Meteorological contributions to the image's shift at the Clementine Gnomon

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Abstract The nutation contribution to the measured obliquity at the Winter solstice are compared to the meteo contribution, with accurate multi-parameter data (image's position and atmospheric pressure and temperature). The results for the Clementine Gnomon are visible only near the Winter solstice, where 1 mm equals 2 arcseconds, and 4 mm of image's shift are equivalent to 20 mb of pressure's increase, and 15° C of air temperature drop.

Sommario Le componenti dell'obliquità misurata al solstizio, vengono distinti dai contributi atmosferici (pressione, e temperatura). Per lo Gnomone Clementino a s. Maria degli Angeli, i dati utili a questo studio sono ottenibili solo nelle 7 settimane attorno al solstizio d'inverno, prima e dopo. Al solstizio l'effetto è massimo: 1 mm corrisponde a 2 secondi d'arco, 4 mm di spostamento dell'immagine corrispondono ad una variazione di 20 mb di pressione atmosferica, e una diminuzione di 15°C di temperatura.

Keywords: positional astrometry, atmospheric refraction, atmospheric parameters.

Introduction: maximum resolution near the winter solstice

From November to February the last 15 meters of the meridian line of Santa Maria degli Angeli in Rome are used; ±50 days from the winter solstice offer the better geometrical conditions to study the contribution of the atmospheric pressure, being the image from 60 to 110 cm wide, and the correspondace angle-mm from 0.6 to 1 mm = 2 arcseconds. The larger solar spots are also visible in this period as pale grey spots oscillating beacuse of the turbulence. The meteo shows often very clear sky near the solstice, with high pressure, and grey days when the image is difficult to be discerned. In total from October 30th to December 21st, 20 days of observations have been realized, and 30% more were technically possible. Until November 15, presently, the image is formed among the benches of the church, while after it is in front of the presbytherium (and on Sundays the measures cannot be done

for the holy mass ongoing).

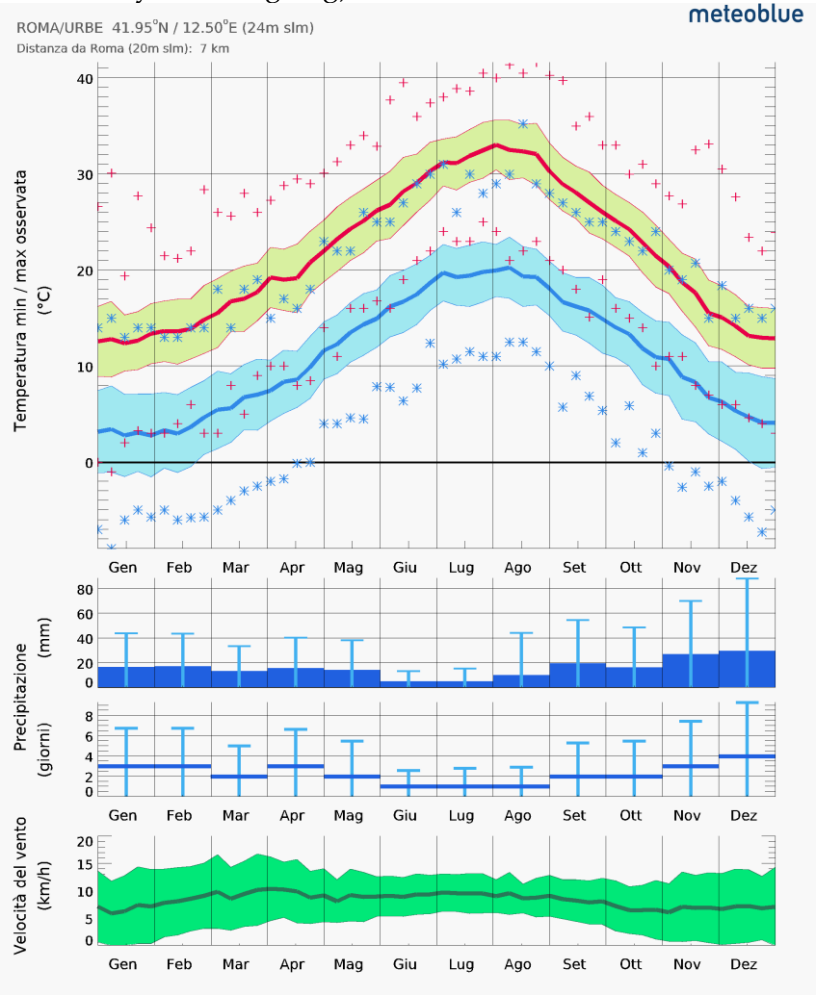


Fig. 1 Climatic data >10 yr of Roma Urbe airport; meteoblue.

In this period of time the weather in Rome is usually perturbed and rainy, but a solstice campaign is always performed until the Christmas day, using limited acquisition during high masses, because these data are unique for many astrometrical studies: either meteo contributions, either obliquity variations and nutation component (± 9 arcsec at

maximum each 9 yrs, which are 4.5 mm at the Winter solstice).

