

# Mikhail Lomonosov: Father of Russian Science

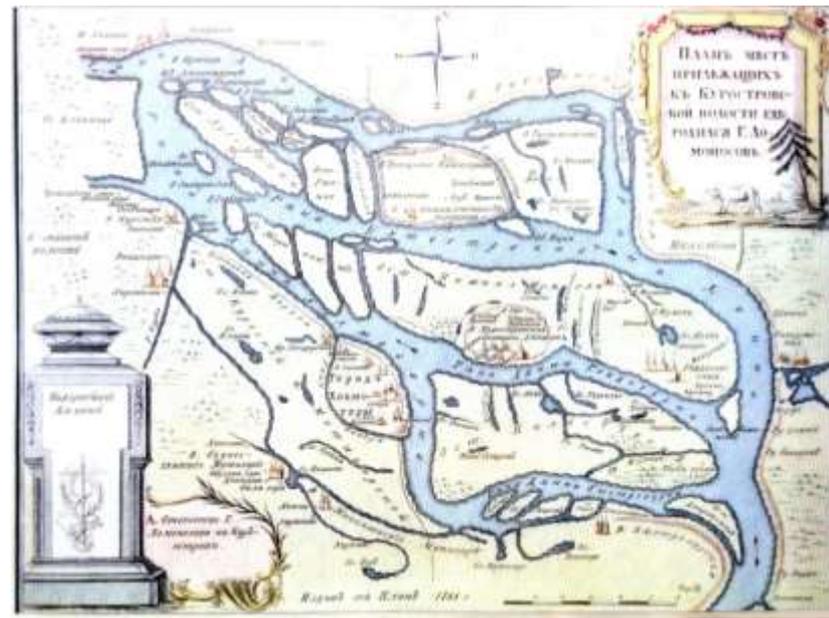
Robert P. Crease  
Stony Brook University

Vladimir Shiltsev  
Fermilab

Portraits of Lomonosov (1711-1765):  
In his 30s (left) and 50s (right)



# Maps of Pomorie, (ca 19 cent.) and of Kholmogory region (1771)



# Caravan and Sleigh

















Michail Vasil'evic LOMONOSOV  
1711 — 1765

Student der Marburger Universität  
1736 — 1739

Großer russischer Gelehrter  
und Schriftsteller

gründete 1755 die Moskauer Universität,  
die seinen Namen trägt.

„Везде исследуйте всечасно,  
Что есть велико и прекрасно,  
Чего еще не видел свет.“

„Überall erforschet ohne Unterlaß,  
was herrlich ist und wunderschön,  
was die Welt noch nicht gesehen.“

# Marburg Diploma

1  
Allesamtliche Vorzögerer dieses Herrn Michael Lomonosoff Matheseos et  
Philosophie Studiosus gebürtlich aus Archangel, nachdem er in hiesiger Drillingen  
Studiorum gratia allhier anlangend, nunmehr wieder von Petersburg, Göttingen  
am 17. d. d. 1744. nach Marburg zu kommen, und sich in dem hiesigen  
Wissenschaftlichen Institut zu Marburg eingeschrieben. Und da er alle in der Oben  
bezeichneten Wissenschaften sich sehr gründlich ergründet, und abgesehen Studiosum  
Lomonosoff aller Collegen Lob, und die hiesigen Professoren, und Repetenten zu loben, am  
17. d. d. 1744. bey obgenannten Vorfallenszeiten zu erwideren alle Zeit erbitte. Und da  
zu verfahren, so wird ihm von dem hiesigen Senat mit dem Universitäts Insiegel bekräftigt  
werden. So geschahen Marburg d. 17. d. May 1744.



Pro Rector Pro Cancellarius  
Decani Doctores und Professores  
der Universität Marburg  
Joh. Frid. Hamberg  
nt. d. d. Pro Rector.

# NEWTON & RUSSIA

*The Early Influence, 1686-1795*

Valentin Il'ich

КНИЖКА  
ИСТОРИИ  
НАУКИ  
И ТЕХНИКИ  
в СССР  
и за границей  
в 1950 году

Издательство  
«Мир»  
Москва, М-79  
1950 г. 100 стр.

Цена 40 коп.



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# School & Scientific Tradition



**Gottfried Wilhelm von Leibniz**

1646 – 1716



**Christian Wolff**

1679 - 1754



**Mikhail Lomonosov**

1711 - 1765

**In Germany  
1737-1741**





# Mosaics “Battle of Poltava” (1764)

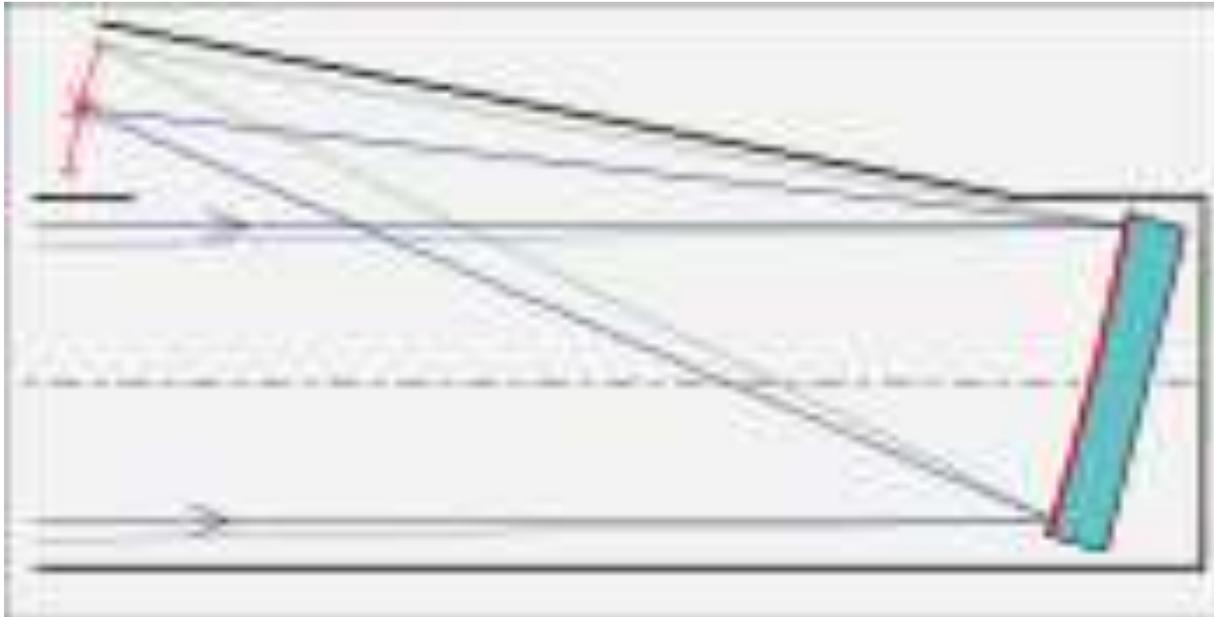


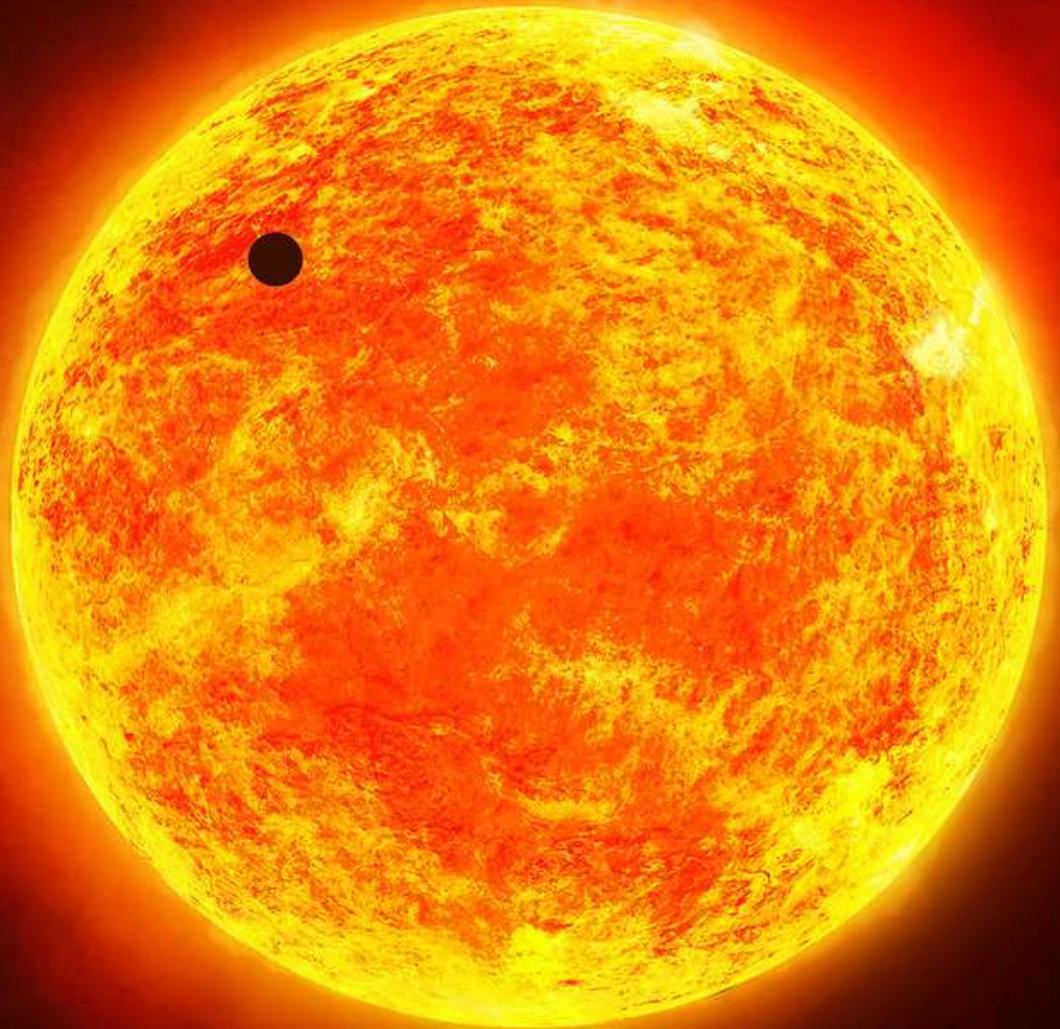
Lomonosov Tercentennial

6.4 x 4.8 m









Q



# **Reveal the Genius:**

## **An Amazing Story of Experimental Reconstruction of Lomonosov's Discovery of Venus's Atmosphere**

Vladimir Shiltsev (Illinois)

