Mercury Transit and Sunset on May 9, 2016

Hans Jelitto

Photos taken at the Hamburg University of Technology (TUHH) and at the northern riverside of the Elbe

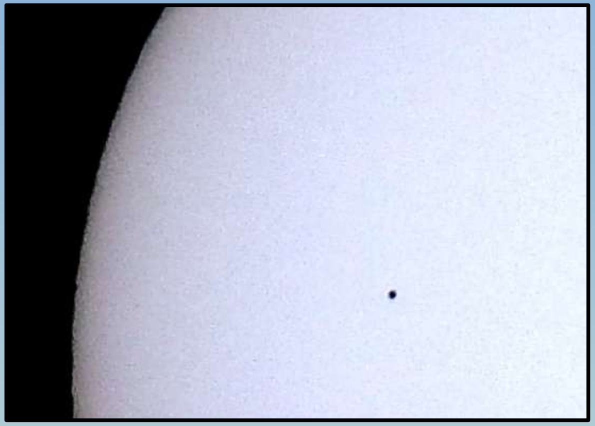
Outline

1. Introduction
2. Technical and calculated data
3. Mercury transit, May 9, 2016
4. Sunset
5. Future transits and Giza pyramids

Appendix (technical info, references)

3rd edition, Oct. 2018

1. Introduction



Primarily, this presentation is a compilation related to the Mercury transit on May 9, 2016. Such a transit means that the planet Mercury passes in front of the solar disk as seen from the Earth. This happens about 13 to 14 times per century. However, these transits cannot always be observed, because daytime is needed and the sky should not be covered with clouds.

In addition to the presentation of technical data and pictures of the transit, it is shown that astrophotography is possible with relatively simple camera equipment.

Finally, some data of the Mercury transit in the year 3088 AD are provided, which probably play a role with respect to the Giza pyramids.

Camera:

Fujifilm FinePix S1, 50x opt. Zoom, 316 €.
(Hints for optimal image quality are provided in the appendix.)

Filter:

Baader AstroSolar®, sun filter foil, OD 5.0, with a custom-made carton mounting. "OD" means optical density; transmission = 10^{-5}.

Adjustment of camera:

- ISO: 100
- Image stabilizer: off
- Zoom (nominal): 50x
- Program selection knob: P
- Correction of aperture: −1
- Focus mode (auto): center
- Short-time delay release: 2 sec

After release:

Hands off from camera and tripod!

CAUTION !

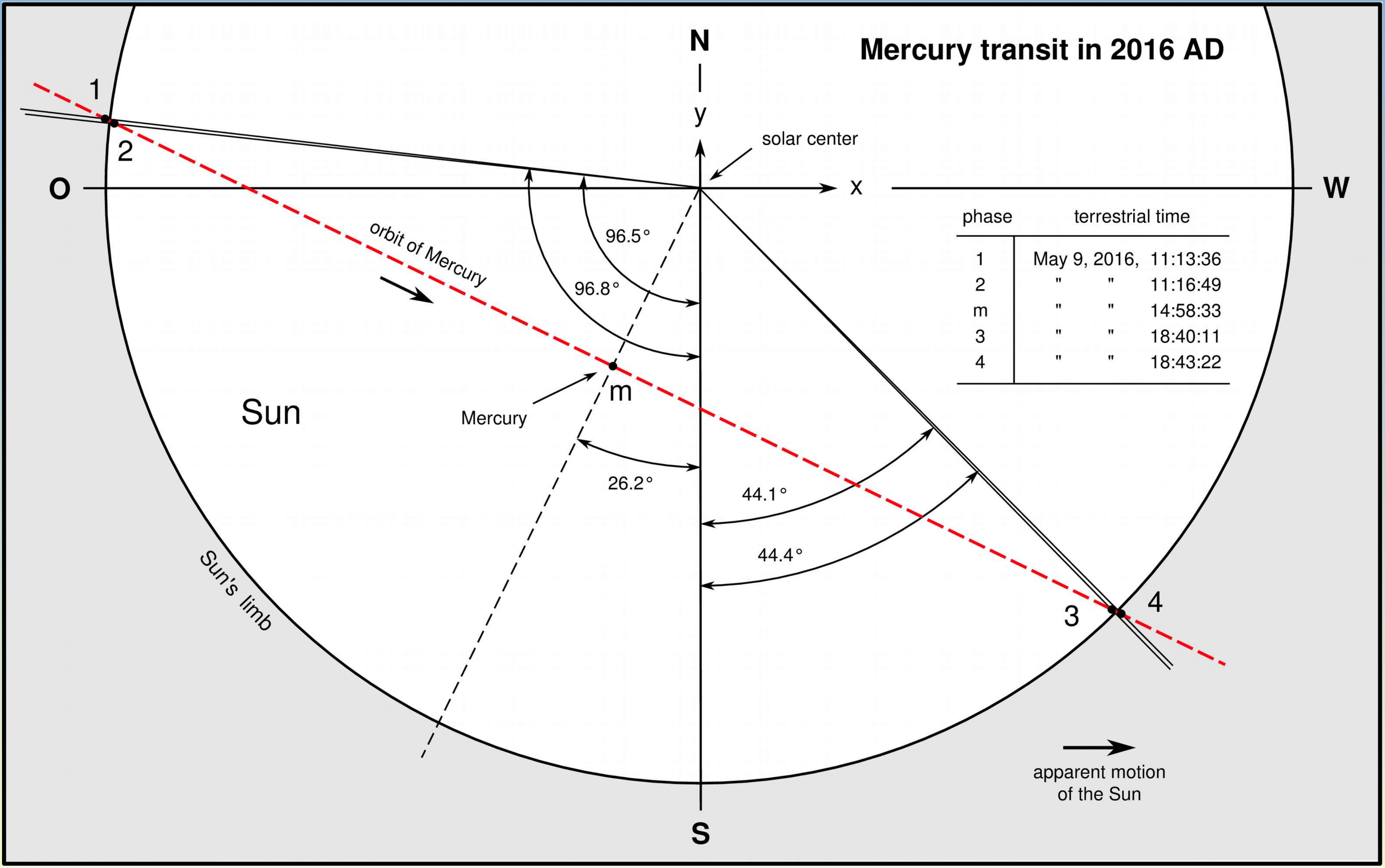
Care must be taken when using an optical device, like a telescope, for observing the Sun with the naked eye or with a digital camera. In all cases, an appropriate sun filter has to be used! Otherwise, sunlight – being too intense – could severely damage the eye or the optical chip of the camera. The only exception is when the Sun is situated very close to the horizon.

The geocentric transit phases and position angles of the Mercury transit are calculated with the P4 program [1, 2]. For this program, written in Fortran (gfortran), we tried to use the most reliable and accurate data.

Main features of P4 (concerning transits):

a) Astronomical basis: Theory VSOP87 by P. Bretagnon and G. Francou [3, 4].
b) Solar photospheric radius (695508 km): T. M. Brown, J. Christensen-Dalsgaard [5].
c) Time-dependent obliquity of the ecliptic: Equation from A. D. Wittmann [6].
d) ΔT, conversion of time scales, TT to UT: NASA, F. Espenak and J. Meeus [7, 1].
e) Conversion JDE to calendar date: J. Meeus [8] (algorithm extended for JDE < 0).
f) 3D geometrical problems: Support by books of J. Meeus [9] and A. Danjon [10].

References and more technical details are provided in the appendix.



True-to-scale representation of the Mercury transit in 2016 with the transit phases (contact points) 1, 2, m, 3, 4, and position angles, both calculated with P4 on the basis of VSOP87.

When comparing the dates with transit data from books or the Internet, the used time scales and calendars have to be considered! The main possibilities are:

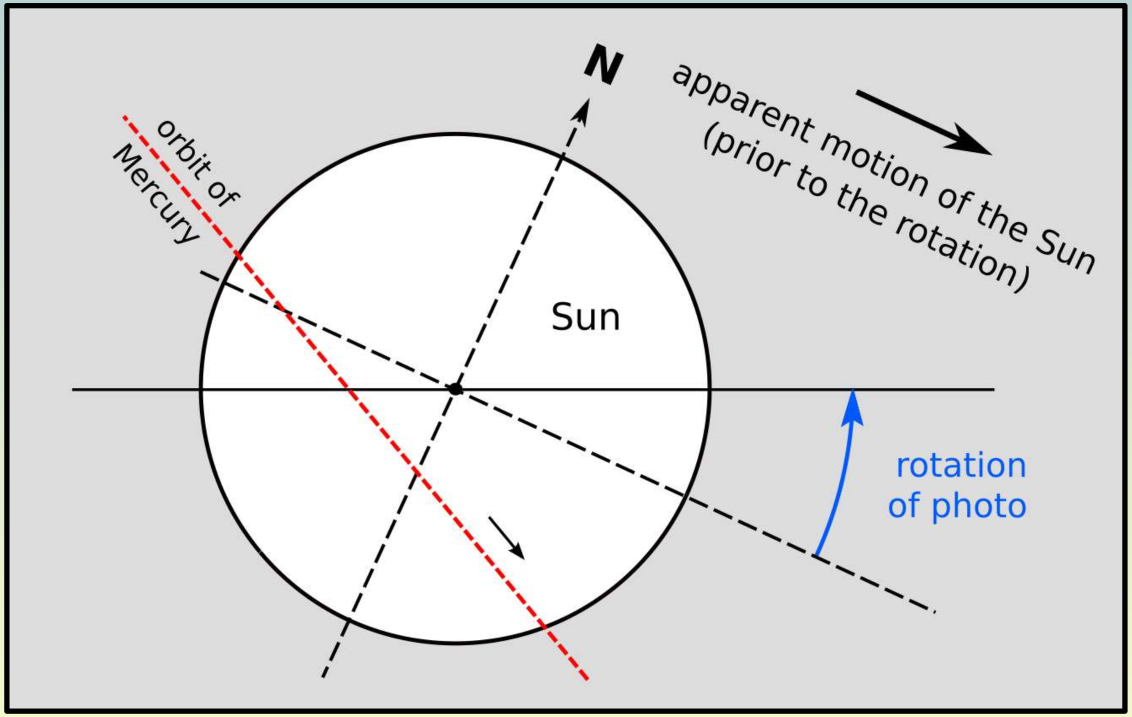
1) Time scale: **Terrestrial Time** (TT) or **Universal Time** (UT). UT is appropriate for the last few centuries and present time. TT, a linear time scale, can be used for all times including the remote past and the remote future. A brief description of the main time scales is compiled in the appendix.

2) Calendar: **Gregorian** or **Julian calendar**. The Gregorian calendar is the standard. Nevertheless, sometimes the ancient Julian calendar is used for the corresponding dates before October 15, 1582.

3) Counting the years: The **astronomical** or the **historical counting**. In the historical counting, the year zero is missing. So, this aspect becomes important for years before Christ. (In the P4 program the astronomical counting is used.)

The observation of the Sun and Mercury began at the TUHH (Hamburg University of Technology).

The following photos of the Sun are rotated individually in such a way that the apparent motion of the Sun in the sky due to the Earth's rotation becomes horizontal. This means that the central axis, pointing to the northern celestial pole, becomes vertical. Thus, the positions of Mercury can be compared with the calculated predictions.



