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Detection of circumstellar dust shell around supergiant TV Gem from milliarcsecond resolution near infrared observations

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Abstract. The M1 supergiant TV Gem has been observed at 2.2 μm by lunar occultation technique. The central star has been resolved from our observations. We have also detected the circumstellar dust envelope around this star from our light curve. The detected circumstellar dust envelope has an radius of ~ 20 R_H with star to shell flux ratio of ~35 at 2.2 μm. A simple radiative transfer dust shell model constrained by our occultation observations, 9.7 μm silicate emission feature strength and far IR excess seen in IRAS observations shows that the dust is probably restricted to two well separated dust shells – the inner shell is at a radial distance of ~20 R_H and the outer one is at ~500 R_H. Sporadic dust condensation in TV Gem is suggested, which might be a general phenomena in late type supergiants.

1. Introduction

High Angular Resolution (HAR) observations of evolved giants and supergiants in the infrared can answer some of the most interesting questions related to grain condensation, mass loss and hence stellar evolution. Lunar occultation is a powerful and productive technique at present for achieving HAR particularly in the near infrared region, because of the reduced background of scattered moonlight compared to the optical region. The technique consists of recording the straight edge diffraction pattern of the starlight produced by the sharp edge of the moon and obtaining HAR by mathematical modelling. The most attractive aspect of the method is its ability to achieve high one dimensional angular resolution down to 1 - 2 mas with an accuracy which can be as high as ~ 0.1 mas. However careful consideration of various factors like optical bandwidth of the filter used, telescope aperture and time constant of recording system that influence the occultation light curve is necessary before such HAR can be achieved in practice.

A program of observing lunar occultations in the near infrared (1 - 5 μm) is in progress at the Physical Research Laboratory, Ahmedabad, India to investigate the circumstellar dust envelope around late giants and supergiants. Several occultations have been successfully observed mainly in the K band. A rare opportunity to observe the lunar occultation of M1 supergiant TV Gem was successfully utilized. In this paper we report the detection of a circumstellar dust shell around the star consistent with the strong silicate emission feature and far infrared excess seen in IRAS observations.

2. Observations

The lunar occultation observations presented here were carried out at the 0.75 m telescope at Kavalur (78°, 49' 45"E, 12° 34' 35"N, 725 m) during early 1993. Event prediction was computed with a code developed by us which is accurate to few seconds. The occultation event reported here was a disappearance event at the dark limb of the moon.

The instrument used was a LN_2 cooled InSb based high speed infrared photometer. Occultation event reported here was observed in the standard K filter ($\lambda = 2.2\ \mu m$, $\Delta\lambda = 0.4\ \mu m$). A 2 mm circular diaphragm was used which corresponds to 42" field on the sky. Data sampling was at a rate of 1 KHz for 30 seconds using a 16 bit high speed A/D converter (Keithley system 575). The absolute timing of the event was not recorded, since it is not relevant for the present work.

3. Data analysis

Data analysis was performed using two different methods. The first method is the standard nonlinear least squares (NLS) technique and the second method is a model independent algorithm (MIA). In the case of NLS, a model is assumed for the one dimensional brightness distribution of the source (along the direction of occultation) with a set of physical parameters and the problem is to obtain best statistical estimations for these parameters along with other scaling parameters like source intensity, background intensity, velocity component of the moon along the direction of occultation and the time of geometric occultation.

The data reduction using NLS method can be used to model complicated geometry for the stellar photosphere and the circumstellar dust envelope. However, the NLS method demands the knowledge of the geometry of the source which is not always possible in practice. In such cases, MIA can be advantageously used. MIA is a composite algorithm which makes use of the NLS method and Lucy's deconvolution algorithm wherein a guess profile is assumed for the brightness profile of the source and is iteratively modified to obtain a better fit for the data.

4. Discussion

TV Gem is a distant oxygen rich supergiant classified as M1 lab. It is a short period semi regular pulsating variable of variability type SRc with a period of 182 days. The distance is estimated to be 1200pc. The circumstellar gaseous environment of TV Gem has been studied in the CO (1 – 0) and CO (2 – 1) lines in the millimeter region. From the CO velocity profile, an expansion velocity (V_e) of 12 km/s has been derived. The mass loss rate ($\dot{M} \alpha\ V_e^2\ d^2$) for a distance of 1200pc to the source is $2 \times 10^{-6}\ M_O\ yr^{-1}$, assuming a $[CO/H_2]$ ratio of

5 x 10^{-4} typical of oxygen rich starts. The 9.7 μm silicate emission feature seen in IRAS LRS and the infrared excess present in the IRAS photometric data for TV Gem unambiguously points to the presence of dusty circumstellar shell.

