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ASTRONOMY AND ASTROPHYSICS

# The Structure of Gould's Belt

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**Summary.** A comparative study of optical and radio-astronomical data was made of a section of Gould's Belt from $l = 300°–12°$. Two strong neutral hydrogen concentrations are associated with Sco OB2 and with the Lupus section of the Sco-Cen association. The mean plane of the gas is slightly below the optical equator. A plane self-gravitating model was applied to obtain a mean total density of 0.23 $M_\odot$ pc$^{-3}$ in the plane of the Belt, giving a total mass of $\sim 7\ 10^6\ M_\odot$, out of which about 7% is in the form of neutral hydrogen. In the Lupus gas concentration the hydrogen content is about 14%, indicating that star formation is less advanced there. Finally, the possibility that Gould's Belt is either rotating or oscillating rigidly is discussed.

**Key words:** Gould's Belt — gas dynamics — stellar associations

## I. Introduction

Gould's Belt is an expanding complex of stars, gas and dust outlined on the sky by the brighter OB stars, which follow a great circle tilted by about 18° to the galactic plane. A review of the available information on the structure of this system is given by Stothers and Frogel (1974), herein referred to as SF. The kinematics of the stars has been analysed by Lesh (1968) and Frogel and Stothers (1977); that of the gas by Lindblad et al. (1973), herein referred to as LGSS. They applied the theory of expanding groups affected by differential galactic rotation, formulated by Blaauw (1952), to derive an expansion age of around 5 10$^7$ yr.

The early radioastronomical studies of Lilley (1955) and Davies (1960) served to prove that a large amount of neutral hydrogen is associated with Gould's Belt, which Lindblad (1967) called "feature *A*". However, there is a paucity of detailed neutral hydrogen data relevant to Gould's Belt in the southern hemisphere.

In the present work we analyze new 21 cm line data in Sect. II and III; in Sect. IV we apply a plane self-gravitating model to the data to estimate the mean density and total mass of the system, and the fraction of mass in the form of neutral hydrogen. In Sect. V we study the properties of a large hydrogen concentration in Lupus, while Sect. VI deals with the problem of the tilt of the layer, and our conclusions are summarized in Sect. VII.

## II. Neutral Hydrogen Data

Neutral hydrogen associated with Gould's Belt covers a wide range in galactic latitude $b$; according to LGSS its radial velocity is in the range $0 \lesssim V_r \lesssim 8$ km s$^{-1}$. This low velocity makes it difficult to separate from other galactic contributions near $b = 0$, and limits the range in galactic longitude $l$ in which Gould's Belt can be easily resolved in 21 cm spectra. The optimal regions can be narrowed down as follows:

a) SF found that OB stars belonging to Gould's Belt thave their central plane inclined 18° ± 1° to the standard IAU galactic plane; it runs farthest above the galactic plane at $l = 25° \pm 1°$ and below at $l = 205° \pm 1°$. Thus, in the sectors $l = 325°–85°$ and $l = 145°–256°$ the Belt runs between 9° and 18° from the galactic plane, and is therefore easier to study.

b) In the second and fourth quadrant of galactic longitude, differential rotation causes most hydrogen to have negative radial velocities, thus avoiding superposition with Gould's Belt gas which has positive radial velocity. In these two quadrants the model of LGSS predicts $V_r > 2$ km s$^{-1}$ (a minimum to reduce blending with hydrogen near $V_r = 0$) for $l = 155°–180°$ and $l = 300°–360°$.

Combining both criteria, the most favourable regions

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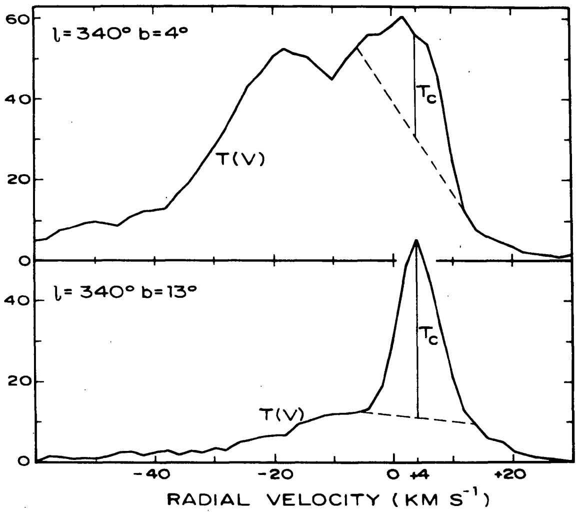



