PRELIMINARY RESULTS ON AN H-ALPHA MAP OF THE GUM NEBULA OBTAINED WITH THE D-2-A SATELLITE

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I. Introduction

Data on H-alpha emission from the Gum Nebula were obtained first by Gum and Allen in 1952. They discovered an intense emission centered at the galactic coordinates $\ell = 226°$, $b = -8°$, with a diameter of at least 15°. However, the filter used had a large bandwidth, so that the limits of the nebula and its absolute intensity were not obtained.

A map of the Milky Way in the southern hemisphere was published by Johnson in 1960. The resolution was 2 to 3 arc minutes. The filter had a bandwidth of 326Å, centered on 6560Å, and was therefore transparent to the [N II] lines at 6548Å and 6583Å and to the telluric emissions of oxygen and OH. The maximum intensity found between 07^h00^m and 08^h00^m Right Ascension was about 60 Rayleighs, from which Johnson subtracted 5R of night sky emission (1.5×10^{-5} erg $cm^{-2} s^{-1}$ $sterad^{-1}$).

II. H-alpha Experiment on D-2-A

The purpose of this experiment is to study the hydrogen emissions in the terrestrial atmosphere. These include the telluric H-alpha emission, which is supposed to have an intensity of a few R. This emission was discovered through ground-based observations, however, such measurements are strongly contaminated by night sky emissions, due largely to OH. It has been proven that the OH emissions arise between the altitudes of 80 km and 120 km. A further contamination of the ground-based observations is due to a strong continuum, originating from about the same altitudes, whose source has not yet been proven. The H-alpha experiment on D-2-A was therefore designed as a monochromatic photometer that would provide measurements of weak H-alpha emission originating at altitudes of a few hundred or thousand km, free of contamination by other telluric emissions. It was found immediately that the Gum Nebula was recorded by the instrument as a much more intense feature than the geocoronal emission; this note presents a map of the data that were obtained a few weeks before the G.S.F.C. Symposium on the Gum Nebula and Related Problems.

A. Spacecraft

D-2-A, launched April 15, 1971 from Kourou (French Guyana), is a 96-kg, sun-stabilized spacecraft. The orbit parameters at launch were: apogee 702 km, perigee 453 km, and inclination 45°.

The satellite is a cylinder whose axis is kept parallel to the sun-spacecraft direction by an active stabilization system with an accuracy of a few arc minutes. The satellite rotates about this axis with a period of 60 seconds.

Two types of optical experiments are carried by D-A-A; the first kind has its optical axis parallel to the rotation axis and the second kind has its optical axis perpendicular to the rotation axis. The H-alpha photometer is of the second type, and therefore every 60 seconds, its optical axis traces out a great circle on the celestial sphere, orthogonal to the sun-spacecraft direction (i.e.: orthogonal to the ecliptic plane). Forty of these circular scans are made per satellite orbit, and the circle rotates across the sky at 1° per day due to the orbital motion of the Earth. Thus a complete map of the sky can be obtained in six months.

B. Optics

The photometer (Fig. 1) is a very simple system, comprising one lens, two filters, and a dual-cathode photomultiplier. The lens L (diameter = 100 mm, focal length = 500 mm) projects an image of the sky in its focal plane. The flat mirror M is used to rotate the beam by 92°, because of spacecraft geometrical constraints.

Before the focal plane, a shutter, actuated by a photodiode, protects the photomultiplier against a strong signal, as obtained during the daylight part of the orbit. This shutter also holds the two small mirrors M_1 and M_2 that are used, together with the light source C, for on-board calibration measurements.

In the focal plane, the two interference filters F_1 and F_2 are placed in front of a dual cathode photomultiplier; the wavelengths of peak transmissions for these filters are 6563Å and 6530Å. Thus, the incident beam is split into two beams, one at H-alpha and the other at (H-alpha - 33Å). Each of these beams hits a separate photocathode.

The photomultiplier has two cathodes but only one multiplier system, and there is only one amplifier for the two channels. For 1/16 second, one photocathode is fed and the corresponding gate of the counter is open; thus a measure at one wavelength is obtained. For the next 1/16 second, the other photocathode is fed and its gate is open, so that a measure at the second wavelength is obtained. This procedure is repeated 7 times and the results are integrated, providing one

7/8 second observation every 2 seconds. The signal is processed by a pulse-counting technique with threshold discrimination and a floating point counter, and transmitted via PCM telemetry.