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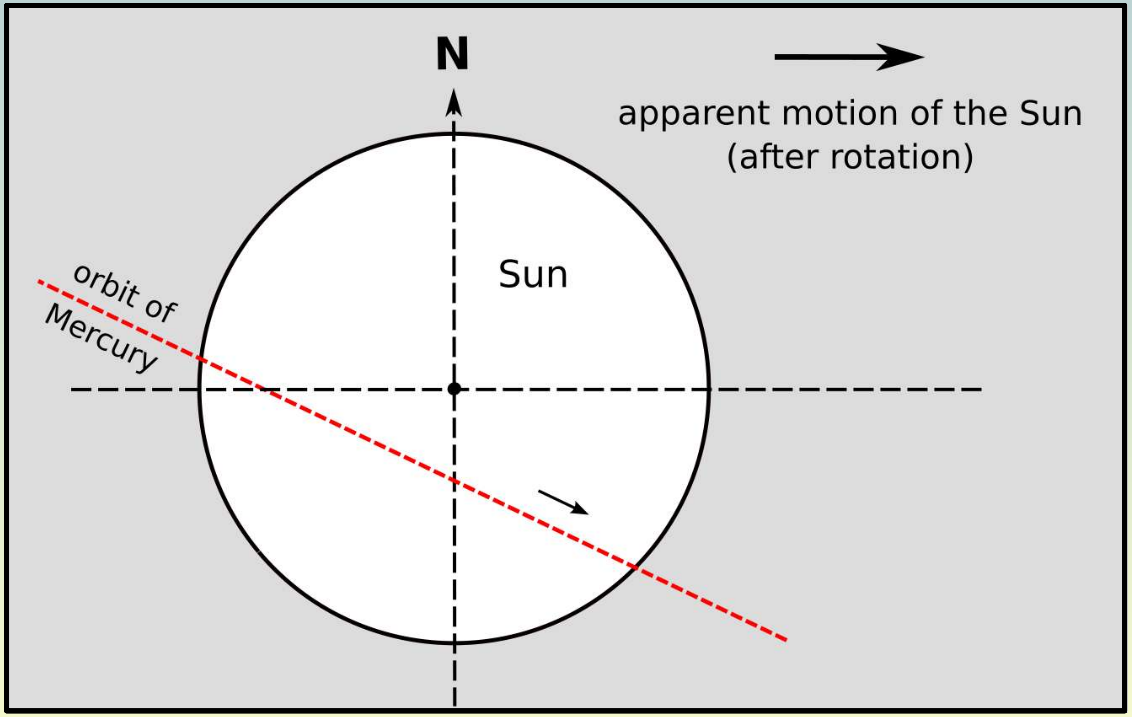

3. Mercury transit, May 9, 2016

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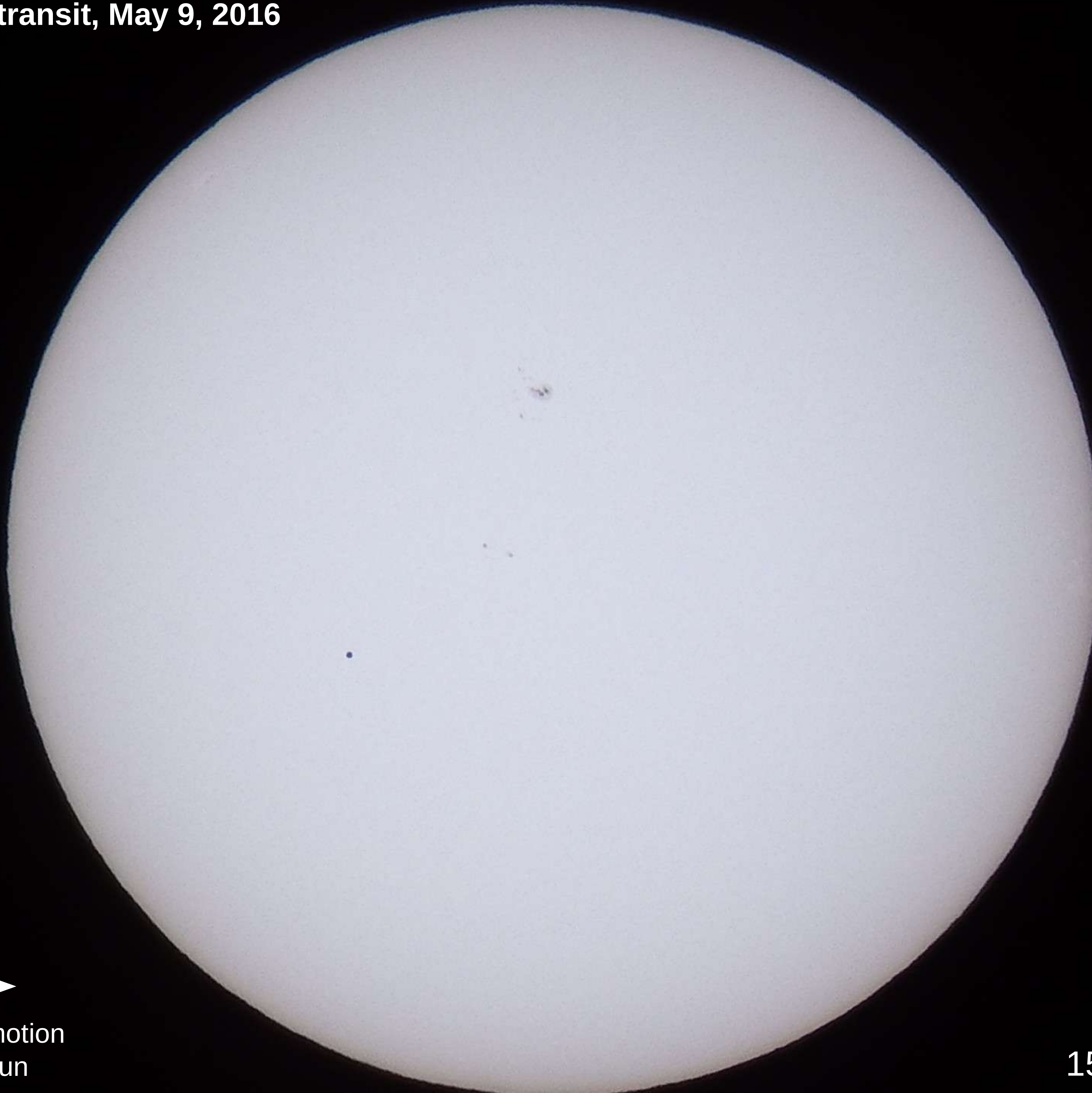
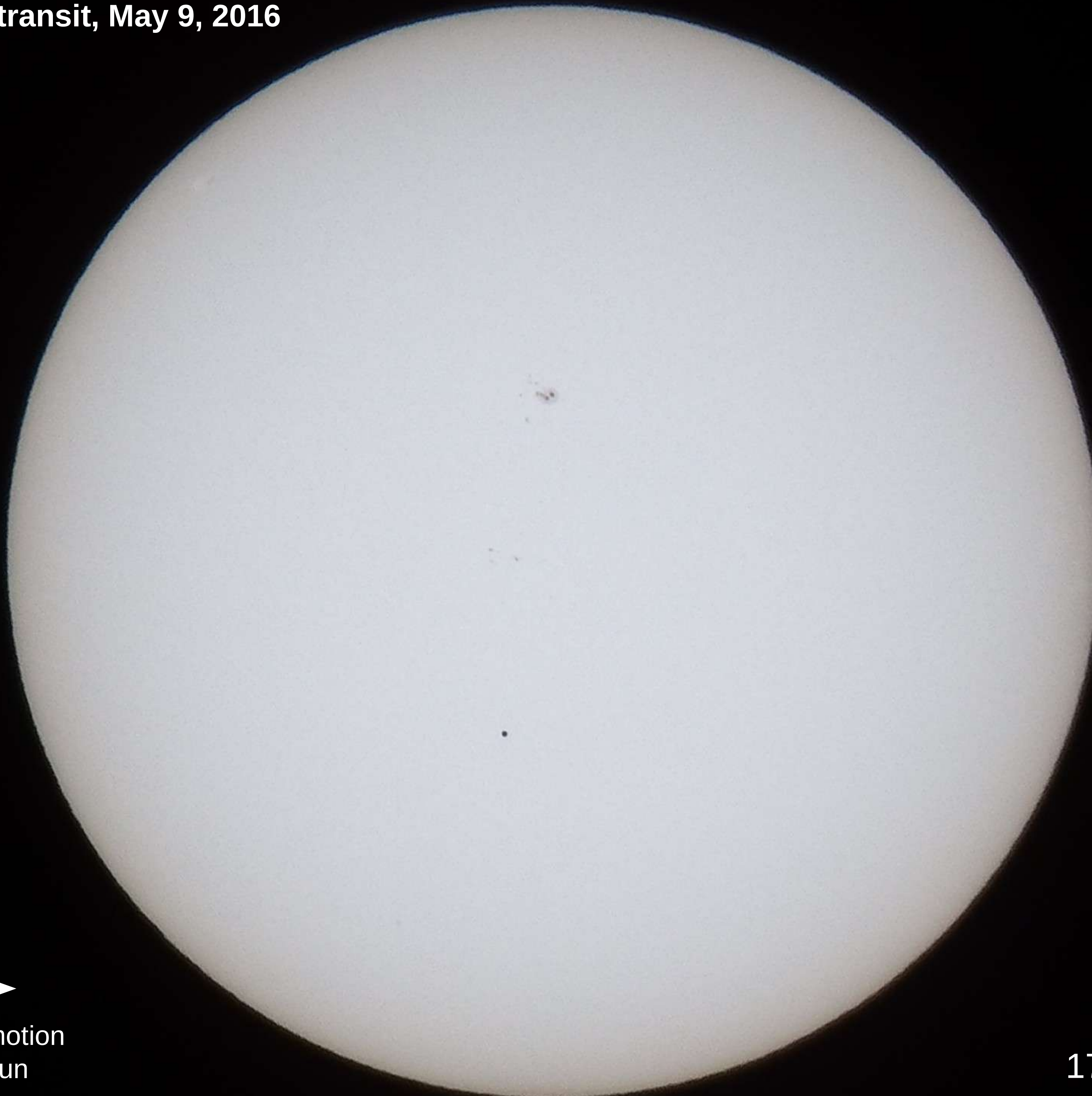