**Fig. 1.** Portions of two 21 cm line profiles. At higher latitudes (lower panel) the line emitted by hydrogen belonging to Gould's Belt, at $V = 4\ \mathrm{km\,s^{-1}}$, dominates the profile and its peak intensity $T_c$ is accurately given by Eq. (1). Near the galactic plane (upper panel) the Belt gas appears only as a shoulder on a complex line profile. The dashed line represents the interpolated background assumed by Eq. (1)

are $l = 155°$–$180°$ at negative $b$ and $l = 325°$–$360°$ at positive $b$. In the present paper we are discussing data from an extensive survey (Poeppel and Vieira, 1974, 1977; Olano et al., 1977) that covers the second region. Because of availability, we have extended this region to include all data, at intervals of 1°, from $l = 300°$–$12°$ for $b = +3°$–$+17°$; $l = 320°$–$345°$ for $b = +18°$–$+26°$; and $l = 346°$–$350°$ for $b = 18°$–$20°$, for a total of 1344 points. Data at each point consist of the average of two or more profiles of the brightness temperature, at 106 values of the velocity with separation equal to the channel width of $2\ \mathrm{km\,s^{-1}}$.

An inspection of the data showed that far from the galactic plane a single narrow line dominates the spectra, occurring close to the velocity predicted by LGSS. It is superimposed on a weak emission, probably made up of many componenents, extending over a wide velocity range. Fig. 1 shows such a profile, as well as another one at lower latitude. In the latter, the belt gas appears only as a shoulder on the positive velocity side of a wide, assymetric profile. Since at higher latitudes the line emitted by gas belonging to the Belt seems to maintain a rather constant width we are only interested in obtaining peak values. Therefore, we have devised a simplified procedure to handle this mass of data. We eliminate the background contribution by computing a corrected brightness temperature $T_c$ with the interpolation formula

$$T_c = T(V_L) - 0.5[T(V_L + 10\ \mathrm{km\,s^{-1}}) + T(V_L - 10\ \mathrm{km\,s^{-1}})] \qquad (1)$$

where $V_L$ is the value given by LGSS's model. For a gaussian line centered at $V_L$ with velocity dispersion $\sigma_v = 2.5\ \mathrm{km\,s^{-1}}$, superimposed on a straight line background, Eq. (1) gives the peak temperature with a relative error of 0.03% which is far less than the noise. A shift of the line away from $V_L$ will cause an underestimate of the peak temperature, but tests made in regions far from the galactic plane with well defined line profiles show that Eq. (1) gives results that are accurate within a few K. Strong blending may cause both under and overestimates, but it is unimportant for $b > 5°$.

While many authors prefer a gaussian analysis, several reasons are against it. Firstly, near the plane, where blending is most important, saturation of a line whose optical depth profile is gaussian will produce a non-gaussian temperature profile. Therefore, a spin temperature $T_s$ must be assumed, which may be different for galactic and Belt gas. Secondly, gaussian analysis is usually ambiguous, giving different results depending on the assumed number of components (Takakubo and van Woerden, 1966). And thirdly, if velocity gradients and clumpiness exist along the line of sight, the peak due to the Belt gas may not be gaussian, or even symmetrical. Therefore, the simple procedure outlined above is probably not less reliable than the more cumbersome gaussian analysis, at least in the present case.

The velocity $V_L$ predicted by the model was rounded off to the following values: $V_L = 2\ \mathrm{km\,s^{-1}}$ for $l = 300°$–$314°$, $V_L = 3\ \mathrm{km\,s^{-1}}$ for $l = 315°$–$329°$, and $V_L = 4\ \mathrm{km\,s^{-1}}$ for $l = 330°$–$12°$. When necessary $T(V)$ was interpolated from the data to obtain the values used in Eq. (1). A few negative values of $T_c$ occurred in regions of low brightness. Figure 1 shows two typical profiles, while Fig. 2 shows the run of uncorrected $T(V = 4\ \mathrm{km\,s^{-1}})$ and corrected $T_c$ as a function of latitude at $l = 340°$. $T_c$ is practically symmetric about $b \cong 11°$, which gives confidence in the adopted procedure.

