The 2003/2004 Superoutburst of SDSS J013701.06-091234.9

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Abstract

We report on time-resolved photometry of the superoutburst of an SU UMa-type dwarf nova, SDSS J013701.06-091234.9 in 2003 December-2004 January. The obtained light curves definitely show superhumps with a period of 0.056686 (12) d, which is one of the shortest superhump periods among those of SU UMa-type dwarf novae ever observed. Considering quiescent photometric studies, we estimated the fractional superhump excess to be 0.024. Spectroscopic observations by Szkody et al. (2003) provided evidence for TiO bands despite the short orbital period, implying that the system has a luminous secondary star. We draw a color-color diagram of SU UMa-type dwarf novae in quiescence using 2MASS archives, revealing that the location of this star in the color-color diagram is deviated from the general trend. The distance to the system was roughly estimated to be 300±80 pc, using the empirical period-absolute magnitude relation and based on the proper motion.

Key words: accretion, accretion disks — stars: dwarf novae — stars: individual (SDSS J013701.06-091234.9) — stars: novae, cataclysmic variables — stars: oscillations

1. Introduction

Dwarf novae are a subclass of cataclysmic variables that consist of a white dwarf primary with an accretion disk and a Roche-lobe-filling late type secondary star (for a review, see Warner 1995, Hellier 2001).

SU UMa-type stars are a subclass of dwarf novae exhibiting two types of outburst: normal outbursts lasting for a few days and superoutbursts for weeks, during which ~ 0.2 mag modulations called superhumps are always observed. Many models have been proposed in order to explain outbursting properties for SU UMa-type dwarf novae. The most promising one is the thermal-tidal instability model (for a review, see Osaki (1989)) that is also supported by observations.

Most cataclysmic variables below the period gap are believed to evolve towards short orbital periods due to gravitational-wave radiation. Minimum of the orbital period of CVs (usually referred to as period minimum) has been proposed to be around 65 min (Kolb, Baraffe 1999). It is expected that near the period minimum, where the secondary begins to degenerate, the inversion of mass-radius relation causes the orbital period to become longer with evolution. Some authors claim that WZ Sge-type dwarf novae, which is a subtype of SU UMa-type dwarf novae, may have experienced the inversion (Patterson et al. 2005). It is widely accepted that most of CVs below the period gap continue the above mentioned standard evolutional sequence.

Recently, theory predicts another evolutional sequence for CVs (Baraffe, Kolb 2000, Podsiadlowski et al. 2003). Given a certain range of mass for the primary and the secondary, the secondary does not become fully convective in its interior, which leads the secondary to have perpetual magnetic braking even below the period gap. As a consequence, the orbital period can become shorter than even the theoretical period minimum. AM CVn stars (Nelemans 2005), whose orbital periods are less than 60 min, are the most promising systems that experienced the aforementioned scenario. EI Psc (= 1RXS J232953.9+062814, Wei et al. 2001, Uemura et al. 2002, Thorstensen et al. 2002a, Skillman et al. 2002, Zhou,
Qiu 2002) and V485 Cen (Olech 1997) may be possible candidates for the progenitor of AM CVn stars.

SDSS J013701.06-091234.9 (hereafter J0137) was first identified as a cataclysmic variable by Szkody et al. (2003). Optical spectroscopy for J0137 showed double-peaked Hα profiles, as well as TiO bands. Radial velocity studies exhibited a periodicity of 84 min.

An eruption of J0137 had been only recorded by the All Sky Automated Survey (Pojmanski 2002) as ASAS 013701-0912.6 until the 2003 December outburst was caught. The first recorded data showed that the object brightened up to 12.6 in V band on 2001 May 27, then gradually faded down to 13.4 on June 9, 2001, and finally became below the detection limit on June 20, 2001.

When light curves showed superhumps with an amplitude of 0.2 mag, confirming J0137 as an SU UMa-type dwarf nova.

During quiescent photometric observations of J0137, Pretorius et al. (2004) serendipitously discovered a brightening of the object at HJD 2452993.67590 with a magnitude of V = 12.8, while on HJD 2452991.64767 the magnitude was below the detection limit. Thus the time of the maximum brightness is restricted to be on HJD 2452994 or HJD 2452995.