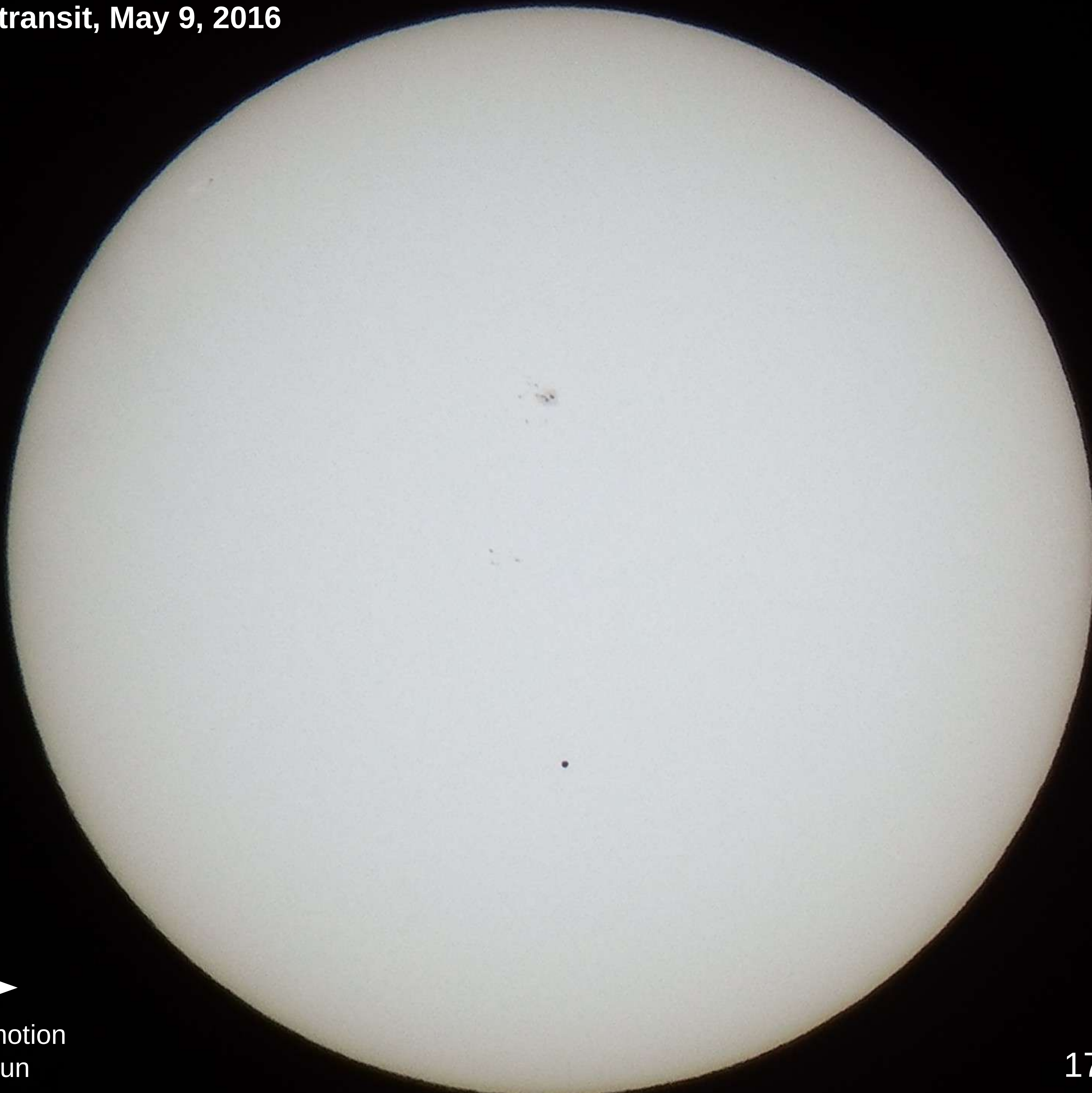
3. Mercury transit, May 9, 2016



apparent motion
of the Sun

17:14 MESZ

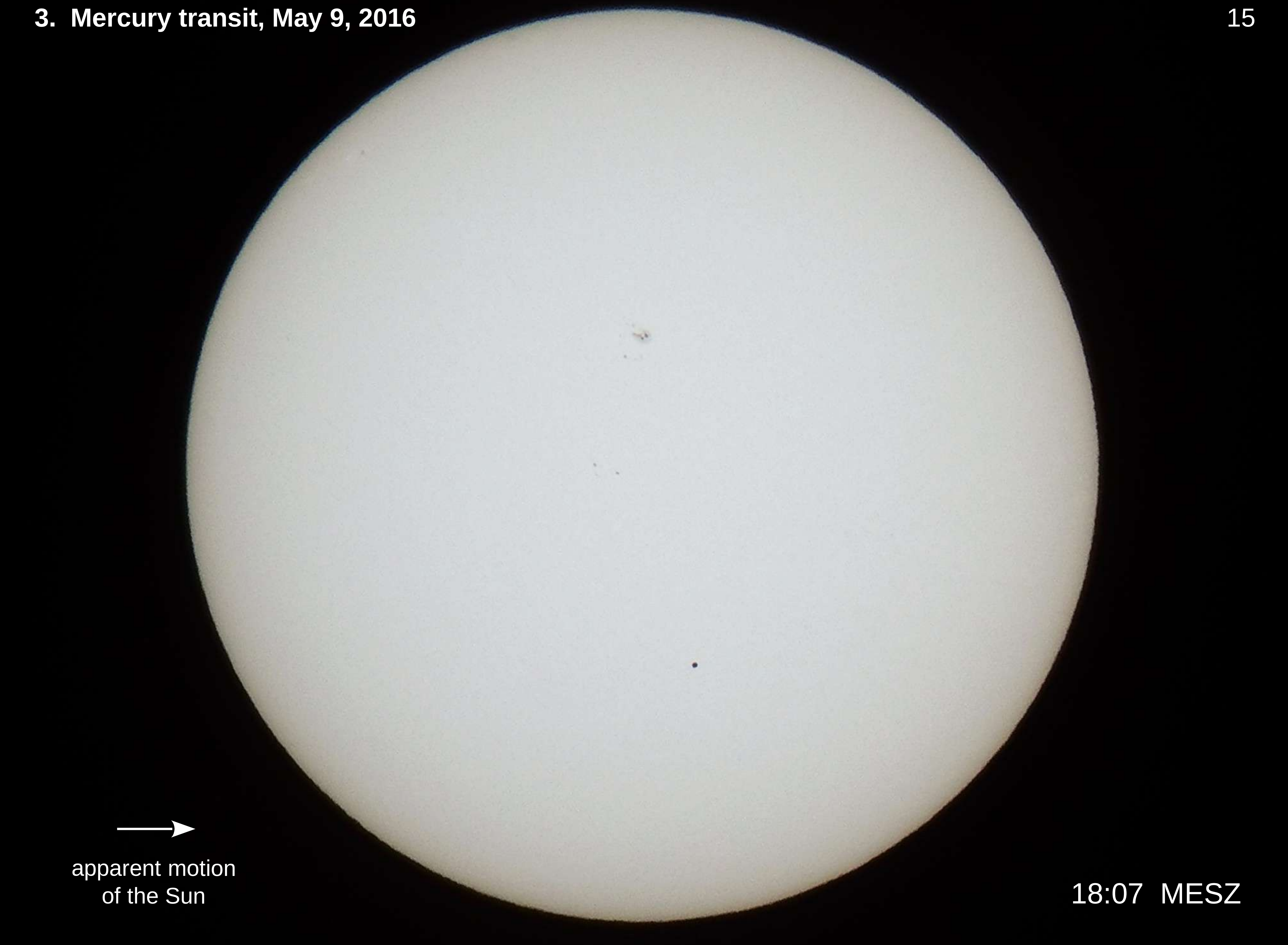
3. Mercury transit, May 9, 2016



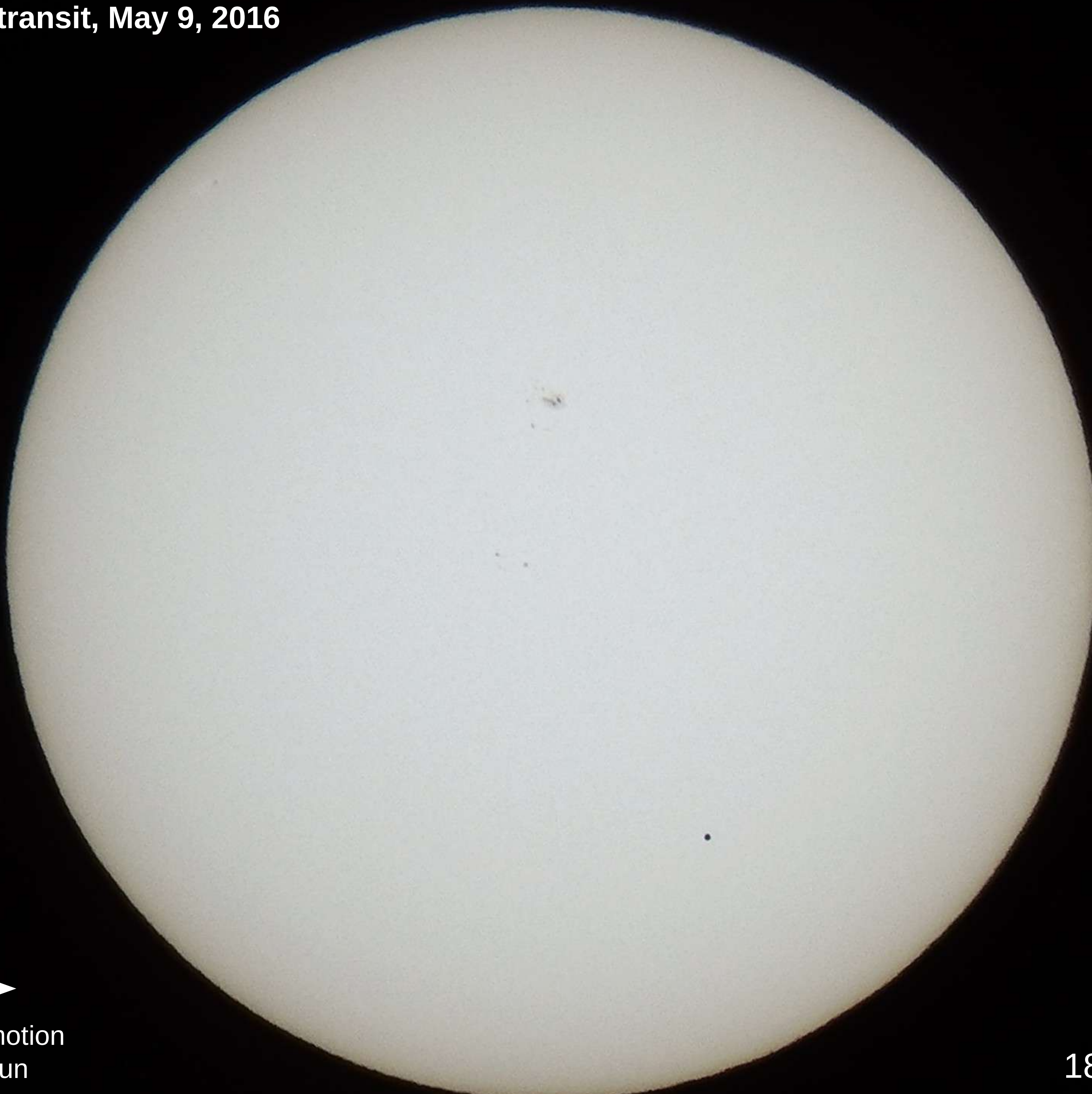
apparent motion
of the Sun

17:43 MESZ

3. Mercury transit, May 9, 2016



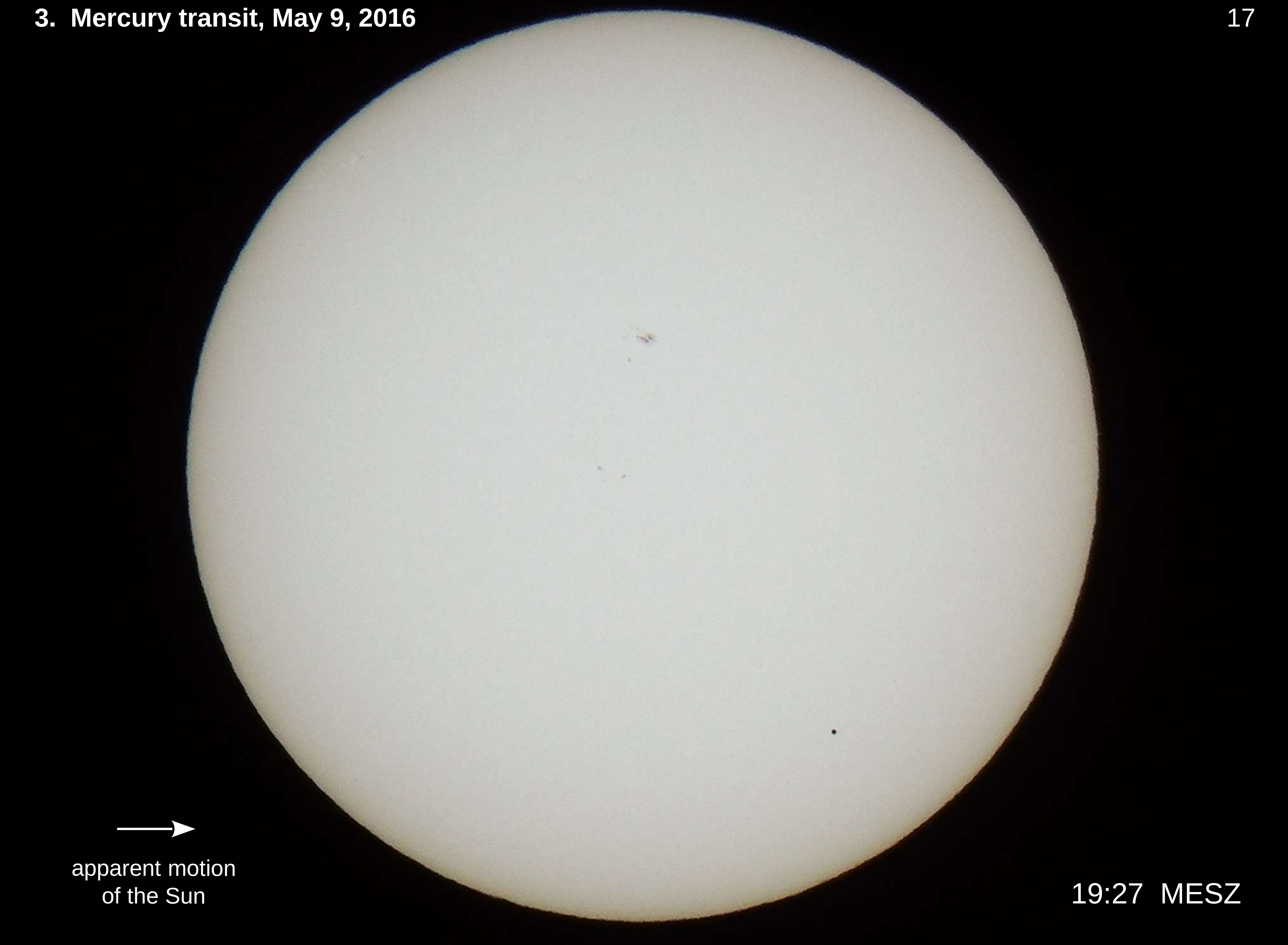
3. Mercury transit, May 9, 2016



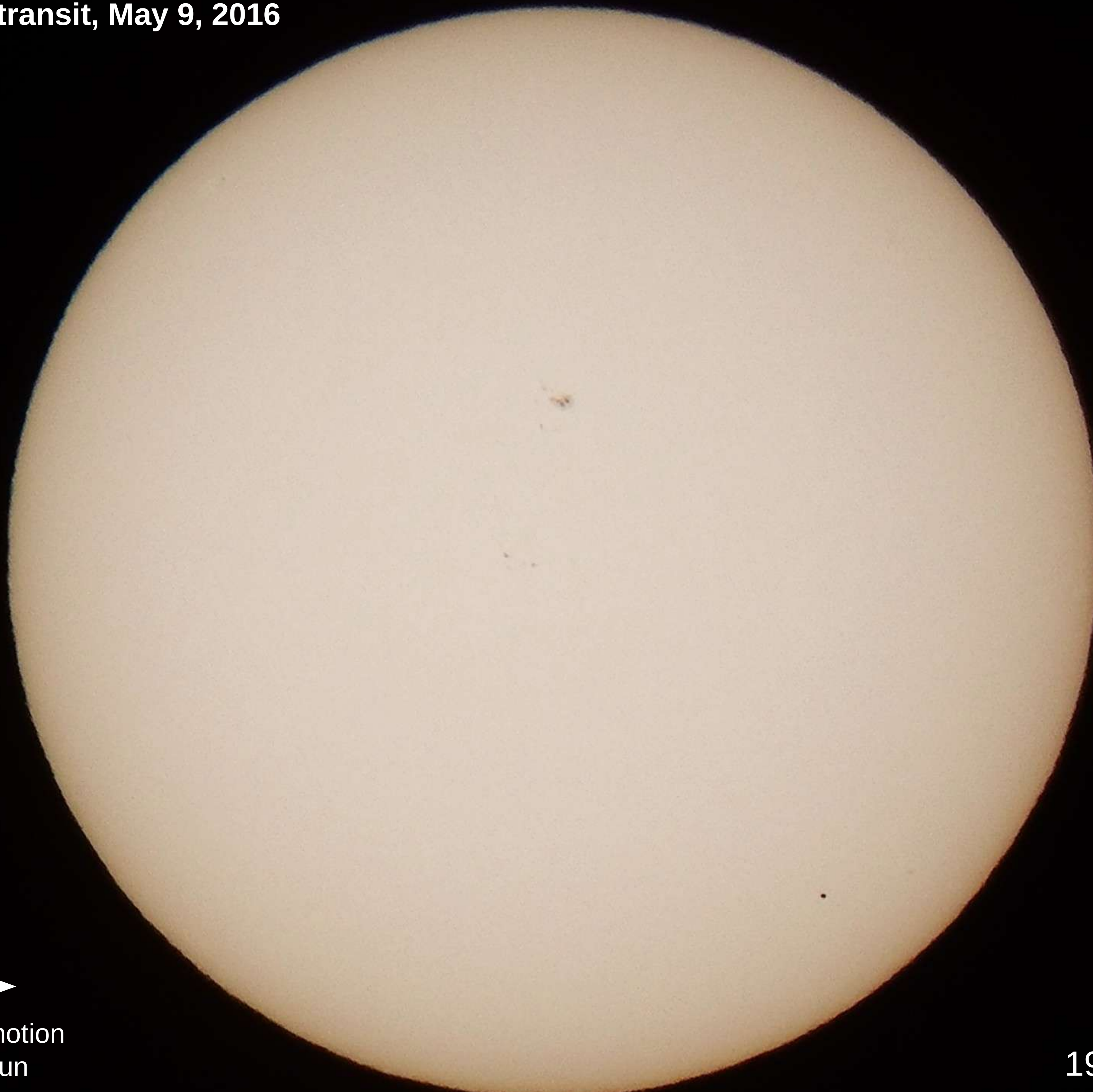
apparent motion
of the Sun

18:52 MESZ

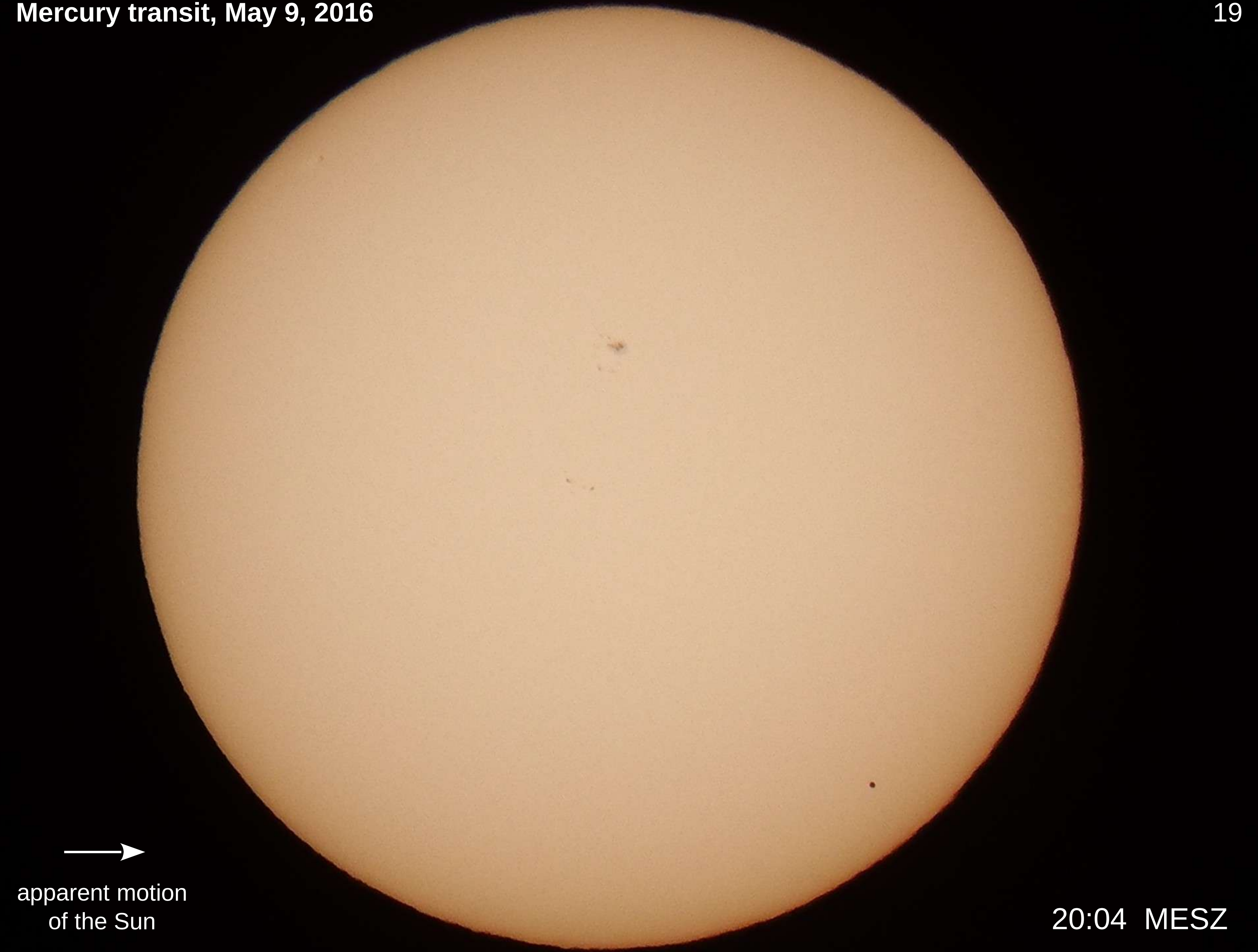
3. Mercury transit, May 9, 2016



3. Mercury transit, May 9, 2016



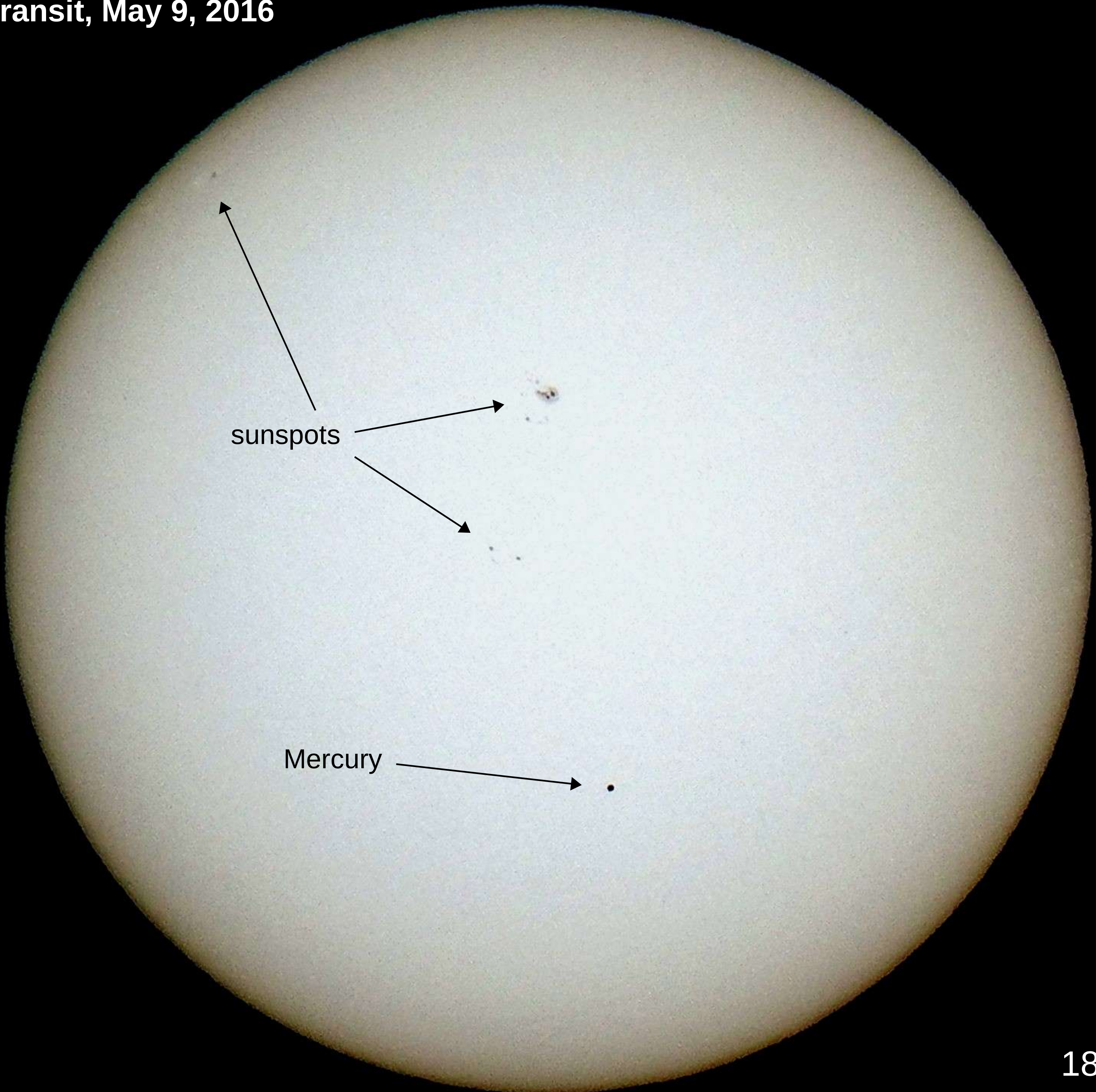
3. Mercury transit, May 9, 2016



