Revista Mexicana de Astronomía y Astrofísica, Volumen 2, Enero 1977.

ON AN H II CONDENSATION IN NGC 2175

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Received 1976 July 14

RESUMEN

La intensa condensación H II dentro de NGC 2175 (S 252) contiene una estrella brillante, de V = 11.05 y una débil con V = 14.15 las cuales están separadas por 16.2 segundos de arco. La fotometría fotográfica y fotoeléctrica ha permitido la estimación de los tipos espectrales como B1.5 V y B9 V respectivamente. Parece dudoso que la primera de ellas pueda excitar la condensación H II. En dos placas con prisma objetivo la estrella débil muestra líneas intensas de emisión. Sobre interferogramas Fabry-Pérot en Hα, en donde las dos estrellas caen dentro del anillo central, el brillo de éstas es casi el mismo. Este hecho ha permitido la estimación de la energía radiada en Hα de la estrella débil como 6.3×10^{33} erg s^{-1}. Espectros de la condensación proporcionan velocidades de la línea Hα que son unos 30 km s^{-1} más positivas que las obtenidas con las líneas prohibidas.

ABSTRACT

The very dense H II condensation inside NGC 2175 (S 252) contains a bright star, V = 11.05 and a faint star, V = 14.15, separated by 16.2 arc seconds. Photographic and photoelectric photometry of the stars permits an estimate of the spectral types not earlier than B1.5 V and B9 V respectively. It seems doubtful whether the first star can excite the H II condensation. On two objective prism plates the fainter star shows intense emission lines. On Fabry-Pérot interferograms (in Hα) the two stars fall within the innermost ring and appear of equal brightness. This circumstance allows an estimate of the energy radiated in Hα of the faint star as 6.3×10^{33} erg s^{-1}.

Spectra of the condensation have yielded velocities from the Hα line about 30 km s^{-1} more positive than those from the forbidden lines.

Key words: H II REGION — PHOTOMETRY — EMISSION STAR.

I. INTRODUCTION

The extended H II region (S 252) surrounding the galactic cluster NGC 2175 contains a small but conspicous H II condensation of roughly elliptical shape. Two stars, a bright and a faint one, separated by 16.2 arc seconds lie within its boundaries close to the opposite edges of the knot. Figure 1 (Plate 3) is an enlargement of the region from a 103a O plate taken with the Tonantzintla Schmidt Camera. Garnier & Zuckermann (1971) have made a study of this condensation particularly of its bright star (S 252a) which they consider to be the source of the excitation. They state furthermore that the knot is a very young object, a later stage of a compact H II region. Results of a study on this H II knot have been reported by this author (Pişmiş 1974) pointing out that the faint star (S 252b) has intense emission lines. In a later study Grasdalen and Carrasco (1975) have investigated the physical nature of the nebulosity and conclude that the object has an age 2×10^6 years and is primarily a reflection nebula due to a dense neutral cloud, and is surrounded by a thin, high density, low excitation ionized zone.

This paper presents essentially the same results reported earlier by this author but unpublished so far, with the addition of some photoelectric photometry of the stars within the H II knot.

II. PHOTOMETRY OF THE TWO STARS

Several plates were available in the region of NGC 2175 obtained with the 32" — 26" Schmidt Camera of Tonantzintla Observatory with the appropriate combination of plate and filter to give magnitudes in the UBV system. A list of the plates used appears in Table 1.

TABLE 1

PHOTOGRAPHIC MATERIAL USED FOR MAGNITUDE DETERMINATION

Plate Number	*Spectral Region*	*Exposure*	*Date*
AC 6851	U	18 min	Dec 11, 1958
ST 4407	U	18 min	Jan 16, 1969
AC 4154	B	9 min	Dec 1, 1954
AC 4155	B	3 min	Dec 1, 1954
AC 6848	V	9 min	Dec 10, 1958
ST 4410	V	9 min	Jan 15, 1969

The B and V magnitudes of stars S 252a and S 252b were determined by measuring the plates with an Eichner astrophotometer. U magnitudes, however could not be obtained in this way as the brightness of the nebulosity, due evidently to the λ3727 doublet of [O II], which would vitiate the results. Therefore the U magnitudes were estimated by measuring the photographic image diameters at two mutually perpendicular positions with a Mann measuring machine. As a check, the B and V plates were measured once again in the same fashion; the results agreed satisfactorily with the astrophotometer magnitudes. In all cases the standards used were the photoelectric magnitudes in the cluster NGC 2175 s (Pişmiş 1970).

