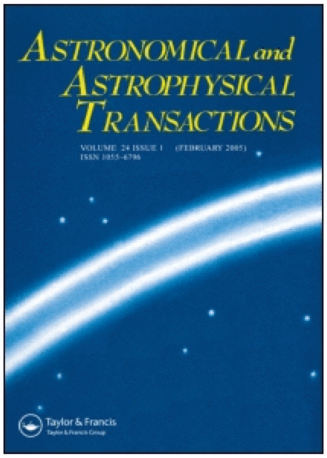

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Source functions and profiles of λλ4571, 5173 Mg I lines in chromosphere models of quiet Sun, solar flares and T tauri stars

U. Sh. Bayazitov [a]; I. Kh. Saghidullin [a]
[a] Theoretical Physics Department, Bash. Ped. Institute, Ufa, Russia

Online Publication Date: 01 August 1997
To cite this Article: Bayazitov, U. Sh. and Saghidullin, I. Kh. (1997) 'Source functions and profiles of λλ4571, 5173 Mg I lines in chromosphere models of quiet Sun, solar flares and T tauri stars', Astronomical & Astrophysical Transactions, 14:1, 11 - 18
To link to this article: DOI: 10.1080/10556799708213565
URL: http://dx.doi.org/10.1080/10556799708213565

Astronomical and Astrophysical Transactions, 1997,
Vol. 14, pp. 11–18
Reprints available directly from the publisher
Photocopying permitted by license only

SOURCE FUNCTIONS AND PROFILES OF $\lambda\lambda$4571, 5173 Mg I LINES IN CHROMOSPHERE MODELS OF QUIET SUN, SOLAR FLARES AND T TAURI STARS

U. Sh. BAYAZITOV and I. Kh. SAGHIDULLIN

Theoretical Physics Department, Bash. Ped. Institute, Oct. Revolutzii Str., 3-a, Ufa, 450000, Russia

(Received February 2, 1996)

The formation conditions of the $\lambda\lambda$4571, 5173 Mg I lines in the atmospheres of quiet Sun, solar flares and T Tauri stars (TTS) are considered. It has been found that the line λ4571 is formed in local thermodynamic equilibrium (LTE) conditions only in the quiet Sun. In the case of the more dense atmospheres of solar flares and TTS the line λ4571 Mg I is formed higher than the temperature minimum and for this line the LTE approach is not applicable.

Comparisons of computed and observed profiles of line λ4571 Mg I in the atmospheres of solar flares and TTS can provide information about ionization radiation in these objects.

KEY WORDS Non-LTE calculations, Sun, solar flares, T Tauri stars

1 INTRODUCTION

In the paper by Mauas *et al.* (1988) interesting behaviour of line λ4571 Mg I in the conditions of the quiet Sun's atmosphere is described. Namely, the given line is formed in the region of temperature minimum and its source function is close to the Planck function. This is relevant to the applicability to it of the LTE approximation. For this reason line λ4571Å becomes the ideal indicator of temperature change with height in the Sun's atmosphere, especially in the temperature minimum region. However, the question of the behaviour of this line in the atmospheres of other objects remains to be studied.

Our purpose is the study of the above-named line, as well as the strong line λ5173 Mg I in the conditions of more dense extreme atmospheres of solar flares and T Tauri stars (TTS).

2 METHOD OF INVESTIGATION

To realize the theoretical research we applied the MULTI code (Carlsson, 1986) for non-LTE calculations of spectral line profiles.

We have used the 13-level Mg I atom from Mauas *et al.* (1988). The collisional cross-sections, photoionization cross-sections, oscillator strengths and damping parameters of lines are also taken from this work.

We have used a semi-empirical atmospheric model (photosphere + chromosphere) of the quiet Sun from Maltby *et al.* (1986). We assumed solar flares models from Avrett *et al.* (1986) (the $F1^*$ model is appropriate to weak flares, $F2$ to flares of average power and $F3$ to white light flares). For TTS we have used the semi-empirical chromospheric model (model A) from Calvet *et al.* (1984). Although this type of TTS model does not correctly describe all observational data (the gas-dust disk models and extended envelopes are more appropriate for active TTS) the model of Calvet *et al.* is an extreme kind of dense star chromosphere. For this reason it is interesting to investigate the behaviour of $\lambda\lambda4571$, 5173 Mg I lines in this model.