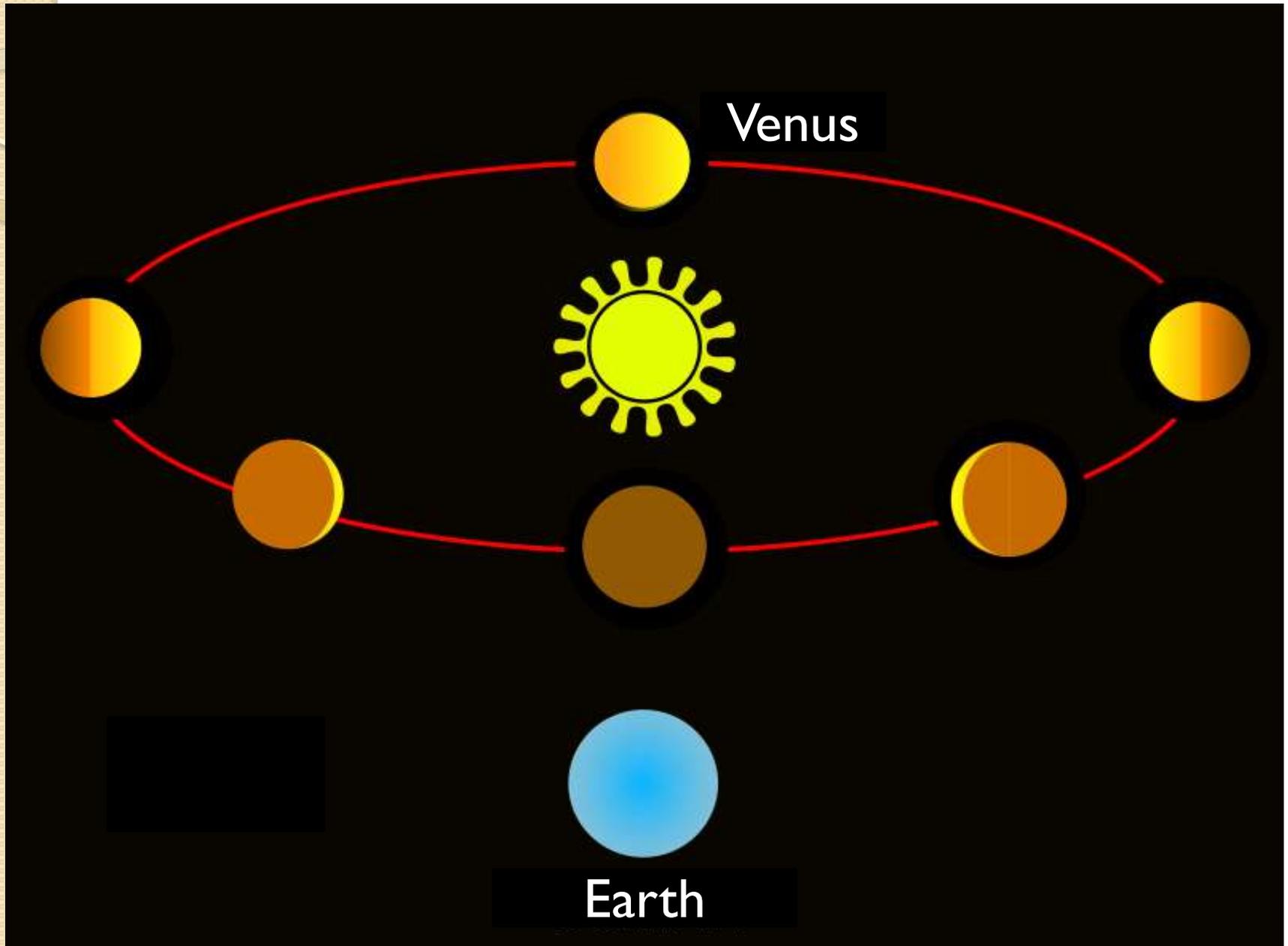
Alex Koukarine (California)

Yuri Petrunin (Colorado)

Igor Nesterenko (Siberia)

Randall Rosenfeld (Canada)

