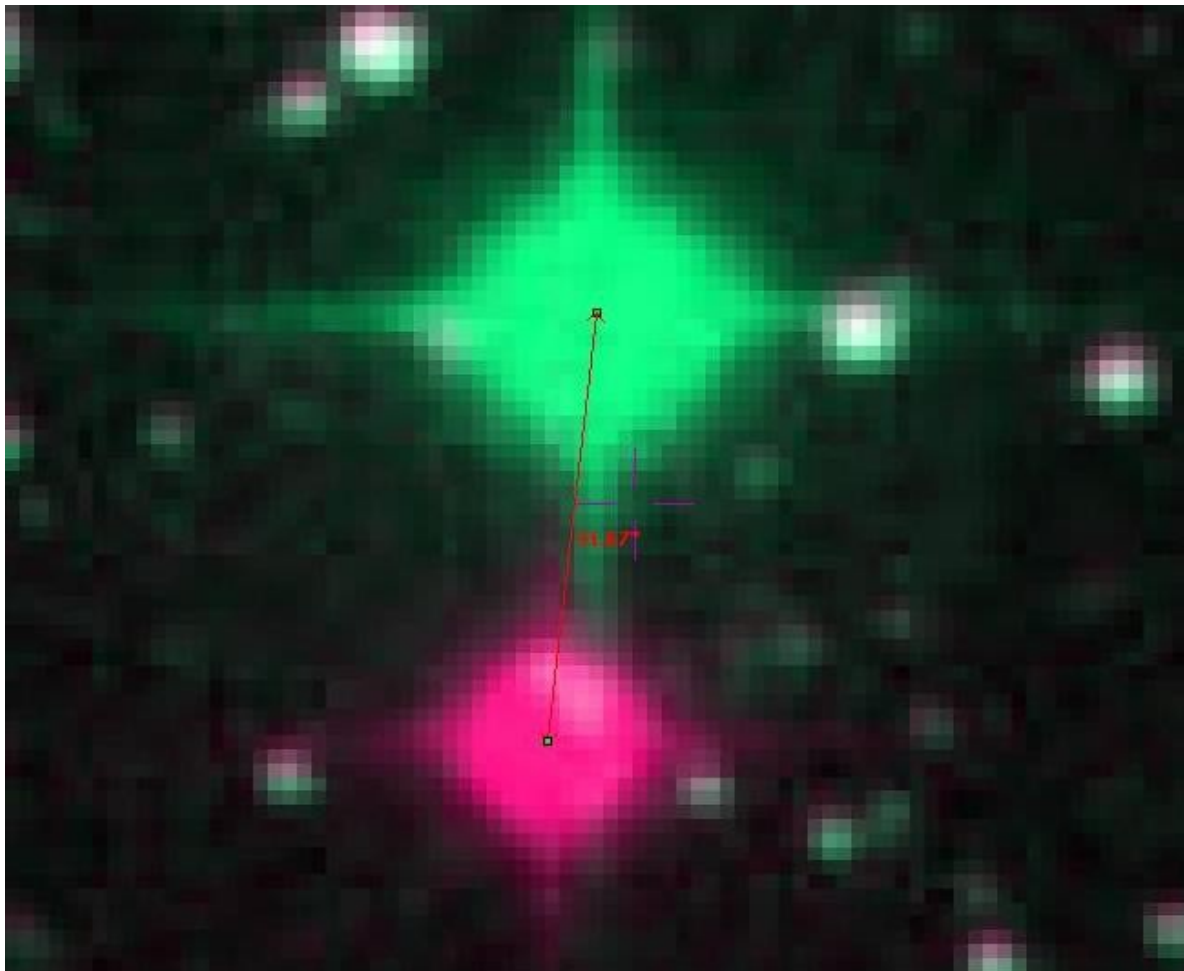


# Proper Motion of Barnards Star

Information and contacts: <http://vo-for-education.oats.inaf.it> - [iafrate@oats.inaf.it](mailto:iafrate@oats.inaf.it)



Florian Freistetter, ZAH, Heidelberg  
[florian@ari.uni-heidelberg.de](mailto:florian@ari.uni-heidelberg.de)

*Our project depends on your support. If you found our material useful, we kindly ask you to acknowledge it in your publications, or to write us an email ([iafrate@oats.inaf.it](mailto:iafrate@oats.inaf.it)), or like it on our Facebook page ([www.facebook.com/V0edu](http://www.facebook.com/V0edu)). Thanks!*

Within this case you learn that stars that seem "fixed" on the sky may actually move, even if their motion is so slow for the naked eye to be undetectable. You compare two photographs of the Barnard's Star taken several years apart and will be able to estimate its displacement on the sky. Your estimate will be very close to actual measurements.