The magnesium abundance was taken equal to $\log(A)_{\mathrm{Mg}} = 7.48$.

Microturbulent velocity from corresponding models of atmospheres was taken into account.

The photoionization radiation of the stars and the Sun is strongly influenced by bound-free transitions. Unfortunately this radiation field is not known with sufficient accuracy. For this reason we have used radiation temperature (T_{rad}). Generally, it is believed that for deep layers of atmosphere T_{rad} is approximately equal to the local electronic temperature and in external layers the ionization is described as the constant value of the radiation temperature. This means physically that the ionization in the top layers of the atmosphere comes from the radiation field of deeper layers.

3 RESULTS

Our calculations for the quiet Sun model have shown satisfactory consistency with the results of Mauas *et al.* (1988). The calculated profiles of line $\lambda4571$Å for models of atmospheres except of TTS are shown in Figure 1. We also considered line $\lambda5173$ Mg I and compared it with the observed lines in the spectrum of the quiet Sun (Figure 2). The influence of the instrumental contour is small and has not been taken into account.

As visible from drawings, for the quiet Sun model consistency of theoretical profiles with observed profiles for both lines is achieved. However in the case of $\lambda4571$Å the theoretical profile is wider and in the case of $\lambda5173$Å it is narrower. Also for line $\lambda5173$Å the calculated equivalent width is a little higher than those observed. This may be due to inexact selection of atomic and damping parameters of Mg I atom transitions by Mauas *et al.* (1988).