The plateau stage of the superoutburst lasted more than 2 weeks. The value is slightly longer than that of ordinary SU UMa-type dwarf novae. Combined the duration of the plateau stage with the fact that the amplitude of J0137 exceeded 6 mag, the object is within the framework of large-amplitude SU UMa-type dwarf novae (TOADs, Howell et al. 1995). The mean decline rate during the plateau stage was about 0.08 mag d−1. A rebrightening feature is clearly shown on HJD 2453018, which is often observed in WZ Sge-type dwarf novae and SU UMa-type dwarf novae with short superhump periods. This implies that J0137 has some relation with these systems.

We performed a period search of the object during the plateau stage of the superoutburst after subtracting the linear declining trend. Figure 2 shows the theta diagram using PDM method (Stellingwerf 1978), which indicates 0.056698 (10) days is the best-estimated superhump period. It should be noted that the obtained superhump period is comparable to that of WZ Sge-type dwarf novae, AL Com (0.05722 d, Ogami et al. 1997), HV Vir (0.05820 d, Ishioka et al. 2003), and WZ Sge itself (0.05721 d, Patterson et al. 2002).

### 3. Results

#### 3.1. Light curve

Figure 1 represents the obtained light curve of the 2003-2004 superoutburst of J0137. Quiescent photometric observations for the variable were performed by Pretorius et al. (2004) on HJD 2452989 and HJD 2452990, when the object was as faint as V = 18.6 (Pretorius et al. 2004). Then Pretorius et al. (2004) serendipitously detected the outburst of the object at HJD 2452995.29032, with a magnitude of V = 12.5. ASAS-3 system also detected the eruption of the object at HJD 2452993.67590 with a magnitude of V = 12.8.

The mean superhump profile during the plateau stage is shown in figure 3. A rapid rise and slow decline is typical of that of SU UMa-type dwarf novae. Figure 4 shows the daily evolution of superhumps during the plateau stage. Each light curve is folded by the superhump period of 0.056698 d.

We also investigated the existence of early superhumps on HJD 2452996. Early superhumps, having a double-peaked profile and a period almost the same as their orbital period, are characteristic of WZ Sge-type dwarf novae (Osaki, Meyer 2002, Kato 2002, Patterson et al. 2002). As can be seen in the top-left panel of figure 4, the superhumps had already developed on HJD 2452996, which is in agreement with the observations by

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1. Some authors use the term “echo outburst”.
2. Early superhumps are also called orbital humps (Patterson et al. 2002) or early humps (Osaki, Meyer 2002). The difference among these authors is originated from their interpretation of physical process near the bright maximum.
Fig. 1. The resulting light curve of SDSS J0137. The abscissa and the ordinate mean the heliocentric Julian day and the magnitude close to $R$, respectively. A rebrightening could be seen around HJD 2453018.

Fig. 2. Results of a period analysis by applying the PDM method to the data during the plateau stage. The abscissa and the ordinate denote periods in the unit of day and theta, respectively. After subtracting linear decline trend of the light curve, we determined $P = 0.056698$ days as the best-estimated period of superhumps. The second peak close to the above derived period seems to be alias. However, we cannot exclude the possibility of a real periodicity.
Fig. 3. Phase-averaged daily light curves of superhumps during the plateau stage, after folded by P=0.056698 days. The vertical and the horizontal axis denote the relative magnitude and phase, respectively.

Fig. 4. Phase-averaged light curve of superhumps in SDSS J013701.06-091234.9, covering between HJD 2452996 and HJD 2453007, folded by 0.056698 d. The vertical and the horizontal axes denote the relative magnitude and the phase, respectively. A rapid rise and slower decline, which is a typical feature of superhumps, are shown during the early stage of observations.
Table 1. Journal of observations.

