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Parque Pereyra Iraola

1968

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1968

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(1966/1969)

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PROLOGO

En el presente Boletín se han incluído los trabajos (o sus resúmenes) presentados en la 12a. reunión de la Asociación Argentina de Astronomía. La misma se llevó a cabo los días 24 y 25 de marzo de 1966 en el Instituto Argentino de Radioastronomía en ocasión de la inauguración del radiotelescopio que este Instituto opera conjuntamente con la Carnegie Institution of Washington.

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Carlos M. VARSAVSKY
Editor

THE GALACTIC CENTRE

F.J.Kerr

(CSIRO Radiophysics Laboratory, Australia)

I would like to start by bringing the good wishes of Australian radio astronomers to this new group which is joining us in the radio study of the southern sky.

The nuclear regions of galaxies are generally considered as regions of high density, with population II stars in a "nuclear bulge". In some galaxies, the presence of gas in the nucleus is shown by the appearance of the OII 3727 doublet, sometimes with a high velocity dispersion. Some nearby galaxies (e.g. M 31, M 33, M 51) show a small very bright spot, right at the nucleus, of the order of 10 pc in diameter. Non-circular velocities have been found near the centre in some galaxies.

Optical observations of our own galactic nucleus are very difficult, as there is at least 9^m of absorption between us and the centre. Baade has studied a star cluster near the centre (in the bulge), and Courtes has observed ionized hydrogen patches with high velocities, which are presumably in the nucleus. But there are very few optical observations, and the main study must be done by radio. We in the south are very well placed for work on the central region.

There are several radio approaches, involving the continuum and various radio lines. The region is found to be very complex, and many problems remain.

THE CONTINUUM

The most interesting (that is the most informative) region of the continuum is 1-100 cm in wavelength. Over all of this range, the main radiation is from the Milky Way belt, with a concentration in the region of the centre.

The first striking conclusion about the central part is the small angular width of the emitting layer, which must be quite thin, with no relation to the stellar bulge.

Two types of continuum emission processes take place in the Galaxy: (i) thermal emission from HII regions, through free-free transitions, and (ii) non-thermal emission from the synchrotron process, from electrons spiralling in a magnetic field. The two types can be best distinguished by their spectra. The thermal component becomes relatively more important as the wavelength is reduced.

The strong central source is known as Sagittarius A. The central complex was first resolved into separate components by Drake (1960). Subsequently the details of the regions have been studied in the following published surveys:

Authors	Wavelength cm	Beamwidth
Cooper and Price (1964)	11	6.7
Broten et al (1965)	6	4.0
Downes, Maxwell and Meeks (1965)	3.6	4.2
Hollinger (1965)	2.1	5.9
Downes, Maxwell and Meeks (1965)	1.9	2.2

These surveys all show a number of components, one to the south, and three to the north of the central peak. (The papers should be consulted for details). Spectral studies have been carried out by Cooper and Price (1964), Burke (1965), and Downes (1965). By separating the components as well as possible, and then comparing the data at different wavelengths all agree that the main Sgr-A component is non-thermal in origin, whereas the other components all appear to be thermal.

There is no direct evidence from the continuum observations themselves that all the components are actually located in the vicinity of the centre; however our hydrogen-line absorption observations indicate that the three strongest components, and probably the whole complex, are physically associated, and located at the centre.

The angular size of the strong central component is 4 min arc, equivalent to 12 pc at the distance of the galactic centre. The best position for Sgr A, from all the available observations, is:

$$\left.\begin{array}{l}\alpha = 17^{h}\ 42^{m}\ 28^{s}\\ \delta = -28^{\circ}\ 58'\ 5\end{array}\right\}(1950) \qquad \begin{array}{l}l^{II} = 359^{\circ}\ 58'\\ b^{II} = -0^{\circ}\ 03'\end{array}$$

We have surveyed a larger area of 60 square degrees around the galactic centre (Kerr and Sinclair, in preparation). The results for the whole region are not yet available, but the pattern of the "ridgelines" shows some interesting features (Figure 1). This pattern is extremely symmetrical about the position of Sgr A, and in fact shows a higher degree of symmetry than any other aspect of the galactic centre observations. It also includes features which are steeply inclined to the galactic equator and strongly suggest ejection of material. The main galactic ridge shows a pronounced tilt over several degrees of longitude, which is in the same sense as that found for high-velocity neutral hydrogen.

21-cm HYDROGEN LINE

Very strong absorption effects are found in the spectrum of Sagittarius A in the frequency range of the 21-cm hydrogen line (Figure 2). There are deep absorption components associated with hydrogen in the nearby spiral arms (near zero velocity) and in the "3-kpc" arm (near -50 km sec). Absorption is found over a wide range of negative and positive velocity.

In the vicinity of the centre, both absorption and emission show considerable fine structure (Rougoor 1964, Kerr 1964, Kerr and Vallak 1966). Large outward motions are indicated for much of the hydrogen. An example of the detail available is shown in Figure 3, which gives the hydrogen distribution along the equator in the longitude range 355°-5°.

One of the most interesting features in the central region is the way that the high velocity meterial is inclined to the galactic plane.

Figure 4 shows the latitude of the high velocity ($|v| > 100$ km/sec) peak as a function of longitude; the diagram is based on positive-velocity material for $\ell^{II} > 360^\circ$, and negative-velocity gas for $\ell^{II} < 360^\circ$. The pattern is roughly symmetrical, with a long extension out of the galactic plane on each side. The southern feature probably joins on to the 3-kpc arm, which is itself well north of the plane over a considerable range of longitude; however the northern section appears to fade out at the northernmost longitudes.

The major "expanding" arm, usually known as the 3-kpc arm, can be followed from $\ell^{II} = 4^\circ$ to 336°, but it is not clear whether it is a single continuous feature. There is a major complexity at 348°, and another at about 342º, and the overall arrangement is not clear. There are probably several branches, and also cross-links to other parts of the spiral pattern.

A possible structure for the whole central region is shown in Figure 5. In the centre is a rapidly-rotating feature, possibly a disk as proposed by the Dutch, with some expansion motion in its outer parts. From this disk there may be a rudimentary bar, inclined to the galactic plane, which contains much of the high-velocity material. Further out, and possibly connected to the bar, is the "3 kpc arm", with a less regular counterpart on the opposite side.

Minor features are certainly present, but cannot be located in space. There is a general appearance of quadrantal symmetry. The picture proposed here is consistent with the observations, but cannot be regarded as well established, as there is no way of establishing distances for most of the hydrogen in the central regions.

OH LINES

The OH group of lines near 18 cm has been observed in the galactic nucleus by the Australian group (Robinson et al 1964; Bolton et al 1964). The OH abundance in some parts of this region is 100 times that observed near the Sun. The relative strengths of the various lines are quite different from those expected theoretically and the ratios vary greatly from point to point. The OH observations in this region have all been in absorption so far, except for a small component of emission at one point.

The OH absorption spectrum for Sgr A is shown in Figure 6 for the 1667 Mc/s line. The two strongest components are at velocities around + 40 and -120 km/sec. The great strength of the former component indicated that a considerable proportion of the OH has a component of motion towards the Sgr-A source, i.e. presumably towards the "centre". Components at the OH velocities can be seen in the hydrogen absorption profile (Figure 2), but they are much less important in the hydrogen pattern.

In discussing the distribution and motions of the OH sources, Bolton et al (1964) stress some minor features which appear to have a constant velocity over a few degrees of longitude. However, the greatest kinetic energy appears to be associated with a slow rotational motion.

The present author considers that the OH is located in the outer part of the nuclear "disk", because it extends over several degrees in longitude, and also it exhibits a low rotational velocity. Rougoor (1964) has already suggested that the rotational velocity of the hydrogen falls off in this region.

HYDROGEN RECOMBINATION LINE

Mezger (1966) has recently detected a hydrogen line near 6 cm, which corresponds to the transition from $n = 109$ to 108, in two components of the galactic centre source. The line was not observable in the main Sgr-A component. As this line is only emitted in H II regions, this results supports the view that the central component is nonthermal in origin, while the other components are thermal.

X-RAYS

A number of X-ray sources have recently been found in observations from rockets. The only one identified so far is associated with the Crab nebula. There is a cluster of other sources in Sagittarius and Scorpius. None of these coincides with the radio source Sgr A, but the clustering in this direction suggests a relation with the nuclear disk (Johnson 1966). However it should be emphazized that no individual correlations have been found with nuclear objects and it should be noted that the X-ray sources show a greater apread in latitude than the radio-emitting region in the nucleus.

CONCLUSION

The central region has many complexities. We have some idea of its structure, but our interpretation must still be inconclusive. There is a forthcoming series of lunar occultations of the galactic centre, from 1967 to 1970, which should yield more information on the fine structure of the region. Unfortunately, parallax moves the apparent position of the Moon northwards for a southern observatory, and consequently Parkes and Pereyra will not see any occultations of Sgr A. In this case, we must leave the main work to northern observatories.

I conclude this review about one part of the galaxy by saying that there is still plenty to be discovered, as in fact there is in the whole Galaxy. I am sure that this new telescope, which is so well placed geographically for galactic studies, will play an important part in attacking the many problems that are to be found in the Galaxy.

