Influence of light-curve sampling on the periodicity determination in case of subparsec super-massive black hole binaries

Saša Simić[1], Luka Č. Popović[2], Anđelka Kovačević[3] and Dragana Ilić[3]

1) Faculty of sciences, Department of physics, University in Kragujevac, Radoja Domanovića 12, 34000 Kragujevac, Serbia,
2) Astronomical observatory, Volgina 7, 11000 Belgrade, Serbia
3) Faculty of mathematics, University in Belgrade, Studentski trg 16, 11000 Belgrade, Serbia

Abstract:

Here we explore the periodicity determination in the light curves of super-massive binary black holes (SMBBHs) considering different observation sampling during a monitoring period.We use a theoretical model of an SMBBH system which assumes the variability in the light curves is due to dynamical effects. We simulate several observational light curves assuming different cadences, and estimate the periodicity using the Lomb-Scargle (LS) algorithm. We found that the lack of observational data could reduce the significance level of periodicity determination, but still a rough periodicity could be estimated.

INTRODUCTION

In the case of merging galaxies, one can expect that subparsec super-massive binary black holes (SMBBHs) are located in their central parts (Begelman 1980). There are a number of galaxies where a collision can be detected and that potentionally have SMBBH in their centar. The final scenario of a mergers is coalescence event (Merritt 2005) that happens, producing a new super-massive black hole.

To explore posibilities for detection of such objects it is necessary to investigate SMBH signatures in the continuum and broad line light curves of AGNs. This motivates us to develop a model (Popović 2020) and demonstrate variability that was used in exploring periodicity of well known SMBBH candidate (Kovačević et al 2019). Here we continue our investigation of the possible periodicity in the SMBBH light curves, i.e. exploring the perspective of AGN monitoring to find good candidates for SMBBHs. Particularly in this work we consider influence of different observation sampling to determination of the periodicity, that is expected to be present in the SMBBH light curves.