| Date       | HJD(start)$^*$ | HJD(end)$^*$ | N$^†$ | Exp(s)$^‡$ | Code$^§$ |
|------------|---------------|-------------|-------|-----------|--------|
| 23 Dec, 2003 | 52996.86904  | 52996.98490 | 151   | 30        | njh    |
|            | 52996.88505  | 52997.03497 | 327   | 30        | kyo    |
|            | 52997.29186  | 52997.44838 | 444   | 28        | BM     |
| 24 Dec, 2003 | 52997.85696  | 52997.98659 | 159   | 30        | njh    |
|            | 52997.93928  | 52998.10752 | 360   | 30        | kis    |
|            | 52997.98697  | 52998.11349 | 203   | 30        | gets   |
| 25 Dec, 2003 | 52998.91343  | 52999.05886 | 303   | 30        | kis    |
| 26 Dec, 2003 | 52999.86686  | 53000.0316  | 176   | 30        | njh    |
| 27 Dec, 2003 | 53000.88082  | 53001.08705 | 418   | 30        | kis    |
|            | 53000.96131  | 53001.09511 | 425   | 40        | mhh    |
|            | 53000.61786  | 53000.69084 | 100   | 45        | DRS    |
| 28 Dec, 2003 | 53002.29974  | 53002.43352 | 375   | 28        | BM     |
| 29 Dec, 2003 | 53002.87155  | 53003.07811 | 359   | 30        | gets   |
| 30 Dec, 2003 | 53003.89347  | 53004.08564 | 322   | 30        | gets   |
|            | 53004.25485  | 53004.36336 | 308   | 28        | BM     |
| 31 Dec, 2003 | 53004.95170  | 53005.03557 | 40    | 30        | gets   |
| 1 Jan, 2004  | 53005.88064  | 53006.05076 | 176   | 30        | gets   |
| 2 Jan, 2004  | 53006.23946  | 53006.27625 | 48    | 60        | AO     |
| 3 Jan, 2004  | 53007.03134  | 53007.05456 | 47    | 30        | kis    |
| 4 Jan, 2004  | 53008.96772  | 53009.04763 | 76    | 30        | kis    |
| 5 Jan, 2004  | 53009.89337  | 53009.91637 | 42    | 30        | gets   |
| 6 Jan, 2004  | 53010.92457  | 53010.93495 | 18    | 30        | kis    |
| 7 Jan, 2004  | 53011.93861  | 53011.97924 | 65    | 30        | kis    |
| 8 Jan, 2004  | 53012.93191  | 53013.00878 | 96    | 30        | kis    |
| 10 Jan, 2004 | 53014.87110  | 53014.93196 | 48    | 30        | gets   |
| 12 Jan, 2004 | 53016.98983  | 53017.02530 | 37    | 30        | gets   |
| 13 Jan, 2004 | 53017.98725  | 53018.04615 | 92    | 30        | kis    |
| 14 Jan, 2004 | 53018.92030  | 53018.98921 | 105   | 30        | kis    |
| 15 Jan, 2004 | 53019.96453  | -            | 1     | 30        | kis    |

$^*${HJD-2400000, $^†$Number of frames $^‡$Exposure times $^§$observer’s code. (see Table 3.2)}

Pretorius et al. (2004). However, we cannot exclude the possibility that early superhumps did emerge near the maximum, and disappeared before our observations.

3.3. Superhump period change

The maximum timings of superhumps measured by eye are listed in Table 3. The typical error is an order of 0.001 d for each maximum. A cycle count $E$ is set to 7 at the first detected maximum, corresponding to HJD 2452996.9277. A linear regression of the superhump maximum timings yielded the following equation:

$$HJD(\text{max}) = 2452997.3248(9) + 0.056686(12) \times E$$  \hspace{1cm} (1)

The obtained $O-C$ diagram is demonstrated in figure 6, where the dashed line denotes the beginning of late superhumps discussed in Pretorius et al. (2004). The data can be apparently fitted by a quadratic function. However, considering the argument by Pretorius et al. (2004), in which they have enough data to explore superhump period changes during the later stage of the outburst, the break in Figure 6 is caused by a sudden jump of phase as seen in some SU UMa-type dwarf novae. Thus we conclude that, except the phase change on HJD 2453007, presumably due to late superhumps, there were almost no changes in superhump periods during the present superoutburst.

4. Discussion

4.1. Outburst properties

The overall light curves provided firm evidence of superhumps, which allows us to identify the object as a new SU UMa-type dwarf nova. The obtained superhump period is 0.056686 (12) d, one of the shortest superhump periods among SU UMa-type dwarf novae ever known. The plateau stage lasted more than 2 weeks, and a rebrightening took place at least once after the termination of the plateau stage. The amplitude of the object exceeded 6 mag, and the light curve of J0137 has similarity to that of the 1998 superoutburst of WX Cet (Kato...
Fig. 5. $O-C$ diagram of the superhump maximum timings of J0137 during the superoutburst. A calculation is performed based on the equation (3). The vertical and the horizontal axes denote $O-C$ and the cycle count, respectively. We set $E = 0$ to HJD 2452996.9277. Note almost no changes of the superhump period till HJD 2453002. The dotted line indicates the beginning of late superhumps suggested by Pretorius et al. (2004).

