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DISCOVERY OF THE SECOND PG 0943+521-TYPE DWARF NOVA V1159 Ori

This star was discovered to be variable by Wolf and Wolf (1906), called 36.1906, and then suggested by Kippenhahn (1953) to be a possible member of U Gem stars. In the New Catalogue of Suspected Variable Stars (Kukarkin et al. 1982), it was designated as NSV 02011 with a brightness range of $m_{pg} = 13.3 - 14.2$. The subsequent photographic observation by Natsvlishvili (1984) revealed that its magnitude varied from 12.5 at maximum to 16.6 at maximum, and it was finally named V1159 Ori of INS: type in the 68^{th} namelist of variable stars (Kholopov et al. 1987).

Jablonsky and Cieslinski (1992) made spectroscopic and photometric observations and proposed its orbital period of 0.05890 ± 0.00001 days, which suggests that V1159 Ori is a good candidate for an SU UMa star. Their observations, however, could not reveal superoutbursts or superhumps expected for this class of CVs. The peculiar nature of V1159 Ori was already suggested by their estimate of short outburst cycle length of 4.35 days together with its small outburst amplitude. VSOLJ (Variable Star Observers League in Japan) started CCD and visual observations, part of which was published by Kiyota (1993). These observations indicated presence of bright (reaching $m_V \sim 12.1$) outbursts, some of which bore the characteristics of superoutbursts.

The present outburst of V1159 Ori was first detected by the RoboScope, Indiana University Automated Photometric Telescope (Honeycutt and Turner 1992). It was independently discovered on Dec. 23 at m_V=12.9 by M. Yamada (VSOLJ; private communication). We made photometric observations on 1994 Dec. 23 and 24 using CCD camera (Thomson, TH7882CDA, 576 × 384 pixels with 23 μm square pixel size) attached to the Cassegrain focus of 0.6-m reflector with Johnson V-band filter at the Ouda Station, Kyoto University (Ohtani et al. 1992). The mode of 2 × 2 on-chip summation was employed. A total of 225 frames were taken between 23.154 and 23.270 UT under clear sky, and 57 frames between 24.144 and 24.264 UT interrupted for 82 minutes by clouds. The exposure time was 30 seconds on Dec. 23 and varied between 60 and 180 seconds on Dec. 24.

We reduced the data using the personal-computer-based aperture photometry package developed by one of the authors (T.K.). This package automatically subtracts bias-frames, applies flat fielding and enables us to estimate the instrumental magnitudes. The aperture size was 9" in radius. The sky level was determined from pixels whose distance from the individual objects are between 24" to 48".

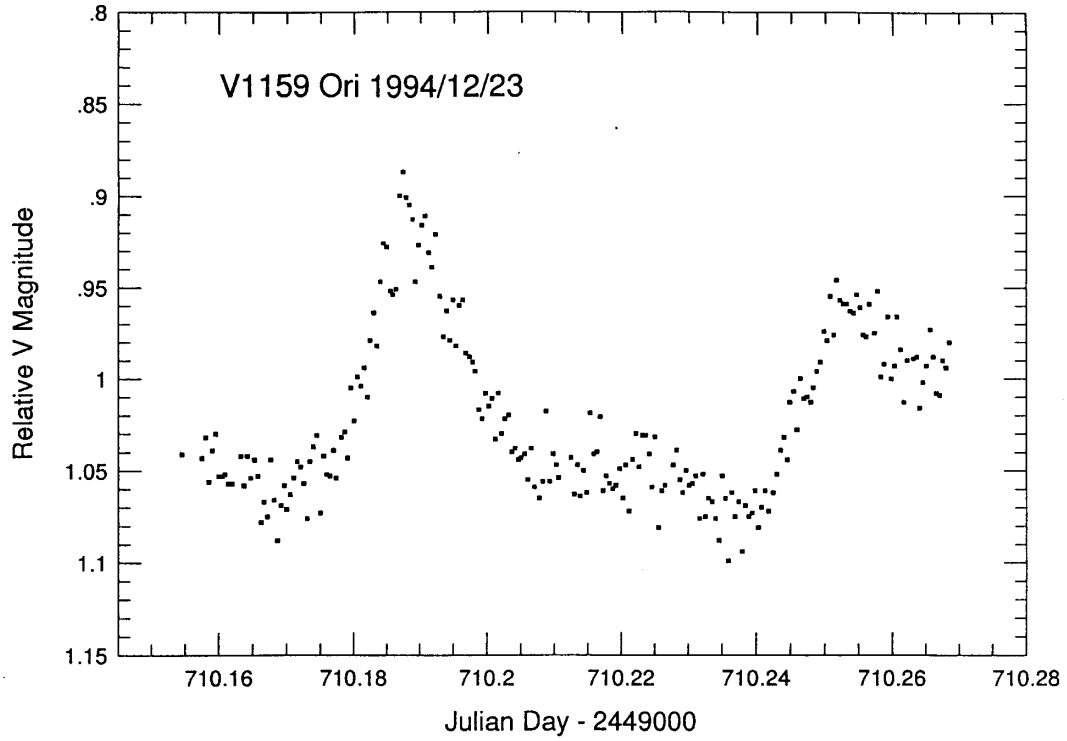

Figure. 1. V-band light curve of V1159 Ori on 1994 Dec. 23. The zero point of the relative magnitudes corresponds to V=11.99.