If used in the classroom this use case is very easy to perform and pupils can easily discover the motion of the star. However, the interpretation of the results needs an informed explanation at the intermediate level.

## Stars do move!

Even if the stars are called „fixed stars“ sometime, they are not really fixed. This word was chosen in ancient times, when one did not know much about the real nature of the celestial bodies. To distinguish them from the „moving stars“, that change their position every night. Today we know, that those are planets and that also the „fixed“ stars do move – although their motion is very small and it took some time for the astronomers to measure it.

There are different reasons why a star changes its position on the sky. There are apparent changes, due to the motion of the Earth around the Sun (parallax) and due to the finite velocity of light (aberration). And there is also a real change of position, due to the *proper motion* of the star.

A star, moving on the sky, is changing its right ascension and declination. The following formula gives the change during a certain time:

$$\mu_{\delta} = \mu \cos(\theta)$$

$$\mu_{\alpha} = \mu \frac{\sin(\theta)}{\cos(\theta)}$$

The total proper motion per time unit is called  $\mu$ ;  $\theta$  is the angle, in which the star is moving (North = 0°).

## How fast is Barnards Star

The star with the fastest proper motion measured so far is Barnards Star. How fast it really is, can be found out with Aladin:

We start Aladin and then switch to undergraduate mode:

edit → user preferences → profile → undergraduate

Restart Aladin to validate the new configuration.

Open the server selector

File -> Open

Switch to tab „Aladin images“, enter „Barnard Star“ in the „target“ field and hit „submit“.

The available pictures of Barnards Star are listed. To investigate the proper motion, we chose two picture, that were made at different times. The longer in between, the better. Let's choose two images from the POSSII-Catalogue (13' x 13'). The column „date“ shows when the pictures were made. We take the images from 1991 and 1988.

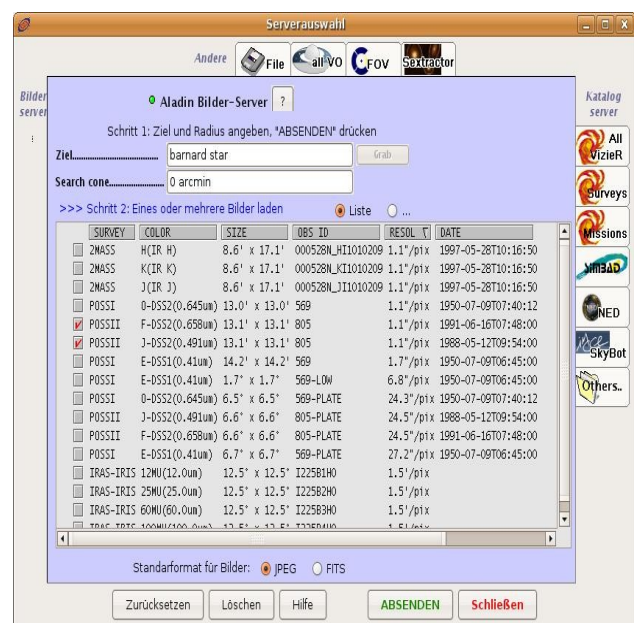


Bild 1: Choosing the pictures of Barnards Star

Klick on „Submit“ to load the pictures in Aladin.

We now can combine the two images to a movie and see if the star has moved. Therefore we use the „blink“ function:

*image* → *blink / movie generator*

We specify the images we want to use and hit „create“:



Bild 2: Making a movie

To measure how far the star has moved, we use the „rgb“ function:

*image* → *RGB image builder*

This function is meant to use for the combination of images in different wavelengths to obtain a color picture. But we can use also for our case.

In the „rgb“-window, we chose one of the images for the red channel and one for the green. Clicking „create“ gives a new image



Bild 3: Combining to images

The two images are now superimposed. Where the stars have not moved, they appear white. But Barnards Star *has* moved and thus we see two images: one in green and one in red:

We now magnify the part of the image around the Barnard Star („zoom“) and use the „dist“-tool to measure the distance between the red and the green image. The result will be approx. 32 arc seconds: that is the apparent distance that the star has moved.

But during what time? With a right-click on the images in the Aladin-stack, we can view the properties of the image. There we find the exact time, when the pictures were made:



Bild 4: When were the pictures made?

The relevant information can be found at the label „epoch“. In our case, the pictures were made at May, 12<sup>th</sup> 1988, 09:54:00 and June, 16<sup>th</sup> 1991, 07:47:59. Or, written in decimals:

1988,36115674196  
and  
1991,45468856947.

We can now easily calculate the time that has passed during the two exposures: 3.09353182751 years.

