Revisiting SW J2000.6+3210: a persistent Be X-ray pulsar?

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ABSTRACT
We present a detailed timing and spectral analysis of the Be X-ray binary SW J2000.6+3210 discovered by the Burst Alert Telescope Galactic plane survey. Two Suzaku observations of the source made at six months interval, reveal pulsations at ~890 s for both observations with a much weaker pulse fraction in the second one. Pulsations are clearly seen in the energy band of 0.3–10 keV of X-ray Imaging Spectrometer for both observations and at high energies up to 40 keV for the second observation. The broad-band X-ray spectrum is consistent with a power-law and high-energy cut-off model along with a hot blackbody component. No change in spectral parameters is detected between the observations. We have also analysed several short observations of the source with Swift/XRT and detected only a few per cent variation in flux around a mean value of $3.5 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$. The results indicate that SW J2000.6+3210 is a member of persistent Be X-ray binaries which have the same broad characteristics as this source.

Key words: pulsars: general – X-rays: binaries – X-rays: individual: SW J2000.6+3210.

1 INTRODUCTION
SW J2000.6+3210 is a high-mass X-ray binary (HMXB) which was discovered during a deep survey with the Burst Alert Telescope (BAT) instrument onboard the Swift observatory (Markwardt et al. 2005; Ajello et al. 2008). It had a time averaged flux (15–55 keV) of $2.37 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$ (Voss & Ajello 2010). Optical spectroscopic studies of the source established it as a Be star with an early B V or mid B III spectral type and average magnitude of 16.1 (R) (Masetti et al. 2008). The same study also put a constraint on the distance to the object at ~8 kpc.

SW J2000.6+3210 was observed twice with Suzaku in 2006 with an interval of six months with about 10 ks exposures. It was also observed several times with the Swift/XRT around the same time but only for short intervals. Timing and spectral analysis of the Suzaku observations was reported by Morris et al. (2009). They detected pulsations in the second observation with a periodicity of 1056 s and pulsations were not found in the first observation. A pulse-phase-averaged spectral analysis was also performed.

We have performed a very detailed analysis of the source with both Suzaku and Swift/XRT pointed observations. The Suzaku observations have established pulsations of the source and the pulse profiles have been probed in different energy bands, even in the hard X-ray band for one of the observations. Detailed spectral analysis has been performed. In Section 2, we describe the details of the observations and data reduction. In Section 3, we describe the timing analysis including pulse period detection and the energy-dependent pulse profiles. In Section 4, we present the pulse-phase-averaged spectral analysis followed by discussions in Section 5 and conclusions in Section 6.

2 OBSERVATIONS AND DATA REDUCTION
Suzaku (Mitsuda et al. 2007) is a broad-band X-ray observatory and covers the energy range of 0.2–600 keV. It has two main instruments, the X-ray Imaging Spectrometer (XIS; Koyama et al. 2007) covering 0.2–12 keV range and the Hard X-ray Detector (HXD) having PIN diodes (Takahashi et al. 2007) which covers energy range of 10–70 keV and GSO crystal scintillators detectors covering 70–600 keV. The XIS consists of four CCD detectors of which three are front illuminated (FI) and one is back illuminated (BI).

SW J2000.6+3210 was observed twice with Suzaku in 2006. The observations were separated by six months and were carried out at the ‘HXD nominal’ pointing position. The XISs were operated in ‘standard’ data mode in the window off option which gave a time resolution of 8 s. The details of the observations are listed in Table 1 (Henceforth Obs 1. and Obs 2.). The data reduction was done following the Suzaku ABC guide. For the XIS data, all unfiltered event files were reprocessed with the CALDB version 20120428 and HEASOFT version 6.11. The source being very faint, the XIS event files were free from photon pile-up. XIS light curves and
spectra were extracted from the reprocessed XIS data by choosing circular regions of 4 arcmin radius around the source centroid. Background light curves and spectra were extracted by selecting regions of the same size away from the source. The XIS count rate was 3.8 and 4.9 c s$^{-1}$ for Obs 1 and 2, respectively. Response files and effective area files were generated by using the FTOOLS task ‘XISRESP’. For extracting HXD/PIN light curves and spectra, unfiltered event files were reprocessed. For HXD/PIN background, simulated ‘tuned’ non-X-ray background event files (NXB) corresponding to the month and year of the respective observations were used to estimate the non-X-ray background (Fukazawa et al. 2009), and the cosmic X-ray background was simulated as suggested by the instrument team applying appropriate normalizations for both cases. Response files of the respective observations were obtained from the Suzaku guest observatory facility.

Suzaku is a gamma-ray burst explorer (Gehrels et al. 2004) having Swift observations. Swift is a gamma-ray burst explorer (Gehrels et al. 2004) having Swift observations. FTOOLS ± 1 is also seen FTOOLS task ‘XRTCEN- http://heasarc.nasa.gov/docs/suzaku/analysis/hxd _repro.html for Obs 1 and 2, respectively. Response files ver 20120209). Swift Suzaku ‘EFSEARCH’.

### 3 TIMING ANALYSIS

Timing analysis was performed on the XIS and PIN data of the Suzaku observations after applying barycentric corrections to the event data files using the FTOOLS task ‘AEBARYCEN’. Swift/XRT observations had short exposures and hence did not have enough sensitivity to search for pulsations or perform any further timing analysis. Light curves with a time resolution of 8 s (full window mode of the XIS data) and 1 s were extracted from the XISs (0.2–12 keV) and PIN (10–70 keV), respectively. Timing analysis was performed by summing the XIS 0, 1, 2 and 3 light curves after background subtraction. Fig. 1 shows the XIS and PIN light curves of Obs. 1 and Obs. 2 with a binsize of 8 s.

#### 3.1 Pulse period determination

Initially pulsations were searched in both the observations by applying the epoch folding technique using the FTOOLS ‘EFSEARCH’. Pulsations were weaker in Obs.1 but were clearly detected in both the observations with periods of 889.7 ± 4.7 and 875.6 ± 2.8 s for Obs. 1 and 2, respectively. The pulse period determined is consistent for both the observations and is in contradiction with that found by Morris et al. (2009) who claimed no pulsations in the data of Obs. 1 and a period of 1056 s for Obs. 2.

We note that with ‘EFSEARCH’ a peak in the $\chi^2$ is also seen at ~1056 s in the second observation which is less significant than the peak at ~890 s. Folding the data with this period also reproduced the pulse profiles given in Morris et al. (2009). To further confirm the correct pulse period of the source, we created power density spectrum (PDS) using the FTOOLS task ‘POWSPEC’ from the XIS light curves (0.2–12 keV, see the middle panel of Fig. 2). The PDS on both the observations clearly shows the peak corresponding to the pulse period determined in this work. Lastly, we created Lomb–Scargle periodograms from the background subtracted and detrended (a best-fitting linear function subtracted from the light curve) XIS light curves of the observations (see Fig. 3). The periodograms show clear peaks at the same period. The peaks corresponding to 1056 s are much smaller in amplitude. All of these establish that pulsations of ~890 s exist in the data which correspond to the spin period of the neutron star. Pulse period could not be independently determined from the HXD/PIN data for the first observation (Obs. 1). Epoch folding performed on PIN data of Obs. 2 however shows the evidence of a peak at the frequency corresponding to the pulse period.

We have further investigated the 1056 s periodicity reported earlier by Morris et al. (2009). In Fig. 3, we have put markers at 1056 s intervals on the XIS light curve. It can be seen that some of the minima coincide with the markers while the others show a secular offset. We infer that the minimum actually occur at ~890 s intervals, which is the pulse period of the neutron star. The PDS on both the observations clearly shows the peak corresponding to the pulse period determined in this work. Lastly, we created Lomb–Scargle periodograms from the background subtracted and detrended (a best-fitting linear function subtracted from the light curve) XIS light curves of the observations (see Fig. 3).

#### 3.2 Pulse profiles and energy dependence

We created the average low-energy pulse profiles from the XIS data (0.3–12 keV) by folding the background-subtracted light curves with the respective pulse periods obtained. As is evident from Section 3.1, pulsations are weaker in Obs. 1 which are also reflected in the corresponding pulse profiles, with Obs. 2 having a higher pulsed fraction. We also obtained the hard X-ray pulse profile (10–40 keV) by folding the background subtracted PIN light curve of Obs. 2 with

### Table 1. List of Suzaku observations.

| Time     | Observation Id   | Effective exposure (ks) |
|----------|------------------|-------------------------|
| 2006-04-12 | 401053010 (Obs. 1) | 9.9                     |
| 2006-10-31 | 401053020 (Obs. 2) | 11.7                    |

### Table 2. List of Swift observations.

| Time     | Observation Id   | Effective exposure (ks) |
|----------|------------------|-------------------------|
| 2005-11-09 | 00035237001 (Sw. 1) | 1.23                    |
| 2006-10-13 | 00035237004 (Sw. 2) | 1.90                    |
| 2006-11-17 | 00035237005 (Sw. 3) | 2.29                    |
| 2006-11-25 | 00035237007 (Sw. 4) | 1.16                    |
| 2006-12-08 | 00035237009 (Sw. 5) | 4.49                    |
the pulse period obtained from the XIS data. This clearly shows that hard X-ray pulsations exist in the source at least up to 40 keV. The pulse profiles for both the observations are shown in Fig. 4 for both the XIS and PIN data. As is evident from the figure, the XIS pulse profiles are complex with the presence of dips. Obs. 2 has a higher pulse fraction \( \frac{F_{\text{max}} - F_{\text{min}}}{F_{\text{max}}} \) and the pulse fraction from the two observations are 20 and 41 per cent. The pulsed fraction in the pulse profile of Obs. 2 given in Morris et al. (2009) at the reported period of 1056 s is lower ~20 per cent. Overall, the PIN pulse profile also looks similar to that obtained from XIS, with a shift in phase of ~0.1 in the minima.

The pulse profiles obtained for the source are typical of that found in many X-ray pulsars, some of which also exhibit strong energy dependence especially in the range below 10 keV. To probe this further, we created energy-resolved pulse profiles with the XIS data (0.3–12 keV) for both the observations by folding the light curves in different energy bands with the respective pulse periods. Fig. 5 shows the energy-dependent pulse profiles for Obs. 1 and 2. Both the observations show a complex energy-dependent nature of the pulse profiles. The narrow dip at ~0.55 for Obs. 1 and ~0.9 for Obs. 2 becomes shallower with energy and disappears at ~5 keV. Energy dependence of the pulse profile is complex as found in many other X-ray binary pulsars (Tsygankov et al. 2007; Devasia et al. 2011; Maitra, Paul & Naik 2012).

### 4 Spectral Analysis

#### 4.1 Pulse-phase-averaged spectroscopy

We performed pulse-phase-averaged spectral analysis of SW J2000.6+3210 using both the Suzaku observations and the two longest observations of XRT (Obs. Id 00035237004 and 00035237009). The other available observations of XRT were used only to estimate the flux of the source on that day and were not used for spectral parameter estimations due to their very short exposures.

For Suzaku, we used spectra from the FI CCDs (XISs 0, 2 and 3), BI CCD (XIS-1) and the PIN. Spectral fitting was performed using XSPEC v12.7.0. The energy ranges chosen for the fits were 0.8–10 keV for the XISs and 15–70 keV for the PIN spectrum, respectively. Due to an artificial structure in the XIS spectra around 0.8–10 keV for the XISs and 15–70 keV for the PIN spectrum, respectively. Due to an artificial structure in the XIS spectra around 0.8–10 keV for the XISs and 15–70 keV for the PIN spectrum, respectively. Due to an artificial structure in the XIS spectra around 0.8–10 keV for the XISs and 15–70 keV for the PIN spectrum, respectively. Due to an artificial structure in the XIS spectra around 0.8–10 keV for the XISs and 15–70 keV for the PIN spectrum, respectively.

The Fe Kα line detected by Morris et al. (2009) was not found to be significant by us. We derived the upper limits for a narrow Fe Kα line in the spectra by fixing its energy and width at 6.4 and 0.01 keV, respectively, and deriving an upper limit on the normalization and hence the equivalent width of the line. The 90 per cent confidence level upper limits of the equivalent width for a narrow Fe line at 6.4 keV were derived to be 15 and 13 eV for Obs.1 and Obs. 2, respectively. The blackbody temperature were ~1.19 and 1.50 keV, and the radius of the emitting region were ~377 ± 65 and 345 ± 58 m of 8 Kpc and the same observations, respectively. The high temperature of the blackbody component and the small emission region support its origin from the polar cap region rather than being a reprocessed component (Paul et al. 2002). This aspect is further discussed in Section 5.