If one looks carefully at the sunspots, when going through the previous photo sequence, it is possible to see the slow rotation of the Sun. The apparent rotational period is approximately 28 days. However, the differential rotation is dependent on the position between the equator and the poles of the Sun.

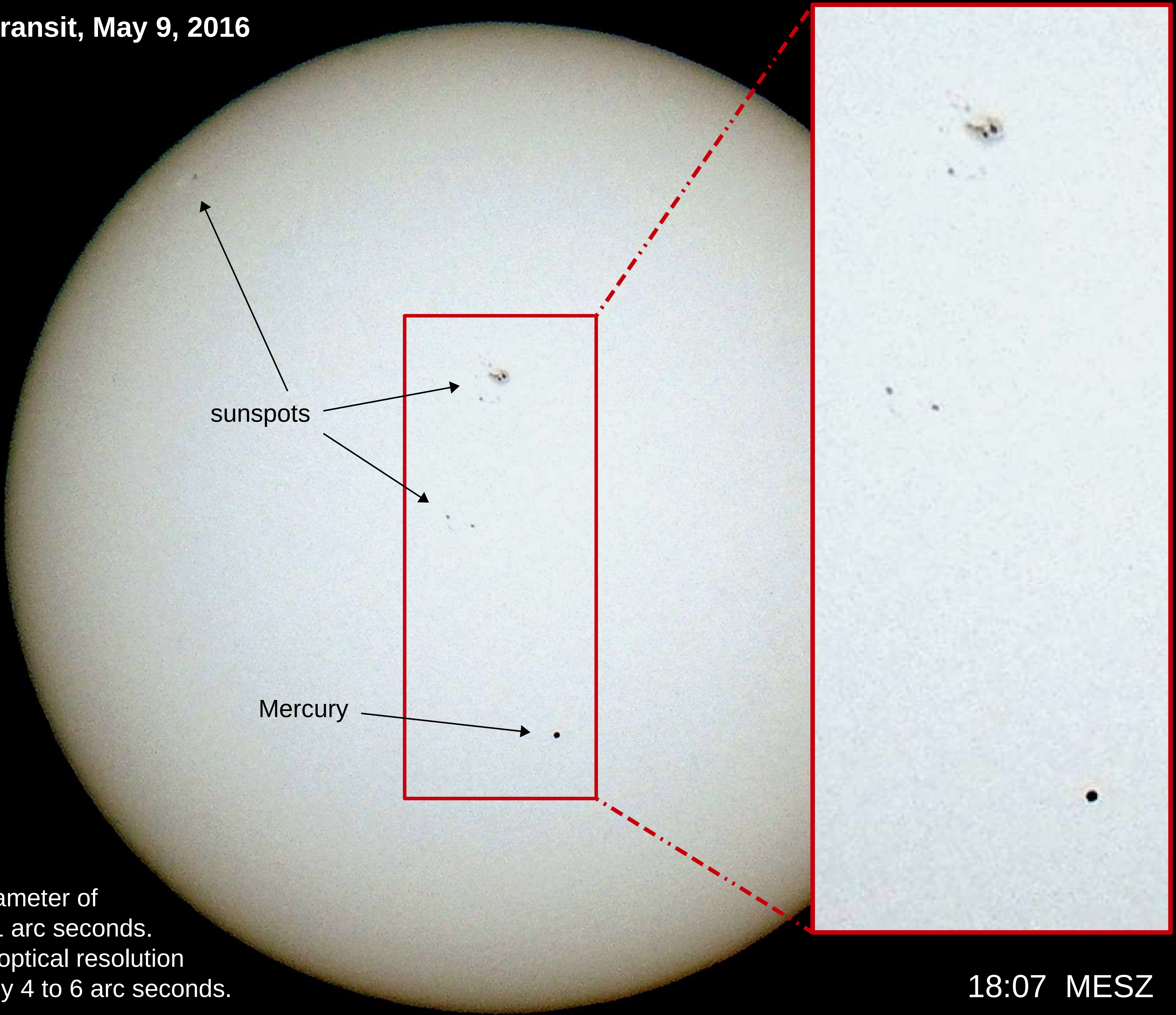
The next image is given with increased contrast. Therefore, let's go back 2 hours and have a closer look.

3. Mercury transit, May 9, 2016



18:07 MESZ

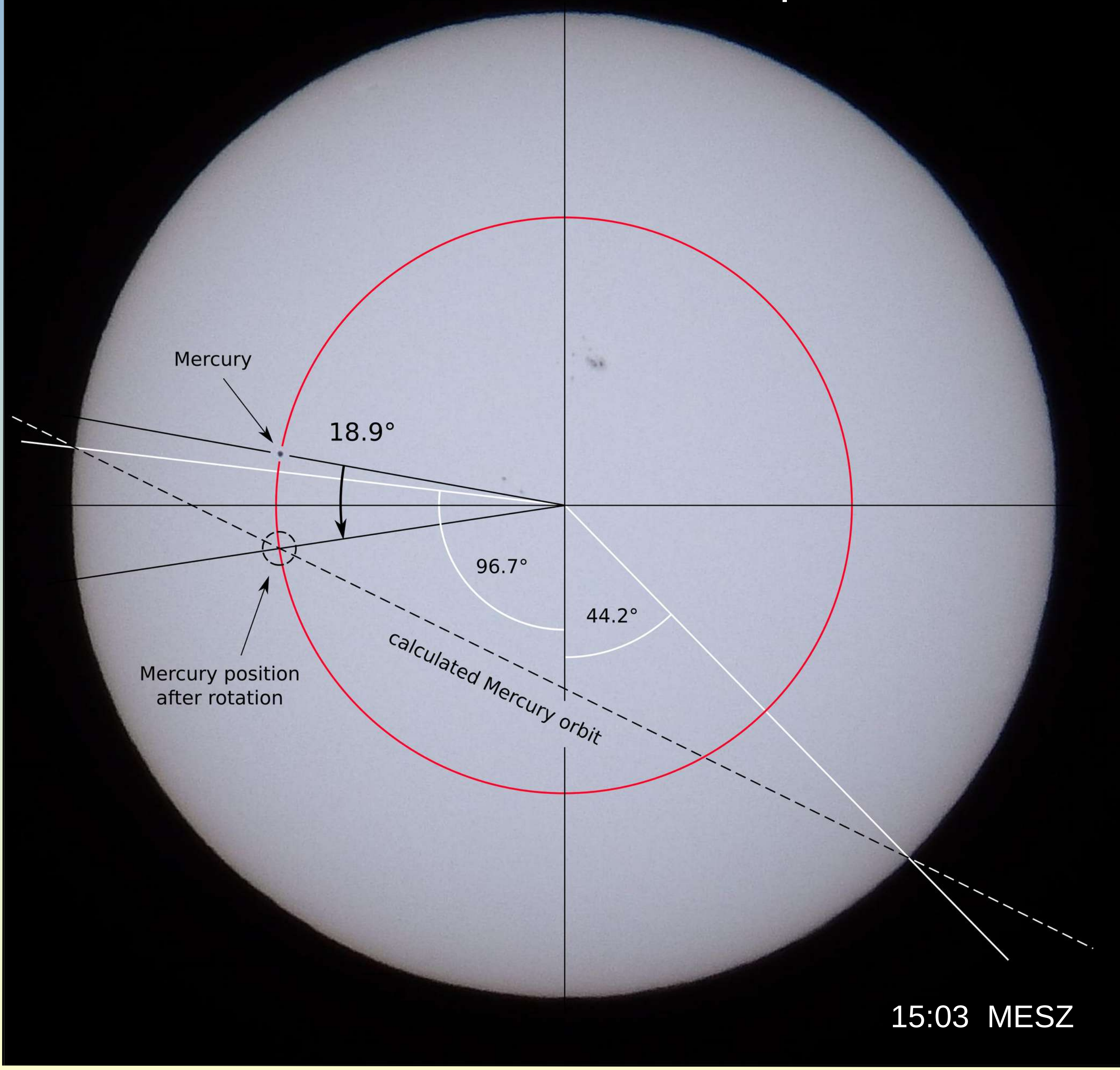
3. Mercury transit, May 9, 2016



The angular diameter of Mercury is 12.1 arc seconds. Therefore, the optical resolution is approximately 4 to 6 arc seconds.

18:07 MESZ

Graphical construction of the rotation angle used for the transit photo on slide 11



Brief description for those who intend to rotate their own transit pictures accordingly:

At first, we have to mark exactly the solar center on the photo. The white lines represent the calculated (averaged) position angles and provide the basis of the construction. The left intersection of the red concentric circle with the theoretical trajectory of Mercury fixes the rotation angle to approximately 18.9°.

Counterclockwise rotation of the photo by this angle places Mercury at the correct position.

This procedure was performed only with the first transit photo. To simplify matters, the rotation angles of the pictures on slides 12–19 were determined by comparing the orientations of the Sun spot arrangements.

