“Measuring in space with shadows from Antiquity to the European Sentinels”

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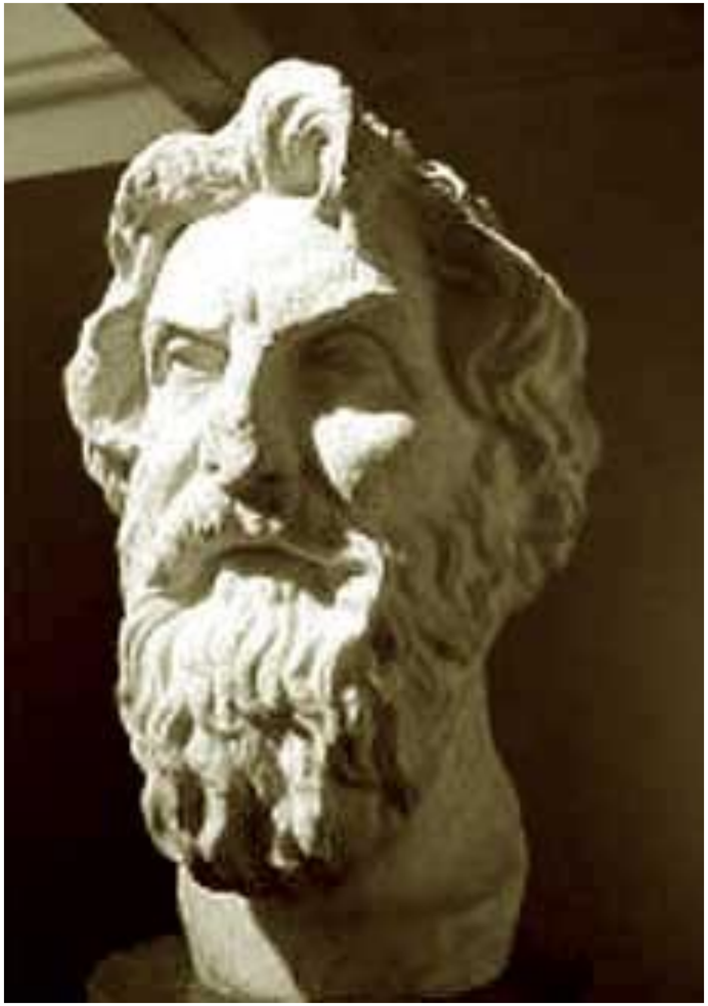
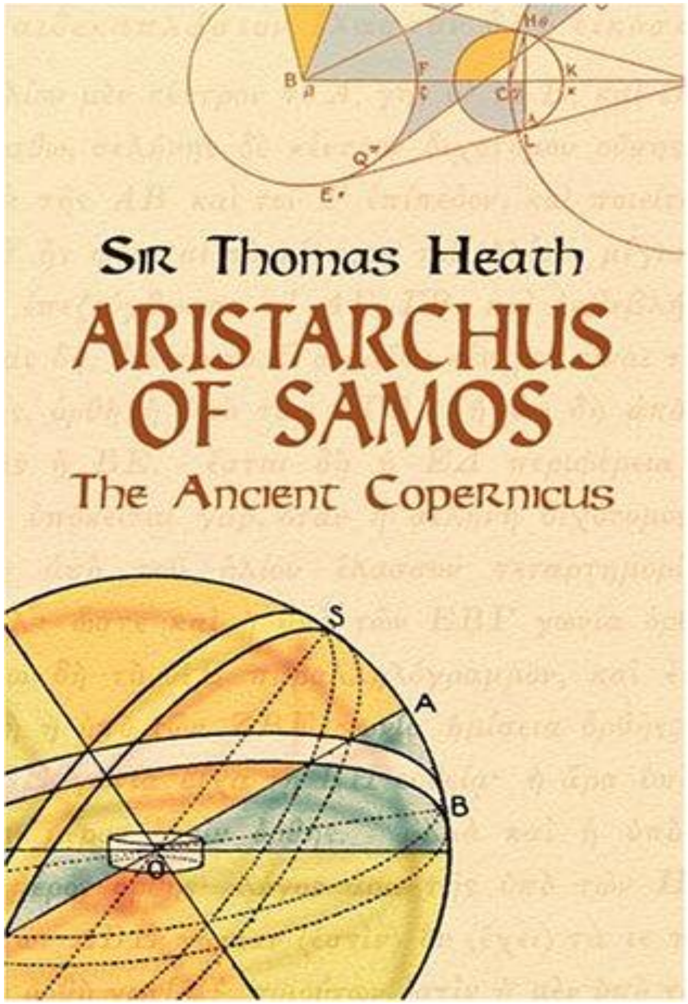
Hail Amun-Ra!

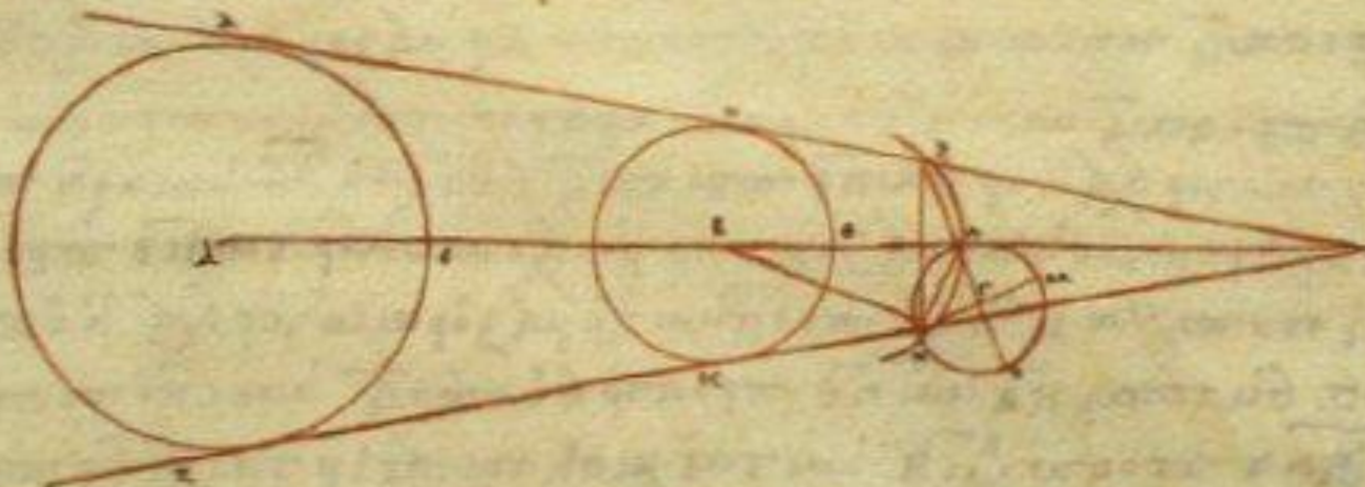

CONSTANTINVS
PER CRVCEM
VICTOR
A S SILVESTRO HIC
BAPTIZATVS
CRVCIS GLORIAM
PROPAGAVIT



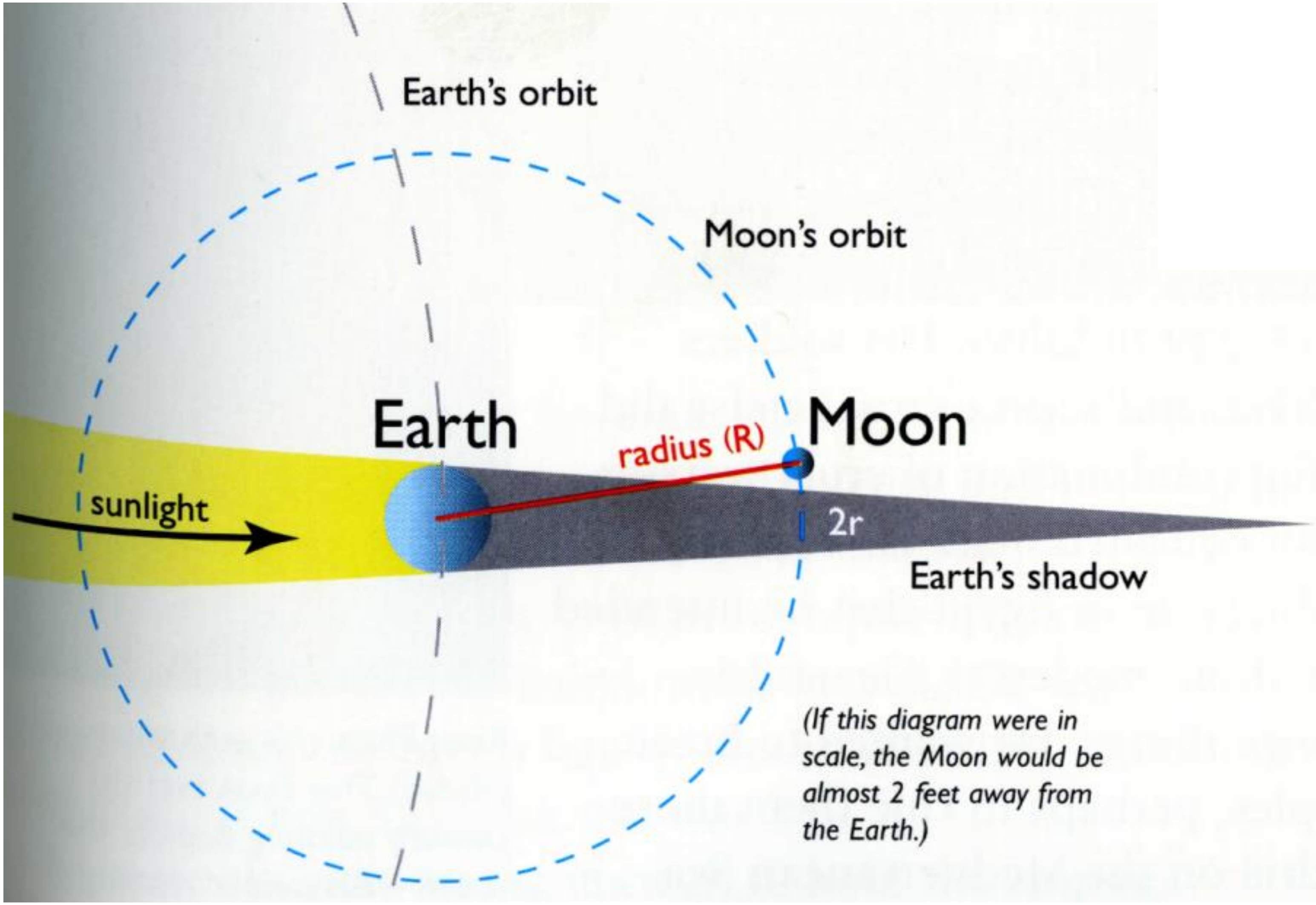

Sir Thomas Heath
ARISTARCHUS
OF SAMOS
The Ancient Copernicus

c. 310 – c. 230 BC

ὡς ͵ϛρι πρὸς ͵ϛρα, τοῦ ἡλίου καὶ τοῦ ϙ ϛρ ἔσται ταῦτα ... τῆς διαμέτρου τοῦ
διορίζοντος ἐν τῇ σελήνῃ τό τε ... καὶ τὸ λοιπὸν τῆς δι-
αμέτρου τῆς σελήνης ἐλάσσων μέν ἐστιν ἢ β, μείζονα δὲ λόγον ἔχει
ἢ ὃν τὰ πη πρὸς με: ϙ



... αὐτῶν ἴσος ... ἀπὸ τοῦ α̅ τῇ ΚΒ πρὸς ὀρθὰς ἡ
παράλληλος ὅτι ἡ ΞΝ τῆς διαμέτρου τοῦ ἡλίου ἐλάσσων μέν ἐστιν ἢ θ
μέρος, μείζονα δὲ λόγον ἔχει πρὸς αὐτὴν ἢ ὃν τὰ κβ πρὸς σκε.