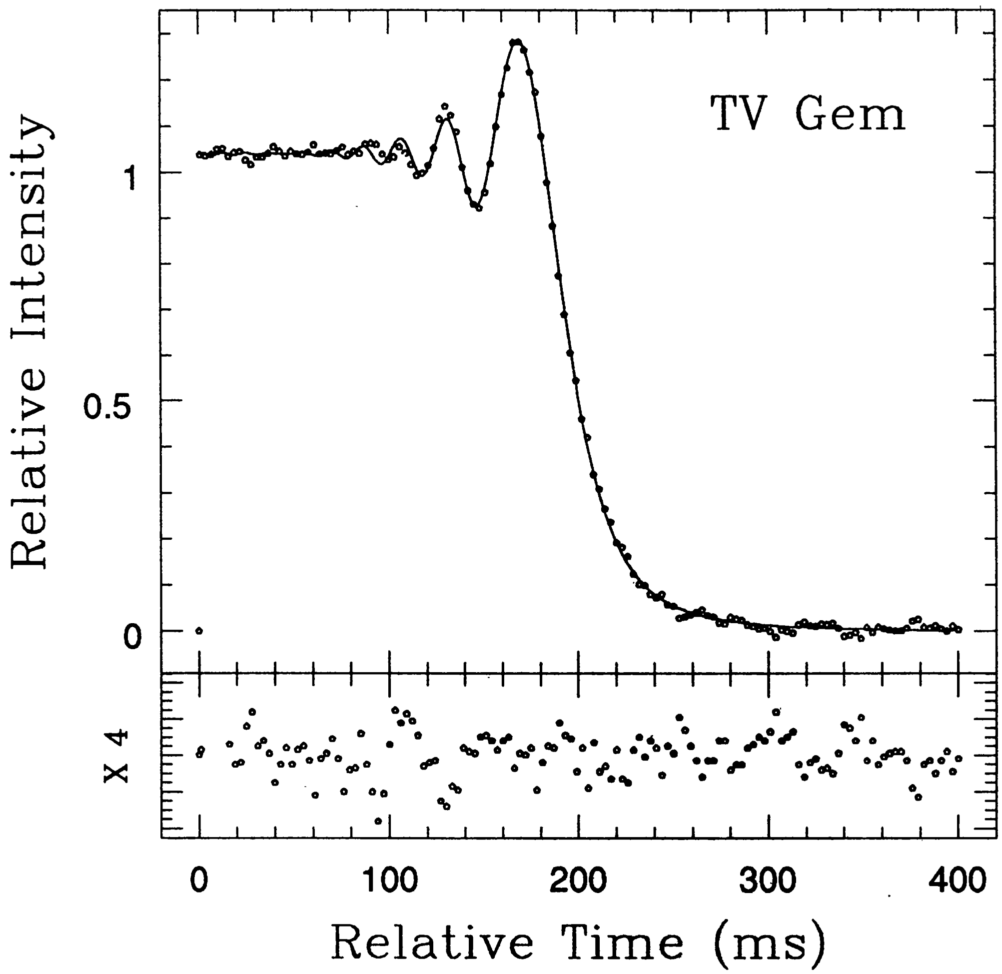

Figure 1. Occultation light curve of TV Gem (dots) fitted using MIA (solid line) is shown in the upper panel. Lower panel shows the residuals of the fit enlarged by a factor of 4.

The observed light curve fitted using MIA is shown in Fig. 1. The recovered brightness profile is fairly symmetric. For the best fit model we derive the FWHM of the shell extent to be 100 ± 20 mas and the star to shell flux ratio at 2.2 μm to be 35. The stellar angular diameter can be accurately determined in this two component model. This value is 4.9 ± 0.3 mas. From the above angular size and bolometric flux obtained from available photometric data, we derive an stellar effective temperature of 3670 ± 125K.

To examine the dust distribution around TV Gem in the light of our occultation observations, an analysis of the 9.7 mm silicate feature exhibited by this star and the far infrared shell flux has been carried out using a simple rediative transfer model of an optically this isothermal shell. We find that the dust exists mainly in two well separated shells suggesting that the dust exists mainly in two well separated shells suggesting that the dust condensation in TV Gem is not a continuous process. Out observations, in conjunction with infrared spatial interferometric observations of multiple shells on a similar supergiant α Ori, suggest that mass loss and the consequent dust condensation is probably a sporadic process operating over a time scale of a few decades in late type supergiants.

Conclusions

We have investigated the circumstellar environment around the supergiant TV Gem from milliarcsecond resolution observations in the near infrared using lunar occultation technique. Accurate estimation of stellar angular diameter and effective temperature are made from our observations. Occultation light curve reveals the presence of a warm dust zone in the region 15 – 20 RH. In addition, another cooler shell at ~ 500 RH is needed to explain the IRAS photometric data, particularly at 60 mm. The presence of dust in two isolated shells suggests an episodic or sporadic mass loss in TV Gem.

Acknowledgements

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