Fig. 6. Near-infrared color-color diagram of SU UMa-type stars listed on Table 3. Some listed stars including ER UMa stars are suspected to be observed during outbursts. Such stars for which we cannot evaluate typical errors, are precluded. An extinction correction is not operated because most of SU UMa-type dwarf novae are not distant and the effect is marginal. Note that the location of J0137 is far from that of other stars, suggesting the peculiar nature of the object.
et al. 2001a) and that of 1996 superoutburst of SW UMa (Nogami et al. 1998) in terms of the decline rate, a duration of the plateau stage, and an outburst amplitude. This certifies J0137 as a large amplitude SU UMa-type dwarf nova (TOADs, Howell et al. 1995).

4.2. superhump period changes

It had been considered that superhump periods of SU UMa-type dwarf novae decrease with time. However, since the 1995 superoutburst of AL Com, some objects have been confirmed to increase the superhump period with time. Such systems include AL Com (Nogami et al. 1997), V485 Cen (Olech 1997), EG Cnc (Patterson et al. 1998, Kato et al. 2004a), SW UMa (Semeniuk et al. 1997; Nogami et al. 1998), V1028 Cyg (Baba et al. 2000), WX UMa (Semeniuk et al. 1997; Nogami et al. 1998), V485 Cen (Olech 1997), EG Cnc (Patterson et al. 1998, Kato et al. 2004a), and Nogami et al. (2004b).

Recently, Uemura et al. (2005) discovered that an SU UMa-type dwarf nova, TV Crv exhibits two types of the superhump period change: positive $P_{\text{dot}} = P_{\text{sh}}/P_{\text{in}}$ during the 2001 superoutburst without a precursor and almost no changes $P_{\text{dot}}$ during the 2004 superoutburst with a precursor. Uemura et al. (2005) suggests that this difference mainly depends on the disk radius before a superoutburst is triggered. At the beginning of an outburst, if the accretion disk has large masses beyond the 3:1 resonance radius at which an eccentric mode originates, the mode sufficiently propagates outward because of the plenty matter beyond the 3:1 resonance radius, so that the outer region of the accretion disk becomes more eccentric, leading to the positive $P_{\text{dot}}$.

J0137, when based on the arguments by Uemura et al. (2005), was likely to have insufficient mass at the ignition of the outburst. As a consequence, an eccentric mode could not propagate so far as other SU UMa-type dwarf novae exhibiting positive $P_{\text{dot}}$. The validity of Uemura’s arguments should be explored in the future observations for SU UMa-type dwarf novae with short orbital periods, and should be tested by hydrodynamical simulations.

4.3. distance

If the orbital period of the system and the maximum $V$ magnitude of a normal outburst are known, one can roughly estimate the distance to the object. In this subsection, we try to estimate the distance to J0137 in the same manner as that used by Kato et al. (2003), Nogami et al. (2004a), and Nogami et al. (2004b).

An empirical relation derived by Warner (1987) is that the absolute $V$ magnitude at the maximum is the function of the orbital period of the object, that is,

$$M_V = 5.64 - 0.259P,$$

where $P$ is the orbital period in the unit of hour. This relation, however, can adapt only to a low inclination system, at most, to an intermediate inclination system. In the case of J0137, we need caution to use the equation (2). First, although equation (2) should be used to the maximum magnitude of a normal outburst of SU UMa stars, a

| E | HJD max | error$^\dagger$ |
|---|---------|--------------|
| -7 | 52996.9277 | 0.003 |
| 0 | 52997.3240 | 0.001 |
| 1 | 52997.3796 | 0.001 |
| 2 | 52997.4374 | 0.003 |
| 10 | 52997.8903 | 0.003 |
| 11 | 52997.9470 | 0.001 |
| 12 | 52998.0049 | 0.003 |
| 13 | 52998.0615 | 0.003 |
| 29 | 52998.9736 | 0.007 |
| 30 | 52999.0268 | 0.002 |
| 46 | 52999.9335 | 0.001 |
| 59 | 53000.6714 | 0.003 |
| 63 | 53000.8971 | 0.002 |
| 64 | 53000.9553 | 0.003 |
| 65 | 53001.0144 | 0.002 |
| 66 | 53001.0690 | 0.008 |
| 88 | 53002.3156 | 0.006 |
| 89 | 53002.3735 | 0.001 |
| 90 | 53002.4286 | 0.008 |
| 98 | 53002.8806 | 0.001 |
| 99 | 53002.9372 | 0.003 |
| 100 | 53002.9933 | 0.002 |
| 101 | 53003.0470 | 0.001 |
| 117 | 53003.9510 | 0.001 |
| 118 | 53004.0085 | 0.005 |
| 119 | 53004.0660 | 0.005 |
| 123 | 53004.2922 | 0.005 |
| 124 | 53004.3497 | 0.006 |

$^\dagger$ unit in day.