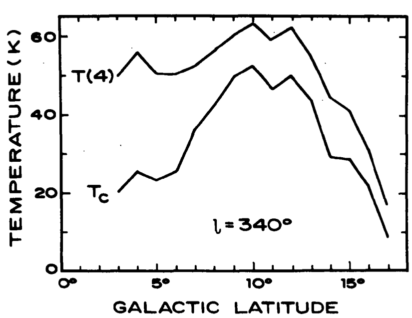



**Fig. 2.** Brightness temperature at galactic longitude $l = 340°$ for $V = 4\ \mathrm{km\,s^{-1}}$ as a function of latitude. While the upper curve, not corrected for background, still shows a maximum away from the galactic plane, Gould's Belt appears more clearly in the lower curve, corrected by Eq. (1), as an almost symmetrical peak centered around $b \cong 11°$

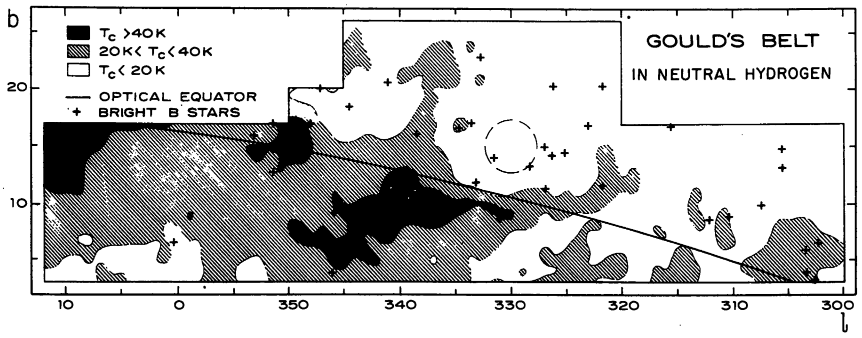



**Fig. 3.** Contour map of corrected peak brightness temperature $T_c$ in galactic coordinates. Also shown are B stars belonging to Gould's Belt (Bertiau, 1958) and the optical equator (Stothers and Frogel, 1974). The dashed circle indicates schematically the position of the Lupus Loop, a supernova remnant

Figure 3 is a contour map of $T_c$ in galactic coordinates. Because of the approximate nature of Eq. (1), a coarse spacing (20 K) was used for the isophotes in order to avoid crowding the map with detail that may not be real; thus, the broad features shown in Fig. 3 are insensitive to the errors discussed above. Several aspects are apparent:

a) For $l > 330°$, the Belt is quite conspicuous, with intensity dropping both away from and towards the galactic plane. Three concentrations of large angular extent predominate. B stars that according to Bertiau (1958) are members of the Scorpius-Centaurus association which belongs to the Belt, are also shown in Fig. 3. Many of these stars are associated with emission or reflection nebulae; while the neutral hydrogen concentrations tend to avoid individual stars, there exists a gross correlation with stellar subgroups like Scorpius OB2 near $l = 350°$, $b = 17°$, and the Lupus section around $l = 340°$. The Lupus Loop, a nearby supernova remnant, is also in a low intensity region.

b) For $l < 330°$ (Fig. 3) the intensity is much lower and rather patchy. This agrees with models such as that of Lindblad (1967), LGSS, and Grape (1975) which place the observer near the edge of an expanding gas cloud precisely in this direction.

c) The optical equator of Gould's Belt, plotted in Fig. 3 as defined by SF, runs about 3° above the mean plane of the gas layer. This is marginally significant in view of the accuracy of $\pm 1°$ of the optical equator, and the limited extent of our 21 cm data.

## III. Gas Content of the System

Because of the observed clumpiness, and in order to derive some representative average parameters of the Belt, we select a rather broad region covering 15° in longitude centered at $l = 2°$. Averaging $T_c$ at each latitude we obtain the diagram of Fig. 4a. Let $T_c(0)$ represent the brightness in the central plane of the gas; the corresponding peak optical depth is given by

$$\tau_c(0) = -\ln(1 - T_c(0)/T_s) \quad (2)$$

where $T_s$ is the spin temperature of the Belt gas, assumed to be uniform. If the optical depth has a gaussian line profile, with velocity dispersion $\sigma_v$, the column density $N_{\rm H}(0)$ of neutral hydrogen (in atoms cm$^{-3}$ pc) is