The dark current is measured once every 236 seconds when the shutter is closed for 7/8 second.

Both wavelengths are recorded independently, and the H-alpha emission is determined by subtracting the 6530Å intensity from the 6563Å intensity while taking the proper ratio into account.

C. Instrumental Performance

Field of view. For each channel, the field would be 1° 20' × 2° 40' for a stationary spacecraft. However, during a measurement interval of 1 second, the satellite rotates by 6°. Deconvolution of the signal allows us to reduce the field from (6 + 2)° to 2°.

Spectral response. Fig. 2 illustrates the response of the two channels; the bandwidth can be taken safely as about 20.5Å.

Absolute calibration. The response of the instrument to a secondary source was determined. This source, a white Osram flat tungsten ribbon lamp, has been calibrated carefully against a primary standard from the Physikalisches Institut in Berlin. The estimated preliminary error in the absolute value is less than 50%; this error should be reduced when evaluation of the experiment is completed.

It is found that the instrument yields 75 pulses for 1R of H-alpha light; the dark current is less than 100 pulses per second.

Linearity. The linearity is excellent over the range of 0.5R to 120R.

In-flight performance. The instrument was turned on by ground command on April 19, 1971, and it functioned as planned. During the "day" portion of the orbit, the stray light is strong and the shutter remains closed. The dark current during the orbit "night" is 60 pulses per second (0.8R).

The ratio of the calibration signals in the two channels as measured in orbit is identical to the laboratory value, and the absolute values of the calibration signals are also unchanged.

We conclude that the equipment is providing accurate and reliable measurements.

III. Results

The intensity of the continuum observed outside the Milky Way is 0.6R/Å and the intensity of the geocoronal H-alpha emissions is in the (5 to 1)R bracket. The brightest feature observed so far is the Gum Nebula. Figure 3 shows an example of a part of the maps obtained over the line AB (see the chart, Fig. 4). The intensity plotted in Fig. 3 is obtained, as explained above, by subtracting the 6530Å intensity from the 6563Å intensity, with an appropriate calibration factor. The great strength of the Gum Nebula H-alpha emission as compared to those of the geocorona and the Milky Way is obvious.

The maximum intensity recorded in the Gum Nebula in the present observations is 44R, in good agreement with Johnson's results but definitely on the low side.

Figure 5 contains the essence of the results presented in this paper, a map obtained from the data collected during April 20 to May 4, 1971.* Again, H-alpha data have been plotted after first subtracting the continuum. This map will be extended and completed, since good data have been obtained down to the date of writing (July 2, 1971). As of this date, the extent in declination of the Gum Nebula appears to be 30° to 35°. The resolution of the D-2-A map is inferior to that of the Johnson maps, but it is more extended, the intensity is given in steps of 5R instead of 15R, and since our bandwidth is 20.5Å there is no contamination by astrophysical emission features.

A complete map of the absolute intensities, with a resolution of 2° and a bandwidth of 20.5Å will be available at the end of 1971.

