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THE DIFFERENTIAL EXTINCTION TOWARD NOVA CYGNI 1992

I. Introduction

The intrinsic luminosity of an astronomical object is one of its most important physical characteristics. Without the intrinsic luminosity, our understanding of it would not be complete. These statements may be taken one step further for novae: Not only is the intrinsic luminosity important for nova astrophysics, but it is also important for cosmological astrophysics because novae are used as distance indicators.

Unfortunately, the intrinsic luminosity estimates of objects are hindered by varying amounts of extinction due to dust grains along the line of sight. There are several methods for determining the extinction. Some of them require an *a priori* knowledge of the object's properties. Others do not require this knowledge, e.g., measuring the strength of the 0.22 μm feature (Bless and Savage 1972), but they are not always reliable.

A lower limit to the differential extinction may be obtained from linear polarization observations of stars within a few degrees of the desired object (*cf.* Section II). With this lower limit, an improved upper limit to the object's distance (and luminosity) may be obtained (as compared to upper limits derived assuming no extinction).

II. The Technique

In a global sense, the average differential extinction ($\langle dA_V/\,dr\rangle$; in mag kpc^{-1}) is approximately the same along most lines of sight within the local spiral arm because the distribution of interstellar dust grains is nearly uniform. The average differential interstellar linear polarization ($\langle dp/\,dr\rangle$; in % kpc^{-1}), however, depends on the angle between the line of sight and the Galactic magnetic field which aligns the dust grains. At the present time, there is no satisfactory one-to-one relationship between $\langle dA_V/\,dr\rangle$ and $\langle dp/\,dr\rangle$, but a useful inequality can be derived.

For stars near the Galactic plane, the interstellar linear polarization and the color excess are related by a simple inequality (Serkowski, Mathewson, and Ford 1975; hereafter SMF), namely

$$p \lesssim 9\,E(B-V)\,, \tag{1}$$

where p is the interstellar linear polarization (%) and $E(B-V)$ is the color excess (mag). Note that the upper limit corresponds to lines of sight which are perpendicular to the spiral arm. The interstellar reddening can be expressed in two ways,

$$R \stackrel{\Delta}{=} \frac{A_V}{E(B-V)} = \frac{\lambda_{max}}{0.18\,\mu m}\,, \tag{2}$$

where R is the reddening, A_V is the extinction (mag), and λ_{max} is the wavelength of the interstellar linear polarization peak (μm). Note that the first equality is the definition of reddening and the second is an empirical formula (SMF). Along most lines of sight, $R \approx 3$ (Johnson 1965).

If we assume that both A_V and p are linear functions of distance with zero intercepts, i.e.,

$$A_V = \left\langle \frac{dA_V}{dr} \right\rangle r \tag{3a}$$

and

$$p = \left\langle \frac{dp}{dr} \right\rangle r \, , \tag{3b}$$

we obtain a lower limit for $\langle dA_V / dr \rangle$ when all the above equations are combined,

$$\left\langle \frac{dA_V}{dr} \right\rangle \gtrsim \frac{\lambda_{max}}{1.6} \left\langle \frac{dp}{dr} \right\rangle \, . \tag{4}$$

Note that λ_{max} does not change by more than a few percent across the entire sky, so the error introduced by this factor is relatively small compared to the total uncertainty of the inequality.

In order to estimate $\langle dp / dr \rangle$, we must search the literature for stars, within a few degrees of the desired line of sight, that have been observed polarimetrically *and* have reliable distances. With these data in hand, a least-squares fit to Equation 3b may be performed to get $\langle dp / dr \rangle$. There are, however, a few pitfalls which must be avoided. Firstly, all stars that are known to be polarization variables must be excluded from the analysis, because they are intrinsically polarized and will skew the results. Secondly, there are many regions of the sky which have relatively few stars with linear polarization observations and reliable distances. Thirdly, the interstellar medium in some parts of the sky is more "clumpy" than the average. Lastly, the magnetic field in some parts of the Galaxy may be tangled and non-uniform. Any one of these problems may make this technique difficult to use.

