cients, bolometric albedos, etc.) the number of adjustable parameters could be appreciably lowered. The analysis revealed that the system HD 224113 is a detached one with the secondary being an A0V type star. The results for the masses and radii of both components strongly support the trend to values which are about 20–30 % smaller than standard values commonly used up to now. For detailed results the reader is referred to my article which will soon be published in *Astronomy and Astrophysics.* It is quite funny that an error in a radial velocity catalogue caused this investigation revealing one more early-type binary suitable for a high-precision determination of the absolute system parameters.

Some Old and New Facts About the Local Group of Galaxies and the Extragalactic Distance Scale

O.-G. Richter, ESO

The number of nearby external galaxies known or believed to lie within about 1.5 Mpc of our own Galaxy (an often used value for the size of the local system) is a rather interesting function of time. In Table 1 I have listed all known such galaxies ordered by absolute magnitude, their date of discovery and some modern data. They form what is called—since nearly 60 years now—the *Local Group* (LG). (The information given in the tables is not claimed to be complete. A reader with a flair for detective work may succeed in adding all the missing data. My primary source for the historical data was the book *The Search for the Nebulae* by Kenneth Glyn Jones [1975, Alpha Academic, The Burlington Press, Foxton, Cambridge].) Before the invention of the telescope only three galaxies were known with certainty, out of which only one appeared in old catalogues, namely the Andromeda nebula. In Fig. 1 the drawing of G.-L. Le Gentil is shown together with a modern photograph. This is in fact the first drawing of a nebula in the history of astronomy. The Persian astronomer Al-Sûfi (903–986), who included the nebula in "the girdle of Andromeda" in his star catalogue, may also have known the LMC, which—according to R. H. Wilson (1899, *Star Names and their Meanings,* 1963 reprinted as *Star Names, Their Lore and Meaning,* Dover Publ., New York)—he might have meant with an object called the "white ox" (Al-Bakr). Both Magellanic Clouds were certainly known since the earliest voyages to the southern hemisphere and they are mentioned from 1515 on, when the Italian navigator Andraes Corsali (in 1516) drew a (rather crude) map of the southern sky. In the latest edition of his famous catalogue, Charles Messier in 1781 mentioned 3 members of the LG, but not the Magellanic Clouds and—even stranger—not NGC 205. This latter galaxy (proposed by K. Glyn Jones to be named M 110) was found on the 27th of August 1783 by Caroline Herschel. In a later paper C. Messier claimed to have detected it already in 1773; this claim has later been supported by H.-L. D'Arrest. William (Wilhelm Friedrich) Herschel and his son, John Herschel, who detected most of the nebulae listed later by J. L. E. Dreyer in his *New General Catalogue of Nebulae and Clusters of Stars* (1888, abbreviated as NGC),