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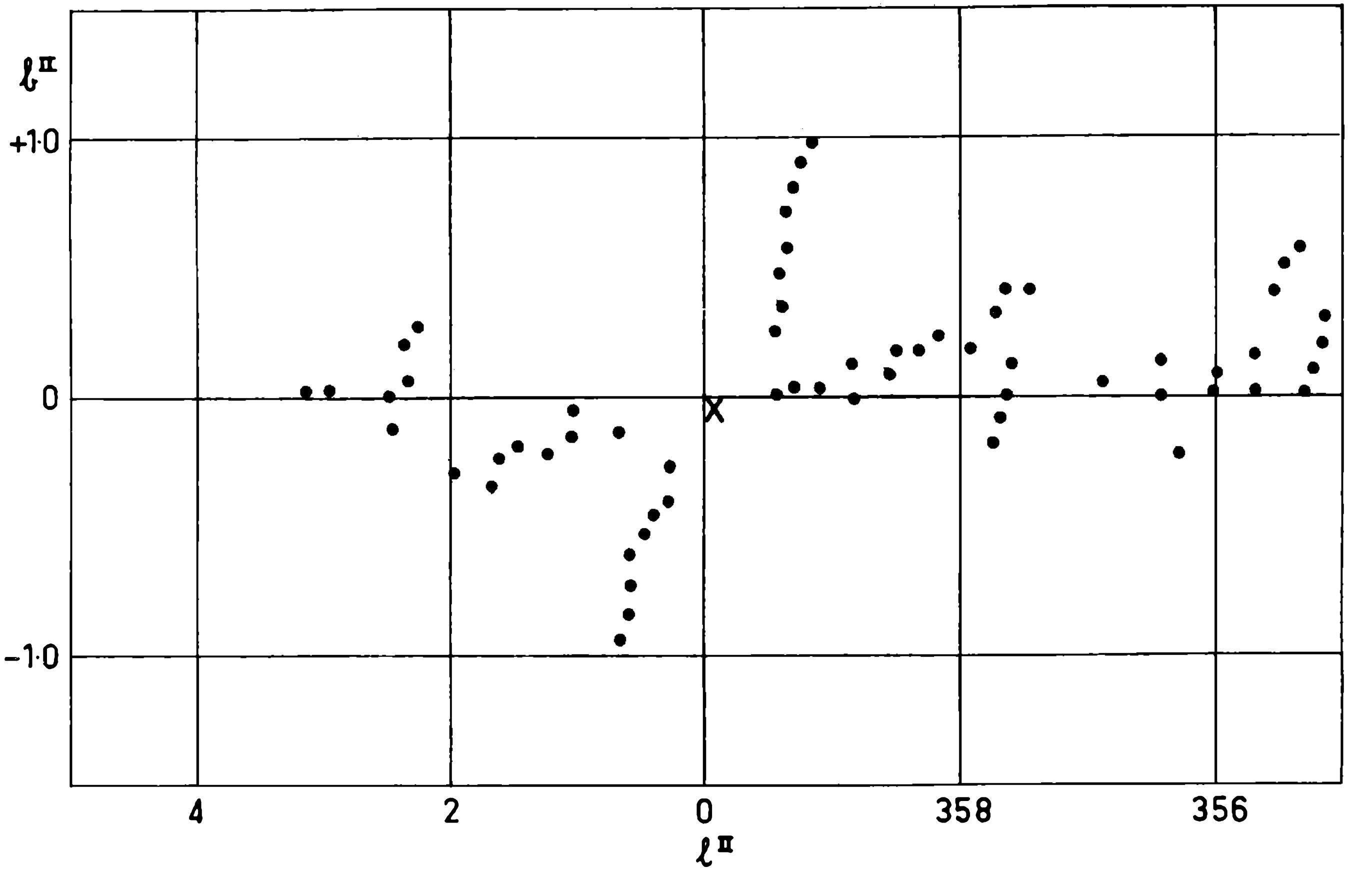
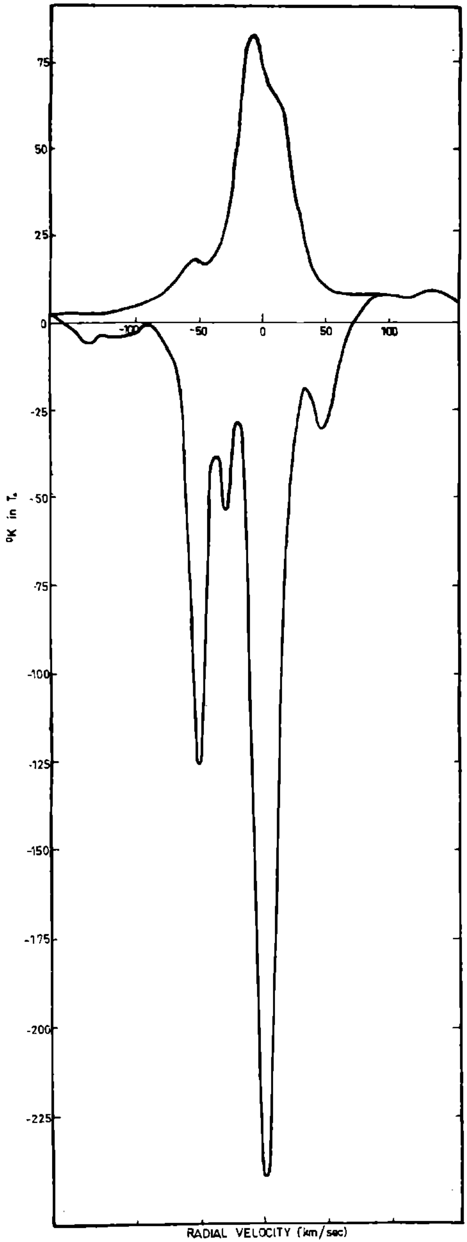
LEGENDS TO FIGURES

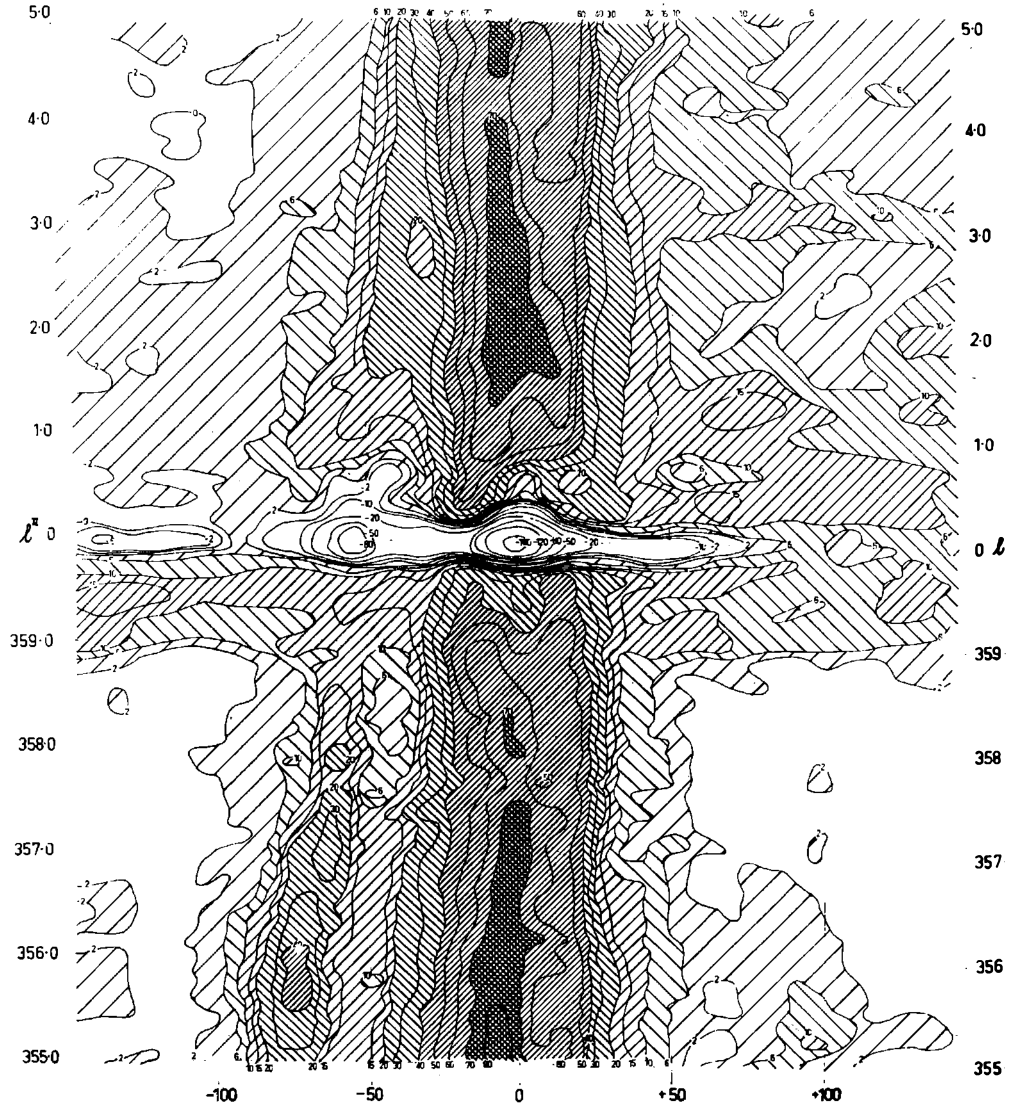
Fig. 1	Location of 20-cm continuum "ridge lines" in the galactic centre region.
Fig. 2	21-cm absorption profile for Sgr A, together with the estimated emission profile in the absence of absorption.
Fig. 3	Hydrogen contour diagram along galactic equator (scale unit = 1.4°K in T_A).
Fig. 4	Latitude of high-velocity hydrogen peak.
Fig. 5	A possible structure for the galactic centre region.
Fig. 6	OH absorption profile for Sgr A (1667 Mc/s). The 21-cm profile is drawn as a dashed line, on an arbitrary scale. (Robinson *et al*. 1964).