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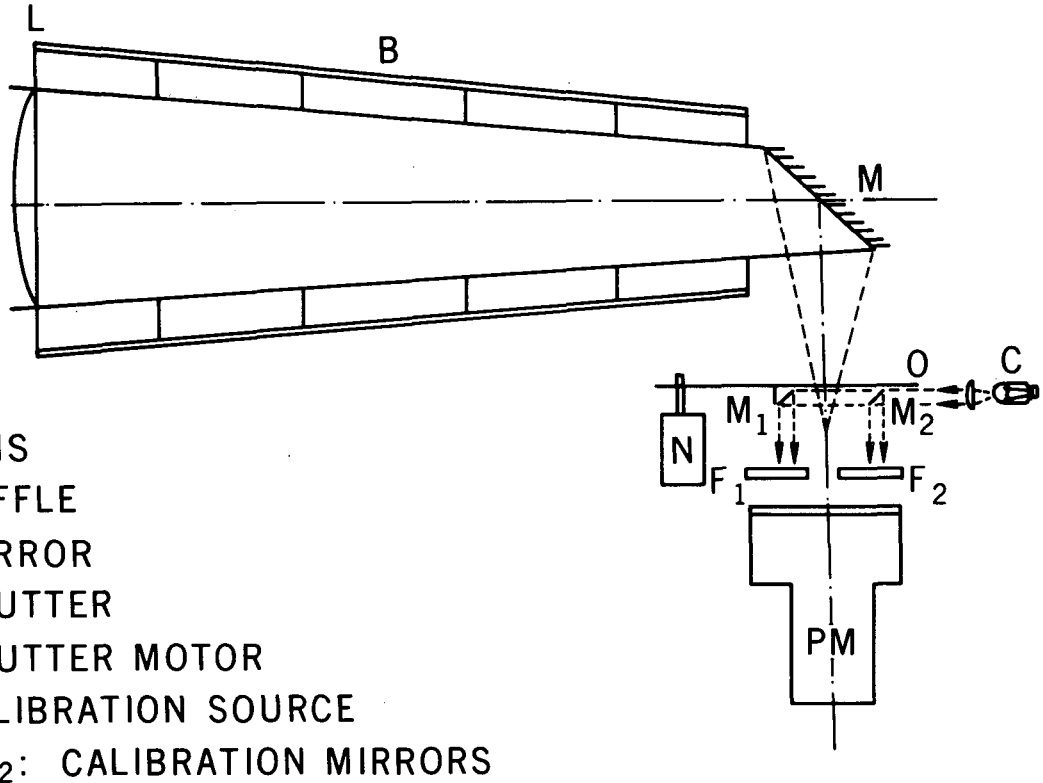
*Editor's Note: In Figure 5 we have had to lump together the authors' data for intensities <10R and <15R, due to difficulties in presentation. SPM



L LENS
B BAFFLE
M MIRROR
O SHUTTER
N SHUTTER MOTOR
C CALIBRATION SOURCE
M_1 - M_2: CALIBRATION MIRRORS
F_1 - F_2: INTERFERENCE FILTERS
PM: DUAL CATHODE PHOTOMULTIPLIER

Figure 1. Optical schematic of the H-alpha photometer on satellite D-2-A.

