures of decoupling have been found:

- counter-rotation and, more generally, misalignment of the kinematic axes of the stellar component in the central region with respect to the main galaxy body (Franx and Illingworth, 1988);
- anomalous velocity gradients and dispersion profiles in the central parts (see, e.g., Tonry, 1984; Jedrzejewski and Schechter, 1988);
- central light excess (Kormendy, 1985).

More recently, central unresolved

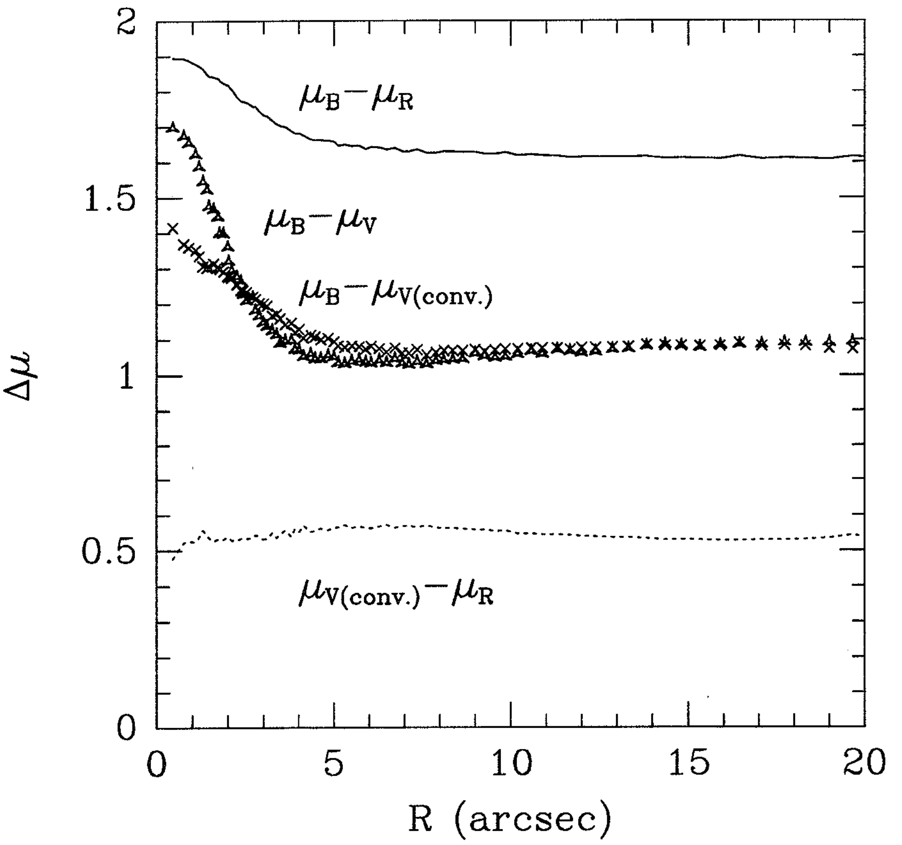

Figure 1: *The colours $\mu_B - \mu_R$ (solid line), $\mu_B - \mu_V$ (symbols), and $\mu_V - \mu_R$ (dotted line) are plotted versus the radius in arcsec. Since the V frame was taken with a seeing smaller than the B and R frames, we convolved the V image to obtain a $V_{conv.}$ frame of comparable seeing. As a reference we show both the colours derived from the original image ($\mu_B - \mu_V$, triangles) and those obtained from the convolved image ($\mu_B - \mu_{V(conv.)}$, crosses).*

nuclei similar to the well-known one in M87 (Young et al., 1978), have been discovered in several ellipticals (Jarvis, 1990) and seem to be a much more common phenomenon than previously thought, as pointed out in a very impressive manner by the HST observation of the core of NGC7457 (Lauer et al., 1991). The nature and physical interpretation of these nuclei are still subject of discussion, since up to now only few cases have been studied with the necessary high resolution. Two hypotheses are:

- *external origin:* the surviving core of a cannibalized companion with very high central density;
- *internal origin:* a self-gravitating massive stellar cluster or even a density cusp induced by a massive black hole.