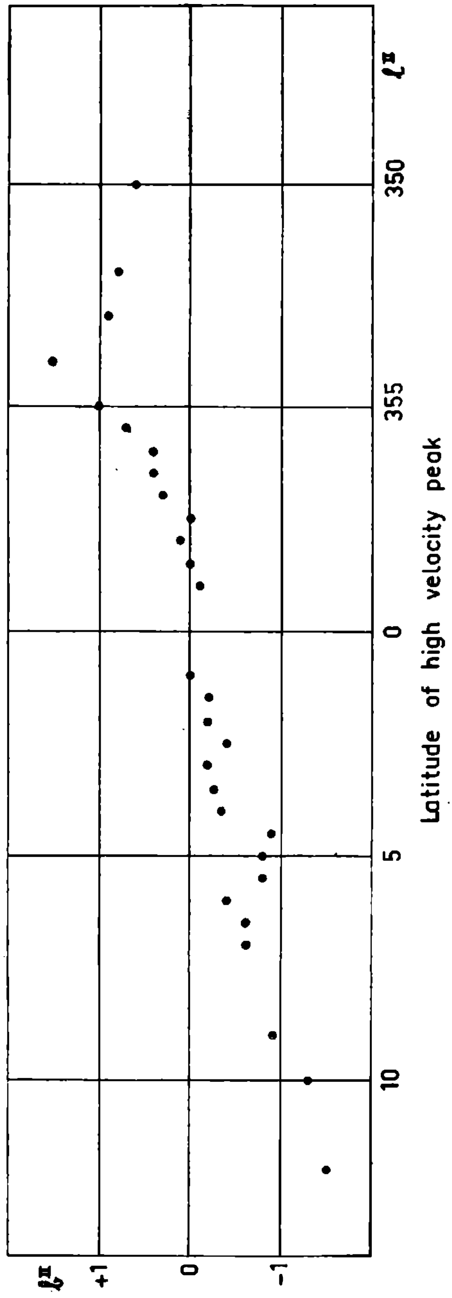
20cm continuum ridge lines

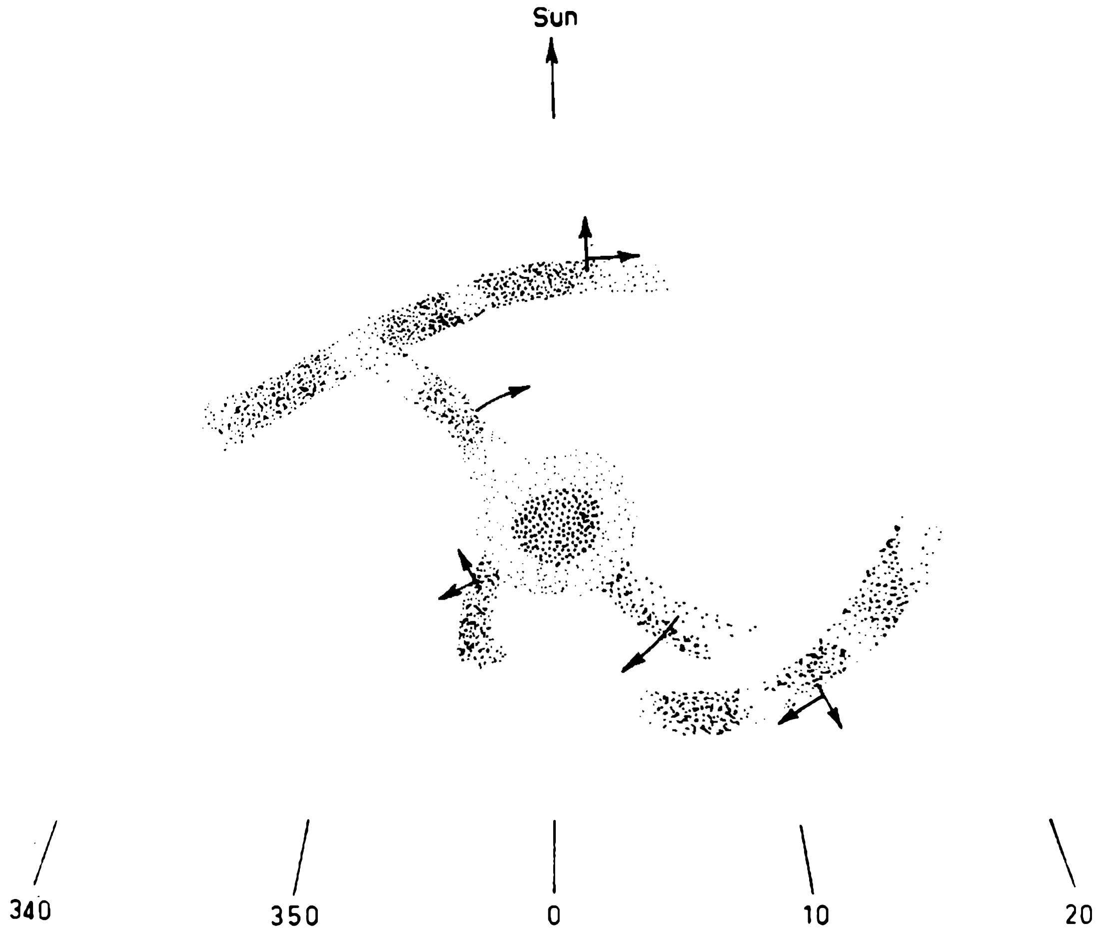


GALACTIC CENTRE - Assumed emission & observed absorption profiles.

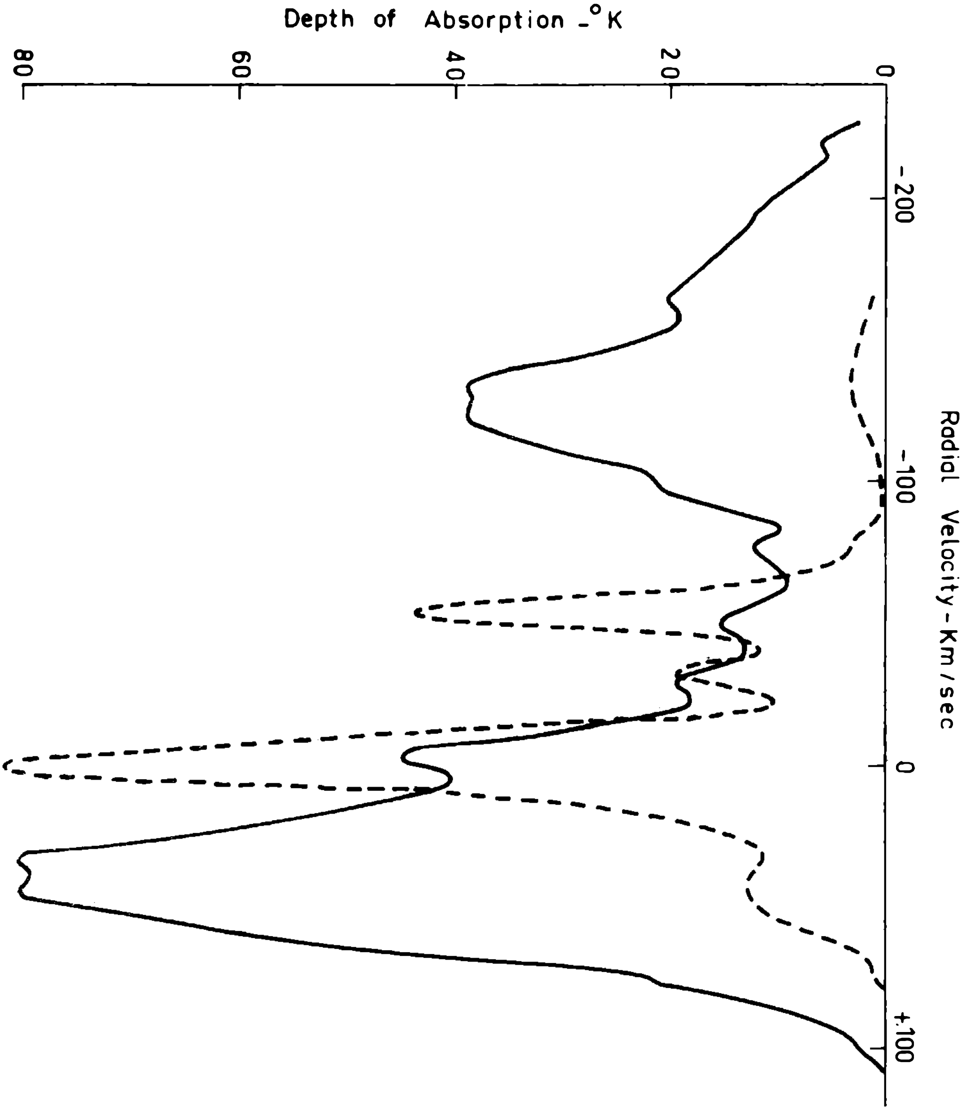


CONTOUR DIAGRAM ALONG GALACTIC EQUATOR (Scale unit=1·2 °K in T_A)


Latitude of high velocity peak
l^{II}
350
355
0
5
10
b^{II}
+1
0
-1



A possible structure for the galactic centre region


Depth of Absorption -°K
0
20
40
60
80
Radial Velocity - Km/sec
-200
-100
0
+100

THE RADIO SPECTRUM OF THE GALAXY

Bernard F. Burke, MIT/RLE

The progress of human knowledge often seems to come in sudden bursts of activity, with resting periods in between, when the new concepts are exploited, fitted into existing pictures of the physical world, or the pictures of the world modified to fit the new insights. In astrophysics, radio spectroscopy may well be in the midst of such an active phase. Two decades have passed since van de Hulst suggested, in 1944, that the ground state hyperfine transition in Hydrogen, the celebrated 21-cm line, should be an exceptionally useful tool in studying the galaxy. Several years of laboratory struggle culminated in the almost simultaneous discovery, first at Harvard by Ewen and Purcell, and then by the Leiden and Sydney groups, of the emission line. In a remarkably short time, the broad picture of hydrogen emission was sketched out, the spiral structure of the galaxy demonstrated, and then commenced the assimilation period - not a dull time at all, but a time of hard work, as new and puzzling features of the hydrogen emission and absorption were brought to light. Some of us have brooded over the existing hydrogen models of the galaxy, in many ways so pleasing but still disquieting. A simple glance at the Leiden-Sydney map shows that the galaxy looks very different from the northern and southern hemispheres. Even more striking, however, have been the observations that clearly do not fit, even qualitatively, our pre-existing notions of galactic center, from which hydrogen gas seems to be streaming at velocities ranging to 200 km/sec. and more, in amounts that may be as great as one solar mass per year - a rate high enough to deplete all the mass in the center within the present lifetime of the galaxy.