# Sun, Venus and Earth



# Transits of Venus over Sun's Disc

lasts about 6 hours

**1761: June 6**

**1769: June 3-4**

**1874: Dec 8-9**

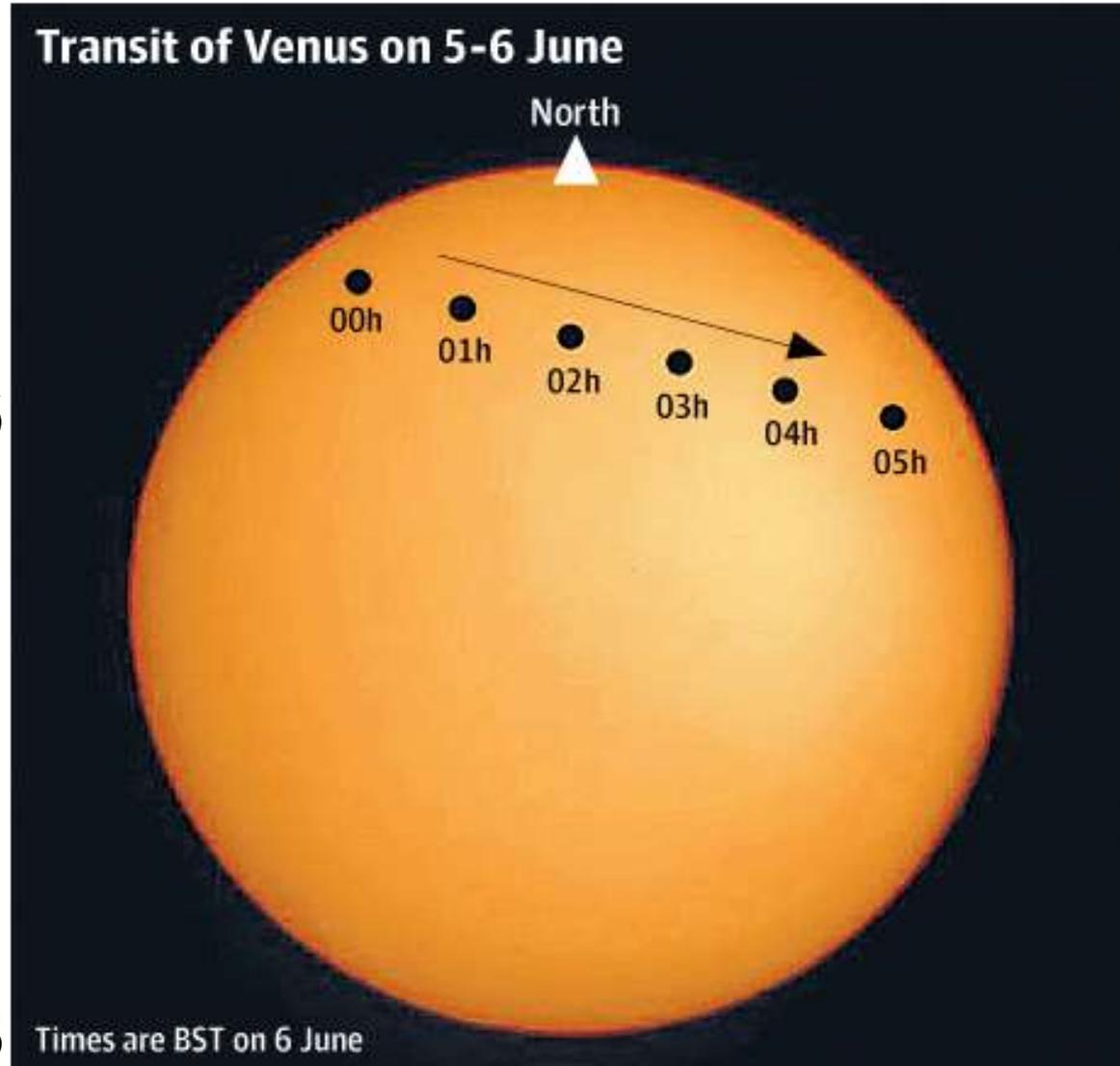
**1882: December 6**

**2004: June 8**

**2012: June 5-6**

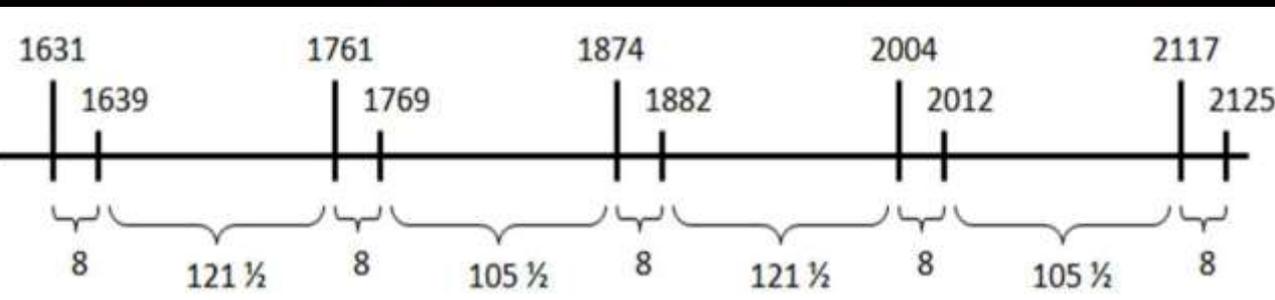
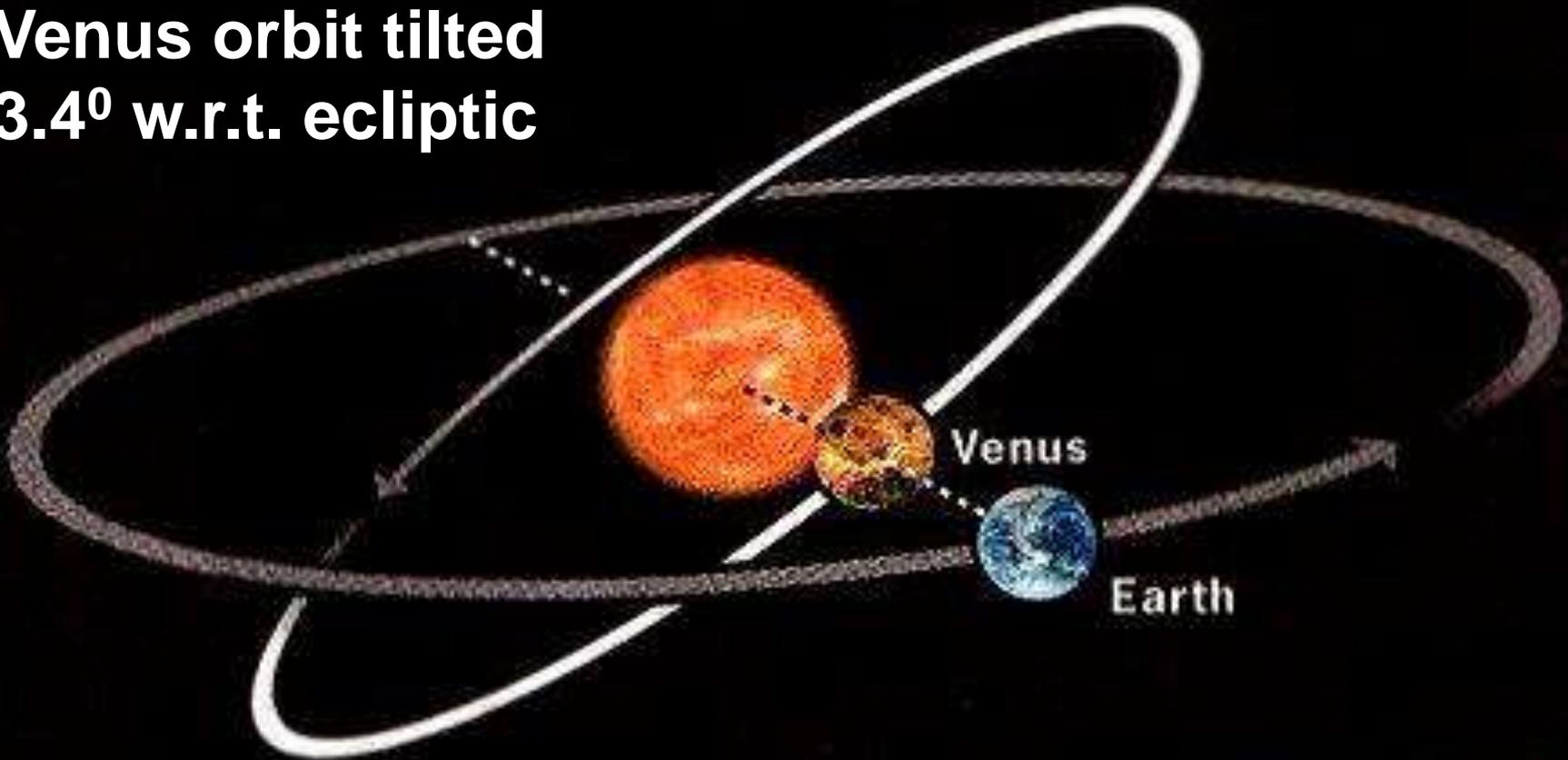
**2117: Dec 11**

**2125: December 8**



# Why So Rarely? Tilted Orbits

Venus orbit tilted  
 $3.4^\circ$  w.r.t. ecliptic



Venus overtakes the Earth on the inside every 584 days, but because of the inclined orbit, transits occur only four times every 243 years

# Discovery of Venus's Atmosphere

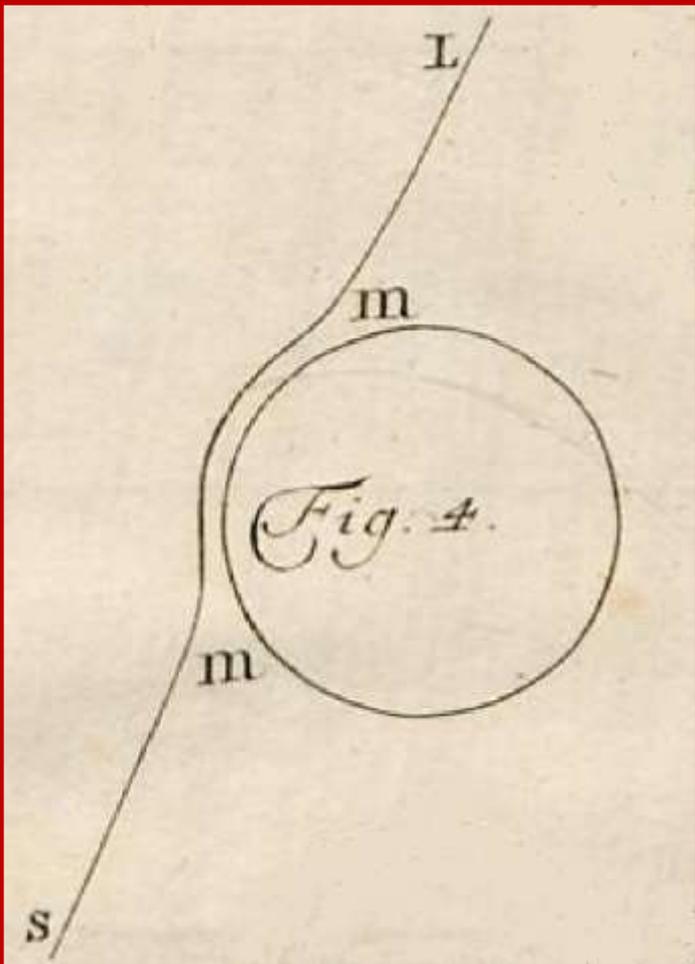
- **In 1761**, Mikhail Lomonosov observing the transit of Venus noted appearance of luminous arc over the part of the planet off the Sun's disc at egress:

«...From these observations, Mr. Councilor Lomonosov concludes that the planet Venus is surrounded by a significant air atmosphere similar to (if not even greater than) that which surrounds our terrestrial globe...»

