Chin. J. Astron. Astrophys. Vol. 7 (2007), No. 3, 375–379
(*http://www.chjaa.org*)

Chinese Journal of
Astronomy and
Astrophysics

# The Multi-Wavelength Quasar Survey III. Quasars in Field 836 *

Yu Bai[1], Yang Chen[1], Xiang-Tao He[1], Jiang-Hua Wu[2], Qing-Kang Li[1], Richard F. Green[3] and Wolfgang Voges[4]

[1] Department of Astronomy, Beijing Normal University, Beijing 100875; *cheny@bnu.edu.cn*
[2] National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012
[3] Kitt Peak National Observatory, NOAO, Tucson, AZ85726-6732, USA
[4] Max-Planck-Institute für Extraterrestrische Physik, D-85740 Garching, Germany

Received 2006 June 15; accepted 2006 October 25

**Abstract** This is the third paper in a series connected with our Multiwavelength Quasar Survey. The survey is aimed to provide a quasar sample more complete than any previous survey by using a combined selection technique to reduce selection effects. We present the observational results for the X-ray candidates in field f836. We found 15 X-ray AGNs in this field of which eight are new discoveries. The X-ray data and optical spectra of these AGNs are given. We give the X-ray candidate selection criteria, which proved to be highly efficient in isolating X-ray AGNs.

**Key words:** galaxies: active: individual (field f836) — X-rays: galaxies: quasars

## 1 INTRODUCTION

This paper is the third in a series of papers (He et al. 2001, hereafter Paper I; Chen et al. 2002, hereafter Paper II) describing the results from the Multiwavelength Quasars Survey (MWQS), a survey aimed at obtaining a sample of $\sim 350$ new AGNs brighter than $B = 19.0$ by using some well-defined and consistently applied selection criteria. Candidates are selected from the ROSAT All-Sky Survey (RASS) data, the optical plates are from the UK Schmidt Telescope, and the radio data are from the Faint Images of the Radio Sky at Twenty centimeters (FIRST, Becker et al. 1995) and the NRAO VLA Sky Survey (NVSS, Condon et al. 1998) in four fields of sky. The scientific objectives and the detailed candidate selection procedures have been described in Paper I and Paper II.

This paper reports the observational results for X-ray candidates in field f836. The X-ray candidate selection criteria adopted are given in Section 2 and are the same as that of Paper II. Section 3 describes the observations and results for the X-ray candidates in field f836. Eight new AGNs are discovered.

Throughout this paper, we assume a standard Einstein-de Sitter cosmological model with $H_0 = 50\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$ and $q_0 = 0.5$.

## 2 X-RAY CANDIDATE CRITERIA

The criteria adopted in Paper II are

1. The X-ray flux limit is 0.02 count $\mathrm{s^{-1}}$.
2. X-ray-to-optical flux ratio is $\log(f_\mathrm{x}/f_\mathrm{o}) \geq -1.0$.
3. The source extension parameter log(ext)<1.8.

* Supported by the National Natural Science Foundation of China.

These criteria have proved their high efficiency in isolating X-ray AGNs, so they were kept in the observation of field f836. Table 1 lists all the X-ray selected AGN candidates in this region. The first column gives the ROSAT source designation. Column 2 lists the ROSAT count rate in count $\mathrm{s}^{-1}$. Column 3 shows the X-ray-to-optical flux ratio. Column 4 lists the logarithm of the source extent, and Column 5 is the $B$ magnitude obtained from USNO−A2.0 (see *http://ftp.nofs.navy.mil/projects/pmm/a2.html*).