It is most appropriate, for a location such as the Pereyra Station, that the galactic center passes almost directly overhead, making it a prime target for study.

Another great puzzle is the observation of very high velocity clouds at distances far from the plane of the Milky Way, observed by the Leiden group. So far, all the hydrogen seems to be coming at us, and none streaming away. The sky has been covered most fully in the Northern hemisphere, however, and it will be exciting to see if, in that part of the galaxy that lies invisible to northern observers, the same pattern will hold.

These are subjects of dynamics, however, and not appropriate to my subjects, and I give them as examples only, to illustrate the extent of our ignorance of the interstellar medium. Clearly, the more independent parameters that can be measured, the more complete will be our knowledge; and so the question of studying the interstellar medium by means of other spectral lines becomes important.

Two years ago, Barrett, Meeks, Rogers and Weinreb added the first new lines to the list when they discovered the hydroxyl radical, OH, in absorption in the spectrum of Cassiopeia A. All four lines in the ground-state lambda doublet have now been seen at 1612, 1665, 1667 and 1720 Mc/s - or approximately 18 cm wavelength. Absorption measurements of OH have been particularly exciting in the direction of the galactic center where, as already mentioned, we know that peculiar motions exist. The intensity of the OH absorption lines was far greater than anticipated, by a factor of at least a hundred, and it is ironic to contemplate that these lines are so intense that any of the workers in the field during the past 15 years could have easily detected them. They did not try, however, for two reasons: the existing models predicted only very weak absorption, and the frequencies of the lines were not well known. Here, a partnership between the laboratory worker and the astronomer is essential, and in several laboratories there are now proceeding measurements of the spectra of the radicals CH and SiH. These, too, are made from abundant species of element, and would represent a powerful extension of our knowledge of the state of the interstellar medium.

So far I have only discussed absorption-line spectroscopy, but perhaps the most exciting observations during the past year have been of the OH line in emission by the groups at M.I.T., Harvard and Berkeley. The pattern of OH emission in the sky seems to be entirely different from that of Hydrogen, which can be seen in emission over almost the entire sky. Instead, the OH emission can only be detected near ionized hydrogen, or HII, regions. The observations are less than a year old, but some characteristics are clear.

The OH emissions is strongly polarized, with circular polarization predominating, although there is some linear polarization, as well. The pattern is complex, for at each line frequency in the multiplet one sees several components, corresponding, presumably, to different discrete clouds, each with its appropriate doppler shift. Since each discrete cloud should exhibit all four multiplet components, the patterns observed at the four line frequencies should all be similar, each doppler component appearing at the correct doppler shift. This regularity is not observed, and the observed patterns at 1612, 1665, 1667, and 1720 Mc/s bear little or no resemblance to one another. Since each doppler component is strongly polarized, the Zeeman effect is suspected, with magnetic fields of the order of a milligauss required to destroy the similarity in patterns. The individual Zeeman components should still be identifiable, however, and the patterns related to one another. Unfortunately, this has not been possible so far, although one can make a pseudo-fit for any given member of the multiplet. Different doppler components, and different magnetic fields are required to fit all the observations, however, and while many are conviced that the Zeeman effect is somehow responsible, the solution has not yet been given. (A recent attempt by the Manchester group seems to be such a pseudo-fit - they were unable to observe the weaker members of the multiplet.)

The relative intensities of the OH lines are especially striking when one compares observation with theory. The relative intensities can be worked out by standard quantum mechanical calculations, which predict that the lines at 1612, 1665, 1667 and 1720 Mc/s should be in the ratios 1 : 5 : 9 : 1. In many of the observations to date, however, the 1665 Mc line is by far the most intense, reaching an intensity 50 or 100 times that of the 1667 Mc line - an intensity anomaly of at least 100. The emission lines are often extraordinarily sharp, and Barrett and his coworkers have an example in which the line breadth corresponds to a kinetic temperature of only 5°K, although the intensity of the line suggests a radiation temperature of at least 15°. Some doppler components are even more intense, and in the direction of the galactic center, one emission component must have a brightness temperature of at least 1500°K.

These anomalous intensities, and in particular the anomalous ratios, suggest highly non-thermal state distributions, and it appears likely that we are viewing some sort of cosmic maser, excited by the radiation from the neighboring HII, amplifying the galactic background radiation.

Another category of spectral line has recently been brought to light. The Russian astrophysicist Kardashev several years ago predicted that in an ionized hydrogen region, the hydrogen atoms as they recombine could emit discrete lines in the radio region. These are simply the lines arising from transitions between very highly excited states in the energy level diagram, with enormous Bohr orbits corresponding to n = 100-200 -- enormous floppy atoms a micron or so in size. A year ago two Russian groups reported discovery of one of these lines, and confirmation at the NRAO by Hoglund and Metzger followed shortly. Such transitions as n=109-108 (near 6000 Mc/s) and n = 167-166 (close to the hydrogen line) have already been observed, and these lines promise to be a powerful tool in probing the physical condition of HII regions. At very low frequencies, the line intensities and widths should be determined by the Stark effect and thus give a direct measurement of the local electron densities. At higher frequencies, the line widths are determined mostly by internal velocities, and their use will be more closely related to conventional hydrogen line analyses.

Before closing, I wish to make some remarks on a radio line that may never be observed at all. The cyanogen molecule CN is known to exist in interstellar space because optical absorption lines can be observed from electronic transitions within the molecule. The ground state of the molecule consists of a series of rotational levels, only the lowest of which should be populated. In some cases, however, two optical absorption lines are seen, corresponding to the transitions from both the lowest and first excited rotational states. Field has suggested, on the basis of a footnote in Herzberg's classical work on diatomic molecules, that the second line should be expected, since Penzias and Wilson's measurement recently of a finite background temperature at 4000 Mc/s. Their measurement has been interpreted as direct evidence of the initial explosive formation of the cosmos -- an inference of such importance that alternate tests must be sought. Field remarked that the second CN line would be expected from radiation equilibrium with a 3°K blackbody temperature, and thus would regard the CN absorption lines as direct confirmation of a 3°K background temperature at 3 mm wavelength. If the first two levels are in radiative equilibrium, the microwave rotational line could never be seen, and thus one can state that failure to observe the CN microwave line at 3 mm (116,000 Mc/s) would be a confirmation of the 3°

blackbody temperature of space. It would be misleading, however, to imply that this is the only explanation at this time, since Sciama has calculated that electronic collisions are equally effective and that the second optical absorption line is thus an indication, not of the blackbody temperature of space, but of the ionization condition to be found in those regions where CN exists. We can perhaps be encouraged that, far from the cosmos being explained, we are simply confronted with another puzzle that only further observations can shed light on.

REMARKS ON SOME CLASSICAL PROBLEMS OF CELESTIAL MECHANICS (ABSTRACT)

C.A.Altavista

Several problems not yet solved arise when expansions of the disturbing function are considered. Main troubles are due to the large number of terms of the periodic developments. Such difficulties lead to search the representation of a very great amount of terms with small amplitudes, by means of closed expressions. Balance should be performed between the amount of the arithmetic errors introduced by the consideration of the full original developments and the errors due to the chosen approximate representations. It is also interesting to point out that developments are strongly shortened when true (or eccentric) anomaly is used as independent variable. This statement implies a change in the setting of the solution of the classical three-body problem. Moreover, it is observed, that usual formulae which give the errors of the elementary arithmetic operations may not be valid in view of the presence of a "range of ambiguity", owing to the particular structure of the developments which represent the solutions of the disturbed problem, in the sense that many coefficients of the periodic terms are compatible with observable quantities, i.e. the accuracy of the orbital elements, despite that their "components" may not satisfy this condition. Special theories must be then developed to cover the several fields of the problem, some of which are in progress at present.

SOBRE LA EVOLUCION DE LAS ESTRELLAS PECULIARES

C. Jaschek y M. Jaschek

(Observatorio Astronómico La Plata)

Las estrellas peculiares se caracterizan en lo que a su composición química respecta por una abundancia excesiva de elementos con $Z>26$, que puede llegar a dos órdenes de magnitud con respecto a la abundancia solar.

Los intentos de explicación de estas anomalías de abundancia han relacionado casi siempre éstas con los campos magnéticos muy fuertes de estas estrellas. Valores típicos de la componente horizontal del campo medio de la estrella son del órden de un millar de gauss.

Burbidge, Burbidge, Fowler y Hoyle en 1957 propusieron un esquema que se base esencialmente en la existencia de partículas aceleradas en los campos magnéticos variables, que inician reacciones del tipo (p,n). Si los neutrones se termalizan luego, pueden iniciar una serie de síntesis, que permiten fabricar elementos pesados a partir de otros más livianos, como por ejemplo de los del pico de hierro.

La teoría en este caso [illegible] que deben tener picos de abundancia los elementos que tienen isótopos con un número mágico de neutrones (2-8-14-20-28-50-82-126). Dos dificultades serias de la teoría son que: a) la predicción no siempre se cumple y que b) hay elementos superabundantes que no tienen isótopos con capas cerradas de neutrones.

Recientemente Fowler, Burbidge, Burbidge y Hoyle (1965) propusieron que además de las reacciones arriba detalladas puede haber otras (las pertenecientes a los así llamados "procesos r") en los que se desencadena una producción excesiva de neutrones durante un lapso pequeño ($t<100^s$) que permite sintetizar algunos elementos que no pueden ser producidos por el proceso anterior. Para que se produzcan las reacciones que liberan los neutrones se necesita sin embargo condiciones tan extremas que hay que recurrir al "flash de helio" cuya existencia a su vez está ligada al estado gigante de la evolución de las estrellas. En resumidas cuentas, para poder postular el proceso r hay que postular que las estrellas peculiares son ex-gigantes.

