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A filar micrometer for double stars observation

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Abstract. Double stars astrophysics is an excellent introductory suggestion to observational astronomy. Because it is fun, it is a great way to attract and disseminate science, especially when you want to compare data from the catalog of these stars with our measurements. It is also an essential to work, as a carefully made double star measurement has permanent value. The measurements support the determination of the apparent orbits of these stars, which, in turn, help us calculate the stars' masses. Moreover, double star observation offers some of the most beautiful night sky views and is particularly good in small telescopes where colors are most evident. The ease of observing them is also remarkable, as they are among the most common objects in the sky. Light pollution, a common problem in urban centers, is not inconvenient for their observation. Historically, the observation of binary stars has been carried out with the Filar Micrometer, a specialized eyepiece developed for astrometry measurements. A typical filar micrometer consists of a reticle with two thin parallel wires that can be moved by the observer using a micrometer screw mechanism. The wires are placed in the focal image plane of the eyepiece so that they remain neatly superimposed on the object under observation. At the same time, the movement of the micrometer moves the wires along the focal plane. With the filar micrometer, it is possible to measure the separation of the binary pair (ρ) and the position angle (θ). As part of this work, we propose the reconstruction of a homemade filar micrometer, based on an old project published in the Sky and Telescope magazine in 1977 by the astronomer Jorge Polman. We intend to make some observations to test its efficiency in the systematic measurements of the Paraná sky binaries. With this, we also intend to help those interested in the study of binaries to reproduce this device and start an observation program that will provide essential data for professional astronomers.

Resumo. A astrofísica de estrelas duplas é uma excelente sugestão introdutória à astronomia observacional. Por ser divertido é um ótimo meio de atração e divulgação de ciência, principalmente quando se deseja comparar os dados do catálogo dessas estrelas com nossas medidas. Também é um trabalho essencial, pois uma medida de estrela dupla feita com cuidado tem valor permanente. As medições suportam a determinação das órbitas aparentes dessas estrelas, que, por sua vez, nos ajudam a calcular as massas das estrelas. Além disso, a observação de estrelas duplas oferece algumas das mais belas vistas do céu noturno e é particularmente boa em pequenos telescópios onde as cores são mais evidentes. A facilidade de observá-los também é notável, pois estão entre os objetos mais comuns no céu. A poluição luminosa, problema comum nos centros urbanos, não é inconveniente para sua observação. Historicamente, a observação de estrelas binárias tem sido realizada com o Micrômetro Filar, uma ocular especializada desenvolvida para medições astrométricas. Um micrômetro filar típico consiste em um retículo com dois fios finos paralelos que podem ser movidos pelo observador usando um mecanismo de parafuso micrométrico. Os fios são colocados no plano de imagem focal da ocular, de modo que permaneçam sobrepostos ao objeto sob observação. Ao mesmo tempo, o movimento do micrômetro move os fios ao longo do plano focal. Com o micrômetro filar é possível medir a separação do par binário (ρ) e o ângulo de posição (θ). Como parte deste trabalho, propomos a reconstrução de um micrômetro filar caseiro, baseado em um antigo projeto publicado na revista Sky and Telescope em 1977 pelo astrônomo Jorge Polman, com o qual planejamos fazer algumas observações para testar sua eficiência nas medições sistemáticas dos binários do céu paranaense. Com isso, também planejamos ajudar os interessados no estudo de binários a reproduzir este dispositivo e iniciar um programa de observação que fornecerá dados essenciais para astrônomos profissionais.

Keywords. Astrometry – binaries: visual – Instrumentation: miscellaneous

1. Introduction

If we could look at the astronomical practice of the last century, we would notice much difference in the exercise of the professional activity practiced today. Almost all observational astronomy was visual, but today very few professional astronomers look through the eyepieces of their telescopes. It took a long time to gather astronomical data, sometimes a lifetime, for a significant discovery.