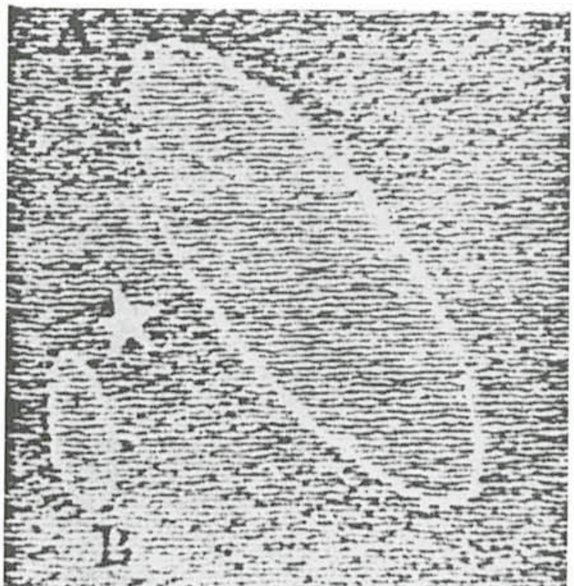
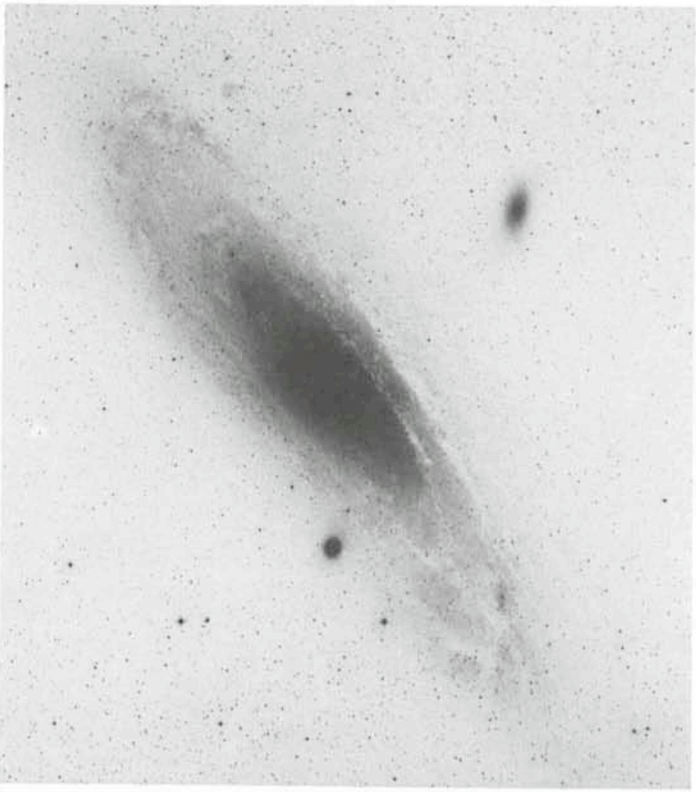


Fig. 1: *Le Gentil's drawing from 1749 of the Andromeda nebula and its companion M 32 compared with the Palomar Schmidt photograph (IIa-D+Wr12, courtesy M. Dopita and S. D'Odorico). The identification of the drawn star is not completely obvious (another supernova?). North is up and east to the left.*



could add only one (!) galaxy to the LG. This emphazises the difficulties the astronomers still working without photographic techniques had with relatively low surface brightness galaxies. By the time of the completion of the second *Index Catalogue* (IC) in 1908 (also by Dreyer) twelve galaxies in the LG were known. When it finally became clear in 1925 (through the work by E. Hubble) that most of the nebulae were "island universes" (so called by Immanuel Kant already in 1755) outside our own Galaxy it was soon discovered that, apparently, we were member of a small group of these galaxies. This aggregate was then named the "Local Group" by Hubble; he still knew only 13 members including our Galaxy.

After the invention of the Schmidt telescope and later with the advent of the Palomar Observatory Sky Survey a number of dwarf systems were quickly discovered. In a fine review summarizing the knowledge about the LG in 1968 given by S. van den Bergh (*Journ. R. A. S. C.* **62,** 1) already 17 galaxies were listed. Only after the southern hemisphere has been explored by means of the ESO and SRC surveys we can consider our knowledge of members of the LG to be fairly complete. Aside from those mentioned in Table 1 (out of which one, IC 5152, is—according to J. L. Sersic and M. A. Cerruti [1979, *Observatory* **99,** 150]—a very doubtful member only) some other objects have been considered as possible members, most notably the two galaxies Sextans A and Sextans B. Most of the other objects considered at one time or another to be dwarf members of the LG galaxy "club" (see Table 2) are now believed to be very distant globular clusters, sometimes called "intergalactic tramps". One notable exception is the Phoenix object, discovered by ESO astronomer H.-E. Schuster (see *The Messenger* **4,** 3) and believed to be an extremely distant globular cluster, which was shown by Canterna and Flower (1977, *Astrophysical Journal* **212,** L57) to be a dwarf galaxy with a (rather uncertain) distance of about 1.8 Mpc. This would place it just outside the boundary of the LG. I am not aware of any further study of this interesting object. The latest addendum to the list of known LG members—the Pisces system LGS 3—dates back to 1978.

