THE INFLUENCE OF THE NIGHT SKY ON VELOCITY DETERMINATIONS FROM OPTICAL ABSORPTION LINES

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L'analyse numérique de spectres d'absorption de galaxies montre que des erreurs systématiques jusqu'à 500-600km/s peuvent apparaitre dans les mesures de vitesses radiales entre 5200 et 9200 km/s. Ces erreurs sont produites par la superposition du spectre du ciel nocturne aux longueurs d'onde de 4020, 4046, et 4078 Å. La "structure de bandes" trouvée par Tifft dans le diagramme m_v, V_R de l'amas de galaxies dans Coma peut provenir de ce type d'erreur systématique.

It has been known for quite some time that measurements of galaxy radial velocities derived from absorption line spectra can have systematic errors of 50-150 km/s (de Vaucouleurs and de Vaucouleurs, 1967; Roberts, 1972). Even for fairly bright galaxies, errors of this magnitude can be attributed to distortion of the galaxy spectrum by that of the night sky (Simkin, 1972). This contribution reports recent computer experiments which show that even larger systematic errors (500-600 km/sec) can arise from night sky distortions. These systematic errors occur in the redshift region 5200-9200 km/s and are increasingly serious for galaxies with nuclear magnitudes fainter than 15.

The experiments were motivated by the well demonstrated "banding" structure in the m_v, V_R diagram of the Coma cluster discovered by Tifft (1972, 1974). This band structure is clearly significant yet inexplicable in terms of currently accepted theories about the dynamics of clusters of galaxies. Most of the radial velocities for galaxies in the Coma cluster, however, are derived from absorption line measurements on low dispersion spectrograms. These are particularly dependent on the positions of the Ca H and K absorption lines in the galaxy spectra and at the redshift of the Coma cluster a strong night sky Hg emission feature (4046 Å) falls right in the same region of the spectrum. This emission feature could easily distort the

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H and K lines to give some of the velocity structure that shows up in Tifft's bands. The mechanism for such a distortion is illustrated in fig.1, where the position of Hg 4046 relative to Ca H and K is shown for different galaxy redshifts. Between 5200 and 5600 km/s the Hg 405 line encroaches upon the red wing of the Ca H line, shifting its centroide towards the blue. Similarly, at higher redshifts, the Ca H line is shifted towards the red when the galaxy's velocity lies between 6200 and 6600 km/s and the Ca K line is blue shifted between 7900 and 8300 km/s and redshifted between 8900 and 9300 km/s. These distortions would tend to shift the measured radial velocities of galaxies whose true redshifts lie in the regions 5200-5600, 6200-6600, 7900-8300, and 8900-9300 out of these regions. These are precisely the regions where the "gaps" occur in the band structure for the Coma and A2199 clusters (Tifft, 1974).

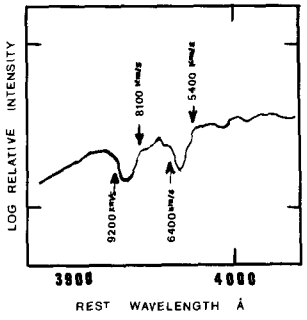

Fig. 1
Relative positions of galaxy H and K to night sky Hg at different redshifts.

To measure the magnitude of the distortion outlined above, computer simulations of 300 composite galaxy+night sky spectra were constructed from data obtained at Kitt Peak National Observatory in January 1975. These simulated spectra were scaled to represent galaxies ranging in redshift from 5200 to 9200 km/s and in magnitude (4.8" at 100 mpc) from 15 to 17.50 mag. The Ca H and K absorption lines in these composite spectra were "measured" for radial velocity using a technique identical to that used when measuring spectrograms with a "grant" comparator. The measured velocities were quite different from the original input velocities. Differences between measured velocity and input velocity were often as high as 500-600 km/sec in some regions (Fig.2). These differences are greatest for input velocities around 6200, 7200, and 8200 km/s, the regions where encroachment of the Hg 405 night sky line might cause distortion of the H and K lines. The magnitude of this distortion is, however, much greater than can be explained by an encroaching Hg line.

