tronomical silicate. With a dust mass 0.05 solar masses, inefficient dust emission at $\lambda > 30\ \mu$ lowers the luminosity by only 0.1 dex.

Pulsar emission, absorbed and reradiated by dust in the ejecta (IAUC 4746), seems the most likely explanation of our observations. Other spectroscopic signatures of such input should be sought.

Subsequent IR observations in January and February 1990 substantiate the flattening of the light curve.

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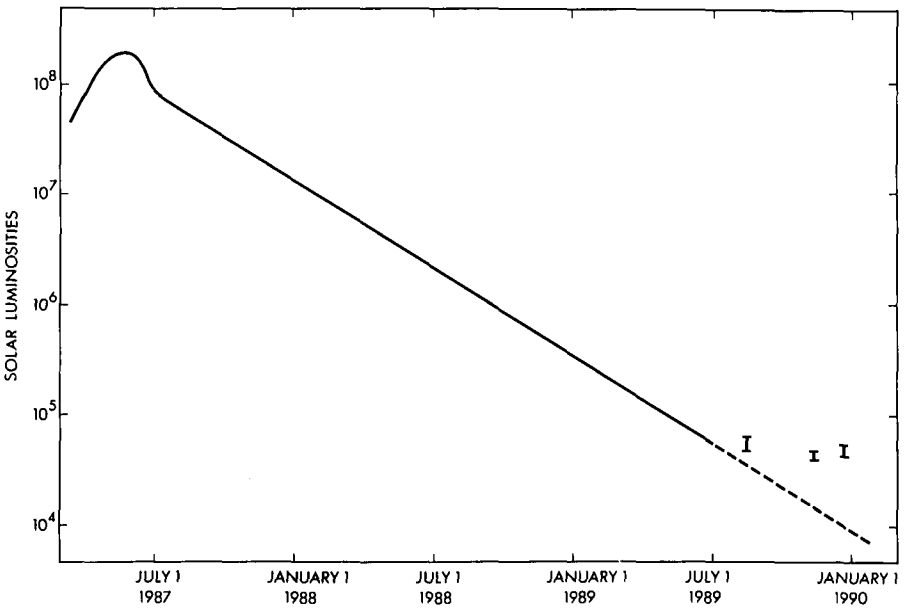

The bolometric light curve of Supernova 1987A ▶

A Photometric Study of the Bright Cloud B in Sagittarius

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1. Introduction

The study of the intrinsic properties of variable stars provides important information about stellar populations in the galactic bulge. The period of a variable star has the advantage of being independent of the distance, whereas the general distribution of stars in a colour-magnitude diagram is strongly influenced by the interstellar absorption.

It is this particular property of the variable stars which has led to numerous photographic studies since 1951 in the direction of the galactic centre, in order to detect such stars and to measure the distance between the Sun and the centre of our Galaxy. In the course of this work various objects have been studied, such as the areas around the globular cluster NGC 6522 and the sources SgrI and SgrII in which many variables of the RR Lyrae type have been detected (blue variables, giants of spectral type A-F with $0.2 < P < 0.5$ and A (amplitude) < 0.8, distance indicators used in particular for the determination of the extragalactic distance scale).

But the study of red variable stars in these regions is even more important and fruitful because we know that M-type giants are a major component of the stellar population in the central regions of galaxies of types E, S0 and Sb (our galaxy is of type Sb or more exactly SAB (rs) bc according to de Vaucouleur's classification scheme).

In 1958, Nassau and Blanco (1958) were the first to prove, with the help of objective prism plates, that there exists a large number of M giants in the field of the globular cluster NGC 6522. This work was later followed and enriched by V and I plates (Klube, 1966), on which the detection of M giants was facilitated by means of the large values of the colour index (V-I).

On the other hand, the accumulation of photographic data in J, H, K, L of the Johnson system for long-period variables (LPVs) detected in the Magellanic Clouds and in the solar neighbourhood (Wood and Bessel, 1983), as well as the refinement of the pulsation theory for Mira Ceti type variables (Fox and Wood, 1982) have permitted the deduction of certain fundamental physical properties of the LPVs. It was in this way that Wood and Bessel, in 1983, were able to show that the LPVs near the galactic centre differ considerably from those in the Magellanic Clouds and in the Local Group: While the J-K colours in these three regions are practically the same for $P < 250$ days, the LPVs near the centre of the Galaxy are particularly red when compared to other variable stars of the Mira Ceti type and they are all stars of spectral type M.

In 1965, working in particular in the red and near infrared photographical regions of the spectra ($\lambda_{eff} \sim 640$ and 830 nm), I detected 421 red variable stars (Terzan 1965, 1966, in the field of one square degree centred at the star 45 Oph ($\alpha = 17^h\ 24^m.1$; $\delta = -29°\ 49'$).

In the same year, Arp (1965) studied the particularly important question about the contamination of the population in the region of NGC 6522 by the projection in the same field of the images of the stars situated between the cluster and the Sun. He concluded that about 90% of the stars which have a colour (B-V) = 1.0 are indeed stars at large distance which belong to the population in the central region of the Galaxy and resemble a stellar cluster and where the difference in magnitude from the centre to the exterior (in the direction from the galactic centre towards the Sun) is only 0.3 mag.

In 1966, Clube demonstrated that the stars which have $V > 15.5$ and $B\text{-}V > 1.6$ are mainly situated in the galactic bulge.

Then, in 1976, Lloyd Evans (1976) after a comparison of V and I plates taken in three selected fields towards the galactic centre (NGC 6522, SgrI, SgrII), confirmed the predominance of red stars in the galactic bulge. He detected, in particular, 121 red variable stars of the Mira Ceti type having periods significantly longer than those located in globular clusters.

This short historical overview in which only a few important steps in the study of the content of the galactic bulge have

been mentioned, shows how interesting it is to continue the photometric study of the central region of the Galaxy, in order to enrich our knowledge about the content of the galactic bulge and to search for those objects (variable stars, open and globular galactic stellar clusters, diffuse objects, galaxies, proper motion stars, planetary nebulae, etc.) which populate the bright cloud B in Sagittarius or are seen in this central direction of the Galaxy.

2. Plan and Method of Working

The plan and method of working, the chronology and place of the observations, the method of dividing into 4 parts a large field of $10° \times 10°$ centred on the star 45 Oph, the reason for the creation and study in the first place of a central field O and the description of the proposed stages in the advancement of the programme of work have been described previously (Terzan, 1977; Terzan et al., 1982; Terzan and Turati, 1985; Terzan and Ounnas, 1988).

When the analysis of our U, B, V and R plates, covering a field of $10° \times 10°$, centred on star 45 Oph, is finished, we will undertake an individual study of all these new variable stars, in order to determine for the majority of them the period, the amplitude and the type as well as a study of the spatial distribution, not just in square degree but also in the different types of variability.

The last phase of this programme will necessitate a great deal of work in photoelectric or photographic photometry in one or several of the four chosen spectral domains U, B, V and/or R as a function of their luminosity.

Thus we hope to reach the final goal of our research which is essentially the analysis (detection and study) of the objects populating the galactic bulge and offering a very rich subject matter to contemporary astrophysics and enabling us to advance our knowledge of the central region of the Galaxy.

3. Variable Stars

3.1 OBSERVATIONS

All of the photographic plates studied for the present work originate from two series of observations made:

– in June-July 1968, by Terzan at the 48″ Schmidt telescope (f/2.44, 67.″1 mm^{-1}) of Mount Palomar Observatory, on $10'' \times 10''$ plates;

– since 1976, by technical collaboration of Schuster at the ESO 1-m Schmidt telescope (f/3, 67.″5 mm^{-1}) of ESO/Chile, on $12'' \times 12''$ plates.