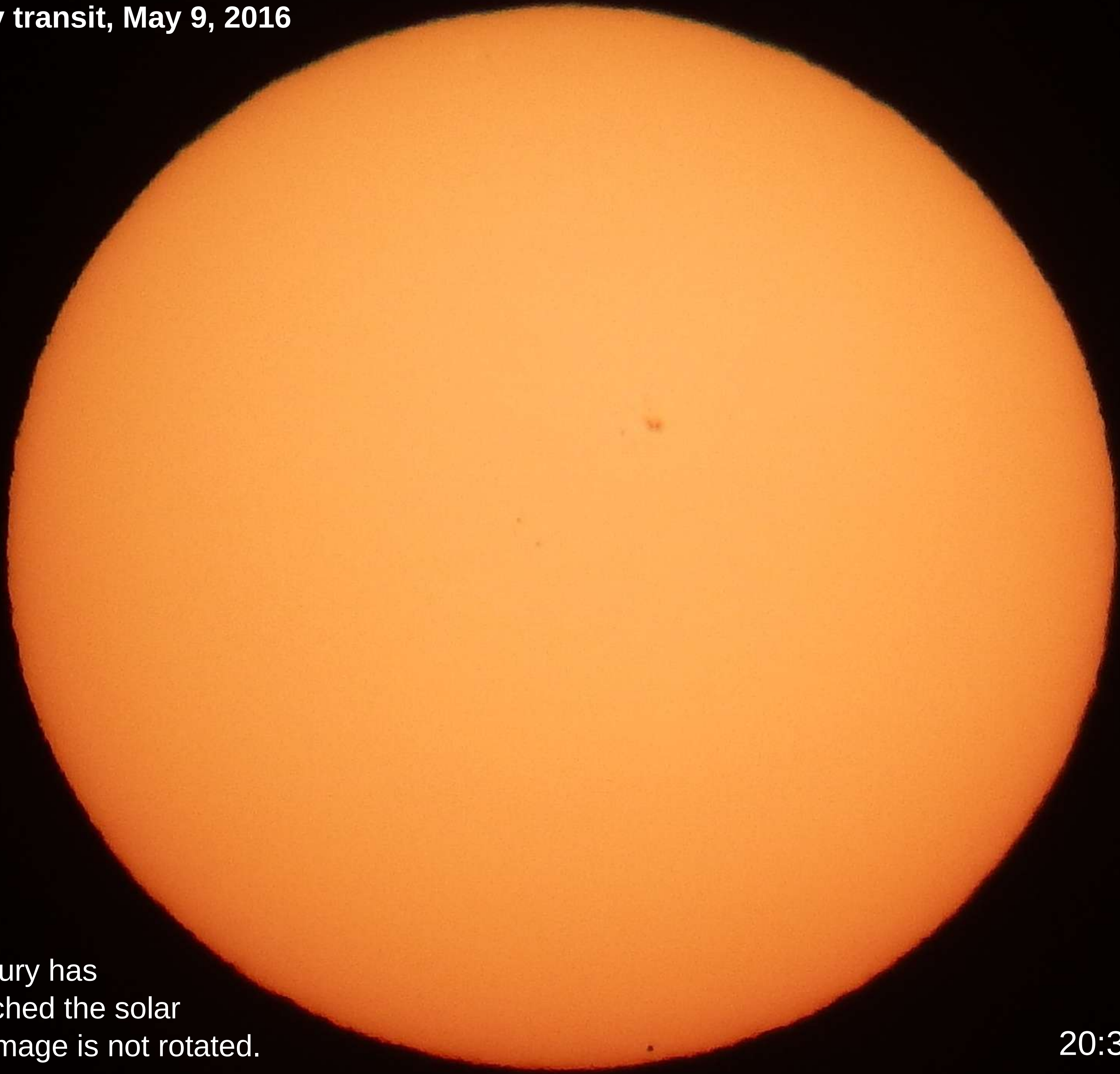
During the afternoon, the observation point was transferred to the northern riverside of the Elbe, eastward from Kirchwerder, to have a free view to the horizon.


Here, life is very calm and quiet – except ...

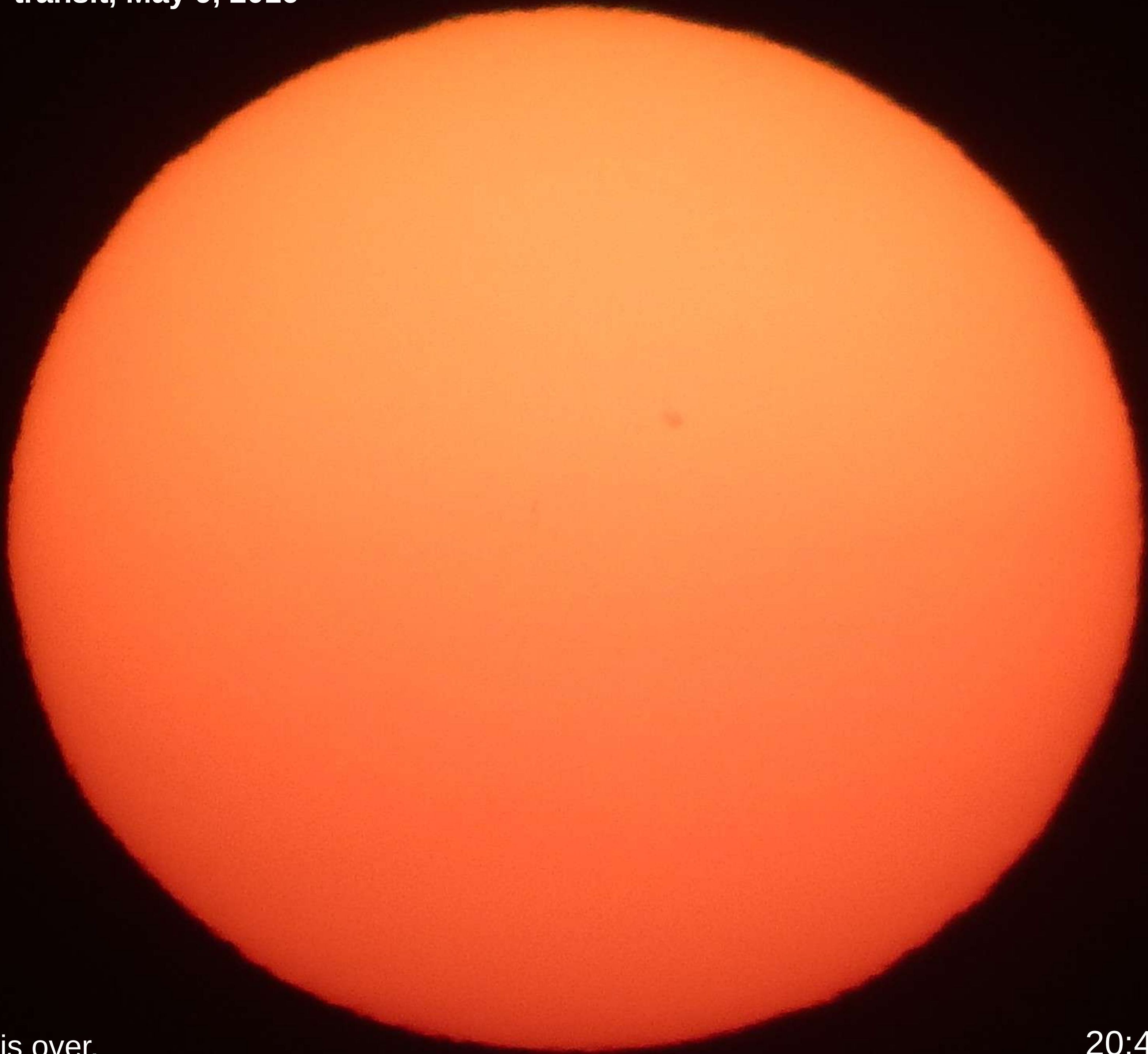
Meanwhile, the Sun is situated near the horizon and atmospheric turbulence begins to disturb the image (see next slides).

This photo was taken with the sun filter. The question is:

Where is Mercury?



Here, Mercury has almost reached the solar limb. This image is not rotated.



The transit is over.

20:48 MESZ

4. Sunset

This and the following images are recorded without the sun filter.

20:53 MESZ


20:56 MESZ


21:00 MESZ


21:00 MESZ


21:01 MESZ


21:01 MESZ

Let's get back to the transits!
Some information about future Mercury transits is provided in the following two tables.

(By the way, the next Venus transit in front of the Sun will happen on December 11, 2117.)

Mercury transits until 2140 AD

(geocentric transit phases, universal time UT)

Date, time:	1	2	nearest	3	4	sep [“]	ΔT [sec]
May 9, 2016	11:12:27	11:15:39	14:57:23	18:39: 1	18:42:13	–318.5	69.7
Nov. 11, 2019	12:35:31	12:37:13	15:19:46	18: 2:23	18: 4: 5	75.9	71.5
Nov. 13, 2032	6:41: 6	6:43:11	8:54: 3	11: 4:57	11: 7: 2	572.1	79.5
Nov. 7, 2039	7:18: 6	7:21:19	8:46:39	10:12: 1	10:15:14	–822.3	84.6
May 7, 2049	11: 3:49	11: 7:22	14:24:11	17:40:54	17:44:26	511.8	92.4
Nov. 9, 2052	23:53:46	23:55:33	2:29:52	5: 4:16	5: 6: 3	–318.7	98.8
May 10, 2062	18:16:37	18:20:14	21:36:54	0:53:29	0:57: 5	–520.5	118.6
Nov. 11, 2065	17:24:26	17:26: 9	20: 6:14	22:46:24	22:48: 7	180.7	126.1
Nov. 14, 2078	11:42:31	11:44:51	13:41: 1	15:37:13	15:39:33	674.3	154.4
Nov. 7, 2085	11:42:49	11:45:22	13:34:32	15:23:44	15:26:17	–718.5	170.1
May 8, 2095	17:20:50	17:24: 0	21: 5:28	0:46:48	0:49:57	309.8	191.9
Nov. 10, 2098	4:35:28	4:37:12	7:16:32	9:55:57	9:57:41	–214.7	200.1
May 12, 2108	1:40: 2	1:44:43	4:15:51	6:46:55	6:51:36	–724.7	222.6
Nov. 14, 2111	22:15:32	22:17:17	0:53: 0	3:28:47	3:30:33	283.3	231.1
Nov. 15, 2124	16:49:42	16:52:31	18:28:17	20: 4: 4	20: 6:53	778.9	263.3
Nov. 9, 2131	16:14: 0	16:16:12	18:22:26	20:28:43	20:30:55	–614.4	281.0

Remarks:

a) Calculated with "P4"; ΔT is determined with "DATUM-2" [2, 7] (UT = TT – ΔT).
b) "Nearest" indicates the nearest approach of Mercury to the solar center.
c) "Sep" is the nearest separation in arc seconds; "+/–" indicates "above/below" the center of the solar disk (as seen from the northern hemisphere).
d) The calculations are based on the solar radius of 695508 ± 26 km [5] and on the Mercury radius of 2439.7 ± 1.0 km [11, p. 173].

Mercury transits until 2140 AD

(continued – geocentric position angles and semidiameters of Sun and Mercury)

Date,	P1	P2	near.	P3	P4		s(Sun)	s(Mer.)	Ser.
May 9, 2016	83.21	83.47	153.78	224.10	224.36		949.72	6.04	7
Nov. 11, 2019	109.84	109.79	24.27	298.76	298.71	/	968.62	4.98	6
Nov. 13, 2032	77.48	77.05	23.41	329.77	329.34	/	969.13	4.97	4
Nov. 7, 2039	173.30	174.25	205.56	236.87	237.82	/	967.54	4.98	10
May 7, 2049	30.96	30.49	333.34	276.20	275.73		950.35	6.02	9
Nov. 9, 2052	133.92	134.12	204.77	275.42	275.62	/	968.13	4.98	8
May 10, 2062	97.06	97.54	154.10	210.67	211.14		949.69	6.04	7
Nov. 11, 2065	103.28	103.16	23.94	304.71	304.60	/	968.66	4.98	6
Nov. 14, 2078	69.29	68.72	23.06	337.40	336.83	/	969.17	4.97	4
Nov. 7, 2085	162.90	163.56	205.25	246.95	247.60	/	967.57	4.98	10
May 8, 2095	44.71	44.46	333.65	262.84	262.59		950.30	6.02	9
Nov. 10, 2098	127.22	127.36	204.45	281.53	281.67	/	968.15	4.98	8
May 12, 2108	113.71	114.58	154.43	194.28	195.15		949.61	6.05	7
Nov. 14, 2111	96.72	96.54	23.60	310.65	310.47	/	968.72	4.98	6
Nov. 15, 2124	59.64	58.85	22.70	346.55	345.76	/	969.23	4.97	4
Nov. 9, 2131	154.14	154.62	204.94	255.26	255.74	/	967.64	4.98	10

Remarks:

a) Position angles are measured counterclockwise from the y-axis.
b) "Near." indicates the position angle at nearest separation.
c) The slash ("/") indicates "ascending node."
d) "S" is the semidiameter (visible radius) in arc seconds.
e) "Ser." denotes the serial number of the transit (convention from the website of the NASA/Goddard Space Flight Center).

