

# Stargazers Corner: Focus on Zeta Ursae Majoris - Mizar

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**Abstract:** : This is a general interest article for both the double star viewer and armchair astronomer alike. By highlighting an interesting pair, hopefully in each issue, we have a place for those who love doubles but may have little interest in the rigors of measurements and the long lists of results. Your comments about these mini-articles are welcomed.

## Introduction

My first view of a double star through a telescope was an inspiring sight and just as with many new observers today, the star was Mizar. As a beginning amateur telescope maker (1951) I followed tradition and began to use closer doubles for resolution testing the latest homemade instrument. Visualizing the scale of binaries, their physical separation, Keplerian motion, orbital period, component diameters and spectral characteristics, all things I had heard and read of, seemed a bit complicated at the time and, I might add, more so now! Through the years I found that simply sketching the telescopic appearance of doubles was great fun and my stargazing notes show many such entries. It is only recently that I began to measure doubles from my backyard observatory with homemade telescopes. Certainly, the sight of Mizar, some 53 years ago, set the stage.

In this article we journey a little closer to Mizar. Even though the intricacies of this pair were known 100 years ago, it remains a fascinating modern-times object.

## Mizar and Alcor

Mizar “the apron” is the 2<sup>nd</sup> magnitude star marking the bend in the Big Dipper’s handle and is visually partnered with 4<sup>th</sup> magnitude Alcor just 11.8 minutes of arc away. Alcor is listed in the Washington Double Star Catalog (WDS) as the C component of Mizar (STF 1744 AC) If Alcor “the rider” can be spotted with the naked eye you have reasonably sharp vision. The

Arabs long ago named Alcor “Saidak” or “the proof” as they too used it as a test of vision. Alcor shares nearly the same space motion with Mizar and about 20 other stars in what is called the Ursa Major stream or moving cluster. The Big Dipper is considered the closest cluster in the solar neighborhood. Alcor’s apparent separation from Mizar is more than a quarter light year and this alone just about rules out this wide pair from being a physical (in a binary star sense) system and the most recent line-of-sight distance measurements give a difference between them of about 3 light years, ending any ideas of an orbiting pair. When observing Mizar and Alcor together at low power you will see a 7.6 magnitude star between them and somewhat south-southeast. Mizar’s proper motion will carry it to near optical alignment with this fainter star in about 2,600 years, giving future observers a beautiful telescopic triple!

## Mizar Itself

The first double star discovered was Mizar. It was found by Benedetto Castelli<sup>1</sup> in 1617 and later independently by Riccioli in 1650 and has remained to this day one of the most popular “showpiece” pairs for the sky watcher. Because of the many discovery and technical “firsts” connected with Mizar, it was later informally dubbed the “pioneer star”. This double is designated STF 1744 AB in the WDS catalog. Its sky coordinates are 13 hours 23.9 minutes in right ascension and +54 degrees 56' in declination. In my 3-inch aperture 20 power finder, the primary (A) and secondary (B) are clearly seen with black sky between

### Stargazers Corner: Focus on Zeta Ursae Majoris - Mizar

them. Through the 9-inch main telescope, Mizar is widely split even with the lowest power eyepiece. The 3.8 magnitude secondary is separated from the primary by 14.4 seconds of arc and the position angle is 152 degrees (2000), having slowly increased by 6 or 7 degrees since the first reliable measure by F. G. W. Struve in 1820. Even so, a much earlier measure by Bradley in 1755 is of rather good quality and must be figured in. It is the earliest entry for Mizar in the WDS catalog. My most recent separation measurement (2006) seems to support a very slow closing since 1820.

The orbital period is probably thousands of years, even so it will likely make thousands of orbital trips before the brighter component moves off the main sequence, thus starting its journey to the realm of the giants. This journey, as we shall see, has some unusual complications!

Under very clear skies, both components appear pretty much white to my eyes at 150 power. Sometimes the fainter component looks barely tinged with yellow, but I chock it up to an illusion! They are listed as spectral class A2V for A and A7V for B. This indicates an effective temperature of about 8,800 and 7,500 degrees Kelvin respectively. The V designation indicates that both are main sequence or dwarf stars.

The sun is also a dwarf, but less massive and much cooler and would appear a rather dim 6th magnitude star if placed alongside Mizar. The actual distance to the pair is 78 light years and, according to Burnham's *Celestial Handbook*, the orbital diameter is 5 times bigger than Pluto's. Second in its string of firsts, Mizar was the first double to be photographed, an amazing achievement by Bond in 1857. He used wet plates and the Harvard College Observatory's 15-inch Merz & Mahler "Great Refractor". In a way, this ushered in the field of long focus photographic astrometry! Years ago, as part of Harvard's documentation of the instrument, I had the somewhat nervous pleasure of assisting in the measurement of the individual radii of curvature of this historic doublet.