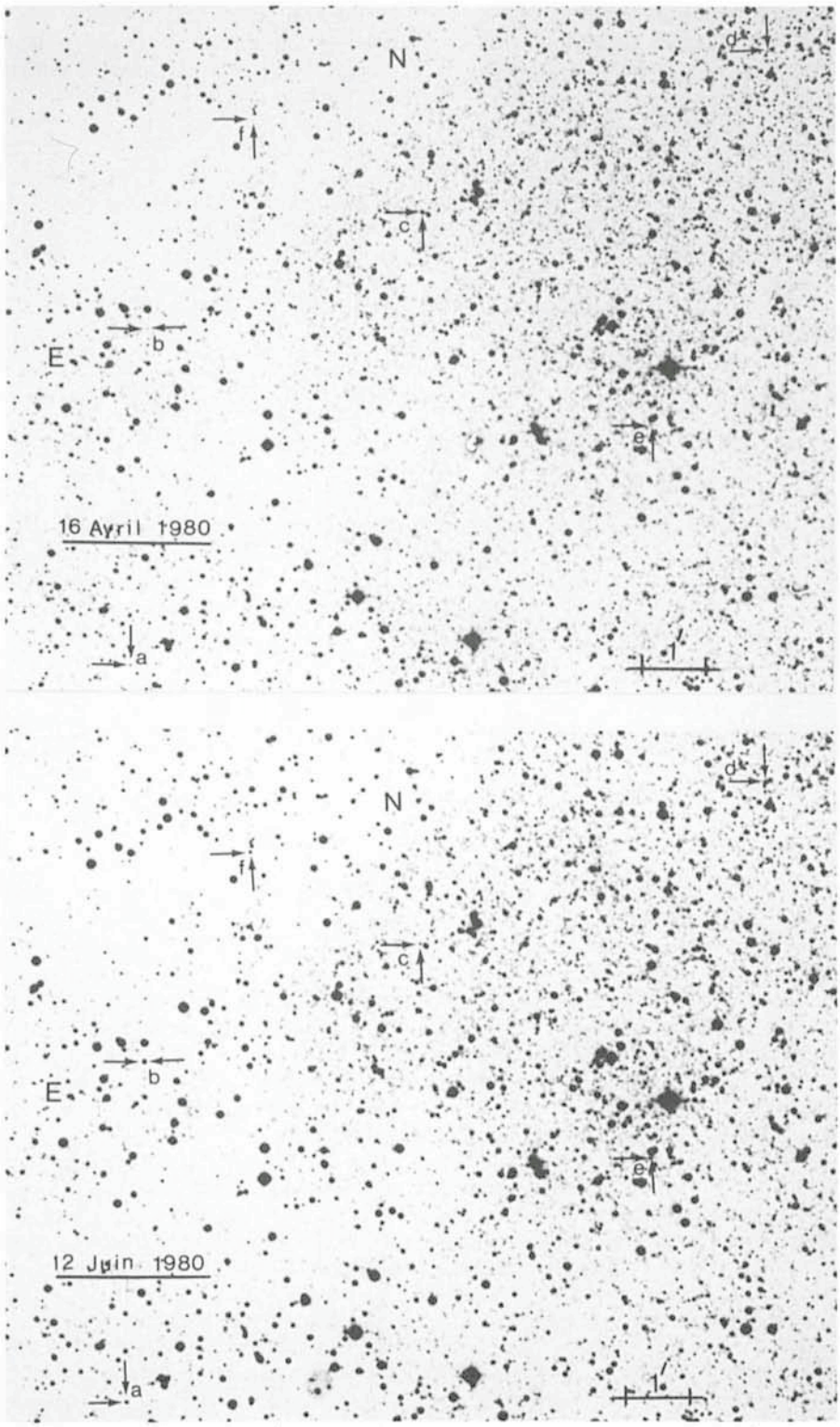


Figure 1: *New variable stars detected north of the globular cluster Terzan 1: $\alpha = 17^h\,32^m\,35^s$, $\delta = -30°\,26'\,18''$.*
Top: R plate ($\lambda_{eff} = 6400$ Å) No. 3716, taken on April 16, 1980 with the ESO Schmidt telescope on La Silla.
Bottom: R plate ($\lambda_{eff} = 6400$ Å) No. 3757, taken on June 12, 1980 with the ESO Schmidt telescope.