Table 2 lists the resulting V magnitudes and B-V and U-B colors of the two stars as well as their photoelectric V magnitudes and B-V, V-R, V-I colors obtained in December 1975 (one night) with the 60-inch photometric telescope at the Observatory at San Pedro Martir, B. C. The adopted magnitudes are also given. To serve as a comparison the photoelectric magnitudes of S 252a and of HD 42088, the O6.5 V star, given by Hiltner (1956) also appear in that table.

We note here that there is a large discrepancy between the photoelectric U-B and the photographic U-B of S 252b. We expect the photographic determination to be the more reliable one as the intensity of the nebular λ3727 [O II] doublet would not affect the diameter measurements whereas it would affect the photoelectric measurements. Thus the U magnitude will be estimated brighter than real, causing a spuriously large negative U-B color. Moreover in the color-color diagram the larger U-B color (—0.58) would give an unacceptably large absolute magnitude for the star S 252a.

TABLE 2
PHOTOMETRIC DATA FOR THREE STARS

Star	V	B-V	U-B	V-R	V-I	Notes
252a	11.00	+0.35	−0.20	....	....	pg, this paper
252a	11.00	+0.42	....	+0.50	+0.84	pe, this paper
252a	11.04	+0.39	−0.58	....	....	Hiltner (1956)
252a	11.00	+0.39	−0.20	+0.52	+0.84	adopted
252b	14.10	+0.60	+0.60	....	....	pg, this paper
252b	14.23	+0.51	....	+0.83	+1.10	pe, this paper
252b	14.16	+0.56	+0.60	+0.83	+1.10	adopted
HD 40288	7.55	+0.06	−0.89	+0.14	+0.13	this paper; U-B by Hiltner (1956)

III. THE YIELD OF THE PHOTOMETRIC DATA

The adopted U-B and B-V colors of stars S 252a and S 252b and of HD 42088 are compared with the unreddened color-color relation. Such comparison has yielded a comparable reddening for both stars: namely E(B-V) = 0.50 (HD 40288 shows a reddening of 0.40 magnitudes). Assuming R = 3.3 as given by Grasdalen and Carrasco (1975) for this region, the total visual extinction would be 1.65 magnitudes. As there does not exist a good determination of the spectral types for S 252a and much less for S 252b we have attempted to make an estimate of the spectral types in the following way: the distance to the H II condensation and hence to the stars is adopted as 2.5 kpc (Grasdalen and Carrasco 1975). The apparent V magnitude of S 252a is 11.05; with an extinction of 1.65 magnitudes we obtain $M_V = -2.6$. The calibration of Walborn (1972) gives -2.7 for the absolute magnitude of a B1.5V star. We shall therefore adopt a spectral type of B1.5 V for the star S 252a. It is doubtful whether a star of this type will have enough ultraviolet photons to ionize the region. In similar fashion the spectral type of S 252b is estimated to be around B9V-A0. A check on these spectral types may be obtained by using the U-B, B-V colors of Table 2, namely -0.20 and $+0.35$ for the S 252a and $+0.56$ and $+0.60$ for the S 252b, respectively. With the color-color relation and the associated spectral types (Becker 1963) we obtain roughly B2V and A0 for the bright and faint stars respectively; however this may not constitute an entirely independent determination.

IV. THE Hα EMISSION OF S 252b

Two objetive prism plates taken with the Tonantzintla Schmidt Camera, on 103aE emulsion through a Wratten 29 filter (exp. times 40 and 90 min respectively), have exhibited a very intense Hα emission from the star S 252b. Figure 2 (Plate 4) shows an enlargement of the 40 min exposure plate of the region of NGC 2175 where the emission-line star is marked.

Six interferograms on NGC 2175 were obtained by the photographic Fabry-Pérot technique with the focal reducer attached to the Cassegrain focus of the 1-meter telescope at the Tonantzintla Observatory: the interference filter has a halfwidth at Hα of 10 Å (emulsion: Kodak special 098-01). On none of these interferograms did the H II knot fall on an interference ring so that a determination of velocity was not possible. However an interesting by-product emerged: on all interferograms the fainter star S 252b appeared at least as bright as the star S 252a if not slightly brighter (see Figure 3, Plate 5), We recall that the V magnitude of S 252b is fainter than that of S 252a by nearly 3 magnitudes.