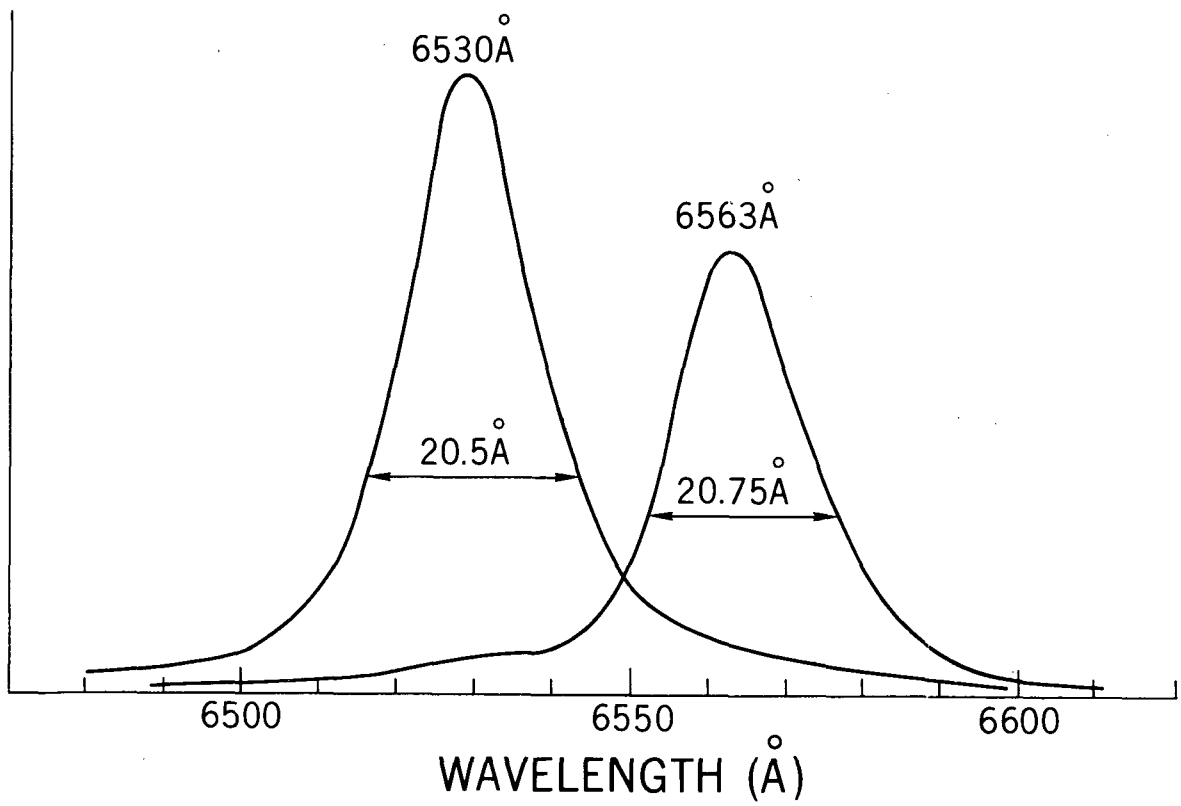


Figure 2. Transmission curves for the two channels of the H-alpha photometer.

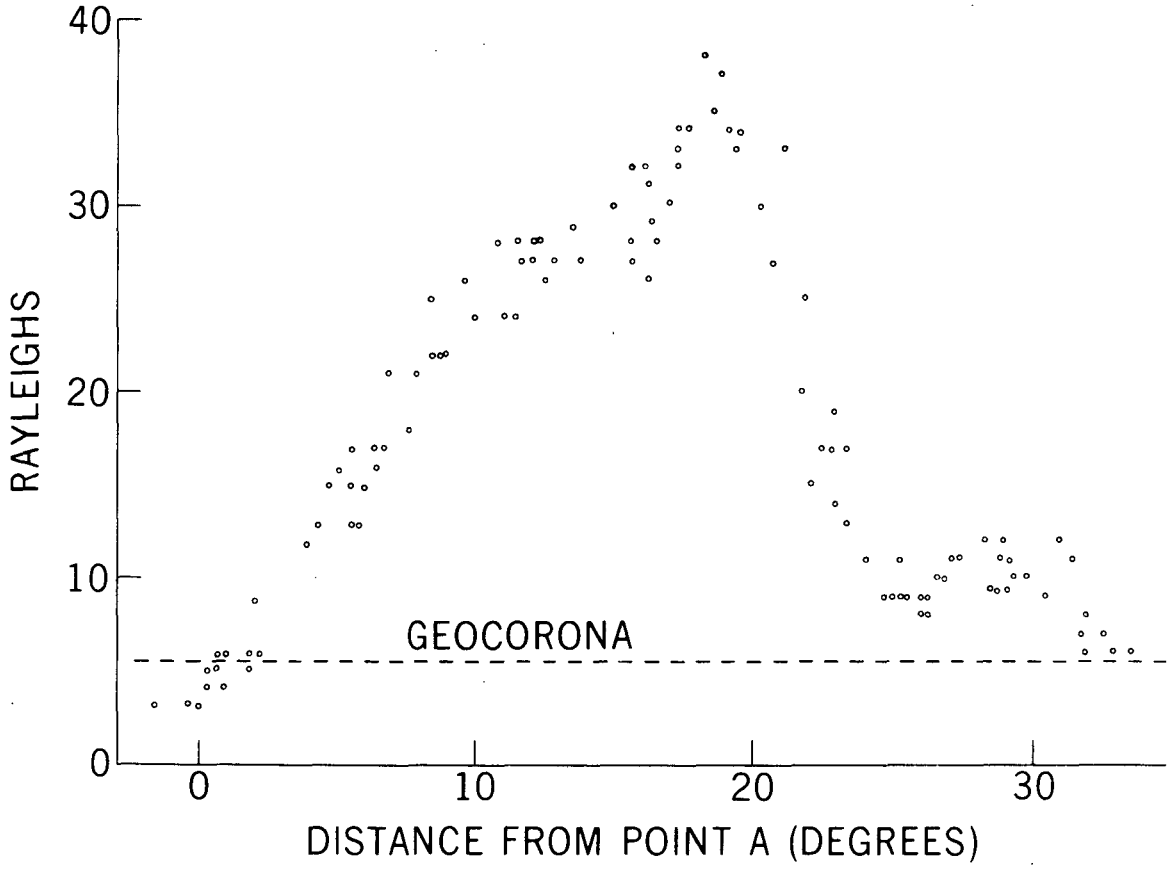


Figure 3. H-alpha intensity measured along the line segment AB in the Gum Nebula region on April 29 – May 2, 1971 (see Figure 4). The dashed horizontal line indicates the geocoronal intensity.