3.1.1 Detection

The blink microscope of the Observatoire de Lyon was used to make comparisons among all the B, V and R plates of the fields A, D and B. Equipped with 5 eyepieces of different magnification, the mechanical, optical and electronic performance of this instrument enables the detection of a difference in brightness of the order of 0.2 mag and the reading, with a precision of $\pm 3\,\mu$ of the X; Y

coordinates relative to an arbitrary origin.

On the other hand, the provision, on one of the beams which scans the plate, of an optical system comprising two lenses, enables, by making small changes in positioning, the compensation

- for the difference in focal length occurring between the exposure of plates (at the same telescope) on different occasions, or
- for the difference in scale between two plates originating from different telescopes but with comparable scales (67".1 mm^{-1} for Palomar Schmidt telescope/67".5 mm^{-1} for ESO Schmidt telescope).

3.1.2 Measurements of the coordinates (α, δ; l, b)

The measurement of the coordinates X and Y of each variable star and their transformation into α and δ (equinox 1950.0) and then into l and b, was done at ESO Garching with the microdensitometer S 3000-Optronics.

The precision of the measurements for α and δ is $\pm$ 0".3.

3.2 RESULTS

3.2.1 Variable stars of types L and/or M

In chronological order of the reductions, we have detected:

- Field O: 621 red variable stars (Terzan et al., 1982) (Fig. 1)
- Fields A + D: 1592 red variable stars (Terzan and Ounnas, 1988)
- Field B: 1238 red variable stars (Terzan, 1990)

In all 3451 stars.

The histogram (Fig. 2) shows N, that is the number of stars for which it has been possible to determine the "observed amplitude", in amplitude steps of δm = 0.5 magnitude. It shows that

(1) of a total of 1862 variable stars, 503 have an amplitude between 2.1 and 3.0 magnitudes. This is only a preliminary result, because of the 3451 new variable stars discovered in fields O + A + B + D, we have only been able to define A = R [max] – R [min] for 1852 of them. The others have a R [min] which is uncertain: approximately equal to or fainter than 18 mag.

The grouping of these 493 variable stars in an amplitude interval between 2.1 and 3.0 mag. leads us to formulate the hypothesis that in the direction of the galactic centre the variable stars of L and/or M type are probably more numerous than in other regions of our Galaxy.

The confirmation or the disproval of this hypothesis is only possible after the termination of the studies of the variables in the remaining field C and the construction of the light curves and the determination of the type of variability for all of the variables which have been discovered.

(2) The number of variable stars decreases very rapidly towards large amplitudes.

3.2.2 Cepheids and/or RR Lyr type variable stars

The detection and the study of new, short-period variable stars of RR Lyr and Cepheid type is the subject of another research programme which will follow and complement the current work.