El objeto de la presente comunicación es discutir la evidencia observacional relacionada con esta teoría y para ello se apelará a las evidencias cinemáticas. Se sabe en efecto, tanto por la teoría como por la observación, que la dispersión de velocidades de un grupo de estrellas tiende a incrementar en función de la edad del grupo. De ahí que el valor de este parámetro puede decidir en forma simple si las estrellas peculiares son o no ex-gigantes.

Para esto computamos la dispersión de las velocidades radiales substrayéndole previamente la componente solar. Los datos se tomaron del "Catálogo de Estrellas Brillantes" de Miss Hoffleit. En la tabla 1 están reunidos los valores obtenidos

Tabla 1

Dispersión de velocidades en función del tipo espectral

Enanas			Gigantes		
T.Esp.	N	σ	T.Esp.	N	σ
B6-B8	102	12	A0-A9	74	15
B9-A1	94	13	F0-F9	87	18
A5-F0	61	14	G0-G9		25
A pec.	130	11			

Notas: N=número de objetos. σ = dispersión de velocidades, en km/sec.

Del último renglón se desprende que es insostenible suponer que las estrellas peculiares sean ex-gigantes, ya que su dispersión es similar a la de las estrellas de la secuencia principal.

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LOS COLORES Y LAS ANOMALIAS DE ABUNDANCIA EN ESTRELLAS PECULIARES

M. Jaschek y C. Jaschek

(Observatorio Astronómico, La Plata)

En base a un análisis espectroscópico de placas de alta dispersión de estrellas peculiares de los grupos de manganeso y de silicio, se analizó la relación entre las anomalías de abundancia y los colores UBV. Se concluye que la relación no es de naturaleza unívoca.

El trabajo "in extenso" será publicado en otro lugar.

OBSERVING THE INTERSTELLAR MAGNETIC FIELD

H.C. van de Hulst

(Sterrewacht, Leiden, Netherlands)

1. A LOOK AT HISTORY

Discoveries in present-day astronomy and radio astronomy come with such a rapid succession that results found five years ago are "old" and those of ten years ago "classical". Yet, sometimes, it is good to look back in order to see the present efforts in a proper perspective.

Exactly 15 years before today's dedication, on 25 March 1951, Ewen made the first positive observation of the 21-cm line in the attick of the Harvard physics laboratory. Two years later, when the first excitement of the discovery was over and the first spiral arms had been mapped, Lovell commented that relatively too much attention had been paid to this "predictable" branch of radio astronomy. The radio continuum might prove far more exciting, just because it was basically not understood. His remark was well taken, for the study of this continuous spectrum has now led us to such exciting studies as the quasars, new problems in cosmology and -closer to home-means to map the galactic magnetic fields. I shall deal in this paper only with the last subject.

Astronomers did not wake up promptly to this opportunity. The theory of radiation of an electron moving in a magnetic field at relativistic speeds had been known for half a century. Suggestions that this "synchrotron mechanism" could be a source of continuum radio waves were in the literature since 1950, but were not pursued. The breakthrough came with Shklovsky's bold suggestion that the white optical spectrum of the Crab nebula, a notorious puzzling object, could arise from this mechanism. Soon this suggestion found a spectacular confirmation by several measurements culminating in Woltjer's map of the optical polarization on plates of the nebula taken by Baade (Woltjer, 1957).

From that moment on, the determination of the polarization of the general galactic radio continuum with the aim of (a) establishing its character as synchrotron emission and (b) mapping the magnetic fields, has been high on the list of desiderata for radio astronomy. The first exploratory survey in the Netherlands was made in 1960. Since that time many improvements have been introduced. Surveys at four wavelengths have been completed and Mr.Brouw at Leiden is preparing a thesis on these topics. Less extensive measurements of the same kind have been performed at Cambridge (England) by Bingham. In Australia Matthewson has completed with a narrower beam a polarization survey of the southern sky at 408 Mc/s and has explored interesting areas at three different frequencies.

2. SEVERAL WAYS TO OBSERVE THE MAGNETIC FIELD

Before coming to a more detailed discussion, let us see what ways exist to establish the presence of a magnetic field in the galaxy at all. (Table 1). We shall briefly review these methods one by one.

TABLE 1

Ways to observe the galactic magnetic field

		Kind of observation		
		optical	radio	other
action of magnetic field =	at source =	(synchrotron emission, only in special objects)	Zeeman effect H Zeeman effect OH Synchrotron emission	
	en route =	interstellar polarization	Faraday effect	
	dynamical =	strange shapes		cosmic ray confinement

a. ZEEMAN EFFECT

This effect would provide the most direct way of measuring the field. The only eligible line is the 1420 Mc/s line of hydrogen. A magnetic field in the line of sight can be observed as a frequency separation of 28 c/s per 10^{-5} gauss between the left-hand and right-hand circular polarization. Measuring this separation obviously requires line components with steep sides. These are present in the absorption profiles seen with the brighter discrete sources as background.

More complete measurements have changed the initially positive results into (-2±5) x 10^{-6} and (-3±3) x 10^{-6} gauss for the best observed clouds (Verschuur and Davies, 1966). Hence so far the data are meagre: only a few HI clouds, for those only the line-of-sight component, and for that only an upper limit. Sharp emission components might be studied in the same way but again are found only in a few places.

An attempt to explain the line-profile and polarization of one OH line by means of Zeeman effect required several clouds with fields of the order of 10^{-3} gauss (Davies et al., 1966). It does not seem that this explanation can be maintained if the other OH lines are also taken into account.

b. INTERSTELLAR POLARIZATION

This effect can be used as a tracer of the magnetic field, but not for a firm measurement of its magnitude. It provides a wealth of data, which have, since the discovery in 1949 formed the most important observational basis for all speculations regarding the topology of the magnetic field near us. The suggestion by Chandrasekhar and Fermi (1953), that spiral arms might be tubes of force, was inspired by these data.

The traditional name does not say much, because any galactic field is interstellar and any method to observe it involves polarization. A more correct name would be: optical dichroism of the interstellar medium. In a medium two "modes" of electromagnetic wave propagation, each with a characteristic polarization, may propagate with a different velocity (birefringence) and/or unequal losses (dichroism). In interstellar space the optical modes are linear, or very nearly so; Gehrels (1966) has observed a slight rotation of the plane of polarization, which would mean that the modes have an elliptical component. The losses (interstellar extinction) are generally ascribed to dust grains and the fact that the absorption may be some 5-10 percent higher in one mode than in the other must be due to non-random orientation of these grains in a magnetic field.

A great effort has been expanded by observers and theorists over the past 35 years in order to find the nature of these grains. Yet their physics and chemistry is by no means settled yet. Two recent symposia (Edinborough, 1948; Troy, 1965) may serve for sufficient reference.

Skipping these uncertainties and, consequently also the theories of the orientation mechanism, we can still say that it is almost certain that the linear polarizations thus observed display the average transverse comments of the magnetic fields between the stars observed and us. The distances involved range from 100 pc to 2000 pc. Larger distances require measurements of fainter stars; shorter distances require measurement of weaker polarization. In both directions further progress is being made.

c. FARADAY EFFECT

Faraday effect, or circular birefringence is another propagation effect. A linearly polarized wave passing through the medium suffers a rotation of the plane of polarization due to the presence of free electrons and a longitudinal component of the magnetic field. The rotation is by

$$R\lambda^2 \text{ radians}$$

where λ is the wavelength in meters and R is the, already traditional, rotation measure in radians/m^2:

$$R = 0.81\int N_e \,(B \cos\theta)\; d\ell$$

where N_e = number of free electrons per cm^3

$B \cos\theta$ = longitudinal component of magnetic field in microgauss

$d\ell$ = element of pathlength in parsec

Either the general synchrotron continuum, or a discrete (usually extragalactic) source may provide the original, linearly polarized wave.

The interpretation of these data is more secure than that of the optical polarization, because an accurate numerical value of the rotation measure is found. Uncertainties arise, first of all in estimating how much of the rotation occurs in the (extragalactic) source itself. The rotation in the terrestrial ionosphere can be eliminated quite nicely by comparing measurements made in the course of a night. An additional complication is that different values of the rotation measure are lumped in the finite beam and finite bandwidth. The effect is to reduce the amount of polarization and to cause deviation from the λ^2 law. The initial fear was that these effects might delete all observable polarization. This may still be true in many directions and for most of the distant source regions. Hence, one interpretation of regions of strong observed polarization, is that they simply are local "clearings" in the Faraday cover. One of the most pressing problems now is to find objective criteria for weighing this type of explanation against other explanations in which such reasons are structural features of a galactic arm.

d. DYNAMIC EFFECTS

The possible role of the magnetic field in the dynamics of the interstellar gas had been recognized by Spitzer, Alfvén, Biermann and others, well before direct evidence of the field was ever observed. We do not wish to review the theoretical arguments, which are many (see for instance, Woltjer 1961). Direct observational evidence for a magnetic field could show up by a striking pattern, as it does, e.g. in the "polar plumes" of the sun's corona. The dark and bright nebulae in our galaxy displayed so beautifully in the Palomar sky atlas have indeed many striking features. But I should hesitate to quote any of these as evidence for magnetic fields.

A second undeniable observation is the presence of cosmic rays in our galactic system. This has often been quoted as "proving" the existence of a confining magnetic field. Unfortunately, this argument breaks down at the very highest energies, for the gyration radius of a 10^{20} eV proton in a 3×10^{-6} gauss field is 30000 parsec. The criterion at what energy it would start to be applicable would have to come from the position of a knee in the energy spectrum, which at the high-energy end is still somewhat vague (Malhotra et al, 1966).

3. WHAT CAN WE INFER FROM THE OBSERVED POLARIZATION?

We now return to the synchrotron emission. The observational effort of measuring galactic polarization is wedged between two severe dificulties. At the low-frequency end there is too strong Faraday rotation; at the high frequencies the entire brightness, and hence also its polarized part, becomes extremely faint. Unfortunately, it is also a race against time, because radio astronomy has not even been able to reserve through the International Telecommunications Union its claim for a free band every octave (which is already too widely spaced for Faraday measurements) and television stations are rapidly filling up their assigned frequency bands. Systematic errors, arising largely from ground radiation have been overcome and it not necessary anymore to conclude that "magnetic fields in the galaxy are parallel to the pinetrees in Dwingeloo".