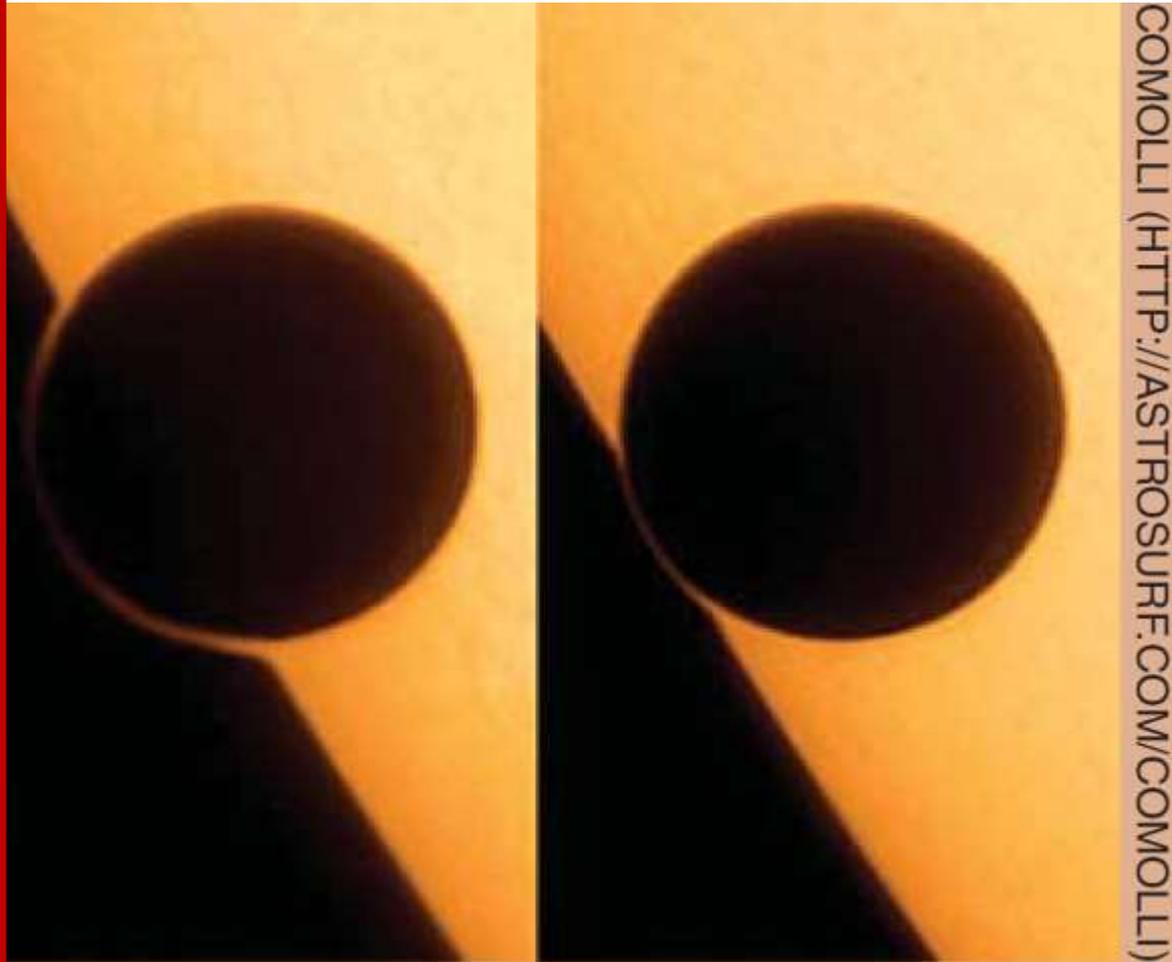


Source: "The Appearance of Venus On The Sun, Observed At The St.Petersburg Imperial Academy Of Sciences On May 26, 1761." , StP.Acad.Sci. Print, July 17, 1761

# Lomonosov's Arc: 1761 and Now



From Lomonosov's  
1761 paper



COMOLLI (HTTP://ASTROSURF.COM/COMOLLI)

Modern-day telescope image showing aureole  
appearing at early stages the 2004 Transit of Venus

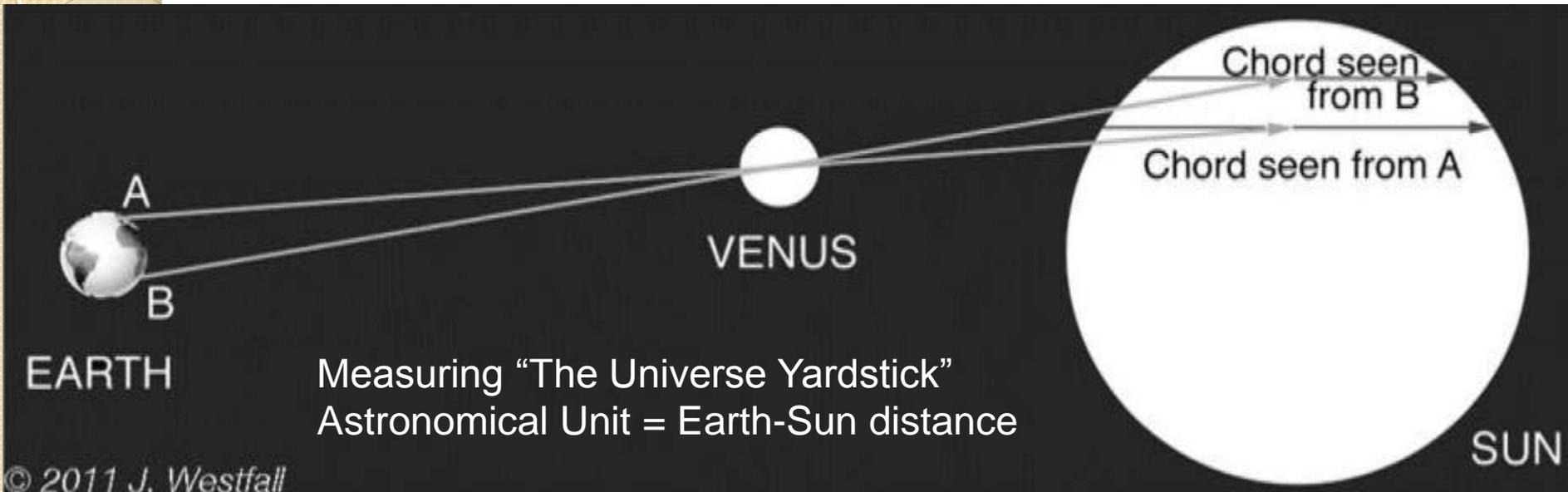
# Lomonosov was:

- The first to publish a scientific paper
  - submitted July 4<sup>th</sup>, published July 17, transl. to German and sent abroad Aug. 1761
- The only one who understood it's not a nuisance and gave detailed description
  - 17 pages, 8 figures
    - compare to few lines – ½ page max in other few reports
- Correctly explained the effect by refraction of solar rays in Venus's atmosphere

*...end of story !? – not so fast*

# Open Questions:

- 18<sup>th</sup> century transits were well observed



- 1761 Transit: over 170 astronomers at more than 100 locations on Earth - coordinated
- 1769 Transit: >130 observers, many knew about the arc seen 8 years earlier and sought it
- The best observers and instruments
- Only a dozen reported seeing the arc - why?

# 19<sup>th</sup> and 21<sup>st</sup> Centuries Transits

- Seeing Lomonosov's arc not that easy!
  - E.g., in 2004, < 40% of amateurs saw it – and most of them, too, knew and sought for it!
  - It was a challenge even for some pro's →

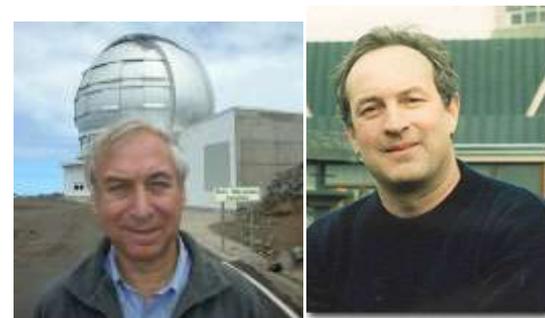
- Prof. J.Pasachoff & Dr. W.Sheehan (after ToV 2004)

– “poor quality of 18<sup>th</sup> c. telescopes”

– “...*Zeitgeist*”

– “...saw what he wanted to see”

– “...most probably – optical illusion”



*Journal of Astronomical History and Heritage*, 15(1), 3-14 (2012).

**LOMONOSOV, THE DISCOVERY OF VENUS'S ATMOSPHERE,  
AND EIGHTEENTH CENTURY TRANSITS OF VENUS**

# Critical Resolution : Experimental Replication

- Prepare for the June 5<sup>th</sup> 2012 Transit :
  - Telescope - “like Lomonosov’s”
  - Solar filter - “like Lomonosov’s”
  - Methods of observations - “like Lomonosov’s”
- And – very much desired - in several places
  - as the weather is not predictable

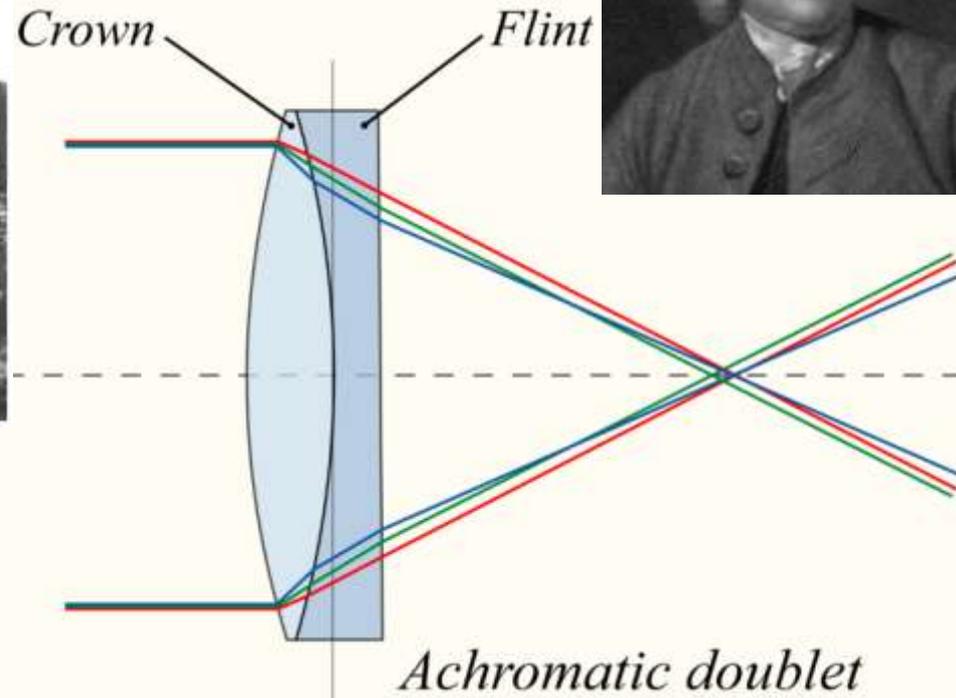
# Lomonosov's Telescope

- “...4 ½ feet long...of two glasses” ... type ?
  - hints: “glasses=lenses”; check Academy's Museum

