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EXTINCTION PROPERTIES OF DUST IN THE ULTRAVIOLET AND THE IONIZATION OF HELIUM IN GALACTIC H II REGIONS

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ABSTRACT

Some observational evidence is found in NGC 2024 to suggest that the presence of dust grains in an H II region affects the He^+/H^+ abundance ratio in the region. The evidence is presented by an anticorrelation between the $H\alpha/H\beta$ line ratio, as measured in different points in the nebula, and the He I $\lambda5876/H\beta$ line ratio in these points. No such relationship is found in NGC 6334. The observations in this nebula, however, are not in conflict with the above suggestion. Instead, they probably indicate a large amount of interstellar dust along the line of sight to this nebula. The observations of weak radio helium recombination lines in H II regions may thus be explained on the basis of selective absorption of helium ionizing photons by dust grains in those nebulae.

Subject headings: abundances, nebular — nebulae, individual — radio lines

I. INTRODUCTION

Many galactic H II regions have been observed in radio frequencies and were found to be sources of hydrogen or helium recombination lines (Cesarsky 1971). When both hydrogen and helium lines are observed in a source, the ratio of the energy in a helium line to the energy in a corresponding hydrogen line can serve as a measure of the abundance of ionized helium relative to ionized hydrogen in the emitting volume (by "abundance" of an ion, we mean an average over the entire observed volume). Whereas in some radio sources the ionized helium abundance derived from radio recombination lines is "normal," i.e., about 10 percent of ionic hydrogen by number, there are a few other sources in which the helium line temperature and line width yield a much smaller ratio of ionized helium to ionized hydrogen (Churchwell 1970).

Cesarsky discussed some possible interpretations of the radio observations in the sources with weak helium lines. He showed that low abundance of helium in these nebulae or excitation of these sources by stars of low temperature are unlikely explanations. Density fluctuations in the source are also inadequate as an explanation of the weak radio helium lines. Gas condensations in a nebula affect the geometry of the ionization regions by allowing low-excitation zones to exist near hot stars (Van Blerkom and Arny 1972). They are unable however, to affect significantly the total number of ionizations of the different ions in the nebula. Most of the radio observations are made with a low spatial resolution, and the abundances derived from them apply to the entire radio source with all of its ionization zones. These abundances are therefore only slightly sensitive to density fluctuations.

Another possible interpretation of the weak helium lines in radio sources was offered by Cesarsky (1971), who suggested that the low degree of ionization of helium is caused by the extinction of helium-ionizing photons in the nebula by some process

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that competes with the ionization of helium itself. One such process could be absorption by dust grains in the nebula. If a nebula is rich with dust grains that absorb ultraviolet radiation at frequencies $\nu > 1.8\nu_0$ (ν_0 being the hydrogen ionization limit frequency) more efficiently than at $\nu_0 < \nu < 1.8\nu_0$, then the ratio of ionized helium to ionized hydrogen in the nebula will be smaller than the ratio in a pure gaseous nebula with the same ionizing stars (Mathis 1971). Recent observations by Bless and Savage (1972) tend to support the assumption about the absorption cross-section of interstellar grains in the ultraviolet. Bless and Savage found that the extinction curve of interstellar dust rises rapidly from λ1350 to λ1050, the limit of the range of their Orbital Stellar Observatory spectrum scanner. If this trend were to continue beyond the helium ionization limit, the extinction would indeed be much larger at helium ionization frequencies than at hydrogen ionization frequencies.

Infrared observations in NGC 2024 by Harper and Low (1971) revealed a large infrared flux from this nebula. According to Harper and Low, the most likely interpretation of the infrared emission is thermal radiation by dust particles heated by the ultraviolet radiation in the nebula. When the Lyman continuum flux in the nebula is estimated from the observed continuum flux of the radio source by the method outlined by Rubin (1968), the infrared flux is found to be larger than expected by a factor of 5.5. Thus, the infrared measurements indicate the presence of large amounts of dust in NGC 2024. The apparent disagreement in the energy considerations of the radio and the infrared fluxes on the one hand, and the weak helium lines observed in this source on the other, are together at least qualitatively consistent with the last interpretation. The ionizing stars of NGC 2024 are hot and numerous enough to explain the infrared flux. The true spectral distribution and flux of the ionizing radiation, however, are not properly reflected by the radio flux when Rubin's calculations are applied, because Rubin's method requires a pure gaseous nebula. The ultraviolet flux that is missing from the ionization energy balance of the gas is the flux that heats the dust grains. In particular, the hard-ultraviolet photons are taken away from the radiation field by the dust grains, and helium in the nebula is less ionized than in the absence of dust.