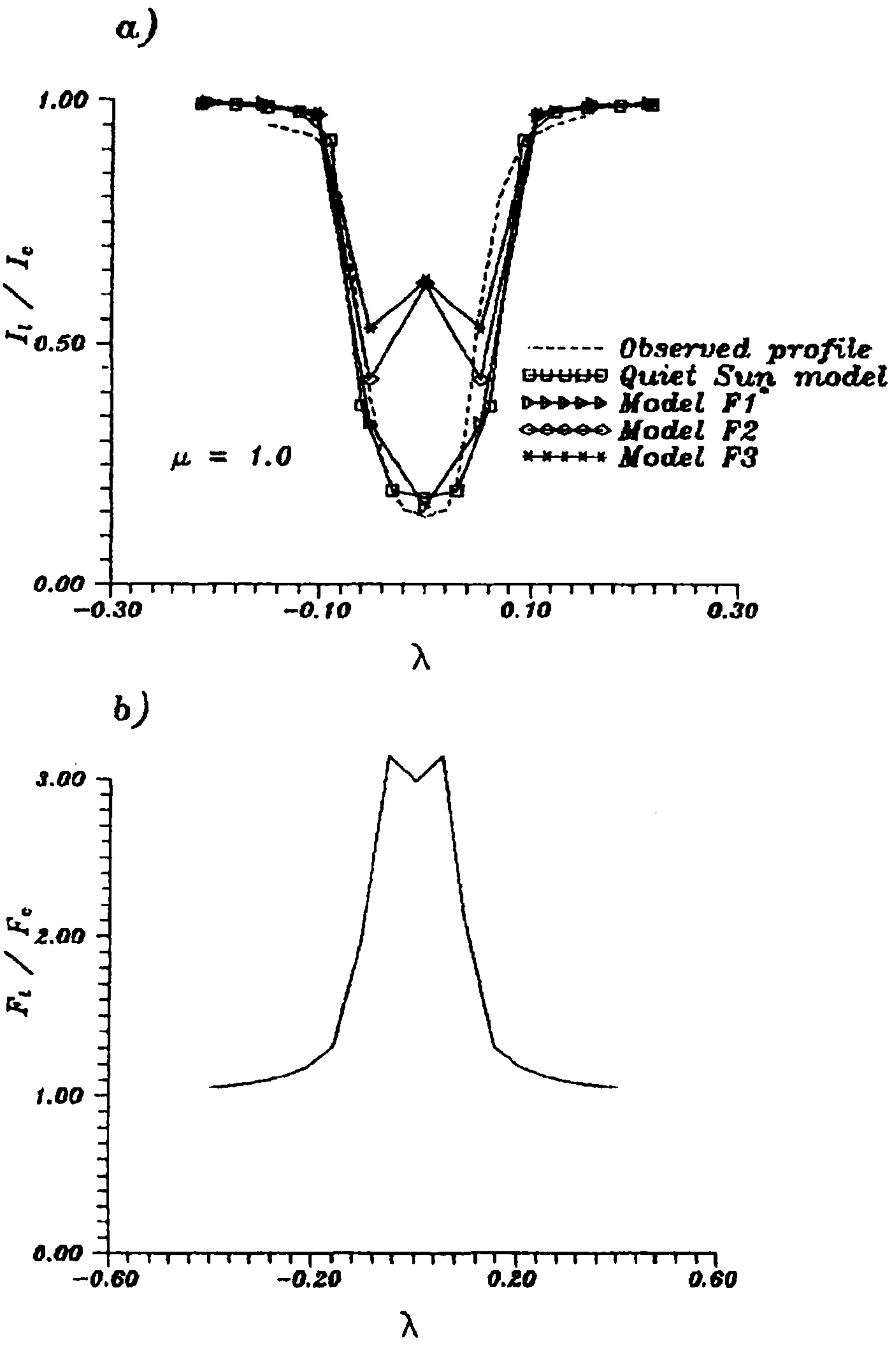

Figure 1 Computed profiles of λ4571Å for *a*, Sun models and *b*, a TTS model. The dotted line is the observed profile of the quiet Sun.