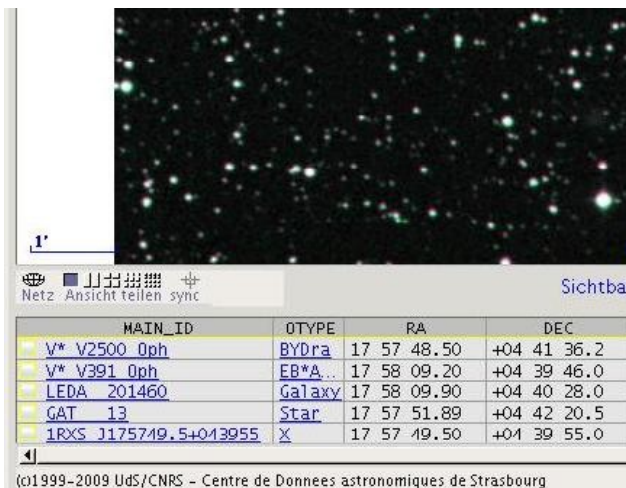
Thus, the proper motion per year for Barnards star is **10.35 arcseconds/year!**

## Further Analysis

If the star moves 10.35 arcseconds per year along the celestial sphere, what is its real velocity through space? To calculate that value, we have to know the distance of Barnards Star.

To obtain this information, we load a catalogue: *File -> Load catalogue -> Simbad Database*

The catalogues symbol is now displayed in the stack on the right side. With the „mark“-tool we select the objects of the catalogue in the image and the database entries are shown in the measurement window:



MAIN_ID	OTYPE	RA	DEC
V* V2500 Oph	BYDra	17 57 48.50	+04 41 36.2
V* V391 Oph	EB*A	17 58 09.20	+04 39 46.0
LEDA 201460	Galaxy	17 58 09.90	+04 40 28.0
GAT 13	Star	17 57 51.89	+04 42 20.5
1RXS J175749.5+043955	X	17 57 49.50	+04 39 55.0

Bild 5: Data from the catalogue

Barnards Star is here listed under its other name: „V\* V2500 Oph“ („V“ means „variable“ since Barnards Star is a variable star). Clicking on its name opens the Simbad-Database in the webbrowser where one can find all relevant data:

### Basic data :

V\* V2500 Oph -- Variable of BY Dra type

```
Other object types: EB* ( ) , BY* ( ) , * (AC2000, ASCC, BU, CSI, GAT, GGRV, (
(CI, G, LFT, LHS, LSEP, LTT, NLTT) , V* (V*, CSV, NSV) , :
ICRS coord. (ep=2000) : 17 57 48.4983 +04 41 36.245 ( ~ ) [ 14.24 10.45
FK5 coord. (ep=2000 eq=2000) : 17 57 48.498 +04 41 36.25 ( ~ ) [ 14.24 10.45 67
FK4 coord. (ep=1950 eq=1950) : 17 55 22.71 +04 33 14.1 ( ~ ) [ 84.21 61.89 67 ]
Gal coordinates : 031.0087 +14.0627 ( ~ ) [ 14.24 10.45 66 ] A 199
Proper motions mas/yr [error ellipse]: -798.71 10337.77 [1.66 1.22 67] A 1997A6A...323I
Radial velocity / Redshift / cz : km/s -106.8 [-] / z = -0.000356 [-] / cz -106.78 [
Parallaxes mas: 549.30 [1.58] A 1997A6A...323I...49P
Spectral type: M4Ve C ~
Fluxes (7) : B 11.28 [-] C ~
V 9.54 [-] C ~
R 0.7 [-] B 2002AJ...125...904M
I 7.9 [-] E 2003AJ...125...984M
J 5.24 [-] C 2003yCat.2246....0C
H 4.83 [-] C 2003yCat.2246....0C
K 4.52 [-] C 2003yCat.2246....0C
```

essential notes: • not [BD+04 3561](#)

Bild 6: Barnards Star at Simbad

„Parallaxes mas“ indicates the parallax of the star in milliarcseconds (mas). It is given as 0.549 arcseconds

We now can calculate easily the distance  $r$  to Barnards Star:

$$r = 1 / 0.549 = 1.82 \text{ pc}$$

We now know, that Barnards Star is 1.82 parsecs away and shows an apparent motion of 10.35 arcseconds per year.

Simple trigonometry gives the real distance, that Barnards Star covers in a year:

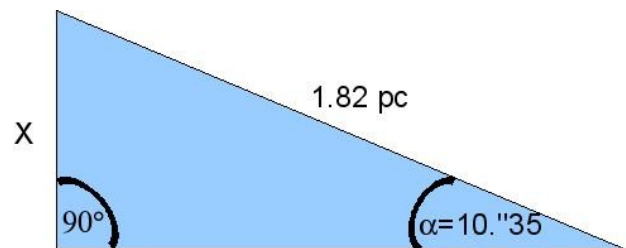


Bild 7: Trigonometry

The distance  $X$  that the star moves during a year is 0.0000912 parsec or. 2813000000 km. That corresponds to a tangential velocity of **90 km/s or 321000 km/h.**



## Motion on the celestial sphere

The visible motion of Barnards Star on the sky is also influenced by other factors: the motion of the earth around the sun; the influence of the moon on the motion of the earth, etc.