The purpose of the observations reported here was to find evidence for this interpretation of the radio observations, which is significant not only for the theory of emission line formation but also for the extinction properties of interstellar grains in the far-ultraviolet region of the spectrum.

II. METHOD AND ASSUMPTIONS

The search for evidence of the effect of dust on the ionization of helium consisted of observing helium and hydrogen lines at different points in an H II region and of looking for a correlation between the amount of dust at each point and the relative intensity of the helium line. The amount of dust is measured by the deviation of the Hα/Hβ line ratio from the value predicted by the recombination theory. In anticipating such a correlation, we make the following assumptions about conditions in the observed medium.

1. *Uniform helium abundance*. The ratio of helium (atomic or ionic) to hydrogen is uniform throughout the nebula. Any variation in the helium-to-hydrogen line ratio must be attributed to a variation in ionization.

2. *Uniform illumination*. The spectrum of the ionizing radiation at each observation point is the same. If the medium is optically thin in the observed lines, then the gas emitting into the entrance slit of the scanner at each observation point is a slab across the entire nebula in the direction of the line of sight. Each emitting slab runs through the ionization spheres of one or more hot stars in the nebula. We assume that the combined spectrum of all the stars that ionize a slab is the same for all observed slabs.

3. *Nonuniform dust distribution.* The observed slabs in the nebula do differ from each other in their content of dust grains.

4. *Reddening variation in the nebula.* Most of the variation in the interstellar reddening of the observed spectral lines among the different points in a source is due to variation in the dust content within the nebula itself and not to variation in the dust along the line of sight between the observer and the nebula.

We shall discuss the validity of the assumptions in § IV. Here we comment only on assumption 3 that an inspection of photographs of the two nebulae NGC 6334 and 2024 (figs. 1 and 2 [pls. 7 and 8]) suggests that these two objects are indeed rich in dust and that the distribution of dust within them is far from uniform.

III. OBSERVATIONS

We have observed two galactic H II regions, NGC 2024 and NGC 6334, with the Kitt Peak National Observatory No. 1 36-inch (91-cm) telescope, and a spectrum scanner designed and built under the direction of J. I. Danziger of the Harvard College Observatory. These two nebulae show weak helium recombination lines in their radio spectra (Churchwell 1970; Cesarsky 1971). Eight points in NGC 2024 were observed in 1972 between March 5 and 8, and six points in NGC 6334 were observed between April 28 and May 7. Figures 1 and 2 show photographs of the two optical nebulae taken from the *Palomar Sky Survey.* The individual points of observation at each nebula for which data are given here, as well as the extension of the radio sources in the two nebulae, are marked on the photographs. Table 1 lists the offset coordinates of the points in NGC 6334 with respect to the star SAO 208700, and table 2 gives the offset coordinates of the points in NGC 2024 with respect to ζ Ori. The dimensions of the entrance slit were 4.4 × 0.55 mm which correspond to 130″ × 15″ on the sky. The exit slit width was 0.610 mm, giving 20 Å resolution at half the peak of the instrumental profile in the first order. We scanned across three regions in the spectrum: λλ6612–6508, λλ5920–5848, and λλ4877–4846. The observed profile at each region was fitted by a least-squares method to a convolution of the instrumental profile and the prominent emission lines in each region. In the first region, the lines considered were Hα and N II λλ6584 and 6548. In the second region, the lines were He I λ5876 and the two Na I sky lines λλ5896 and 5890. In the third region, the line considered was Hβ. The intensity of the lines and the slope of the background noise and continuum were the parameters determined by the least-squares method. We have observed standard stars from Hayes's (1970) list in order to apply to the observed intensities the proper correction for atmospheric extinction and instrumental response. Table 3 gives the corrected value of $r_\alpha = I_{H\alpha}/I_{H\beta}$ and $r_{He} = I(5876)/I_{H\beta}$ at the observation points in the two nebulae. Data are not given for points in which the derived intensity of the He I λ5876 line was smaller than twice the probable error.

