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NUCLEAR STELLAR POPULATION OF NGC 772 (ARP 78)

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RESUMO. O espectro da região nuclear (5"x13") da galáxia de Arp Sb I NGC772, obtido com o espectrógrafo IDS no telescópio de 1.5 metros no ESO-Chile, foi usado para a síntese de população estelar através da análise de linhas de absorção e contínuo. Os resultados mostram que o fluxo em torno de 5360 A é dominado por estrelas tipo G e K. O último e fraco ciclo de formação estelar foi encontrado com turn-off-point (TOP) em AOV. A possível associação entre dois objetos vizinhos de alta velocidade de recessão e os fenômenos nucleares é discutida.

ABSTRACT. The nuclear spectrum (5"x13") of the Sb I Arp's galaxy NGC772, obtained with the IDS spectrograph at the 1.5 mts ESO telescope, was used to synthesize the stellar population through the analysis of the absorption features and the continuum. The results show that the flux around 5360 A is dominated by G and K stars. The last and weak star formation cycle was found with turn-off-point (TOP) at AOV. The possible association between two nearby high redshift objects and nuclear phenomena is discussed.

Key words: GALAXIES-NUCLEI — STARS-POPULATION

I. INTRODUCTION

The Sb I galaxy NGC772 is a very interesting object from the Arp's Catalogue, which form a pair with the E3 object NGC770. The Byurakan nuclear type of NGC772 is described as a non stellar but intense central concentration borrowed in long exposure plates (de Vaucouleurs, de Vaucouleurs and Corwing, RC2 Catalogue, 1976). The presence of NGC772 in the Arp's Catalogue (no. 78) is fully justified since there are two other small galaxies so close to NGC772 as NGC770 in the sky projection, with radial velocities of about 20000 Km/s, which Arp has claimed to be connected by faint filaments to NGC772 (Arp 1970a).

The interest on the possible association of NGC772 with the two high receding velocity galaxies was revived by the talk of Burbidge in this meeting on "Violent phenomena in nuclei of galaxies and QSO", where lines of quasars and Arp like associated objects were widely discussed (see also Burbidge 1987). The main question is that if these high receding objects would be matter released from the nucleus of NGC772, the phenomenon should have left some nowadays detectable evidences. This topic will be discussed with regard to the problem of star formation.

The stellar population analysis was carried out by the synthesis of absorption features and continuum through the Gunn and Stryker stellar library (1983, hereafter GS) using a non-linear constrained optimization method described by Dottori and Pastoriza (1986, hereafter DP).

II. OBSERVATIONS AND SPECTRUM REDUCTION

The observation of NGC772 was carried out in the night of november 16th in 1984 at the 1.5 mts ESO telescope with the IDS detector with a slit of 5 x 13 arcsec. and a dispersion of 225 A/mm, given a final resolution of 11 A FWHM in the range 3700-8000 A. The integration time was 50 minutes. The data reduction was performed by the IHAP system (Middelburg 1979), currently used at ESO-Garching. The calibrated spectrum is shown in fig. 1, corrected to rest frame by a receding velocity of 2443 Km/s (Sandage 1981) and dereddened by the normal law for our galaxy and by E(B-V)=0.07 (RC2) for internal absorption. As can be seen in fig. 1, the noise/signal relation increases strongly below 4000 A but still the H and K of CaII are well defined.

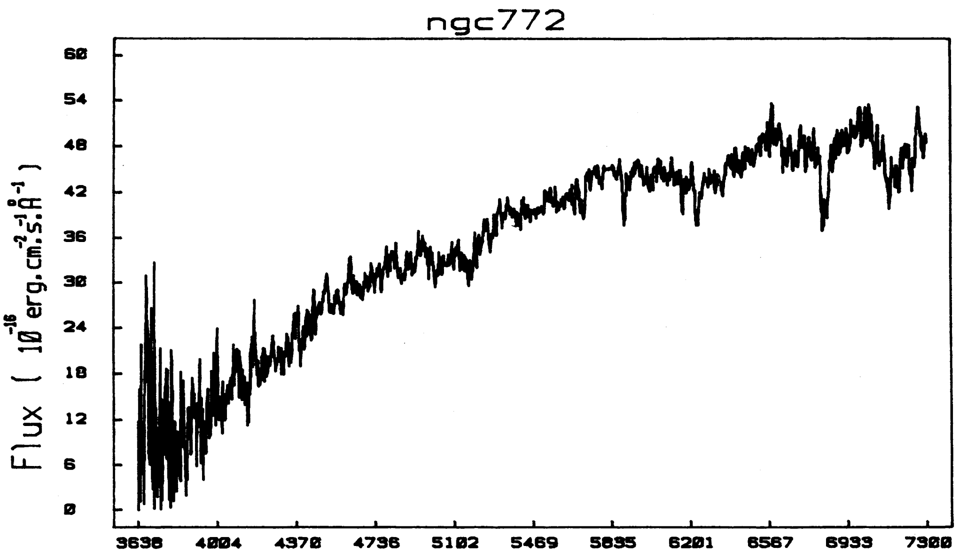


Fig. 1. Observed spectrum of NGC 772.

III. DATA TREATMENT

The synthesis method, fully described in DP, finds out the best solution for the star population minimizing the difference between the features equivalent widths of the galaxy observed spectrum and the features of a synthetic spectrum obtained from the combination of different proportions of stellar types. Iteratively, a non-unique solution is obtained for the vector { X(l,i) } by the equation F(X) = 0 for

$$F(X) = \sum_{l} \{ Wg(l) - \sum_{i} [X(l,i) \; Ws(l,i)] \}^{2} \qquad (1)$$

where Wg(l) is the equivalent width of the feature l in the galaxy spectrum, Ws(l,i) is the equivalent width of the feature l in the stellar type i, and X(l,i) is the proportion, relative to the continuum, which stellar type i participates in the feature l of the synthetic spectrum, constrained by an IMF and the evolution of the main sequence (hereafter MS) stars. Basically, each component of the { X } vector must be positive and may not represent a number of stars greater than one given by one or more starbursts, each one following an IMF. For the giants, we take into account that their number can not exceed the number of stars that already have left the MS. The computational method used is the Hooke and Jeeves (1962) penalty function method, based on a constrained non-linear programming.

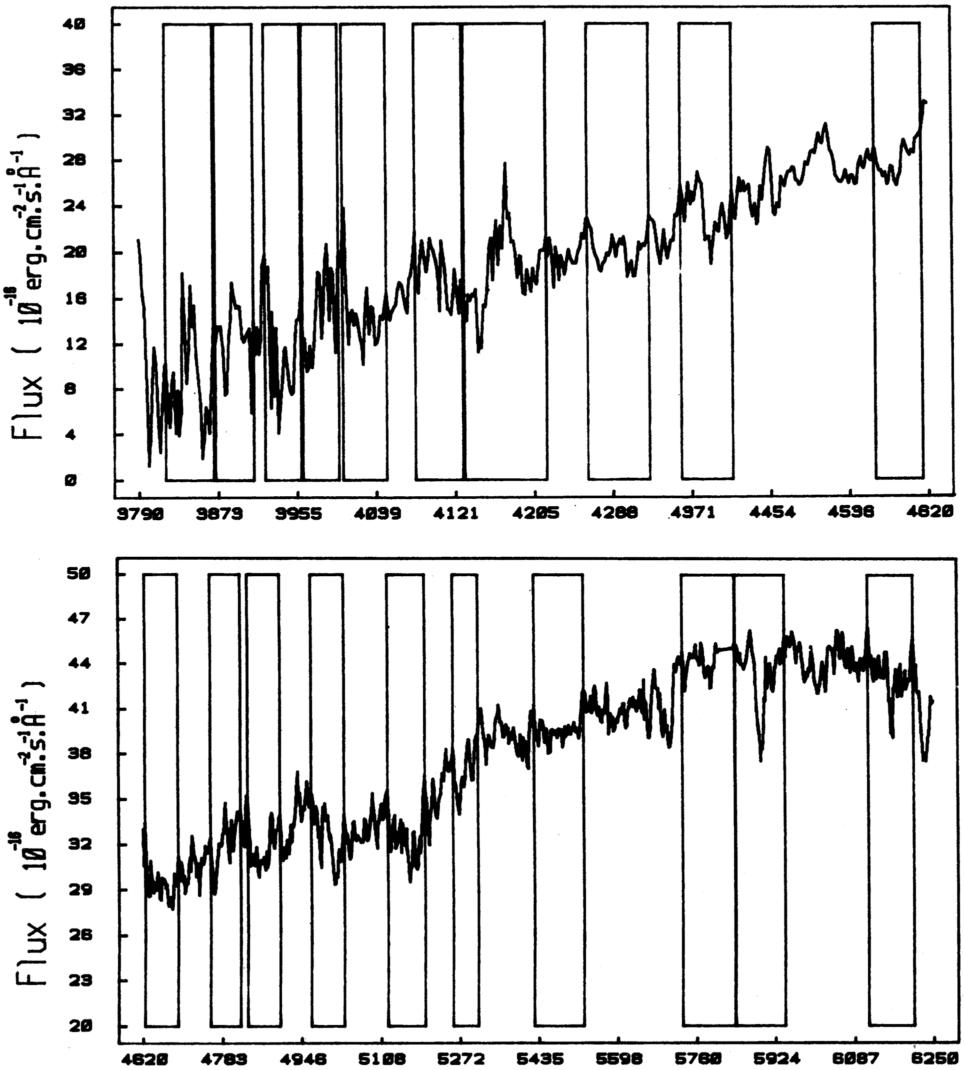


Fig. 2 Adopted spectral windows. Features identified in Table 2.

In order to give appropriate data for the synthesis we selected 22 representative stellar types, 13 for the MS and 9 for the giant branch, from the GS spectra catalogue and built up a self-consistent equivalent width and continuum base. The chosen stars are: 9 Sgr (O5V), -1 935 (B1V), HR 7174 (B6V), Theta Vir (A0V), Praesepe 114 (A5V), Praesepe 37 (F0V), BD+293891 (F6V), BD+263780 (G0V), HD 227547 (G5V), HD 190470 (K3V), +38 2457 (K8V), GL 49 (M2V), GL 65 (M5V), HR 7467 (B3III), Alpha Oph (A5III), Rho Cap (F2IV), HR 6516 (G6IV), 46 L Mi (K0III), Mu Leo (K2III), HD 50778 (K4III), -2 3873 (M0III) and Z Cyg (M8III). The metallicity of these stars is normal and their use in this synthesis is justified by the relation MgI5174/Hδ (Heckman 1980) for NGC772. The stellar features Ws are the same as those identified in the galaxy spectrum , defined by the spectral windows in fig. 2 . The equivalent width of the stellar absorptions features are in good agreement with previous published values (Alloin et al. 1971; Pritchet and van den Bergh 1977) as was discussed by Schmidt (1986).

TABLE 1. Stellar proportions and absolute number of stars of the model.

Type	%	Number (E5)
O5V	0	0
B1V	0	0
B6V	0	0
A0V	4.00	4
A5V	2.53	9
F0V	1.99	14
F6V	1.36	25
G0V	1.14	39
G5V	18.81	1230
K3V	14.69	3830
K8V	3.13	4700
M2V	0.96	5240
M5V	0.55	27400
B3III	0	0
A5III	13.32	151
F2IV	0	0
G6IV	18.81	1950
K0III	18.81	214
K4III	0	0
M0III	0	0
M8III	0	0

TABLE 2. Equivalent width of the observed and synthetic features.