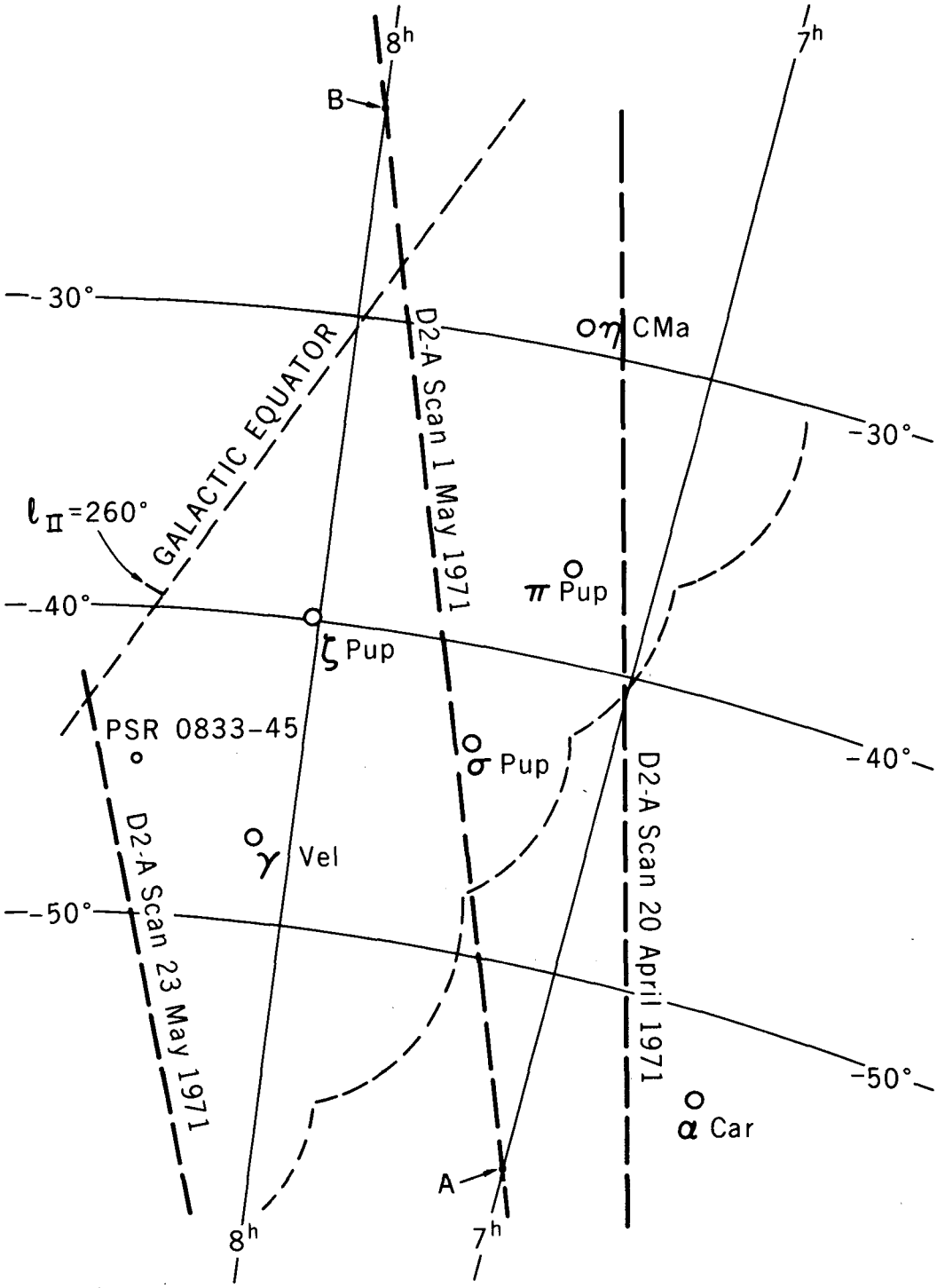


Figure 4. Sketch showing the position of line AB in the sky. The curved, dashed line indicates the western boundary of the region surveyed by H. M.Johnson. The coordinates are Right Ascension and Declination (1950).