The APFS-toll of the german virtual observatory (GAVO) allows a visualistaion of the real motion of a star on the celestial sphere

It can be accessed at [http://dc.zah.uni-heidelberg.de/apfs/res/apfs\\_new/hipquery/form](http://dc.zah.uni-heidelberg.de/apfs/res/apfs_new/hipquery/form).

Enter „Barnard Star“ in the „Object“ field and specify the timescale. Lets look at the motion between June 1<sup>st</sup> 2009 and June 1<sup>st</sup> 2014. The output interval („interval of generation“) should be 24 hours. As „output format“ we choose a graphical represantation and select „VOPlot“.

**GAVO**  
Virtual Observatory

### APFS HIP Simple Query

This service computes apparent and/or intermediate places of the stars in the Hipparcos main catalogue. The positions can be given either in the CIO system (default) or the old equinox system.

If you give a position or an object resolvable by Simbad, the service will choose the nearest Hipparcos star for the ephemeris.

**Object**: Barnard Star  
Enter a Hipparcos catalogue number, or a (decimal, comma-separated) pair

**Start date**: 01 / 06 / 2009 (day/month/year)  
Start date of generated ephemeris

**End date**: 01 / 06 / 2014 (day/month/year)  
End date of generated ephemeris

**Interval of generation (hrs)**: 24  
Number of hours between two apparent positions

**Output in**:  CIO system  
 (old) equinox system

**Output format**: VOPlot [\[Result link\]](#) ★  
output verbosity: H

Try [ADQL](#) to query our data.  
Please report errors and problems to [GAVO staff](#). Thanks.  
[Privacy](#) | [Disclaimer](#)

Bild 8: Motion of Barnards Star with GAVO

Clicking „Go“ starts the calculation and the graphical user-interface.

There we have to adjust the correct columns for „x“ and „y“. We want to have the right ascension („raCio“) at „x“ and the declination („dec“) at „y“. A click on „plot“ draws the new image.

We can now see how the position of the star is changing during time. There are five loops that correspond to the five years from 2009 to 2014 and are due to the motion of the earth around the sun. The superimposed linear motion from the lower left to the upper right is the real proper motion of the star:

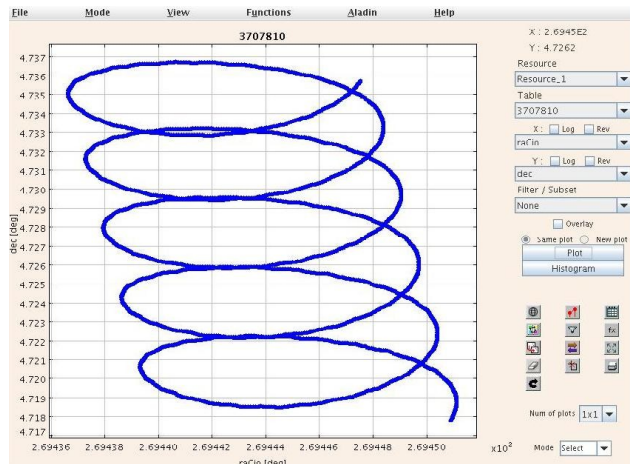


Bild 9: Motion of Barnards Star

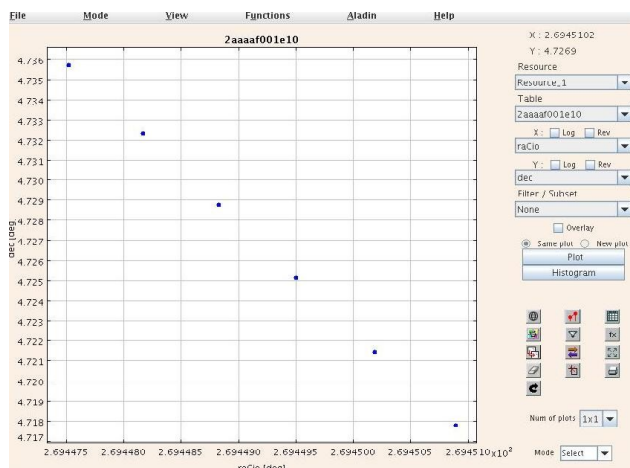


Bild 10: Motion of Barnards

That gets more clear, if we change the output interval from 24 hours to 8766 hours (one year). The motion of the earth is now filtered out and we can see the linear proper motion of Barnards Star: