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Measuring deviations of minimum predicted times in eclipsing binary stars as an active teaching methodology

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Abstract. The "Science in the Caatinga" project executes a series of science activities in public schools in an arid part of Pernambuco, Brazil. Pedagogically based on active teaching methodologies, these activities can be divided into science teaching, science communication and observational practices. In this latter, students are stimulated to analise how light coming from Eclipsing Binary Stars (EBs) varies, expecting to detect deviations of the minimum predicted times (during primary eclipses) for these systems. The equipment set consists of a 42cm SCT telescope + CCD. However, in spite of detecting such variations is not a trivial task, demanding a huge number of observations over time, all efforts are worthwhile since, in addition to help students developing an intuition about some mathematical and physical concepts, can also provide scientific information which can reflect real physical changes in the star system, such as mass transfer, starspots or effects related to accretion disks. Core objectives of the project are: a) A better understanding of astronomy through a hands-on experience; b) Introducing students to photometric techniques and how these can inform on the evolution of EBs; c) Building an observational database to support, further on, other students in achieving successful detections.

Resumo. O projeto "Ciência na Caatinga" executa uma série de atividades científicas em escolas públicas de uma árida região de Pernambuco, Brasil. Pedagogicamente baseadas em metodologias de ensino ativo, tais atividades podem ser divididas em ensino de ciências, comunicação em ciências e práticas observacionais. Nesta última, os estudantes são estimulados a analisar como a luz proveniente de estrelas binárias eclipsantes (BEs) varia, com o objetivo de detectar desvios nos tempos mínimos previstos (durante eclipses primários) para esses sistemas. O equipamento empregado consiste em um telescópio SCT de 42cm + CCD. No entanto, apesar de detectar tais variações não ser uma tarefa trivial, exigindo um robusto número de observações ao longo do tempo, todos os esforços valem a pena pois, além de ajudar os estudantes a desenvolverem uma intuição sobre alguns conceitos matemáticos e físicos, também podem fornecer informações científicas que reflitam mudanças físicas reais no sistema estelar, como transferência de massa, manchas estelares ou efeitos relacionados à discos de acreção. Os principais objetivos do projeto são: a) Proporcionar uma melhor compreensão da astronomia por meio de uma experiência prática; b) Introduzir os estudantes às técnicas fotométricas e em como estas podem fornecer informações sobre a evolução das BEs; c) Construir uma base de dados observacionais para apoiar, posteriormente, outros estudantes na obtenção de detecções bem-sucedidas.

Keywords. Teaching of Astronomy – (Stars:) binaries: visual – Photometry

1. Introduction

The "Science in the Caatinga" project, through a series of science activities and using celestial bodies as boundary objects, aims to contribute to science teaching in public schools in six cities (Itacuruba, Floresta, Belém do São Francisco, Petrolândia, Jatobá and Tacaratu) in the Itaparica's Region, an arid part of the State of Pernambuco, Brazil. These activities, pedagogically based on active teaching methodologies like Project Based Learning (Luchesi & Lara. 2022), can be divided into three main axes: science teaching, science communication and observational practices. In this latter, preparing observing runs trying to detect deviations of minimum predicted times in eclipsing binary stars help students to intuit about some useful math and physics concepts (Da Luz & Álvares. 2014).

Eclipsing Binaries (EBs) are binary star systems in which their orbital planes are side on as seen from Earth so that, as stars move around each other, there are eclipses. Usually, these stars are so close together that cannot be telescopically separated. Instead, we know they are EBs analysing how light coming from the system varies. Primary eclipse occurs when the brighter star is fully obscured by the fainter for a time, occurring the minimum brightness of the system.

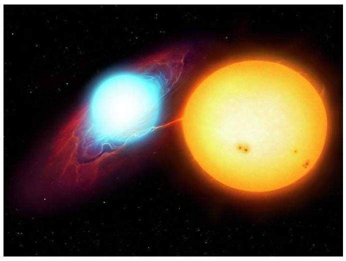

Figure 1. Eclipsing binary stars system. Font: BBC Sky at Night Magazine

2. Methodology

EB stars generally display such regularity in their periods that any deviation of the actual time of minimum from the predicted time may be significant. The regularity is such that after one minimum has been chosen as a starting epoch, future minima can be calculated using a linear mathematical relationship, standard elements of an epoch and a period published in international catalogs. This relationship is then used to project a table of calculated times of central eclipse to form an ephemeris of opportunities to observe the actual time of minimum. Observers use the efemerides of

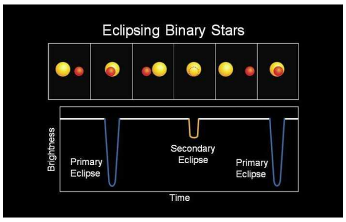

Figure 2. Eclipsing binary stars: light curve and eclipses. Font: Juniata College

Figure 3. 16-inch (42 cm) f/10 Schmidt-Cassegrain telescope:side view. Font: Authors

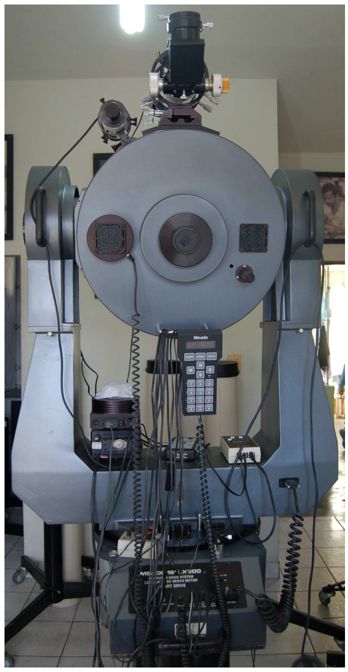

Figure 4. 16-inch (42 cm) f/10 Schmidt-Cassegrain telescope:rear view. Font: Authors

some program stars to plan observing runs on individual stars in order to establish the observed time. By comparing that observed time with the calculated time of central eclipse (O-C) on a regular basis, it is possible to detect secular changes in the period of the star that can reflect actual changes in the physical system (Kallrath 2009). Stars that exhibit such changes in period represent opportunities to study the physical characteristics of the system more intently in order to understand the nature of the physical changes taking place, for example, in a process of mass transfer between the two stars, star spots or a loss of mass from the system.

Thus, students are involved in doing observations over some selected EB systems taken from the American Association of Variable Star Observers Eclipsing Binaries Section (Williams & Saladyga 2011) using a 16-inch (42 cm) f/10 SCT with a f/5 focal reducer, CCD camera and software package, aiming to photometrically track their brightness changes over time. Observations started in 2024 priorizing long period EBs. Later, students reference the SIMBAD Astronomical Database, using data of spectral types of both stars, in order to properly compare them, getting insights about the complexity evolving the formation of these pairs, which can facilitate the apprehension of some physics concepts related to thermodynamics, such as the Planck's Law, Black-Body Radiation and the Stefan–Boltzmann's Law (Longhini 2010). After observations, students will be able to analyse and report their results, receiving support and advice from the scientific staff of the project (Larmer & Mergendoller 2015).

3. Conclusions

However, detecting such variations requires a large number of observations over a reasonable interval of time. Thus, our goal, at least initially, focuses on: a) Enabling students to be introduced to the photometric technique and how it can inform on the evolution of EBs, even if they do not detect the expected variations; b) Building an observational database to support, further on, other students in achieving successful detections; c) Give a better understanding of astronomy through a hands-on experience; d) Provide the students with an understanding of stellar variability from both the spectroscopic and the photometric point of view.

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