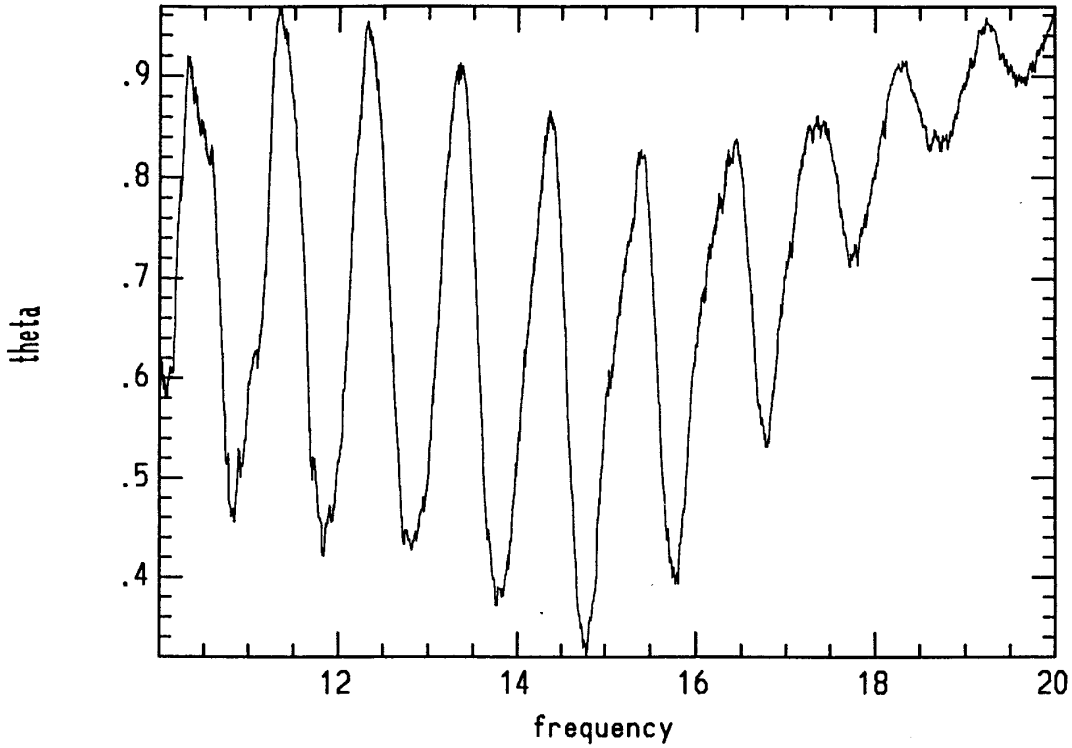

Figure. 2. The theta diagram by PDM on the data of V1159 Ori on 1994 Dec. 23 and 24.

Figure 1 shows the light curve of differential magnitude between V1159 Ori and a comparison star on Dec. 23. The comparison star is "c" in Jablonsky and Cieslinski (1992), whose V magnitude is given as 11.99 in thier Table 1. A decay of amplitude of humps is seen in the figure and the similar modulation was also observed in PG 0943+521 (Nogami et al. 1995). We analysed the light curve, using phase dispersion minimization (PDM) method (Stellingwerf 1978) implemented in IRAF package (IRAF is distributed by National Optical Astronomy Observatories, U. S. A.). Figure 2 shows the Θ diagram, whose abscissa is frequency (day^{-1}). The lowest minimum point in Θ corresponds to 0.06764 days. Robertson et al. (1995) independently detected the same hump features and reported that they are repeated with a period of 0.067 ± 0.001 days.

The difference in the photometric and spectroscopic periods confirmed the superhump nature of these humps. The outburst observed by Jablonsky and Cieslinski (1992) did not show superhump-like modulation and corresponds to normal outburst of usual SU UMa-stars. Thus, V1159 Ori was unambiguously identified to be an SU UMa-type dwarf nova with a superhump period of 0.06764 ± 0.0001 days. The present discovery of superhumps in V1159 Ori, together with its extreme shortness of its outburst recurrence time, its long duty cycle (Jablonsky and Cieslinski 1992, Kiyota 1993), and its extremely short supercycle (recurrence time of superoutbursts) (Robertson et al. 1995), has established a new subgroup of peculiar dwarf novae whose prototype is PG 0943+521 (Kato and Kunjaya 1995, Misselt and Shafter 1995, Osaki 1995).

The fact that the supercycle of V1159 Ori (44.5 days, Robertson et al. 1995) is almost equal to that of PG 0943+521 (43 days) is possibly not accidental. According to Osaki (1995), the shortest supercycle predicted by disk-instability theory under a given strength of the tidal torques is about 40 days and the supercycle is insensitive to the mass transfer rate from the secondary around this minimum value. However, as first pointed out in the case of PG 0943+521 by Kato and Kunjaya (1995) and later confirmed by numerical simulation by Osaki (1995), a dwarf nova with minimum supercycle length should have much ($\sim$ ten times) larger mass transfer rate than those of usual SU UMa-type dwarf novae, near the borderline between nova-like stars and SU UMa-type dwarf novae. For a dwarf nova with an orbital period below the period gap, it is generally believed that its mass transfer is powered by the gravitational-wave radiation, that is, its rate is mainly dependent on the orbital period. The shortness of the orbital period of V1159 Ori (0.05890 days, Jablonsky and Cieslinski 1992) and the superhump period of PG 0943+521 (0.06549 days, Kato and Kunjaya 1995) implies small mass transfer rates in the present scheme of CVs, which are clearly in conflict with such large mass-transfer rate expected from their outburst behavior.

The present discovery of "another" PG 0943+521 star suggests that this type of CVs may not considered to be unique but form a larger population in CVs than ever expected. In this case, the present picture of the mechanism of mass transfer and the evolution of CVs below the period gap would unavoidably be modified.

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Daisaku NOGAMI
Taichi KATO
Seiji MASUDA
Ryuko HIRATA
Dept. Astron., Faculty of Sci.
Kyoto University
Oiwake-cho, Kitashirakawa
Sakyo-ku, Kyto 606-01 Japan

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