### The Spectrograph and Interferometer Team-Up

Through the Doppler effect, Mizar A was found to be a spectroscopic binary by E. C. Pickering in 1889 by the cyclic doubling of its spectral lines, just beating out H. C. Vogel's discovery of the spectroscopic duplicity of Algol and Alpha Virginis for the first detected example. Probably as an artifact of infrequent observation, Pickering arrived at a false interval of 52 days (orbital period of 104 days) using his objective prism

instrument. In 1899-1900 Vogel turned the power of the newer and larger Potsdam double telescope on Mizar; publishing his findings in 1901. Employing a slit type prism spectrograph, Vogel found substantially the same differential radial velocity value as Pickering, however, he determined the interval to be ~10.25 days leading to the modern value of 20.5386 days for the orbital period or about one fifth of Pickering's. In 1925 Francis Pease resolved the pair using the 20-foot beam interferometer attached to the 100-inch at Mt. Wilson (see Figure 1) and determined their separation to be 0.01 arcsecond. The pair is now designated PEA 1 Aa in the WDS Catalog. This was an early example of a spectroscopic pair measured by visual methods, the first being Capella measured by Anderson in 1919 with an earlier interferometer



**Figure 1:** The 20 ft beam as seen in the Mt. Wilson Interferometer Museum. Photo: courtesy of Dr. Brian Mason.

### Stargazers Corner: Focus on Zeta Ursae Majoris - Mizar

having its double aperture plate located 24-inches inside focus on the 100-inch. The double star resolution of the stellar interferometer is more than twice that of a single circular aperture.

In the simplest system, two small, say, 6-inch sub apertures are placed over a single large telescope aperture and slowly and symmetrically moved apart until the fringe pattern in the focused star image completely disappears having taken care to align the apertures in the direction of the double's position angle by peaking fringe contrast along the way. At the point of fringe disappearance the resolution (separation of the observed double) is equal to  $\lambda / 2D$  where  $D$  is the separation of the dual apertures. If the point of fringe disappearance remains constant for any position angle then it is the star's diameter that is measured, a very rare occurrence and only with the nearest giants! The resolution can be further increased by attaching a long beam to the front of the main telescope and, now with four mirrors, gain greatly on the aperture spacing as was done with the 100-inch with the 20-foot beam.

These basic ideas are nowadays implemented in special interferometers with enormous mirror spacing such as the Navy Prototype Optical Interferometer (NPOI) located on Anderson Mesa in Arizona. To see beautifully reconstructed time-lapse images of Mizar A taken by NPOI see *Sky & Telescope* November 1996 page 40 and, later, a movie made with the same instrument which can be seen at: <http://www.nofs.navy.mil/projects/npoi/science/mizarmov.gif>. Both components of Mizar A are the same brightness, mass and spectral class, an optimum condition for top results with both the spectrograph and interferometer

### The Evolution of Mizar A

Here we have the interesting situation of two identical stars orbiting only 18 million miles apart. Assuming they evolve synchronously, there will come a time when their expanding gaseous envelopes contact. What a challenging problem for the astrophysicist; will the evolutionary process be somehow altered as the two stars orbit in each others envelope? What occurs during orbit decay? Does one component gain an edge over the other, thus beginning a mass transfer cycle? What sort of giant is finally realized, assuming survival? If the two stars merge, doubling the mass, do we have the seeds of a neutron star?

### More About the Doppler Effect

Spectroscopic doubles are revealed by the Doppler effect, which shifts a component's spectral lines red-

ward when it is receding in its orbit and blueward when approaching. In the case of Mizar A the lines of both components are seen equally strong and the maximum differential shift is about two Angstroms or one half thousandth of the visible spectrum. This line doubling in the instance of Mizar and a number of other examples, is easily resolved in a good stellar spectrograph. For most spectroscopic doubles only one spectrum is seen because their companions are too faint. In these single-lined doubles, a relative reference wavelength is usually not observed, so a source, such as an iron arc in olden times, is admitted through the spectrograph slit to provide well known "at rest" spectral lines.

