Capella - Betelgeuse - Canopus vs. Canopus - Achernar - Fomalhaut and also Vega and Acrux.

Full post with detailed answers

Aug 07th, 2016

Hello to all,

In my recent *Skywatcher Quizz* post (*http://fer3.com/arc/m2.aspx/Skywatcher-Quizz-Couëtte-jul-2016-**g35938**)* I wrote : " *(10) To-morrow morning, I will admire the magnificent unique and only 1st Magnitude star line-up : **CANOPUS - ACHERNAR - FOMALHAUT** from East to West about one hour before Sun rise* ".

Well ... I was not entirely right then. You will learn why hereafter …

****

This morning when flying my A343 towards an easterly direction to land at Darwin (*again !*) in the last part of the night, and while we had to twist our necks to admire from the cockpit right windows our well known and now familiar *Canopus - Achernar - Fomalhaut* alignment *(with this latter star being our neck twisting one) ……*

… I was amazed to "*discover*" a *second remarkable 1st Magnitude Star alignment* just in front of us - just over the horizon and surrounding the Darwin City lights glowing against a dark night contrast - as follows:

> *On AUG 04th, 2016 by 18:50 UT, from a position around 100 NM West of Darwin, N.T. Australia (we were flying towards the East), and at FL140 I could see from left to right in our front windows **CAPELLA - BETELGEUSE - CANOPUS** *** above the horizon at respective heights not exceeding 20 degrees.*

This one is definitely a *splendid alignment* of bright Celestial Navigational Stars too, looking that it spans over a wider range than the other one.

****

Let us then take the opportunity to crunch a few numbers in the following drill:

For *each of* the " *Canopus - Achernar - Fomalhaut* " and " *Capella - Betelgeuse - Canopus* " alignments:

1 - Compute the angular separation between its extreme stars (i.e. *Canopus - Fomalhaut* and *Capella - Canopus*), and compare it to the sum of the angular separations when proceeding through the intermediate star (e.g. the sum of the angular separations between *Capella - Betelgeuse* and *Betelgeuse - Canopus*).

The comparisons here-above already give 2 interesting results:

> 1.1 - Comparing the 2 segments of each same alignment enables to check how well they equally visually “balance” each other, with the best results being visually obtained when the distances of each segment are [nearly] equal.
>
> I am under the visual impression that the *Capella - Betelgeuse* angular separation is almost the same one as the *Betelgeuse - Canopus* angular separation. This does not seem to be so much the case for the other " *Canopus - Achernar - Fomalhaut* " alignment. *True ??? Wrong ???*

***WRONG:** Canopus-Achernar-Fomalhaut are [amazingly] almost equidistant: 39,4 ° and 39,1°, while Capella-Betelgeuse-Canopus are really not: 39,5 ° and 60,4 °. Interesting to notice that the Canopus-Achernar angular separation is almost the same as the Capella- Betelgeuse angular separation: respectively 2.368,4 vs. 2.364,6 arc minutes.*

1.2 - Comparing the direct angular distances between the extreme stars (e.g. *Canopus* - *Fomalhaut*) with the sum of the 2 intermediate segments gives a rough approximation of the “Quality” of the alignment itself. The closer they are, the better the alignment.

2 - Let us then use a different method to estimate how well the stars of each alignment are lined up together.

Compute the angular minimum separation *between* each middle-star (*Achernar* and *Betelgeuse* in our both examples) *and* the great circle joining the extreme stars (respectively *Canopus* - *Fomalhaut* and *Capella* - *Canopus* here). *The smaller this minimum separation, the better their overall alignment*.

Again, I am under the visual impression that *Capella* - *Betelgeuse* - *Canopus* are better aligned in this respect than *Canopus - Achernar - Fomalhaut* , i.e. that the *Capella* - *Canopus* great circle comes closer from *Betelgeuse* than the *Canopus* - *Fomalhaut* great circle does from *Achernar*. *True ??? Wrong ???*

WRONG: *Canopus-Achernar-Fomalhaut is a [much] better alignment: Achernar lies just 1° from the Canopus - Fomalhaut great circle while Betelgeuse lies 3,1° from the Capella-Canopus great Circle.*

We should notice that this second tool in part 2 used to rate the quality of the alignments is much better than the first tool in part 1. It is exactly like rating very small angles through sines instead of cosines. Sines perform much better under such cases.

3 - From the above we can attempt defining a *First Magnitude 3 Star alignment* as being an *Alignment of 3 First Magnitude Stars [almost] equally spaced and [almost] on the same great circle and visible simultaneously from one same point on the Earth Surface*. I also wish to add that such stars should clearly single out of their environment. In other words: the more isolated such bright stars are, the more remarkable and prestigious their alignment. So an alignment including one of the bright stars of [/ close to] *Lady Southern Cross* would be less remarkable in this respect.