3 It also should be noted that TT Boo shows both decrease and increase of superhump periods (Olech et al. 2004).
normal outburst has not been observed for J0137. Second, spectroscopic observations of J0137 (Szkody et al. 2003) shows doubly-peaked profile of Hα, implying an intermediate or high inclination. For the first caution, we used that the magnitude of a normal outburst is 0.5±0.5 mag fainter than that of a superoutburst. For the second caution, the absence of an eclipse can rule out the possibility of a high inclination system of J0137. Thus, substituting 1.3283 (hr) into P, we obtain $M_V \approx 5.3$. Assuming the transverse velocity to be 100km/s (Thorstensen 2003), the distance to J0137 is estimated to be about 320 pc, which does not contradict that derived above.

4.4. Secondary star

SU UMa stars with short orbital periods, including WZ Sge stars, show almost no evidence for the secondary star in the optical spectrum (e.g., Howell, Ciardal 2001). A quiescent spectrum of J0137, however, clearly exhibits TiO bands around 7000 A (Szkody et al. 2003), suggesting that a contribution of the M-type secondary star is significant even in the optical range. This implies a peculiar nature of the object when taking into account the orbital period of J0137 is close to the theoretical period minimum.

In order to quantitatively investigate secondary stars in SU UMa stars, we extracted infrared magnitudes of SU UMa stars from the 2MASS catalog (Table 4) (cf. Hoard et al. 2002). These magnitudes could reflect on the secondary star of J0137 has much later spectral type than that of other SU UMa-type dwarf novae, and (6) the fractional superhump excess of J0137 is a large value of 0.024 for its short orbital period, suggesting that an evolutional sequence of J0137 is slightly deviated from that of other SU UMa-type dwarf novae, and (6) the fractional superhump excess of J0137 is a large value of 0.024 for its short orbital period, suggesting that an evolutional sequence of J0137 may be slightly deviated from that of standard CVs. This implies that J0137 places an missing link between ordinary SU UMa stars and a progenitor for AM CVn stars.

5. Conclusions

Photometric observations of the superoutburst of J0137 from December 2003 to January 2004 revealed that (1) the mean superhump period is 0.056686 (12) d, which is one of the shortest superhump periods among SU UMa-type dwarf novae, (2) the amplitude of J0137 during the superoutburst exceeded 6 mag and the plateau stage of J0137 lasted about 2 weeks, which confirmed J0137 to be a new member of SU UMa-type dwarf novae with a large amplitude, (3) the changes of superhump period were hardly observed during the plateau stage, but a signature of late superhumps appeared, (4) a distance to J0137 is roughly estimated to be 320±80 pc, based on the measured proper motion for the object and an empirical relation given by Warner (1987), (5) based on the 2 MASS observations, the secondary star of J0137 has much later spectral type than that of other SU UMa-type dwarf novae, and (6) the fractional superhump excess of J0137 is a large value of 0.024 for its short orbital period, suggesting that an evolutional sequence of J0137 may be slightly deviated from that of standard CVs. This implies that J0137 places a missing link between ordinary SU UMa stars and a progenitor for AM CVn stars.

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Table 4. J, H, and K magnitudes of SU UMa stars in the 2MASS catalog.