There is thus indication that on the interferograms at Hα we are witnessing in the faint star the contribution of its intense Hα emission line which is filling up nearly the totality of the passband of the interference filter much like the continuum of a star that shows up on an interferogram wherever the star happens to fall. This circumstance permits at once a determination of the power radiated in the Hα line of the faint star. If the stars are of equal brightness at Hα, the total energy in the continuum of the bright star should be equal to the total energy emitted by the faint star in the Hα in addition to its continuum within 10Å. An estimate of the energy in the continuum of the stars B1.5 V and B9 V was therefore carried out in the region of λ6563 within 10Å. The adopted physical parameters relevant to such computation are:

Star	Temperature	$R/R_\odot$
S 252a	24250 °K	6.33
S 252b	11020 °K	2.89

The radii and temperatures are interpolations from Allen (1973).

Using these values and the Planck law of radiation the energy contained in the Hα emission of S 252b is found to be of the order of 6.3×10^{33} ergs s^{-1}, about 1.5 times the energy radiated by the Sun per second. The computed energy would remain the same whether the Hα line covered wholly or not the passband of the interference filter. It may be remarked that whether the Hα line covers the totality of the passband or not could be guessed by observing the relative brightness of the two stars if they happen to fall at different regions of the inter-ring separation. Inspection of the available interferograms shows that the relative brightness of the stars does not vary appreciably, indicating that the whole width of the window is probably covered by the Hα of the faint star.

A search for the variability of S 252b on some 50 IN Schmidt plates did not yield a positive result. What the role of this faint emission star may be in the physical processes of the emission knot is not clear at the moment.

V. RADIAL VELOCITY OF THE CONDENSATION

Three spectra of the HII knot were obtained with a long slit (5.8 arc sec) fixed at different directions using the Boller and Chivens spectrograph at the Cassegrain focus of the 1-meter reflector at Tonantzintla. Details regarding the spectra are given in Table 3.

The espectra are not calibrated photometrically so that no physical parameters of the knot such as electron density or temperature could be obtained.

The three spectra were however measured for radial velocity. The average velocities based on this material yield 56±6 km s^{-1} from the Hα line, while the forbidden lines [N II] λ6584 and [O II] $\lambda\lambda$3727, 3729 show a much lower radial velocity, of around 24±5 km s^{-1}. Although the velocities were found to be somewhat different at differing distances from the point of maximum intensity such differences (of the order of ±5 km s^{-1}) may not be physically significant as the intensity and quality of the lines are also variable along the slit. At any rate on the two spectra where Hα and [N II] lines could be measured the radial velocity of the Hα line was 32 km s^{-1} more positive than that from the forbidden lines of [N II]. These velocities are to be compared with the radial velocities of the region at large.

TABLE 3

SPECTRA OF THE CONDENSATION

Plate	Emulsion	Exposure	Dispersion	Sp line measured
BM 604	Eastman IIaE	2 hours	155A mm^{-1}	Hα, [N II] λ6584
BM 606	Eastman II a O	4 hours	61A mm^{-1}	[O II] λ3727, λ3729
BR 706	Kodak Sp. 098-01	40 min	245A mm^{-1}	Hα, [N II] λ6584

The radial velocity of HD 42088 the source of excitation of the H II region NGC 2175 where the knot is embedded, is 22.8 km s^{-1} (Abt and Biggs 1972). On one of our interferograms the Hα velocities from 40 points on NGC 2175 yielded 23.4±3 km s^{-1}, quite comparable to that of the star. We note that it is the velocity from the forbidden lines, +24 km s^{-1}, that is in excellent agreement with the above values and not the velocity from the Hα line, which, as stated earlier is shifted to the positive velocities by 32 kh s^{-1}. Whether the discrepancy between the velocities of the Hα and the forbidden lines is caused by a systematic error or is a manifestation of the physical properties of the region, of the intense or perhaps variable Hα radiation of S 252b, cannot be decided with the presently available data. More spectra of the condensation are needed to settle this point. In addition, the radial velocity of the Hα emission line in S 252b should be measured in order to study the possibility that a substantial contribution to the Hα emission in the condensation may be due to dust-scattered light from S 252b.

In conclusion we may state that our results are consistent with the assumption that the stars S 252a (B1.5 V) and S 252 b (B9 V) are within the H II condensation. The existence of strong emission lines of the B9 star, attaining an intensity of the order of 6.3 × 10^{33} erg s^{-1} in Hα, sets an upper limit to the age of the knot; this upper limit is compatible with the age of the knot, 2 × 10^6 years as suggested by Grasdalen and Carrasco (1975).

