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# SEARCHING FOR PLANETARY NEBULAE IN GLOBULAR CLUSTERS[1]

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RESUMEN

Se presentan resultados preliminares de una búsqueda de nebulosas planetarias en cúmulos globulares de la galaxia. Esta búsqueda se realiza obteniendo imágenes directas con filtros interferenciales en H$\alpha$, [O III] $\lambda$5007, y continuos adyacentes. Las imágenes, a las que se les sustrae el continuo, se examinan buscando objetos con líneas en emisión. Hasta ahora se han examinado 32 cúmulos globulares. Con este procedimiento se redescubrieron las dos nebulosas planetarias conocidas previamente: K648 en M15 y GJJC-1 en M22 pero ninguna otra planetaria ha sido detectado. Se discute este resultado.

ABSTRACT

Preliminary results of a survey for planetary nebulae in galactic globular clusters are presented. Direct imaging with narrow H$\alpha$, [O III] $\lambda$5007 and adjacent continuum filters are obtained. Continuum-subtracted images are analyzed in order to detect emission line objects. At present, 32 globular clusters have been observed. The previously known planetary nebulae K648 in M15 and GJJC-1 in M22 were easily re-discovered, but no other planetary nebula has been detected so far. The apparent lack of planetary nebulae in globular clusters is discussed.

*Key words:* **PLANETARY NEBULAE: GENERAL — STARS: POPULATION II**

## 1. INTRODUCTION

Planetary nebulae (PNe) are considered to be the evolutionary product of low and intermediate mass stars (1–8 $M_{\odot}$). The study of these objects provides information about the ejection process of the nebular material and the evolution of the progenitors. However, probing the evolution of such stars using PNe is difficult because the distances are generally very uncertain and the ages of the progenitor stars are unknown.

Another interesting point is that accurate abundance determinations of the elements seen in PN spectra can be made. Among these elements, O, Ne, Ar, and S are believed to indicate the chemical composition of the interstellar medium in the epoch when the progenitor stars were formed, while He, N, and C show evidence of enrichment due to stellar nucleosynthesis. According to their chemical composition, kinematics, and position in the galaxy, PNe have been classified as Types I, II, III, and IV, where Type I PNe are Population I objects while Type IV PNe are Population II (Peimbert 1978). Most of the known PNe belong to Types I to III (disk or thick disk population) and the sample of extreme Population II PNe (halo objects) is limited to only 5 planetaries in which the chemical composition behavior is not understood (Peña et al. 1993).

[1]Based on data obtained at the Observatorio Astronómico Nacional, San Pedro Mártir, B.C., México.

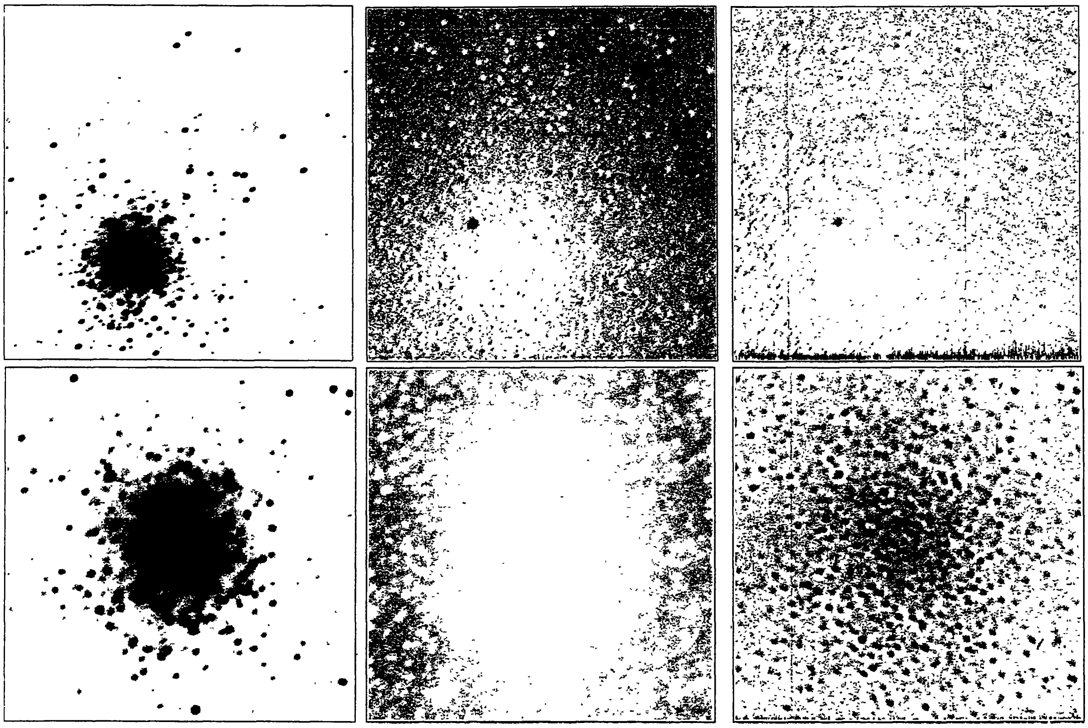

Fig. 1. CCD direct image, continuum-subtracted H$\alpha$ and [O III] $\lambda$5007 images of NGC 7078 (upper) showing K648 and NGC 6273 (lower) where no candidate was detected.