TABLE 1

COORDINATES OF THE OBSERVATION POINTS IN NGC 6334, RELATIVE TO THE STAR SAO 208700

Observation Point	Δα Time min	Δα Time sec	Δδ (arc min)
I	−0	12	+ 0.38
II	−0	17	+ 4.73
III	+0	11	− 2.66
IV	−0	41	−17.75
V	+0	20	−18.24

TABLE 2

COORDINATES OF THE OBSERVATION POINTS IN NGC 2024, RELATIVE TO THE STAR ζ ORIONIS

Observation Point	$\Delta\alpha$ Time min	$\Delta\alpha$ Time sec	$\Delta\delta$ (arc min)
I	+1	10	+1.98
II	+1	27	+1.98
III	+1	08	+4.60
IV	+0	52	+4.30
V	+1	43	+2.40
Center of radio source	+1	18	+2.00

IV. DISCUSSION

Table 4 gives the line ratios $r_\alpha^{(t)} = I_{H\alpha}/I_{H\beta}$ and $r_{He}^{(t)} = I(5876)/I_{H\beta}$ as obtained from recombination theory (Clarke 1965; Brocklehurst 1972) under different temperatures and densities. In deriving the values in table 4, we assumed Baker and Menzel's (1938) case B for hydrogen and case A for helium. We see that $r_\alpha^{(t)}$ and $r_{He}^{(t)}$ are almost independent of the density in the range of densities expected in diffuse nebulae and that they are only weakly dependent on the temperature. In the following discussion, we shall adopt $r_\alpha^{(t)} = 2.85$ and

$$r_{He}^{(t)} = 1.4 N_{He^+}/N_{H^+} \, .$$

If we assume that cascade recombination is the main production mechanism of the hydrogen and the helium emission lines in NGC 2024 and 6334, then the large differences between the numbers in tables 3 and 4 must be due to reddening by dust grains. Different line ratios could also be obtained if Baker and Menzel's case C prevailed. This is the case where stellar radiation in the Lyman lines excites neutral hydrogen directly. It was shown, however, by Seaton (1968) that under conditions typical of H II regions in the Galaxy, the rate of recombination of ionized hydrogen exceeds the rate of excitation of neutral hydrogen by two orders of magnitude.

The extinction of light by dust between an observer and a source is given by

$$I^o(\lambda) = I^{(t)}(\lambda) \exp(-\tau_\lambda) \, , \tag{1}$$

TABLE 3

OBSERVED VALUES OF $r_\alpha = I_{H\alpha}/I_{H\beta}$ AND $r_{He} = I(5876)/I_{H\beta}$ AT SEVERAL POINTS IN THE TWO H II REGIONS NGC 6334 AND NGC 2024

	Point I	Point II	Point III	Point IV	Point V
NGC 6334:					
$r_\alpha \pm \Delta r_\alpha$	12.6 ± 0.9	17.9 ± 1.8	20.0 ± 3.0	21.5 ± 6.6	18.6 ± 3.5
$r_{He} \pm \Delta r_{He}$	0.28 ± 0.05	0.29 ± 0.08	0.42 ± 0.12	0.35 ± 0.27	0.47 ± 0.16
NGC 2024:					
$r_\alpha \pm \Delta r_\alpha$	7.5 ± 0.8	5.9 ± 1.0	6.9 ± 1.0	6.8 ± 0.4	3.9 ± 0.4
$r_{He} \pm \Delta r_{He}$	0.11 ± 0.02	0.13 ± 0.08	0.07 ± 0.04	0.06 ± 0.02	0.14 ± 0.04

TABLE 4

THEORETICAL LINE RATIOS $r_\alpha^{(t)} = I_{H\alpha}^{(t)}/I_{H\beta}^{(t)}$ AND $r_{He}^{(t)} = I^{(t)}(5876)/I_{H\beta}^{(t)}$ COMPUTED FOR RECOMBINATION THEORY CASE B FOR HYDROGEN AND CASE A FOR HELIUM AT THREE VALUES OF ELECTRON TEMPERATURE, IN THE ELECTRON DENSITY RANGE OF 10^4–10^2 cm^{-1}

T_e	2.10^4	1.10^4	5.10^3
$r_\alpha^{(t)}$	2.74	2.84	2.99
$N_{H^+}/N_{He^+}r_{He}^{(t)}$	1.15	1.35	1.58

where $I^o(\lambda)$ is the observed intensity of the light, $I^{(t)}(\lambda)$ is the true intensity, and τ_λ is the optical depth of the dust in the line of sight. If the dust is well mixed with a homogeneous emitting gas, the extinction is

$$I^o(\lambda) = I^{(t)}(\lambda)\,\frac{1-\exp(-\tau_\lambda)}{\tau_\lambda}\,. \tag{2}$$