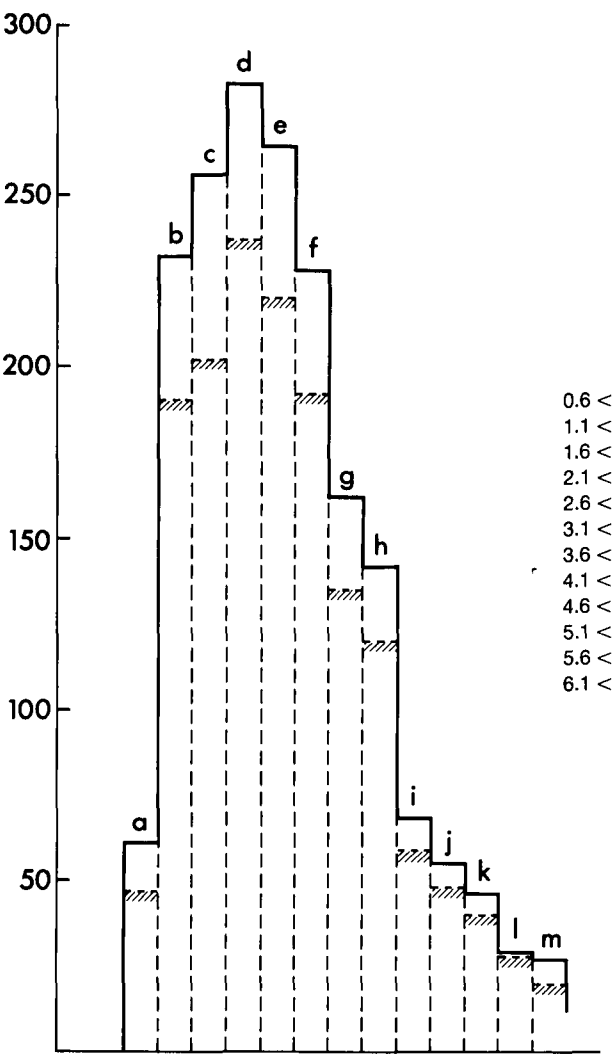
We already have many U and B plates covering the fields O, A, B, C, and D. An UBV photometric sequence has already been established (Terzan and Bernard, 1981) for the future measurements. For the time being, we try to enlarge our plate collection, by repeating the B observations, 2 or 3 times each night, in order to establish the light curves (for the RR Lyr variables) by means of a large number of measurements.

4. Planetary Nebulae

In view of their spatial distribution – mainly in the galactic plane with a strong concentration towards the glactic centre – the current study will eventually lead us towards the discoveries of new planetary nebulae. The number of planetary nebulae known in our Galaxy is now 1180, cf. the new catalogue by Acker (1990).

It is estimated that the total number may be of the order of 20,000, but this is only an approximate estimate in view of the uncertain knowledge of the distances, even if R_o, the distance between the Sun and the galactic centre, is quite well known.

What concerns the detection of new planetary nebulae in the direction of the galactic centre, the possibilities are rather small because optical studies in this direction are made very difficult by the strong and very irregular extinction over the entire field. Contrarily, planetary nebulae are strong emitters in the far-infrared spectral region and the IRAS (Infra-Red Astronomical Satellite) measurements can help us to make new identifications. The IRAS Survey in the



FIELD	A+D+B+O	A+D+O
a < 0.5	61	47
0.6 < b < 1.0	232	190
1.1 < c < 1.5	256	202
1.6 < d < 2.0	282	237
2.1 < e < 2.5	265	220
2.6 < f < 3.0	228	192
3.1 < g < 3.5	162	135
3.6 < h < 4.0	141	120
4.1 < i < 4.5	68	59
4.6 < j < 5.0	55	48
5.1 < k < 5.5	46	40
5.6 < l < 6.0	29	28
6.1 < m	27	20
	1852	

Figure 2.