Today we live in a technological age where it is possible to receive more data from space than we can process, and both the speed and the volume of this information continue to increase. The human eye was gradually replaced by more efficient light collectors, such as photographic emulsions and CCD cameras, and data processing was attributed to calculators and computers.

However, despite all these scientific-technological advances, there are still some fields of professional astronomy where visual work is relevant. One of them pertains to the systematic observation of nearby double stars.

The study of binaries, gravitationally bound star systems, is of great importance in stellar astrophysics, revealing much about stars' physical and evolutionary characteristics. For example, the regular orbital motion of its components shows that Newton's law of universal gravitation is valid for objects located at great distances from the Earth. Furthermore, the knowledge of some orbital data of the double stars made it possible to measure their distance and evaluate the total mass of the binary system and, in some cases, even the individual mass of its components.

The human eye has two significant merits as a light receptor: it perceives the image of a star very quickly, so it can react to transient moments of good vision; in addition to being connected to the most efficient computer that exists, the human brain, which allows a quick analysis of results. Sometimes these advantages make the human eye superior to photography in observing double stars separated by less than two seconds of arc.

> It is a common belief among some observers that the CCD camera has rendered visual micrometry obsolete. Nothing could be further from the truth. One of the properties lost with the use of CCDs for double-star measurement, whether by speckle interferometry or integrated imaging, is dynamic range. It is very difficult for CCDs to measure doubles with components of substantially different brightnesses or faint pairs that are very close. For these challenging pairs, visual micrometry still remains the best measurement technique. Because so few professionals remain in this field, qualified amateurs are badly needed. Double-star micrometry has always had a significant percentage of amateur observers in its ranks. For example, Paul Baize, perhaps the greatest double-star observer who's ever lived, made 25,000 measurements and calculated 200 orbits! With several thousand visual double stars within range of 3- to 8-inch telescopes, today's amateurs are in a unique position to make contributions to double star astronomy that they previously may not have thought possible (Tanguay 1999, 116-121).

This work intends to invite the reader to enter the fascinating world of binaries, attracting more people to this important area of astronomy and helping to spread science; in particular, we will rescue an old project of a filar micrometer by the Dutch astronomer Jorge Polman. This equipment is of great scientific importance, widely used by astronomers, professionals, and amateurs in measurements of double stars, comets, and even lunar craters.

With this, we want to encourage the disciplined study of binaries by the Brazilian astronomical community and the engagement of amateur astronomers and astronomy clubs throughout the country in the measurement of neglected systems since a professional micrometer is costly for most people.

2. The Observant Dutch

This research originated in the works of Jorge Polman, a Dutch observant who was a pioneer in teaching and disseminating astronomy in Brazil.

Johannes Michael Antonius Polman, his given name, was born in Amsterdam on January 7, 1927, the son of Herman Polman and Cornelia de Vries. From a very young age, he was always an aficionado of the science of the stars. However, his attention was radically changed when Europe went to war.

At 13, Polman witnessed the invasion of Nazi Germany into his country, which lasted five years until the liberation of Holland by Allied troops. It was a challenging period for his family, even going through the terrible hongerwinter[1](famine winter) in late 1944.

At the end of World War II, at 18, he tried to resume his studies at the University. However, again, he must interrupt his academic activities to get involved in another war. This time, the Royal Dutch Army called him to participate in the Indonesian National Revolution. According to (Prazeres 2004, 19-37), he belonged to the armored infantry, where he learned to maneuver tanks. In one of his fights, he observed death up close, wounded on the left side of his face. Luckily, he recovered without sequelae, just a scar on his cheek. The conflict lasted until 1949 when the Netherlands gave up this colony.

Back home, Polman, tired of all the hardships of war, makes the decision never to participate in them again. To ensure his resolution, he enters the Catholic seminary in Rotterdam. After some time, he was invited to continue his theological studies in Brazil. He then decided to leave for America aboard the ship *Andrea C*, owned by the shipping company *Costa Cruceros*. The voyage took about 30 days to cross the Atlantic, disembarking in the port of Rio de Janeiro on November 10, 1952.