Nowadays various methods of introducing reference lines are employed. For instance, one may place an Iodine vapor cell or a Bromine cell in the optical path to produce extremely sharp and precisely known absorption features. These cells or chambers have thin optical quality windows on each end and are pretty much optically harmless to the spectrograph's image quality. In a pinch one may even use the near IR water vapor and oxygen absorption lines of our own atmosphere which are naturally superimposed on the doubles spectrum. These "telluric" lines (bands) generally tend to be too wide and asymmetrical for the highest precision, but, as an aside, do work reasonably well for amateur radial velocity studies of expanding nova shells.

One may conveniently introduce calibration lines in the traditional way using a low pressure spectral lamp such as Thorium-Argon, sending its light through the top and bottom of the spectrograph's slit with two tiny right angle prisms. Finally, it is possible to observe a close-by field star of non-varying radial velocity and use its lines as a reference for a differential velocity measurement. By bracketing the binary's spectrum with before and after reference star exposures (placed above and below the binary's spectrum) the corrections described below are quite small, however, extreme care must be taken that the "plate" and spectrograph optics are not disturbed during the three exposures.

In the absence of various optical techniques<sup>2</sup> to make the single-lined pair's radial velocity measure differential in nature, one must compensate for the variation in radial velocity caused by the earth's rotation and our rapid speed around the sun. The observation, thus corrected, is called heliocentric or sun centered.

For very short period spectroscopic binaries an-

### Stargazers Corner: Focus on Zeta Ursae Majoris - Mizar

other correction must be made called "light time". Again, as with the radial velocity corrections, the orbital period is corrected for the moving earth to agree with the measures of a hypothetical sun-centered observer. Without this velocity of light correction the orbit for equatorial objects would be observed as much as 8-minutes early or 8-minutes late depending on our position around the sun.

As mentioned, the actual separation of our subject spectroscopic pair is only 18 million miles and the components are considered detached. Some pair's components are so close to each other that they exchange mass in a barbell or peanut shaped "semi-detached" or even "contact" configurations, one of the best examples being Beta Lyra, just about the most inexplicable double star known.

#### The Spectrograph and Astrometry Get a Test

Well, the story is not yet finished as Mizar B was also discovered to be a spectroscopic duo! This amazing discovery was by E.B. Frost in 1908. The period of this pair was measured to be about 182 days by various astronomers of the time, however, more recent results have pinned-down the period to 175.55 days. This required pretty sharp spectrographic work for that era.

To top all this off, it has been determined (or at least there are strong indications) through astrometric methods that another member is orbiting the B com-

ponent at a greater distance with a period of 57 years with a semi-major axis of 0.13 arc seconds. Is Mizar quintuple?

Figure 2 shows a cropped CCD image taken with an SBIG ST-7 CCD camera in photometric I-band light at the 278.82-inch focus of LSO's 9-inch refractor as part of a two night measure of the pair. The seeing was only mediocre, typical of New England conditions.

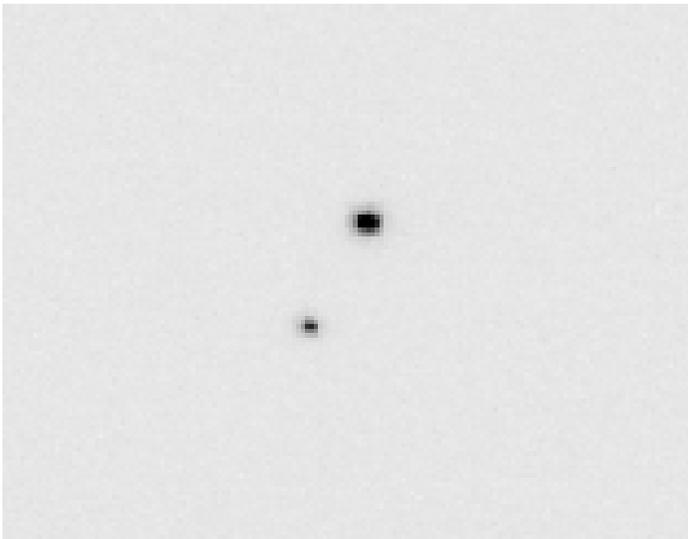
So, the next time you view beautiful Mizar, form an imaginary image of the astonishing array of stars that make up this busy system.

#### Acknowledgements

I wish to thank Dr. Brian Mason for his generous help with many of the historical details in this article.

#### References

- 1) Leos Ondra, A new View of Mizar, *Sky & Telescope*, July 2004, pp 72-75.
- 2) Frank Giesecking, Measuring Radial Velocities with an Objective Prism, *Sky & Telescope*, February 1979, pp 142-145.s



**Figure 2:** CCD images of Mizar's A and B components. North is up, East left.