**Table 1** The X-ray AGNs Candidates

| ROSAT Name | Count Rate | $\log(f_{\mathrm{x}}/f_{\mathrm{o}})$ | $\log(\mathrm{ext})$ | $B$ |
|---|---|---|---|---|
| 041101.7−015125 | 0.021 | −0.470 | 1.771 | 17.1 |
| 041132.8+023600 | 0.083 | −1.154 | 1.771 | 13.9** |
| 041143.7−001034 | 0.041 | 0.824 | 1.301 | 19.6 |
| 041150.8−005324 | 0.027 | −0.687 | 1.771 | 16.3 |
| 041200.6+004322 | 0.034 | 0.743 | 1.279 | 19.6 |
| 041208.0−022733 | 0.023 | −0.628 | 1.771 | 16.6 |
| 041241.4+013226 | 0.020 | 0.433 | 1.771 | 19.4 |
| 041242.2+000306 | 0.012 | −0.449 | 1.771 | 17.8* |
| 041306.8−005006 | 0.031 | −1.343 | 1.000 | 14.5** |
| 041345.4+011402 | 0.013 | −0.719 | 1.771 | 17.0* |
| 041435.5−014644 | 0.037 | −0.097 | 1.255 | 17.4 |
| 041436.4+001821 | 0.023 | 0.410 | 1.771 | 19.2 |
| 041510.3−014329 | 0.020 | 0.440 | 1.771 | 19.4 |
| 041535.4+030636 | 0.024 | −0.284 | 1.771 | 17.4 |
| 041612.7−012006 | 0.036 | −0.276 | 1.000 | 17.0 |
| 041615.8+012641 | 0.021 | −0.306 | 1.771 | 17.5 |
| 041630.2+020127 | 0.021 | −0.592 | 1.771 | 16.8 |
| 041634.8+014603 | 0.028 | 0.739 | 1.771 | 19.8 |
| 041652.6+010533 | 1.699 | 1.200 | 1.176 | 16.5 |
| 041727.4+012643 | 0.033 | −0.593 | 1.771 | 16.3 |
| 041729.9−010016 | 0.025 | 0.613 | 1.771 | 19.6 |
| 041802.9+020108 | 0.040 | 0.287 | 1.771 | 18.3 |
| 041808.5+011328 | 0.021 | 0.204 | 1.771 | 18.8 |
| 041828.3+011555 | 0.041 | −0.663 | 1.771 | 15.9 |
| 041837.3+023352 | 0.030 | 0.521 | 1.146 | 19.2 |
| 041839.8+014244 | 0.033 | 0.402 | 1.771 | 18.8 |
| 041902.1+022551 | 0.060 | 0.749 | 1.771 | 19.0 |
| 041906.0+022734 | 0.049 | −0.423 | 1.771 | 16.3 |
| 041917.9+022419 | 0.061 | 0.875 | 1.771 | 19.3 |
| 041920.3+022832 | 0.045 | 0.978 | 1.771 | 19.9 |
| 041920.5+022013 | 0.066 | 0.710 | 1.771 | 18.8 |
| 041927.7−000805 | 0.030 | 0.686 | 1.771 | 19.6 |
| 041927.9+023526 | 0.030 | 0.170 | 0.845 | 18.3 |
| 041937.2+022847 | 0.115 | −0.049 | 1.771 | 16.3 |
| 041956.8+022128 | 0.085 | 0.899 | 1.771 | 19.0 |
| 042000.3+021706 | 0.055 | 0.914 | 1.771 | 19.5 |
| 042035.7−000418 | 0.044 | 0.774 | 1.771 | 19.4 |
| 042051.2+000549 | 0.036 | 0.444 | 1.079 | 18.8 |
| 042053.3−023700 | 0.038 | 0.431 | 1.771 | 18.7 |
| 042056.8+014727 | 0.022 | −0.132 | 1.771 | 17.9 |
| 042110.5−011159 | 0.026 | 0.663 | 1.041 | 19.7 |
| 042120.2−004739 | 0.035 | −0.882 | 1.771 | 15.5 |
| 042253.9+022016 | 0.031 | 0.374 | 1.771 | 18.8 |
| 042304.5−012230 | 0.022 | −0.376 | 1.771 | 17.3 |
| 042314.8−024813 | 0.038 | −0.813 | 1.771 | 15.6 |
| 042315.1−012019 | 0.105 | 0.512 | 0.778 | 17.8 |
| 042331.3−011553 | 0.033 | 0.563 | 1.771 | 19.2 |
| 042331.8−013935 | 0.039 | −0.480 | 1.771 | 16.4 |
| 042347.4+024833 | 0.025 | 0.370 | 1.771 | 19.0 |
| 042359.4+022607 | 0.022 | −0.204 | 1.771 | 17.7 |
| 042446.8+003600 | 0.052 | −0.474 | 1.771 | 16.1 |
| 042458.4+024830 | 0.022 | −0.212 | 1.771 | 17.7 |
| 042530.0−004706 | 0.057 | 0.726 | 1.771 | 19.0 |
| 042542.8−021352 | 0.154 | 0.517 | 1.114 | 17.4 |
| 042730.0+024249 | 0.034 | 0.178 | 1.740 | 18.2 |
| 042752.2+004925 | 0.039 | 0.236 | 1.771 | 18.2 |
| 042813.8+013451 | 0.033 | 0.807 | 1.771 | 19.8 |
| 042819.6−015423 | 0.060 | −0.291 | 1.771 | 16.4 |
| 042837.2−025212 | 0.024 | −0.124 | 1.771 | 17.8 |
| 042854.3+024836 | 0.020 | −0.763 | 1.771 | 16.4 |
| 042936.0−025301 | 0.101 | 1.053 | 1.771 | 19.2 |
| 043046.5+030327 | 0.025 | −0.552 | 1.771 | 16.7 |
| 043123.8−023338 | 0.031 | 0.134 | 1.771 | 18.2 |
| 043136.9−024116 | 0.257 | −0.221 | 1.771 | 15.0 |
| 043402.4−011154 | 0.075 | 1.286 | 1.114 | 20.1 |
| 043424.8−011432 | 0.027 | −0.404 | 0.903 | 17.0 |
| 043426.2−030041 | 0.033 | −0.358 | 1.255 | 16.9 |
| 043445.0+030623 | 0.021 | 0.122 | 1.230 | 18.6 |
| 043449.4+013036 | 0.037 | −0.147 | 1.771 | 17.3 |
| 043450.3−010026 | 0.021 | −0.468 | 1.771 | 17.1 |
| 043456.9−011406 | 0.029 | 0.152 | 1.771 | 18.3 |