By using planetary nebulae located in globular clusters, several difficulties —such as distance and age— are overcome, and systematic studies of Population II PNe can be achieved. A comparison of the abundances derived from PNe with those derived from stars would provide some new clues to the chemical evolution of globular clusters. Until now, only two of the known halo PNe are located in globular clusters. They are the well-known K648 in NGC 7078 (M15), and the peculiar, recently-discovered GJJC-1 in NGC 6656 (M22) (Gillett et al. 1989). Previous surveys for planetary nebulae in globular clusters are incomplete or unpublished, therefore, in 1993 we started a systematic search for these objects.

## 2. EXPECTATIONS

The number of PNe which one expects to discover by a systematic search in globular clusters can be estimated in several ways.

In the galactic bulge, within 3° from the galactic center (corresponding to a total mass of about 1.5–3 $\times 10^9$ $M_\odot$, Lindquist, Habing, & Winnberg 1992) there are about 250 planetary nebulae according to the estimate of Pottasch (1992). If the production rate of PNe in globular clusters is the same as in the galactic bulge, by searching a number of globular clusters containing a total mass of $2 \times 10^7$ $M_\odot$, about 2 or 3 PNe should be found.

Using the fuel consumption theorem (Renzini & Buzzoni 1986), the number of planetaries expected in analyzing a number of globular clusters, globally totaling $10^7 L_\odot$, would be about 2 to 3 (if a typical PN lifetime of $10^4$ years is assumed).

## 3. OUR SURVEY

Motivated by the reasons presented in section 1 and given the uncertainties in the estimates shown in section 2, we have undertaken a program of CCD imaging of globular clusters with narrow interference filters centered on the nebular lines H$\alpha$ ($\lambda_0$ = 6570, $\Delta\lambda$ = 80, it includes the [N II] lines) and [O III] ($\lambda_0$ = 5007, $\Delta\lambda$ = 80), and the adjacent continua, looking for PNe candidates. Imaging is complemented with spectroscopy of the candidates discovered.

TABLE 1. GLOBULAR CLUSTER DATA

| object | $M_V^a$ | Mass[b] ($10^5\ M_\odot$) | Imaging[c] Hα | OIII | Spectrum[c] | Comments |
|---|---|---|---|---|---|---|
| NGC 288 | −6.6 | 1.04 | 5 | ... | ... | no detection |
| NGC 2419 | −9.6 | 16.3 | 20 | 20 | ... | no detection |
| NGC 4147 | −6.0 | 0.62 | 10 | 15 | ... | faint candidate |
| NGC 4590 | −7.3 | 1.92 | 15 | 15 | ... | no detection |
| NGC 5024 | −8.9 | 8.38 | 20 | 20 | ... | faint candidate |
| NGC 5053 | −6.1 | ... | 20 | 20 | ... | no detection |
| NGC 5272 | −9.2 | 11.0 | 10 | 10 | ... | no detection |
| NGC 5824 | −9.6 | 16.0 | 12 | 10 | ... | no detection |
| NGC 5904 | −8.8 | 8.15 | 15 | 20 | ... | no detection |
| NGC 5986 | −8.4 | 5.60 | 10 | 10 | ... | no detection |
| NGC 6121 | −7.0 | 1.50 | 15 | 15 | ... | no detection |
| NGC 6218 | −7.5 | 2.46 | 10 | 10 | ... | no detection |
| NGC 6229 | −8.1 | 4.30 | 10 | 10 | ... | no detection |
| NGC 6273 | −9.6 | 16.9 | 15 | 20 | ... | no detection |
| NGC 6356 | −8.9 | 8.61 | 10 | 12 | 10 | two faint candidates resulted stars |
| NGC 6366 | −6.2 | ... | 10 | 12 | ... | no detection |
| NGC 6402 | −9.3 | 12.9 | 20 | 20 | ... | faint candidate |
| NGC 6440 | −8.8 | 7.60 | 10 | 10 | ... | no detection |
| NGC 6553 | −8.3 | 4.96 | 10 | 12 | 15 | candidates resulted field stars |
| NGC 6553.1 | " | " | 5 | ... | ... | 2.5′ W, no detection |
| Kod 1 | ... | ... | 10 | ... | ... | no detection |
| NGC 6656 | −8.5 | 6.18 | 10 | 10 | ... | M22, GJJC-1 detected |
| NGC 6656.1 | " | " | 10 | 10 | ... | M22 ($8^s$ E), no detection |
| NGC 6656.2 | " | " | 10 | 10 | ... | M22 (3′ N), no detection |
| NGC 6656.3 | " | " | 10 | 15 | ... | M22 (3′ E; 2′ S), no detection |
| NGC 6712 | −7.3 | 2.07 | 12 | 15 | ... | faint candidate |
| NGC 6712.1 | " | " | 12 | 15 | ... | 3′ S–E, no detection |
| NGC 6749 | −6.2 | ... | 15 | 20 | 15 | two faint candidates resulted stars |
| NGC 6749.1 | " | ... | 10 | ... | ... | 2′ S, no detection |
| NGC 6838 | −5.8 | 0.51 | 10 | 15 | ... | faint candidate |
| NGC 6934 | −7.5 | 2.39 | 10 | 15 | ... | no detection |
| NGC 6981 | −6.9 | 1.42 | 10 | 12 | ... | no detection |
| NGC 7006 | −7.7 | 2.77 | 12 | ... | ... | no detection |
| NGC 7006.1 | " | " | 7 | ... | ... | 7′ S, no detection |
| NGC 7078 | −9.2 | 11.9 | 10 | 10 | ... | M15, K648 detected |
| NGC 7089 | −9.1 | 10.4 | 10 | 15 | ... | no detection |
| NGC 7099 | −7.2 | 1.77 | 10 | 10 | ... | no detection |
| Pal 13 | −3.3 | 0.05 | 15 | ... | ... | no detection |
| NGC 7492 | −5.0 | ... | 15 | 15 | .. | no detection |