Contours of radio intensity in H II regions, optical isophotes, and theoretical considerations suggest that there is a large gradient in the electron density from one or more central points in the nebula outward. The distribution of dust in an H II region is probably different. It was shown by Pariiskii (1961) that the obscuration in the H II region M17 cannot be due to dust that is well mixed with the emitting gas. The observations reported here are also inconsistent with such a picture. Considerations of the dynamics of dust in H II regions, specifically when radiation pressure is taken into account, indicate that if dust exists in an H II region, its distribution is such that the ratio of dust to free electrons increases from the center outward. The extinction law for such a distribution lies between the two extreme cases mentioned above; its exact form depends on the behavior of the electrons-to-dust ratio along the line of sight. Here we use the first extinction law which can be written as

$$\log I^{(t)}(\lambda) = \log I^o(\lambda) + cf(\lambda)\,, \tag{3}$$

where $f(\lambda)$ is a reddening function given by Seaton (1960) and c is a reddening constant characteristic of the point of observation. We have an expression of the form of equation (3) for each of the three observed lines. By subtracting the expression for Hβ from the other two and by eliminating c between them, we obtain

$$\log\left(\frac{r_\alpha^{\,o}}{r_\alpha^{\,t}}\right) = \frac{f(6563)}{f(5876)}\log\left(\frac{r_{He}^{\,o}}{r_{He}^{\,t}}\right)\,. \tag{4}$$

From table 4, expression (4), and the value of $f(\lambda)$ given by Seaton, we obtain

$$\log\left(\frac{r_\alpha^{\,o}}{2.85}\right) = 1.54\log\left(\frac{r_{He^o}}{0.14}\right) - 1.54\log\left(10\,\frac{N_{He^+}}{N_{H^+}}\right)\,, \tag{5}$$

which we write as

$$s_\alpha = 1.54 s_{He} - 1.54 B\,.$$

If the abundance ratio $\rho_{He} = N_{He^+}/N_{H^+}$ is constant throughout the nebula, the observation points plotted in the (s_α, s_{He})-plane should fall along a straight line, the normal reddening law, with a slope of 1.54. The intersection of the line with the s_{He} axis corresponds to the state of no reddening and therefore can give the value of ρ_{He}.

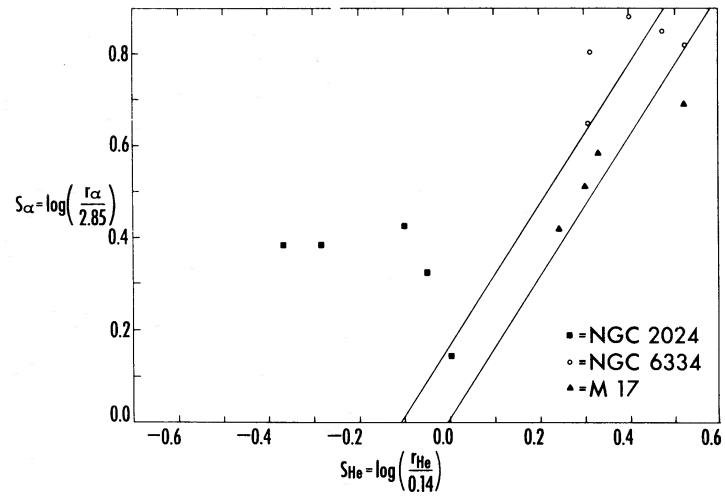

FIG. 3.—Plot of s_α versus s_{He} for the three H II regions NGC 2024, NGC 6334, and M17. The two straight lines are the reddening laws for the two last sources.

In practice, ρ_{He} does vary from point to point in the nebula. If the points of observation are still scattered around the normal reddening line, as is the case for NGC 6334 in figure 3, it means that the relation between s_α and s_{He} is dominated by this law. The interpretation of such a distribution could be that there is no correlation between the amount of dust in the nebula and the ionization of degree of helium. The scatter around the reddening line is then the result of the non-validity of assumption (2) of § II. Alternatively, assumption (2) can be retained, but assumption (4) must be abandoned. One can interpret the distribution of points for NGC 6334 as an indication that the variation in the amount of interstellar dust between the observer and the different points of observation is large enough to wipe out any possible correlation between the amount of dust in the nebula itself and the value of ρ_{He}. From the point of intersection of the reddening line, drawn through the points of NGC 6334 with the s_{He} axis, we derive for this nebula $\rho_{He} = N_{He^+}/N_{H^+} = 0.077 \pm 0.013$, which is within the error limits of the determination of ρ_{He} from radio observations by Churchwell (1970), who gives $\rho_{He} = 0.059 \pm 0.02$.