*These two sources are newly identified AGNs with the X-ray count rate $\leq$ 0.02 count $\mathrm{s}^{-1}$.
**These two sources are known AGNs with $\log(f_{\mathrm{x}}/f_{\mathrm{o}}) \leq -1.0$.

## 3 OBSERVATIONS AND RESULTS

Our survey in field f836 covers an area of $6^{\circ} \times 6^{\circ}$, centered on R.A.= $04^{\mathrm{h}}20^{\mathrm{m}}$, decl.=$00^{\circ}00'$ (J2000.0). After a preselection, 67 X-ray candidates were obtained. In order to observe more effectively, we set the optical magnitude range at $B$ $\leq$19.0. Finally, 40 candidates were left, including one known quasar, three known Seyfert galaxies, one known BL Lacertae object, and two Highly Polarized objects (Véron-Cetty & Véron 2003). From December 1996 to November 2005 (Wu et al. 2003), we have observed 23 candidates on the 2.16 m optical telescope at the Xinglong Station of National Astronomical Observatories, Chinese Academy of Sciences (NAOC). As a test of the sample completeness, some X-ray sources which do not meet the criteria were also observed. We used a 195 Å $\mathrm{mm}^{-1}$ grating and a Tektronix $1024 \times 1024$ CCD detector. The spectral coverage was 4000–8000 Å, with a spectral resolution of about 13 Å. The spectra were reduced with IRAF. The spectroscopic results led to the discovery of eight AGNs, four stars, and eleven unclassified objects. Among the newly discovered eight AGNs, four have absolute magnitudes of $M_B < -23.0$ and are classified as quasars (Paper I), and the other four are classified as Seyferts. The unclassified objects have spectra with signal-to-noise ratios too poor to allow unambiguous classification.

