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RETROSPECTIVE ON "THE SEARCH FOR BLUE STARLIKE OBJECTS IN THE DIRECTION OF THE POLES OF THE GALAXY", BY HARO & LUYTEN (1962)

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RESUMEN

Presento una revisión sobre la relevancia del artículo de G. Haro y W. J. Luyten, 1962, BOTT, 3, 22, 37, sobre objetos azules débiles en una dirección cercana al polo sur galáctico. Discuto el trabajo llevado a cabo por Haro, Luyten y sus colaboradores sobre la búsqueda de estrellas azules débiles y menciono algunas de sus implicaciones para el estudio de galaxias azules y cuásares.

ABSTRACT

I present a review of the paper by G. Haro and W. J. Luyten, 1962, BOTT, 3, 22, 37, on Faint Blue Stars in the Region near the South Galactic Pole. I discuss the work carried out by Haro, Luyten, and collaborators on the search for faint blue stars and mention some of its implications for the study of blue galaxies and quasars.

Key Words: galaxies: starburst — quasars: general — stars: horizontal-branch — subdwarfs — white dwarfs

1. INTRODUCTION

In the thirties and forties of the last century it was thought that the vast mayority of stars were yellow and red, and that blue stars were main sequence objects mainly confined to the Galactic disk. It was also thought that almost no blue stars were located in the direction of the Galactic poles and that most bright galaxies were yellow or red.

These ideas were challenged by the work of Haro, Luyten, and Zwicky, among others. The paper on faint blue starlike objects by Haro & Luyten (1962) played an important role in this controversy. In what follows I will present a short review on this paper and some of its implications.

I presented short accounts on the astronomical work by Haro in previous meetings (Peimbert 1983, 1997).

2. SURVEYS OF FAINT BLUE STARLIKE OBJECTS

In Table 1 I present a series of papers published between 1927 and 1968, mainly dedicated to the search of faint blue starlike objects, FBSO, in the direction of the Galactic poles.

Of the 4454 stars in the direction of the north Galactic pole studied by Malmquist (1927, 1936) only 15 have a color index smaller than 0.00. The 15 stars are brighter than $m = 14$, and ten of them are brighter than $m = 10.0$. In the thirties and forties it was thought that blue stars were mainly main sequence stars and none were expected to be far away from the plane of the Galaxy.

Humason & Zwicky (1947) searched for white dwarfs in the direction of the Hyades and the north Galactic pole, they found 48 faint blue stars of which 17 are white dwarfs and 29 probably horizontal branch stars with absolute magnitudes around cero.

The success attained by Humason & Zwicky (1947) in their search for FBSO and his interest on white dwarfs led Luyten (1953) to start an ambitious program to search for faint blue stars. Most of his work, that appeared in the series *A Search for Faint Blue Stars* (1953–1969), was based on blinking pairs of plates to search for stars earlier than about F0.

Haro developed a photographic method at Tonantzintla Observatory for the study of T Tauri stars with strong UV radiation (Haro & Herbig 1955; Haro 1956). On a 103a-D plate three exposures, slightly displaced from each other, were taken with three different filters: ultraviolet (Corning 9863 + fused quartz), yellow (Corning 3384 + Corning 7740), and blue (Corning 5030 + Scott GG-13). The exposure times for each filter were calibrated to yield three similar images for an A0 star. In addition to objects with a UV excess this procedure permits to identify those objects with spectral type A0 or earlier. This method under Haro's suggestion was used by Iriarte & Chavira (1957) and Chavira (1958, 1959) to search in the direction of the Galactic poles for FBSO similar to those discovered by Malmquist (1927, 1936),

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TABLE 1

NUMBER OF FAINT BLUE STARLIKE OBJECTS KNOWN

	Method		
Reference	2 plates	3 images	Spectroscopic
Malmquist(1927, 1936)[a]	15	...	...
Humason & Zwicky (1947)[b]	48	...	...
Luyten et al. (1953-1956)	1200	...	...
Iriarte & Chavira (1957)	...	817[c]	...
Chavira (1958)	...	419[c]	...
Cowley (1958)	...	...	96
Feige (1958, 1959)	114	...	...
Luyten et al. (1958-1961)	2222	1505[c]	...
Chavira (1959)	...	772[c]	...
Slettebak & Stock (1959)	...	...	601
Haro & Luyten (1962)	...	8746[d]	...
Luyten et al. (1962-1968)	3933	2624[d]	...
Zwicky & Luyten (1967)	218	...	...
Rubin et al. (1967)	...	232[d]	...
Philip (1967)	...	...	34
Philip & Sanduleak (1968)	...	...	180
Total	7750	15115	911

[a]Data from two sets of exposures in a given plate, one without filter and the other with a yellow filter.