Russian Academy's Pulkovo  
Observatory Telescope Museum (1944)

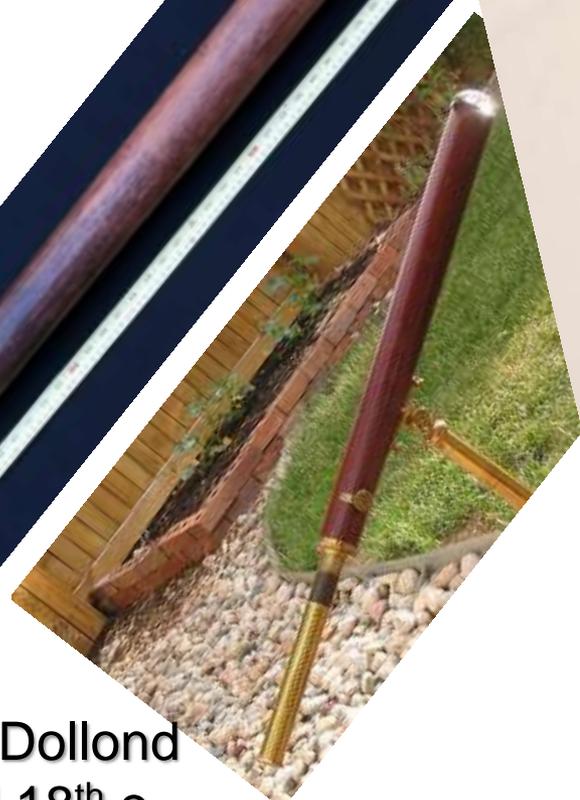


John Dollond (1706-1761)  
Optician, London, FRS  
Patent 1758



(Y.Petrinin) → 1939 publication by A.Nemiro →  
1886 “Struve's List” → “...one of these Dollond  
achromats was used by famous Lomonosov to  
make the biggest discovery – he discovered the  
existence of an atmosphere of Venus during its  
passage through the disk of the Sun in 1761”

4 ½ ft - Dollond  
2<sup>nd</sup> half 18<sup>th</sup> c



2 ft - Dollond  
end 18<sup>th</sup> c



3 ft - Dollond  
ca 1800

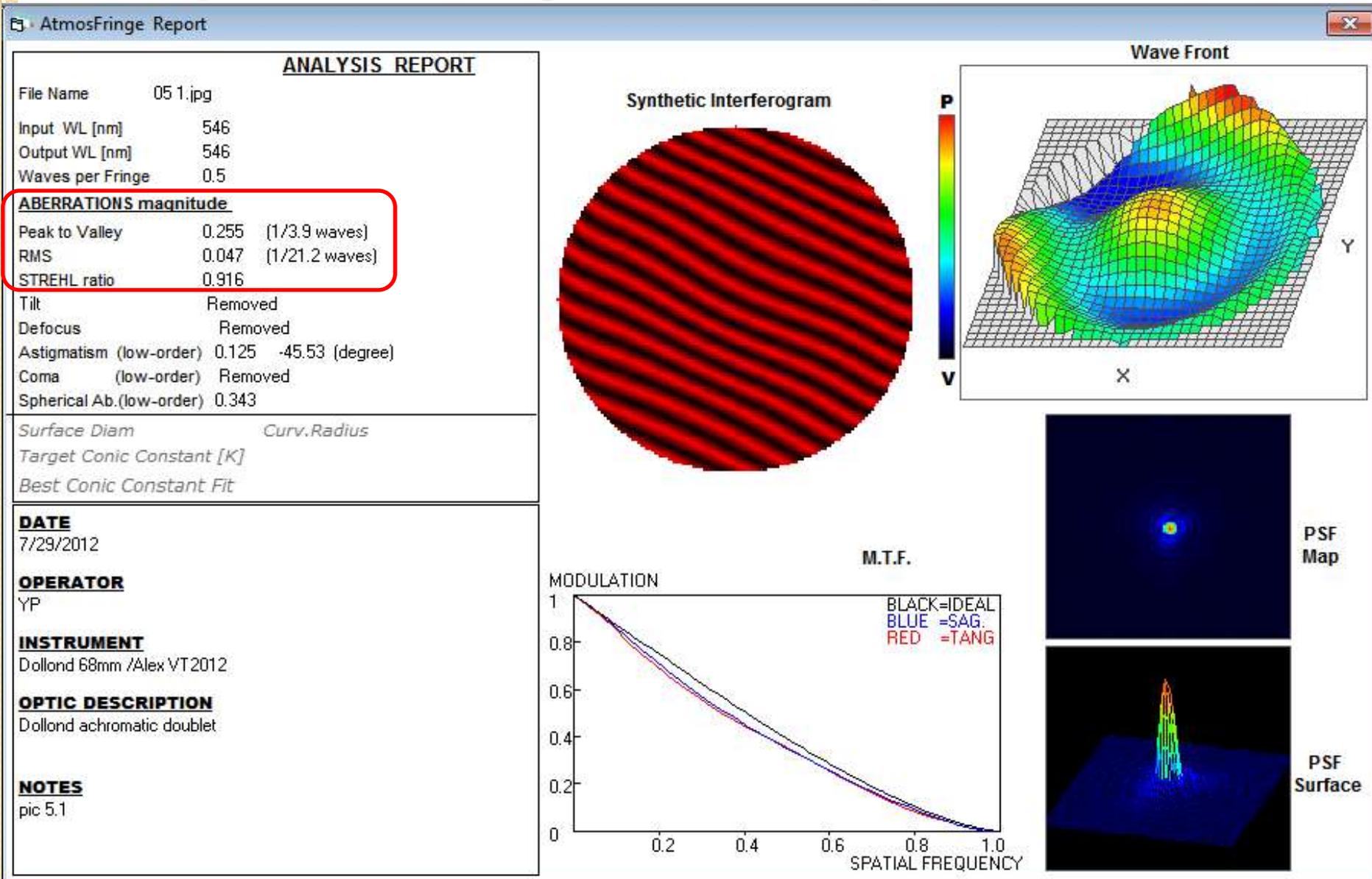


2 ft - C. West  
ca 1820

# Our Antique Telescopes “of two lenses” (achromats)

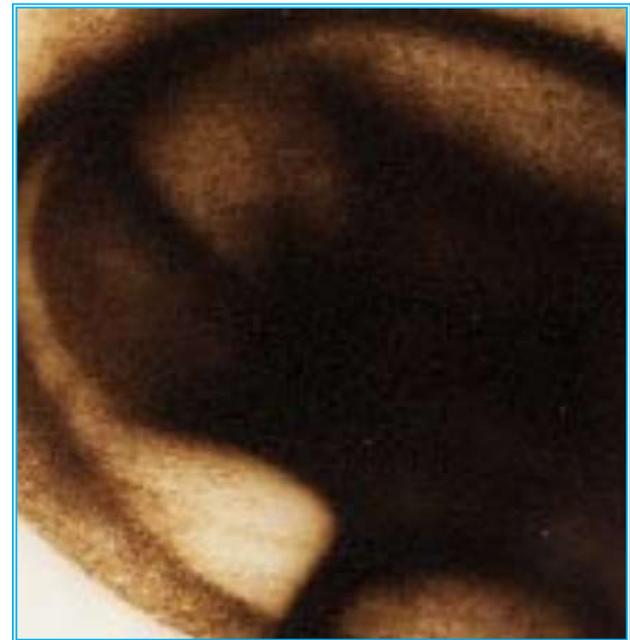
# 4½ ft Dollond Achromat - 2<sup>nd</sup> half 18<sup>th</sup> century

## Optics Quality Test – Superb Results !



# Lomonosov's Filter

- “...The tube had attached a not-so-heavily smoked glass, for he intended to observe only the beginning and the end [of the transit]...”
  - Several references to strong effects on his eyes (see next)



*How to assure the glass is “not-so-heavily” smoked ?*

# HARPER'S WEEKLY.

JOURNAL OF CIVILIZATION.

Vol. XXVII—No. 1523

NEW YORK, SATURDAY, APRIL 28, 1883.

THE BOSTON & COPY  
READ THE TRADE OF OFFICERS.



THE TRANSIT OF VENUS.—From the Pictures of J. G. Hendon.