Earth's orbit
Moon's orbit
Earth
radius (R)
Moon
sunlight
2r
Earth's shadow
(If this diagram were in scale, the Moon would be almost 2 feet away from the Earth.)

We think the ancient astronomers may have waited patiently for a lunar eclipse. Then, they timed how long it took for the Moon to pass through Earth's shadow. The result led to a surprisingly close estimate of the Moon's distance. We can imagine how it might have been done.

Suppose Aristarchus pictured the Moon's orbit as a giant circle (it is, almost). Geometry being a strong suit, he saw that the distance from Earth to the Moon equals the radius of that large circle. So he labelled the distance with a capital R (see diagram at right).

It never fails; the circumference of every circle – including the Moon's orbit – is always 2**π**r. Since **π** (pi) is about 3.14…, Aristarchus multiplied by 2 to get **6.28R**. The time it takes the Moon to cover that circumference (one orbit around Earth) is **T = 656 hours** (about 27 days).

To Aristarchus, it was obvious that the diameter of the Earth equals the diameter of its shadow. (It's actually smaller, but close enough.) During an eclipse, the Moon passes through that shadow. So he set the shadowed part of the Moon's orbit equal to **2r** (or I Earth diameter). Finally, a total lunar eclipse happened, and the Moon passed through Earth's shadow in about **t = 3 hours.**

Aristarchus now had all the numbers he needed. He knew that the ratio of a whole orbit (6.28R) to the shadow length (2r) is the same as the ratio of the whole orbit time (T) to the shadow time (t). Or:

$$\frac{6.28R}{2r} = \frac{T}{t}$$

Aristarchus entered the two times (T and t):

$$\frac{6.28R}{2r} = \frac{656 \text{ hours}}{3 \text{ hours}}$$

The rest was arithmetic:

$$\frac{6.28R}{2r} = 219$$

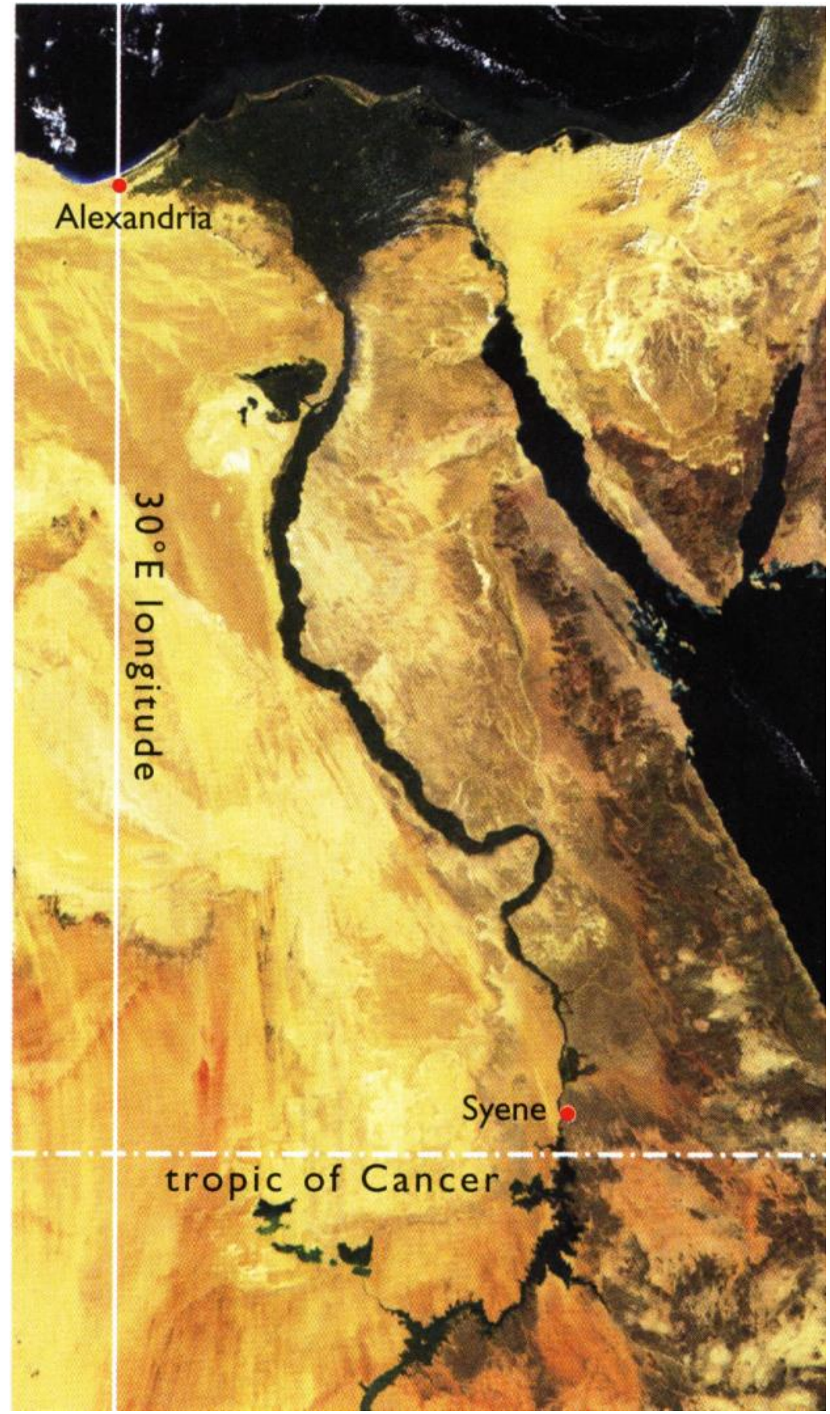
$$6.28R = 437r$$

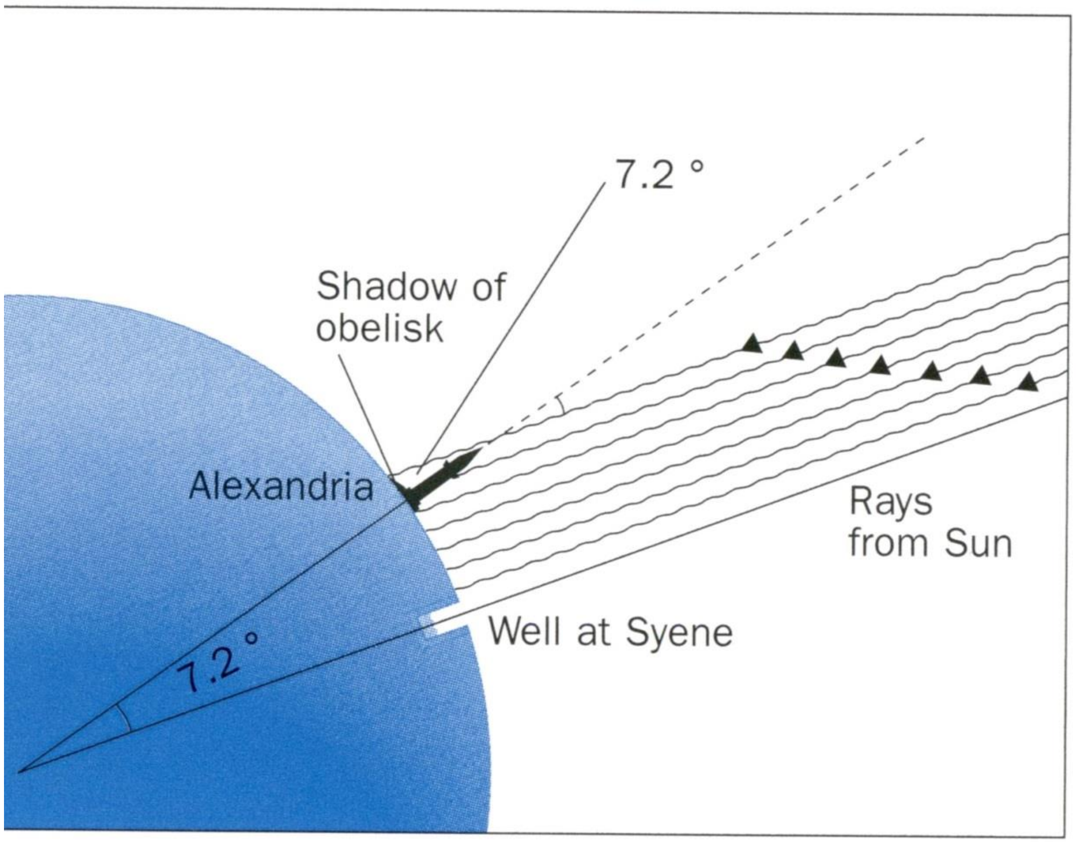
$$R = 70r$$

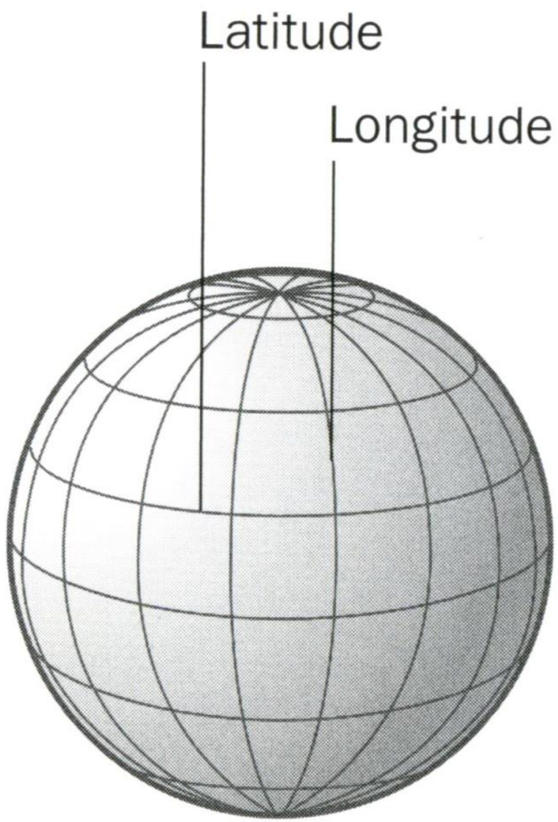
This simple equation meant that the distance to the moon (R) is about 70r-or 35 Earths in a row. We know now that it's closer to 60 radii, but that's not the point. Aristarchus did something no one else had done before, and he did long before lasers came around.

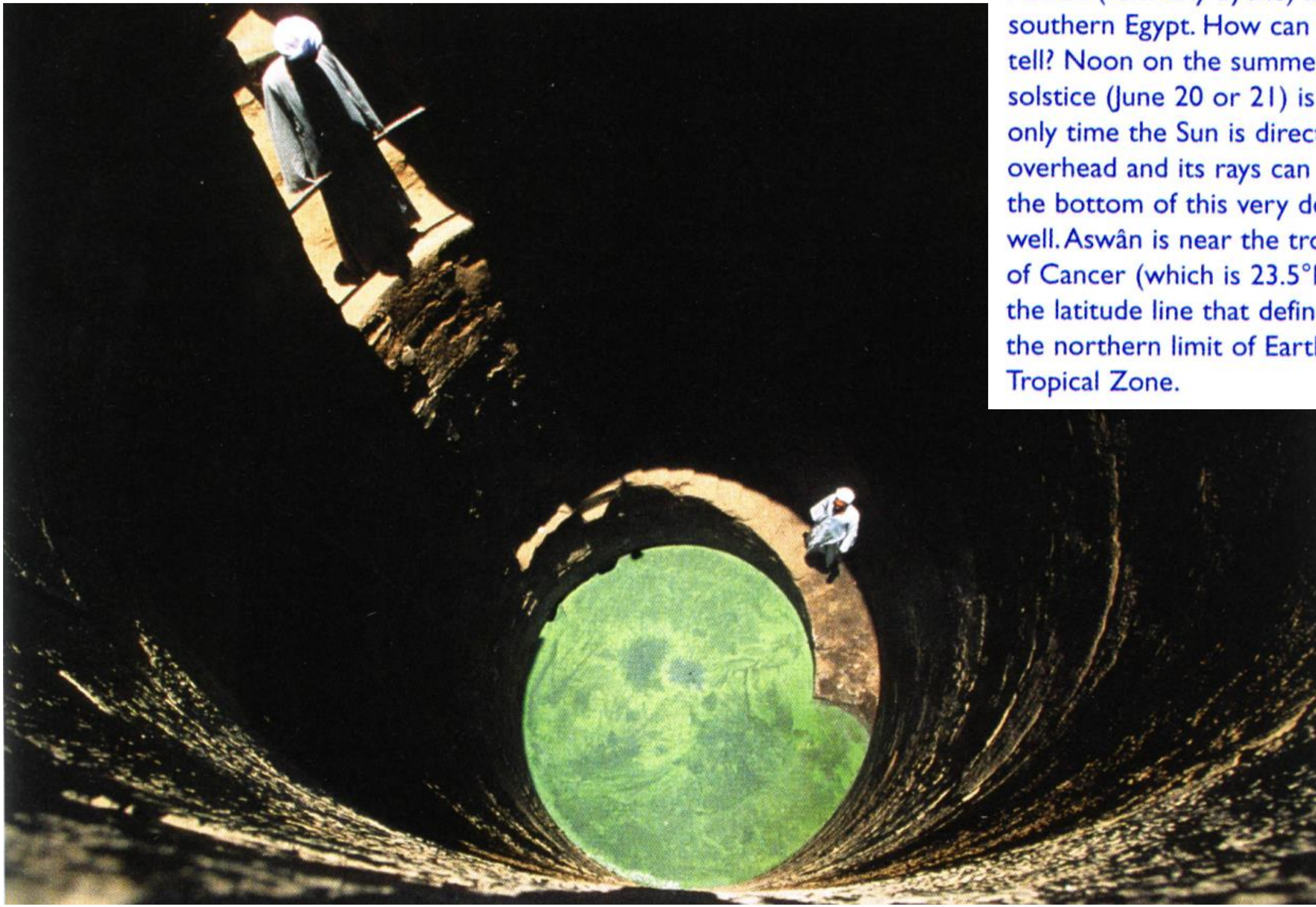
c. 276 BC – c. 195/194 BC

Eratosthenes is known as the Father of Geodesy (jee-OD-uh-see), the science of Earth measurement. Besides measuring the whole globe, he mapped the known world, from Britain to Ceylon and from the Caspian Sea to Ethiopia. He also made a star map with 675 stars, and he wrote a treatise on Greek comedy.

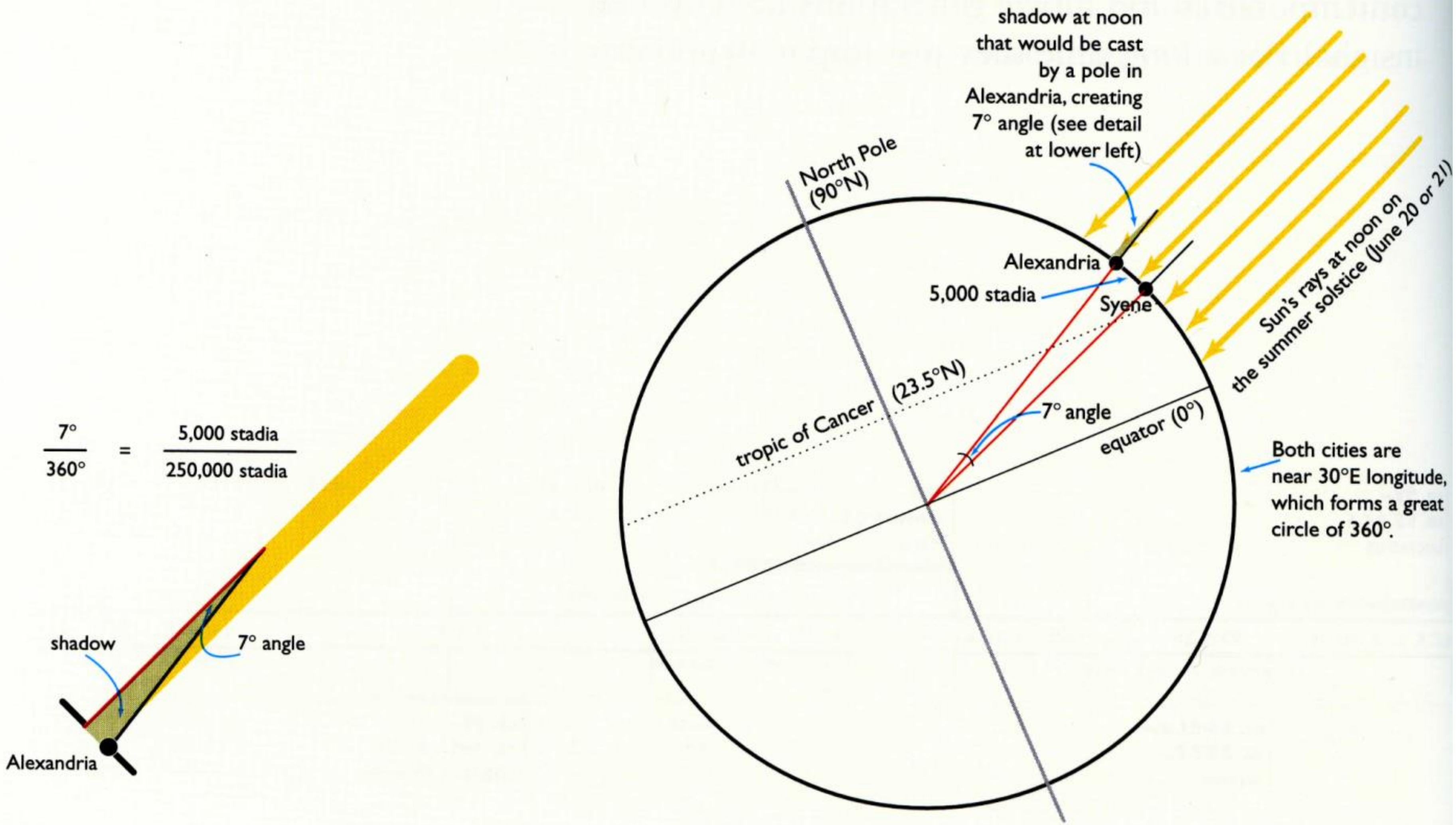



7.2 °
Shadow of obelisk
Alexandria
Rays from Sun
Well at Syene
7.2 °


Latitude
Longitude

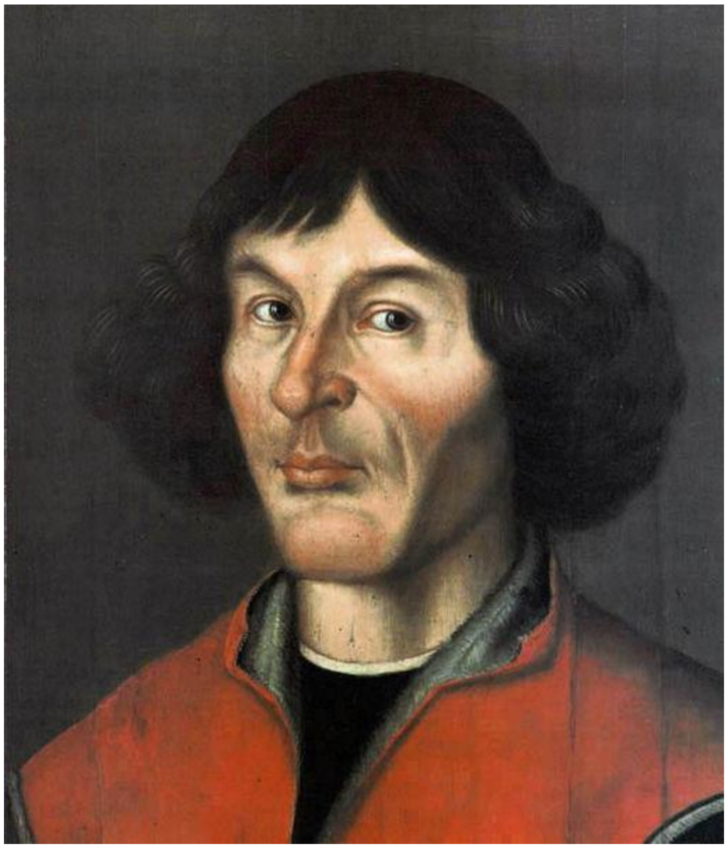


It's exactly noon in the city of Aswân (formerly Syene) in southern Egypt. How can you tell? Noon on the summer solstice (June 20 or 21) is the only time the Sun is directly overhead and its rays can reach the bottom of this very deep well. Aswân is near the tropic of Cancer (which is 23.5°N), the latitude line that defines the northern limit of Earth's Tropical Zone.

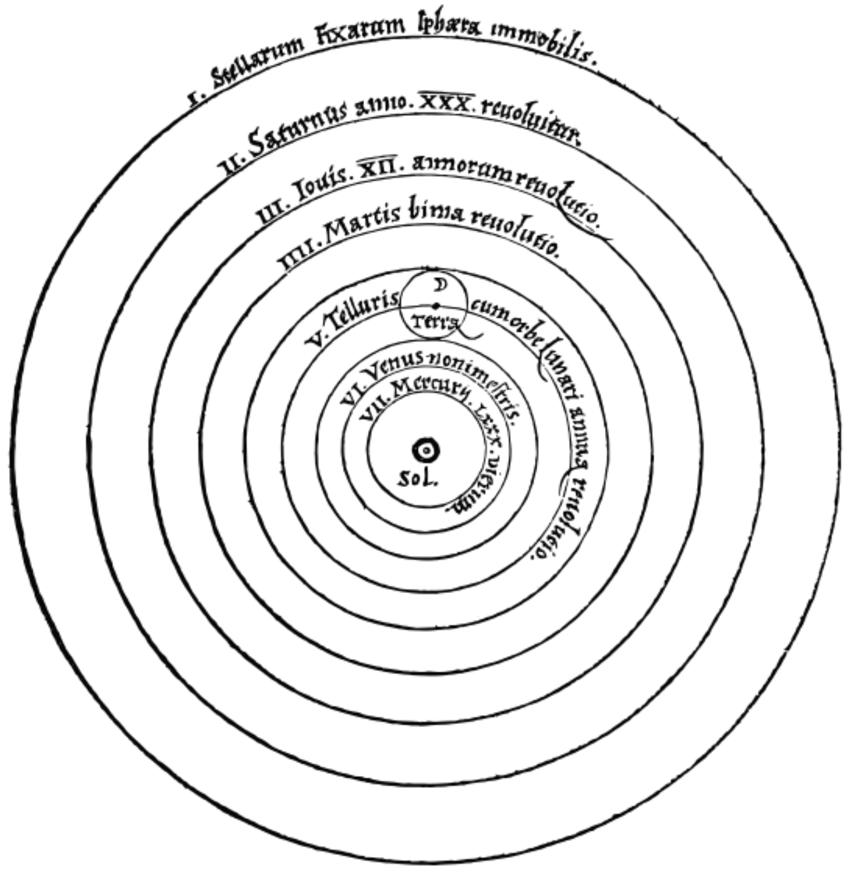


$$\frac{7^\circ}{360^\circ} = \frac{5{,}000 \text{ stadia}}{250{,}000 \text{ stadia}}$$

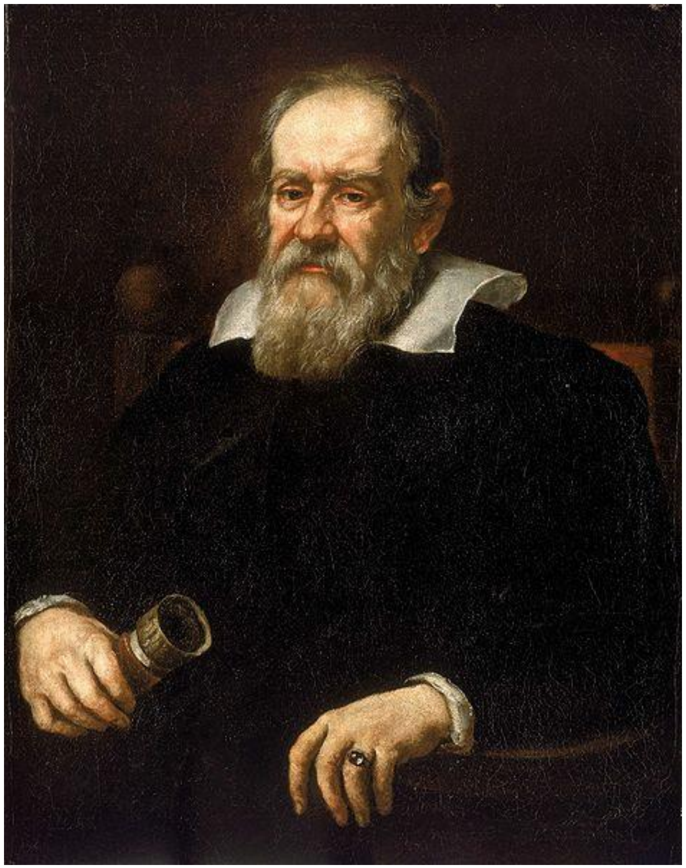
Nicolaus Copernicus
(1473 – 1543)



heliocentrism theory diagram



Galileo Galilei
(1564 – 1642)



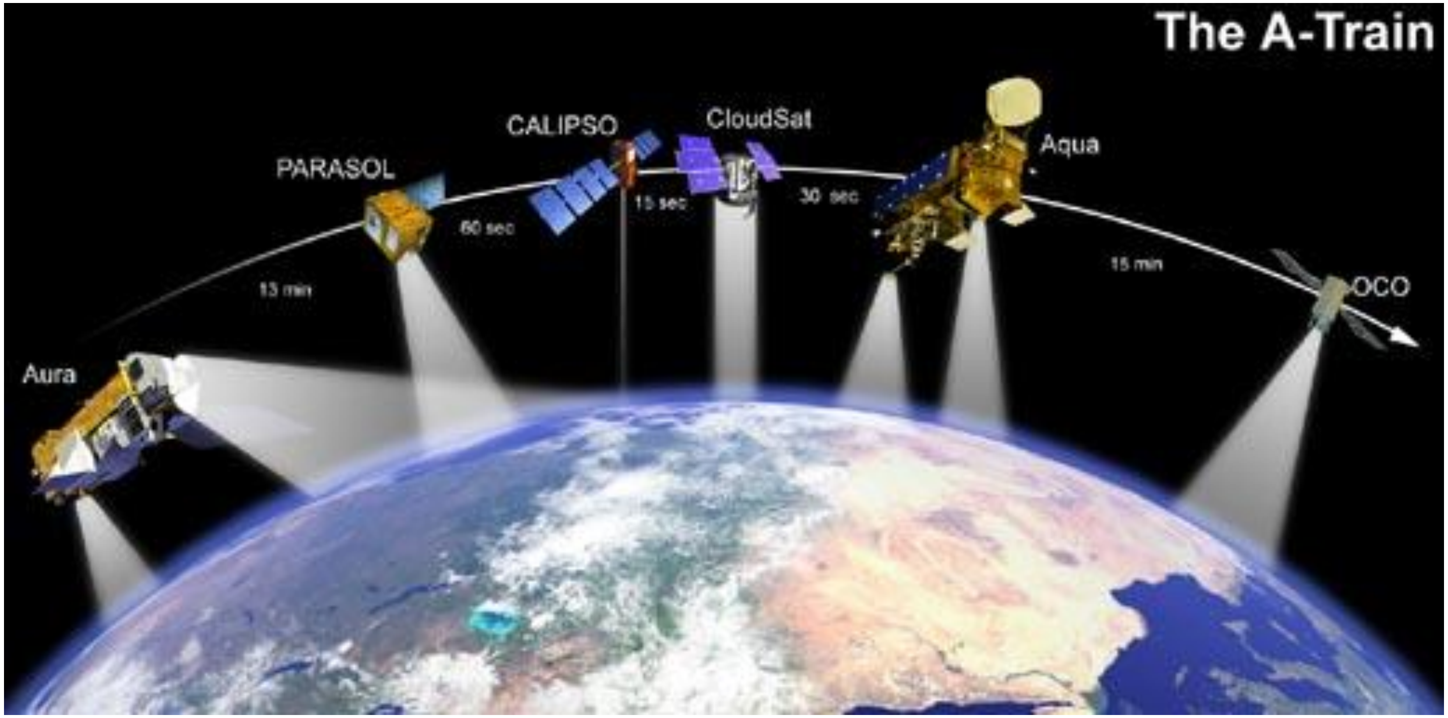
Tomasso Caccini
(1574 – 1648)

Father Tommaso Caccini, a Dominican monk and inveterate scandal-maker, was the chief instigator of Galileo's troubles. On December 20, 1614, Caccini preached a sermon in Florence that condemned mathematics and alleged that Copernicanism was either heretical or very close to it. Caccini, a "turbulent ignoramus," contended that Copernicus' Sun-centered system contradicted Scripture's description of an Earth-centered system.

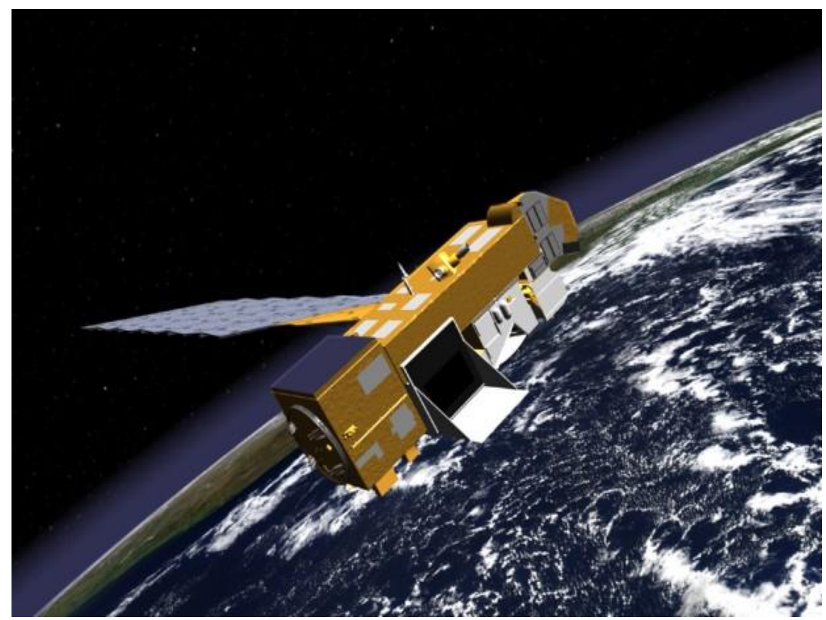
In March of 1615, Caccini traveled to Rome and denounced Galileo before the Holy Office. In his deposition, Caccini claimed that Florence was full of "Galileists" who denied miracles, claimed God was an accident, and espoused Copernican views. Caccini's move was part of a plot calculated to force Rome to act against Galileo.

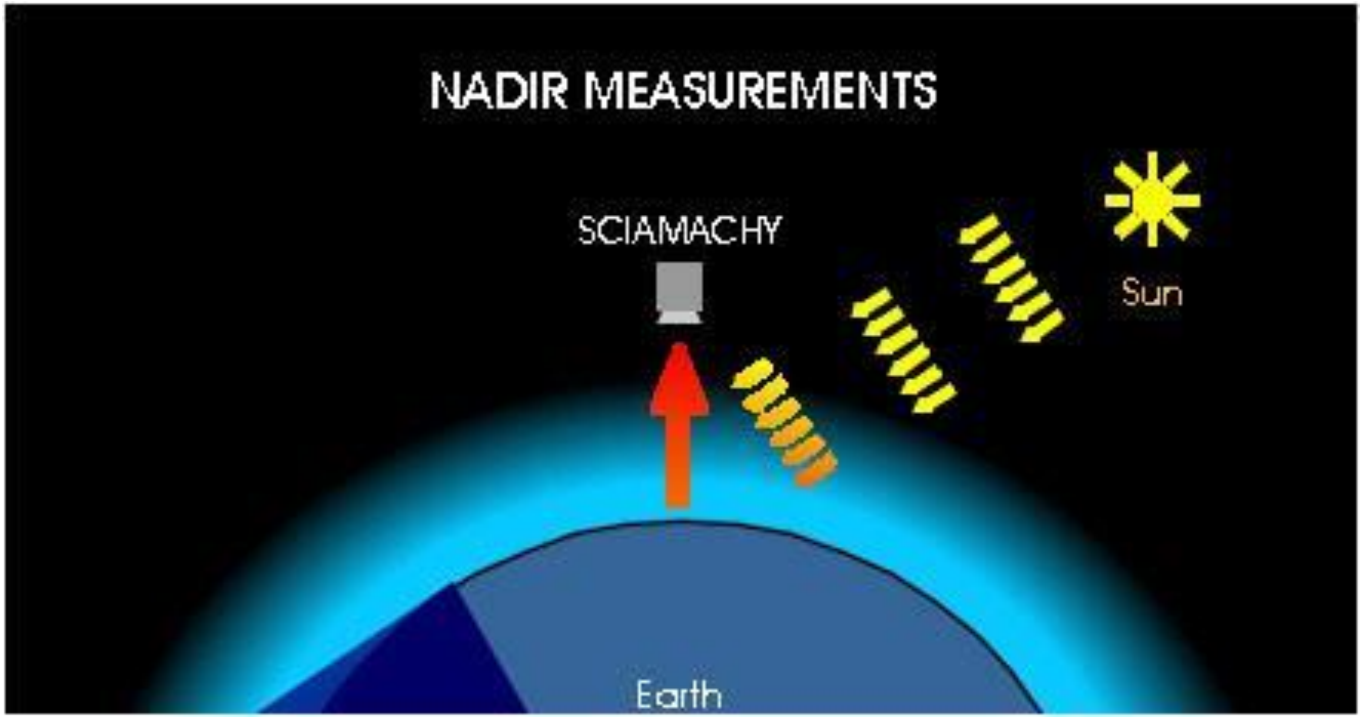
Galileo accurately sized up his enemy, describing Caccini as a person "of very great ignorance, no less a mind full of venom and devoid of charity." Caccini's own brother shared this appraisal, calling his sibling "a dreadful fool" whose "ugly drives" and "performance...makes no sense in heaven or earth."

After playing his role in gaining Galileo's admonition in 1616, Caccini managed to earn the enmity of powerful Cardinal Borghese and was forced to leave Rome. He spent his later years as Prior of San Marco in Florence.

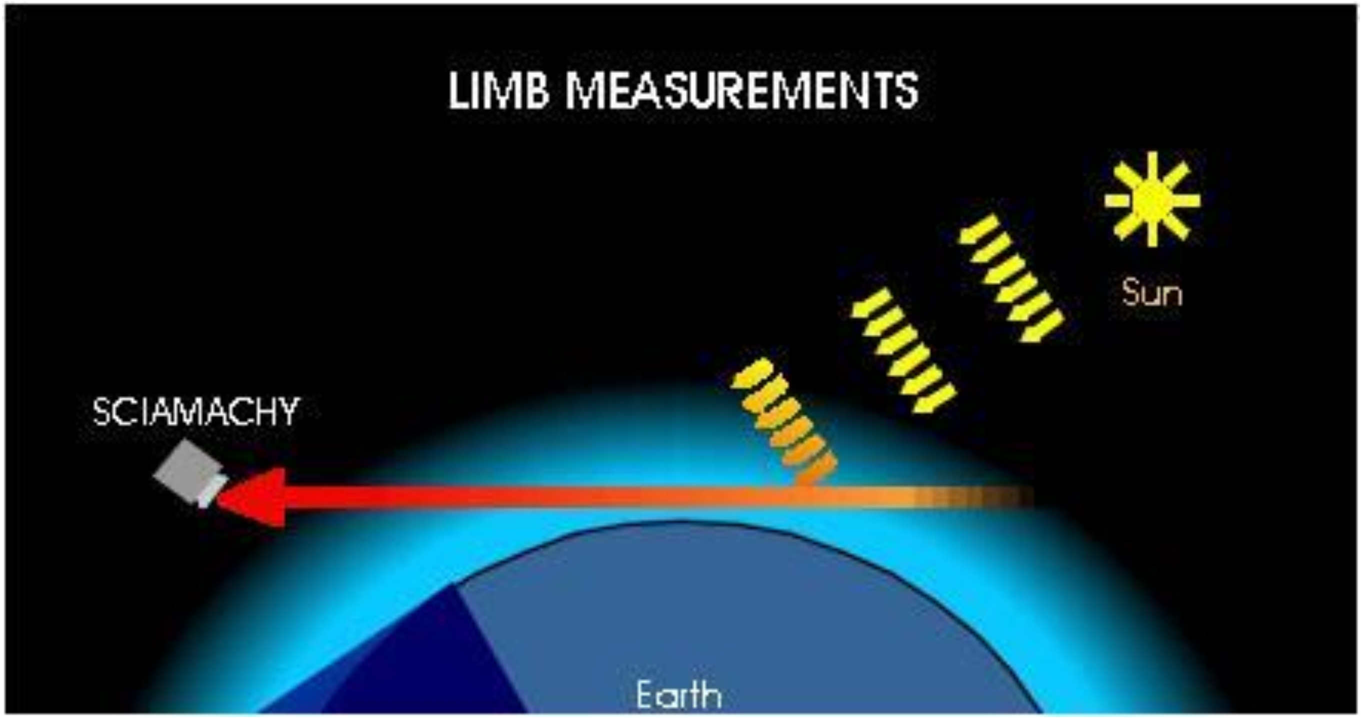

The A-Train
Aura
PARASOL
CALIPSO
CloudSat
Aqua
OCO
13 min
60 sec
15 sec
30 sec
15 min