Further work on this region and on the involved stars is desirable. The ionization structure, isophotal contours, a detailed study of the velocity structure of the nebula, possible variation of the Hα emission of S 252b may shed light on the physics of this interesting object.

It is a pleasure to thank E. Chavira who has taken the Schmidt plates used in this study. I also wish to acknowledge the assistance of E. Recillas-Cruz for the determination of the photographic magnitudes. My thanks go to I. Hasse for measuring the spectrograms and to M. A. Moreno and L. Carrasco for the photoelectric observations.

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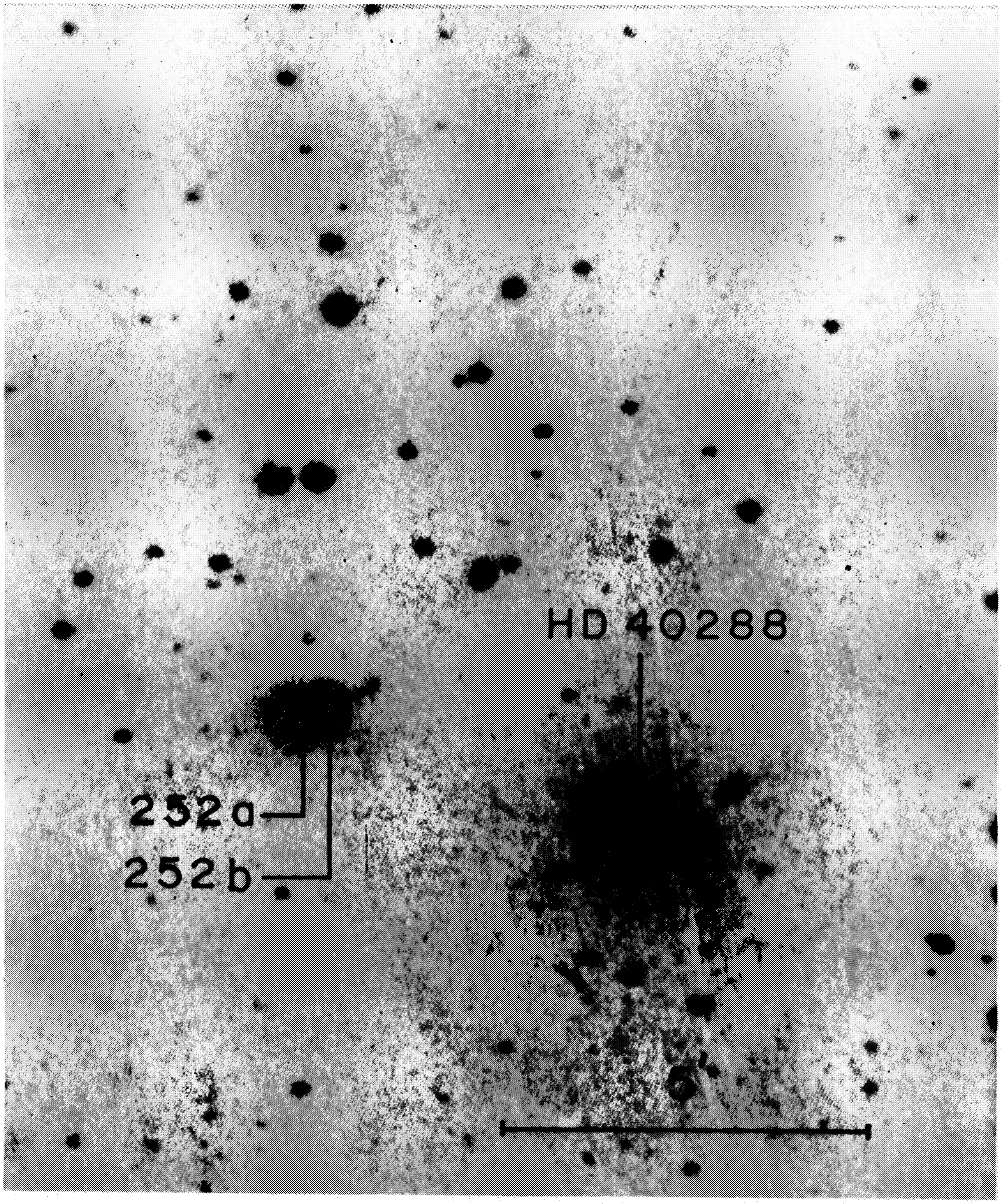

Fig. 1. (Plate 3) Enlargement of a 103a0 plate taken with the Schmidt Camera of Tonantzintla Observatory on NGC 2175; the exposure time is 9 minutes. The two stars in the H II condensation are indicated by their number. The brightest star of the region is HD 40288 which is the source of the excitation of the large H II region. North is at top and east at left.