In his book *Morphological Astronomy* F. Zwicky estimated the total number of LG galaxies—based on *his* version of the luminosity function—absolutely brighter than -7^m to be 92! Where should we search for those not listed in the tables? S. van den Bergh already pointed out that even within the LG strong subclustering occurs. Apparently two dominant galaxies, M 31 and our Galaxy, are surrounded by "clouds" of smaller galaxies. There are only a few exceptions from this "rule", e. g. IC 1613 or M 33; some astronomers place the latter galaxy even into the M 31 subsystem. We know (at least) nine "satellite" galaxies around our own Galaxy and some more may be hidden behind the disk of the Galaxy (i. e. in the zone of avoidance). If we accept the standard view that M 31 is about 3 times as massive and as luminous as our Galaxy we could perhaps assume that it is surrounded by also 3 times as many dwarf systems as our Galaxy. One could then, in fact, expect up to about 60 satellite galaxies arround M 31, whereas only 7 have been found so far. These possible dwarf galaxies near the Andromeda nebula should then have apparent (blue) total magnitudes fainter than $\sim 14^m$, but certainly not fainter than about 18^m. As S. van den Bergh (1974, *Astrophysical Journal* **191,** 271) has already performed a search for such galaxies and found only the 3 already mentioned in 1972 (*Astrophysical Journal* **171,** L31), we have to believe that most galaxies belonging to the LG are known by now. Therefore it seems unlikely that many more dwarfs (in the LG) will be discovered in the future. As D. Lynden-Bell (1982, *Observatory* **102,** 202) has suggested, many of the dwarf galaxies around our Galaxy are