For the sake of completeness, some data of "current" Venus transits are added.

Venus transits from 2000 to 2300 AD

(geocentric transit phases, UT, and position angles)

Date, time:	1	2	nearest	3	4	sep [“]	ΔT [sec]
June 8, 2004	5:13:42	5:33: 9	8:19:44	11: 6:20	11:25:46	–626.9	64.6
June 6, 2012	22: 9:48	22:27:45	1:29:35	4:31:25	4:49:22	554.4	67.8
Dec. 11, 2117	23:58:25	0:21:33	2:48: 2	5:14:32	5:37:40	723.6	246.0
Dec. 8, 2125	13:15: 3	13:38:44	16: 1:23	18:24: 2	18:47:42	–736.4	266.0
June 11, 2247	8:41:45	9: 3: 6	11:33: 3	14: 3: 0	14:24:21	–691.3	564.7
June 9, 2255	1: 7:52	1:24:54	4:37:49	7:50:44	8: 7:46	491.9	586.7

Date,	P1	P2	near.	P3	P4		s(Sun)	s(Ven.)	Ser.
June 8, 2004	116.33	119.47	166.31	213.15	216.29		944.71	29.11	3
June 6, 2012	40.69	38.13	345.43	292.73	290.17		945.03	29.13	5
Dec. 11, 2117	57.86	53.68	13.84	334.00	329.82	/	973.59	31.80	6
Dec. 8, 2125	152.01	156.35	194.85	233.36	237.70	/	973.31	31.78	4
June 11, 2247	122.44	126.24	167.28	208.32	212.12		945.01	29.13	3
June 9, 2255	46.00	43.85	346.38	288.90	286.75		945.29	29.15	5

Remark: The used Venus radius of 6099.5 km includes the opaque atmosphere of almost 50 km height. This corresponds to the classical semidiameter of 8.41 arc seconds (1 AU distance) [9, p. 16].

Apropos future transits

Astronomical events like transits, in combination with the constellation of other planets, offer a perfect method for the precise definition of points in time, several thousand years in the past or in the future. The planets of our solar system would be like the hands of a gigantic clock, in which Mercury determines the celestial seconds.

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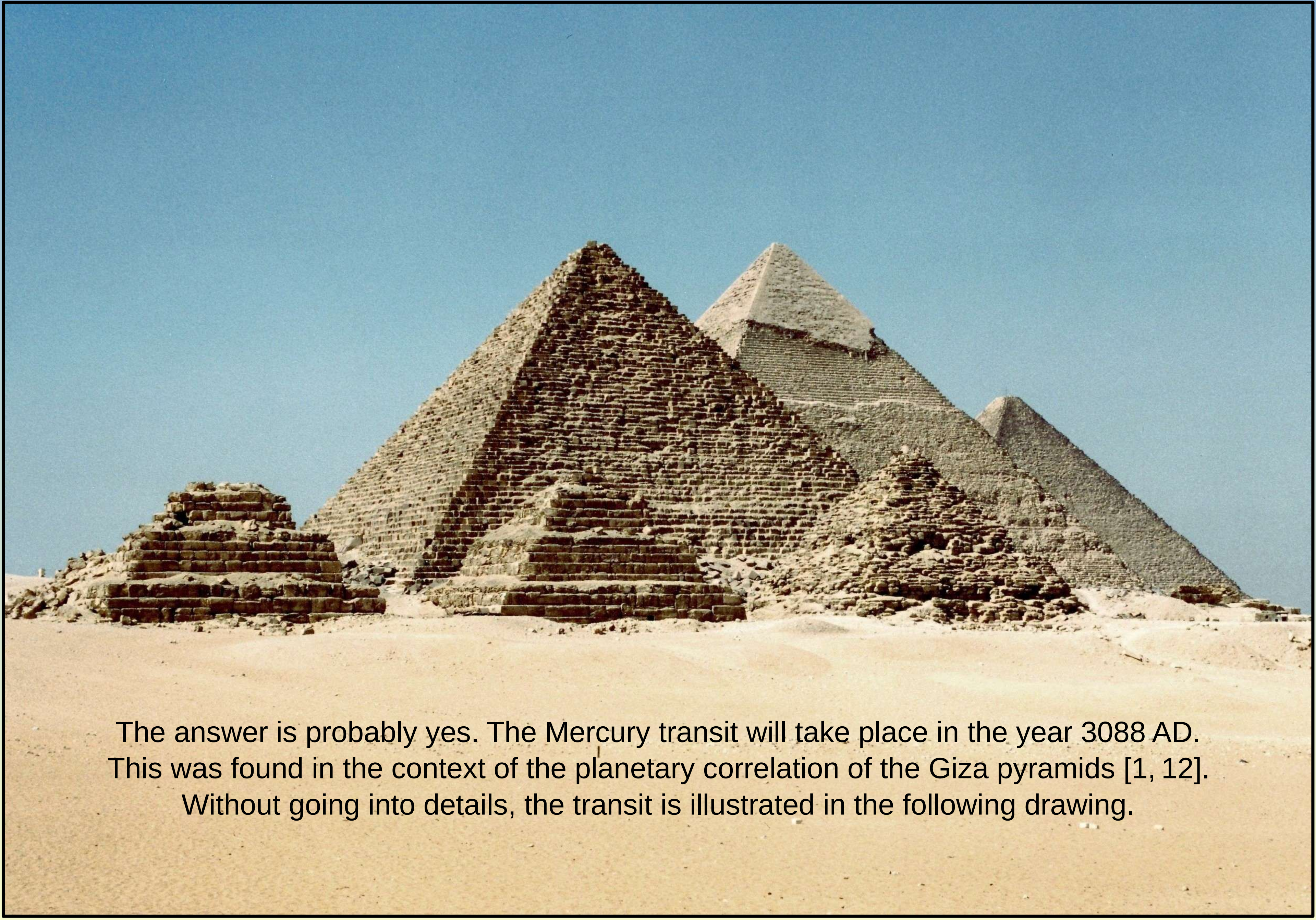
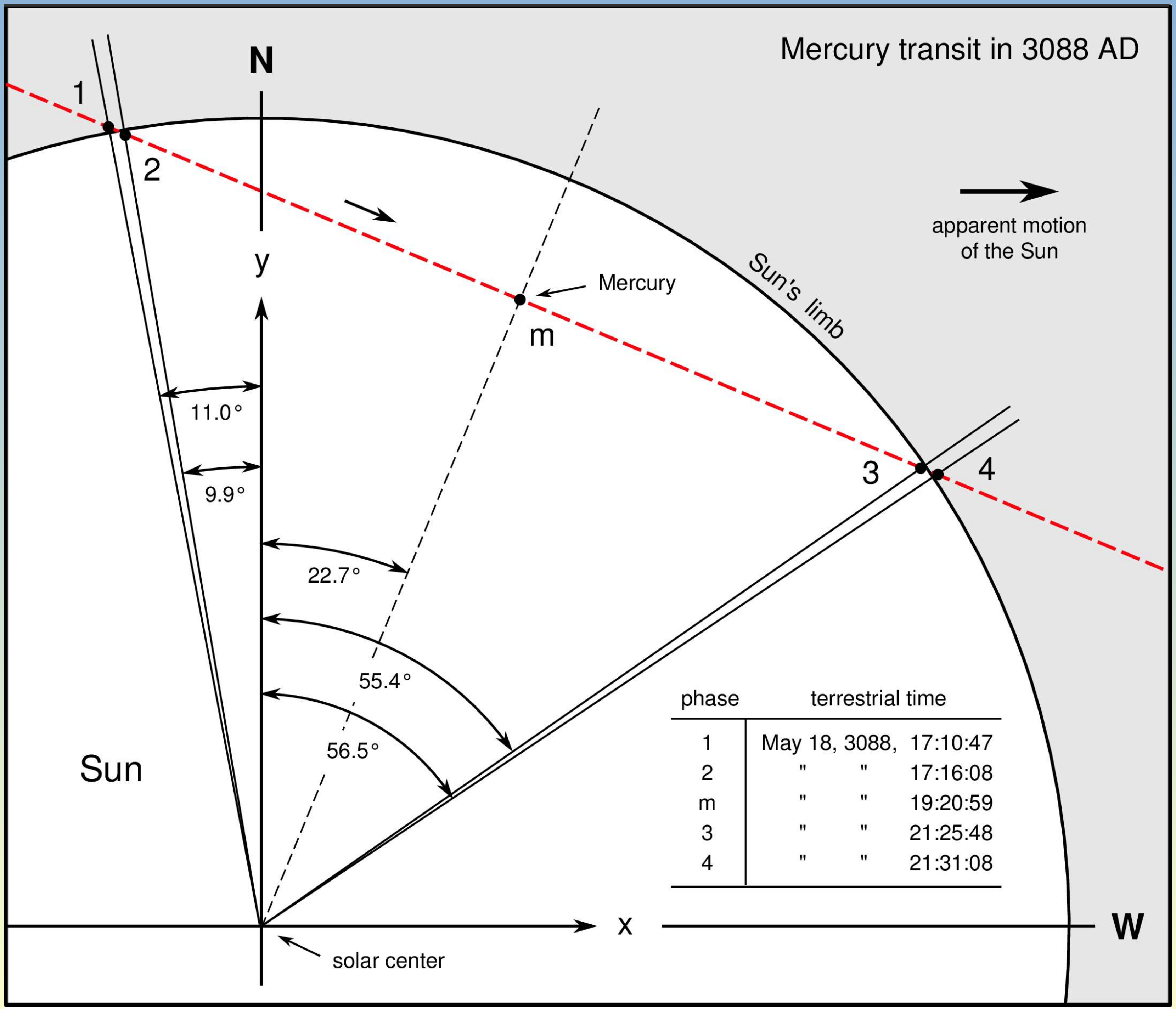
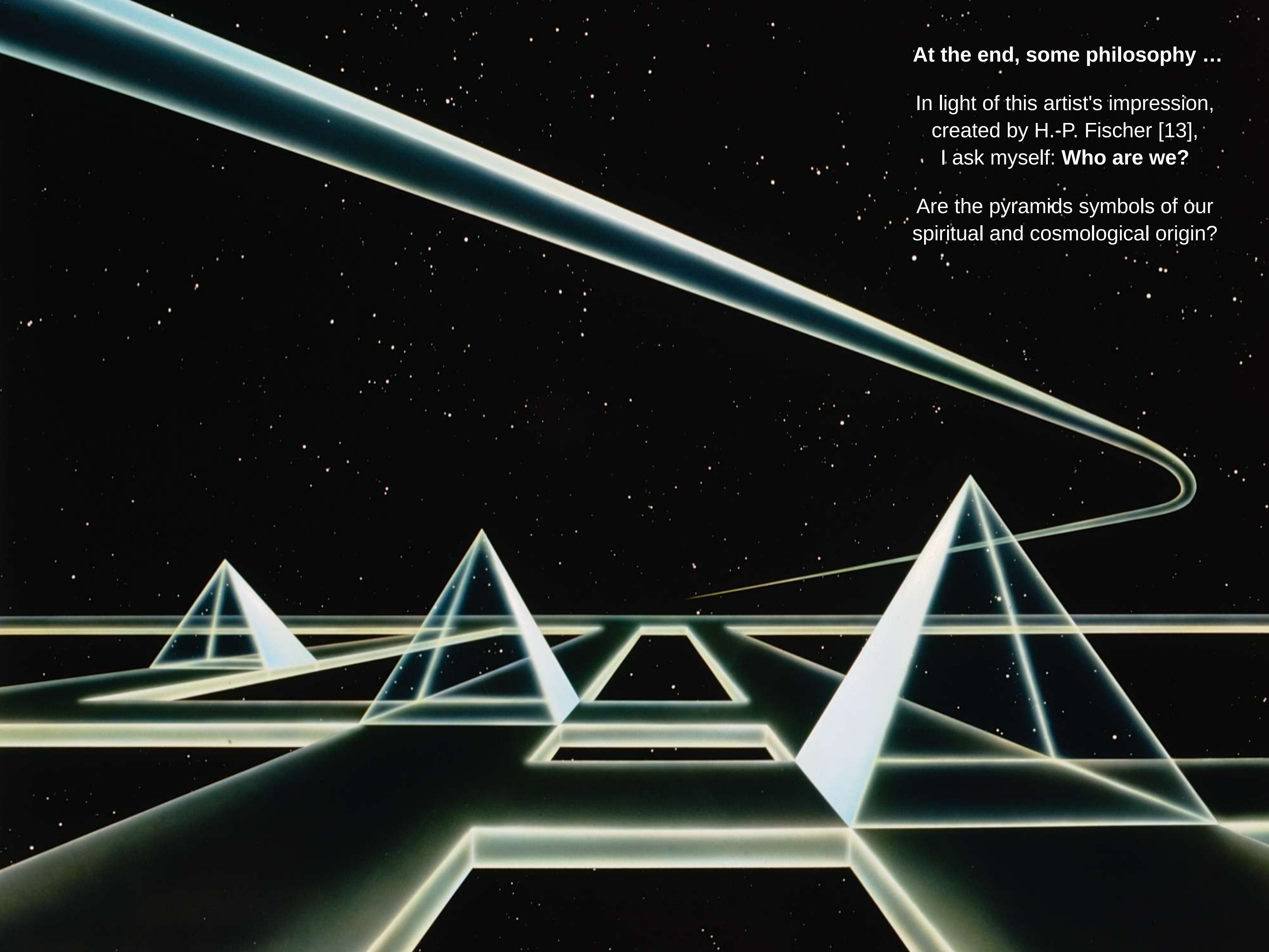
Does a specific Mercury transit play a key role with regard to the Egyptian pyramids in Giza?