Although the source exhibits complex energy-dependent pulse profiles, the statistical quality of the data was not sufficient to perform pulse-phase-resolved spectroscopy and further probe the energy-dependent nature of the dips.
Figure 2. The first panel shows the epoch folding results for Suzaku Obs. 1 and 2 (left- and right-hand panels) using the summed XIS light curves (0.3–12 keV). The second panel shows the PDS created for the same light curves showing the frequency corresponding to the pulsation period of the source as indicated by the arrows. The third panel shows the Lomb–Scargle periodogram of the same light curves clearly showing the pulsating frequency of the source indicated by arrows.

The Swift/XRT spectra can be fitted well only with a power law with interstellar absorption, and no additional component was required. This may be due to the further limited statistical quality of the XRT data. The best-fitting parameters of the spectral models are given in Table 3. Fig. 6 shows the phase averaged spectra for both the Suzaku and the longest exposure XRT observations. The obtained spectral parameters are consistent within errors between the two Suzaku observations. Consistency was also checked between the parameters obtained from the XRT and Suzaku data by fitting the Suzaku spectra with the same model as for XRT. Results show that while the power-law photon index ($\Gamma$) and interstellar absorption $N_{H}$ are consistent, the power-law normalizations are slightly higher for the Suzaku observations. The 0.3–10 keV flux obtained from all the Suzaku and XRT observations show flux variations by 25 per cent around the mean value of $3.5 \times 10^{-11}$. Assuming the distance to the source to be 8 Kpc, the average luminosity is in the range of $\sim 2-4 \times 10^{35} \text{ erg s}^{-1}$. The flux obtained from all the Swift/XRT observations are tabulated in Table 3.
Figure 3. Summed XIS light curve (0.3–12 keV) of Suzaku Obs. 2 marked at every 1056 s, showing the shift in the minima of the light curve and return every 5–6 cycle.

Figure 4. The XIS (0.3–12 keV) pulse profiles of the two Suzaku observations are shown in the top two panels (left – Obs. 1 and right – Obs. 2). PIN profiles of the same observations are shown in the bottom panels.

Figure 5. The left and right figures show the energy-dependent pulse profiles from 0.3–12 keV created using the summed XIS light curves for Obs. 1 and 2, respectively. The pulse profiles denote normalized intensity.
Table 3. Best-fitting phase averaged spectral parameters of SW J2000.6+3210. Errors quoted are for 90 per cent confidence range.

| Parameter       | Obs. 1       | Obs. 2       | Sw. 1       | Sw. 2       | Sw. 3       | Sw. 4       | Sw. 5       |
|-----------------|--------------|--------------|-------------|-------------|-------------|-------------|-------------|
| \( N_{\text{H}} \) (10^{22} \text{ atoms cm}^{-2}) | 1.2 ± 0.2    | 1.4^{+0.2}_{-0.1} | 1.2^{+0.7}_{-0.6} | 1.7^{+0.4}_{-0.3} | –           | –           | –           |
| PowIndex        | 0.84^{+0.41}_{-0.50} | 1.04^{+0.13}_{-0.22} | 0.83^{+0.40}_{-0.37} | 1.15^{+0.22}_{-0.21} | –           | –           | –           |
| Ecut (keV)      | 7.0 ± 3.8    | 6.2^{+0.8}_{-0.9} | –           | –           | –           | –           | –           |
| Efold (keV)     | 11.2^{+9.9}_{-3.5} | 25.0^{+25.7}_{-9.6} | –           | –           | –           | –           | –           |
| Norm \(^a\)    | 0.001^{+0.005}_{-0.008} | 0.003 ± 0.0009 | 0.021 ± 0.001 | 0.046 ± 0.001 | –           | –           | –           |
| \( K T \)       | 1.3^{+0.3}_{-0.1} | 1.5 ± 0.1    | –           | –           | –           | –           | –           |
| \( K T_{\text{Norm}} \) | 0.6^{+0.4}_{-0.2} | 0.5^{+0.2}_{-0.1} | –           | –           | –           | –           | –           |
| \( \chi^2_{d.o.f} \) | 1.18/343 | 1.16/358 | 0.61/21 | 0.94/60 | –           | –           | –           |
| Flux (XIS) \(^b\) (0.3–10 keV) | 3.2 ± 0.01 | 5.7 ± 0.01 | –           | –           | –           | –           | –           |
| Flux (PIN) \(^c\) (10–70 keV) | 7.6 ± 0.01 | 12.3 ± 0.01 | –           | –           | –           | –           | –           |
| Flux (XRT) \(^d\) (0.3–10 keV) | 3.2 ± 0.01 | 5.7 ± 0.01 | 3.4 ± 0.01 | 4.2 ± 0.01 | 3.1 ± 0.01 | 3.5 ± 0.01 | 3.5 ± 0.01 |

\(^a\) photons keV^{-1} \text{ cm}^{-2} \text{ s}^{-1} \text{ at } 1 \text{ keV} .

\(^b\) \(^c\) \(^d\) Flux is in units of \(10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1} \) and are in 99 per cent confidence range.

5 DISCUSSION

We present a detailed timing and spectral analysis of SW J2000.6+3210 using Suzaku and Swift/XRT observations. We established the pulse period of the source to be 890 s and investigated its pulse profile at different energy bands from 0.3 to 40 keV. Though the pulse period determined is different from that reported in Morris et al. (2009), we have shown that 890 s is the strongest periodicity existing in the data and the earlier report of a periodicity at 1056 s is apparently an artefact. The broad-band energy spectrum can be fitted with a power-law high-energy cut-off and blackbody...
model. We did not detect any change in the spectral parameters for the different observations taken with Suzaku and Swift ranging from 2005 November to 2006 December with the existing quality of the data.

The detection of strong pulsations in the system indicates that accretion is prevalent in the source and matter is being channelled along the magnetic field lines on the poles of the compact object, probably a neutron star. The nature of the companion is identified to be a Be star through optical spectroscopic observations. Further, the X-ray pulse profiles and the nature of the X-ray spectra resemble that of Be X-ray binary pulsars. But due to the lack of any certain signatures like rapid spin change, we cannot rule out the compact object to be a white dwarf (intermediate polar). The spin change rate of an accreting magnetized compact object can be expressed in terms of the compact object parameters and the X-ray luminosity as (Frank, King & Raine 2002):

$$ \nu \simeq 2.7 \times 10^{-12} m^{-3/7} R_6^{6/7} I_X^{6/7} I_3^{1/7} Hz^{-1} $$

with the symbols having usual meaning. Assuming that SWJ000 has an average 0.3–40 keV X-ray flux of 15 $\times$ 10$^{-11}$ erg cm$^{-2}$ s$^{-1}$ (i.e. an X-ray luminosity of 3 $\times$ 10$^{35}$ erg s$^{-1}$ at a distance of 8 kpc), the total change of pulse between the two Suzaku observations is expected to be of the order of 2 s for a neutron star and 0.02 s for a white dwarf. However, the pulse periods measured from the two Suzaku observations are not accurate enough to establish a sufficient change in pulse period which can rule out the possibility of a white dwarf as the compact object.

A Be binary system can exhibit a wide variety of luminosities and the (0.3–70 keV) luminosity estimate of this source ($\sim$2–4 $\times$ 10$^{35}$ erg s$^{-1}$) is within the range of luminosities of this class of sources. Being an optically confirmed Be binary system, its orbital period is expected to be in the range of 100–600 d as estimated from the ‘Corbet’ diagram of pulse period versus orbital period Corbet & Mason (1984), assuming the source to be in spin equilibrium.

Lastly, SW J2000.6+3210 is characterized by a long pulse period, persistent low X-ray luminosity ($\sim$10$^{34}$ erg s$^{-1}$), low X-ray variability and probably reside in a wide binary orbit. All these properties indicate that it is a persistent Be X-ray binary, see Reig (2011). The first sources discovered in this class were X Persei and RX J0146.9+6121 (Haberl, Angelini & Motch 1998). Both of them have relatively low X-ray luminosities ($\sim$10$^{34}$ erg s$^{-1}$) and long spin periods (837 s X Persei and 1412 s RX J0146.9+6121). Two more sources, RX J1037.5+5647 (860 s) and RX J0440.9+4431 (202.5 s) were discovered later by Reig & Roche (1999) which belong to this class. Recently, a possible new persistent Be X-ray binary pulsar SX Peh was discovered in the Small Magellanic Cloud (Hénaux-Brunet et al. 2012). Incidentally, the X-ray pulse profile of SW J2000.6+3210 resembles that of RX J1037.5+5647 with a two peaked structure and a dip in between both in the low- and high-energy bands. The pulse periods are also very similar. It may also be noted that a very low cut-off energy (2–4 keV) was required to fit the spectra of all these sources. We also required a low cut-off energy $\sim$6–7 keV to fit the energy spectra, in contrary to the 10–20 keV cut-off energy usually found in X-ray binary pulsars. SW J2000.6+3210 may thus be an addition to a growing subclass of persistent Be X-ray binaries. Additionally, the presence of a hot blackbody component in the energy spectrum of this source further favours its classification as a Be X-ray pulsar, as all the sources of this class discovered so far has indicated the presence of the same blackbody component at similar temperature and radius of the emitting region (La Palombara et al. 2012, 2013). This hot blackbody spectral component is likely to be the neutron star polar cap emission as indicated by its high temperature and emitting region of $<1$ km.

A possible model for these systems is a neutron star orbiting a Be star in a wide orbit and thus accreting matter only from the outer low density regions of the circumstellar envelope of the companion. Non-detection of Fe Kα line further supports this scenario of scanty material in the vicinity of the neutron star.

It is also worthwhile to mention in this context that the claim of the source being a heavily absorbed X-ray binary as mentioned in Morris et al. (2009) is contradictory to that found by us. Spectral fitting of the phase averaged spectra shows that the source has only a moderate N$_{HI}$ that is consistent with its optical extinction value of 4.0 (Masetti et al. 2008). In addition, pulsations are also detected in the low-energy range ($<1$ keV).

6 CONCLUSIONS

The main conclusions of this work are the following:

(i) We have accurately determined the pulse period of the Be X-ray binary SW J2000.6+3210 and detected pulsations in the source up to 40 keV.

(ii) We have probed the pulse profiles in different energy bands and established the complex energy-dependent nature of the pulse profiles especially in the soft X-rays.

(iii) We have also measured the flux of the source from observations varying over the span of a year and have reported a persistent low flux level varying by only a few per cent. We argue that the low flux level along with the long pulse period and the presence of a hot blackbody spectral component indicate that the source is a member of a growing class of persistent Be X-ray pulsars with the other members of the class being X Per, RX J0146.9+6121, RX J1037.5–5647 and RX J0440.9+4431.

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REFERENCES

Ajello M., Greiner J., Kanbach G., Rau A., Strong A. W., Kennea J. A., 2008, ApJ, 678, 102
Barthelmy S. D. et al., 2005, Space Sci. Rev., 120, 143
Burrows D. N. et al., 2005, Space Sci. Rev., 120, 165
Corbet R. H. D., Mason K. O., 1984, A&A, 131, 385
Devasia J., James M., Paul B., Indulekha K., 2011, MNRAS, 417, 348
Frank J., King A., Raine D. J., 2002, Accretion Power in Astrophysics, 3rd edn. Cambridge Univ. Press, Cambridge, p. 398
Fukazawa Y. et al., 2009, PASJ, 61, 17
Gehrels N. et al., 2004, ApJ, 611, 1005
Haberl F., Angelini L., Motch C., 1998, A&A, 335, 587
Hénaux-Brunet V. et al., 2012, MNRAS, 420, L13
Koyama K. et al., 2007, PASJ, 59, 23
La Palombara N., Sidoli L., Espósito P., Tiengo A., Mereghetti S., 2012, A&A, 539, A82
La Palombara N., Mereghetti S., Sidoli L., Tiengo A., Espósito P., 2013, preprint (arXiv:1301.5120)
Maitra C., Paul B., Naik S., 2012, MNRAS, 420, 2307
Markwardt C. B., Tueller J., Skinner G. K., Gehrels N., Barthelmy S. D., Mushotzky R. F., 2005, ApJ, 633, L77
Masetti N. et al., 2008, A&A, 482, 113