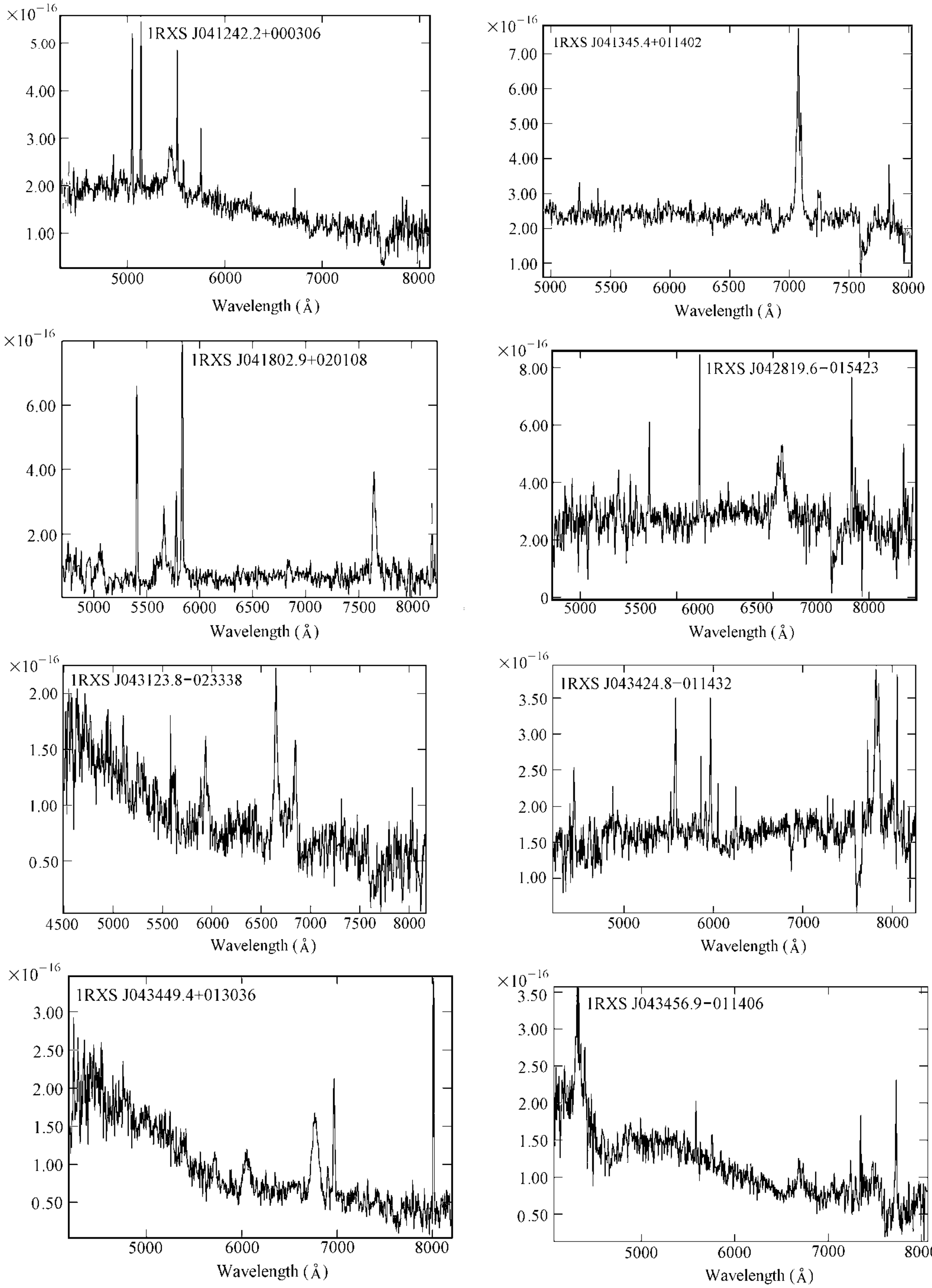


**Fig. 1** Spectra of new AGNs in field f836. Spectral flux ($F_\lambda$) is in $\mathrm{erg\,cm^{-2}\,s^{-1}\,\AA^{-1}}$.