## Smoked glass – BAD?

*“...These children, depicted on the April 28, 1883, cover of Harper’s Weekly, are at risk of serious eye injury. They are using smoked glass, which is not sufficient.”*

**( Chuck Bueter at <http://transitofvenus.nl/wp/observing/six-ways-to-see-the-transit/> )**

*“...The 1874 and 1882 transits were popular phenomena as well as astronomical ones (as evidenced by, for instance, this Harper's cover of urchins watching the transit through [the inadequate eye protection of] smoked glass.)”*

**Watching the Rare Transit of Venus From 1639 to Today, Suzanne Fischer, *The Atlantic* Jun 4 2012**

Solar viewing filters



Posted by: Seth Jarvis  
April 9th, 2012

# DO NOT ATTEMPT TO USE:

~~Double sunglasses~~

~~Polarized sunglasses~~

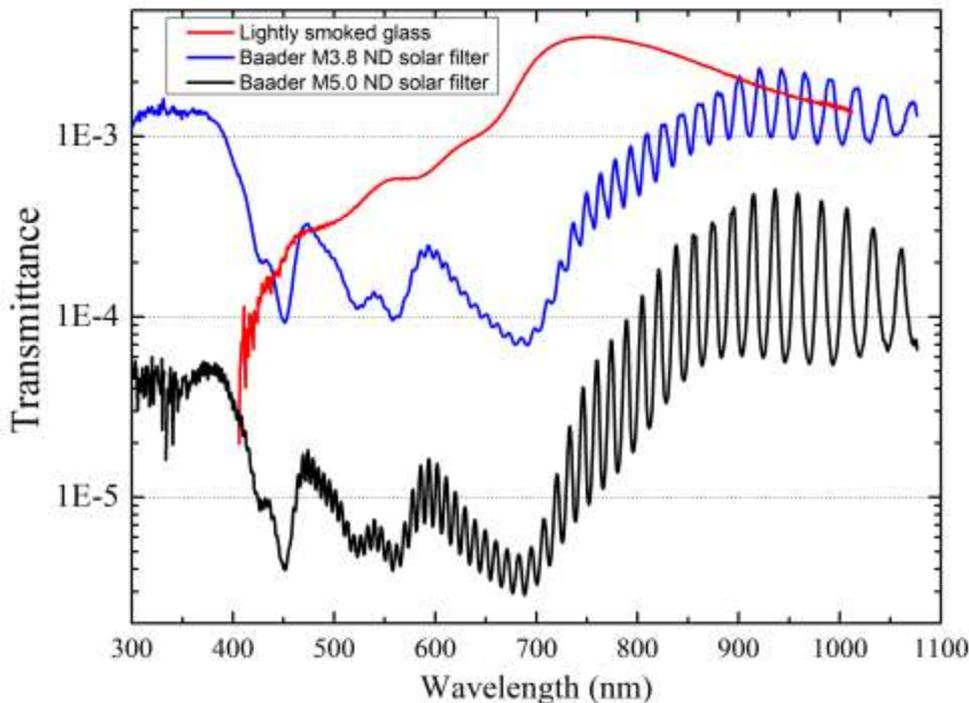
**Smoked glass**

~~Exposed camera film~~



# “...Not-so-heavily Smoked Glass”

- Try-out strategy: “tolerable level” was set as such when yellow fantoms lasted <10 sec (eye recovery time) after watching the Sun thru the filtered scope for 20-30 sec



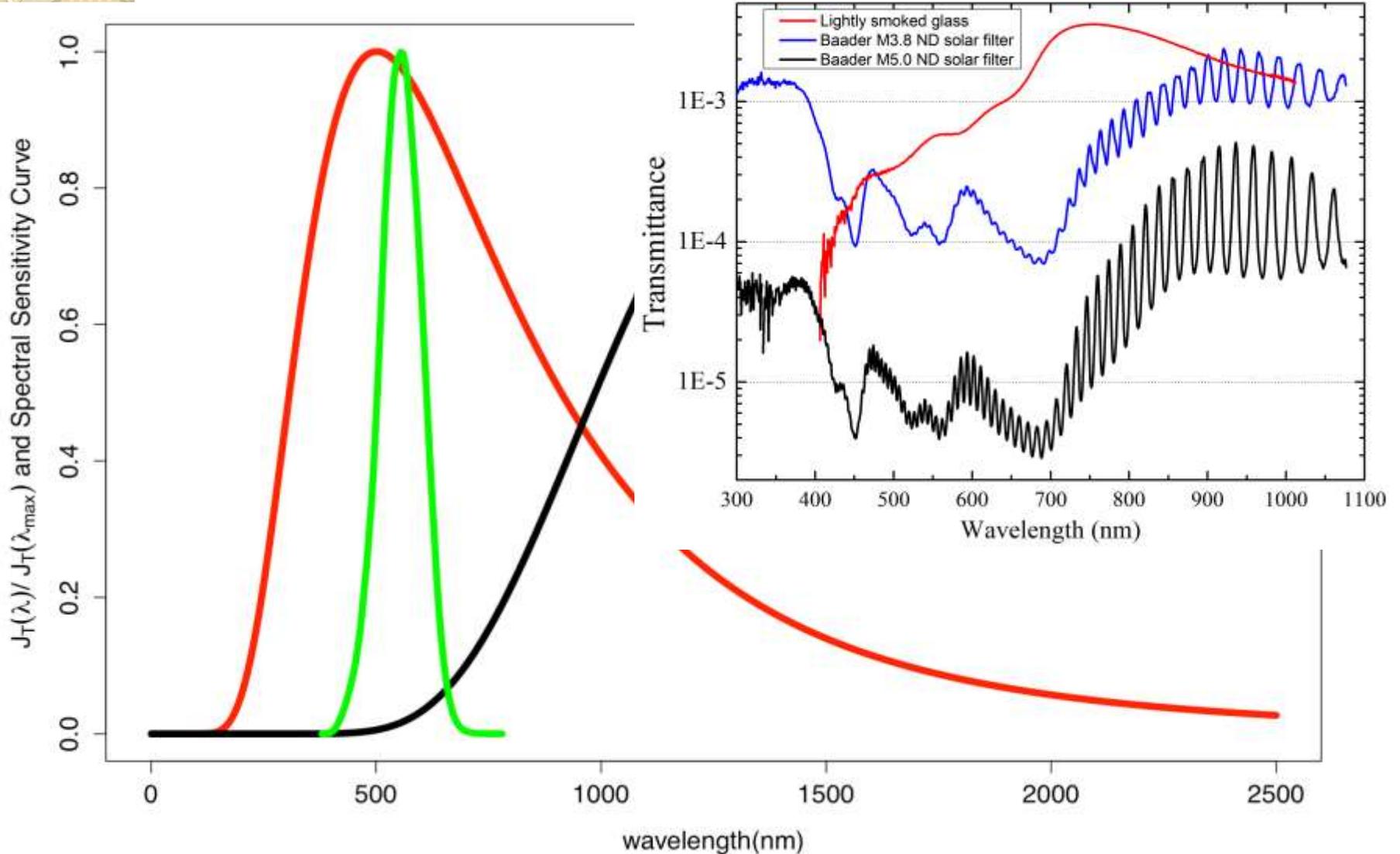
*The filter was found to be 1:1700  
(compare to standard 1:100,000 M5 ND)*



...relatively modest telescope aperture adds safety

# Sun Spectrum vs Eye Sensitivity

smoked glass seems to be safer than modern ND filters ?



# Lomonosov's Observations

- "...he [Lomonosov] intended to observe the beginning and the end of the phenomenon only and then to use the power of the eye, and give [his] eyes a respite for the rest of the transit."
- "...not seeing any blackening [at ingress] and thinking that his tired eyes were the cause for this blurring, [he] got away from the tube."
- "...during the entire observation the tube was permanently directed in such a way that Venus was always in its center, where its [Venus'] edges appeared crispy clear without any colors."

“... To give [his] eyes a respite...”