It is possible to discriminate between the various hypotheses when photometric and spectroscopic data are confronted in detail with models. A young massive star cluster would be identified by the presence of a colour gradient in the core. A relatively "normal" young stellar population would be bluer than the rest of the galaxy, while a young star cluster made of very low-mass stars would be redder. A cannibalized companion would be detected more easily from the decoupled core kinematics mapped by taking spectra at various position angles. Even the hypothesis of a cusp induced by a central black hole can be investigated with ground-based observations. A black hole would induce both a cusp in the light distribution and a peak in the central velocity dispersion. Models with a central black hole and based on a distribution function which is of general applicability to ellipticals (Bertin, Saglia and Stiavelli, 1988) predict well-defined relations between these two observables. Such relations are confirmed by N-body simulations and models for the adiabatic black-hole growth (Lee and Goodman, 1989). Central compact nuclei also influence the shape of isophotes in the core (Gerhard and Binney, 1985; Norman, May and van Albada, 1985).

Evolutionary models of Active Galactic Nuclei predict that many nearby galaxies should contain a central massive black hole (Padovani, Burg and Edelson, 1990). The available mass function for central black holes in Seyfert nuclei peaks at $M_{BH} = 2 \times 10^7 M_\odot$ and has a tail extending toward larger masses. However, alternative models for Seyfert galaxies have recently been put forward (Terlevich and Melnick, 1985). In such models, Seyfert activity is explained in terms of starbursts. If this is the correct interpretation, then the number of galaxies containing a massive black hole in their core is much smaller and the black hole masses can be very different.

A Pilot Project: IC4296

In the following, we will describe in more detail our preliminary results for IC4296. This galaxy shows some of the above-mentioned signatures and is therefore an ideal object for a feasibility study for a larger project. IC4296 is a radio galaxy with jets extending out to about 5.1 kpc (H_0=50 km s^{-1} Mpc^{-1}) from the centre with its kinematical axes apparently not aligned with the radio jet. In addition, this galaxy was found to be also an X-ray emitter (see, e.g., Killeen, Bicknell and Carter, 1986, hereafter KBC). The most recent studies of this object are the very complete photometric and kinematic study by KBC, and the kinematic studies by Efstathiou, Ellis and Carter (1980, hereafter EEC), and Franx, Illingworth and Heckman (1989, hereafter FIH). Especially the kinematic properties of the objects are not clear. The results by EEC indicate a constant velocity dispersion profile in the inner regions, while both KBC and FIH show a steep raise inside 5 arcsec.

In order to clarify the ambiguous issue, we carried out a study of the photometric and kinematic properties of this object. During an observing run at the ESO/MPI 2.2-m we obtained direct images of IC4296 in R (5 and 10 minutes exposure time) and in B (10 and 15 minutes exposure time). A 640 × 1024 RCA CCD was used yielding a scale of 0.176 arcsec pixel^{-1}. Unfortunately, the weather conditions were not optimal for our purpose. The average seeing was not better than 2 arcsec. In addition, a 30-second V-band exposure was obtained at the 3.6-m telescope equipped with EFOSC and a similar RCA CCD as on the 2.2-m (0.337 arcsec pixel^{-1} scale) under better seeing conditions (1.2 arcsec).

After dark and bias subtraction and flat-field correction, the images were aligned with each other. Then, the single exposures in each band were added together, eliminating also the cosmic-ray hits. Surface photometry was carried out using the PLEINPOT package, kindly made available by P. Prugniel. For all the colours we have derived luminosity profiles and determined position angle, ellipticity and "boxiness" of the isophotes. From our preliminary results,

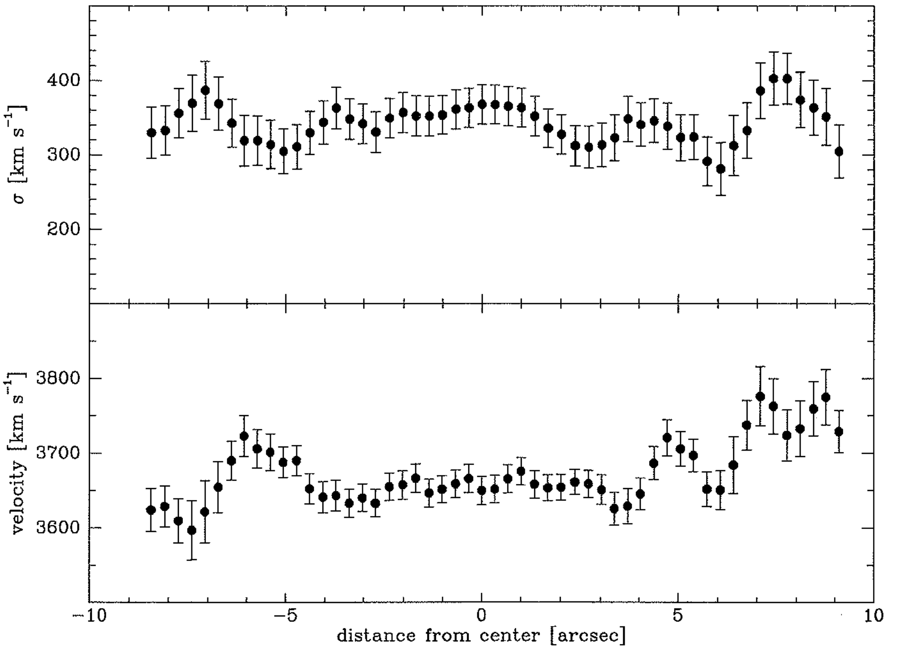

Figure 2: *Velocity-dispersion profile (upper panel) and rotation curve of the stellar component of IC4296 along the optical major axis (PA = 46°).*

distribution in the field of a supermassive black hole (Lee and Goodman, 1989). High-resolution kinematic data may pose constraints on this hypothesis. A long-slit spectrum along the optical major axis of IC4296 (PA = 46°) was obtained at the 3.6-m telescope equipped with EFOSC. Operating the grism O150 and a 1.5 arcsec slit, a resolution of ≈ 3.7 Å was obtained over the spectral range covered (λλ 5000–7000 Å). The integration time was 1 hour. In addition, also high S/N-ratio spectra of non-rotating K giants were secured in the same instrumental configuration in order to be used as velocity templates. The seeing was about 1.7 arcsec. The scale perpendicular to the dispersion is 0.337 arcsec.

The standard data reduction procedures of dark and bias subtraction, flat-field correction and wavelength calibration were performed. The night sky was subtracted from the galaxy spectrum using the light from the un-

shown in Figure 1, it appears that the core region (r ≤ 2 arcsec) is redder by about 0.2 magnitudes than the rest of the galaxy. No large-scale colour gradient is observed. The latter finding is in agreement with KBC, who used combined CCD and photograpic material for their surface photometry. The B–V central gradient appears steeper than the B–R gradient. In order to test whether this was a consequence of the better seeing of the V frame, we convolved the V image in order to obtain the same seeing as the B and R frames and derived again the V luminosity profile. As it is apparent in Figure 1, the convolved V profile is consistent with the R profile and no V–R colour gradient is observed. It is very likely that the core is not resolved even in the original V band frame. KBC found a significant U–B colour gradient within 5 arcsec from the core, a smaller B–V gradient and no V–R gradient. Our results are compatible with theirs, considering our somewhat better seeing. The B–R and B–V gradients obtained by us compare well with the U–B gradient obtained by KBC. Possible interpretations of the observed gradient (which has the opposite sign of the one observed in the core of M87) can be ascribed to the presence of a star cluster made of low-mass stars, to emission from ionized gas in the core, or to the presence of nuclear dust. The last hypothesis was ruled out by KBC since they failed to detect a gradient in B–V.

In addition to the colour gradient, the luminosity profiles show apparantly sizeable deviations from the $R^{1/4}$ law. They may partly be due to the seeing, but could also be caused by stellar re-

Second Announcement

Progress in Telescope and Instrumentation Technologies

ESO, Garching, 27–30 April 1992

The European Southern Observatory is organizing a Conference to be held in Garching bei München, Germany, 27–30 April 1992.

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contaminated border regions of the spectrum. Cosmic-ray events were removed by means of a median filter. The calibrated data were then analysed using a modified and revised version of the Fourier-Quotient Package (Bertola et al., 1984) yielding the stellar velocity dispersion profile and rotation curve.

The heliocentric velocity of IC4296 derived from absorption and emission lines is 3650 km s^{-1} which is in good agreement with previous works. The obtained rotation curve and velocity-dispersion profile are presented in Figure 2. Our preliminary results agree reasonably with those by KBC and FIH, although the presence of a central steep increase in velocity dispersion is not that evident as in theirs. The upper limit to the central dark mass in IC4296, based on rough estimates, is of the order of $10^9 M_\odot$. More stringent limits will probably be possible once the data will be fully analysed and properly modelled.

Analysis of the emission lines reveals a LINER-type spectrum, although underlying absorption lines are very strong and the Hα emisson is significantly diluted. The emission lines appear very narrow with typical velocity dispersions of about 140 km s^{-1} after subtracting the instrumental profile. As measured from the [N II] (λ 6583 Å) line, the emission is confined in ≈ 3 arcsec diameter core region. The amount of emission is not incompatible with the red photometric excess.

Our conclusions are that, although in general better than previous work, the seeing conditions were not good enough to resolve the core of IC4296. Therefore, no firm upper limit on the mass of a dark central component can presently be set. The data leave room for the presence of even a supermassive central dark object. The observed colour gradients could be explained as due to the presence of dust in the nuclear region, which is quite commonly found in ellipticals (Sparks et al., 1985).

One Step Ahead: An Observational Strategy

We are now carrying out a detailed study of a number of bona-fide candidate objects in order to investigate properly the wide range of core phenomena. A sample of early-type galaxies was selected which has systemic velocities ≤ 5000 km s^{-1}. We chose early-type objects because for them the interpretation of the data is made easier by the presence of a predominantly old massive stellar population, so that recent episodes of star formation and anomalous colours can be more easily singled out.

Since our angular resolution will in general be of the order of ≈ 1 arcsec, we cannot expect to gather any useful information for objects more distant than 50 h^{-1} Mpc. In addition to select relatively close-by galaxies, we have also considered objects for which some "anomalies" have already been detected in the cores: counter-rotation or kinematical decoupling, unresolved or very compact core radio sources, central light excesses. For these galaxies, we are planning to obtain long-slit spectra along several position angles in order to derive information on the stellar velocity field and on the velocity dispersion profile, as well as on the presence of emission lines. In addition, we intend to obtain direct images of the central regions in at least two (e.g. B and R), but possibly more, colour bands. When confronted with stellar dynamical models, these data will allow us to put upper limits on the mass of any central condensation and to suggest which model is in better agreement with the observed features.

As a follow-up of the study of a few "promising" objects we plan a complete survey of the properties of the cores of early-type galaxies. In fact, a complete survey of core properties of ellipticals is still missing. The most complete collection of data available so far is the compilation by Lauer (1985) of photometry for the cores of 42 early-type galaxies. Lauer's sample, however, was not complete and based on observations performed in a single band at the Lick Observatory 1-m telescope under average seeing conditions. In addition, no such survey is available for the southern sky. Our estimated "detection" limits (seeing ≈ 1 arcsec) for the case of a central light excess caused by a central black hole in a typical elliptical are: (i) $M_{BH} \gtrsim 10^9 M_\odot$ to resolve the cusp, (ii) $M_{BH} \gtrsim 10^8 M_\odot$ to observe the seeing convolved cusp as a "core within the core" at the 0.1-magnitude limit. For the northern part of the survey, we have already obtained time at the 2.5-m Nordic Telescope.

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PLANETA TERRA – NOSSO DESTINO COMUM is the title of an international conference on ecology, which will be held in Rio de Janeiro in 1992, under the auspices of the United Nations. Under the umbrella of this conference, a number of scientific events, conferences and exhibitions in other scientific fields, e.g. in medicine and astronomy, will take place.

As an early kick-off, ESO's travelling exhibition was opened in the planetarium by Marcelo Alencar, Mayor of the City of Rio, on May 2. Attending the opening ceremony were members of the diplomatic representations of ESO's member countries, officials from the City and State Governments, scientists, etc. Speeches were held by the Mayor, the director of the planetarium, A. Cobbett, and by Jorge Melnick of ESO, who, on the basis of astronomy, emphasized the need for fundamental research and international collaboration in science.

The exhibition was presented several times on nationwide TV and also in full-page articles in the leading Brazilian newspapers and magazines, and no less than 3,000 visitors were registered during the first weekend.

The next stop of ESO's itinerant exhibition will be in Buenos Aires in July this year on the occasion of the XXIst General Assembly of the International Astronomical Union.

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