TABLE 1: Galaxies belonging to the Local Group

No.	Name	Discoverer and Date of Discovery	Position	Type	B_T	D (Mpc)	$M_B^{o,t}$
1	M 31 (NGC 224)	Al-Sûfi?, ≤ 964	00^h 40^m +41°	Sb	$4^m.38$	0.67	$-21^m.61$
2	The Galaxy	?, ≤ 550 B. C.	17^h 42^m −28°	Sbc		0.01	$-20^m.6$:
3	M 33 (NGC 598)	C. Messier, 25. Aug. 1764	01^h 31^m +30°	Sc	$6^m.26$	0.76	$-19^m.07$
4	Large Magellanic Cloud	Al-Sûfi??, ≤ 1515	05^h 24^m −69°	SBm	$0^m.63$	0.06	$-18^m.43$
5	Small Magellanic Cloud	A. Corsali?, ≤ 1515	00^h 51^m −73°	Im	$2^m.79$	0.08	$-16^m.99$
6	IC 10	L. Swift	00^h 17^m +59°	Im?	$11^m.70$	1.3:	$-16^m.2$:
7	NGC 205 (M 110)	C. Messier, 10. Aug. 1773	00^h 37^m +41°	S0/E5 pec.	$8^m.60$	0.67	$-15^m.72$
8	M 32 (NGC 221)	G.-J. Le Gentil, 29. Oct. 1749	00^h 40^m +40°	E2	$9^m.01$	0.67	$-15^m.53$
9	NGC 6822	E. E. Barnard, 1884	19^h 42^m −14°	Im	$9^m.35$	0.56	$-15^m.11$
10	W.L.M. system	M. Wolf, 1908	23^h 59^m −15°	IBm	$11^m.29$	1.6	$-15^m.04$
11	IC 5152	D. Steward	21^h 59^m −51°	Sdm	$11^m.68$	1.6:	$-14^m.6$:
12	NGC 185	W. Herschel	00^h 36^m +48°	dE3 pec.	$10^m.13$	0.67	$-14^m.59$
13	IC 1613	M. Wolf, 1907	01^h 02^m +01°	Im	$9^m.96$	0.77	$-14^m.50$
14	NGC 147	H. L. D'Arrest, 1856	00^h 30^m +48°	dE5	$10^m.36$	0.67	$-14^m.36$
15	Leo A (Leo III)	F. Zwicky, 1940	09^h 56^m +30°	IBm	$12^m.70$	1.59	$-13^m.49$
16	Pegasus system	A. G. Wilson, ≤ 1959	23^h 26^m +14°	Im	$12^m.41$	1.62	$-13^m.37$
17	Fornax system	H. Shapley, 1938	02^h 37^m −34°	dE0 pec.	$9^m.04$	0.16	$-11^m.98$
18	DDO 155 (GR 8)	G. R. Reaves, ≤ 1955	12^h 56^m +14°	Im	$14^m.59$	1.3:	$-11^m.2$:
19	DDO 210 (Aquarius)	S. van den Bergh?, ≤ 1959	20^h 44^m −13°	Im	$15^m.34$	1.6:	$-11^m.0$:
20	Sagittarius dIG	H.-E. Schuster, 13 June 1977	19^h 27^m −17°	Im	$15^m.6$	1.10	$-10^m.65$
21	Sculptor system	H. Shapley, 1937	00^h 57^m −33°	dE3 pec.	$9^m.0$	0.08	$-10^m.6$
22	Andromeda I	S. van den Bergh, Oct. 1971	00^h 43^m +37°	dE3	$13^m.9$	0.67	$-10^m.60$
23	Andromeda III	S. van den Bergh, ≤ 1972	00^h 32^m +36°	dE	$13^m.9$:	0.67	$-10^m.6$:
24	Andromeda II	S. van den Bergh, ≤ 1972	01^h 13^m +33°	dE	$13^m.9$:	0.67	$-10^m.6$:
25	Pisces system (LGS 3)	C. T. Kowal et al., 29. Oct. 1978	01^h 01^m +21°	Im	$15^m.5$	1.0:	$-9^m.7$:
26	Leo I (Regulus)	A. G. Wilson, 1950	10^h 05^m +12°	dE3	$11^m.81$	0.19	$-9^m.62$
27	Leo B (Leo II)	R. G. Harrington, 1950	11^h 10^m +22°	dE0 pec.	$12^m.3$	0.19	$-9^m.25$
28	Ursa Minor system	A. G. Wilson, ≤ 1955	15^h 08^m +67°	dE4	$11^m.6$	0.09	$-8^m.2$
29	Draco system	A. G. Wilson, ≤ 1955	17^h 19^m +57°	dE0 pec.	$12^m.0$	0.10	$-8^m.0$
30	Carina dE	R. D. Cannon et al., 1977	06^h 40^m −50°	dE4	(> 13)	0.09	$-5^m.5$::

TABLE: 2: Objects once thought to be Members of the Local Group

Name	Discoverer and Date of Discovery	Position
Phoenix	H.-E. Schuster, March 1976	$01^h 49^m$ −44°
Sextans B	F. Zwicky, ≤ 1942	$09^h 57^m$ +05°
Sextans C (Pal 3)	A. G. Wilson, ≤ 1955	$10^h 03^m$ +00°
Sextans A	F. Zwicky, ≤ 1940	$10^h 08^m$ −04°
Ursa Major (Pal 4)	F. Zwicky, ≤ 1953	$11^h 26^m$ +29°
Serpens (Pal 5)	A. G. Wilson, ≤ 1955	$15^h 13^m$ +00°
Capricorn (Pal 12)	R. G. Harrington & F. Zwicky, ≤ 1953	$21^h 43^m$ −21°
Pegasus B (Pal 13)	A. G. Wilson, ≤ 1955	$23^h 04^m$ +12°
UKS 2323-326	A. J. Longmore et al., ≤ 1975	$23^h 23^m$ +32°

probably tidal debris of the encounter between the—once larger—LMC (called Greater Magellanic Galaxy) and our Galaxy. As there are no obvious candidates—similar to the LMC—for such an encounter with M 31 we then must *not* expect many such dwarf systems around that galaxy (opposite to the statement made earlier). Anyway, I don't think that we can ever reconcile F. Zwicky's estimate of nearly 100 LG members. This implies that the luminosity function of galaxies *has* a maximum at a yet poorly determined absolute magnitude, and further that this maximum may lie nearer to bright galaxies than believed hitherto.

Now, why should we make every effort to study our neighbours in outer space? As they are the nearest objects of their kind, we can determine their global parameters and study their "ingredients" with the highest possible observational accuracy. Absolute parameters can, of course, only be determined when the distances to these galaxies (or their constituents) are known. This immediately leads us to the question: How can we measure such "astronomically" large distances? Well, we simply assume that the physics of individual objects are the same everywhere in the universe. With some of them in our Galaxy, preferably in the solar neighbourhood, where distances are (a bit) easier to measure, we may solve this problem. Now, which objects are really reliable distance indicators? Or, in other words: Which objects have a very small disperion in their intrinsic physical properties? It is exactly at this point that "extragalactic" astronomers start to disagree.

Nowadays we have two "schools", one represented by A. Sandage and G. A. Tammann (ST) and the other by G. deVaucouleurs (dV) and to some extent also by S. van den Bergh; they come to results differing by factors of up to two, where the difference is not the data used, but the underlying philosophy. You may take the point of view (dV) that one should use as many distance indicators as possible in order to "share the risk" of eventual unreliability. One may then hope that systematic errors balance out. I could find about 20 or so different indicators in the literature and I found it hard (based on purely physical considerations) to believe in even only half of them. This brings us to the second possible way of thinking (ST): Take only the most reliable indicators, i.e. those of which the physics is (believed to be) understood, and forget all the others. As the results may now be looked at as being more reliable as in the aforementioned case, there is the (everlasting) risk that all distances have to be revised, if only a single indicator becomes revised. This is so because, in general, every distance indicator is applicable only over a certain range in distances (i.e. one builds a distance "ladder"), or is only available from certain distances on. There are only two indicators whose usefulness is agreed upon by everybody, namely the δ Cephei stars via their period-luminosity (or

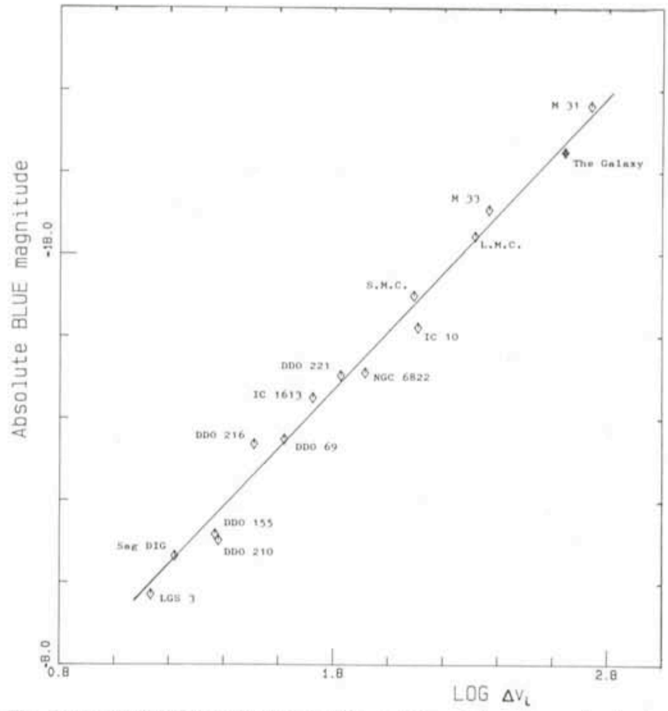


Fig. 2: *The Tully-Fisher relation for the spiral and irregular galaxies in the Local Group.*

period-luminosity-colour) relation, and the brightest red supergiant M stars via their assumed upper limit in absolute magnitude. One more indicator, namely supernovae of type I, is also commonly used, but the absolute (blue) magnitude during maximum differs considerably between the "schools": dV uses $-18^{m}.6$, ST $-19^{m}.7$, and theoreticians require at least $-19^{m}.2$ and some even predict $-20^{m}.2$ or so!