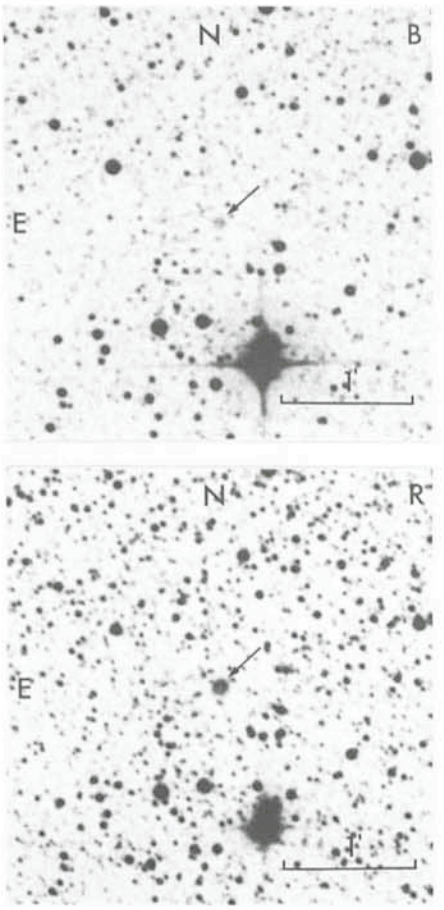


Figure 3: *Identification charts in B and R of a new possible planetary nebula: $\alpha = 17^h\ 39^m\ 24^s$, $\delta = -25°\ 44'\ 05''.5$; $l = 2.3$, $b = 2.3$. Position on ESO/R (No. 520): X = 102 mm; y = 110 mm.*

12–1000 μm region overcomes the difficulty of the strong extinction in the visible region. But the limited spatial resolution of the IRAS measurements (3–5 arcminutes) is an inconvenient obstacle for the identification of individual objects and it gives no information about their morphology.

Despite all the advantages and disadvantages of the choice of observation (photographical or IR), the continued study of our UBVR plates of the central region of our Galaxy has enabled us to discover 10 new PN candidates (Terzan and Ounnas, 1988) in fields A and D. After the photometric study of field B, this list has been enlarged by 16 other candidates.

Figure 3 shows photographic reproductions in B and R of one of our most recent PN candidates.

This demonstrates that good plates always have surprises in stock for us and that "The ESO/SERC Survey of the Southern Sky is by far not exhausted of its riches!" (Saurer and Weinberger, 1987).

5. The Discovery of Galaxies in a Direction Near the Galactic Centre

In 1978, I detected three diffuse objects (Terzan et al., 1978a, b) 2 degrees west of the galactic centre, and only 5 degrees from the galactic plane. These detections were made on ESO Schmidt telescope plates and were subsequently confirmed by photographic observations with the ESO 3.6-m telescope.

In 1980, when 24 other diffuse objects in the same region were announced (Terzan and Ju, 1980), I put forward the hypothesis that most of them could be galaxies, seen through a "second transparent window", a region with less interstellar obscuration. Unfortunately, the observed images did not allow any morphological study.

The possible confirmation of the extragalactic nature of these objects necessitated the establishment of a new

