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Research Note

Is KT Mon a classical nova?

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Abstract. KT Mon has been considered as a classical nova in 1942 based on its light curve and spectroscopy. However, we noticed a unusual feature for a nova soon after its maximum: the early presence of high excitation emission lines such as HeII and NIII. We propose previously overlooked interpretations that KT Mon can be either a WZ Sge-type dwarf nova and an X-ray transient, although the possibility of an unusual or a recurrent nova is not completely excluded. If KT Mon is a WZ Sge-type dwarf nova, the system is expected to have a brown dwarf secondary. If KT Mon is an X-ray transient, the system is a good candidate for the nearest black-hole binary. Within our knowledge, the observed features seem to more strongly support the latter possibility. In all possibilities, we can expect a recurrent outburst in meaningfully near future.

Key words. accretion, accretion disks – novae, cataclysmic variables – stars: dwarf novae – X-rays: bursts – stars: individual: KT Mon

1. Introduction

KT Mon (Nova Mon 1942) was discovered by A. N. Vyssotsky on a Harvard plate taken on 1943 January 2. The object was first recorded at $m_{\rm pg}$ = 10.3 on 1942 December 30. Gaposchkin (1954) presented a light curve and a description of a spectrum taken by Vyssotsky on the discovery plate. According to Gaposchkin (1954), the object rather rapidly faded (2 mag in 27 d). The object was fainter than $m_{\rm pg}$ = 13.35, 13.9 d prior to the first positive record on 1942 December 30. Gaposchkin (1954) described the low-resolution spectrum by Vyssotsky as "broad bright lines Hβ, Hγ, Hδ, 4686 HeII and 4640 NIII". From these findings, Gaposchkin (1954) concluded that KT Mon is a nova. Duerbeck (1987) classified the object as an established moderately fast nova.

However, several authors have noted the peculiarity of KT Mon. Payne-Gaposchkin (1977) deduced the distances of past novae, and found three stars (KT Mon, CG CMa and WX Cet) are more than 15 kpc distant from the Galactic Center. The two objects in this list, CG CMa (Kato et al. 1999; Duerbeck et al. 1999) and WX Cet (Bailey 1979; O'Donoghue et al. 1991; Kato et al. 2001) are now established to be SU UMa-type dwarf novae (For a recent review of dwarf novae and SU UMa-type dwarf novae, see Osaki 1996 and Warner 1995, respectively.) Regarding KT Mon, Payne-Gaposchkin (1977) described that "KT Mon: whose spectrum observed by Vyssotsky, and whose light curve obtained by Gaposchkin (1954) place it unequivocally as a nova" and suggested that "further study might find KT Mon to be recurrent" based on this unusual distance estimate. Similar long-distance estimates have been given in Warner (1987); Shafter (1997). No quiescent counterpart has been reported down to mag 20 (Duerbeck 1987).

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2. Overlooked unusual features of KT Mon

In addition to the unusually long distance estimate (Payne-Gaposchkin 1977), which originally questioned the classical nova-nature of KT Mon, we further noted a previously overlooked peculiarity from the available material.

The early presence of high excitation lines, particularly HeII λ4686 and NIII λ4640, is unusual for typical development of nova spectra (Payne-Gaposchkin 1957; Bode & Evans 1989; Williams 1992), since strong appearance of NIII λ4640 Bowen brend requires high-energy photons (van Paradijs & McClintock 1995). Such a condition is hard to achieve during the early stage of a classical nova outburst when thermal emissions from a lower ($\sim 10^4$ K) temperature expanded atmosphere of the white dwarf dominates. High-excitation emission lines can appear when the contracting nova (pseudo)photosphere reaches $T_{\rm eff} \sim 2.5 \times 10^4$ K (see e.g. Bode & Evans 1989 Chap. 5), which then produces sufficient high-energy UV photons. This condition is expected to be achieved at ~2.5 mag below the optical maximum, which agrees with the general observational records (Williams et al. 1994). From an examination of photographic records of past nova spectra, these lines were reported to appear at around 4 mag below the optical maximum. Only a few very fast novae (e.g. V2487 Oph, Filippenko et al. 1998) and fast recurrent novae (e.g. U Sco, Sect. 3.1) are known to exhibit these high-excitation lines soon after their maxima, which are presumably caused by an unusually thin ejecta. Since the decline rate of KT Mon was not particularly fast, this object apparently did not achieve this condition at the time of Vyssotsky's observation.