$$N_{\rm H}(0) = 1.49\, \sigma_v T_s \tau_c(0) \quad (3)$$

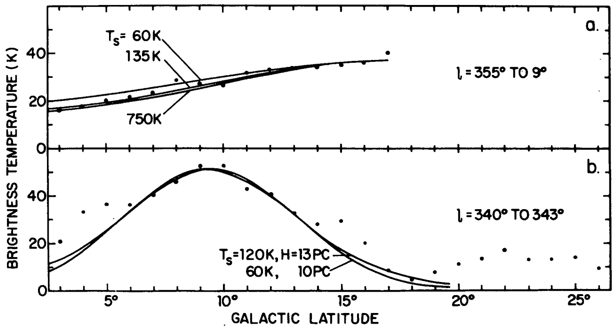
where $T_s$ is expressed is degrees Kelvin and $\sigma_v$ in km s$^{-1}$. Optical data by SF indicate that in this direction (Ophiucus) the Belt has an equatorial depth $X$ of 300 pc. If the gas has approximately the same extent, the mean hydrogen number density is given by

$$n_{\rm H}(0) = N_{\rm H}(0)/X. \quad (4)$$

From Fig. 4a, $T_c(0) \cong 37$ K, and according to Lindblad (1967), $\sigma_v = 2.5$ km s$^{-1}$ for Gould's Belt. The value of $T_s$ is more uncertain; the observation of molecular radiation (e.g., LGSS; Hughes and Routledge, 1972) is evidence of the existence of low temperatures in the densest regions. A lower limit is the highest brightness temperature we observed ($T_c \cong 57$ K at $l = 341°$, $b = +9°$), while an upper limit is that given if there is no turbulence so that all energy is thermal, i.e.

$$\tfrac{1}{2} k T_s = \tfrac{1}{2} m_{\rm H} \sigma_v^2 \quad (5)$$

where $k$ is Boltzmann's constant and $m_{\rm H}$ is the mass of the hydrogen atom, which yields 757 K. We have calculated




**Figs. 4a and b.** Filled circles: corrected peak brightness temperature $T_c$ as a function of galactic latitude averaged in two longitude regions. The lines represent models from Sect. IV and V fitted to the data. The parameters used in Fig. 4a and b are explained in the text and listed in Table 1a and b respectively

**Table 1.** Parameters of model gas layers
a. Gould's Belt

| Adopted | | | | | | Results | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_s$ (K) | $H$ (pc) | $X$ (pc) | $R$ (pc) | $\sigma_v$ (km s$^{-1}$) | $T_c(0)$ (K) | $\tau_c(0)$ | $n_H(0)$ (cm$^{-3}$) | $M_H$ ($10^6\ M_\odot$) | $\rho_T(0)$ ($M_\odot$pc$^{-3}$) | $M_T$ ($10^6\ M_\odot$) | $M_H/M_T$ |
| 60 | 31.7 | 300 | 400 | 2.5 | 37 | 0.96 | 0.71 | 0.56 | 0.23 | 7.3 | 0.08 |
| 135 | 31.7 | 300 | 400 | 2.5 | 37 | 0.32 | 0.54 | 0.42 | 0.23 | 7.3 | 0.06 |
| 750 | 31.7 | 300 | 400 | 2.5 | 37 | 0.05 | 0.47 | 0.37 | 0.23 | 7.3 | 0.05 |

b. Lupus concentration

| Adopted | | | | | | Results | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_s$ (K) | $H$ (pc) | $A$ (pc) | $D$ (pc) | $\sigma_v$ (km s$^{-1}$) | $T_c(0)$ (K) | $\tau_c(0)$ | $n_H(0)$ (cm$^{-3}$) | $M_H$ ($10^3\ M_\odot$) | $\rho_T(0)$ ($M_\odot$ pc$^{-3}$) | $M_T$ ($10^3\ M_\odot$) | $M_H/M_T$ |
| 60 | 10 | 40 | 170 | 1.0 | 51 | 1.90 | 2.1 | 5.3 | 0.37 | 37 | 0.14 |
| 120 | 13 | 40 | 170 | 1.0 | 51 | 0.55 | 1.2 | 4.0 | 0.22 | 29 | 0.14 |

$n_H(0)$ for $T_s = 60$, 135 and 750 K using Eq. (2), (3) and (4) and the parameters given above. The result, shown in the eighth column of Table 1a, is about 0.6 atoms cm$^{-3}$ and is not very sensitive to $T_s$. Davies (1960), assuming smaller dimensions, obtained the larger density of 2 atoms cm$^{-3}$.