III. Nova Cygni 1992

For Nova Cygni 1992, we are indeed fortunate. Not only have a lot of good quality linear polarization measures and distances been obtained in a single survey (Appenzeller 1966), but the dust grains and magnetic field in this part of the galaxy appear to be reasonably well behaved as well.

According to SMF, $\lambda_{max} \approx 0.52$ μm (determined empirically from their own linear polarization measures) in this part of the sky, which means that $\lambda_{max} / 1.6 \approx 0.3$. The size of the field had to be a bit larger than desired, $\approx \pm 10°$ (typically it is $\approx \pm 5°$) in order to obtain enough stars for the least-squares fit. A list of the field stars may be found in Table 1, and a plot of the linear polarizations versus distance may be found in Figure 1.

There appears to be a linear trend in the polarization, but unfortunately there are not many points at distances comparable to that of the nova, between

2 and 3 kpc (Quirrenbach *et al.* 1993; Starrfield 1993; Wagner 1993). We assume because of the Galactic geometry that $\langle dp/dr \rangle$ is constant to 3 kpc. The fit gave $\langle dp/dr \rangle \approx 0.6\%$ kpc^{-1}. This value is close to what is expected for a line of sight at an ≈ 45° angle to the spiral arm (the value is ≈ 1.2% kpc^{-1} for lines of sight perpendicular to the spiral arm; Elias 1990). Therefore, $\langle dA_V/dr \rangle \gtrsim 0.2$ mag kpc^{-1}.

Table 1

The Linear Polarization of the Nova Cygni 1992 Field Stars

Star (HD/BD)	$V/B-V/U-B$	Stellar Class	$d/l^{II}/b^{II}$ (kpc)/(°)/(°)	$\bar{p}_L{}^a/\bar{\theta}^a$ (%)/(°)
195068	5.59/+0.30/+0.04	dF0	0.036/86.14/+6.40	0.02(0.03)/62(26)
195338	7.48/+1.17/+0.96	G7 II	0.540/84.85/+5.14	0.70(0.06)/17(3)
196090	7.79/+1.43/+1.56	K3 III	0.220/84.94/+4.26	0.47(0.06)/18(4)
+46°3014	8.43/+0.52/+0.02	F7p V	0.073/85.87/+3.06	0.23(0.11)/151(13)
198345	5.55/+1.47/+1.78	K5 III	0.130/86.97/+2.72	0.13(0.03)/75(7)
199612	5.86/+1.05/+0.93	G8 II-III	0.140/88.93/+2.49	0.12(0.03)/78(8)
190149	6.97/+1.64/+2.02	M0 II-III	0.380/79.32/+7.15	0.12(0.06)/100(12)
191854	7.46/+0.69/+0.22	G5 V	0.028/79.98/+5.77	0.09(0.05)/173(15)
192514	4.81/+0.09/+0.11	A3 III	0.056/82.71/+6.87	0.10(0.02)/60(5)
192535	6.16/+1.52/+1.83	K4 III	0.130/79.85/+4.93	0.26(0.03)/91(3)
192867	7.24/+1.61/+1.94	M1 III	0.310/80.66/+5.08	0.27(0.06)/99(6)
192869	7.85/+0.55/+0.08	F6 IV	0.105/79.19/+4.08	0.17(0.06)/76(10)
193090	7.10/+1.50/+1.82	K5 III	0.260/81.87/+5.58	0.09(0.04)/85(11)
193217	6.31/+1.63/+1.91	K4 II	0.370/79.69/+3.99	0.35(0.05)/112(4)
193536	6.44/-0.13/-0.69	B2 V	0.520/82.82/+5.80	0.20(0.06)/68(7)
193701	6.67/+0.45/+0.41	F5 IV	0.066/82.12/+5.12	0.12(0.07)/126(15)
194152	5.57/+1.07/+1.01	K0 III	0.068/82.70/+5.04	0.11(0.03)/79(9)
194220	6.22/+0.95/+0.76	K0 III	0.096/80.46/+3.32	0.09(0.03)/92(9)
194479	7.46/+1.08/+1.01	K1 III-IV	0.140/82.00/+4.12	0.10(0.07)/79(19)
194708	6.91/+0.44/+0.11	F6 III	0.240/80.42/+2.72	0.24(0.06)/82(7)
195100	7.59/+0.85/+0.49	G5 III	0.200/81.02/+2.66	0.19(0.10)/96(14)
195405	7.99/+0.64/+0.27	G2 IV	0.100/80.62/+1.95	0.26(0.05)/81(5)
195506	6.44/+1.14/+1.09	K2 III	0.135/83.60/+3.99	0.03(0.04)/170(27)
195985	7.69/-0.12/-0.54	B5	0.740/83.12/+3.03	0.40(0.09)/33(6)
198151	6.24/+0.06/+0.02	A3	0.078/85.83/+2.06	0.09(0.03)/93(9)
+44°3582	8.51/+0.36/+0.06	F0n III	0.225/84.58/+0.79	0.09(0.13)/116(29)
199081	4.72/-0.14/-0.58	B5 V	0.135/84.90/-0.19	0.17(0.02)/88(4)
199098	5.44/+1.11/+0.95	G8 III	0.058/85.82/+0.31	0.15(0.07)/66(13)
199395	6.71/+1.44/+1.75	K4 III	0.190/84.38/-1.15	0.29(0.05)/83(5)
199580	7.21/+0.97/+0.74	K0 III-IV	0.100/84.17/-1.65	0.24(0.07)/109(9)
199761	7.97/+0.46/+0.13	F4 III	0.160/87.51/+1.05	0.06(0.07)/142(26)
199870	5.55/+0.97/+0.84	G9 III-IV	0.041/85.55/-0.83	0.07(0.02)/119(9)
200102	6.63/+1.05/+0.72	G1 Ib	1.150/86.13/-0.69	0.38(0.04)/32(3)
200527	6.24/+1.68/+1.84	M3 Ib-II	0.940/86.27/-1.17	0.12(0.02)/69(5)
200560	7.68/+0.97/+0.78	K2.5 V	0.017/87.12/-0.47	0.05(0.06)/6(27)
200805	8.28/+0.81/+0.66	F5 Ib	1.950/86.75/-1.16	1.88(0.07)/47(1)
201065	7.55/+1.76/+1.89	K5 Ib	2.000/88.26/-0.13	0.89(0.07)/43(2)
201456	7.81/+0.53/+0.08	F8 V	0.052/86.20/-2.65	0.37(0.10)/82(7)
201924	7.83/+0.78/+0.42	G9 V	0.028/87.81/-1.86	0.14(0.06)/76(12)
202312	7.33/+0.87/+0.50	G5 II-III	0.360/87.89/-2.37	0.23(0.06)/85(7)