A relatively large (~1.5) color index (blue-red) inferred by Gaposchkin (1954) also needs to be reexamined. Taking into the recent observation of Hα flux of post-outburst novae (Ciardullo et al. 1990) into account, the contribution of the Hα line to the R band is estimated to ~1.0 mag. Although much of the originally reported color index was tentativity attributed to interstellar reddening in interpreting KT Mon as being a classical nova (Payne-Gaposchkin 1977; Shafter 1997), a more recent estimate of the maximum reddening in this direction $E(B-V) = 0.545$ or $A_V = 1.806$ (Schlegel et al. 1998) suggests that the observed color more strongly reflects the contribution of the Hα emission line. If the ejecta was indeed unusually thin as in recurrent novae, the contribution of the Hα line, however, might be insufficient (cf. Sekiguchi et al. 1988) to explain the overall color index.

3. New interpretations

In recent years, more categories of eruptive objects have been identified to show high-excitation emission lines during their early stage of outbursts: U Sco-type recurrent novae (Rosino & Iijima 1988; Sekiguchi et al. 1988; Iijima 2002), WZ Sge-type dwarf novae (Baba et al. 2002; Kuulkers et al. 2002) and X-ray transients (Tanaka & Shibazaki 1996; van Paradijs & McClintock 1995). Considering the strong expected impact if KT Mon indeed belongs to any of these objects, we further examine these possibilities.

First of all, we have performed the prenova search with available plate scans (the DSS1 red, the DSS2 red, blue, infrared) and available catalogs in the VizieR service. Gaposchkin (1954) gave a position of nova as $6^h19^m58\overset{s}{.}8$, $+5°29'46''$ (equinox 1900), which precesses to $6^h25^m18\overset{s}{.}9$, $+5°26'28''$ (J2000.0). Duerbeck (1987) reexamined the Harvard plates and give the position as $6^h25^m18\overset{s}{.}46$, $+5°26'31\overset{''}{.}7$. Duerbeck (1987) further indicated that the identification by Khatisov (1971) (who used the crude GCVS position for identification) with a GSC-cataloged star having position end figures $19\overset{s}{.}69$, $32\overset{''}{.}88$ (GSC 2.2.1) is incorrect. Taking this indication into consideration, the position of Duerbeck (1987) must have an accuracy better than 10″. We confirmed that there is no promising optical, IR, and X-ray counterpart within 10″ from the Duerbeck (1987) position. We have thus confirmed the safe upper limit of the quiescent KT Mon to be $V = 20$.

3.1. Recurrent nova?

This possibility was originally considered by Payne-Gaposchkin (1977), but has been overlooked to date. Since the outburst amplitude of KT Mon is larger than 10, we can safely exclude the possibility of a recurrent nova with a giant secondary (Anupama & Mikolajewska 1999). The remaining possibilities are a U Sco-like object or an IM Nor/CI Aql-like object (Kiss et al. 2001; Matsumoto et al. 2001; Kato et al. 2002b). The former class represents extremely rapidly evolving novae and the latter slower ones. The reported light curve of KT Mon (Gaposchkin 1954) (decline by 2 mag in 27 d) more suggests the latter class. However, the spectroscopic feature of KT Mon (presence of the HeII emission line) does not resemble the early spectra of IM Nor and CI Aql (see Kiss et al. 2001; Matsumoto et al. 2001), which did not show high excitation lines. Since the difference between these classes can be primarily attributed to the mass of the white dwarf (Hachisu et al. 2000a; Hachisu & Kato 2001), there still remains the possibility that KT Mon is essentially a U Sco-type object, with a slightly less massive white dwarf.

Based on modern calculations (Hachisu et al. 2000a, b), the optical maximum of U Sco corresponds to $M_V = -6.4 \pm 0.4$. By assuming $0 \le A_V \le 1.8$, and the same peak maximum M_V as in U Sco, the range of acceptable distance of KT Mon becomes $6 \le d \le 26$ kpc. This range can only slightly reduce the Galactocentric distance questioned in Payne-Gaposchkin (1977). Even if the distance is acceptable, the upper limit quiescent $M_V = +3.3 \pm 0.4$ is hard to accept for a recurrent nova which requires a high accretion rate (Hachisu et al. 2000b). If KT Mon is indeed a recurrent nova, there is a need for a special unidentified mechanism to reduce the quiescent luminosity.

3.2. WZ Sge-type star?

It has been now widely demonstrated that some of WZ Sge-type dwarf novae show strong HeII and CIII/NIII emission lines during their outbursts. There properties are not inconsistent with the existing observation of KT Mon. Since KT Mon is 3.3 mag fainter than WZ Sge at maximum, a reasonable upper limit of $d \le 200$ pc can be derived from the recent distance estimate of WZ Sge (45 pc, J. Thorstensen 2001, cited in Steeghs et al. 2001). If this interpretation is correct, the quiescent upper limit of KT Mon corresponds to $M_V = +13.5$. This value is not inconsistent with a recent example of a very faint WZ Sge-type object (van Teeseling et al. 1999). Although an argument exists regarding the distance of V592 Her itself (Kato et al. 2002a), $M_V = +13.5$ is not incompatible with a combination of a binary with a cool white dwarf and a brown dwarf (van Teeseling et al. 1999). If KT Mon belongs to WZ Sge-type dwarf novae, this object is a strong candidate for a close binary containing a brown dwarf.

This interpretation may seem to show a difficulty in interpreting the reported large color index (Gaposchkin 1954) in its late-stage light curve. In recent years, however, WZ Sge-type dwarf novae can become exceptionally red ($B - R \sim +1.0$ has been reported, see e.g. Patterson et al. 1998) during the late stage of their outbursts. This red color may explain some part of the color index reported by Gaposchkin (1954). WZ Sge-type dwarf novae are found to frequently show "rebrightenings". In WZ Sge itself, such rebrightenings with amplitudes of 1–2 mag (Ishioka et al. 2002). Since these rebrightenings show a very rapid rise and fall, a scatter in the fragmentary light curve in Gaposchkin (1954) may reflect such a phenomenon.

We also note that V4338 Sgr (Nova Sgr 1990), with similar spectroscopic characteristics to those of KT Mon, has been classified as a possible WZ Sge-type dwarf nova (Wagner et al. 1990).

3.3. X-ray transient?

The presence of strong Balmer and HeII and CIII/NIII emission lines is also very characteristic to X-ray transients (mostly black-hole candidates; see comprehensive reviews van Paradijs & McClintock 1995; Tanaka & Lewin 1995; White et al. 1995). It will be noteworthy that the X-ray transient V404 Cyg = GS 2023+338 (Wagner et al. 1991; Casares et al. 1991) had been considered to be a classical nova based on its 1938 outburst observation (Duerbeck 1987). KT Mon therefore can be an X-ray transient. In particular, the description of the spectrum closely agrees to that of V404 Cyg (Wagner et al. 1991). The decline rate (0.07 mag d^{-1}, see Gaposchkin 1954) is not inconsistent with the statistics of optical properties of X-ray transients (Chen et al. 1997). Since the optical maximum of KT Mon is 0.9 mag brighter than that of the closest "classical" X-ray transient V616 Mon (d = 1.4 kpc, Esin et al. 2000), this interpretation would bring KT Mon to $d \sim 1$ kpc. This possibility makes KT Mon a candidate for a closest black-hole binary. Although a different distance can be acceptable considering wide diversity of properties of X-ray transients (Chen et al. 1997; Mirabel et al. 2001), the strong presence of HeII and CIII/NIII emission lines is more consistent with a high-luminosity X-ray transient. The distance $d \sim 1$ kpc corresponds to a quiescent upper limit of $M_V = +10$. This value is not inconsistent with a short-period system accreting at a very low quiescent accretion rate (cf. van Paradijs & McClintock 1994, 1995). The reported color index is mildly consistent with the reported reddening of V616 Mon $E(B-V) = 0.35$–0.9, Marsh et al. 1994) combined with the redder color during the late stage of outbursts of X-ray transients (e.g. King et al. 1996).

4. Summary

KT Mon has been considered as a classical nova in 1942 based on its light curve and spectroscopy. However, we noticed a previously overlooked unusual feature: the early presence of high excitation emission lines such as HeII. We examine three new possibilities (recurrent nova, WZ Sge-type dwarf nova, X-ray transient). We have found that the possibilities of a WZ Sge-type dwarf nova or an X-ray transient are more consistent with the modern knowledge, although the possibility of a recurrent nova (or a nova with an unusual spectroscopic evolution) is not completely excluded. If KT Mon is a WZ Sge-type dwarf nova, the system should have a brown dwarf. If KT Mon is an X-ray transient, the system is a good candidate for the nearest black hole. In all possibilities, we can expect a recurrent outburst in meaningfully near future (10–100 yr depending on the classification). Detailed observations during the possible next outburst, as well as deep quiescent observations, for this obscure object are strongly recommended.

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