Title
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Permalink
https://escholarship.org/uc/item/94z8k71m

Journal
The Astronomical Journal, 151(5)

ISSN
0004-6256

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Publication Date
2016-05-01

DOI
10.3847/0004-6256/151/5/121

Peer reviewed
BE STARS IN THE OPEN CLUSTER NGC 6830

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ABSTRACT

We report the discovery of 2 new Be stars, and re-identify one known Be star in the open cluster NGC 6830. Eleven Ho emitters were discovered using the Hα imaging photometry of the Palomar Transient Factory Survey. Stellar membership of the candidates was verified with photometric and kinematic information using 2MASS data and proper motions. The spectroscopic confirmation was carried out by using the Shane 3-m telescope at Lick observatory. Based on their spectral types, three Ho emitters were confirmed as Be stars with Ho equivalent widths > -10Å. Two objects were also observed by the new spectrograph SED-Machine on the Palomar 60 inch Telescope. The SED-Machine results show strong Hα emission lines, which are consistent with the results of the Lick observations. The high efficiency of the SED-Machine can provide rapid observations for Be stars in a comprehensive survey in the future.

Subject headings: galaxies: star clusters: individual (NGC 6830) – stars: emission-line – stars: Be – instrumentation: spectrographs

1. INTRODUCTION

Be stars are non-supergiant B-type stars with Balmer emission lines, especially the Hα lines. Be stars are also characterized by their fast rotation, color excess at infrared wavelength, and continuum/emission-line variability (Townsend, Owocki, & Howarth 2004). Koubisky et al. (1997), Hubert & Floquet (1998). Some Be stars show the variability with periods that might be due to pulsation or rotation (Porter & Rivinius 2003). Rivinius, Baade, & Steff (2003). Previous studies have found the enhancement of Be phe-

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nomenon in young clusters (Wisniewski & Bjorkman 2006), Mathew, Subramaniam, & Bhatt (2008), while McSwain & Gies (2005) showed an overall increase in Be frequency with age until 100 Myr. McSwain & Gies (2005) also indicated that Be star formation is not strongly related to the cluster density. Furthermore, the Be star fraction in open clusters seems to be increasing with lower metallicity; between 17.5% and 40% of B stars were found to be Be stars in the Large Magellanic Cloud (LMC) and Small Magellanic Cloud (SMC) (see detailed review in Rivinius, Carciofi, & Martayan 2013).

It is well accepted that the Hα emissions of Be stars originate from the circumstellar material, which is suggested to be a flattened disk (Carciofi et al. 2006, Quirrenbach et al. 1994, 1997, Wood, Bjorkman, & Bjorkman 1997). The disks are found to be in Keplerian rotation and stable (Kraus et al. 2012, Meillard et al. 2012). The material might be moved from the stellar surface to form the circumstellar disk (e.g., the decretion disk) through the combination of fast rotation and other mechanisms, such as nonradial pulsations or magnetic fields (Lee, Osaki, & Said 1991, Porter & Rivinius 2003, Townsend, Owocki, & Howarth 2004, Carciofi et al. 2009). There are several possible origins of the fast rotating star: (1) binary interaction (Pols et al. 1991). During the interaction process, mass and angular momentum can be transferred from the primary star to the mass gainer star, and the latter might be spun-up to a fast rotating star; (2) they might be born as fast rotators; and (3) they have been spun-up during the Main-Sequence (MS) evolution.

To further understand the nature of Be stars, several surveys of Be stars have been carried out in the past. McLaughlin 1932, Jaschek, Jaschek, & Kurewicz 1964, Drew et al. 2005, Drew Chojnowski et al. 2015.
Figure 1. Membership identification. In Figure (b) – (d), open circles represent our Be star candidates, while the red pentagram is the known Be star VES 72. Numbers represent spectroscopically confirmed Be stars NGC6830-1, NGC6830-2, and NGC6830-3 in this study.