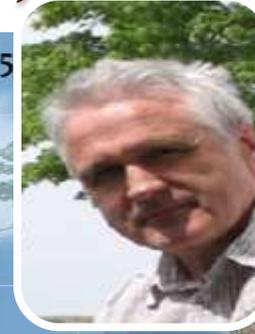


Alfiya Nesterenko

Randall Rosenfeld

# Transit

# June 5-6, 2012



Igor Nesterenko

Yuri Petrunin

Aleks Koukarine

Vladimir Shiltsev



## Simultaneous Observations with Antique Telescopes

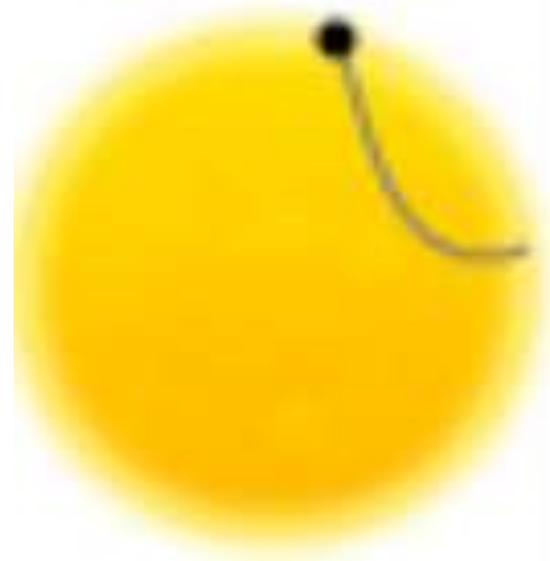
Vladimir Shiltsev PPPL 2014

2012

Transit of Venus

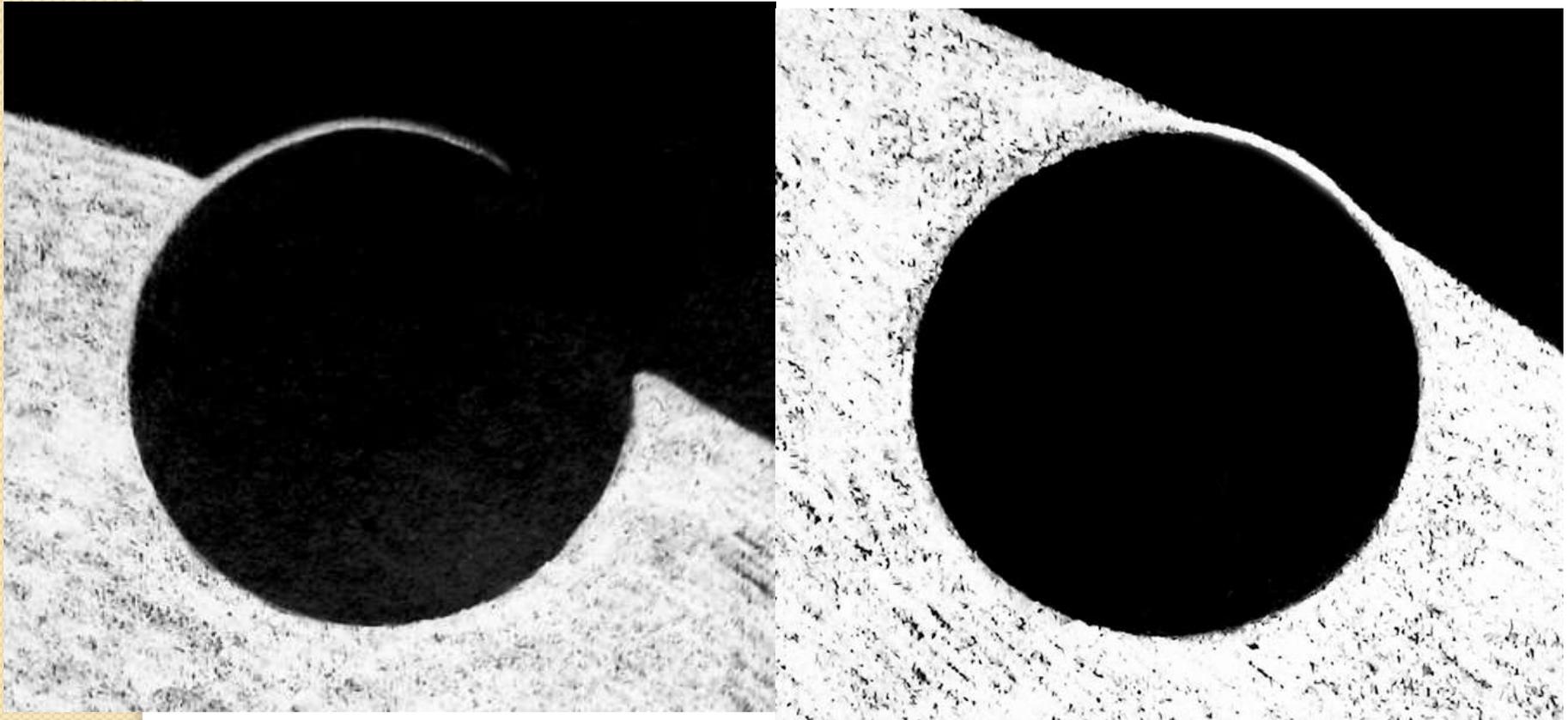
Jun 5

17:04:25



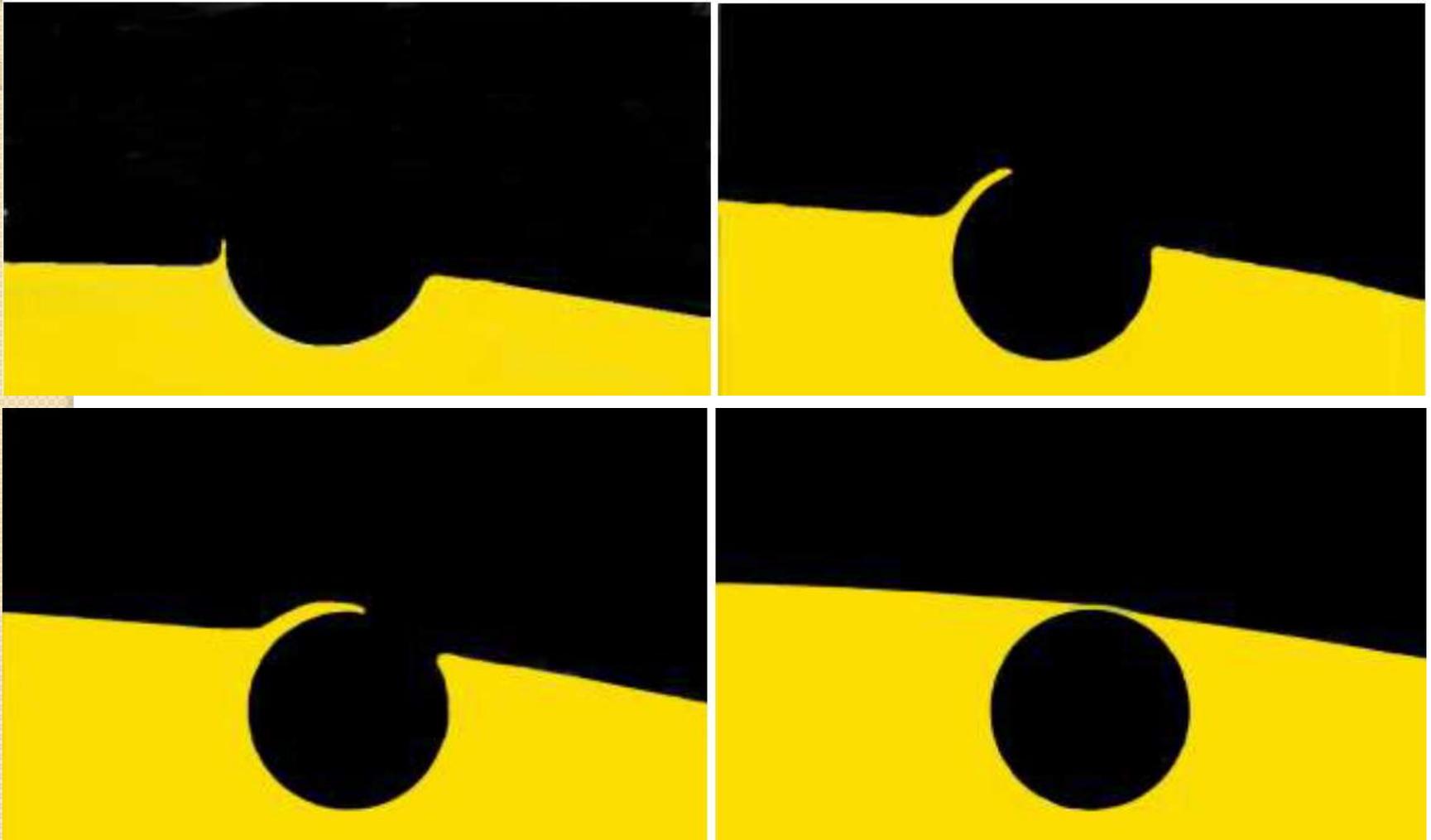
# ToV 05/06/2012: Results

- Bad weather conditions in Colorado (clouds) and Novosibirsk (“seeing” – air turbulence)
- **California (Lick Observatory)-Success !**



# ToV 05/06/2012: Results

Illinois (Batavia) – Success !



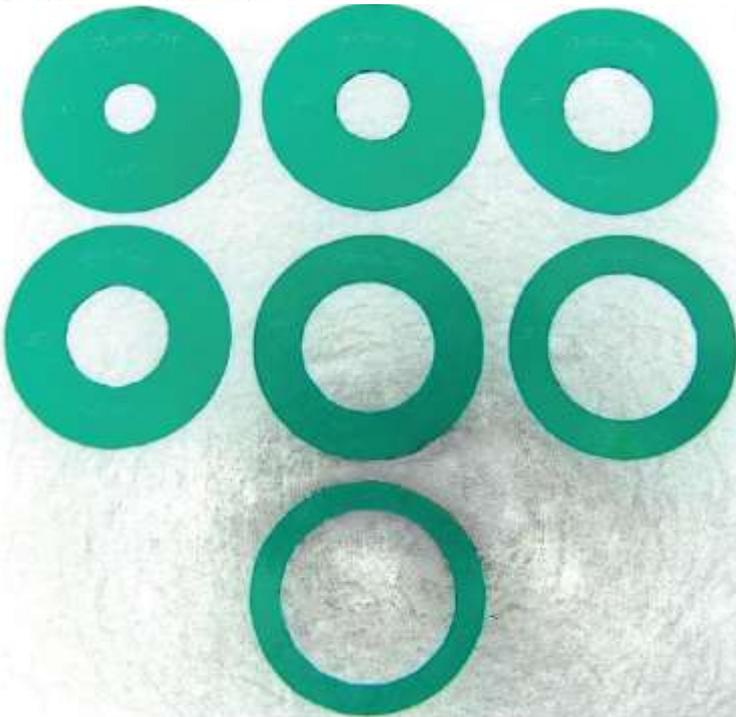
# ToV 05/06/2012: Results

## Canada (Saskatchewan) – Success !



*R. Rosenfeld et al*, used high-quality, modern doublet refractors with changeable aperture stops

- the minimum diameter required for a reliable detection of the arc with a standard 1/100 000 filter was about 50 mm.
- The telescope magnification was a less important variable.