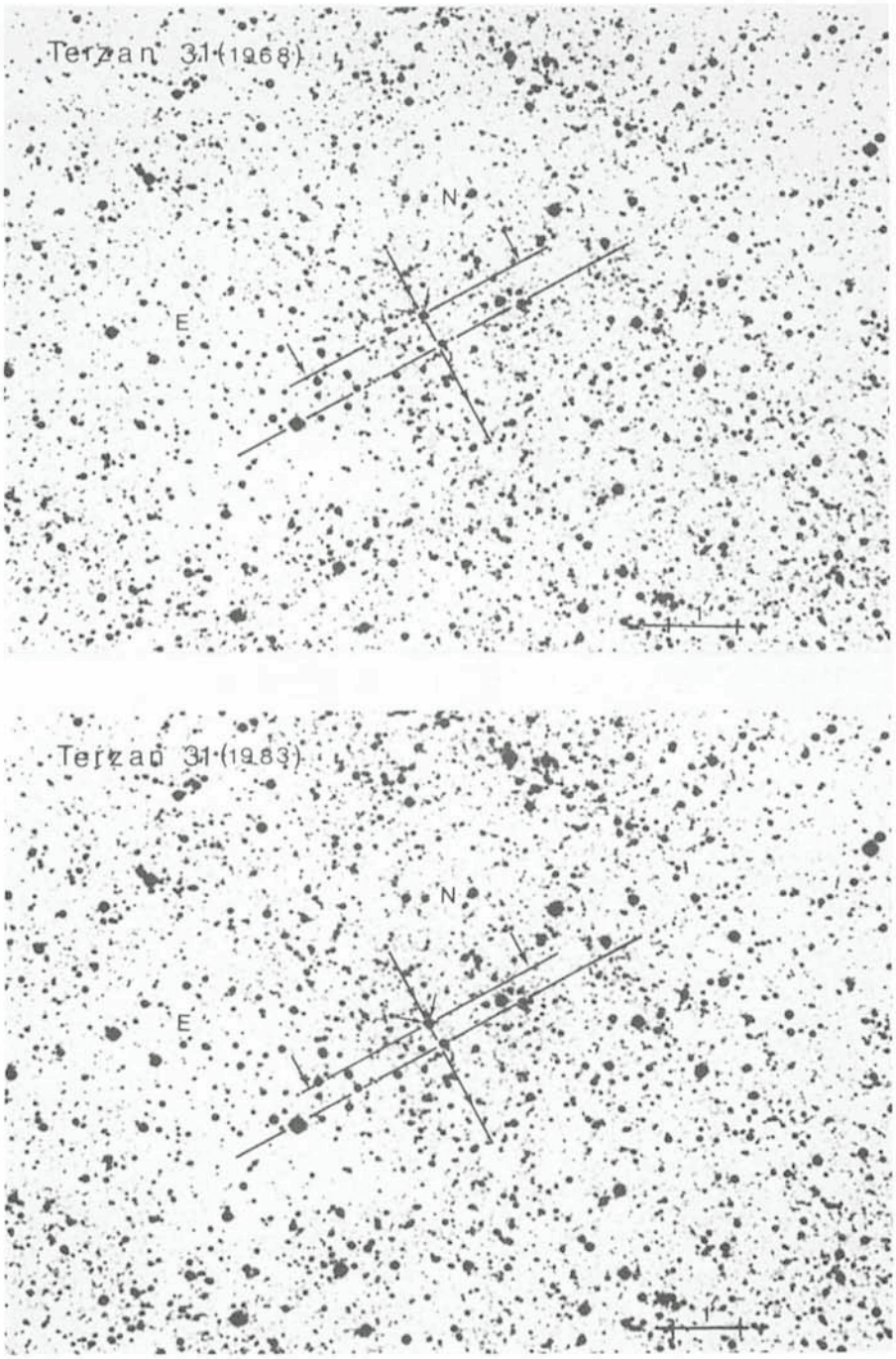


Figure 4: *High proper-motion star Terzan 31: $\alpha = 17^h\ 28^m\ 49^s.9$, $\delta = -29°\ 48'\ 58''.4$; $m_{pg} = 16.5$, $m_r = 15.0$, $\mu = 0''.585$, $\theta = 215°$.*
Top: R plate ($\lambda_{eff} \simeq 6400$ Å) No. PS 3753, taken on June 24, 1968 with the Schmidt telescope of the Mount Palomar Observatory.
Bottom: R plate ($\lambda_{eff} = 6400$ Å) No. 5205, taken on August 1, 1983 with the ESO Schmidt telescope.

observational programme and the taking of plates with a large telescope.

In 1981, Johnston et al. (1981), during their search for an optical counterpart of the extended X-ray source detected with the HEAO 1 Scanning Modulation Collimator near 4 U 1708-23 ($l = 0\overset{\circ}{.}5$; $b = 9\overset{\circ}{.}4$), found an anonymous $z = 0.03$ cluster of galaxies (CL 1709-233), the Ophiuchus Cluster which falls outside the northern limit of a field. Within a $2\overset{\circ}{.}1 \times 2\overset{\circ}{.}6$ rectangle, centred on their so-called "dominant central galaxy" ($17^h\ 09^m\ 25\overset{s}{.}6$; $-23°18'35''$, 1950.0), Johnston et al. have found 108 galaxies and they suggest that the steep-spectrum radio source MSH 17-023 is associated with this cluster.

The successive additions to this list of diffuse objects (originally defined as "galaxy?" or "nucleus of galaxy?" (Terzan, 1985; Terzan and Ounnas, 1988; Terzan, 1990) have now confirmed our hypothesis (Terzan, 1985), namely that:
– there is indeed a "second transparent window", very near the galactic centre, near the north-east border of the Bright Cloud B in Sagittarius,
– the extent of the Ophiuchus Cluster is considerably greater than $2\overset{\circ}{.}1 \times 2\overset{\circ}{.}1$,
– the number of objects which populate it is well above 108 (Johnston et al., 1981).