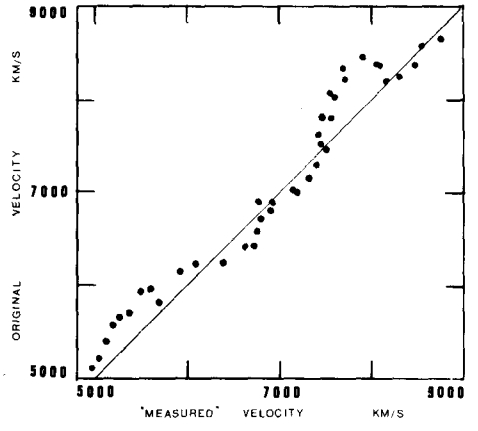

Fig. 2
Actual vs. "measured" velocities for experimental galaxies.

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Inspection of the night sky spectrum in the region 4000-4100 Å shows that the Hg 405 line alone is not responsible for this sizable distortion. There are three emission features in this region; one at ~4020 Å (unidentified), Hg at 4046 Å, and Hg at 4078 Å (cf. Broadfoot and Kendall, 1968). The separation between these emission features is very close to the 35 Å separation between Ca H and K. Detailed inspection of the numerically generated spectra both before and after the addition of night sky features shows that in the redshift regions 6200 and 7200 km/s both the Ca H line and the Ca K line are distorted in the same way by the emission features at 4020 and 4046 Å. Similarly, at 8200 and 9200 km/s the absorption lines are both distorted in the same direction by the night sky features at 4046 and 4078 Å. It is this reinforcing effect where both absorption lines are distorted that leads to the large, systematic discrepancy between the actual galaxy redshift and that measured from the contaminated H and K lines.

The severity of the distortion can be seen in fig.3. Figure 3a is a plot of 70 "galaxies" from the computer experiment described above. These were chosen to be randomly placed within a gaussian distribution in magnitude centered at 16.2 mag with dispersion 0.57 mag and in velocity centered at 6840 km/s with dispersion 1200 km/s. These are the values usually ascribed to the Coma cluster (Tifft, 1972). Figure 3b is a plot of the same galaxies but with measured velocity as abscissa. The gaps in velocity space are striking and, as expected, are more severe for fainter galaxies. Points marked with a + in 3a have been shifted to the right in 3b while those marked with an x have been shifted to the left. Also plotted in figure 3b are Tifft's "bands" for the Coma cluster (Tifft, 1972). This diagram strongly suggests that the Coma band structure reflects systematic errors in the measured radial velocities of the member galaxies and that these errors are caused by night sky spectrum distortion.

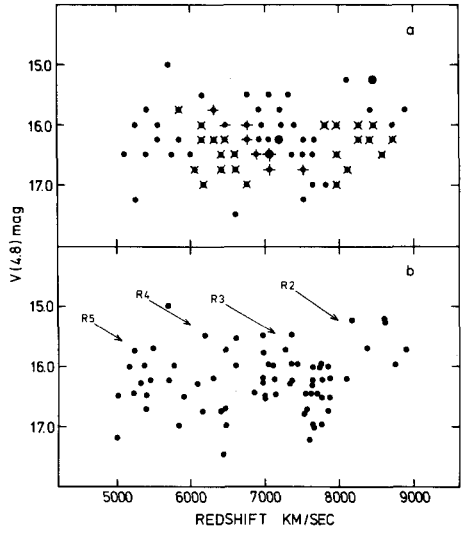

Fig. 3

m_V, V_R diagram for 70 galaxies described in the text (a) random sample (b) same sample, spectra distorted by night sky spectrum.

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A detailed discussion of the results described in this comment may be found in a paper recently submitted to "Astronomy and Astrophysics".

