L AND M BAND INFRARED STUDIES OF V4332 SAGITTARII: DETECTION OF THE WATER ICE ABSORPTION BAND AT 3.05 μm AND THE CO FUNDAMENTAL BAND IN EMISSION

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ABSTRACT

L and M band observations of the nova-like variable V4332 Sgr are presented. Two significant results are obtained, viz., the unusual detection of water ice at 3.05 μm and the fundamental band of 12CO at 4.67 μm in emission. The ice feature is a first detection in a nova-like variable, while the CO emission is rarely seen in novae. These results, when considered together with other existing data, imply that V4332 Sgr could be a young object surrounded by a circumstellar disk containing gas, dust, and ice. The reason for a nova-like outburst to occur in such a system is unclear. But since planets are believed to form in such disks, it appears plausible that the enigmatic outburst of V4332 Sgr could be due to a planetary infall. We also give a more reliable estimate for an epoch of dust formation around V4332 Sgr that appears to have taken place rather late in 1999—nearly 5 years after its outburst.

Subject headings: infrared: stars — novae, cataclysmic variables — stars: individual (V4332 Sagittarii) — techniques: spectroscopic

1. INTRODUCTION

We present here L and M band results on V4332 Sgr. Recent studies of V4332 Sgr have shown that it is an interesting object, and the present results further support this view. V4332 Sgr erupted in 1994 in a nova-like outburst with an outburst amplitude of 9.5 mag in the visible region. There was only one detailed study of the object during its outburst (Martini et al. 1999), which showed that its eruption was different from that of a classical nova or other classes of eruptive variables. Interest in the object has been rekindled because of the recent outburst of V838 Mon, which drew considerable attention because of its light echo (Munari et al. 2002; Bond et al. 2003). It is believed that V838 Mon, V4332 Sgr, and M31 RV (a red variable that exploded in M31 in 1988; Rich et al. 1989) could be members of a new class of eruptive objects (Munari et al. 2002; Bond et al. 2003; Kimswenger et al. 2002). The cause of the outburst in these objects does not appear to be satisfactorily explained by conventional mechanisms. Thus, new theories have been proposed, viz., a scenario involving the merger of main-sequence stars (Soker & Tylenda 2003) and a hypothesis invoking planetary capture by an expanding star to explain the eruption (Retter & Marom 2003). The present data indicate that the second mechanism could be viable in V4332 Sgr.

Recent infrared studies of V4332 Sgr have detected several bands of AlO at a low rotational temperature of 200–300 K (Banerjee et al. 2003). A considerable change in the spectral energy distribution (SED) of the object was seen between Two Micron All Sky Survey (2MASS) data of 1998 and observations in 2003 indicating the formation of a dust shell between these two epochs (Banerjee et al. 2003). A better estimate of the epoch when the dust actually formed is discussed here. Optical spectroscopy of V4332 Sgr in 2003 showed an interesting spectrum dominated by very strong emission in the resonance lines of K i and Na i (Banerjee & Ashok 2004). The SED of the star, derived from optical and IR data, indicated a central star with a blackbody temperature of 3250 K and an IR excess attributed to a dust component at ~900 K (Banerjee & Ashok 2004).

2. OBSERVATIONS

Observations were done using the 3.8 m UK Infrared Telescope (UKIRT). Spectroscopy was done using the UKIRT 1–5 μm Imager Spectrometer (UIST), which uses different grisms to cover the 1.4–5 μm range. L′ (3.77 μm) and M′ (4.68 μm) band photometry—not available earlier for V4332 Sgr—was also done using UIST. Flat-fielding, spectral calibration, and other reduction procedures were done on the same lines as our earlier JHK study of V4332 Sgr (Banerjee et al. 2003). The log of the observations and the observed L′ and M′ magnitudes of V4332 Sgr are given in Table 1.

3. RESULTS

3.1. The Water Ice Feature at 3.05 μm and the CO Fundamental Band Emission

Figure 1 shows the spectrum; the A–X bands of AlO in the HK band, reported earlier (Banerjee et al. 2003), are seen prominently in the present spectrum also but are not discussed here. A remarkable feature—never seen before in a nova-like object—is the deep, solid-state 3.05 μm water ice band formed as a result of the O–H stretching mode. At very low temperatures, atoms and molecules can collide and adhere to a dust grain to produce an ice mantle on the surface. Atoms can migrate from one site to another on the mantle to form a molecule—water ice is believed to form this way with H atoms combining with an O atom. The presence of cold water ice around V4332 Sgr is extremely unexpected since the ejecta of classical novae generally evolve to high temperatures of ~106 K (the coronal phase). Following a standard procedure, we have obtained the optical depth plot of the ice feature by fitting a polynomial to the continuum around it (Gibb et al. 2004). The depth of the ice feature below this continuum was found and converted to an optical depth. The