

EXACT IDENTIFICATION OF LOCATION IN VOJVODINA FROM
WHICH COUNT LUIGI F. MARSIGLI AND JOHANN MÜLER
EXECUTED THEIR QUADRANT MEASUREMENTS IN 1696.
AND THE ACCURACY OF THESE MEASUREMENTS

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Abstract. The well known Italian scientist *Luigi Ferdinand Marsigli (1658-1730)* had his famous work about the Danube printed in the Hague in 1726 under the title "**DANUBIUS PANNONICO – MYUSICUS, observationibus GEOGRAPHICIS, ASTRONOMICIS, HYDROGRAPHICIS, HISTORICIS, PHISICIS**". Amongst other topics, in this book he published his astronomic quadrant measurements (100) and his telescopic observations (51) that he had undertaken with his assistant **Johann Cristopher Müller (1673-1721)** from **April 17** until **August 29 1696**. Between the **11th** and the **14th** of **June**, they performed **2** measurements of the Sun altitude and **7** of the star altitude **in the meridian**. A few weeks later, between July 18 and 25, 1696 Marsigli executed 4 more measurements of the Sun altitude and 9 more of the star altitude in the meridian. All 22 quadrant measurements were made from **two locations, both in present day Vojvodina**.

1. FIRST MEASUREMENT SITE – LOCATION 1

For this measurement site *L.F.Marsigli* wrote: "**AD CONFLUENTES DANUBIUM ET DRAVUM**" = "**At the mouth of the Drava into the Danube**" whilst on the other place he shortly wrote: "**AD CONFLUENTES**" = "**at the mouth**" or just "**CONFLUX.**" = "**mouth**". No further piece of information is given of that site. After years of research and analysis of old geographical charts, the author came to the conclusion that the observational site was at:

Bukcenovac near Apatin, $\lambda = -19^0 01' \pm 1'$ $\varphi = 45^0 36' \pm 1'$

From Bukcenovac, on **June 09, 11, 12, 13 and 14** the team conducted:

7 measurements of star altitude in the meridian

2 measurements of the Sun altitude in the meridian.

NOTE: Today, that location is an agricultural area, the Bukcenovac population having been displaced in 1749.

2. SECOND MEASUREMENT SITE – LOCATION 2

For this measurement site *L.F.Marsigli* wrote: "In Castris, Prope TITUL, in angulo confluxus Danubii citeriori positus" = "In fortified town (fortress) near Titel, which is on this side of the mouth of the Tisa river into the Danube".

On the basis of Marsigli's chart of Tisa's mouth into Danube and current geographical charts, as well as after visiting this location, it seems that the place where Marsigli and his team were situated is very easy to identify. A logical conclusion is that Marsigli's observation team was situated within Titel's fortress ($\varphi = 45^{\circ} 12' 30''$), which existed then atop of Titel hill. Nevertheless, an overall and detailed analysis implies that observation team had to be some 4 km north of the fortress, at the place called "Mosorin swamp", $\lambda = -20^{\circ} 13' \pm 1'$, $\varphi = 45^{\circ} 20' \pm 1'$

Marsigli's observation team in Titel (near it) conducted 13 astronomical measurements:

5 measurements of the Sun's altitude in the meridian

8 measurements of stars altitude in the meridian

For measuring of the Sun and stars altitude in the meridian:

ASTRONOMICAL QUADRANT made out of bronze, with diameter of 2,5 Norich feet (aprox. **80 cm**) which had one horizontal, so called azimuth ring with which one could measure azimuth. Considering the size of the instrument, it can be concluded that **the accuracy of measuring was up to one minute of arc.**

3. ANALYSIS AND ACCURACY OF MEASUREMENTS

The analysis of the measurements (making ephemerides) has been made with the use of the software:

"Sky Charts / Cartes du Ciel", Version 2.75,

© 1998-2001. Patrick Chevalley, France

"Red Shift 3.0" © 1994-1998 Moris Multimedia Ltd.-England

(a group of Russian authors)

In these programs, the basic catalogue was "Sky catalogue 2000,0" and "Sky atlas 2000,0"

Sky Publishing Corporation and The Cambridge University Press © 1998 year, which were made on the basis of the data from the catalogue FK4.

In the upper Table are given results of Marsigli's MEASUREMENTS OF THE SUN AND STARS ALTITUDES near the Drava mouth into the Danube – the village Bukcenovac. Considering exact coordinates of stars (which he didn't have) and refraction (which he didn't take into account) true elevation **ht** and measuring error Δh have been calculated.