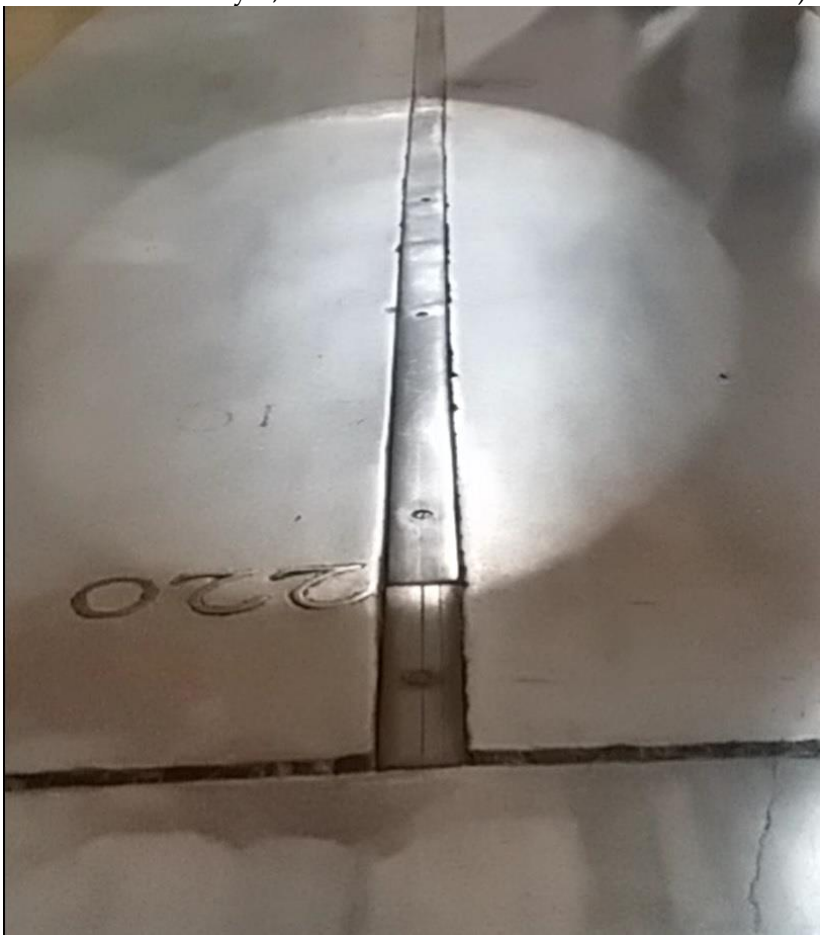


Fig. 2 Southern Solar limb beyond 220, on December 20th 2023.

Cassini and Laplace components The Laplace formula for atmospheric refraction corrects the 60″·tan(z) Cassini term with the 0.067″·$\tan^3$(z) term, expressed both in arcseconds.

For tan(z)=2.2, the maximum for Rome at the winter solstice, the correction attains 0.7″, or 0.35 mm, practically unvisible because of the air turbulence.

The Fall 2023 observational campaign here presented showed that the high pressure-clear sky up to 1036 mb and 10°C-15°C,

moved the center of the solar image up to 4 mm to South, or up in fig. 2, i. e. below 220 position for the Southern solar limb.

Atmospheric refraction and air equation of state the refraction index of dry air at STP conditions (15°C and 1 atm) is n_o=1.000287566+1.34/λ^2 [λ measured in nm],[1] to express the dependance on P=ϱKT the formula below[2] is valid:

$$n = 1 + 7.86 \cdot 10^{-4} p/(273 + t) - 1.5 \cdot 10^{-11} RH(t^2 + 160)$$

with p[mb/10], t [°C] and RH the relative humidity [%], RH=70% normally for Rome, S. Maria degli Angeli). The RH term is 10^{-6} and it can be neglected with respect to the P term.

The dependance on pressure, according to the equation of state, is therefore n=1+2.876·10^{-4}·(P/P_o)=1+α_o·(P/P_o), @ T const.

Changing P_o =1013 mb to P=1018 mb is P=P_o(1+0.005). The Snell's law n_i·sin(i)=n_r·sin(r) with n_r= 1+α_o, changes to n_r=1+ α_o ·1.005. Since at the Winter solstice i=65°, r_o=64.9647° and r=64.96487°, with a difference of 0.61 arcsec.

Changes of ΔP=20 mb give 2.4'' or 1.2 mm, at T constant. Lowering temperatures from 15°C to 0°C increases the refraction index floating part α_o of 5% ten times than ΔP=5 mb.

Conclusions the solstice's instant calculation (obliquity) are affected by nutation (±4.5 mm/18.6 years); this is comparable with the temperature changes (3mm/15°C and 1.2 mm/20 mb). It is common, at the Winter solstice, to have 3-4 mm of image shift toward South, for a n increase due to low temperature and high pressure. Moreover if the limbs are not measured at an angle equal to i°, another positive systematicity is introduced. **Acknowledgments:** to the students of Galileo Ferraris Institute, always present at the solstices' measures.

References C. Sigismondi, *I termini di Cassini e Laplace della rifrazione atmosferica misurati alla Meridiana Clementina*, Gerbertus 9, 103-104 (2016).

[1] https://scienceworld.wolfram.com/physics/CauchysFormula.html
[2] https://emtoolbox.nist.gov/Wavelength/Documentation.asp#AppendixB