4 - Given the definition here-above and in addition to the 2 previously mentioned ones, *are there ANY OTHER first Magnitude 3 Star alignment* in the heavenly skies as seen from our Planet Earth in the Solar System?

5 - There is also a very long - and rather excellent - *First Magnitude 5 (maybe 6?) Star alignment* including *Vega* and *Acrux*. But to the best of my memories it is not entirely visible from any point on Earth, and the stars are not evenly spaced in this one. What is this alignment?

6 - *Just for our number crunchers addicts*:

From the ICAO en-route fix “SIDER” (*not Cider alas !!!*) at position *S 12°48’8 E129°35’8* which we checked at FL140 *on Aug 04th, 2016 at 18h58m53,2s UTC* we overflew a fishing boat. At what Heights and Azimuths could her skipper then see all five stars, i.e. from left to right: *Capella*, *Betelgeuse*, *Canopus*, *Achernar* and *Fomalhaut* ? You may or may not include [standard] Refraction as you wish.

Thanks in advance for publishing your replies.

Important note: *For 1 and 2 no need here to compute the effects of refraction*. The Stars coordinates can be chosen from a number of data bases (current or older *contemporary* Almanacs, or even 2000.0 coordinates) since the final results involving only angular separations are subject to essentially the stars proper motions which are not significant when using our ordinary eyes vision.

*** *Well, I might better say now: Capella - α Orionis ☺ - Canopus !*

Kermit

****

Results from the US Naval Observatory site (http://aa.usno.navy.mil/data/docs/celnavtable.php)

Celestial Navigation Data for 2016 Aug 4 at 18:58:53 UT

For Assumed Position: Latitude S 12 48.8 Longitude E 129 35.8

Object	Almanac Data GHA	Dec	Hc	Zn	Altitude Corrections Refr	SD	PA	Sum	H apparent Height of Eye 0′
	o ′	o ′	o ′	o	′	′	′	′	
CAPELLA	159 01.0	N46 00.5	+ 3 14.7	41.2	-13.0	0.0	0.0	-13.0	+ 3 27.7
BETELGEU	149 28.7	N 7 24.4	+ 7 07.1	80.7	-7.2	0.0	0.0	-7.2	+ 7 14.3
CANOPUS	142 25.1	S52 42.3	+11 22.4	141.9	-4.7	0.0	0.0	-4.7	+11 27.1
ACHERNAR	213 54.5	S57 08.9	+43 54.4	167.7	-1.0	0.0	0.0	-1.0	+43 55.4
FOMALHAU	253 50.8	S29 31.9	+62 35.2	228.7	-0.5	0.0	0.0	-0.5	+62 35.7

Own Results for Aug 04th, 2016

2000.0 Coordinates					
	Capella	Betelgeuse	Canopus	Achernar	Fomalhaut
RA :	05h16m41,4s	05h55m10,3s	06h23m57,1s	01h37m42,8s	22h57m39,05s
Dec :	N 45°59’52,8”	N 7°24’25,4”	S 52°41’44,4”	S 57°14’12”3	S 29°37’20,05”
AV :	280°49’7	271°12’4	264°00’7	335°34’3	015°35’2
Dec :	+ 45°59’9	+ 07°24’4	- 52°41’7	- 57°14’2	- 29°37’3

Capella to Betelgeuse	2.368,4’	Canopus to Achernar	2.364,6’
Betelgeuse to Canopus	3.624,8’	Achernar to Fomalhaut	2.346,6’
Sum of the above	5.993,2’	Sum of the above	4.711,2’
Capella to Canopus	5.984,3’ (100°)	Canopus to Fomalhaut	4.709,8’ (79°)
Relative difference (% change)	+0,15%	Relative difference (% change)	+0,03%
Betelgeuse to Capella↔Canopus	3,1 °	Achernar to Canopus↔Fomalhaut	1,0 °

We can compare with the results here-under which are identical at the eye-sight precision

Horizontal Coordinates affected by [standard] refraction 04 Aug 2016 TT-UT = 69,8 s at 18h58m53,2s from S12°48’8 E129°35’8 Height of Eye *0ft (to compare with US Naval Observatory results*)					
	Capella	Betelgeuse	Canopus	Achernar	Fomalhaut
Az :	41°14’7	80°41’8	141°51’2	167°39’4	228°45’0
Ha :	3°27’9	7°14’3	11°27’1	43°55’4	62°35’6

Capella to Betelgeuse	2.366,8’	Canopus to Achernar	2.361,1’
Betelgeuse to Canopus	3.623,5’	Achernar to Fomalhaut	2.345,7’
Sum of the above	5.990,3’	Sum of the above	4.706,8’
Capella to Canopus	5.980,6’ (100°)	Canopus to Fomalhaut	4.705,4’ (79°)
Relative difference (% change)	+0,16%	Relative difference (% change)	+0,03%
Betelgeuse to Capella↔Canopus	3,2 °	Achernar to Canopus↔Fomalhaut	1,0°

Final comments:

First, the Canopus-Achernar-Fomalhaut is an excellent if not an amazing 1st Magnitude 3 Star alignment. It is much better that the Capella-Betelgeuse-Canopus alignment. Therefore: *Beware of visual illusions!*

Second, refraction effect is totally negligible for naked eye observations.