Finally, a fourth indicator is in general use since 1977, when R. B. Tully and J. R. Fisher (*Astronomy and Astrophysics* **66,** 54) discovered a relation between the absolute total magnitude of a (late-type, rotationally supported) galaxy and its line width in the 21 cm line of neutral hydrogen (HI). This "Tully-Fisher" relation is, again, a rather debatable subject, because (sometimes very) large corrections have to be applied to the observational data. Unfortunately, these corrections are known to vary quite substantially from galaxy to galaxy and, hence, they can be determined and applied only in a statistical manner. Only recently the radioastronomical HI data became complete for the spiral and irregular galaxies in the LG. For a recent calibration of the Tully-Fisher relation I compiled all these data and condensed them into a diagram that is reproduced in Fig. 2. The correlation is evident and looks really convincing. The scatter around the fitted straight line is equal to the combined errors of the magnitudes, distances, inclinations, and 21 cm line widths. This means that there is practically no room for an appreciable intrinsic dispersion for the Tully-Fisher relation. However, in view of the actual uncertainties in the basic data, especially for the galaxies at the faint end, this perfect correlation may well be fortuitous. Anyway, despite the lack of an accepted theory for the underlying physics we may use also this relation for distance estimates. It has been suggested that we see an effect of (nearly) constant surface density in self-gravitating systems, but this has to be worked out in much more detail. The use of all (say, most) other indicators is not at all based on their (known) underlying physical behaviour, but on the *apparently* small dispersion of absolute parameters. In other words, usage of the latter alone would be just *circular reasoning,* and, further, be subject to prejudice. Therefore, I take the liberty to believe only in the above-mentioned four distance indicators: Cepheids, Supernovae I, brightest M supergiants, and the Tully-Fisher relation.

I should like to add that the upper limit to the absolute luminosity of brightest red supergiants may be *constant* from galaxy to galaxy only if enough such massive stars have been formed in the parent galaxy. If, for instance, a dwarf galaxy failed to produce stars at least as massive as about 20 $M_{\odot}$, the brightest red stars will be fainter than expected, and, hence, the distance will be overestimated. On the other hand, the existence of an upper limit to the bolometric magnitude of red supergiants requires a special stellar evolution model, namely, the *very* massive (blue) stars ($\gtrsim 30\ M_{\odot}$) do not evolve into red supergiants but are directly turned into Wolf-Rayet stars, thus becoming supernovae (type II) progenitors.

The supernovae are unfortunately short-lived, transient phenomena. Normally, galaxies we are studying do not please us with the production of a supernova explosion which would help us to derive the parameters for the system. The Cepheids are certainly the best we have to probe the galaxies within about 10 Mpc, not the least so because corrections to data are only minimum. With the introduction of CCD cameras in astronomy we have a tool to reach the required faint limits of $B \approx 26^m$ with ground-based telescopes like e.g. the 3.6 m or even the new 2.2 m at La Silla. Such future observations will ultimately prove or disprove the applicability of all other distance indicators. In the meantime we have to rely on a variety of "rods". Here I recommend (because HI 21 cm line studies are among my prime interests) the Tully-Fisher relation. And this is, at the present state of the art, in favour of the Sandage-Tammann distance scale leading to a Hubble constant of about 50 km/s/Mpc or perhaps a bit higher, but most probably not more than 75 km/s/Mpc.