PLATE 4

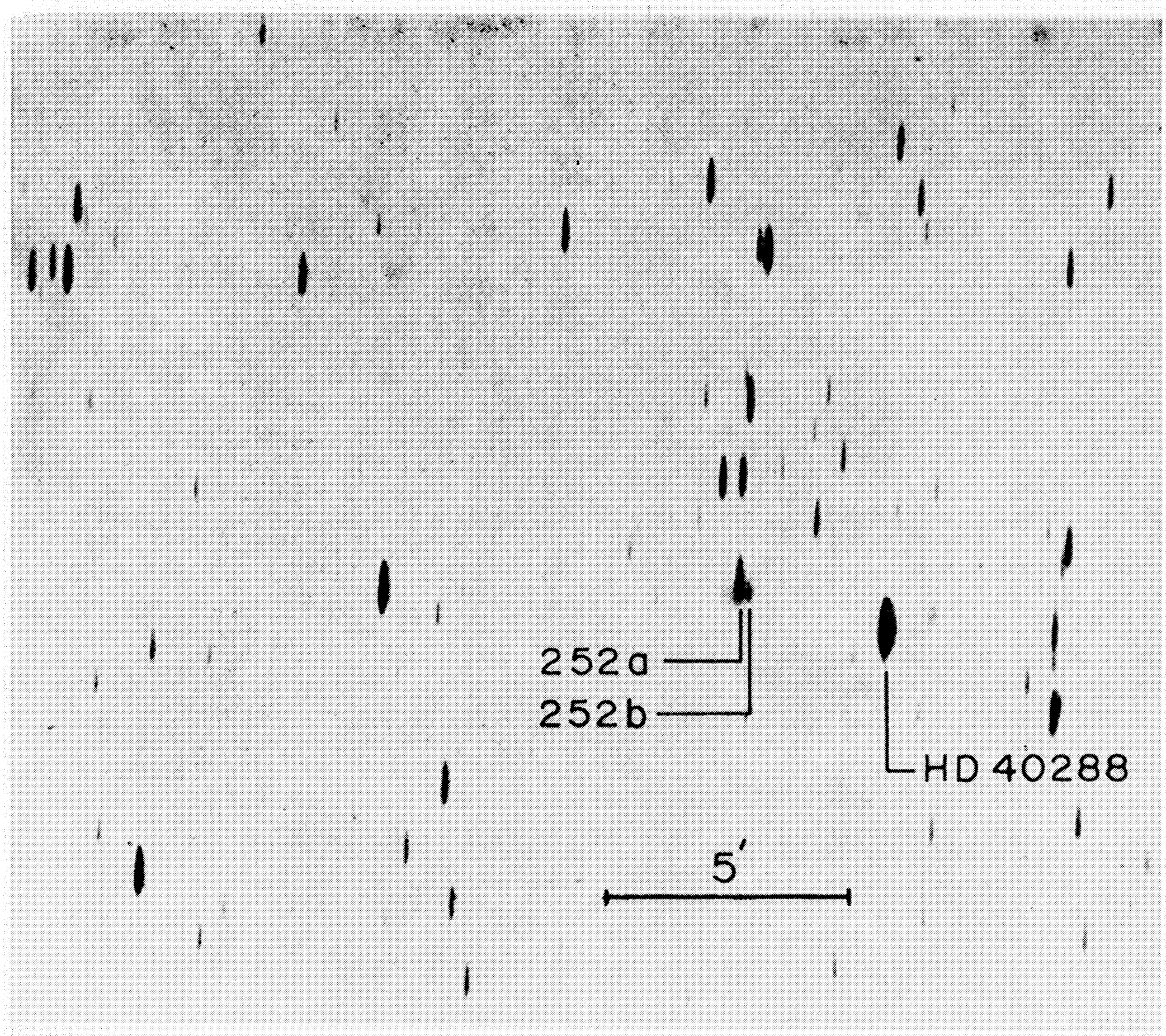

FIG. 2. (Plate 4) Enlargement of an objetive prism plate taken with the Schmidt Camera of Tonantzintla Observatory through a Wratten 29 filter on 103aE emulsion. The exposure time is 40 minutes. The arrow points to the Hα emission line of the faint star, S 252b, in the H II condensation. North is at top and east at left.