In trying to review the interpretation of these valuable data and to assess the already heated arguments in the literature let us first look at the degree of polarization.

The synchrotron emission process by itself gives 50 to 100 per cent polarization. More precisely, if the electron velocities are isotropic and have an energy spectrum proportional to $E^{-\gamma}\,dE$, the brightness is proportional to $\nu^{-\alpha}$ where $\alpha = \frac{1}{2}(\gamma - 1)$ and the degree of polarization is $p = (\gamma+1)/(\gamma+7/3)$ (see, for instance Ginzburg and Syrovatski, 1965). Inserting, the values $\gamma = 2.3$, $\alpha = 0.65$ we get $p = 71$ per cent.

Typical observed figures at 408 Mc/s are 2 °K polarization temperature on 30 °K total brightness temperature (Seeger et al, 1965), which makes 6 per cent polarization. Why is this so much lower than the theoretical value? There is no physical depolarization effect. Only incoherent superposition of radiation with different directions of polarization can produce this effect. We may think of superposition of:

a. unpolarized radiation from a different mechanism (e.g. thermal);
b. different intrinsic polarization along the line of sight;
c. different Faraday rotation because sources are spread slong the line of sight
d. different Faraday rotation or intrinsic polarization side by side in the beam;
e. different Faraday rotation side by side in the bandwidth.

We can exclude a because thermal radiation is weak and no other mechanism is known. Likewise, d cannot be the major cause because of the fairly regular pattern shown by the maps and e because it would be felt only at rotation measures larger than 100. Hence b and c, both of which are line-of-sight effects, remain. In integrating over the line of sight no bias in favour of the nearer of farther portions exists, which would again make the regularity of the maps hard to understand. However, effect d clearly is stronger at larger distance because the beam covers a larger domain of space. So the conclusion seems warranted that we see mainly the polarization produced in the regions of space near us and that ninety percent of the observed intensity arises at larger distances where a combination of effects b, c, and d causes virtually complete depolarization.

This conclusion is consistent with the values of the rotation measure. Only 11 out of 49 discrete (extragalactic) sources listed by Gardner and Davies (1966) have $R < 5$ and many come as high as

40 or 50. Yet the majority of the galactic fields with measurable polarization at two frequencies have $R < 2$ (Mathewson et al,(1966) Brouw, priv. comm.)

The next task is to look for structural details. The main "local" structure in optical astronomy and in hydrogen line studies is formed by the spiral arms. The main features in radio continuum studies in meter waves are three arcs, each part of a circle: the north galactic spur, the Cetus arc, and "loop 3" (Quigley and Haslam, 1965). Rougoor (1966) wishes to string them all together. The most striking feature on the polarization maps so far is Mathewson's ring, a band 60º wide perpendicular to the galactic plane and cutting it at ℓ^{II} = 350º and 150º. (Mathewson and Milne, 1965). This band contains all areas of locally high polarization. One of these near ℓ^{II} = 140º, b^{II} = 3º, has been discussed in detail by Berkhuysen et.al. (1965).

How are these features, observed by different techniques, interrelated? In my opinion it is still too early to decide on a precise model. Much will depend on what the surveys at 1400 Mc/s, now in progress, will show us.

The most convincing suggestion, so far, is that the ring of relatively high-polarization features is perpendicular to the local direction of the spiral arm (Mathewson and Milne, 1965; Mathewson, Broten and Cole, 1966). The magnetic field in the arm then runs from ℓ^{II}= 250º to ℓ^{II} = 70º. To interpret the map of rotation measures presented by Gardner and Davies (1966) in a similar manner seems more questionable, because the values are so large and because Maltby (1966) finds absence of correlation between the degree of polarization and the galactic latitude. Probably the Faraday rotation in the sources themselves can assume higher values than Gardner and Davies admit.

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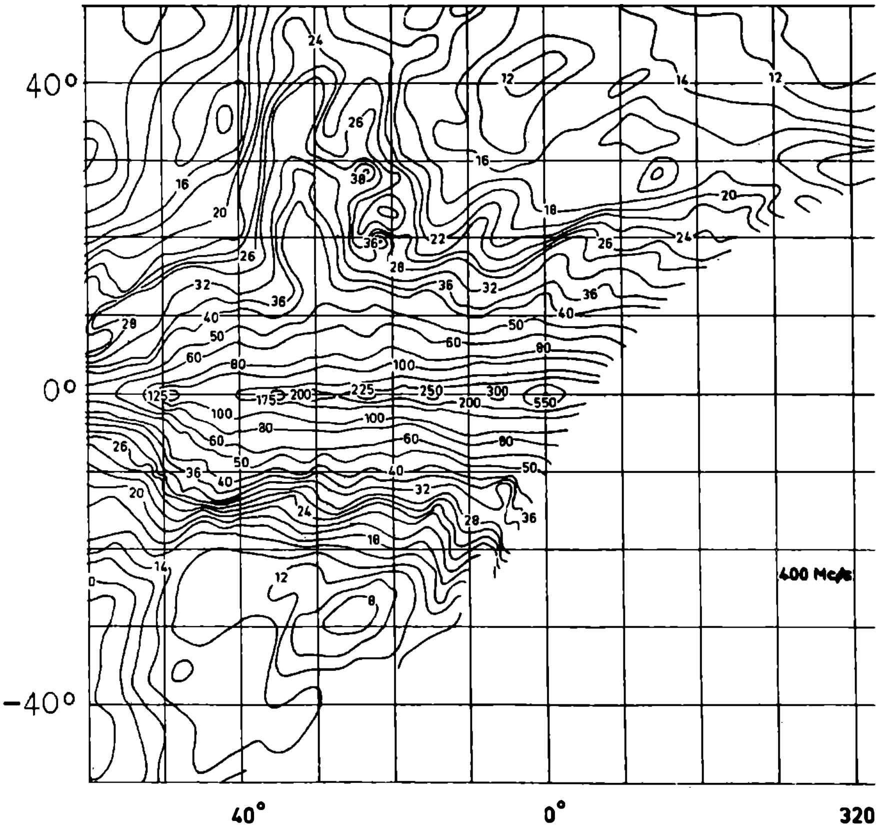
LEGENDS TO FIGURES

Fig. 1	Part of Continuum survey at 400 Mc/s (Seeger et. al. 1965) showing galactic center and base of north galactic spur.
Fig. 2	Part of polarization survey at 820 Mc/s (Brown, unpublished) showing approximately the same area of the sky as Figure 1. Depolarization appears to become less effective toward higher latitudes in the spur.


40°
0°
−40°
40°
0°
320
400 Mc/s
24
12
16
12
26
16
38
16
20
18
20
36
22
26
24
26
28
32
36
32
36
36
40
28
40
50
50
60
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100
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175
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225
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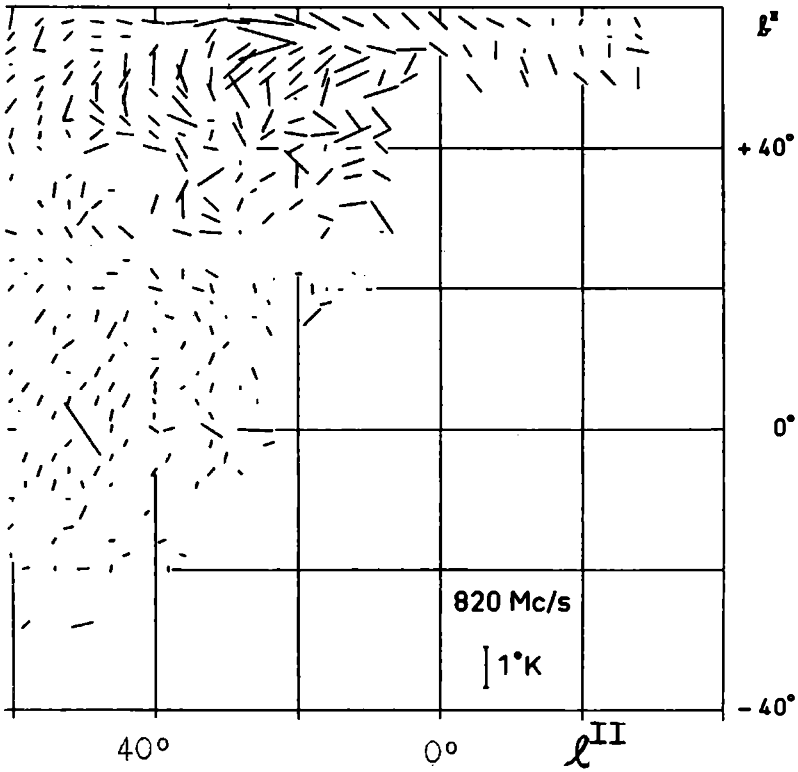
b^{II}
+40°
0°
-40°
820 Mc/s
1°K
40°
0°
l^{II}

VARIACIONES DE BRILLO Y DE COLOR EN ESTRELLAS Be

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Unas 70 estrellas de tipo Be y más brillantes que $m_V = 6^{m}.5$ fueron observadas fotoeléctricamente en el sistema UBV desde enero de 1963 a noviembre de 1965. También un número apreciable de las mismas se midieron en el rojo e infrarojo (R,I).

Cada observación tiene un error medio no mayor de $0^{m}.020$. De este valor se ha estimado que las medidas, o los promedios mensuales como se usaron en la discusión, discordantes en más de $0^{m}.06$ son debidas a variaciones reales de las estrellas.