The difference between the value of ρ_{He} as determined by the radio observations and the value derived from the optical measurements may well be explained within the framework of the hypothesis suggested here. The observation points for the optical measurements are chosen, out of necessity, in regions in the nebula that are unobscured and therefore presumably somewhat poorer in their dust content (see fig. 1). If dust grains destroy helium-ionizing photons more efficiently than hydrogen photons, the He^+/H^+ ratio in these regions is relatively large. The radio source, on the other hand, includes large regions of complete obscurity. These regions are probably richer in their dust content and, hence, poorer in the amount of He^+. The radio result, which is an average over the entire radio source, therefore indicates a smaller He^+/H^+ ratio.

When assumption (4) of § II is valid, we expect a different distribution of points in the (s_α, s_{He})-plane. Again, if there is no correlation between ρ_{He} and the amount of dust or its parameter s_α, and if assumption 2 is invalid, one expects a random distribution of points. If, however, all of our assumptions are valid, there should be a correlation between s_{He} and s_α in the sense that s_{He} is becoming smaller with increasing s_α. The points of NGC 2024 in figure 3 do show such a qualitative correlation. The quantity s_{He}, however, is related to s_α through both the reddening law and the effect of dust on ρ_{He}. The two relations are in opposition to each other. In order to separate the two, we rewrite expression (6) as

$$\log\left(\frac{10N_{He^+}}{N_{H^+}}\right) = B = s_{He} - \frac{1}{1.54}s_\alpha\,. \tag{7}$$

In figure 4 we plot $-B$ versus s_α in the two observed H II regions. If dust grains in a diffuse nebula do have an extinction cross-section, which is larger at helium ionizing frequencies than at hydrogen ionizing frequencies, we expect to find ρ_{He}^{-1} or $-B$ growing with increasing s_α, the parameter measuring the amount of dust. As the number of grains within an observed H II region increases, the reddening law deviates from expression (1) and approaches the form given by expression (2). This expression implies that at a large optical depth of the dust, s_α approaches a limit, $\log(k_\beta/k_\alpha)$, where k_α and k_β are the absorption coefficients of the dust at the Hα and Hβ frequencies. Therefore, the rate of increase of $-B$ should also increase with s_α, as s_α approaches its limit. In figure 4 we indeed find this correlation between $-B$ and s_α for the nebula NGC 2024. As expected from figure 3, no such correlation exists for NGC 6334.

The correlation found in NGC 2024 tends to confirm the validity of our four assumptions of § II for this nebula. In particular, it indicates that assumption 2 is justified to the extent that the effect of the transfer of the ionizing radiation on the He^+/H^+ abundance ratio in the five observed points in the nebula is secondary to the effect of the extinction of the radiation by the local dust grains.

The error bars of the observed points of NGC 2024 are too large for an attempt to derive a quantitative conclusion about the properties of grains in the ultraviolet. We are able, however, to draw a smooth line through the observed points and to extrapolate it to intersect the $-B$ axis. The point of intersection gives the value that ρ_{He} would have taken had no dust existed in the nebula. For NGC 2024, we find the number to be around 0.095, the "normal" helium-to-hydrogen abundance ratio.

From the limiting value of s_α in figure 4, we are also able to separate the interstellar extinction between NGC 2024 and the observer from the total extinction of light from this nebula. We find that the absorption between the observer and the nebula is about 0.5 mag in Hβ.

In NGC 2024 there is again a disagreement between the value of ρ_{He} derived from radio observations and the value derived optically. Cesarsky (1971) gives from his