[b]Data from four different plates.

[c]Tonantzintla Schmidt telescope.

[d]Palomar Schmidt telescope.

Humason & Zwicky (1947), and Luyten and collaborators (1953–1956).

These previous works, including those by Cowley (1958), Feige (1958, 1959), Luyten et al. (1958–1961), and Sletteback & Stock (1959), led to the classic paper on the field by Haro & Luyten (1962) based on Haro's three-image method.

Haro & Luyten used the Palomar 48 inch Schmidt telescope with 103a-D plates and somewhat different filters than those used at Tonantzintla: ultraviolet Scott UG1, yellow Wratten-12 and blue Wratten-47. They took plates for 47 regions covering approximately 1600 square degrees of southern polar regions and found 8746 starlike blue objects, these FBSO are known by their Palomar Haro Luyten number, PHL. The catalogue is complete to about $m = 18.0$ (Sandage & Luyten 1967). Unfortunately no finding charts were published for the PHL objects in 1962, though many identification charts were provided by Haro upon request and the finding charts for one of the regions were published twenty five years later (Haro & Chavira 1987).

It should also be mentioned that Haro and Luyten had been exposed to many of the controversial ideas by Zwicky and that they were interested in testing some of them. Zwicky, following his method of morphological research, thought that many classes of objects as yet unknown existed in the Universe, including single star galaxies, pygmy stars and stars in fast stages of evolution that would fill the observed gaps in the HR diagram. Pygmy stars comprised neutron stars and stars intermediate between white dwarfs and neutron stars.

Also present in Table 1 are other studies on the subject published up to 1968, the year of paper 49 in the series by Luyten and collaborators. Table 1 includes all the FBSO in the lists by Luyten et al., not all of them are in the direction of the poles. No attempt was made to eliminate from each entry in Table 1 those objects included in previous lists.

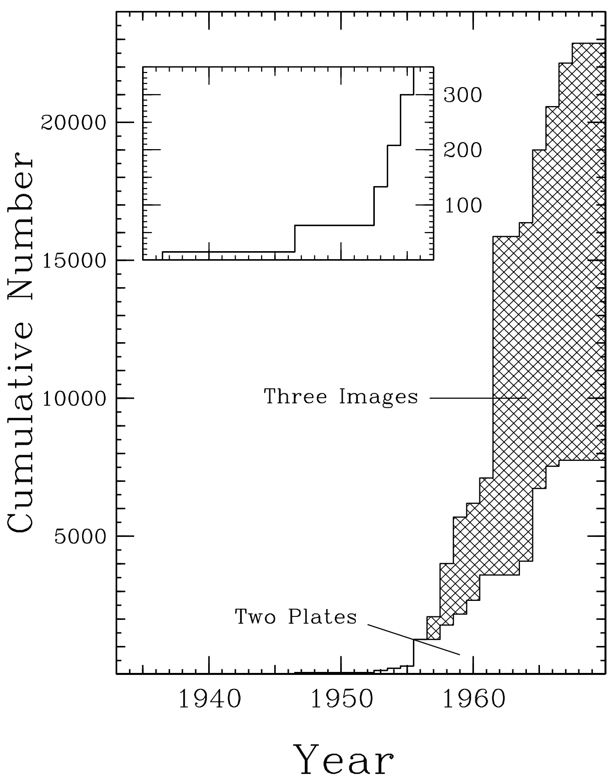

Fig. 1. Cumulative number of faint starlike objects discovered in the 1936–1968 period. The insert is an amplification of the figure for the 1936 to 1955 period, when only 300 faint blue stars, mainly in the direction of the Galactic poles, had been discovered. The contribution to the total number of faint blue objects due to the two plates method is represented by the white area, while that due to the three images method is represented by the shadowed area (see also Table 1).

Most of the FBSO were detected either by blinking two or more plates of different colors (7750 objects), or from the three images method in a single plate (15115 objects). Figure 1 shows the cumulative number of FBSO as a function of time. The three images method proved to have several advantages over the blinking method, mainly due to the higher subjective character of the latter, the main advantages of the three images method were: (a) the smaller time required to analyze the plates, (b) the smaller errors in the color indexes determined, and (c) the three images method provided two color indexes ($U-V$, $B-V$), while in general the blinking method provided only one color index. The FBSO detected from the three images method were divided into three groups: I very definitely blue, II blue, and III bluish or white. In Table 2 we present the distribution among these three groups for the different discovery lists. It is clear from the fraction of objects in each group that the color calibrations by the different observers were not homogeneous.

Haro & Luyten (1962, see also Iriarte 1959; Luyten & Haro 1959; Haro & Chavira 1960; Haro & Luyten 1960) concluded that FBSO include: white dwarfs, nuclei of planetary nebulae, horizontal branch stars, subdwarfs, main sequence stars, variables of the U Gem type, combination spectra and blue galaxies.

3. BLUE GALAXIES

The same photographic material obtained with the Tonantzintla Schmidt for the identification of FBSO at high Galactic latitudes was used by Haro to search for galaxies that show intense ultraviolet radiation. In some of these galaxies the density relation among the blue yellow and ultraviolet images is comparable to that of stars of extremely violet color, such as hot white dwarfs or the nuclei of planetary nebulae. Haro (1956) presented a list of 44 galaxies; for some of them he obtained spectra with the Tonantzintla Schmidt together with an objective prism and found that they show strong emission lines such as 3727 [O II], 3869 [Ne III], 4959 and 5007 [O III], and the Balmer series.

Many of the objects in the list by Haro (1956) turned out to be galaxies with strong emission lines nuclei, some with Seyfert characteristics. This seminal paper induced the search for faint blue galaxies by many observers.

From the three color plates obtained with the 48 inch Palomar Schmidt for the Haro-Luyten catalogue, G. Haro (1982, private comm.) found about 2000 blue galaxies and estimated that there are 1.2 non starlike blue galaxies brighter than about 18th mag. per square degree. These galaxies include Seyferts, blue compacts, starbursts and irregulars. Chavira (1989, 1996) and Chavira & López (1998) have presented lists of blue galaxies detected on three of the original PHL plates.

4. QUASARS

Quasars are objects intrinsically very bright, with starlike appearance, and with broad emission lines that show large redshifts. We now know that they are active galactic nuclei at very large distances from us. The first two quasars were discovered in 1960 and their nature was established in 1963 (Schmidt 1963), when only four of them were known. Immediately a relationship between faint blue objects with stellar appearance and quasars was established, relationship that turned out to be very interesting and controversial.

TABLE 2

FAINT BLUE STARLIKE OBJECTS

Reference	Color group I	II	III
Iriarte & Chavira (1957)[a], Chavira (1958, 1959)[a]	509	363	1136
Luyten et al. (1958–1961)[a]	310	565	222
Haro & Luyten (1962)[b]	1569	2929	4248
Luyten et al. (1962-1968)[b]	772	1207	645
Rubin et al. (1967) [b]	27	93	112
Total	3187	5157	6363

[a]Tonantzintla Schmidt telescope.

[b]Palomar Schmidt telescope.

At the time of the First Conference on Faint Blue Stars (1964) the quasar with the largest redshift was PHL 2871 = 3C9 with $\delta\lambda/\lambda = 2.01$.

Based on the observed $\log N(m)$ versus m plot for objects in the Haro-Luyten catalogue and on the spectra of five faint blue objects, that turned out to be similar to the spectra of Quasi-Stellar Radio Sources, Sandage (1965) concluded that about 80% of the objects fainter than $m = 16$ in the Haro-Luyten catalogue were Quasi-Stellar Galaxies, QSG. Sandage defined the QSG as a new major constituent of the universe. From this very preliminary result he concluded that their surface density is of about four objects per square degree up to $m_{\rm pg} = 19$ and that they were 500 times more numerous than the Quasi-Stellar Radio Sources. Later on, QSG have been known as radio quiet quasars or optically detected quasars.

Sandage (1965) estimated that about 6000 of the PHL objects were quasars, this suggestion produced a great interest on the subject of FBSO. The preliminary results by Sandage were revised and based on more recent results Sandage & Luyten (1967, 1969) estimated that the PHL catalogue contains about 600 quasars.

The importance of the paper by Sandage (1965), and above all of the subject, led the Astrophysical Journal, which at that time was under the directorship of Chandrasekhar, to make an exception: this is the only paper in the magazine's history that has been published with a date previous to its submission. The paper was received on May 15th of 1965 and was published in the first of May issue of the same year. The spectral observations included in the paper were made with the Mount Palomar 200 inch telescope between the 23rd of April and the 6th of May of 1965.

Sandage & Luyten (1967, 1969) revised the preliminary results by Sandage (1965) and concluded that: (a) a large fraction of the FBSO of groups II and III were F and G subdwarfs, similar to main sequence stars in globular clusters, (b) most of the FBSO brighter than $m = 14.5$ were subdwarfs, horizontal branch stars, and main sequence B runaway stars, (c) most of the FBSO fainter than $m = 14.5$ were white dwarfs, quasars, and subdwarfs, (d) the total number of quasars was given by $\log N_T(Q) = 0.75B - 14.0$, which at $B \approx 18$ mag implied 0.4 quasars per square degree and at $B \approx 19$ mag implied about 1.7 quasars per square degree.

By 1993 a small fraction of the FBSO detected in the 1936–1968 period had been observed spectroscopically. From the catalogues by Hewitt & Burbidge (1993) and Véron-Cetty & Véron (1993) and the paper by Haro & Chavira (1987) it is found that at least 198 of the FBSO detected in the 1936–1968 period are quasars. Of those only 12 quasars come from the two plates method searches: 4 from the list by Richter & Sahakjan (1965) which is a subset of the list by Richter (1965) and 8 from the Luyten blue stars lists. Alternatively 186 quasars come from the three images lists, most of these belong to group I (see Table 3). The larger fraction of quasars from the three images lists is in part due to selection effects: a higher confidence in the color determinations and the availability of finding charts.

In 1971 the catalogue by James De Veny and collaborators included only a total of 202 confirmed quasars. Due to the construction of new telescopes and the spectacular advances of the photon detectors

TABLE 3

QUASI-STELLAR OBJECTS

Reference	Color group I	II	III
Iriarte & Chavira (1957)[a]	12	3	15
Luyten et al. (1958–1961)[a]	3	0	0
Haro & Luyten (1962)[b]	54	25	9
Luyten et al. (1962–1968)[b]	60	5	0
Total	129	33	24

[a]Tonantzintla Schmidt telescope.

[b]Palomar Schmidt telescope.

by 2006 there were already around 100 000 identified quasars (Véron-Cetty and Véron 2006).

5. CONCLUSIONS

The early studies of faint blue objects led to: (a) search for more faint blue stars, (b) classify them and divide them among different groups, (c) compute the relative fraction of stars in each group as a function of apparent magnitude, (d) obtain detailed observational properties of representative objects of each group, (e) make models of these representative objects and (f) try to establish evolutionary sequences.

Moreover the search for faint blue objects had strong repercussions on the study of blue galaxies and quasars.

The impulse given to the field of faint blue objects by Haro and collaborators can be estimated by reading the proceedings of the three international Conferences on Faint Blue Stars (Luyten 1965; Philip et al. 1987, 1997), and by considering the large number of citations to the paper by Haro & Luyten (1962) in many areas of astronomy.

Greenstein (1965), in his introductory remarks to the First Conference on Faint Blue Stars, stated the following: "We are grateful to the three originators of the conference, Professors Haro, Luyten, and Zwicky who invented a new subject in astrophysics, with which we are here concerned".

The Third Conference on Faint Blue Stars, organized by A. G. Davis Philip (1997) in New York, was dedicated to Guillermo Haro, in recognition to his pioneer research in this field.

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