Los resultados indican que algo menos de la mitad de las estrellas presentan variaciones, ya sea en la magnitude V, o en el color U-B, o en ambos, Si se representan las variaciones de V contra las de U-B (figuras 1 y 2), se encuentra que cuando V aumenta o disminuye, U-B también aumenta o disminuye en el mismo sentido. En cambio si V aumenta, también se presenta el caso en que U-B disminuye, pero si V disminuye no se han presentado estrellas con U-B aumentando. Los dos primeros casos y el último son fácilmente explicables, no así el tercero. Seguramente la radiación de la envoltura tiene un papel muy importante en este fenómeno.

En la figura 1 se han representado para cada estrella las diferencias entre primero y último promedio, si ellos sobrepasan $0^{m}.06$, y en la figura 2 las diferencias entre dos valores cualesquiera siempre que excedan de $0^{m}.06$, exceptuando diferencias entre el primero y último.

Si representamos las estrellas Be en diagramas color-color (U-V, V-I), (U-B, V-V), (B-V, V-I), y (B-V, V-R) encontramos que la mayoría tiene un exceso ultravioleta, y además presenta un exceso de radiación en longitudes de onda mayores, que no son explicables por efecto de enrojecimiento interestelar.

El trabajo en extenso será publicado más adelante.

(') Miembro de la Carrera del Investigador Científico. Consejo Nacional de Investigaciones Científicas y Técnicas.

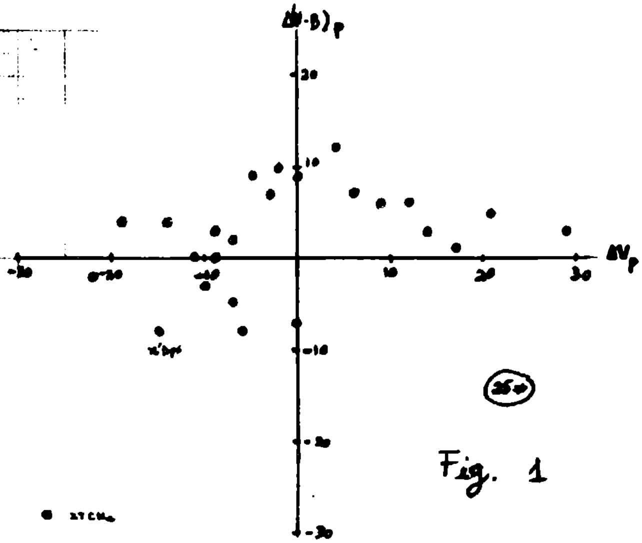
Δ(V-B)p
20
10
-10
-20
-30
-30
-20
-10
10
20
30
ΔVp
26v

Fig. 1

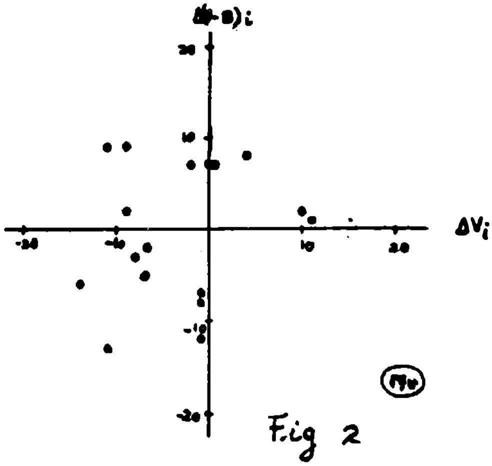
Δ(V-B)i
20
10
-10
-20
-20
-10
10
20
ΔVi
19v

Fig 2

FOTOMETRIA INFRARROJA DE ESTRELLAS T TAURI Y OBJETOS SIMILARES

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SUMARIO

Veintiseis estrellas de la familia T Tauri se han estudiado fotométricamente, desde el ultravioleta (0.36μ) hasta el infrarrojo (5.0μ). La fotometría combinada con los tipos espectrales publicados y los colores intrínsecos de Johnson da excesos de color en todas las longitudes de onda para todas las estrellas. En el infrarrojo, por ejemplo T Tauri y R Monocerotis tienen excesos de color, E_{V-M}, de 6.2 y 8.5 mag., respectivamente. Si estos excesos infrarrojos fueran causados por extinción interestelar, entonces la absorción total en el visual, $A_V \geqslant E_{V-M}$, sería grandísima. Como consecuencia T Tau y R Mon o estarían muy cerca o serían demasiado luminosas.

A partir de la fotometría se pueden encontrar las curvas de energía espectral. Las curvas de T Tau, R Mon y V380 Orionis claramente indican que estos objetos radian excesivamente en el infrarrojo; sin embargo sus tipos espectrales son G5e, Ge y A1:e, respectivamente.

Dos hipótesis se sugieren para explicar el origen de esta radiación infrarroja:

a) las mediciones corresponden a dos o más estrellas. Por ejemplo, una estrella de tipo solar y una estrella similar a TX Camelopardalis nos podrían dar una curva de energía espectral semejante a la obtenida para R Mon.

b) la fotometría en longitudes de onda corta corresponden a un núcleo pequeño, mientras que la de longitudes de onda larga a una envolvente grande.

Si nuestra primera hipótesis fuera la correcta, entonces las estrellas variables de largo período podrían ser estrellas jóvenes. Es conocido que algunas estrellas variables de largo período tienen compañeras. Por ejemplo, R Hya (M6e) tiene una compañera enana de tipo K.

El cómputo de las correcciones bolométricas indica que una estrella infrarroja con una curva de energía espectral parecida a la de R Mon y a una distancia de 690 parsecs, en el diagrama (M_{bol}, T_e)

estaría varias magnitudes arriba de la secuencia principal de edad cero y muy a la derecha. De acuerdo a la teoría evolutiva de Hayashi tal estrella podría llamarse proto-estrella.

Este trabajo se publicará "in extenso" en The Astrophysical Journal, University of Chicago Press.

FOTOMETRIA DE ESTRELLAS INFRAROJAS EN CINCO MICRONES

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INTRODUCCION

Se llamarán estrellas infrarrojas a los cuerpos celestes que radian más de la mitad de su energía en longitudes de onda mayores a un micrón. No deberán incluirse, cuando sea posible, en esta definición a los astros que por extinción interestelar estén radiando principalmente en el infrarrojo. Ejemplos de estrellas infrarrojas son algunas de las estrellas descubiertas por Hetzler (1937), como TX Camelopardalis; los dos objetos descubiertos por Neugebauer, Martz y Leighton (1965) en el Toro (NML-Tauri) y en el Cisne (NML-Cygni); algunas estrellas T Tauri, como R Monocerotis (ver Mendoza, 1966); en general las estrellas tipo Mira (M y S) y las estrellas Carbono de tipo N.

Entre los objetos recién mencionados, los más destacados por su gran radiación en el infrarrojo, se encuentran el objeto NML-Cyg (ver Johnson, Low y Steinmetz, 1965) y R Mon.

Joy (1960) ha clasificado a R Mon como una estrella T Tauri de tipo G. La fotometría UBV, también indica un tipo solar: sin embargo, la energía total entre el ultravioleta y el infrarrojo (5μ) proviene en su inmensa mayoría de longitudes de onda mayores a dos micrones.

El trabajo espectrofotométrico de Wing, Spinrad y Kuhi (1965) indica que el tipo espectral del objeto NML-Cyg corresponde, aproximadamente, a una estrella de tipo S ó M6 no enana. Su curva de energía espectral es muy semejante a la de las supergigantes M del cúmulo h y χ Persei (ver Johnson y Mendoza, 1966) y éstas a su vez a la de las supergigantes M no enrojecidas. La única diferencia estriba en la posición del máximo de estas curvas. La fotometría de las supergigantes M indicá que a mayor enrojecimiento por extinción interestelar, mayor corrimiento del máximo hacia longitudes de onda más largas. Esto sugiere que el objeto NML-Cyg bien pudiera ser una supergigante M6 muy enrojecida por extinción interestelar, en cuyo caso sería la supergigante más tardía conocida. También de la fotometría multicolor se sabe que otras estrellas no supergigantes tienen una curva de energía espectral semejante a la que tienen las supergigantes M; por lo tanto, la sugerencia antes mencionada no pasa de ser una especulación muy atractiva.

En este trabajo se darán observaciones nuevas de un objeto NML (el del Toro), de un objeto Hetzler (TX Cam) y de dos estrellas Carbono (BN Monocerotis y T Lyrae).

LAS OBSERVACIONES

Se han hecho observaciones fotométricas en el sistema UBVRIJKLM de Johnson (1964) de cuatro estrellas infrarrojas: NML-Tauri, TX Camelopardalis, BN Monocerotis y T Lyrae con los telescopios infrarrojos de 28 y 60 pulgadas del Lunar and Planetary Laboratory de la Universidad de Arizona, E.E.U.U. y el equipo descrito en otras ocasiones (ver por ejemplo, Mendoza 1966).

Las observaciones UBVRI se obtuvieron en Septiembre, las JKL en Octubre y las M(5μ) en Diciembre de 1965. Los resultados fotométricos se encuentran en las Tablas 1 y 2. Las columnas de la Tabla 1 dan: primera, el nombre del astro; de la segunda a la última, las magnitudes U, B, V, R, I, J, K, L, M (0.36, 0.44, 0.55, 0.70, 0.90, 1.25, 2.2, 3.4 y 5.0 micrones, respectivamente). La Tabla 2 da los colores U-V, B-V, V-R, V-I, V-J, V-K, V-L y V-M de las estrellas de la Tabla 1. Los valores en cinco micrones, dados en las dos tablas anteriores son el promedio de dos observaciones obtenidas en noches diferentes. Los valores en las otras longitudes de onda corresponden a promedios de observaciones múltiples (de una a siete).

De las Tablas 1 y 2 se nota que el objeto NML-Tau tiene prácticamente los mismos valores B, V, R, I, J, K, L que los publicados (Mendoza, 1965). En cambio TX Cam, un mes después de las observaciones reportadas (Mendoza, 1965) ha cambiado apreciablemente sus valores (R-I). En la Tabla 3 se dan los nuevos índices de color (R-I) y la fecha juliana en que fueron obtenidos. También esta Tabla contiene los valores promedio, correspondientes a las observaciones de marzo y agosto de 1965.