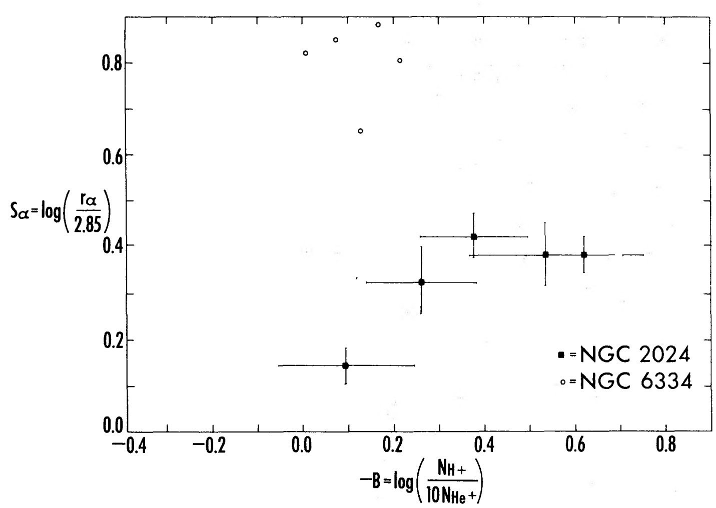

FIG. 4.—Plot of s_α versus s_{He} in NGC 6334 and NGC 2024

radio measurements $\rho_{He} = 0.016$, while at our three points of observation, I, II, and III, which fall within the limits of the radio source, we find the corresponding values 0.04, 0.055, and 0.03. A look at figure 2 reveals that here again the optical points are probably regions of relatively low dust content. Most of the radio source on the other hand, the center and the brighter regions in particular, are entirely obscured optically by a large dust feature (see fig. 4*c* [pl. 7] in Schraml and Mezger 1969). From the radio intensity contours of Schraml and Mezger, it is clear that the average ionized helium abundance derived from the radio lines is heavily weighted toward values in the dust rich regions and therefore it is smaller than the abundance derived optically.

V. COMPARISON WITH OTHER OBSERVATIONS

Emission lines in three H II regions, Orion A (M42 and M43), M8 and M17, have been observed by Peimbert and Costero (PC) (1969). The three nebulae belong to the first group of radio sources mentioned in § I, with a normal He^+/H^+ abundance ratio. In the Orion nebula, it has been already noticed by Johnson (1953) that the intensity ratio of helium lines to hydrogen lines decreases with the distance from the center of the nebula. This behavior indicates that assumption 2 of § II is probably not valid when the observation point is moved away from the center. Thus the low value of r_{He} at point IV of PC is probably due to the fact that the emitting gas of this point is outside the helium ionization zone of the exciting stars at the center. The three remaining points observed by PC do fall roughly along the normal reddening line in (s_α, s_{He})-plane. The intersection point of the line with the s_{He} axis gives, for this nebula, $\rho_{He} = 0.086 \pm 0.010$, which is in very good agreement with the radio result $\rho_{He} = 0.083 \pm 0.005$ (Churchwell 1970).

The six observation points of PC in the H II region M8 are scattered in the (s_α, s_{He})-plane in an apparent random distribution. This means that at least one of the four assumptions of § II is not valid for this source. There is no way to decide, from the presently available observations, which among the four assumptions is nonvalid.

In the H II region M17, PC have observed four distinct points. Figure 3 shows the distribution of the points in the (s_α, s_{He})-plane. The points fall along a straight line with the slope given by the reddening law. The intersection of this line with the s_{He} axis gives for this nebula $\rho_{He} = 0.099 \pm 0.013$, which corresponds very well with the radio determination of $\rho_{He} = 0.091 \pm 0.008$ (Churchwell 1970).

The most likely interpretation of the observation in Orion and in M17 is therefore that the nebulae are poor in intrinsic dust and that most of the reddening and the variation in it from point to point occur in the interstellar space between the observer and the nebulae. In M17 helium is ionized throughout the nebula, giving the normal He^+/H^+ abundance ratio. This interpretation is in line with the conclusions arrived at by Pariiskii (1961) from his analysis of radio and optical observations in M17. In the Orion Nebula, dust is probably bordering the helium emitting zone, mixed with gas in an H II and He I outer region. Thus it is not unlikely that the radius of the helium ionization sphere in Orion is determined by the presence of dust at some distance from the center and not only by the transfer of the helium ionizing radiation in the gas. The existence of an outer region of ionized hydrogen and neutral helium in Orion was inferred by Batchelor and Brocklehurst (1972) from a fitting of optical and radio observations to a variable density model of the nebula.

Infrared fluxes have been detected by Harper and Low (1971) from 11 H II regions. These observers interpret the infrared fluxes as thermal radiation of dust grains heated by the ultraviolet radiation in the nebulae. Five of the infrared sources belong to the second group of the radio sources with weak helium emission lines. The interpretation of the infrared radiation as emanating from dust, and the placement of the dust grains within these five H II regions, are consistent with our interpretation of the weak helium lines. Three of the infrared sources, however, belong to the first group of radio sources with the normal He^+/H^+ abundance ratio. Our interpretation of these infrared measurements will be that in these three sources the emitting dust lies mainly outside the H II region or at least outside the He II region, possibly pushed out by radiation pressure.

VI. CONCLUSIONS

We have found in the diffuse nebula NGC 2024 an anticorrelation between the amount of dust, as measured by the parameter s_α, and the degree of ionization of helium. This result supports the interpretation of the weakness of the radio helium lines in this nebula as a consequence of the low ionization of helium caused by the extinction of helium ionizing radiation by dust grains. The relation between $-B$ and s_α implies also that the absorption cross-section of dust grains in NGC 2024 beyond the helium ionization limit is larger than immediately beyond the hydrogen ionization limit. This result agrees with the findings of Bless and Savage (1972) that the extinction of interstellar grains in the ultraviolet, beyond λ1350, increases with frequency.

