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NGC 2209: THE NATURE OF THE DARK PATCH THROUGH THE HR DIAGRAM

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RESUMEN. Discutimos la naturaleza de la gran mancha obscura proxima al centro del cúmulo rojo NGC 2209 de la LMC. Elaboramos un diagrama HR en base a imágenes B y V tomadas con CCD con el telescopio de 4 mts del CTIO en Chile. Las 5 estrellas superpuestas a la mancha no tienen un enrojecimiento substancial,lo que indica que la mancha es una estructura interna del cúmulo. La edad y la metalicidad son también discutidas.

ABSTRACT. The aim of this paper is to present a study of the nature of the dark patch located near the center of the LMC cluster NGC 2209. We use a deep HR diagram of the cluster and we analyse the photometric properties of a few stars that appear projected on top of the patch. The photometric observations in the BV system were carried out with a CCD camera at the CTIO 4 mt telescope, with exposure of 15 minutes in a photometric night of excelent seeing. Our conclusion is that the patch is an internal feature of the cluster. We also discuss the controvertial problem of the metallicity and age of the cluster.

Key words: GALAXIES-MAGELLANIC CLOUDS — CLUSTERS

I. INTRODUCTION

The LMC red cluster NGC 2209 presents a conspicuous dark patch of approximately 15 arc sec in diameter located at about 10 arc sec from its center. Hodge (1960) argued that the feature could be an absorption globule either internal to the cluster or galactic, or else, belonging less probably to the LMC itself, owing to the large distance of the cluster from the main body.

The aim of this paper is to present a study of the nature of the dark patch on the basis of a deep HR diagram of the cluster and the analysis of the photometric properties of the few stars that appear projected on top of the patch.

We also discuss the controversial problem of the metallicity and age of the cluster (Walker, 1971; Gascoine et al.1976; Gustaffson, 1977).

The feature is compared with similar ones appearing in MW globular clusters (Roberts, 1960; Kamagy and Wiatt, 1978).

We show in plate I the I CCD frame where the large dark patch described in the preceding section, as well as other similar features which are not so conspicuous can be seen. The five stars superposed on the main patch are clearly distinguishable.

The HR diagram was built for 800 stars in three zones: r < 50 and r < 100 arc sec and the remaining CCD frame. Both circles are practically free of field stars. Tables with coordinates, V magnitudes and (B-V) colors can be furnished under special request. The stars on top of the dark patch are identified in plate I. The HR diagram for the largest circle is shown in figure 1, and the place of the five stars, number 483, 485, 495, 503 and 518 are identified. The diagram show clearly the Herzprung gap, and the Turn Off Point (TOP). The two reddest stars are the carbon stars W46 and W50 (Mould and Aaronson, 1982).

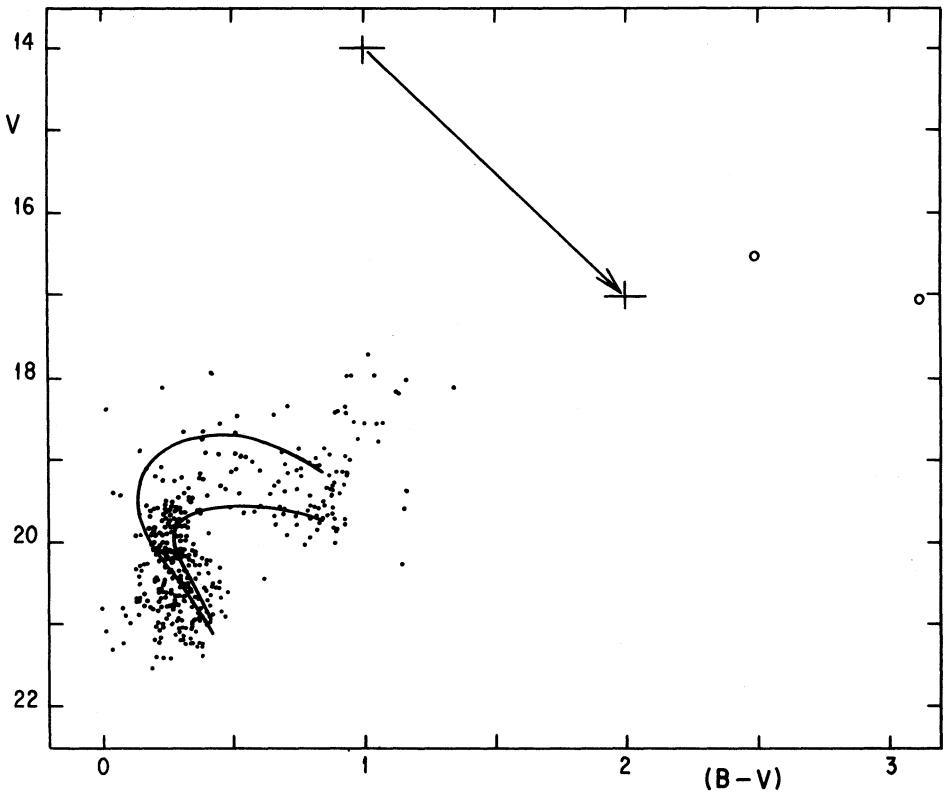

Fig. 1. HR diagram with the Yale isochrones corresponding to Y = 0.20. The large dots represent the 5 stars on the patch. Circles are the mentioned Carbon stars.

II. THE OBSERVATIONS

The observations were carried out with a CCD camera at the CTIO 4 mts telescope with exposure of 15 minutes with filters B, V and I in photometric nights of excellent seeing. Standard stars currently used at CTIO were observed for calibration.

The reduction was made at Garching with the program DAOPHOT which allows to analyse the internal errors of magnitudes and colors due to the degree of clumpiness of the stars within the cluster, taking into account the PSF.

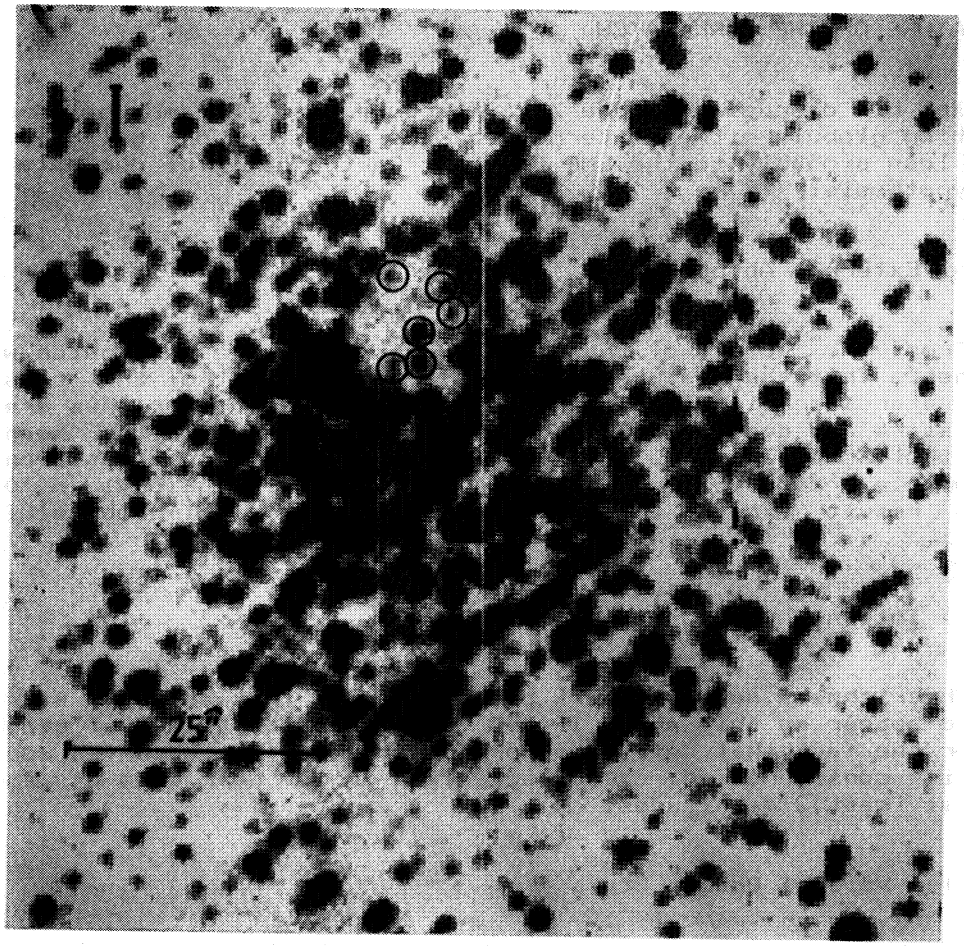

Fig. 2. CCD frame in color I showing the 5 stars on the patch.

III. THE AGE AND METALLICITY OF NGC 2209

In the last two decade there has been controversy on the metallicity of NGC 2209: Gascoigne et al.(1976) derived Fe/H = -1.2 from the HR diagram and DDO photometry of two giants. Gustaffson et al.(1977) suggested Fe/H = -0.5 by comparing the same HR diagram with detailed tracks for the pre-He-flash evolution. Gascoigne(1980) could not obtain a definite value, deriving Fe/H = -1.2 using photometry with the Washington system and -0.6 from a large sample of stars by means of DDO photometry.

The quality of our data give new insight on the question. We compare the HR diagram with the Yale isochrones (Ciardullo and Demarque, 1979) in figure 1. Assuming Y = 0.20 the best fit parameters are as follows: Apparent distance modulus (V - MV) = 18.46, reddening E(B-V) = 0.15, age 1.2 $\pm$ 0.2 E9 yrs and Z = 0.004 . The derived reddening is higher than the expected in the LMC field (E(B-V) = 0.06 , Aaronson and Mould, 1980), but this one would

require a solar metallicity for the cluster. Conversely a low metal abundance Fe/H = -1.2 implies an unacceptable reddening E(B-V) = 0.30. Thus a compromise value for the metallicity is Fe/H = -0.6, and a total reddening of E(B-V) = 0.15, which favours the hypothesis of a global absorption E(B-V) = 0.09 associated to the cluster.

IV. THE NATURE OF THE DARK PATCH

In his discussion Hodge (1960) argued that the dark patch could be be an absorption globule either internal to the cluster or galactic, or else belonging less probably to the LMC itself. On the basis of our data we discuss all the hypothesis:

a) External Absorption

From the color of the stars projected on the dark patch we can test the hypothesis that the feature be a dust cloud in front of the cluster. From the five stars previously identified, the three fainter ones are among the bluest MS stars and consequently unreddened with respect to the mean MS. The two brightest one are in the subgiant region and their position in the HR diagram imply a reddening, if present, at most of E(B-V) = 0.10. This surprising result exclude the possibility of an external globule of absorbing dust.

b) Internal Absorption

The richness near the dark patch indicate that about 90 stars would be expected to appear on this area. If the feature is due to a dust globule inside the cluster the fact that only fine unreddened stars are observed would require the following configuration: a compact cloud in the near edge of the cluster absorbing at least 2 magnitudes.

c) A Void of Bright Stars

The feature could also be explained by a fluctuation in the distribution of bright stars within the cluster. This view was previously proposed by Roberts (1960) in connection to galactic globular clusters . Kanagy and Wiatt (1978), in a discussion on M3, M13 and M15 conclude that structures of voids within globular clusters are very improbables.

V. DISCUSSION

The necessity to associate an extra absorption to the cluster in order to make compatible the observations with reasonable parameters of the LMC, and the TOP with the evolutionary tracks models of Ciardullo and Demarque (1979), lead to a model for NGC 2209 which associate a tenuous global absorption around the cluster with well defined denser regions. Assuming that the dark patches in NGC 2209 are due to gas/dust clouds associated to the cluster, the discussed one, which is 3.6 pc in diameter is 5 times larger than the largest absorption globules found in M3, M13 and M15 (Kanagy and Wyatt, 1978). The minimal absorption of 2 mg supposed in the previous paragraph for our dark patch lead to a column hydrogen density (including H2) nH = 5.8*E21*E(B-V) or equivalently

3.7*E21 at. cm-2. The value of the absorption as compared with cool interstellar clouds, can be fitted to typical dark nebulae (Spitzer, 1978). The real size of the patch furnish the following physical characteristics (Scheffler, 1982), M/Mo = 100-150, kinectic temperature 20-40 K for NH = 500 cm-3. Under these conditions of temperature and density the virial theorem (Roberts, 1960) require M/Mo = 800 in order to have a stable cloud.

VI. CONCLUSION

We conclude that there is dark matter associated to NGC 2209. That is in form of globules within the cluster and also as a tenuous surrounding cloud that produce an extra absorption of 0.09 above the mean value of the LMC. We deduce an age of 1.2*E9 yrs and a metallicity Fe/H = -0.6, for Y = 0.20.

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