BN Monocerotis, estrella Carbono de tipo N2, ha sido observada extensamente por Edmondson y Giclas (1944). Estos autores obtuvieron magnitudes fotográficas en tres colores: azul, amarillo (visual) y rojo. Nuestras magnitudes azul y roja son del mismo orden que las fotográficas correspondientes. Las magnitudes visuales difieren casi en una magnitud, siendo la de nosotros la más débil. Esta estrella fué la única que sólo tiene una observación entre U y L. En contraste, la otra estrella Carbono, T Lyrae (tipo C6.5; N3) ha sido observada por nosotros extensamente. Durante el período de observación, arriba mencionado, T Lyr estuvo un poco más brillante en BVRI, que durante las observaciones efectuadas en 1964 y publicadas por Mendoza y Johnson (1965).

LA DISTRIBUCION DE ENERGIA ESPECTRAL

Las curvas de energía espectral para NML-Tau, TX Cam, BN Mon y T Lyr se dan en la figura 1. Se han calculado usando la calibración absoluta de Johnson (1965) y se han normalizado a uno en el máximo. Es notable en esta figura la gran similitud de las curvas de las dos estrellas Carbono (T Lyr y BN Mon) y la gran diferencia entre ellas y las curvas correspondientes a NML-Tau y TX Cam. Estas dos últimas estrellas tienen entre sí curvas semejantes. Repetimos, en la figura 1 hay dos tipos de curvas de energía espectral, a saber, una dada por las estrellas Carbono y la otra por las estrellas NML-Tau y TX Cam.

CORRECCIONES BOLOMETRICAS Y TEMPERATURAS EFECTIVAS

Se han calculado las correcciones bolométricas, BC, para las estrellas de la Tabla 1, siguiendo el procedimiento descrito por Johnson (1964), el cual consiste principalmente de una integración numérica bajo la curva de energía espectral. El resultado de esta integración se compara con el valor correspondiente del Sol.

También se han calculado las temperaturas efectivas, usando el último resultado de Johnson (1966a). Su técnica sólo requiere conocimiento del índice de color I-L. Johnson encuentra resultados muy satisfactorios para un gran rango de temperaturas.

Los resultados, de ambos cálculos, para los objetos bajo estudio se encuentran en la Tabla 4. Se obtuvieron sin tomar en cuenta los efectos que pudiera haber por extinción interestelar.

CONCLUSIONES

Se puede concluir de la fotometría presentada, de la de Johnson, Mendoza y Wisniewski (1965) y de la de Mendoza (1965) que bajo ciertas circunstancias la fotometría puede usarse para separar estrellas Carbono. Johnson (1966) sugiere que la forma aplanada, característica de las curvas de energía espectral de las estrellas Carbono, observadas se debe a una absorción en el filtro J (1.25μ). Por consiguiente, los objetos infrarrojos que prácticamente no radien en las vecindades de un micrón, no podrían separarse con la técnica arriba mencionada. Por ejemplo, el objeto NML-Cyg y R Mon, nada más de la fotometría infrarroja no se podría concluir que no fueran estrellas Carbono. El objeto NML-Tau y TX Cam, a partir de la fotometría infrarroja, sí se puede concluir que no son estrellas Carbono (ver figura 1). El tipo de variaciones que se han encontrado en estos dos objetos lo tienen las variables de largo período de tipos M y S. El índice de color (U-B) del objeto NML-Tau es característico de las variables Mira (o Ceti).

Los resultados de esta investigación, por lo tanto, están en conformidad con nuestros resultados previos (*loc. cit.*) y los de Wing, Spinrad y Kuhi (1965).

Es un placer expresar nuestro agradecimiento al Dr. H.L.Johnson por sus comentarios y facilidades de observación y a la Organización de Estados Americanos por la beca que le permitió al autor trabajar en la Universidad de Arizona (E.E.U.U.).

ABSTRACT

New observations in 5μ have been obtained for the Infrared Stars NML-Tau, TX Cam, BN Mon and T Lyr. The results of this photometry, plus additional measurements in U, B, V, R, I, J, K, L, are given in Tables 1 and 2.

The effective temperatures and bolometric corrections for the four objects under study are found in Table 4.

We confirm the flat-typed maximum for Carbon Stars. Johnson suggests that it is caused by some absorption within the J-filter.

We may conclude that the objects TX Cam and NML-Tau are not Carbon Stars (see Figure 1), most likely, they are M or S long period variables, because of the light variations and the strong (U-B) - typical of Mira Stars. This is in agreement with our previous results and the spectrophotometric results of Wing, Spinrad and Kuhi.

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TABLA 1

LAS MAGNITUDES DE CUATRO ESTRELLAS INFRARROJAS

Estrella	U	B	V	R	I	J	K	L	M
NML-Tau	15.8:	16.05	12.77	7.40	3.38	1.17	-1.22	-2.31	-2.64
TX Cam	--	17.0:	14.7:	9.12	4.86	2.59	-0.13	-1.36	-1.48
BN Mon	17.7	15.12	10.56	7.67	5.77	4.61	2.33	1.66	1.64
T Lyr	--	13.37	7.88	5.07	3.43	2.54	0.31	-0.29	0.17

TABLA 2

LOS COLORES DE CUATRO ESTRELLAS INFRARROJAS

Estrella	U-V	B-V	V-R	V-I	V-J	V-K	V-L	V-M
NML-Tau	3.0$^{(+)}$	3.28	5.37	9.39	11.60	13.99	15.08	15.41
TX Cam	--	2.3	5.6	9.8	12.1	14.8	16.1	16.2
BN Mon	7.1	4.56	2.89	4.79	5.95	8.23	8.90	8.92
T Lyr	--	5.49	2.81	4.45	5.34	7.57	8.17	7.71

(+) U-B varió de -0.04 a -0.72

TABLA 3

INDICE DE COLOR (R-I) de TX CAM

R-I	D.J.
4.28	2439032.8512
4.24	2439033.8817
4.25	2439034.8415
4.26	promedio septiembre, 1965
4.54	promedio marzo, 1965 (+)
4.66	promedio agosto, 1965 (+)

(+) Mendoza (1965)

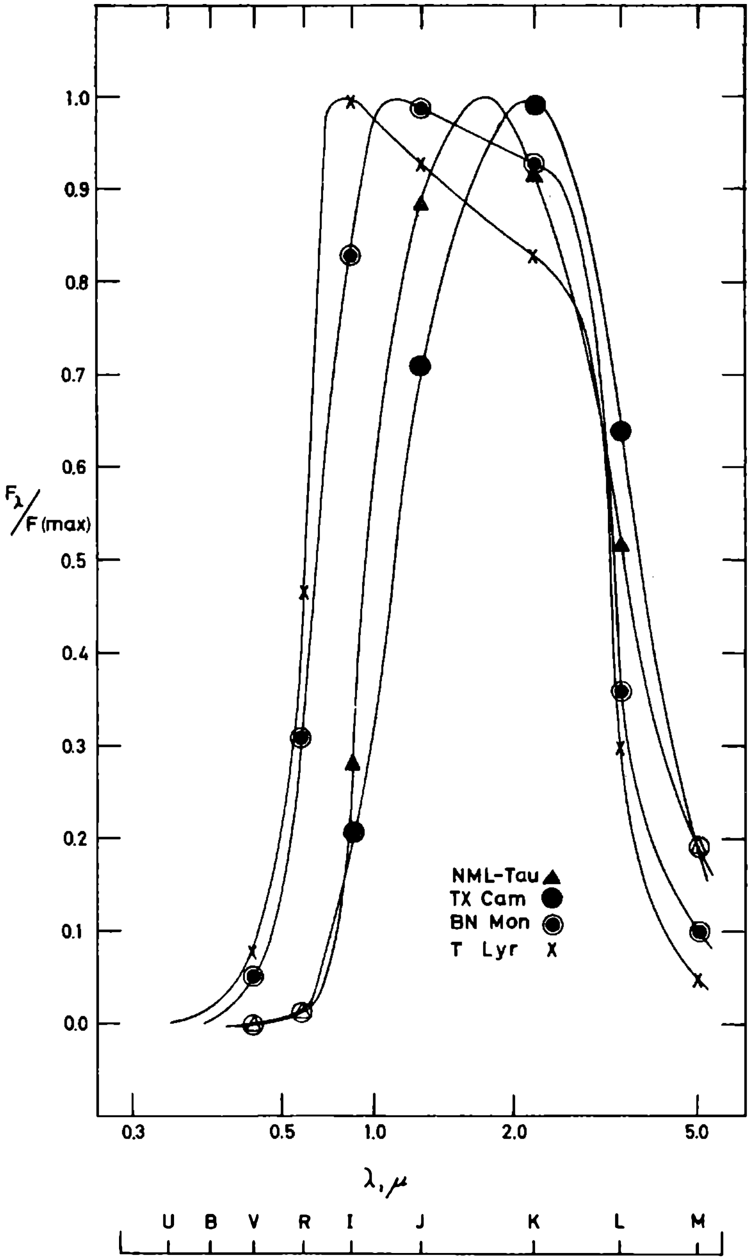
TABLA 4

TEMPERATURAS EFECTIVAS Y CORRECCIONES BOLOMETRICAS DE CUATRO ESTRELLAS INFRARROJAS

Estrella	T_e (ºK)	BC (mag.)
NML-Tau	1600	-11.3
TX Cam	1500	-12.1
BN Mon	2000	-5.1
T Lyr	2125	-4.5

PIE DE LA FIGURA

Figura 1. Curvas de distribución de energía espectral para NML-Tau, TX Cam, BN Mon y T Lyr.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0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
$F_\lambda / F(\max)$
0.3
0.5
1.0
2.0
5.0
λ, μ
U
B
V
R
I
J
K
L
M
NML-Tau ▲
TX Cam ●
BN Mon ◉
T Lyr X

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