Now I present the context for the—apparently decoupled—two previous parts of this contribution. If we now apply those four distance indicators to the galaxies in the environment of the Local Group we get the impression that the concept of a local *group* probably can no longer be maintained. Rather we may be embedded in a local *filament* which can be traced at least from the Sculptor group to the "Local Group" and further to the M 81 group, i.e. over more than 5 Mpc. So only a few years after the start of the discussion of filamentary structure in the universe at large we begin to discover this structure in the galactic neighbourhood and in the local supercluster.

Concluding one may say that the routes of reasoning of G. deVaucouleurs and of A. Sandage and G. A. Tammann have both many pros, but perhaps also as many cons. What I wish to say is that one should not blindly trust every statistical application of a *new* distance indicator. This may well imply that the next who writes on the topic of extragalactic distances will show that what I have written here cannot be trusted! As a preventive excuse I may mention that I have written this short contribution while I was observing at La Silla with the ESO 1.5 m telescope where the necessary guiding was interfering.

Detailed references to the data used for Fig. 2 can be obtained from the author.

Multiple Stars—a Nuisance to the Observers

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Already in popular textbooks you can read that double stars are frequent phenomena in the Milky Way. In the first instance this concerns the visual double stars that every one can admire through the telescope. They constitute a considerable fraction of the total stellar content, with a certain statistical frequency dependence upon spectral type and luminosity class that may partly be physically significant but, to an overwhelming extent, is conditioned by selection effects.

If we add the spectroscopic binaries, we increase the number by at least an order of magnitude and if we take into account also the higher multiples, we may find that the number of stars in multiple systems exceeds the number of single stars.

Multiple stars of any type are generally revealed more or less by accident. This means that we have to count upon a considerable number of undetected multiple systems. It is a well-known fact that visual binaries with equal components are much easier to discover than those with a magnitude difference of say 2^m or more. A statistical survey of available double star catalogues will show a significant overrepresentation of components with rather equal temperature, and it is obvious that this effect is predominantly an observational bias. For most studies, however, the visual binaries are harmless objects which do not constitute any real menace to your projects, so we leave them in peace here. Sometimes, of course, you also encounter some sort of semi-visual binaries, i.e. systems which are classified as single objects in the CD and HD catalogues but which can be resolved in the telescope under particularly good seeing conditions. Such objects may be harassing enough to observe, especially if you try to get a spectrum and cannot be convinced that you have one and the same component on the slit all the time. If the seeing disk is larger than the angular separation of the components, their relative contribution to the resultant spectrum is highly dependent upon the centring on the slit. Personally I suspect that

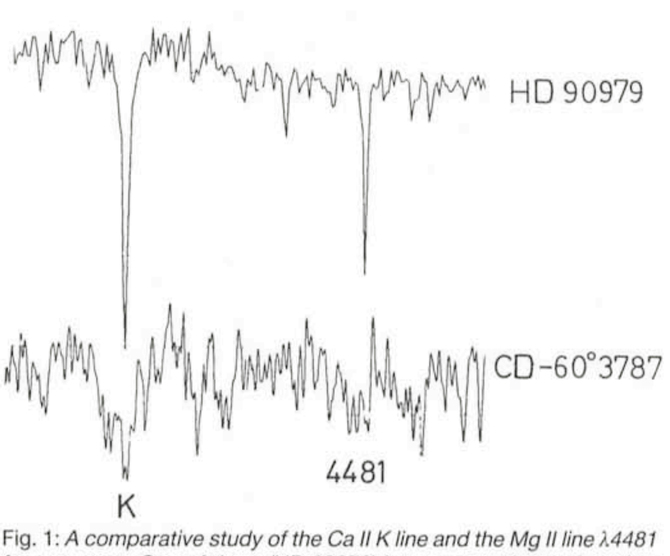

Fig. 1: *A comparative study of the Ca II K line and the Mg II line λ4481 for two stars. One of them (HD 90979) has apparently a rather slow rotation and no companions. The other one (CD −60° 3787) shows a very complicated spectrum due to multiplicity.*