The answer is probably yes. The Mercury transit will take place in the year 3088 AD.
This was found in the context of the planetary correlation of the Giza pyramids [1, 12].
Without going into details, the transit is illustrated in the following drawing.



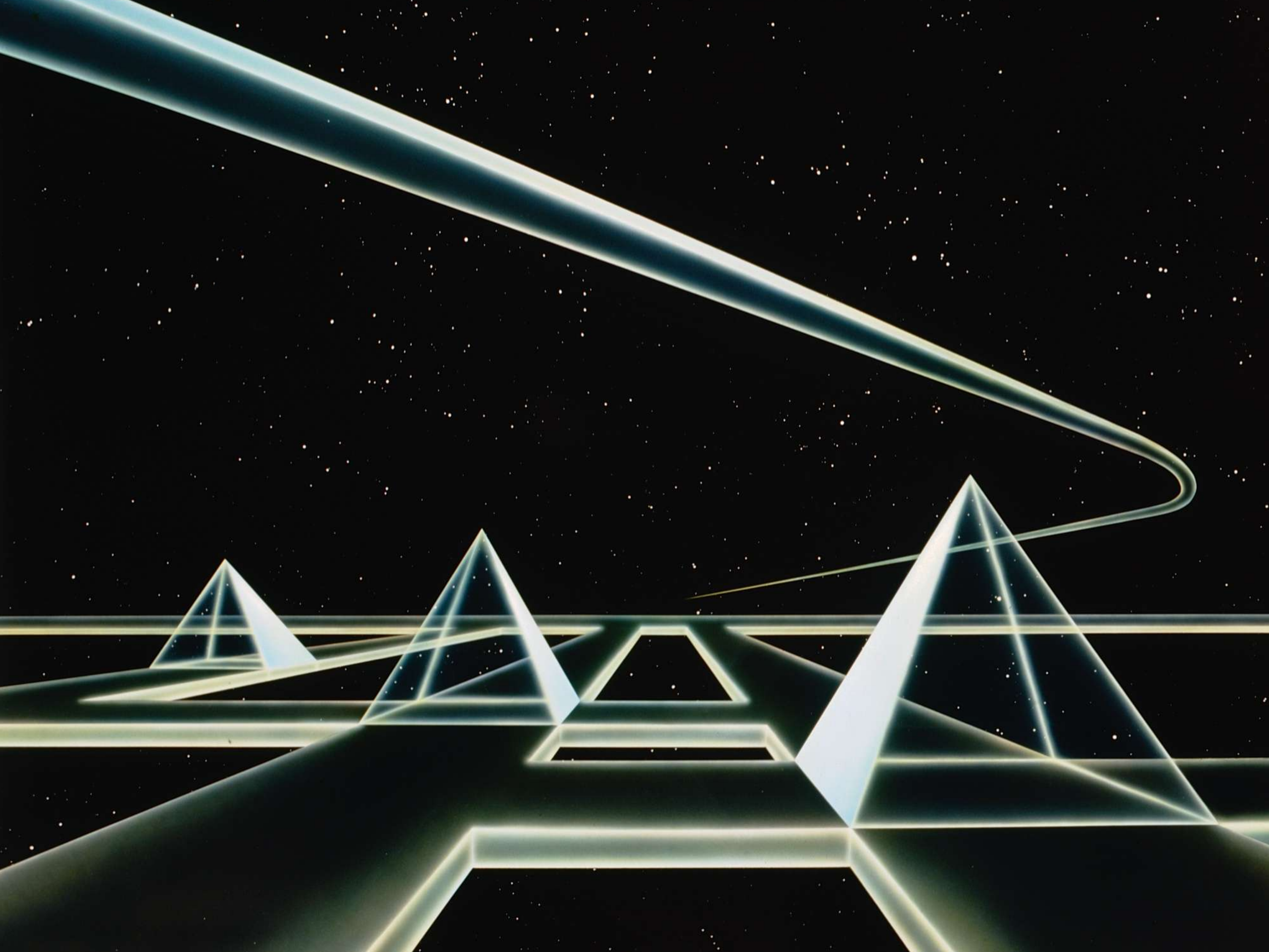
Calculated with P4 [1, 2] on the basis of VSOP87; ΔT is approximately 1.4 ± 0.6 hours. (For ΔT, see the appendix.)



At the end, some philosophy …

In light of this artist's impression,
created by H.-P. Fischer [13],
I ask myself: **Who are we?**

Are the pyramids symbols of our
spiritual and cosmological origin?




Coming back to our home planet …


Coming back to our home planet …
Many thanks for your attention!

Brief description of the main time scales

UT, Universal Time: Time scale, continuously synchronized to the decelerating rotation of the Earth.

UTC, Coordinated Universal Time: Following UT, primarily linear with constant length of the second, but from time to time changing discontinuously by one leap second. UTC is equivalent to the former Greenwich Mean Time (GMT). It is always:

$$|\mathrm{UT} - \mathrm{UTC}| \leq 0.9 \text{ sec}$$

TT (TDT), Terrestrial (Dynamical) Time: Linear time scale, running constantly without any change. TT is used for astronomical purposes, especially for times in the remote past or future. TT is equivalent to JDE (Julian Ephemeris Day); only their representations differ. TT is a calendar date plus time of day and JDE is a decimal day number.

$$\mathrm{TT} \triangleq \mathrm{JDE}$$

ΔT (Delta-T): The difference between TT and UT. For the most part, ΔT behaves quadratically when going to the past or to the future. At the transit date in 2016, ΔT was approximately 69.7 sec.

$$\Delta T = \mathrm{TT} - \mathrm{UT}$$

MEZ, mitteleuropäische Zeit or **CET, Central European Time:**

$$\mathrm{MEZ} = \mathrm{UTC} + 1 \text{ hour}$$

In May 2016 we had summer time. **MESZ, mitteleuropäische Sommerzeit** or **CEST, Central European Summer Time:**

$$\mathrm{MESZ} = \mathrm{UTC} + 2 \text{ hours}$$

Here, UT, TT, and MESZ are used.

Some more information for astronomers and anyone else who is interested

VSOP87

With the VSOP87 theory [3, 4], the position and the velocity of any planet in our solar system can be calculated. The theory considers gravitational perturbations among all of the planets, including relativistic effects. The final results, being the heliocentric ecliptic coordinates of a planet for a given point in time, are computed with a Fortran subroutine. With $A_{\alpha n}$, $B_{\alpha n}$, $C_{\alpha n}$, $\alpha(max)$, and $N(\alpha)$ representing several thousand parameters (provided in an additional file), and τ being the point in time in Julian millennia, the equation for the x-coordinate of a planet, $X(\tau)$, looks like

$$X(\tau) = \sum_{\alpha=0}^{\alpha(max)} \sum_{n=1}^{N(\alpha)} \tau^{\alpha} \cdot A_{\alpha n} \cdot \cos(B_{\alpha n} + C_{\alpha n}\tau)$$

Obliquity of the ecliptic

Due to gravitational perturbations, the tilt angle between the plane of the Earth's equator and the plane of the Earth's orbit is not constant. For this time-dependent angle, ε, named the obliquity of the ecliptic, the following equation from Axel D. Wittmann is used [6]:

$$\varepsilon = 23.4458042° - 0.856033° \cdot \sin(0.015306 \cdot (T + 0.50747)) \quad \text{with} \quad T = \frac{JDE - 2451545.0}{36525}$$

Considering the speed of light

The travel time of light from Mercury to Earth is a few minutes. During this time the Earth, being the location of the observation, continues to move on its orbit. So, when solving the geometrical problem of calculating the transit phases, the finite speed of light has to be considered. This problem can be solved with an iterative "fixed-point" algorithm, showing fast convergence [1, p. 62].

Transit series

The transits of Mercury and Venus are arranged in the so-called transit series. For Mercury, two successive transits in the same series have a time lag of 46 years. With the convention of the "NASA Eclipse Web Site," the transit in 2016 AD has the serial number 7, and the transit in 3088 AD is the first one of the series with the number 20.

Accuracy of data

The error of ΔT in the table (slide 41) increases from 0.6 to approximately 68 sec (according to [7]), because of the irregular deceleration of the Earth's rotation. Thus, the extrapolation of ΔT into the future implies increasing uncertainty. The corresponding transit phases in UT have the same error, because of UT = TT – ΔT. In contrast, by adding ΔT to UT, we get again TT, which does not have the uncertainty of ΔT. (Notice that VSOP87 computes by using JDE and TT, respectively.) The error of the position angles should be 0.1° or less. The nearest separation and semidiameters of the Sun and Mercury in most cases are accurate up to the last digit.

Photographic image quality

When working with higher light sensitivity (meaning increasing ISO values), the photos taken with digital cameras, and especially superzoom cameras with a small optical chip, show increasing image noise. This means that in the full automatic mode and with decreasing light, the picture becomes less clear because of higher ISO sensitivity.

This can be avoided by not using the full automatic mode. Instead, fix the light sensitivity to a low ISO value, such as ISO 100, and apply one of the other automatic modes, such as P. Of course, this partly requires longer exposure times, but the image stabilizer, which operates very well, helps to equalize this effect. We generally work with ISO 100, and if the exposure time becomes too long, a tripod is used or the camera is fixated in another way (if possible). This applies not only for the S1 but also for other digital cameras.

References

[1] Jelitto, H.: Planetary Correlation of the Giza Pyramids – P4 Program Description. See Internet (2015) RG

[2] Jelitto, H.: P4 Program Package; (includes the calendar program DATUM-2). See Internet (2016) home

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A riddle on slides 48/49

Among the stars, there is one tiny comet. Can you find it? (Search like the astronomers do!)