No correlation of the same kind could be found in NGC 6334. Our observations, however, are not in conflict with the above interpretation of the radio observations. The present observations in this nebula seem to indicate that most of the dust along the line of sight, to the different points in the nebula, lies in the space between the nebula and the observer. Thus, it is still possible that the internal dust in this H II region is indeed responsible for the low ionization of helium, but that the reflection of this effect in the optical spectral lines is being overcome by interstellar reddening in the foreground of the nebula.

It is, in fact, not surprising to find that interstellar reddening dominates the observed intensity of the λ5876 helium line in NGC 6334 and that internal dust dominates it in NGC 2024. While NGC 6334 is at a distance of 2000 pc and in the direction of the galactic center, NGC 2024 lies in the opposite direction and at a distance of only 500 pc (Churchwell 1970; Cesarsky 1971).

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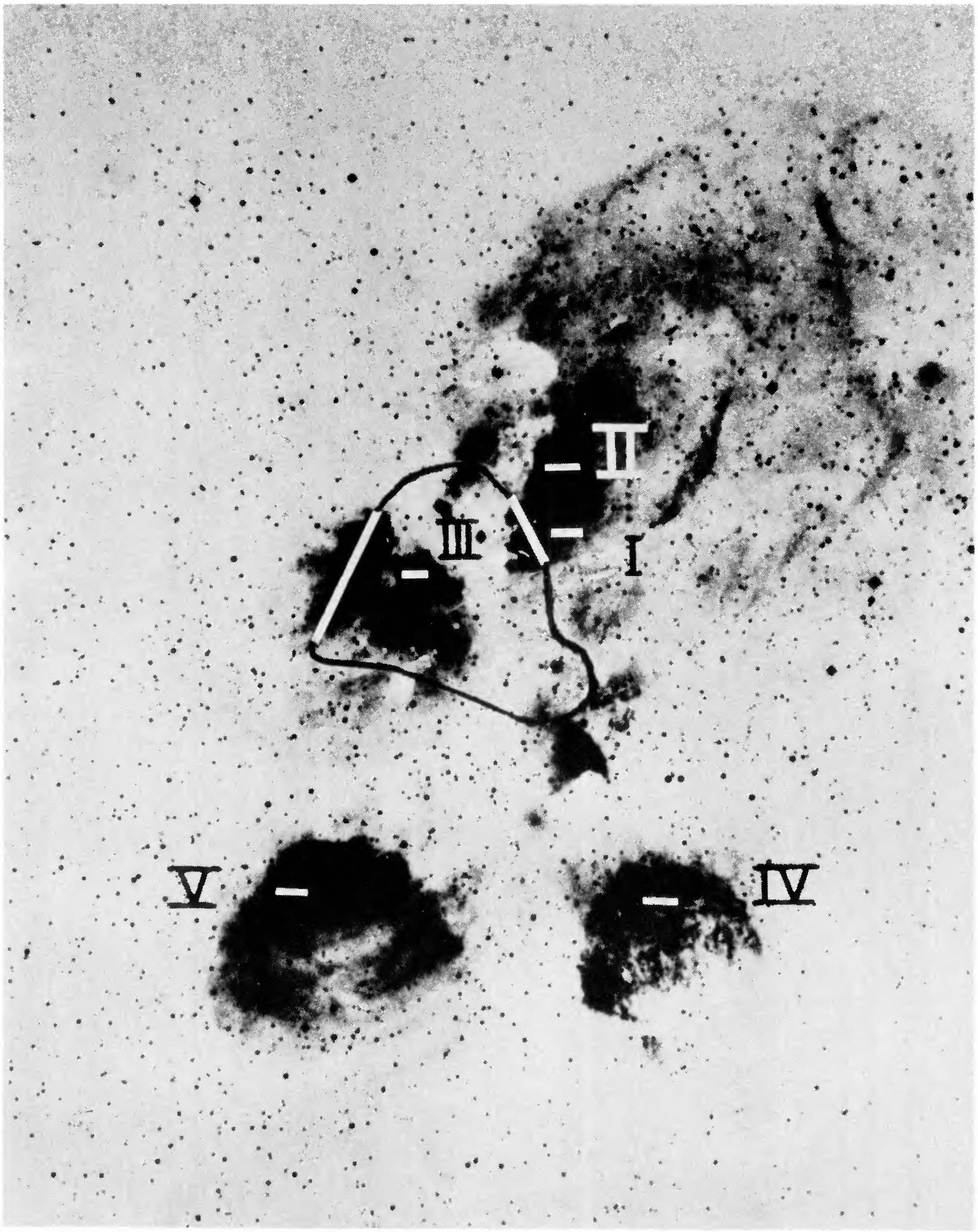

FIG. 1.—Observation points and the radio source in NGC 6334, indicated on a reprint of the nebula, taken from the red *Palomar Sky Survey*. North is at the top, scale is 14".6 mm^{-1}.