## IV. Dynamical Model

To extract more physical information from the observed latitude variation of $T_c$ one needs a model. We shall assume that the system consists of plane parallel layers of self-gravitating gas and stars. The gas is in turbulent motion; its mass elements have a r.m.s. velocity $\sigma_v$ in one coordinate. The stars, formed recently out of this gas, are expected to have the same distribution and motion. In fact Lindblad (1967) found $\sigma_v = 2.5$ km s$^{-1}$ for the gas; Clube (1967), applying a stream solution to 111 Belt stars, found $\sigma_v \cong 3$ km s$^{-1}$.

Camm (1950) has solved simultaneously the Boltzmann and Poisson equations for this case obtaining the exact solution

$$\rho_T(z) = \rho_T(0)\ \mathrm{sech}^2\,(z/H) \tag{6}$$

where $\rho_T(z)$ is the total mass density (stars plus gas) at a height $z$ above the mean plane, $H$ is a characteristic height given by

$$H = \sigma_v(2\pi G\rho_T(0))^{-1/2} \tag{7}$$

and $G$ is the gravitational constant.

The mean absolute height is, using Eq. (6),

$$\langle|z|\rangle = \frac{\int |z|\rho_T(z)dz}{\int \rho_T(z)dz} = H \ln 2. \tag{8}$$

SF give $\langle|z|\rangle = 22$ pc from the plane of Gould's Belt for B0–B5 stars of well determined space position (distance less than 200 pc) which according to Eq. (8) implies $H \cong 31.7$ pc. With $\sigma_v = 2.5$ km s$^{-1}$, Eq. (7) gives $\rho_T(0) = 0.23\ M_\odot$ pc$^{-3}$.

According to SF, the overall dimensions of Gould's Belt are those of a disk, 750–1000 pc in diameter. Assuming an effective radius $R = 400$ pc, the total mass of the system is

$$M_T = \pi R^2 \int \rho_T(z)dz = 2\pi R^2 H\rho_T(0) \tag{9}$$

(i.e., $2H$ is the effective thickness of the layer) which, with the values given above, yields $M_T = 7.3\ 10^6\ M_\odot$. This value is intermediate between the $10^8\ M_\odot$ cited by Allen (1964, p. 267) and $2\ 10^5\ M_\odot$ (Allen, 1973, p. 282).

Similarly, the total hydrogen mass is

$$M_H = 2\pi R^2 H m_H n_H(0). \tag{10}$$

Using the values of the average density $n_H(0)$ obtained in Sect. III (Table 1a) we find $M_H \cong 5\ 10^5\ M_\odot$, twice that estimated by Davies (1960), who assumed smaller dimensions. The gas to total mass ratio $M_H/M_T \cong 0.07$, a value which depends only slightly on the assumed $T_s$ (see Table 1a) and points toward a high efficiency of star formation.

Let $\beta$ measure the latitude with respect to the central plane of the Belt as seen from the Sun. The hydrogen density will be proportional to $\rho_T(z)$ given by Eq. (6); integrating along a line of sight gives the optical depth

$$\tau_c(\beta) = \frac{\tau_c(0)\tanh\left(\dfrac{X}{H}\tan\beta\right)}{\dfrac{X}{H}\sin\beta} \tag{11}$$

which in turn serves to calculate the peak brightness temperature

$$T_c(\beta) = T_s\{1 - \exp[-\tau_c(\beta)]\}. \tag{12}$$

To convert $\beta$ into $b$ along a cut at constant longitude $l_0$ that intersects the central plane of the Belt at latitude $b_0$, we use the relation

$$\sin\beta = \sin(b - b_0)[\cos^2 i + \sin^2 i \sin^2(l_0 - l_\gamma)]^{1/2} \tag{13}$$

where $i$ is the inclination and $l_\gamma$ the longitude of the ascending node of the Belt. Because of the small value of $i$, $\beta \cong b - b_0$. Fig. 4a shows three curves of $T_c(b)$ calculated with the preceding equations using the parameters discussed above, for three values of $T_s$ (the only parameter for which the observations only specify upper and lower limits). The fit to the data is good for practically the whole range of allowed spin temperatures. The parameters and results are collected in Table 1a.