A more precise analysis we will perform if we calculate exact position of selected stars at the time of observation having in view that Marsigli used Hevelius's atlas, the meaning, positions of stars for epoch 1660. Calculating value of refraction, true altitude of stars at the time of measurement can be determined, as well as exact geographic latitude of the measurement site.

By comparing this true value $\varphi_{\mathbf{t}}$ and Marsigli's result $\varphi_{\mathbf{m}}$, the error $\Delta\varphi$ in his measurements of geographic latitude is obtained.

Table 1: REVIEW OF ASTRONOMICAL MEASUREMENTS OF *L.F.MARSIGLI* from LOCATION 1, MOUTH OF THE DRAVA RIVER – BUKCENOVAC near APATIN

| No | Date | Day | Time (CET) H m | Star | Measured altitude hm | Calculated /true/ altitude ht | Measurement error Δh |
|----|---------|-----------|-------------------|------------------------------|-------------------------|-------------------------------------|---------------------------------|
| 1 | June 12 | Tuesday | 20 18 | Arcturus, α Bootes | 65° 13' | 65° 10' | -3' |
| 2 | | | 21 08 | β Ursa Minoris | 60° 11' | 60° 12' | +1' |
| 3 | | | 21 45 | α Serpentis | 51° 50' | 51° 48' | -2' |
| 4 | | | 22 06 | δ Ophiucus | 41° 35' | 41° 31' | -4' |
| 5 | June 13 | Wednesday | 11 34 | SUN | 67° 42' | 67° 41' | -1' |
| 6 | | | 20 59 | β Ursa Minoris | 60° 11' | 60° 12' | +1' |
| 7 | | | 21 41 | α Serpentis | 51° 50' | 51° 48' | -2' |
| 8 | June 14 | Thursday | 11 34 | SUN | 67° 44' | 67° 44' | 0 |
| 9 | | | 20 10 | Arcturus, α Bootes | 65° 13' | 65° 10' | -3' |

Table 2: ERRORS IN DETERMINED GEOGRAPHIC LATITUDES

| No | Star Bayer/FK4 | DEC FK4/1696 | DEC Hevel / 1660 | hm 1696 | Refra. ρ | ht | φ_m | φ_t | $\Delta\varphi$ |
|----|-----------------------------|-----------------|------------------------|------------|------------------|---------|-------------|-------------|-----------------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | A Bootes/526 | 20° 47' 02" | 20° 50' 19" | 65° 13' | 27," 8 | 65° 13' | 45° 37' | 45° 34' | - 3' |
| 2 | B Ursa Minoris / 550 | 75° 23' 54" | 75° 25' 10" | 60° 11' | 34," 5 | 60° 10' | 45° 36' | 45° 34' | - 2' |
| 3 | δ Ophiucus / 603 | 2° 52' 34" | 2° 49' 42" | 41° 35' | 67," 7 | 41° 34' | 45° 35' | 45° 34' | - 1' |
| 4 | α Serpentis / 582 | 7° 24' 45" | 7° 24' 09" | 51° 49' | 47," 3 | 51° 48' | 45° 37' | 45° 36' | -1' |

Table 3: REVIEW OF ASTRONOMICAL MEASUREMENTS OF *L.F.MARSIGLI* from LOCATION 2, MOUTH OF THE TISA RIVER – near Fortress at TITEL

| No | Date | Day | Time (CET) H m | Star | Measured altitude hm | Calculated altitude ht | Measur. error Δh |
|----|---------|-----------|-------------------|-------------------|-------------------------|---------------------------|-----------------------------|
| 1 | July 18 | Wednesday | 20 54 | α Hercules | 59° 27' | 59° 26' | - 1' |
| | | | 21 14 | α Ophiucus | 57° 29' | 57° 29' | 0 |
| 2 | July 19 | Thursday | 11 34 | SUN | 65° 25' | 65° 21' | - 4' |
| 3 | July 20 | Friday | 11 34 | SUN | 65° 13' | 65° 10' | - 3' |
| 4 | | | α Hercules | 59° 31' | 59° 34' | + 3' | |
| 5 | | | α Ophiucus | 57° 32' | 57° 34' | + 2' | |
| 6 | | | μ Ophiucus | 35° 01' | 35° 04' | + 3' | |
| 7 | July 21 | Saturday | 11 34 | SUN | 65° 00' | 65° 58' | - 2' |
| 8 | | | α Hercules | 59° 27' | 59° 37' | + 7' | |
| 9 | | | α Ophiucus | 57° 31' | 57° 34' | + 3' | |
| 10 | | | η Serpentis | 41° 46' | 41° 47' | + 1' | |
| 11 | July 22 | Sunday | 11 34 | SUN | 64° 47' | 64° 46' | - 1' |
| 12 | July 25 | Wednesday | 11 34 | SUN | 64° 10' | 64° 07' | - 3' |