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[a] Parenthesized quantities are 1σ errors.

All of this data was obtained from Appenzeller (1966).

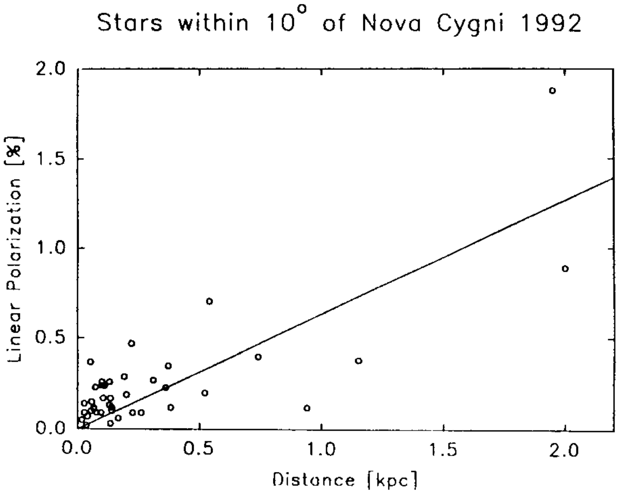

Figure 1.

IV. Conclusion

Wagner (1993) has determined from ultraviolet spectroscopy that $A_V \approx 0.6$ mag. If we assume that the distance to the nova is ≈ 2.5 kpc (Quirrenbach *et al.* 1993), then $A_V \gtrsim 0.5$ mag, consistent with the Wagner result.

Although this technique is usable only in a few instances at the present time, it is still another weapon in the arsenal for determining the extinction. With the advent of more extensive linear polarization surveys in the near future, this method should find a wider applicability.

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