OMI

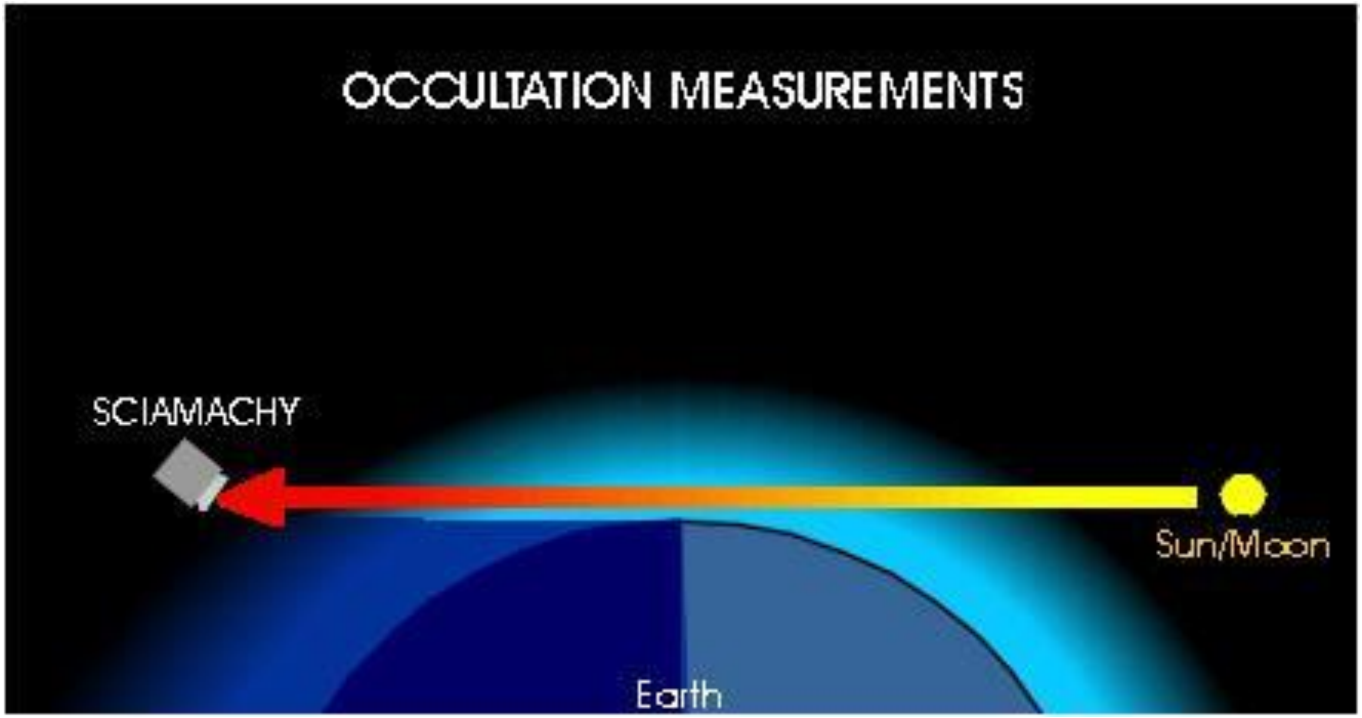




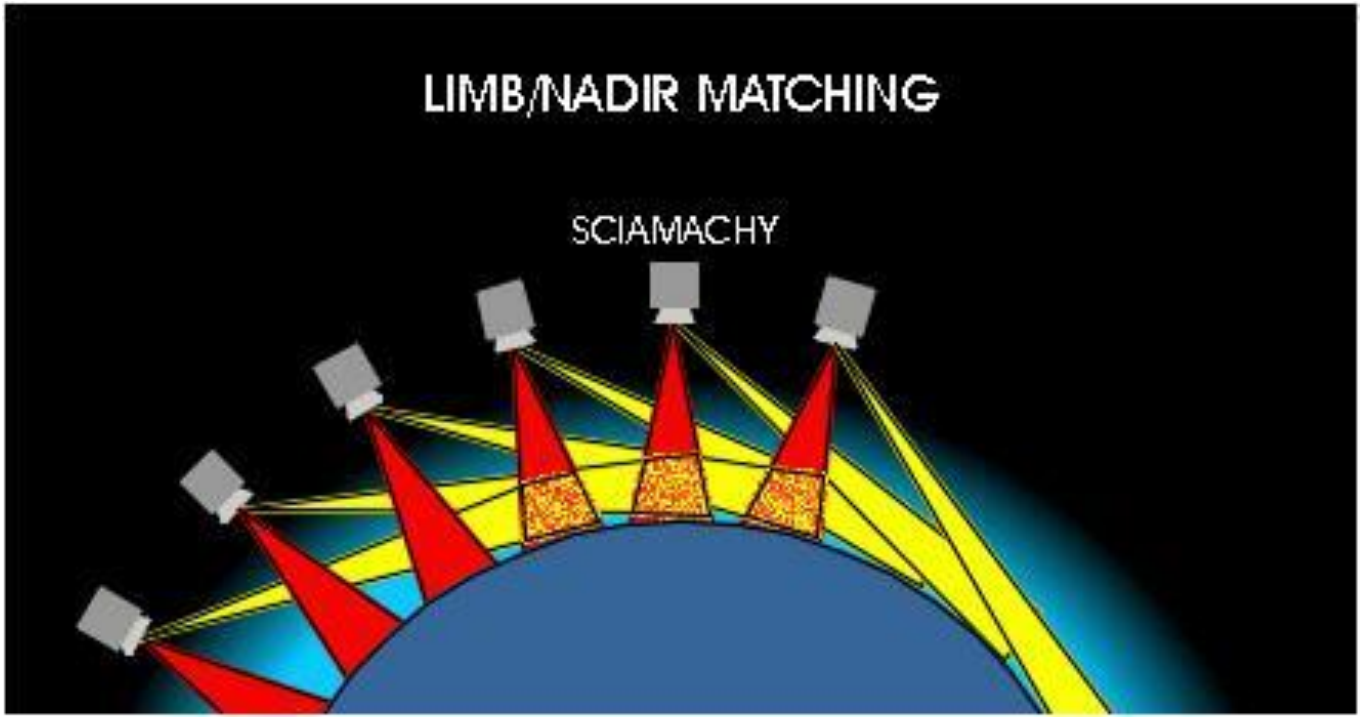
Nadir Geometry In Nadir mode the atmospheric volume directly under the instrument (i.e. the spacecraft) is observed. Each scan covers an area on the ground of up to 960 km across track with a maximum resolution of 26 km x 15 km.



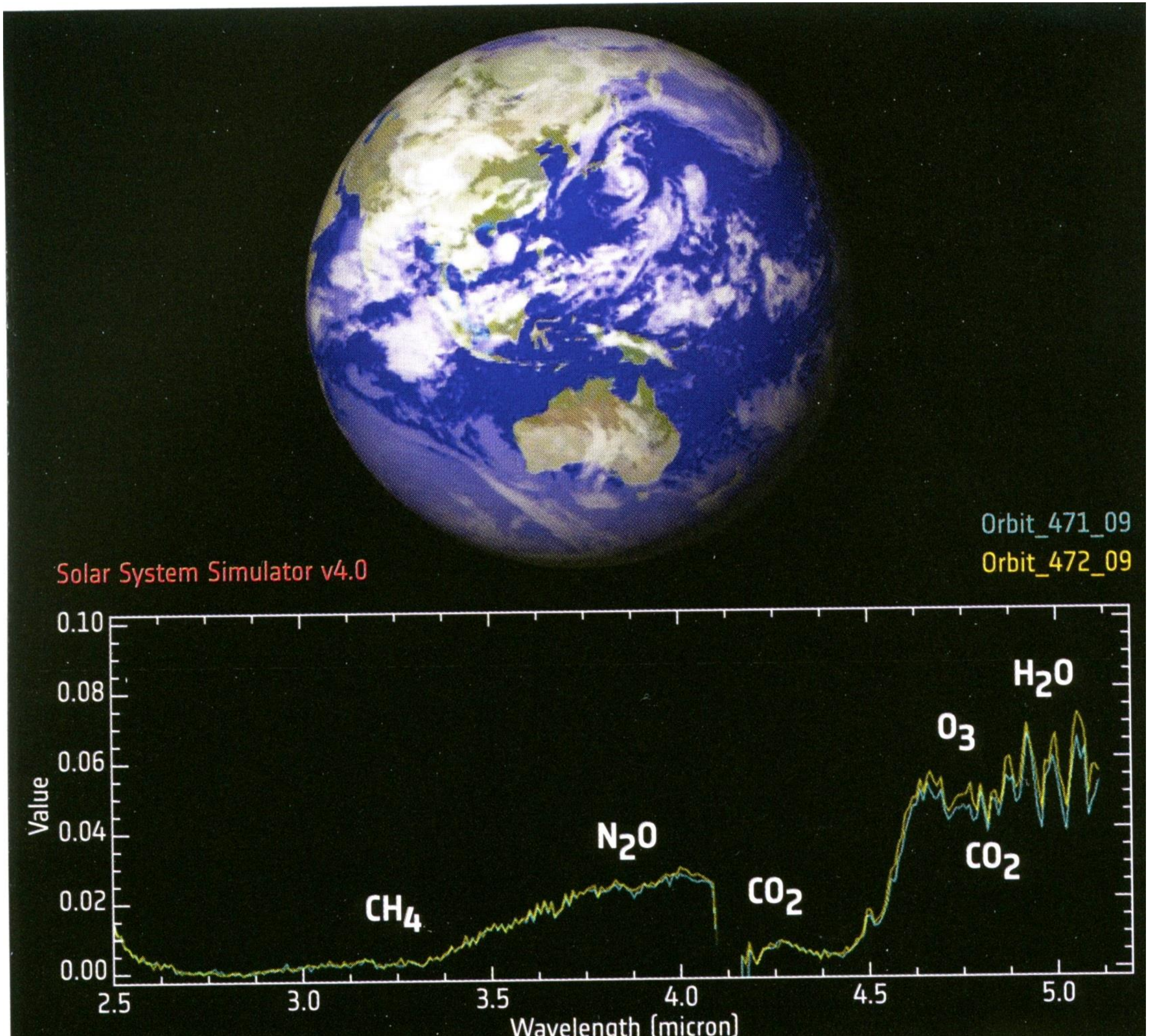
Limb Geometry In Limb mode the instrument looks at the edge of the atmosphere. Scans at different tangent altitudes over a range of up to 960 km in horizontal direction are performed with a geometrical vertical resolution of approximately 2.6 km.



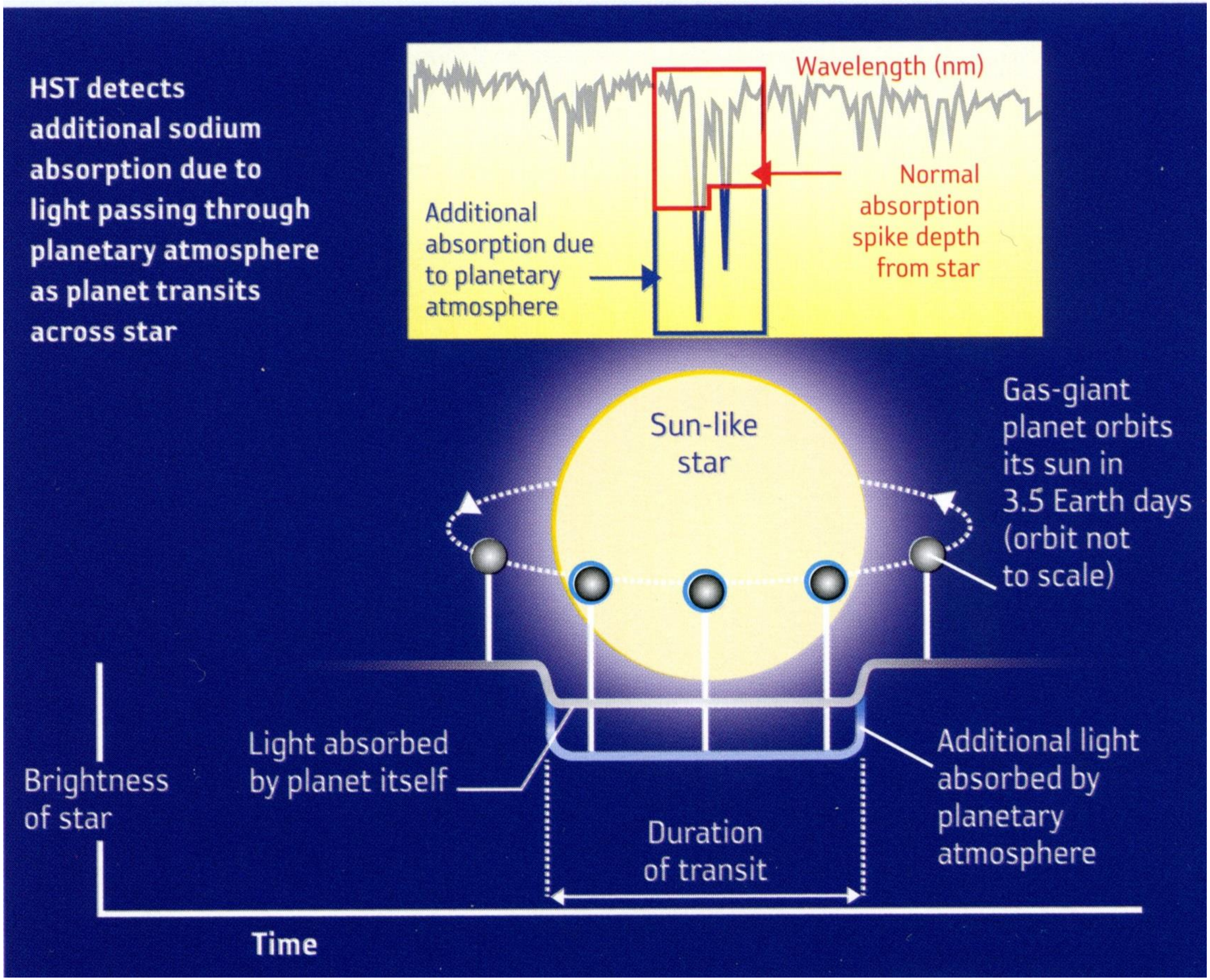
Occultation measurements are performed using the same geometry as in Limb mode, but with the sun or the moon in the instrument's field of view. Atmospheric densities are obtained by comparing measurements of the transmitted solar or lunar radiation with the unattenuated source. Solar occultation measurements are performed regularly during sunrise (latitude range 90° N - 65° N). Lunar occultation measurements during moonrise (between 30°S - 90°S) - which are possible for about one week per month - are used for process studies.



Limb / Nadir Matching One of the most important features of SCIAMACHY is the possibility to observe the same atmospheric volume first in limb and then after about 7 minutes in nadir geometry. By using this Limb/Nadir matching three-dimensional information about the atmosphere can be obtained.



This image composite shows the signatures of methane (CH_4), carbon dioxide (CO_2), ozone (O_3) and nitrous oxide (N_2O), minor species of Earth's atmosphere but powerful greenhouse gases, detected by the Visual and Infrared Thermal Imaging Spectrometer (VIRTIS) on ESA's Venus Express at infrared wavelengths, while the spacecraft was pointing towards Earth along its orbit around Venus. These observations are relevant as they prove that a distant (extrasolar) planet can reveal to an instrument like VIRTIS the signatures of chemical compounds present in the atmosphere and on the surface. During these observations, Venus Express' distance from Earth was about 78 million km. (ESA/VIRTIS/INAF-IASF/Obs. de Paris-LESIA; Earth views: Solar System Simulator JPL-NASA)



General technique for measuring the chemical composition of the atmospheres of eclipsing exoplanets. (SpaceRef.com)

Sentinel-1, the first in the family of Copernicus satellites, is used to monitor many aspects of our environment, from detecting and tracking oil spills and mapping sea ice to monitoring movement in land surfaces and mapping changes in the way land is used. It will also play a crucial role in providing timely information to help respond to natural disasters and assist humanitarian relief efforts.

Source ESA 2014

Soyuz VS07 with the ESA's Sentinel-1A satellite lifted off from Europe's Spaceport in Kourou, French Guiana, launced on 3rd April 2014.

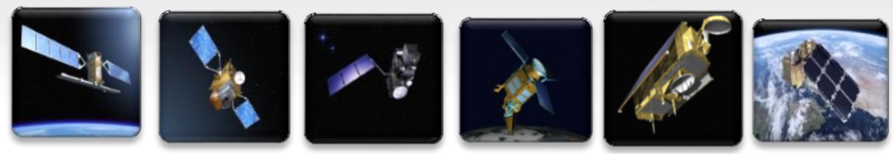
Acquired on 13 April 2014 at 23:57 GMT (14 April at 01:57 CEST) by Sentinel-1A, this image shows a transect over the northern part of the Antarctica Peninsula.

European response to global needs:

- to manage the environment,
- to mitigate the effects of climate change and
- to ensure civil security

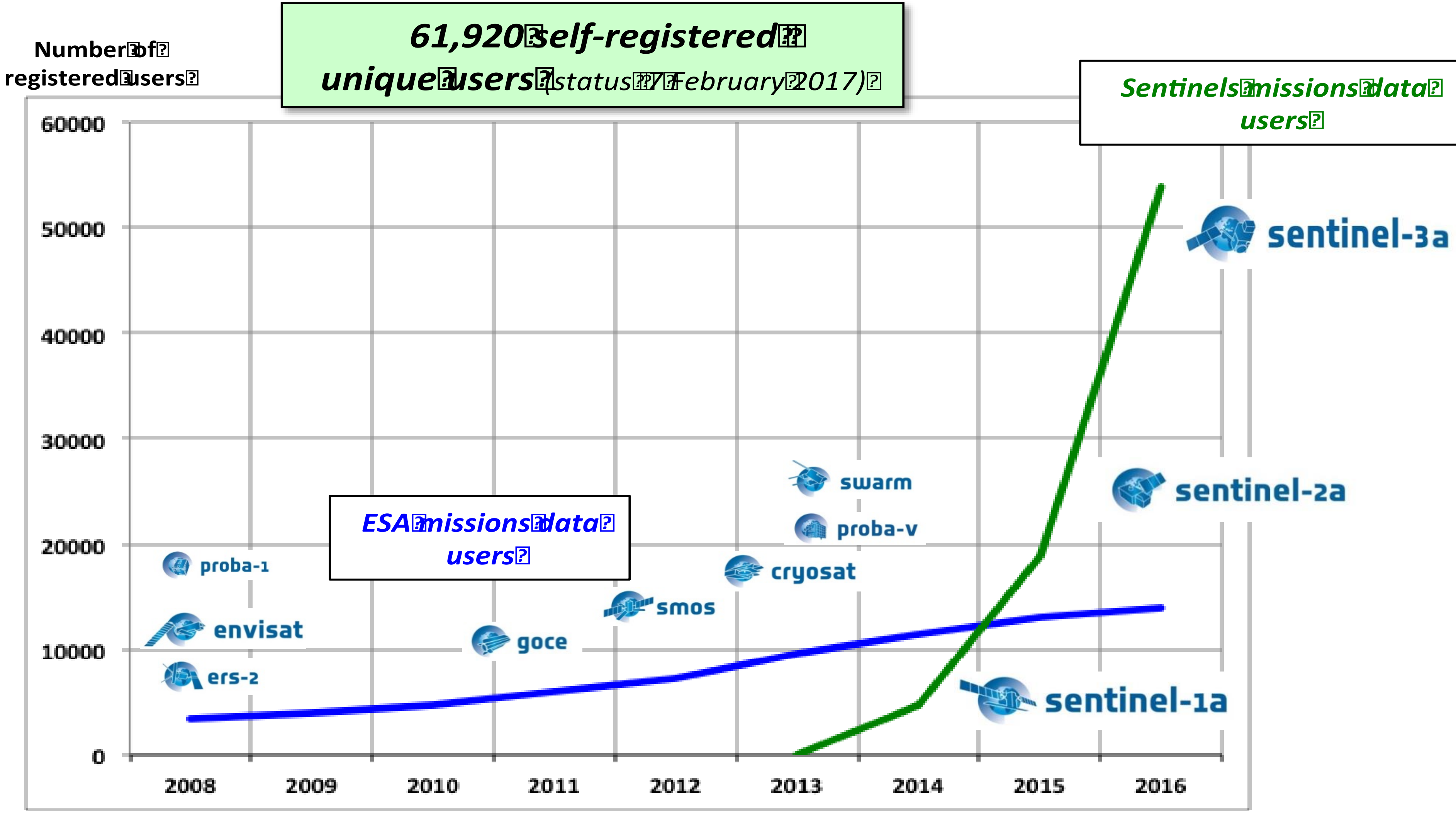
European independence, contribution to global system (GEOSS)

Copernicus Space Component



Copernicus Services Component

Copernicus: Open Data Policy



Sentinel-5 Precursor
COPERNICUS ATMOSPHERE MISSION IN POLAR ORBIT

The ESA Sentinel-5 Precursor (S-5P) is a pre-operational mission focusing on global observations of the atmospheric composition for **air quality** and **climate**.

The TROPOspheric Monitoring Instrument (**TROPOMI**) is the payload of the S-5P mission and is jointly developed by **The Netherlands and ESA**.

S-5P will be provide **enhanced radiometric sensitivity & spatial resolution** enabling sampling of small-scale variabilities specifically in the lower troposphere.

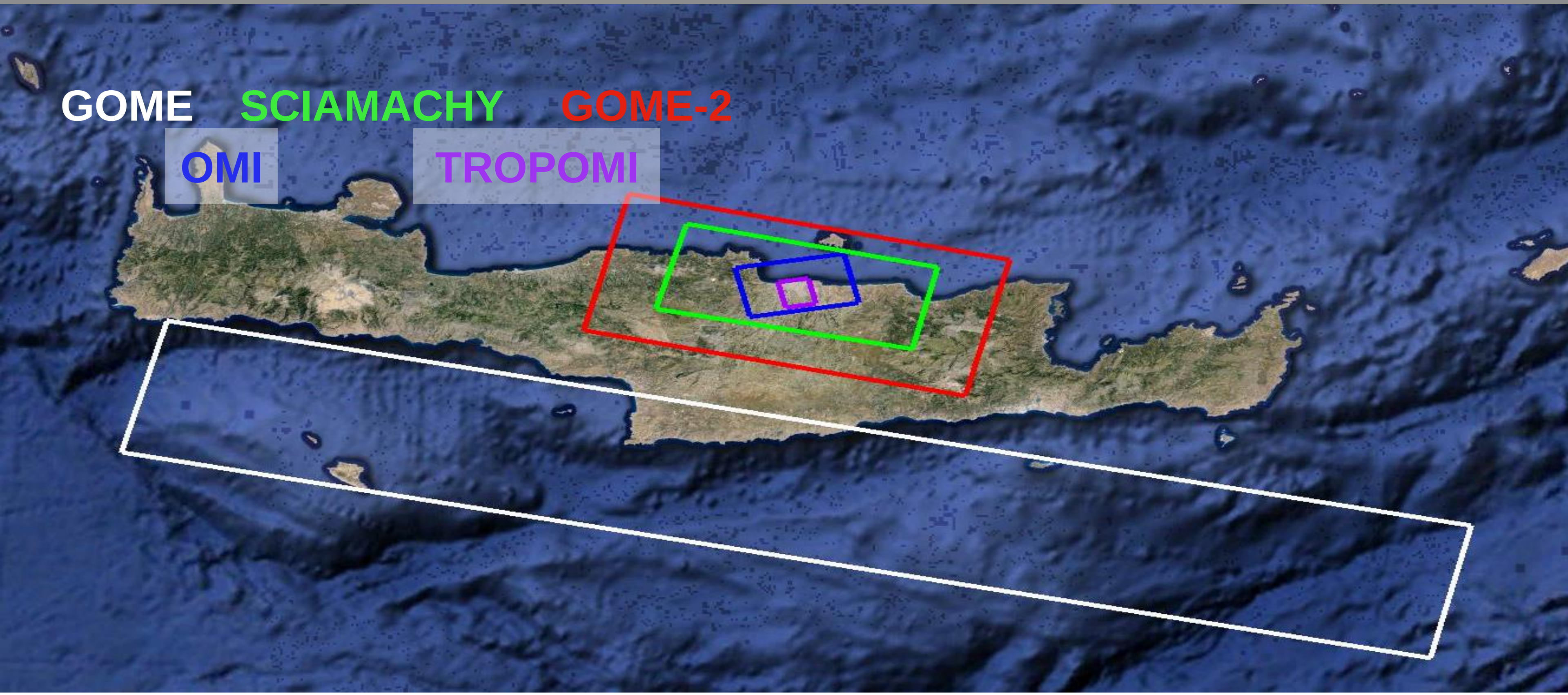
The planned launch date for S-5P is during **August 2017**.