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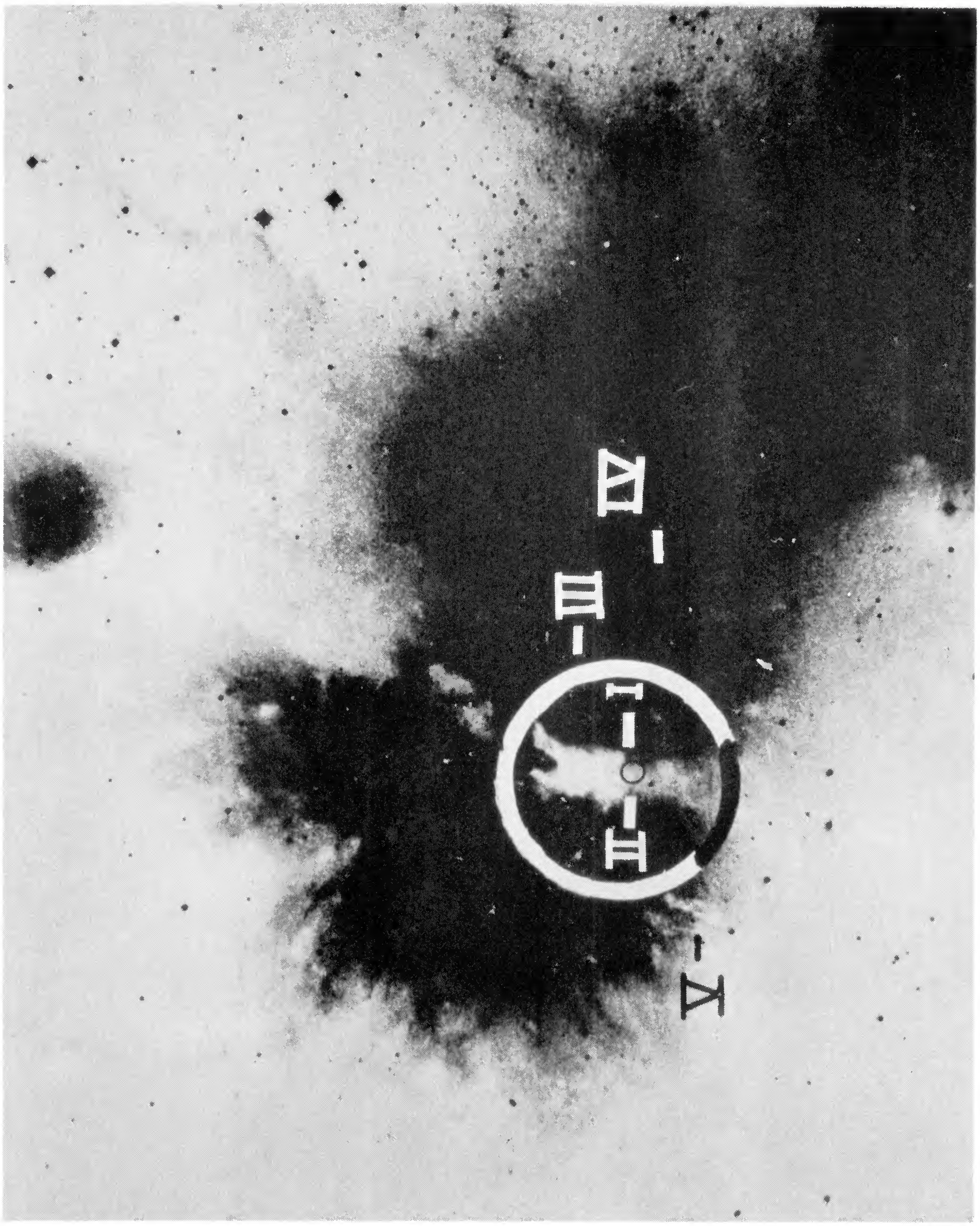

FIG. 2.—Observation points and the radio source in NGC 2024, indicated on a reprint of the nebula, taken from the red *Palomar Sky Survey*. North is at the top, scale is 13'.1 mm^{-1}.

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