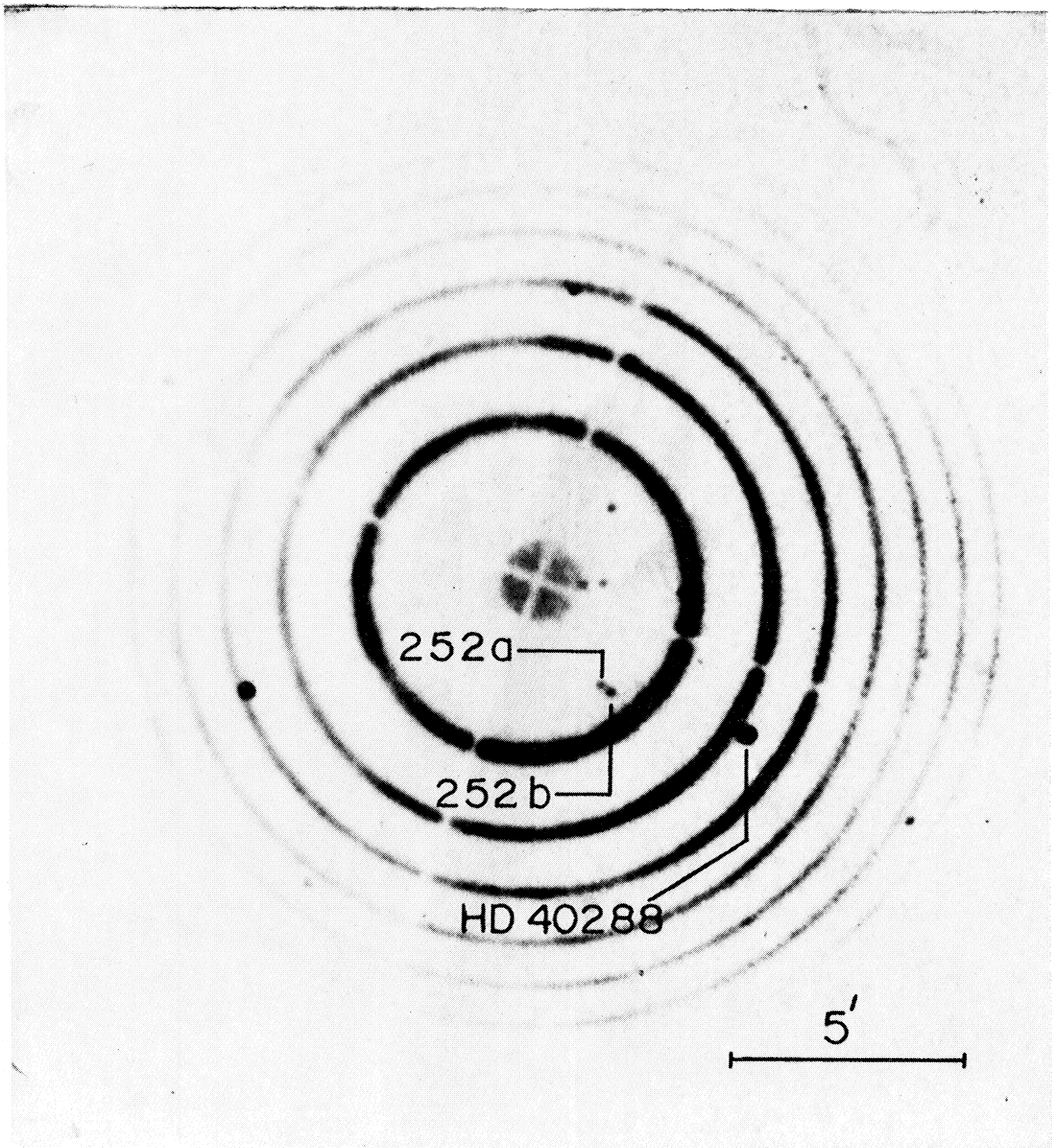

FIG. 3. (Plate 5) Enlargement of an Hα, interferogram of NGC 2175 taken with a Fabry-Pérot equipment attached to the 1-meter reflector at Tonantzintla. The two stars of the condensation indicated by their numbers as in Figure 1 are now of comparable brightness.