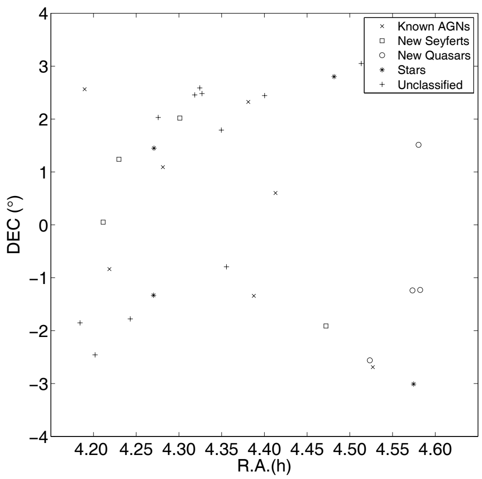


**Fig. 2** Distribution of the X-ray sample on the sky.

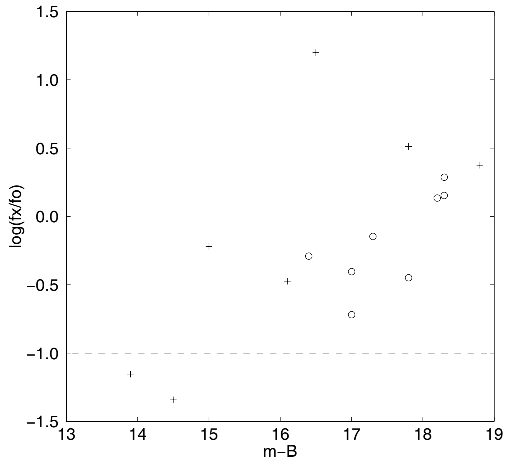


**Fig. 3** $\log(f_{\rm x}/f_{\rm o})$ versus $m_B$: newly discovered AGN (circle), known AGN (plus sign).

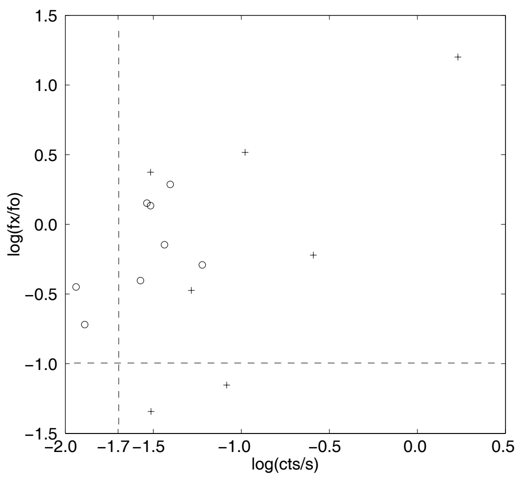


**Fig. 4** $\log(f_{\rm x}/f_{\rm o})$ versus log(cts/s): newly discovered AGN (circle), known AGN (plus sign).

Table 2 gives the observational data for all the 15 AGNs in this field. The first three columns list the ROSAT source designation and optical position. Column 4 shows the emission-line redshift, and Column 5 the $B$ absolute magnitude, calculated by using the equations from Weedman (1986), in which we assume an optical spectral index of $-0.5$ ($F_\nu \propto \nu^\alpha$). All the known AGN $M_B$ are taken from the Catalogue of Quasars and Active Nuclei (Véron-Cetty & Véron 2003 and NED (NASA/IPAC EXTRAGALACTIC DATABASE)). Column 6 shows the abbreviations for the types of the object: Seyfert (Sey), quasar (QSO), BL Lacertae (BL), and Highly Polarized object (Hp). The newly identified X-ray AGNs in our MWQ Survey have been marked on '*'. Two newly discovered AGNs (1RXS J041242.2+000306, 1RXS J041345.4+011402) and two known Seyferts (1RXS J041132.8+023600, 1RXS J041306.8−005006) do not quite meet our criteria. The spectra of the new AGNs are shown in Figure 1.