[a] Data by Webbink (1985).
[b] Data by Aguilar et al. (1988).
[c] Exposure time in minutes.

Data have been gathered since 1993, using the 2.1-m telescope and a 1024 × 1024 UV coated CCD detector at the Observàtorio Astronómico Nacional, San Pedro Mártir, B.C. Each frame covers 4.5′ × 4.5′ in the plane of the sky and it has been centered on the central position of the cluster. Some of the very extended clusters, such as M22, have been observed at different positions.

Globular clusters observed so far are listed in Table 1, where we also include the integrated visual magnitude and the estimated mass of the cluster. Exposure times of the images in each filter are listed in columns 4 and 5. All the data were reduced using the IRAF reduction package. The process for each raw image includes bias-subtraction, flat-fielding and cosmic-ray correction, after which the sky contribution is subtracted to the whole image. H$\alpha$, [O III] and continuum images were normalized by exposure time, before subtracting the continuum. The continuum-subtracted H$\alpha$ and [O III] images have been carefully inspected for emission line objects. Figure 1 shows continuum-subtracted images of M22 (showing K648) and NGC 6273, where no candidate was found. The result of the visual inspection for each cluster is presented in the last column of Table 1. Some of the faint candidates found have been analyzed spectroscopically; this is indicated in column 6 of Table 1.

## 4. PRELIMINARY RESULTS

At present we have analyzed a total of 32 globular clusters which correspond to about $1.68 \times 10^7\ M_\odot$ and $\sim 0.6 \times 10^7\ L_\odot$. According to expectations we should have detected 2 to 3 PNe. The two known PNe mentioned in section 1 were easily re-discovered (see Fig. 1). This shows the validity and sensitivity of our method but no other PN has been clearly detected. Some faint blue candidates remain for spectroscopic verification, although they do not appear as extended objects and most probably they will be identified as faint blue stars.

Similar results have been recently reported from a survey of 48 northern globular clusters by Jacoby & Fullton (1995). There are 22 objects in common between the samples. The total mass accumulated in the two samples is $2.44 \times 10^7\ M_\odot$ and apart from the two known PNe, no new PN was found, when 3 to 4 objects were expected. The result is marginally lower than the expectations presented above. Whether this is significant can only be proven by searching a larger number of globular clusters.

A persistent negative result to find new PNe could be explained in several ways:

– expectations presented in section 2 could be over-estimates for globular cluster population due to possible differences in the evolution of stars in such clusters —for example as a result of metallicity effects. Alternatively, the PNe produced in clusters could be fainter or undetectable. In this respect, Jacoby & Fullton suggest that the low-mass turn-off point in globular clusters could be producing PN nuclei with masses lower than $0.55\ M_\odot$. These stars are believed to have evolutionary heating times that are longer than the kinematical dispersion times for the nebula.

– planetary nebulae formed in globular clusters might have experienced a systematic stripping by the pressure of the ambient interstellar medium, through which the clusters are moving at high velocities (as in the case of GJJC-1, Borkowski, Tsetanov, & Harrington 1993).

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