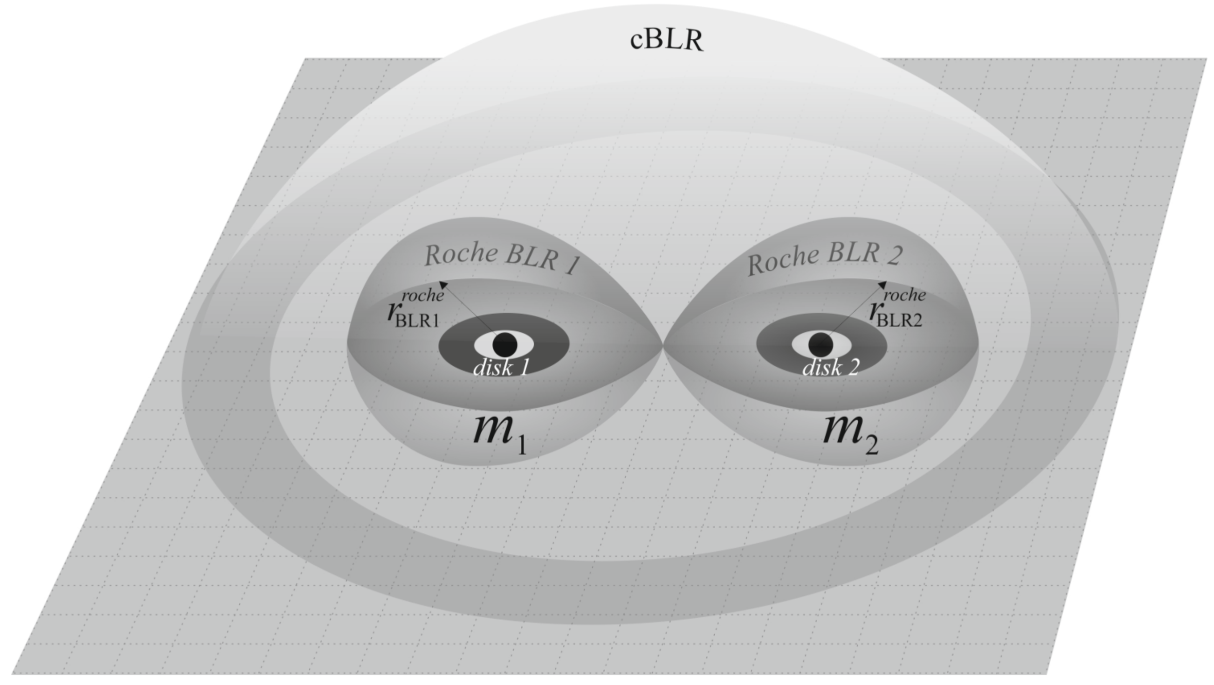

Fig 1. SMBBH system in compact configuration, with designated broad line regions of particular components (BLR1 and BLR2) inside a Roche lobe and common one (cBLR) outside of Roche lobe.

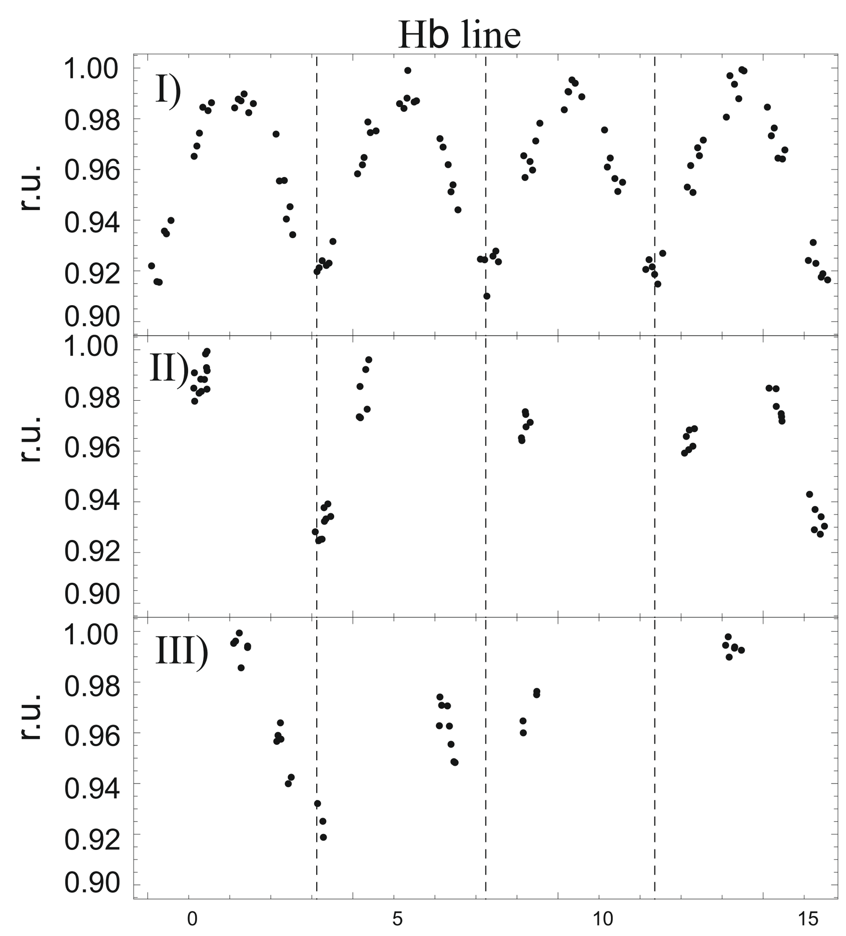

Fig 2. Examples of light curves for emission in Hβ line of SMBBH system ($m_1 = m_2 = 5 \times 10^7 M_{sun}$, a = 0.01pc) during 4 full rotation, for three discussed cases.

We distinguish three different cases:
I) when observations are made in first half of the year, randomly once per month for entire time period of $4P_{orb}$ and
II) and **III)** with reduced number of observations and random cadence in total observational time.

THE MODEL

We consider the case where both components have the accretion discs and broad line region (BLR) that is surrounding the disks (Fig 1.). We accepted the model of a standard optically thick, geometrically thin, black body accretion disc, (Shakura & Sunyaev 1973), with effective temperature as a function of radius from the center. The BLR can have different geometries, but we assumed that is flattened, with the same inclination as corresponding disc. The BLR inner radius is very close to disc outer radius and spans a few tens of light days in diameter.

This region is photoionized by the X-ray and UV radiation from accretion disc. We estimate the BLR size by using the empirical formulas (Kaspi et al. 2005), i.e. using the luminosity at 5100A (for Hβ line). We assumed that BLR is composed from three different regions. First two regions (movable) are defined by the local Roche lobes of components in the SMBBH system and third (static) is a circum binary region (cBLR) spanning around both component, as shown in Fig. 1.

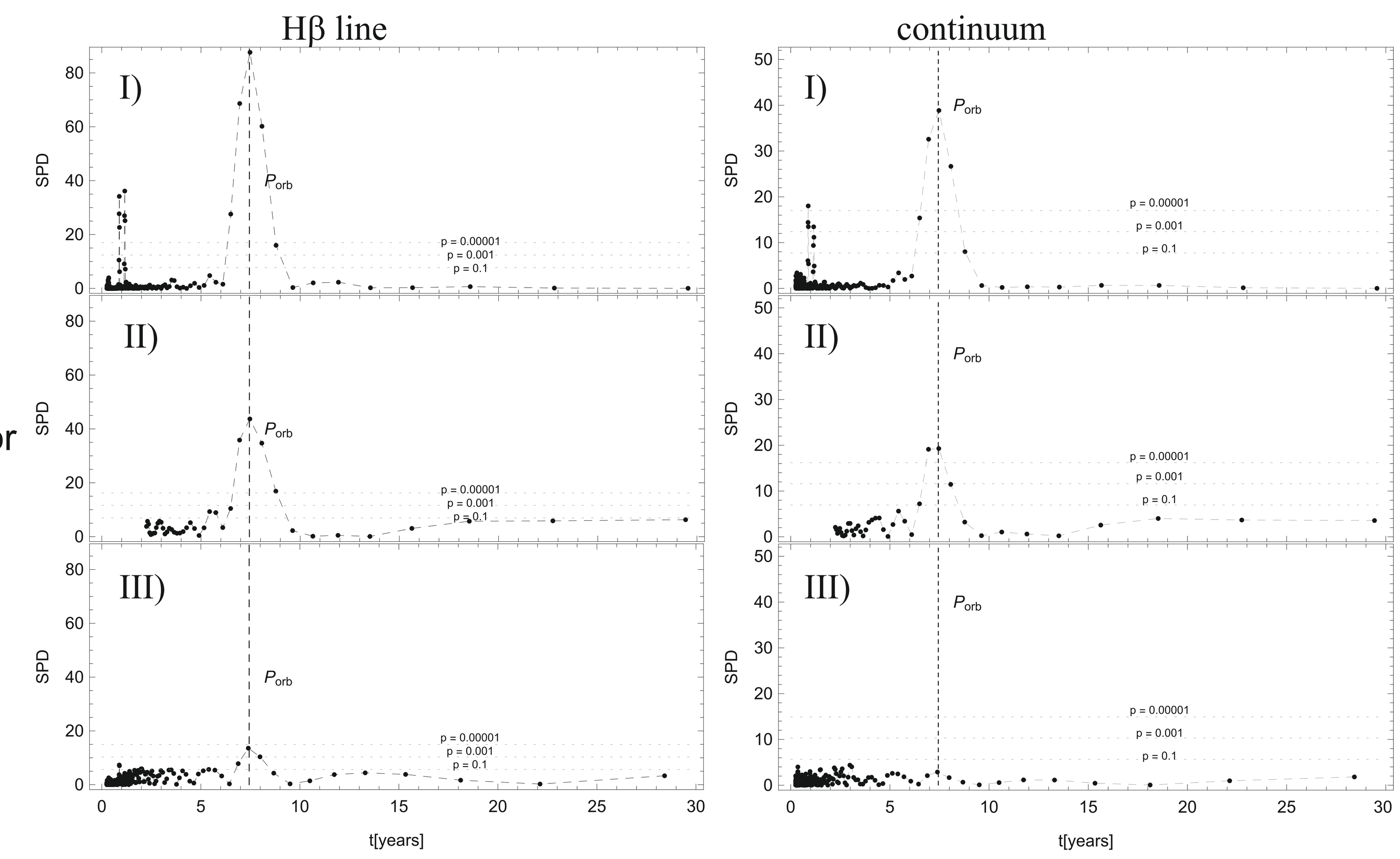

Fig 2. Periodograms for Hβ line and continuum flux in case of SMBBH system derived from defined cases. Horizontal dashed lines present significance level lines.

CONCLUSIONS

- number of observations directly influence level of significance of period discovery.
- irregularity of observational data additionally reduce possibility for period determination.
- in case with low observation number and irregular data distribution we can not expect accurate period computation.

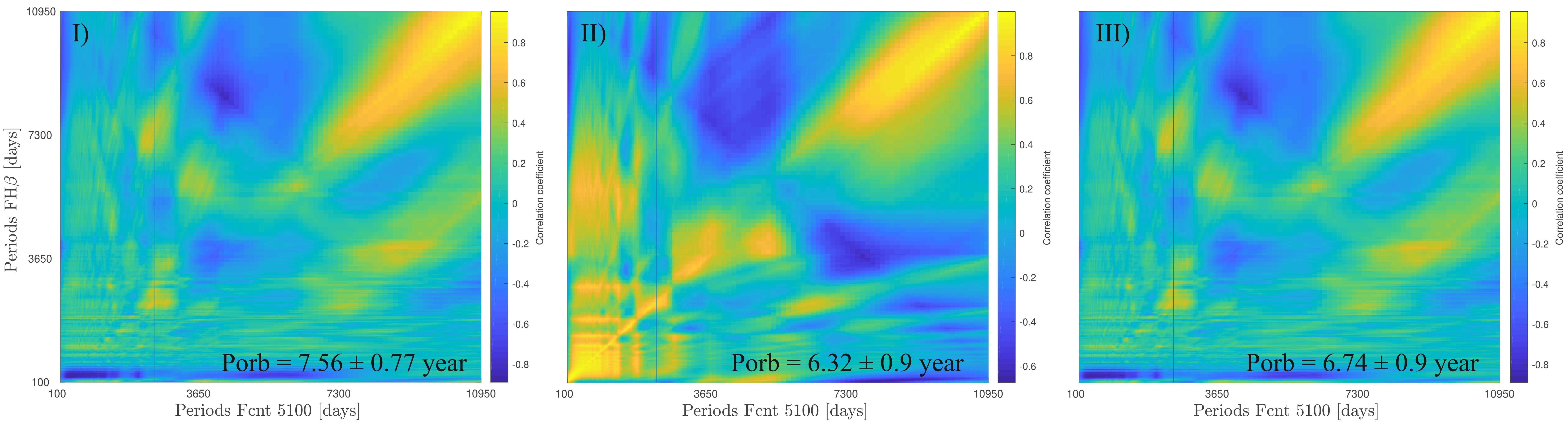

Fig3. 2D correlation maps of periodic signals in the continuum and Hβ. Detected signal is corelation island at the bottom left on main diagonal. From left to right: sampling case **I)** (7.56±0.77yr, case **II**) 6.32±0.9yr, and case **III**) 6.74±0.9yr, respectively. Note that intensity of the signal is decreasing, however correlation values are larger than 0.5.

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