After completing his cycle of studies, he ordained a priest on December 1, 1957, serving as a priest of the order of the Sacred Heart of Jesus in the city of Recife. Interestingly, after this collation, he started using the name Jorge Polman, the name he became known by his Brazilian brothers.

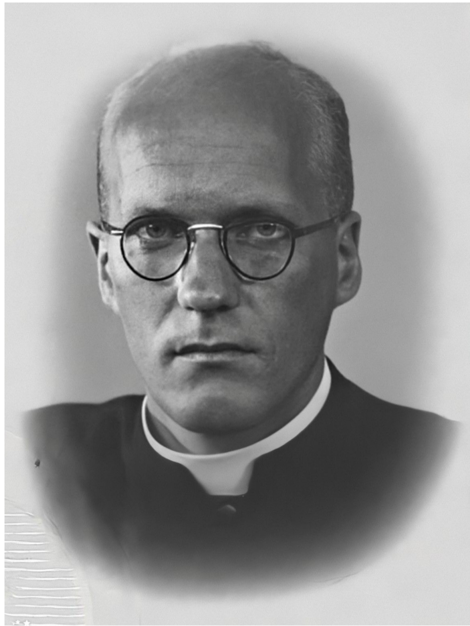

Figure 1. Jorge Polman.

Due to his scientific training, he was invited to teach physical and biological sciences, first at the Paudalho boarding school and later at São João school, located in the Várzea neighborhood in Recife. In his classes, he used astronomy as a pedagogical tool, starting in 1968 the observational practice with some of his elementary school students.

> In a certain science class, I taught optics and brought a telescope to the class. Four of them asked to come, on a Wednesday night, to observe the sky with a telescope. And they were very surprised, immediately asking to come again the next week. Instead of four, eight came, which multiplied and ended up asking me to teach a course. Hence, the Club was born. I could no longer stop the movement that grew by itself in the interest of the students (Gouveia 1985, A8).

These observations were made with a four-inch Newtonian telescope he had brought with him from Holland.

These activities were a huge success, so much so that Polman created an astronomy club in May 1972. The *Clube Estudantil de Astronomia (CEA)*, which became the birthplace of many other astronomical associations, in addition to influencing generations of boys and girls to the scientific area.

On November 30, 1973, one of the club's first significant activities was the observation of the *Kohoutek* comet. On that

[1] It was one of the most severe famines that occurred during the Second World War. For months, German troops blocked food supplies in most of the Netherlands, leaving 4.5 million people desperately hungry.

occasion, Polman and some of his students went to the viewpoint of *Morro dos Guararapes* to observe the comet's passage. According to (Carvalho 1973, 10), viewing it at 03:20 in the morning was possible. The sky was covered by clouds that hampered the activity. In addition, a police car was called to verify an alleged mass at the place. Probably some mother worried about the meeting being delayed.

3. The Micrometer Design

In 1976 he started an audacious project to train the club's students in the measurement of double stars. To do so, he designed his micrometer based on Charles Worley's model, used at the Lick observatory (Worley 1961, 140-141). At the time, Brazil lived under the aegis of the Military Regime, with importing certain materials manufactured abroad prohibited. Therefore, we had to manufacture our instrument with the available local resources.

The original prototype was made of cedar wood, and the micrometer threads were a cobweb, a material strong and thin enough for the reticle. Figure 2 shows a copy of the instrument's design obtained through contacts with the president of the Astronomical Association of Pernambuco (AAP).