| Object | Offset | Period | Jmag (err) | Hmag (err) | Kmag (err) | Type | Remark |
|--------|--------|--------|------------|------------|------------|------|--------|
| El Psc | 1.546  | 0.044567 | 14.684(43) | 14.316(46) | 14.099(62) | SU   | -      |
| GW Lib | 1.588  | 0.05332 | 16.191(88) | 15.586(126) | 15.393(186) | WZ?  | -      |
| BW Scl | 3.029  | 0.054323 | 15.835(83) | 15.493(122) | 14.938(121) | WZ?  | -      |
| DI UMa | 0.640  | 0.054564 | 15.322(59) | 15.202(109) | 15.126(142) | ER   | -      |
| V844 Her | 1.451  | 0.05464 | 16.763(150) | 16.284(204) | 16.078(324) | SU   | -      |
| J0137 | 0.700  | 0.05535 | 16.928(224) | 16.022(198) | 15.296(184) | SU   | -      |
| J1238 | 0.118  | 0.05592 | 16.651(139) | 16.490(238) | 16.424(162) | SU?  | -      |
| HS 2331 | 3.355  | 0.056309 | 15.835(83) | 15.493(122) | 14.938(121) | WZ?  | -      |
| V844 Her | 1.451  | 0.05464 | 16.763(150) | 16.284(204) | 16.078(324) | SU   | -      |
| J0137 | 0.700  | 0.05535 | 16.928(224) | 16.022(198) | 15.296(184) | SU   | -      |
| J1238 | 0.118  | 0.05592 | 16.651(139) | 16.490(238) | 16.424(162) | SU?  | -      |
Table 4. (Continued)

| Object  | Offset | Period | Jmag (err) | Hmag (err) | Kmag (err) | Type | Remark |
|---------|--------|--------|------------|------------|------------|------|--------|
| RZ Leo  | 0.777  | 0.07604| 16.338(116)| 15.664(119)| 15.387(196)| WZ   | -      |
| SU UMa  | 0.464  | 0.07635| 11.777(22) | 11.731(23) | 11.670(21) | SU   | 1      |
| J1730*  | 2.681  | 0.07653| 15.284(47) | 15.189(89) | 15.217(177)| SU   | 1      |
| HS Vir  | 0.859  | 0.07690| 15.016(41) | 14.870(68) | 14.603(91) | SU   | -      |
| V503 Cyg| 2.531  | 0.0777 | 16.370(32) | 15.287     | 15.200     | SU   | -      |
| V660 Her| 1.007  | 0.07826| 11.777(22) | 11.731(23) | 11.670(21) | SU   | 1      |
| CU Vel  | 1.990  | 0.07850| 14.492(32) | 13.989(34) | 13.843(59) | SU   | -      |
| V630 Cyg| 0.594  | 0.07890| 14.679(38) | 14.503(56) | 14.401(69) | SU   | -      |
| J2100*  | 0.086  | 0.079  | 16.100(69) | 16.411(188)| 15.907     | SU   | -      |
| V1113 Cyg| 1.074 | 0.0792 | 15.777(80) | 15.971(219)| 15.070     | SU   | 2      |
| BR Lup  | 1.624  | 0.07950| 15.179(54) | 15.137(77) | 15.078(123)| SU   | -      |
| DH Aql  | 0.853  | 0.08003| 15.932(86) | 15.263(109)| 15.224(163)| SU   | 2      |
| J0549*  | 0.405  | 0.08022| 15.619(50) | 15.210(81) | 14.869(112)| SU?  | -      |
| PV Per  | 0.563  | 0.0805 | 15.181(38) | 15.145(71) | 14.952(114)| SU   | 1, 2   |
| TX Crt  | 0.933  | 0.08209| 16.225(104)| 15.517(100)| 15.212(179)| SU   | -      |
| TX Crt  | 0.594  | 0.0839 | 14.679(38) | 14.503(56) | 14.401(69) | SU   | -      |
| CU Vel  | 1.990  | 0.085   | 16.070(97) | 15.617(135)| 15.283(151)| SU   | -      |
| J2234*  | 0.278  | 0.085   | 16.449(92) | 16.024(140)| 15.571(156)| SU?  | -      |
| J2234*  | 0.278  | 0.085   | 16.449(92) | 16.024(140)| 15.571(156)| SU?  | -      |
| J2234*  | 0.278  | 0.085   | 16.449(92) | 16.024(140)| 15.571(156)| SU?  | -      |
| J2234*  | 0.278  | 0.085   | 16.449(92) | 16.024(140)| 15.571(156)| SU?  | -      |
| J2234*  | 0.278  | 0.085   | 16.449(92) | 16.024(140)| 15.571(156)| SU?  | -      |
| J2234*  | 0.278  | 0.085   | 16.449(92) | 16.024(140)| 15.571(156)| SU?  | -      |
| J2234*  | 0.278  | 0.085   | 16.449(92) | 16.024(140)| 15.571(156)| SU?  | -      |