The shape of the curves of Fig. 4a depends mostly on $X/H$, as seen in Eq. (11). If the values of $T_c$ obtained with Eq. (1) should require a correction, a similar change in $X/H$ would be needed to maintain the fit. A change of up to 20% in this ratio would still be within the uncertainty of the optical data of SF, and would affect very little the results of Table 1a.

## V. The Lupus Hydrogen Concentration

A large, elongated hydrogen concentration can be seen in Fig. 3 extending at least from $l = 330°$–$350°$, but possibly as far as $l = 320°$, near $b = 10°$. Optically this cloud lies in the area of the Scorpius-Centaurus association, mostly in the Lupus section (Bertiau, 1958). Since its appearance is rather flat, we have applied tentatively to this case Camm's model as discussed in the previous section. We assume that the gas cloud is at the distance of the association, $D = 170$ pc (Blaauw, 1964), and has an effective radius $A = 40$ pc in the plane of the Belt (corresponding to a total subtended angle of 27°).

While $\sigma_v = 2.5$ km s$^{-1}$ was typical for the turbulent motion of the many clouds that make up Gould's Belt, a single cloud may have smaller internal motions. We adopt $\sigma_v = 1$ km s$^{-1}$, the value that Bertiau (1958) found for the OB stars in the region, although the hydrogen profile is somewhat wider, presumably due to self absorption and to blending with cloudlets at slightly different velocities. Thus, the upper limit of $T_s$ given by Eq. (5) is 120 K, while, as before, we adopt the lower limit of 60 K. Using Eq. (3) for $N_\mathrm{H}(0)$ we can calculate the mean hydrogen density at $z = 0$

$$n_\mathrm{H}(0) = N_\mathrm{H}(0)/(2A). \tag{14}$$

The equivalent of Eq. (11) is now

$$\tau_c(\beta) = \frac{\tau_c(0)}{\frac{2A}{H}\sin\beta}\left[\tanh\left(\frac{D+A}{H}\tan\beta\right) - \tanh\left(\frac{D-A}{H}\tan\beta\right)\right]. \tag{15}$$

Since $H$ is not known in this case, it remains a free parameter.

Figure 4b shows $T_c(b)$ averaged from data between $l = 340°$ and 343°, the densest part of the cloud. In addition to the main peak, several minor concentrations are visible. The low latitude one could be an effect of blending, while the higher latitude feature is caused by the hydrogen extension seen at $l \sim 337°$.

Adjusting Eq. (12) with $\tau_c(\beta)$ given by Eq. (15) to the data of Fig. 4b, we obtain an acceptable fit to the central peak for $H = 13$ pc if $T_s = 120$ K; the mean hydrogen density $n_\mathrm{H}(0)$, obtained from Eq. (14), is 1.2 atoms cm$^{-3}$. If $T_s = 60$ K, then $\tau_c(0) = 1.9$ which causes considerable self absorption; $n_\mathrm{H}(0) = 2.1$ atoms cm$^{-3}$, and $H = 10$ pc for a reasonable fit.

The total hydrogen mass is

$$M_\mathrm{H} = 2\pi A^2 H m_\mathrm{H} n_\mathrm{H}(0). \tag{16}$$

The density $\rho_T(0)$ can be obtained from Eq. (7), and the total mass is given by

$$M_T = 2\pi A^2 H \rho_T(0). \tag{17}$$

Numerical results are summarized in Table 1b, where the last column shows that with either one of the extreme values of $T_s$ the gas to total mass ratio is $M_\mathrm{H}/M_T \cong 14\%$, about twice the average value obtained in the previous section. This may indicate that star formation is less advanced in this section of the Belt, and may still be continuing.

## VI. Dynamics of the Layer

Lindblad (1974) suggested that Gould's Belt originated, about 5 $10^7$ yr ago, from a gas cloud that collapsed as it crossed the shock associated with the Carina spiral arm. Strauss and Poeppel (1976) pointed out that this one-dimensional compression led to a flat disk, which explains the present shape. We may add that the sudden increase in gas pressure led to expansion in the plane of the disk, the gas being confined by self-gravity in the other direction. The expansion velocity has a theoretical upper limit (Landau and Lifshitz, 1959) of three times the sound speed, thus giving a few km s$^{-1}$ in agreement with the observations.