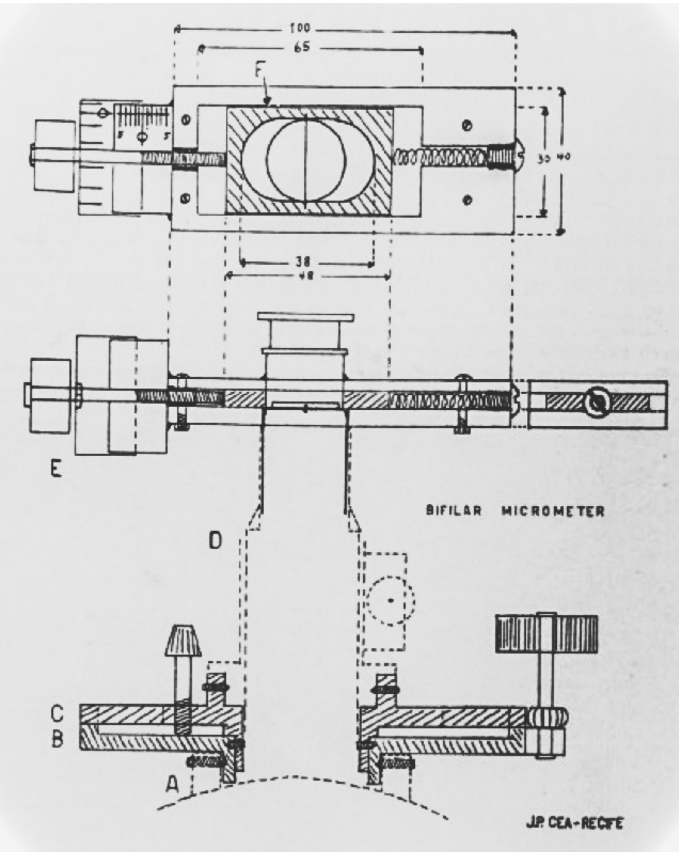

Figure 2. Micrometer schematic drawing.

A 5-inch cedar base plate (B) was affixed to the eyepiece mounting block (A). A 360° acrylic plastic protractor with half-degree divisions was screwed to it. The upper plate (C) has hands in two diametrically opposite windows and can be turned using the knob on the side. This gauge plate has a raised hub to which a Japanese-made pinion and recoil assembly (D) is secured with a set screw.

The micrometer itself (E) is also made of cedar. The top and bottom plates are fixed with four small screws. The bottom contains a spring and 32 threads per inch precision machine screw, controlling the movement of a sliding plate (F). The latter is cut in the center, and the moving wire of the micrometer is placed through the opening. The bottom plate holds the fixed wire and an adapter tube that fits into the rack and pinion bracket. We mount a Zeiss 12mm eyepiece on the top plate.

The moving wire must pass freely back and forth over the fixed wire; however, the wires must always remain parallel and almost in the eyepiece's focal plane. A drum calibrated on the side indicates hundredths of a screw revolution.

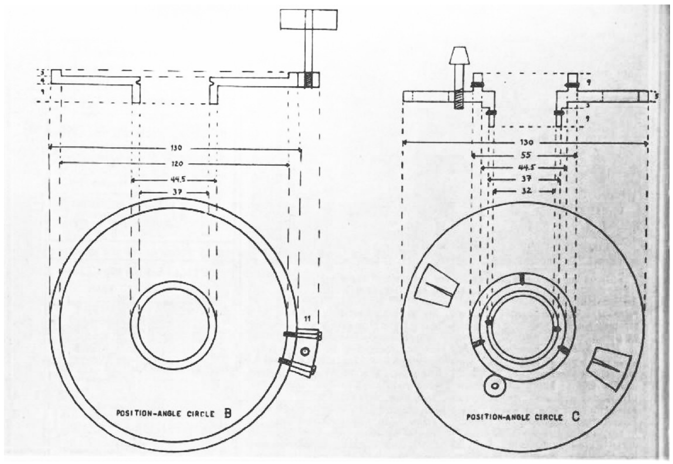

Figure 3. These two disks are also shown in Figure 2. The large knob rotates the micrometer into a position angle, while the other is a clamp.

According to (Polman 1977, 391-396), one of the observer's first tasks is to find the relationship *R* between the drum readings and the lateral separation of the wires. That is the number of arcseconds in the focal plane corresponding to one complete turn of the micrometer screw. For a given telescope and micrometer, the R-value must be carefully determined once and checked if the telescope is modified.