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DISCUSSION

W.G. TIFFT: The spectrogram shown by Simkin greatly exaggerates the night sky spectrum. Normally it is barely visible on spectra of galaxies down to near magnitude 16. There are also several lines of evidence that indicate that Simkin has greatly overestimated possible errors. Nuclei of ellipticals are generally very concentrated. Even a galaxy of faint total magnitude will produce a strong spectrum (narrow) quickly. Exposure times hardly vary at all in going from the brightest galaxies with normal nuclei (as used in Simkin's test) to typical 15 - 16 mag ellipticals. The spectra become much narrower, but within the well exposed part night sky effects scarcely change at all. The faintest Coma galaxies studied in the original Coma work required 20-25 minutes exposure, the brightest 10-15. Spectra were taken only in good seeing and transparency conditions. On all the Steward original Coma spectrograms H and K are easily seen and 4047 of Hg is only rarily visible. Small first order effects of 4047 are easily seen and allowed for and, when very marked, the affected line is simply not used. H and K redshifts in the finally accepted measures differ by no more than 200 Km/sec. The Kintner data is known to be much worse than this and is not typical of available data. There are several intercomparisons of redshifts which also indicate only minor deviations. High dispersion (95 A/mm) spectra by Sargent for 30 or 50 galaxies in common show excellent agreement. Emission line galaxies show no net differences emission - absorption, and emission line data alone shows the banding phenomenon. At least one sky - subtracted Steward scan (and several others mentioned to me personally from other sources) confirm the measured redshifts closely (~ 100 km/sec).

Examination of the "band" figures of Simkin raises further questions. Simkin is unable to show an effect between the two most distinct Coma bands, R3 and R4. The illustration used seems to have gaps built in which the night sky conveniently enhances. Would another or all random samples show such an effect? One might expect vertical gaps from the night sky but not sloping ones. Other clusters with bands (Perseus, A 2199) cover different redshift ranges and show bands directly related to Coma. Personally, I welcome a chance to settle the question of night sky contamination and hope many more sky subtracted scans will become available soon. I believe,

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however, that there is no evidence to support the existence of night sky errors of anywhere near the size Simkin suggests.

S.M. SIMKIN: The night sky spectrum shown in the first slide was printed at high contrast solely for the purpose of pointing out the night sky lines under discussion. I was not trying to suggest that absorption-line galaxy spectra are heavily contaminated by night sky lines. My point is, in fact, just the opposite: on ordinary spectrograms these lines (even the "strong" 4046-7 line) are not obvious but at certain redshifts their influence is tremendous.

Answers to most of Dr. Tifft's comments can be found in the Astron. Astrophys. paper referred to in the text. Two points should be emphasized: (1) I am not trying to expound the position that all velocity substructure found for galaxies in clusters is due to night sky distortions; nor am I suggesting that there is no substructure to the velocity distribution in the Coma cluster. I do believe that the particular pattern of sloping bands found in the Coma cluster is strongly influenced by night sky distortion. I have come to this conclusion in spite of the fact that I originally believed any such effect would be marginal.

(2) My main point is this: Any velocity substructure in Coma or any other cluster is most likely to show up in the more numerous, fainter galaxies in the cluster. The distortions discussed in my talk are most likely to be important for just such fainter objects. Thus, any fine velocity substructure may well be distorted out of its original form. The nature of the effect is that if all "true" redshifts at a velocity, V_R, were distorted to the blue by only 100 km/sec while those at $V_R + \Delta V_R$ were distorted to the red by 100 km/s, and if this is repeated at a redshift of $V_R + V_S$; where ΔV_R is the width of the H or K line, $\sim$ 1200 km/s, and V_S is the separation of the H and K lines, $\sim$ 2600 km/s; then the M_V, V_R diagram would have statistically significant "gaps" or bands at velocities separated by 1200-1300 km/s.

As Tifft has said, the best way to determine absorption-line radial velocities is with equipment that subtracts the night sky. As suggested above, such observations must be accurate to better than 100 km/sec. With present equipment an extensive program at a resolution high enough to give the required accuracy will be very time consuming.

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