(a) Radial density profile of NGC 6830. The gray horizontal line indicates the background density. The green curve shows the best Gaussian fitting results while red and blue vertical lines represent the width of 1σ and 3σ. The black vertical line shows the width of the Gaussian curve of 4σ. (b) 2MASS color-magnitude diagram. The black solid line indicates the isochrone (Girardi et al. 2002) of 125 Mys located at 1.8 kpc. Be candidates are considered to have photometric membership within the red-dashed region, while non-emission-line stars are considered to have photometric membership within the blue-dashed region. (c) Stellar PMs distribution of Be candidates of NGC 6830. The PM of NGC 6830 is (μα, μδ) = (−2.79, −7.40) mas year⁻¹. The inner and outer blue-dashed circles represent 1σ and 2σ regions. We adopted 2σ region to define the kinematic membership. The bars are errors of the PMs. (d) 2MASS color-color magnitude diagram. The gray contours show known Be stars distribution, and we define dashed box to select possible Be candidates.

Because stars in clusters share age and metallicity, Be stars in a sample of clusters with different ages play an essential role in the study of their evolution. Previous studies have searched for emission-line objects in a number of star clusters in the SMC and MW. (Fabregat & Torrejón 2000, Keller et al. 2001, Wisniewski & Bjorkman 2006, Martayan, Baade, & Fabregat 2010, Mathew, Subramaniam, & Bhatt 2008, Mathew & Subramaniam 2011). Particularly, McSwain & Gies (2003) provided the most extensive survey of Be stars in the MW; they investigated 55 clusters and concluded that 73% of the rapid rotators might be spun-up by the effect of mass transfer between binaries. Moreover, McSwain, Huang, & Gies (2009) also showed that the distributions of projected rotational velocity of Be stars and normal B-type stars are significantly different, indicating that they might be different stellar populations, and Be stars cannot be drawn from a sample of normal B stars. Theoretical simulations also imply that most Be stars could be formed during the phase of binary interactions (de Mink et al. 2013, Shao & Li 2014). These studies further supported a spin-up scheme for the evolutionary sequence of Be stars.

Nevertheless, the sample of Be stars in open clus-
The methodology of searching for Be star candidates and identifying membership has been presented in our pilot project. Further details can be found in Yu et al. (2013) and will not be repeated here. Briefly, procedures that we followed in this study are summarized below:

1. Determining the searching region based on the radial density profile. The stars were selected from the PPMXL data set with the S/N ≥ 10 in 2MASS J, H, and Ks bands. The half-Gaussian fitting gives a 3σ radius of 17.85′ (Figure 1a). Because open clusters have irregular shapes, we therefore adopted a box with the side of 48′ (4σ) as our searching region for NGC 6830 to cover possible candidates.

2. Applying the Hα imaging photometry to identify possible Hα emitters. The Hα emitters should have a significant flux excess in the on-line image than in the off-line image, where the on-line and off-line images were taken through the HA 656 and HA 663 narrow-band filters. These images were processed for bias corrections, flat fielding, and astrometric calibration with pipelines developed at the Infrared Processing and Analysis Center (IPAC; Laher et al. 2014). Following the methods and criteria as given in Yu et al. (2013), we selected the Hα emitter candidates that stand out in the plot of the differential HA663–HA656 flux as possible Hα emitters (see Figure 2).

3. Verifying the photometric membership using near-infrared data. The near-infrared J, H, and Ks bands data are obtained from the 2MASS point source catalog (Cutri et al. 2003). Possible photometric members of NGC 6830 are determined by selecting stars within the region that are near the isochrone in the 2MASS color-magnitude diagram (Figure 1b). Considering that Be stars might exhibit a large infrared excess (Lee & Chen 2011), we extended the selection region to J − Ks ∼ 1.2 mag (Figure 1b) for the Hα emitter candidates.

4. Verifying the kinematic membership using the PMs. Because about 10% objects in PPMXL data include spurious entries (Röser et al. 2010), we have averaged their PMs and computed errors. Thus, we used PMs provided by Kharchenko et al. (2012) to calculate the averaged PM (μα,μδ) and standard deviations (σμα, σμδ) of stars within the 47.6′ × 47.6′ region by fitting a Gaussian distribution to the PMs. The adopted 3σ errors propagated from σμα and σμδ. Stars were then considered as the kinematic membership if their PMs are within the 2σμ region (Figure 1c).

5. Selecting possible Be stars from emission-line candidates based on J − H versus H − Ks color-color diagram (CMD). The gray contours as shown in Figure 1d represent the region of 1185 known Be stars (Zhang et al. 2005). Under the assumption that most Be stars have similar infrared colors, we identified Be star candidates as those in NGC 6830 inside the gray-dashed region in the CMD.

Using the above criteria, we identified 11 Be star candidates (Table 1). One candidate was confirmed as the known Be star VES 72 in the cluster NGC 6830 (listed as NGC 6830-2 in Table 1; Hoag & Applequist 1965).
3.1. **SED-Machine Observations**

To demonstrate the feasibility and capability of the SED-Machine in the study of Be stars, we obtained the optical spectra of two bright objects, VES 72 (NGC 6830-2) and a new Be star candidate NGC 6830-1 during its commission runs. Logs of observations are listed in Table 2. Due to time constraints during the commission runs, we only observed the two brightest candidates but not all of our 11 candidates. The SED-Machine, mounted on the Palomar 1.5-m telescope, observations were carried out on 2014 May 1 under a seeing of approximately 2″.

The SED-Machine IFU spectra were reduced independently with the pipelines developed by the NCU and the Caltech PTF team. The IFU data reduction procedures consist of the following: (1) Overscan and bias subtraction; (2) Automatically spectrum identification using a Xe arc-lamp spectra image; (3) Calculating wavelength calibration solutions of every IFU spectra using HgNeXe lamp sources; (4) Simple-sum extraction of all spectra; (5) Reconstructing the image of the sky as seen before prism from surrounding sky identification; (6) Object spectrum extraction with sky spectra subtraction, wavelength calibration and flux calibration.

3.2. **LOT Observations**

To confirm the Hα detection from SED-Machine observations, we re-observed NGC 6830-1 using the Hiyoyu spectrograph on the Lulin One-meter Telescope (LOT). The LOT observations were conducted on 2014 Aug 2 under a seeing of approximately 1.5″. Using a grating of 300 mm⁻¹ and a slit width of 2″, we covered a wavelength range of 3800–7600 Å. The Hiyoyu spectrum was reduced with the IRAF package, following the standard data reduction procedure, i.e., dark, bias-subtracted, flat-fielding-corrected, wavelength calibration, and flux calibration. The wavelength calibration was performed using a HeNeAr lamp. The flux calibration might be not very accurate due to the unstable weather during the observation.

3.3. **Lick Observations**

We used the Kast dual spectrograph on the 3-m Shane telescope at Lick observatory to complete the confirmation of spectral typing of the 11 Be star candidates. The

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1 Image Reduction and Analysis Facility. IRAF is written and supported by the National Optical Astronomy Observatories (NOAO) in Tucson, Arizona.
observing runs were conducted on 2015 June 15 – 16 under a seeing of 1.5″ – 2″ using a 2″ slit width. Using 600/7500 grating on the red side and 600/4310 grism on the blue side, we can cover a wavelength range of 3500–7800 Å. The dispersion on the red side and blue side is 2.32 Å/pixel and 1.85 Å/pixel, respectively. We reduced the spectra using the standard tools in IRAF, including corrections for overscan bias and flat-fielding using the dome flat images. We used NeHg-Cd arc lamps for wavelength calibrations, and standard stars Feige 92 using the dome flat images. We used NeHg-Cd arc lamps including corrections for overscan bias and flat-fielding to reduce the spectra using the standard tools in IRAF, and then applied corrections for wavelength and flux.

4. RESULTS

4.1. SED-Machine and LOT Spectra

In Figure 3 we showed the SED-Machine spectra of the bright Be stars NGC 6830-1 and VES 72 (NGC 6830-2). The spectrum of VES 72 shows prominent Hα emission line, and clear hydrogen and He I λ4471 + Mg II λ4481 absorption lines. We further observed the new Be candidate NGC 6830-1 using the SED-Machine, and the Hiyoyu spectrograph mounted on the LOT. Both SED-Machine and LOT spectra present a clear detection of the Hα emission line, and hydrogen and He I λ4471 + Mg II λ4481 absorption lines, indicating a Be type. With a spectral resolution λ/Δλ ≈ 333 of the Hiyoyu spectrograph, we estimated an equivalent width of Hα emission-line, EW[Hα] = −5Å for NGC 6830-1. Although the spectral resolution is too poor to classify the spectral subtype, the similar brightness of NGC 6830-1 to VES 72 suggests similar subtypes (e.g. B6 type).

4.2. Lick Spectra

We present the spectra of Be star candidates obtained by Lick 3-m Shane telescope in Figure 4. Only three Be star candidates (NGC6830-1, NGC6830-2, and NGC6830-3) show Hα emission and B-type spectra. All candidates are discussed in the following subsections.

4.2.1. Confirmed Be Stars

(1) NGC 6830-1: This candidate shows a prominent Hα emission line with the EW[Hα] of −7Å and hydrogen absorption lines of Hβ, Hγ, Hδ. The EW[Hα] is similar to that of the LOT observation. It also shows He I λ4026, He I λ4387, and He I λ4471 + Mg II λ4481 absorption lines, the features of B-type stars. We thus confirmed the candidate as a newly discovered Be star.

(2) NGC 6830-2: NGC 6830-2 is a known Be star VES 72, a B6 type star with photoelectric observations.
Figure 3. SED-Machine results. The unit of the y-axis is normalized fluxes at 7000 Å in logarithm. Upper panel: SED-Machine spectrum of the known Be star VES 72. We detect the clear Hα emission-line while other Balmer series show absorption features. Middle panel: We also detected a clear Hα emission-line for the Be star candidate NGC6830-1 with the SED-Machine. Lower panel: The Hα emission-line also appears in the LOT spectrum for the same candidate.

(4) NGC 6830-4: We do not detect the Hα emission line for the star, and it shows the Ca II K absorption line, indicating the star might be a late-A or F-type star.

(5) NGC 6830-5: It shows not only the Ca II K absorption line, but also the G-band absorption at 4300 Å. The star is classified as a G-type star.

(6) NGC 6830-6 – NGC 6830-11: Compared to NGC 6830-5, these stars show a stronger G-band absorption, and weaker Hγ and He absorption lines. We classify NGC 6830-6 – NGC 6830-11 as G-type stars.

4.3. Infrared Color

The Be star NGC 6830-3 shows infrared excess H – K_s = 0.316 (Figure 1d), as in many known Be stars. Such infrared excess can be explained by free-free emission from circumstellar disks (Lee & Chey 2011). For comparison, we included the fluxes of 3.4 µm (W1), 4.6 µm (W2), 12 µm (W3) and 22 µm (W4) from Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010), and plotted in Figure 5 the spectral energy distribution between 0.4 µm and 25 µm of three Be stars (Table 3). All of the objects have no significant 22 µm detection, suggesting no presence of warm dust. Although the detection is only an upper-limit, it seems that NGC 6830-3 might have a different W3 – W4 color from NGC 6830-1 and NGC 6830-2. Observations with high resolution and sensitivity are in demand to confirm the 22 µm detection in NGC 6830-3 in the future.

4.4. Optical Variability

Be stars are also known as photometric and spectroscopic variables. Their variabilities show a wide range of timescales from much less than a day (Percy et al. 2002) to more than decades (Okazaki 1997). Compared to normal B type stars, photometric irregular variation is frequently seen in Be stars (Kouniotis et al. 2014). There are three types of variability found in Be stars: (1) short-term variability with time scales of days (Hubert et al. 1997); (2) mid-term variability with time scales of days and weeks with the amplitude of 0.3 mag (Okazaki 1997; Hubert & Floquet 1998); (3) long-term variability with time scales of years and larger amplitudes of > 0.3 mag (Hubert & Floquet 1998). Since the PTF R-band light curve data saturated around 14th magnitudes, we adopted the V-band light curve data from the All Sky Automated Survey (ASAS; Pojmanski 2002) to investigate the variability of our detected Be stars. The ASAS is a project to monitor stars brighter than 14 magnitudes to investigate their photometric variability; thus it is suitable to search for long-term variability with large amplitude > 0.3 mag for Be stars. We chose two stars, star1 and star2 in the same field, as the photometric references to build up the light curves using differential photometry technique. We only used the data with grade A from ASAS catalog, i.e., best data with photometric uncertainties < 0.05 mag in the catalog. The value σ_{sc} was defined as the standard deviation of magnitude difference between the reference and the Be stars, and used to determine the significance of the variability. The σ_{sc} against star1 and star2 of NGC6830-1, NGC6830-2, and NGC6830-3 are 0.15 and 0.14, 0.14 and 0.16, and 0.26 and 0.23 mag, respectively (Figure 6). These σ_{sc} values are all comparable with the systematic errors of
Figure 4. Lick spectra of Be star candidates. Fluxes are normalized at 7000Å.
Figure 4 (Cont.). Lick spectra of Be star candidates
9

Figure 5. Spectral energy distribution between 0.4 \( \mu \text{m} \) and 25 \( \mu \text{m} \). Detections at 22 \( \mu \text{m} \) for these Be stars are upper-limit. Flux density of 445 nm, 658 nm, and 806 nm are adopted from PPMXL; flux density of 1.25, 1.65, and 2.15 \( \mu \text{m} \) are adopted from 2MASS; 3.4, 4.6, 12, and 22 \( \mu \text{m} \) flux density are adopted from WISE.

5. SUMMARY AND DISCUSSION

In summary, we apply PTF’s H\( \alpha \) imaging photometry to identify 11 Be star candidates in NGC 6830. Three stars have been confirmed as Be stars with intermediate and late type spectra by using the SED-Machine on Palomar 1.5-m telescope, the Hiyoyu spectrograph on Lulin 1-m telescope, and the Kast dual spectrograph on Lick 3-m telescope. We suggest that there are three Be stars in the cluster NGC 6830. The spatial distribution of the Be stars might be caused by gravitational disruption over time. We also present the results of the SED-Machine; this study demonstrated that the high efficiency of the SED-Machine can provide rapid observations for Be stars in a comprehensive survey in the future.

We suggest that there are three Be stars in the cluster NGC 6830. McSwain & Gies (2005) studied the fraction of Be stars in eight clusters with an age older than 100 Myr; only four clusters have up to two Be stars. These results indicate that old open clusters lack Be stars. Although our results are consistent with the previous conclusions, it should be noted that either the relaxation process or Galactic external perturbation (Chen et al. 2004) might have happened in open clusters. As shown in Figure 7, the Be star NGC6830-3 is located in the outer region of the cluster, while NGC6830-1 and NGC6830-2 are located in the central region. With an age of 125 Mys, the open cluster NGC 6830 might have a very irregular shape and become loose. The spatial distribution of Be stars could be the consequence of the relaxation process. Since McSwain & Gies (2005) searched Be stars within a fixed angular size, more Be stars could be discovered if a larger size would have been...
Table 3
Flux density of Be Stars in NGC6830

<table>
<thead>
<tr>
<th>ID</th>
<th>0.445um (mJy)</th>
<th>0.658um (mJy)</th>
<th>0.806um (mJy)</th>
<th>1.25um (mJy)</th>
<th>1.65um (mJy)</th>
<th>2.2um (mJy)</th>
<th>3.4um (mJy)</th>
<th>4.6um (mJy)</th>
<th>12um (mJy)</th>
<th>22um (mJy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGC6830-1</td>
<td>137</td>
<td>98.3</td>
<td>95.7</td>
<td>100</td>
<td>69.6</td>
<td>48.3</td>
<td>24.9</td>
<td>14.4</td>
<td>3.397</td>
<td>3.053</td>
</tr>
<tr>
<td>NGC6830-2</td>
<td>119</td>
<td>73.2</td>
<td>61.5</td>
<td>89.5</td>
<td>66.1</td>
<td>45.6</td>
<td>24.1</td>
<td>14.7</td>
<td>4.245</td>
<td>1.717</td>
</tr>
<tr>
<td>NGC6830-3</td>
<td>5.7</td>
<td>14.9</td>
<td>14.6</td>
<td>19.5</td>
<td>14.5</td>
<td>12.6</td>
<td>9.434</td>
<td>5.621</td>
<td>1.717</td>
<td>3.093</td>
</tr>
</tbody>
</table>

Note. — Column 1: ID of targets. Column 2 to 11: Flux density in mJy adopted from PPMXL, 2MASS, and WISE catalog. The detections at 22µm for three Be stars are upper-limit.

Figure 7. Spatial distribution of Be star candidates. The open circles: Be star candidates; red pentagram: the known Be star VES72. Contours represent distribution of stars within a field of 50′ × 50′.

Figure 8. HA656 (Left) and HA663 (Right) images of NGC6830-9. Green arrow indicates the residual cosmic-ray. Black open circles represent the position of NGC6830-9.

Dachs et al. (1988) proposed an empirical relation between the disk fraction $f_D$ and the EW[Hα] for Be stars:

$$f_D \simeq 0.1 \times \frac{EW[H\alpha] - 30\AA}{-30\AA},$$

where $f_D$ is the ratio of disk radiation to total radiation of the star-disk system. The EW[Hα] of the Be stars in NGC6830 are all $>-10\AA$, suggesting the disc fraction $f_D < 0.03$. The result is consistent with Dachs et al. (1988), who showed that most late-type Be stars (B4–B7) have $f_D < 0.1$, while most early-type Be stars (B1–B3) have $f_D > 0.1$.

Several mechanisms might cause long-term variability in Be stars: (1) long-lived strong outbursts (Hubert & Floquet 1998); (2) decline of brightness due to cooling envelope (Koubsky et al. 1997); (3) weak brightness change related to Hα variability. The brightness of NGC6830-1 and NGC6830-2 allow us to investigate the variability with the amplitude larger than 0.15 mag using ASAS data set. We do not discover any significant variability for NGC6830-1 and NGC6830-2. This is consistent with the previous studies; Hubert & Floquet (1998) showed that only 12% of B6-type Be stars have the variability with the amplitude of 0.12 to 0.3 mag. Because large amplitude caused by strong outbursts usually seen in earliest Be stars, it is not surprising that we do not detect variability in these Be stars.

Finally, as a pilot project to search for Be stars in clusters with different ages, we reviewed our selection criteria for NGC663 (Yu et al. 2015) and this work. Eight of 11 Be candidates are classified as A- or G-type stars; most of them have marginal Hα detection in the HA663—HA656 color diagram (Figure 2). This misidentification can be improved by using the 2MASS color-color diagram. As shown in Figure 1d, if we make the selection region (dashed line) to have similar range as the known Be stars, most G-type stars would have been ruled out. Thus, we will change our selection criteria in our future project. Moreover, it should be noted that the star NGC6830-9 has large Hα excess in Figure 2, while the optical spectrum suggested a G-type star with the Hα absorption line. This is caused by the contamination of residual cosmic-ray hitting on the target region, which is not easy to be eliminated. Procedures of removing cosmic-ray around science targets will be performed carefully in the future project.

We thank to the referee for her/his constructive comments. We are also grateful to the staff of Lulin and Lick Observatory for helping the observations. This work is supported in part by the National Science Council, and Ministry of Science and Technology of Taiwan under grants MOST 104-2119-M-008-024 (W.-H.I.), MOST 103-2112-M-008-024-MY3 (W.-P.C.), MOST 104-2112-M-008-012-MY3 (C.-C.N.), and NSC 103-2917-I-564-004 (P.-C.Y.). The Lulin Observatory is funded by the Ministry of Science and Technology of Taiwan, and operated by National Central University of Taiwan. The Lick Observatory is funded by Google Inc., and operated by the University of California. 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 publication makes use of data products from the Wide-field Infrared Survey Explorer, which is a joint project of the University of California.
REFERENCES

Barkhatova, K. A. 1957, Soviet Astronomy, 1, 822
Cutri, R. M., Skrutskie, M. F., van Dyk, S., et al. 2003, yCat, 2246, 0
Jaschek, C., Jaschek, M., & Kucewicz, B. 1964, ZA, 59, 108
Mathew, B., & Subramaniam, A. 2011, BASI, 39, 517
McLaughlin, D. B. 1932, POMIC, 4, 175
Pojmanski, G. 2002, Acta Astronomica, 52, 397
Ritter, A., Ngeow, C. C., Konidaris, N., Quimby, R., & Ben-Ami, S. 2014, COSKAS, 43, 209
Rivinius, T., Carciofi, A. C., & Martayan, C. 2013, A&ARv, 21, 69
Zhang, F., Chen P. S., & Yang, H. T. 2005, New Astronomy, 10, 325