Feature	Wg (A)	Ws (A)
1 – H9 3835	21.5	11.5
2 – H8 3889	8.9	11.4
3 – H of CaII	14.3	9.1
4 – K of CaII	9.1	11.7
5 – FeI 4035	12.8	1.7
6 – Hδ 4102	5.6	8.5
7 – CN band	12.5	5.6
8 – G band	8.4	7.8
9 – FeII 4385	5.8	4.3
10 – CaI 4581	3.2	2.4
11 – Swan band	6.3	3.4
12 – MgH 4780	2.4	2.3
13 – Hβ 4861	5.3	8.3
14 – TiO 4999	4.4	3.4
15 – MgI 5184	8.0	6.0
16 – FeI 5283	2.9	3.4
17 – TiI 5499	5.4	3.6
18 – TiO 5760	2.3	3.2
19 – NaI 5890	5.8	5.3
20 – CaI 6162	6.0	4.0

IV. RESULTS AND DISCUSSION

The stellar proportions X(1,i), respective to 5360 A, that minimize (1) are presented in Table 1 together with the absolute number of stars of each type. As can be seen, 70 % of the energy flux at 5360 comes from G and K stars. The mass to luminosity ratio computed is 1.41 (M = 1.4E9 M$_\odot$, L = 9.9E8 L$_\odot$). The synthetic spectrum is shown in fig. 3. Table 2 gives the observed and the synthetic equivalent widths of the features defined in fig. 2.

The distribution of the synthesized stellar population in the MS can be better visualized in fig. 4 where we have plotted the ratio X(5360,i)/Xs(i) versus spectral type, the vector { Xs(i) } being the stellar proportion obtained from an IMF with χ = 1.45. This ratio merely reproduces the ratio between the number of stars of type i obtained in the synthesis and the number expected by the IMF considered. Therefore the high proportion of G5 and later stars indicates not only the first starburst in the nucleus but also that it was very intense. The determination of its exact stellar type TOP is impaired by the low number of different main sequence stellar types used in this synthesis, but the remarkable step at G5 must depict the TOP of the cycle. A0V is the youngest stellar type of the MS found in the sample, indicating that no significant activity of star formation for objects of mass larger than 3 M$_\odot$ took place in the last E8 years.

The difference of the IMF between the two cycles of star formation is in agreement with the result of McClure et al. (1986) for globular clusters, which show that more metallic systems present steeper IMF.