Strauss and Poeppel (1976) have also stated that the cloud may have been in a state of rotation prior to its collapse, which eventually brought the resulting disk from its initial position, perpendicular to the galactic plane, to its present position, that has an inclination of $\sim 18°$. Since this is not an equilibrium position the disk must still be rotating. In fact, Lesh (1968, p. 381) remarks that northern hemisphere OB stars below the galactic plane move *away* from the plane; from her data we infer a systematic proper motion $\mu \sim 0\rlap{.}''02\ \mathrm{yr}^{-1}$. Interpreted as a rotation, this corresponds to slightly over $\frac{3}{4}$ of a turn in $5\ 10^7$ yr, in agreement with the initial and present positions, and in the sense that the inclination is currently *increasing*.

However, Frogel and Stothers (1977) did not confirm the large velocities perpendicular to the galactic plane reported by Lesh (1968). They suggest that the stars are oscillating about the galactic plane; the period for such a motion is $P \sim 8\ 10^7$ yr. Their data indicate that the stars are currently near the apices of their vertical motion, and they infer that they were formed in the galactic plane $P/4 \sim 2\ 10^7$ yr or $3P/4 \sim 6\ 10^7$ yr ago. Instead, the stars may have been formed in a sheet that was originally inclined with respect to the galactic plane. This sheet would then oscillate rigidly with period $P$, reaching again its maximum inclination every $P/2 \sim 4\ 10^7$ yr. Such inclined structures are predicted in the linear hydrodynamical theory of Nelson (1976a,b) which needs to be extended to include the shocks that would be responsible for the collapse of the initial gas complex leading to star formation.

It remains to be explained why the Belt gas is still moving together with the stars, after crossing the galactic plane at least once. Evidence for a similar tilt of the gaseous and stellar layers comes not only from the present work but was established by the early 21 cm works of Lilley (1955) and Davies (1960). We point out that there is evidence (reviewed by Grape, 1975, p. 81) for a hole in the local distribution of stars, dust and gas and that the Belt stars may have a slightly *larger* tilt than the gas (cf. Sect. II), which is in the right sense if the gas is lagging behind the stars.

A further support for the rotation hypothesis is the possible existence of a helical component of the interstellar magnetic field, which according to Lindblad (1974) and others may be related with Gould's Belt.

## VII. Discussion and Conclusions

Considering the information now available, we are led to the following picture of Gould's Belt. Approximately $5\ 10^7$ yr ago, a large clump of gas ($\lesssim 10^7\ M_\odot$) in the Carina spiral arm collapsed into a self-gravitating disk triggered by the passage of the spiral shock wave.

The compression into a disk led to expansion in the plane of the disk with a velocity of a few km $\mathrm{s}^{-1}$. The disk is currently either rotating or oscillating around an axis parallel to that of the spiral arm. The gas condensed further into smaller clumps, and stars were formed with high efficiency ($\sim 90\%$) and are still being formed. At present the disk is still expanding, with a current diameter of 750–1000 pc.

Previous ideas on the origin of Gould's Belt were influenced by the large energy requirement of the expansion. Hughes and Routledge (1972) postulated a super-supernova explosion, following a similar hypothesis made by Rickard (1968) to understand peculiar gas velocities in the Perseus arm which were later explained by Roberts (1972) as due to the spiral shock waves. Another proposal is Weaver's (1974) collision of two gas streams. The present interpretation is based on the density wave theory, and the expansion energy is supplied by the galactic shock that compressed the gas.

The parameters of the model are summarized in Table 1a; the input parameters are the dimensions ($H$, $X$, $R$) obtained from optical data, and the hydrogen line data ($T_s$, $\sigma_v$, $T_c(0)$). Considering that only $T_s$ is not fully constrained by the observations and that the results are not strongly dependent on its value, the fit to the data (Fig. 4a) is quite good and the numerical results should be reliable unless Camm's model is not a good representation of the physical situation.

The effect of the rest of the Galaxy on Gould's Belt seems to be very small, since there is no evidence of distortion (cf. Fig. 2 of SF). This favors our view that self-gravity is the dominating force.

Future research is necessary in order to distinguish between the rotation and oscillation hypotheses; and the present analysis should be extended to the northern hemisphere 21 cm data.

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