Finally, the Multiple star alignment to be guessed involves Vega-Antares-Acrux. It is then easy to continue this Great Circle around the sky and check for close by other bright stars. *Other stars are ….*

Celestial Navigation Data for 2016 Aug 6 at 13:05:58 UT

For Assumed Position: Latitude S 12 48.8 Longitude E 129 35.8

Object	Almanac Data GHA	Dec	Hc	Zn	Altitude Corrections Refr	SD	PA	Sum
	o ′	o ′	o ′	o	′	′	′	′
ACRUX	325 06.6	S63 11.6	+ 9 18.9	207.1	-5.7	0.0	0.0	-5.7
ANTARES	264 22.9	S26 27.9	+55 21.3	241.7	-0.7	0.0	0.0	-0.7
VEGA	232 36.6	N38 48.3	+38 20.4	357.8	-1.3	0.0	0.0	-1.3

From the data here-above, we can see that Antares lies 3,5° from the Vega-Acrux great circle.

See next page for further details about computing the distance between a point and a great circle.

Computing the distance between a great circle and a point

Let us assume 3 different Stars S1 (AV1,δ1), S2 (AV2,δ2) and S3 (AV3,δ3) : at what distance from the S1-S3 great circle does S2 lie?

We will first assume that **S1** and **S3** are not opposite on the Celestial Sphere, in which case there are infinitely many great circles between them, including the one encountering **S2**. Let us also call **C** the Center of the Earth.
There are a several methods around, all boiling down into the very same results. My favorite one is the following one because we can *see* in 3D what is happening:

From current Equator/Equinox proceed through adequate coordinate changes into a final "pseudo Equator" containing (C,S1,S3) in which S2 "pseudo-Declination" has then become its angular distance to the S1-S3 Great Circle.

One example:

SYSTEM 1 →					
Capella 2000.0		**Betelgeuse 2000.0**		**Canopus 2000.0**	
AV1:	280,8283333°	AV2:	271,206667°	AV3:	264,0116667°
δ1:	45,9983333°	δ2:	7,406667°	δ3:	-52,6950000°

Step 1: Perform a rotation around the North Pole equal to (90°-AV1=-190,8283333°). Hence:

→ SYSTEM 2					
Capella 2000.0		**Betelgeuse 2000.0**		**Canopus 2000.0**	
AV1:	*90,0000000°*	*AV2:*	*80,3783334°*	*AV3:*	*73,1833334°*
δ1:	*45,9983333°*	*δ2:*	*7,406667°*	*δ3:*	*-52,6950000°*

Step 2: Perform a rotation of (δ1-90°=-44,0016667°) around the new "X" Axis (AV 000°-180°). Hence:

→ SYSTEM 3					
Capella 2000.0		**Betelgeuse 2000.0**		**Canopus 2000.0**	
AV1:	*(90,0000000°)*	*AV2:*	*74,8869917°*	*AV3:*	*79,7524033°*
δ1:	*90,0000000*	*δ2:*	*50,5266735°*	*δ3:*	*-9,7384242°*

Step 3: Perform a rotation of (-AV3=-79,7524033°) around the new North Pole. Hence:

→ SYSTEM 4					
Capella 2000.0		**Betelgeuse 2000.0**		**Canopus 2000.0**	
AV1:	*(90,0000000°)*	*AV2:*	*-4,8654116°*	*AV3:*	*0,0000000°*
δ1:	*90,0000000*	*δ2:*	*50,5266735°*	*δ3:*	*-9,7384242°*

Step 4: Perform a rotation of (90°) around the new "X" Axis (AV 000°-180°). Hence:

→ SYSTEM 5					
Capella 2000.0		**Betelgeuse 2000.0**		**Canopus 2000.0**	
AV1:	*90,0000000°*	*AV2:*	*50,6281337°*	*AV3:*	*-9,7384242°*
δ1:	*0,0000000°*	*δ2:*	*-3,0908171°*	*δ3:*	*0,0000000°*

This method was invented by the great Swiss Mathematician ***Leonhard Euler*** (***Euler's*** angles).

In **SYSTEM 4**, since AV3 = 0° **Betelgeuse** AV2 = -4°865 represents its difference in Azimuth relatively to **Canopus**.

In **SYSTEM 5**, both **Capella** and **Canopus** have Declinations equal to 0°, hence **SYSTEM 5 Equator** contains them both.

Hence in **SYSTEM 5 Betelgeuse** Declination is equal to its distance to the **Capella-Canopus** great circle, i.e. 3,1°.