Table 4: ERRORS IN DETERMINED GEOGRAPHIC LATITUDES

| No | Star Bayer/FK4 | DEC FK4/1696 | DEC Hevel / 1660 | hm 1696 | Refra. ρ | ht | φ_m | φ_t | $\Delta\varphi$ |
|----|-----------------------|-----------------|------------------------|------------|------------------|---------|-------------|-------------|-----------------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | α Hercules/640 | 14° 45' 32" | 14° 47' 51" | 59° 27' | 22," 6 | 59° 27' | 45° 21' | 45° 18' | - 3' |
| 2 | α Ophiucus/656 | 12° 49' 31" | 12° 51' __ | 57° 31' | 38," 3 | 57° 30' | 45° 22' | 45° 20' | - 2' |
| 3 | ν Ophiucus/673 | 9° 39' 04" | 9° 39' 17" | 35° 01' | 85," 9 | 34° 59' | 45° 20' | 45° 22' | + 2' |
| 4 | η Serpentis/688 | 7° 24' 45" | 7° 24' 09" | 51° 49' | 47," 3 | 51° 48' | 45° 19' | 45° 19' | 0 |

Today it is easy to determine the values of Sun's declination for Titel for dates when *Marsigli* conducted these measurements, and then to calculate an error Δh .

| No | Date | Marsigli's measurement hm | Calculated elevation ht | Declination of Sun δ | Measur. error Δh |
|----|---------------|---------------------------------|-------------------------------|-----------------------------------|-----------------------------|
| 1 | July 19. 1696 | 65° 25' | 65° 23' | 20° 46' | - 2' |
| 2 | July 20. 1696 | 65° 13' | 65° 12' | 20° 35' | - 1' |
| 3 | July 21. 1696 | 65° 00' | 65° 00' | 20° 23' | 0 |
| 4 | July 22. 1696 | 64° 47' | 64° 48' | 20° 11' | + 1' |
| 5 | July 25. 1696 | 64° 10' | 64° 09' | 19° 33' | - 1' |

Aim of Sun's altitude measurements in the meridian most likely was adjusting the quadrant to the local meridian, in order to conduct measurements of bright stars altitudes in local meridian, with final goal being determination of geographic latitude of Titel. *L.F.Marsigli* wrote about that in the foreword to his book, mentioning that first he had in mind to use measurings of the Sun's altitude for determination of geographic latitude, but that he had given up that idea because he had not had exact data on the Sun's declination.

4. CONCLUSION

During **June** and **July** of **1696**, at the time of the summer war campaign against the Turks, **Bologna Count Luigi F. Marsigli** and his young assistant, German cartographer **Johann Ch. Müller** conducted 22 quadrant measurements, **7 measurings of Sun's altitude** and **15 measurings of altitude of stars**, from two locations in actual Vojvodina:

1. **Bukcenovac:** $\varphi = 45^{\circ} 36'$ (10 km South of Apatin)
2. **Mosorin swamp:** $\varphi = 45^{\circ} 18'$ (4 km North of Titel)

Living and working in a military camp for 24 hours, discharging many regular army duties in engineer company, they had strength to find some free time for realization of these astronomical measurements. In the course of a day, working on numerous, but monotonous army duties, in evening hours they used telescope and quadrant in order to do astronomy. We have to notice that some measurings differ more than the others, but that can be explained by they being tiered.

When comparing their measured results of geographic latitude with the present day coordinates of these locations, we first see very large errors. But, if one performs a detailed analysis which allows more precise identification of these sites, **results are show that error of measuring is within the technical capabilities of the used instrument (80cm quadrant), or just 1'-2'.**

The acquired results show that *L.F.Marsigli* and *J.Ch. Müller* were diligent observers and very fine astronomers, although they worked in very hard, almost impossible conditions. That is why their measurements in 1696 for scientific community have not only historical, but also scientific value.