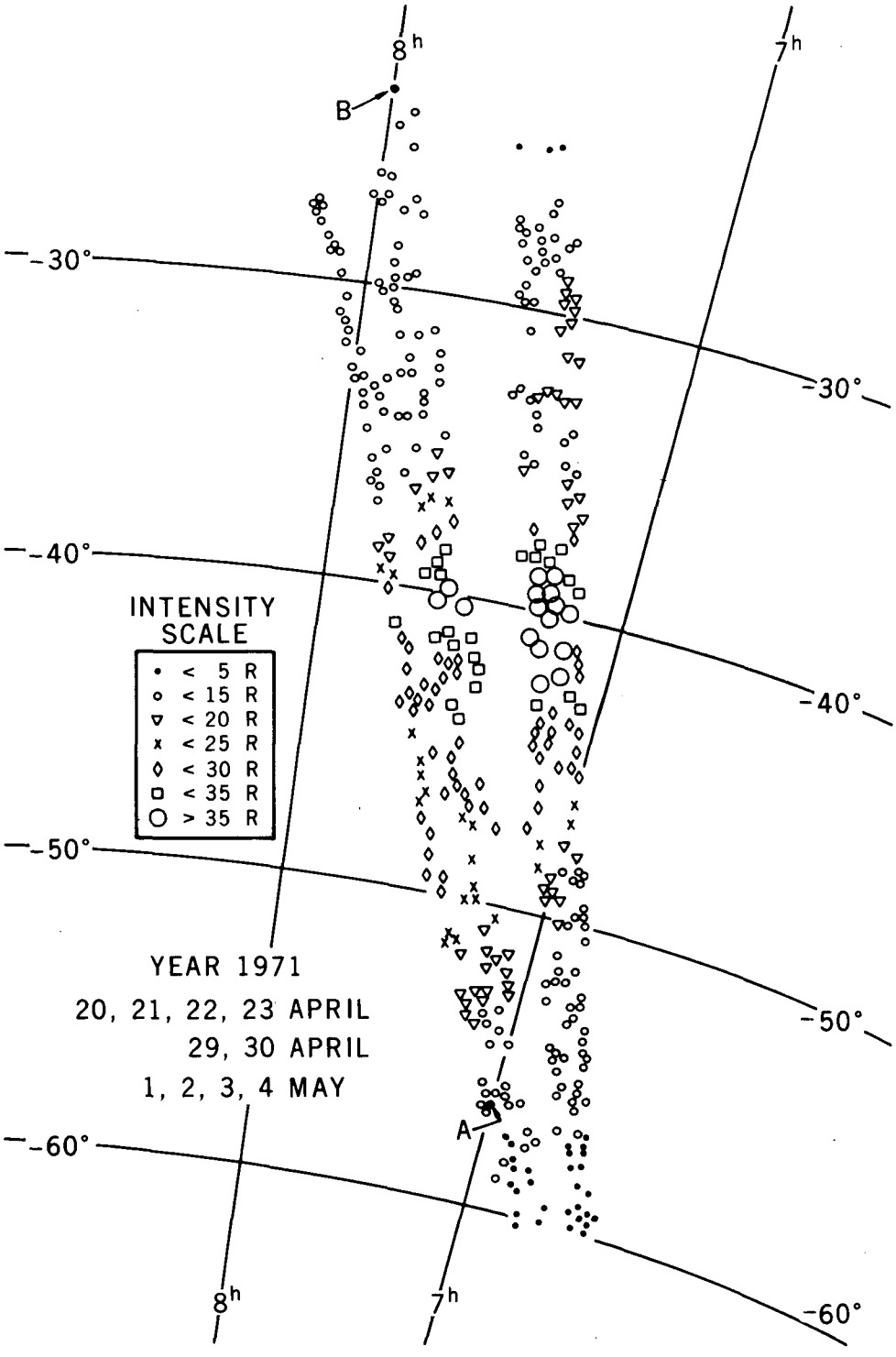


Figure 5. Measurements of the intensity of H-alpha emission from the Gum Nebula region, obtained by the D-2-A satellite during late April and early May, 1971. At each location, the size of the mark indicates the brightness in Rayleighs.

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