7 year design lifetime.

TROPOMI

- UV-VIS-NIR-SWIR nadir view grating spectrometer.
- Spectral range: 270-500, 675-775, 2305-2385 nm
- Spectral Resolution: 0.25-1.1 nm
- Spatial Resolution: 3.5x7km^2
- Global daily coverage at 13:30 local solar time.

Improved Spatial Resolution



S-5P vs SCIAMACHY, GOME-2, OMI:

- Smaller pixels: 3.5x7 km^2
- Larger swath-width (2600 km) with daily global coverage

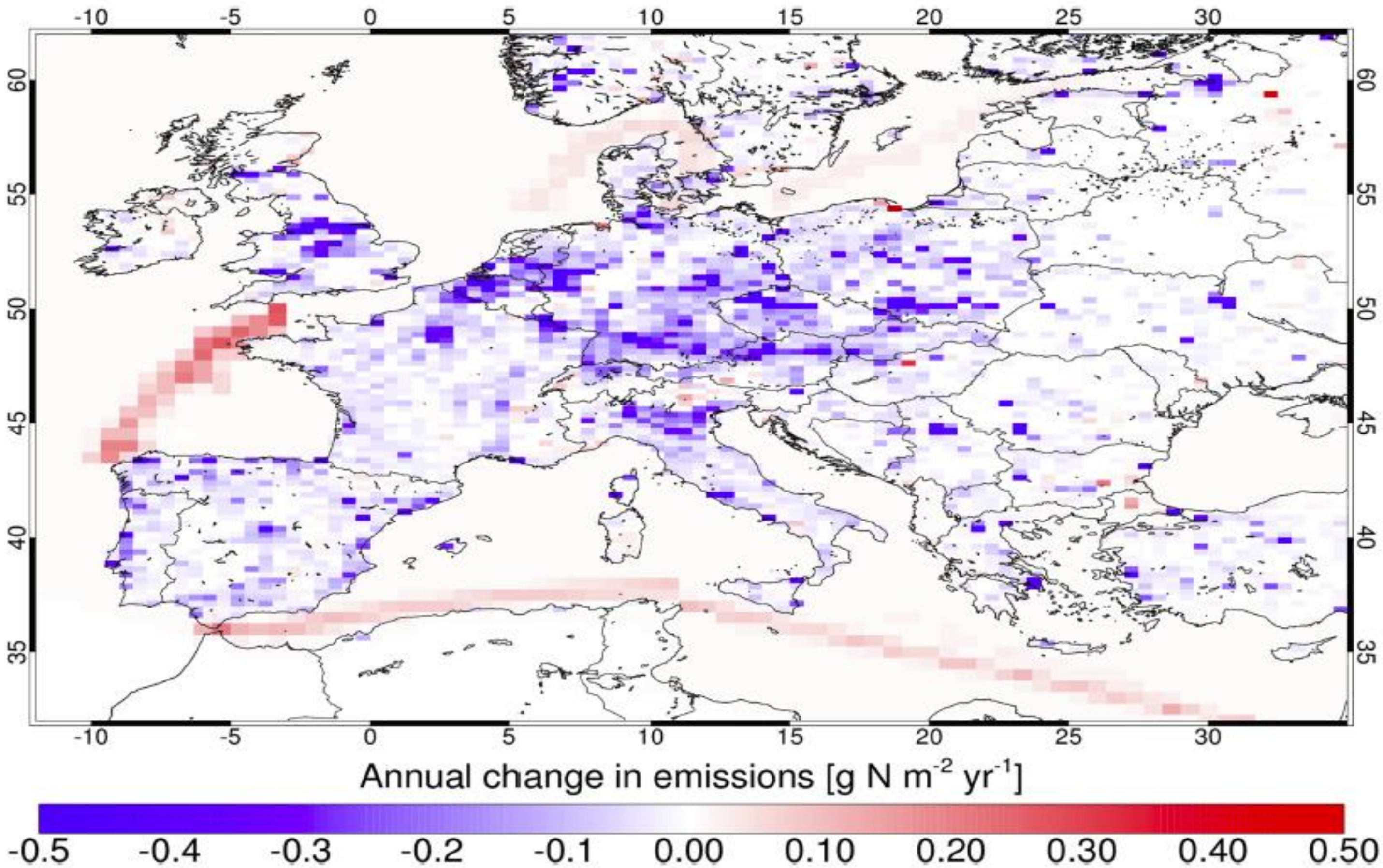
S-5P Data Volume:

- ~1.5 million ground pixels/orbit
- L1: ~35 Gbyte/orbit
- L2: ~3.5 Gbyte/orbit
- Total: ~ 640 Gbyte/day

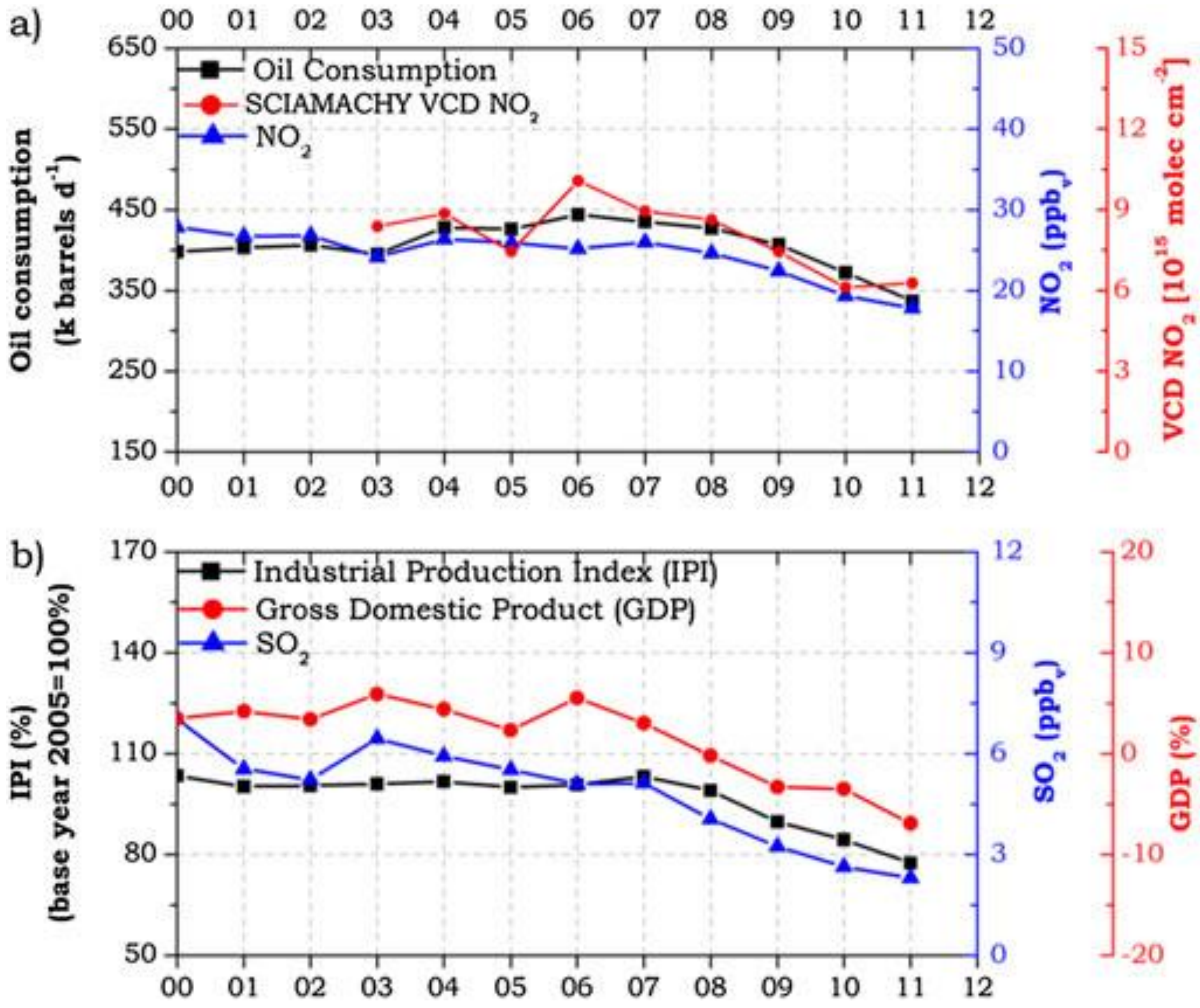
NO_x Pollution over Europe - OMI Data

esa

Annual changes in OMI NO_x emissions (2005-2008)



Quality Assurance for Essential Climate Variables (EU FP7 project QA4ECV, lead by KNMI (F. Boersma), www.qa4ecv.eu



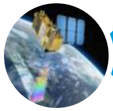
Top row (a) presents the annual means of nitrogen dioxide levels (NO2) over Athens (blue) compared to the tropospheric SCIAMACHY VCDNO2 (red) and the oil consumption per day (black).

Bottom row (b) depicts the annual means of sulfur dioxide (SO2) levels in Athens (blue), the Gross Domestic Product of Greece (red) and the Industrial Production Index, IPI (black); Vrekoussis et al. 2013.

S-5P/TROPOMI: Ready for Launch!

Sentinel Launches

S1A/B: Radar Mission — 3 Apr 2014/25 Apr 2016



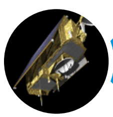
S2A/B: High Resolution Optical Mission — 23 June 2015/6 March 2017

S3A/B: Medium Resolution Imaging and Altimetry Mission — 16 Feb 2016/2017

S4A/B: Geostationary Atmospheric Chemistry Mission — 2022

S5P: Low Earth Orbit Atmospheric Chemistry Mission — 2017

S5A/B/C: Low Earth Orbit Atmospheric Chemistry Mission — 2021



S6A/B: Altimetry Mission — 2020