However, the north point of the position angle circle must be determined each session anew by observing a star close to the celestial equator and meridian (to avoid an atmospheric refraction effect). The star follows perfectly along the fixed wire when the configuration is found. Simple addition or subtraction of 90° gives the north point.

Position angles are measured east (counterclockwise) from the north and can be any value up to 360°. The micrometer can be constructed so that the north point reads close to 0°, but a correction determined by observation must always be applied.

Tests with the instrument were very promising, with an average error below 10% compared to the ephemeris values. The micrometer prototype was sent to a mechanic who duplicated it into brass and aluminum parts. This time 12-micron thick nylon threads were used. The filar micrometer was used at CEA until 1985 when the club's activities ended and the priest Jorge Polman died[2].

[2] For more information about Jorge Polman, we suggest consulting the article The Power of Inspiring Generations: A tribute to Jorge Polman. Brazilian Astronomy Union, 2021 (Guest Articles). Available in the Ouranos Bulletin.

4. Rescue of observational practices

To encourage the astronomical community's observational practice of double stars, we propose the reconstruction of Jorge Polman's filar micrometer. Its construction is relatively simple and low cost and can be reproduced by anyone with mechanical construction skills.

Micrometer designs were standard in specialized magazines and the bulletins of amateur astronomical societies. However, nowadays, they are scarce. In addition to the high costs, the acquisition of commercial micrometers is only possible in the used market.

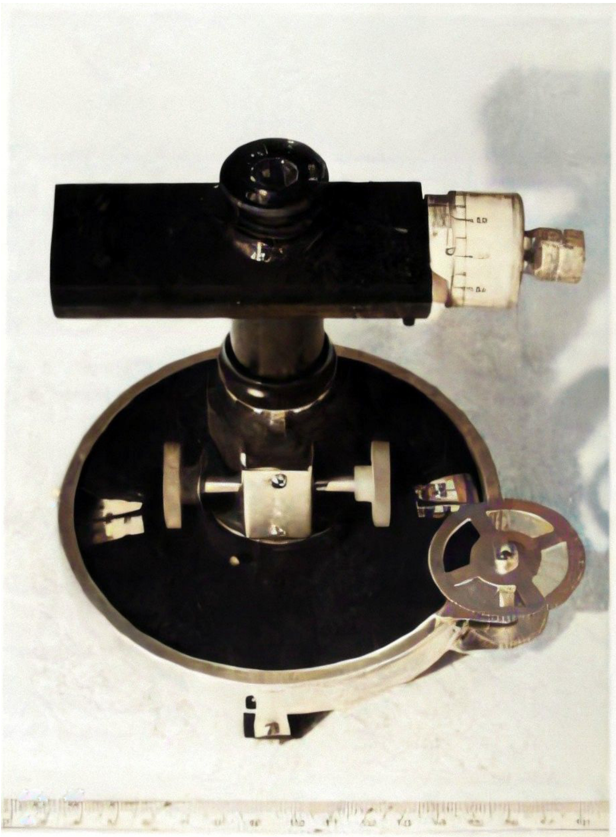

Figure 4. The mounted filar micrometer

With equipment like these, it is possible for any amateur astronomer, with little training, to make measurements of double stars and thus contribute essential data to this astronomical area. These measurements should preferably be sent to the Washington Double Stars (WDS) catalog[3], which compiles the world's most extensive database of double stars. This submission process is usually intermediated by accredited astronomical entities, such as astronomy clubs and amateur societies close to the interested party[4].

The data helps professional astronomers who can determine these systems' orbits and extract the stars' masses and other relevant features.

The micrometer is in the prototyping process, rebuilt by CNC lathes with the support of a digital fabrication laboratory (FabLab). After completing this phase, we intend to use it with the support of the astronomy club of the *Universidade Tecnológica Federal do Paraná* (CAUTEC)[5] and test its efficiency in measuring the binaries present in the sky of Paraná.

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[3] Double Star Program of the USNO.

[4] Double Star Observing Program of the Astronomical League.

[5] Astronomy Club of the UTFPR.