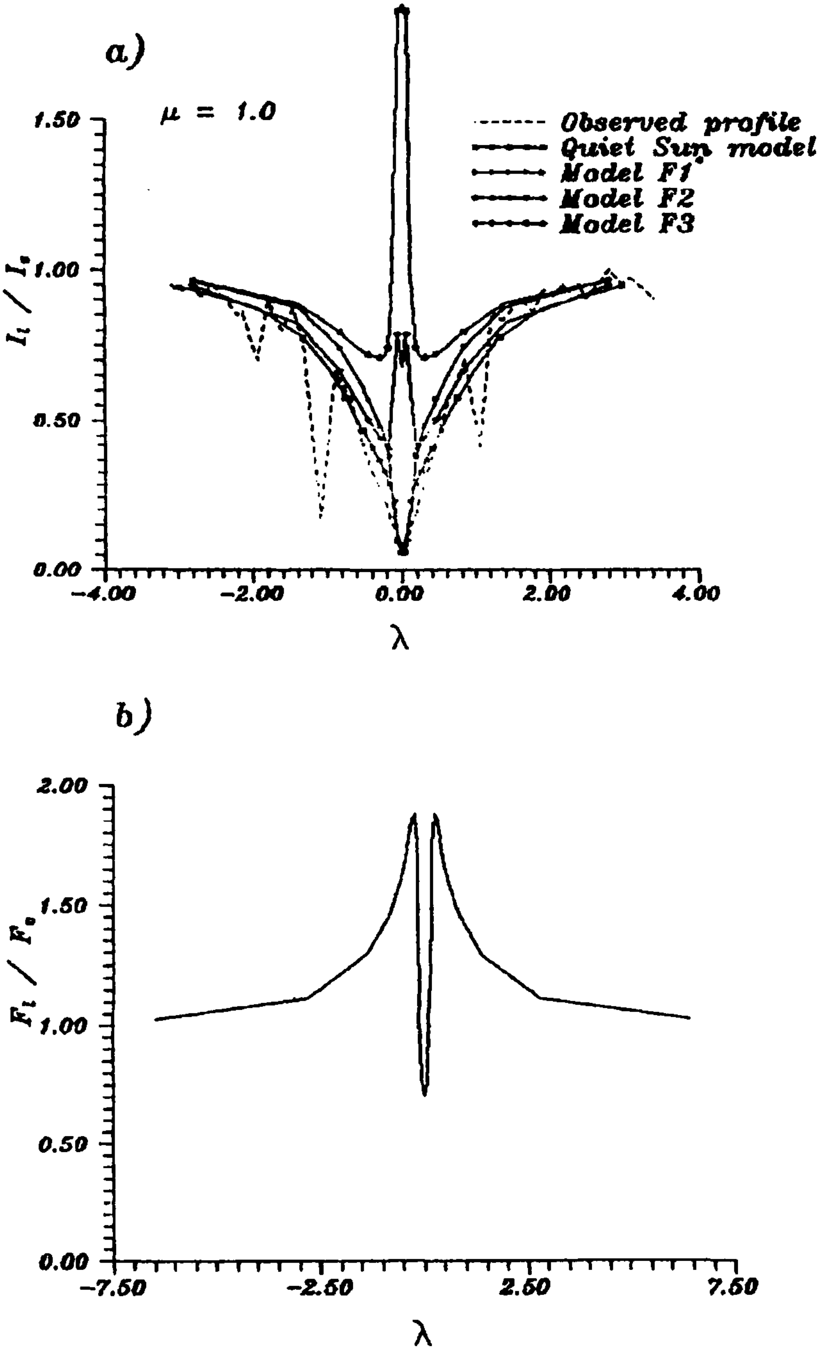

Figure 2 Computed profiles of λ5173Å for *a*, Sun models and *b*, a TTS model. The dotted line is the observed profile of the quiet Sun.

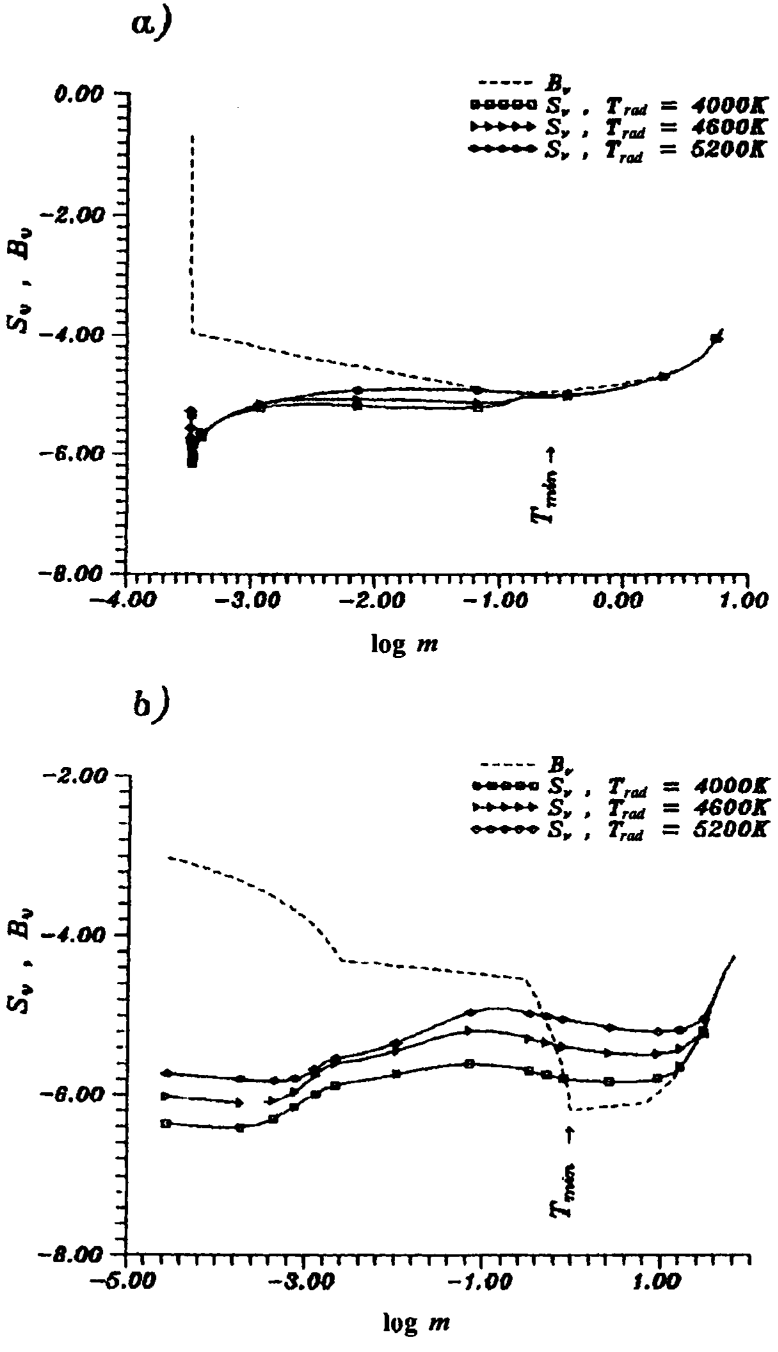

Figure 4 Source function (S_ν) and Plank function (B_ν) for λ5173Å. *a*, Solar flare model $F1^*$ and *b*, TTS model. $T_{\rm min}$ is temperature minimum region.