In June 1986, an observing programme of the Ophiuchus Cluster in UBVR with the ESO Schmidt Telescope was carried out with great success.

The reduction and the continued study of the new plates will permit us to count accurately the galaxies which populate this cluster, as well as to determine the morphological types, their distribution in the cluster. Moreover, it will tell us how large the window is and also the size of the cluster.

6. New Stars With Proper Motions $\mu > 0.2$ arcsec/year

In 1980, 42 nearby stars were detected in the direction of the galactic centre (Terzan et al., 1980) by means of their large proper motions, above 0.2 arcsec per year. One of these (No. 31) had already been mentioned in 1964 (Terzan, 1964) as having a large motion (Fig. 4).

In 1988, the measurements and the study of our plates of fields A and D had enabled me to detect a total of 185 other, new stars with proper motions in excess of 0.2 arcsec per year (Terzan et al., 1988).

When the measurements of all plates of fields O, A, B, C and D have been completed, we shall start a photometric study of these stars, in particular a study of the white dwarfs which may be among them.

Name	X-ray source designation	
Terzan 1	XB 1733-30	(Makishima et al., 1980)
Terzan 2	XB 1724-31	(Grindlay, 1978)
Terzan 3	XB 1745-25	Makishima et al., 1980)

A preliminary observing period (Terzan, May 1989, 1-m telescope with the QUANTACON photometer, UBVRI) within this programme resulted in the measurement of 58 stars, each at least twice over 6 nights (r.m.s. = ± 0.02 mag), but not a single white dwarf was identified.

7. Open and Globular Stellar Clusters

7.1 OPEN CLUSTERS

The presence of a "grouping" of some bright stars on a photographic plate within a relatively small area (~ 1′ – 2′) is by no means proof of the existence of an open galactic cluster, especially in the central direction of the Galaxy. This "grouping", which often is the image of a real open cluster, may sometimes only be the result of a simple "projection" effect of star images in a given direction. for this reason, photometric studies are absolutely necessary.

For instance, object No. 20 (Terzan and Ju, 1980), visible on UBV and R plates, seems to be an open galactic cluster. However, before its true nature can be confirmed, it is necessary to establish and discuss the U-B/B-V and V/B-V diagrams following UBV measurements of all the stars supposed to be "members" of this cluster.

7.2 GLOBULAR CLUSTERS

In 1966, a total of 112 globular clusters were known in our Galaxy. In 1972, after extensive photographic observations and careful reduction of the plates obtained in the red and near-infrared photographic wavelength region, resulting in the discovery of 11 new globular clusters (Terzan 1-11), this number had increased to 123. This represents an increase of 10% of the number of objects, which are the oldest known objects, showing up soon after the Big Bang and whose chemical composition is related to that of galaxies in their earliest evolutionary stages and whose ages constitute an important observational parameter for cosmological models. As an important particularity we may mention that the globular clusters Terzan 1, 2 and 5 are "extended X-ray sources", detected with the HEAO 1 Scanning Modulation Collimator.

At present, after the recent discovery of three other galactic globular clusters by Djorgovsky (1987), their total number amounts to 130. To this list must be added another 13 "candidates" (Terzan, 1985, 8 objects; Terzan, 1990, 5 objects), whose detailed morphological study is envisaged in June 1990 at the ESO 1.52-m telescope.

Conclusion

The importance of this kind of research consists not only in the large number of discoveries of many new members of the one or the other group of objects (variable stars, planetary nebulae, open or globular stellar clusters, proper-motion stars, galaxies, etc.). Above all, it should be stressed that the availability of an extensive collection of observational data now enables us to proceed with a detailed study of the objects which populate the galactic bulge. It provides modern astrophysics with a vast material and promises to increase our knowledge about the central region of our Galaxy.

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