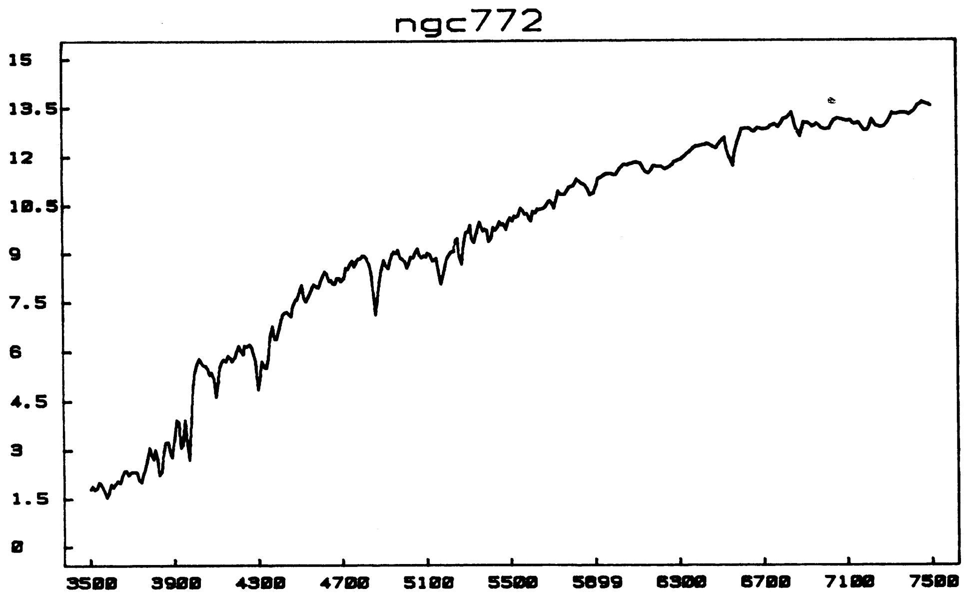
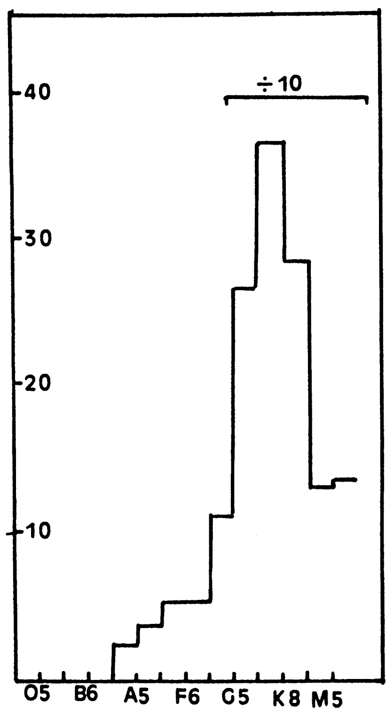


Fig. 3. Synthetic spectrum of NGC 772. The flux is normalized at 5360 A.



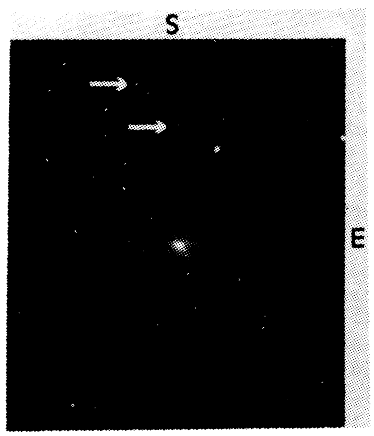


Fig. 4. Ratio X(5360,i)/Xs(i) versus spectral type.

Fig. 5. Reproduction of a two hours IIaO+GG385 plate of NGC 772 obtained at LNA-Brasil. Scale: 12.5 arcsec per millimeter. South up.

As Arp (1970a) has already pointed out, at least one of the high redshift galaxies seems to be in the extension of the long arm of NGC772, Plate 1 (see also Arp 1970b). We consider that if it was ejected its most probable location at present would be the disk plane of NGC772. Taking into account the inclination angle of NGC772 (i = 53 degrees, Schmidt 1986) and the projected distance between NGC772 and this object around 40 Kpc (H = 100 Km/s/Mpc, Vr = 2443 Km/s for NGC772, Sandage 1981, and Vr = 20200 Km/s for the object, Arp 1970a) we estimate that the ejection would have occurred about 2E6 years ago. As already mentioned the last cycle of star formation with TOP at A0V is the last activity, about E8 years ago, detected in the nucleus of NGC772 (it was not found in the IUE catalogue and the radio emission at 21 cm is normal, Fouque 1984). Based on these arguments we conclude that the two high redshift galaxies cannot be objects ejected from the NGC772 nucleus. Furthermore, we point out the existence of several galaxies in the field of NGC772 with similar and smaller size than these two galaxies. Probably then the suggested connection is not an actual link but a projection effect.

V. CONCLUSIONS

There were two cycles of star formation in the nucleus of NGC772 with different IMF and TOP around G5V and A0V. The difference in the IMF between the cycles may be correlated with chemical evolution. The high redshift galaxies near NGC772 cannot be associated with nuclear activity of NGC772 because of the time incompatibility between the age of the last starburst and the time they would have been ejected from the NGC772 nucleus.

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