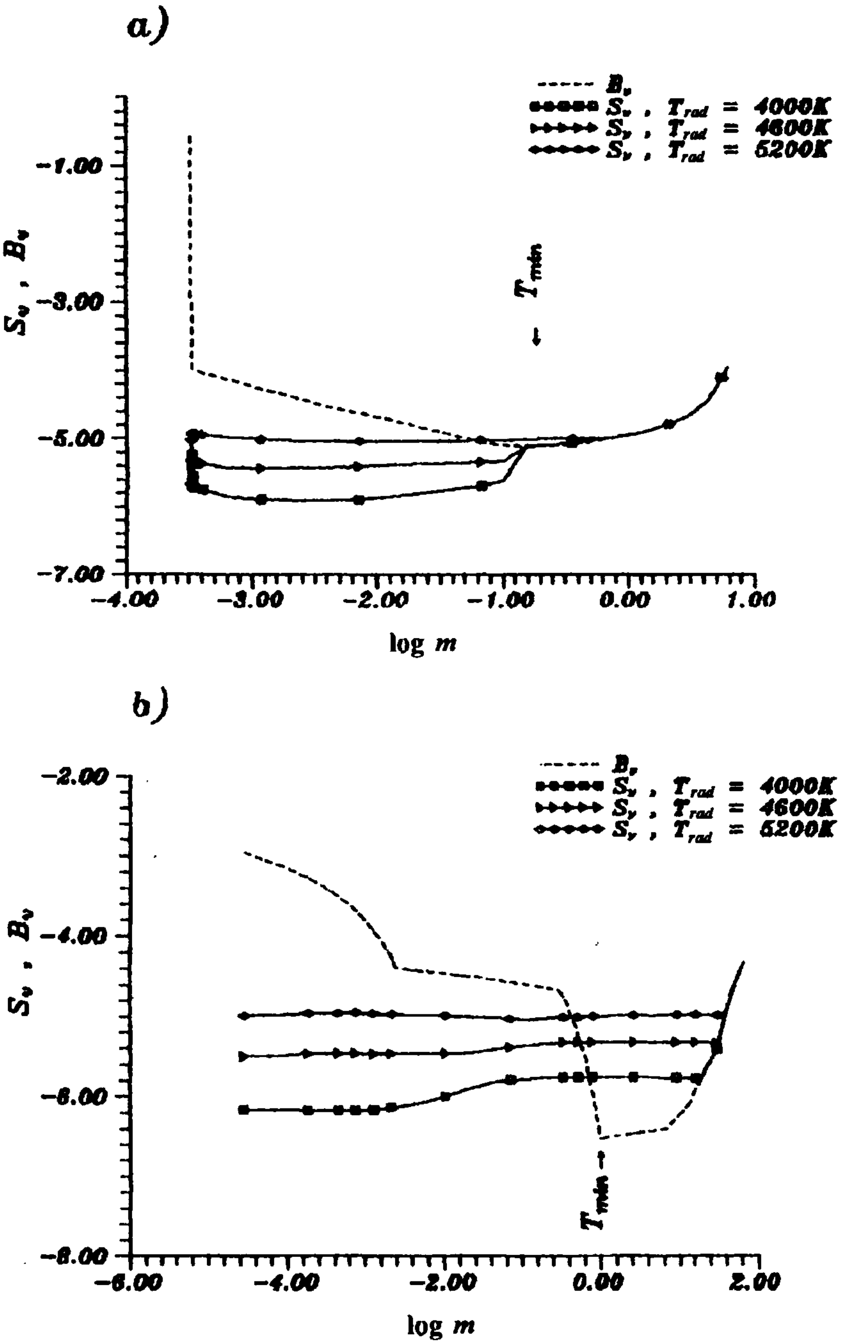

Figure 3 Source function (S_ν) and Plank function (B_ν) for λ4571Å. *a*, Solar flare model $F1^*$ and *b*, TTS model. $T_{\rm min}$ is temperature minimum region.

Table 1. The values of temperature minimum depth and effective layer of lines on a mass scale for the atmospheric models used

Atmospheric model	*quiet Sun*	*F1**	*F2*	*F3*	*TTS*
Temperature minimum depth, log(m)	−1.29	−0.81	−0.28	−0.28	0.00
Effective layer of line λ4571Å formation, log(m)	−1.19	−1.99	−0.55	−0.56	−1.14
Effective layer of line λ5173Å formation, log(m)	−2.49	−3.27	−2.13	−1.87	−2.83

The λ4571Å is an intercombination line and its energetic levels are strongly controlled by electron collisions. For this reason λ4571Å is termalized in the atmosphere of the quiet Sun. Our calculations confirmed the results of Mauas *et al.* (1988) that the depth of formation of line λ4571Å lies in the region of the temperature minimum in the case of the Sun model.

In the case of solar flares and TTS models the photoionization transitions from Mg I levels are strengthened and λ4571Å is formed in non-LTE conditions. For more detail see below. Also for these models λ4571Å is formed in higher temperature minimum regions (see Table 1). It was also found that the formation layer is strongly dependent on the choice of $T_{\rm rad}$ parameter. With increasing radiation temperature the effective layer of line formation displaces deep into. This is due to the fact that the populations decrease and as a consequence the optical thickness in the centre of this line is reduced.

For the models of atmospheres used the dependence S_ν on the choice of $T_{\rm rad}$ parameter is very strong.

The calculations were made for the following fixed parameters $T_{\rm rad} = 4000$, 4600 and 5200 K. The dependence of source functions on depth for lines $\lambda\lambda$4571, 5173Å is shown in Figures 3 and 4. From drawings it can be seen that S_ν at large depths (from the region of the temperature minimum and below) behaves as the Planck function (the given behaviour is observed much more strongly in the case of TTS). With increasing $T_{\rm rad}$ the source function rises and acquires a more flat character for line λ4571Å, but this is not observed for line λ5173Å (see Figures 3 and 4).

4 CONCLUSIONS

During this study the following results were achieved.

(1) Confirmation that, as established by Mauas *et al.* (1988), line λ4571 Mg I is formed in the region of temperature minimum for the atmosphere of the quiet Sun and its source function is strongly termalized, i. e. the LTE approach is applicable.

(2) In the case of the more dense atmospheres of solar flares and TTS line $\lambda 4571$ Mg I is formed higher than the temperature minimum and for this line the LTE-approach is not applicable.

(3) In all the atmospheres investigated the strong dependence of the source function of line $\lambda 4571$ Mg I on the ionization radiation field is presented. The dependence of the stronger line $\lambda 5173$ Mg I is less marked.

(4) Small distinctions between calculated and observed profiles of $\lambda\lambda 4571$, 5173 Mg I lines in the spectrum of the quiet Sun are evident. This highlights the need for further improvement of the atomic data and damping parameters of these lines obtained by Mauas *et al.* (1988).

(5) The intensity of $\lambda 4571$ Mg I is controlled by photoionization processes in solar flares and TTS chromospheres. The comparison of computed and observed profiles of line $\lambda 4571$ Mg I in the atmospheres of stars and the Sun can provide information about ionization radiation in these objects.

Acknowledgements

The authors express their sincere thanks to Professor N. A. Sakhibullin and reviewers for a number of valuable remarks and stimulating criticisms. The work was supported by RFFI Grant No. 95–02–03553.

References

Avrett, E. H., Machado, M. E., and Kurucz, R. L. (1986) *The Lower Atmosphere of Solar Flares*, National Solar Observatory **111**, 216.
Calvet, N., Basri, G., and Kuhi, L. (1984) *Astrophys. J.* **277**, 725.
Carlsson, M. (1986) *Uppsala Astron. Obs. Spec. Rep.*, No. 33, 1–33.
Maltby, P., Avrett, E. H., Carlsson, M., Kjeldseth-Moe, O., Kurucz R. L., and Loeser, R. (1986) *Astrophys. J.* **306**, 284.
Mauas, P. J., Avrett, E. H., and Loeser, R. (1988) *Astrophys. J.* **330**, 1008.