**Table 2** The X-ray AGNs Sample

| ROSAT Name | R.A. (2000) | DEC (2000) | $z_{\rm em}$ | $M_B$ | Type |
|---|---|---|---|---|---|
| 041132.8+023600 | 04 11 22.8 | 02 33 47 | 0.094 | −20.0 | Sey |
| 041242.2+000306 | 04 12 40.8 | 00 03 02 | 0.118 | −21.4 | Sey* |
| 041306.8−005006 | 04 13 07.0 | −00 50 16 | 0.040 | −20.6 | Sey |
| 041345.4+011402 | 04 13 47.2 | 01 14 21 | 0.078 | −21.4 | Sey* |
| 041652.6+010533 | 04 16 52.4 | 01 05 24 | 0.287 | −24.4 | BL |
| 041802.9+020108 | 04 18 03.7 | 02 01 04 | 0.165 | −21.7 | Sey* |
| 042253.9+022016 | 04 22 52.2 | 02 19 27 | 2.277 | −26.7 | QSO |
| 042315.1−012019 | 04 23 15.8 | −01 20 33 | 0.915 | −26.5 | HP |
| 042446.8+003600 | 04 24 46.8 | 00 36 07 | 0.310 | −25.2 | HP |
| 042819.6−015423 | 04 28 19.6 | −01 54 42 | 0.077 | −21.9 | Sey* |
| 043123.8−023338 | 04 31 24.2 | −02 33 41 | 0.365 | −23.5 | QSO* |
| 043136.9−024116 | 04 31 37.0 | −02 41 23 | 0.042 | −20.8 | Sey |
| 043424.8−011432 | 04 34 24.3 | −01 14 25 | 0.191 | −23.3 | QSO* |
| 043449.4+013036 | 04 34 49.8 | 01 30 45 | 0.392 | −24.5 | QSO* |
| 043456.9−011406 | 04 34 56.5 | −01 13 53 | 0.540 | −24.2 | QSO* |

*Newly identified X-ray AGNs.

Figure 2 displays the distribution of the whole sample on the sky. Figure 3 shows the correlation beween the X-ray-to-optical flux ratio and the $B$ magnitude for both the known and newly found AGNs. The dashed line shows our candidate criterion of $\log(f_{\rm x}/f_{\rm o})$. The two known Seyferts do not meet the criterion. Figure 4 exhibits X-ray-to-optical flux ratio versus the count rate of all the AGNs in field f836. The two known Seyferts meet the count rate criterion, but the two newly discovered ones do not. Based on the observations of our MWQS, the criteria we adopted could improve the efficiency of observation (Condon et al. 1998), but it may still miss some AGNs, especially some bright AGNs with larger optical flux. The threshold of X-ray-to-optical flux ratio might be different between sources brighter and fainter than $B$=15. The cause of the difference and more suitable criteria will be discussed in our future work. The other faint sources will be observed with more powerful telescopes. The SDSS (Sloan Digital Sky Survey) has not released the data of this sky field yet. The Point Source catalogue of 2MASS (Two Micron All Sky Survey) has covered this field, and five AGNs in field f836 have strong infrared flux. Two of these are AGNs we identified (1RXS J043123.8−023338, 1RXS J043424.8−011432), the other three are known AGNs (1RXS J041652.6+010533, 1RXS J042446.8+003600, 1RXS J043136.9−024116). These samples have strong X-ray and infrared flux. Further theoretical studies on the radiation mechanism are needed to understand the characteristics of the sources.

**Acknowledgements** We thank Tian-Tian Yuan for corrections for the manuscript of the paper. We acknowledge the MPE for providing the RASS X-ray data, and the MWQS would not have been possible without the active support from the Xinglong Station of NAOC. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. This research is supported by the National Natural Science Foundation of China (Grant 10473013).

## References

Becker R. H., White R. L., Helfand D. J., 1995, ApJ, 450, 559
Condon J. J., Cotton W. D., Greisen E. W. et al., 1998, AJ, 115, 1693
Chen Y., He X. T., Wu J. H. et al., 2002, AJ, 123, 578
He X. T., Wu J. H., Yuan Q. R. et al., 2001, AJ, 121, 1863
Véron-Cetty M.P., Véron P., 2003, A&A, 412,399
Weedman D. W., 1986, Quasar Astronomy, Cambridge: Cambridge University Press, 65
Wu J.H., He X.T., Chen Y. et al., 2003, Chin. J. Astron. Astrophys. (ChJAA), 3, 423