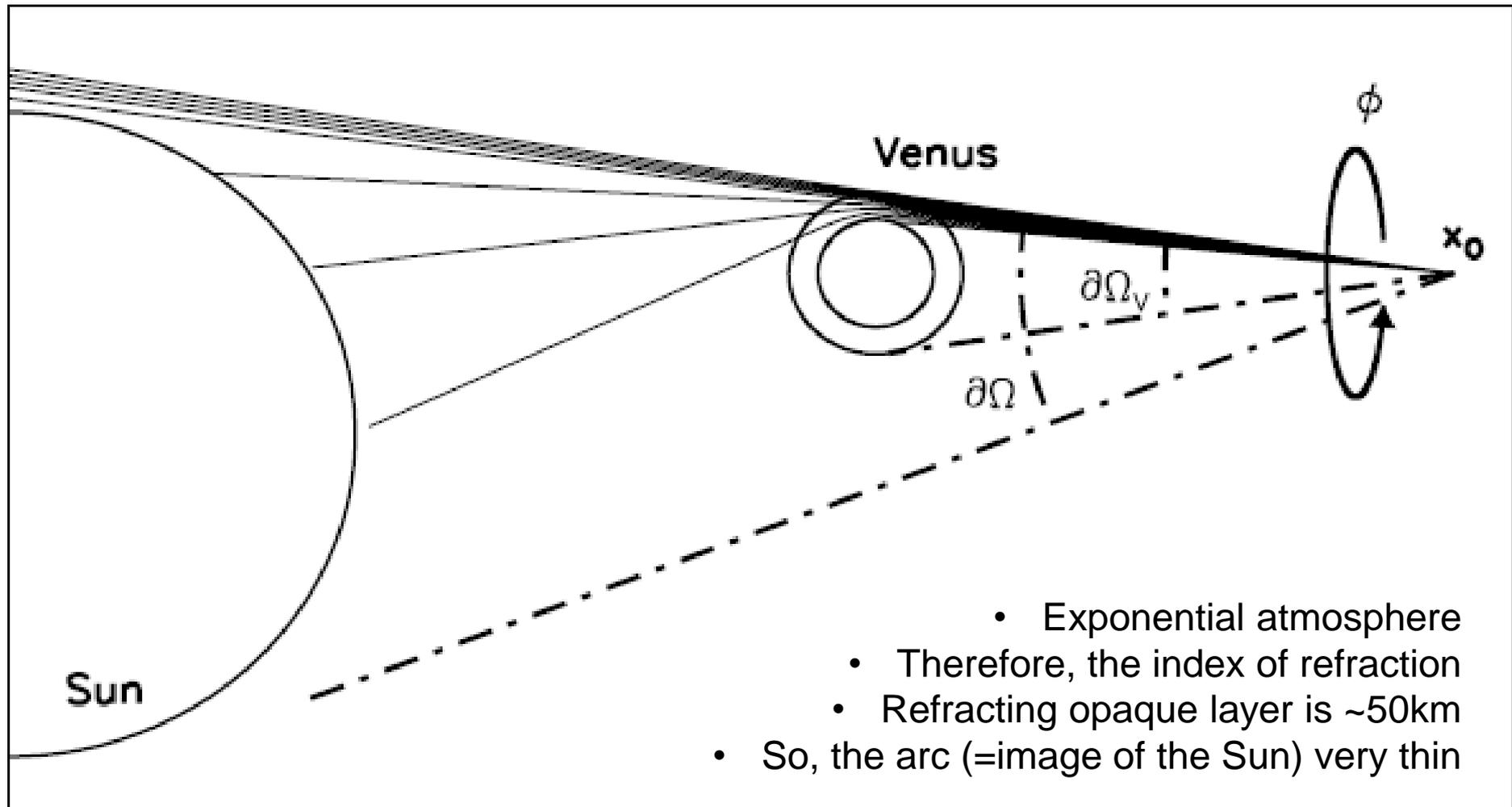


*“...What the results do establish is that the atmosphere of Venus can be seen with small-aperture, high-quality refractors of either 21st- or 18th-century manufacture. Astronomers of the Enlightenment possessed in their best standard equipment the instrumental means to see the aureole. Whether any did will have to be judged through careful analysis of their observational records alone. No aureole observation can be dismissed through a sweeping dismissal of the optics of the day.”*

# Back-up Slides

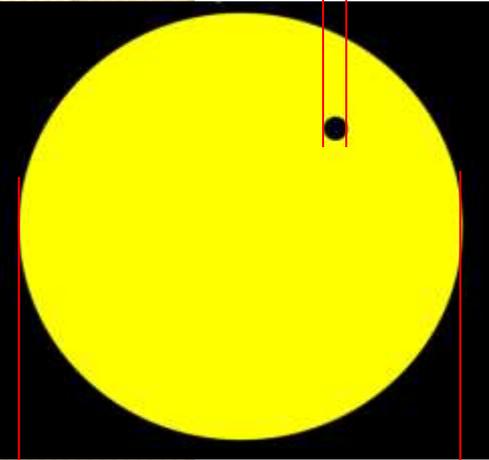
- **Explanation of the *Lomonosov effect*:**
  - Image formation (arc)
  - Image distortion
    - Atmospheric turbulence (seeing)
    - Importance of good optics
    - Diffraction on aperture
  - Detection of faint object
    - Importance of background light
    - Physiological eye response
      - Importance of weak filter

# “Arc” around Venus – due to refraction of Sun rays in atmosphere



# Physics Behind Seeing the Arc (I)

Venus  $\approx 1$  arcmin = 1'  
or 60 arcsec = 60''



Sun  $\approx \frac{1}{2}$  deg  
or 30'  
or 1800''

1 deg = 60 arcmin  
1 arcmin = 60 arcsec  
1 arcsec  $\approx 5 \mu$  radian

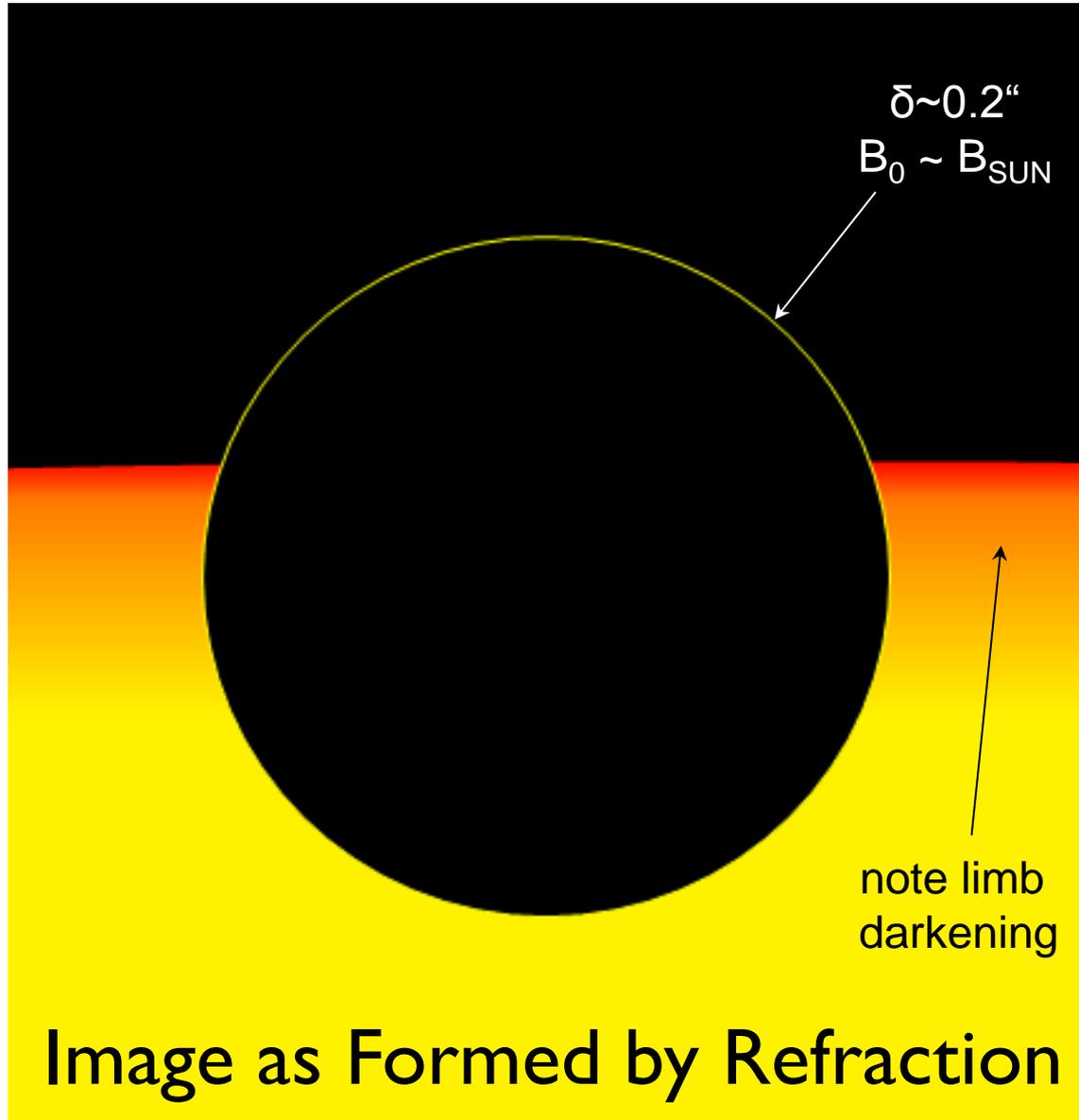


Image as Formed by Refraction

# Physics Behind Seeing the Arc (II)

## Telescope and “seeing” effects

### Effect #1 :

Atmospheric turbulence (seeing)  
 $\Delta \sim 0.1''$ - $1''$  or more

### Effect #2 :

Optics aberrations  
 $\Delta \sim 1''$ - $10''$  or more

- chromatic aberrations – fixed by achromat
- many others – depend on quality ( $\lambda/4$ ) and ( $D/F$ )

### Effect #3 :

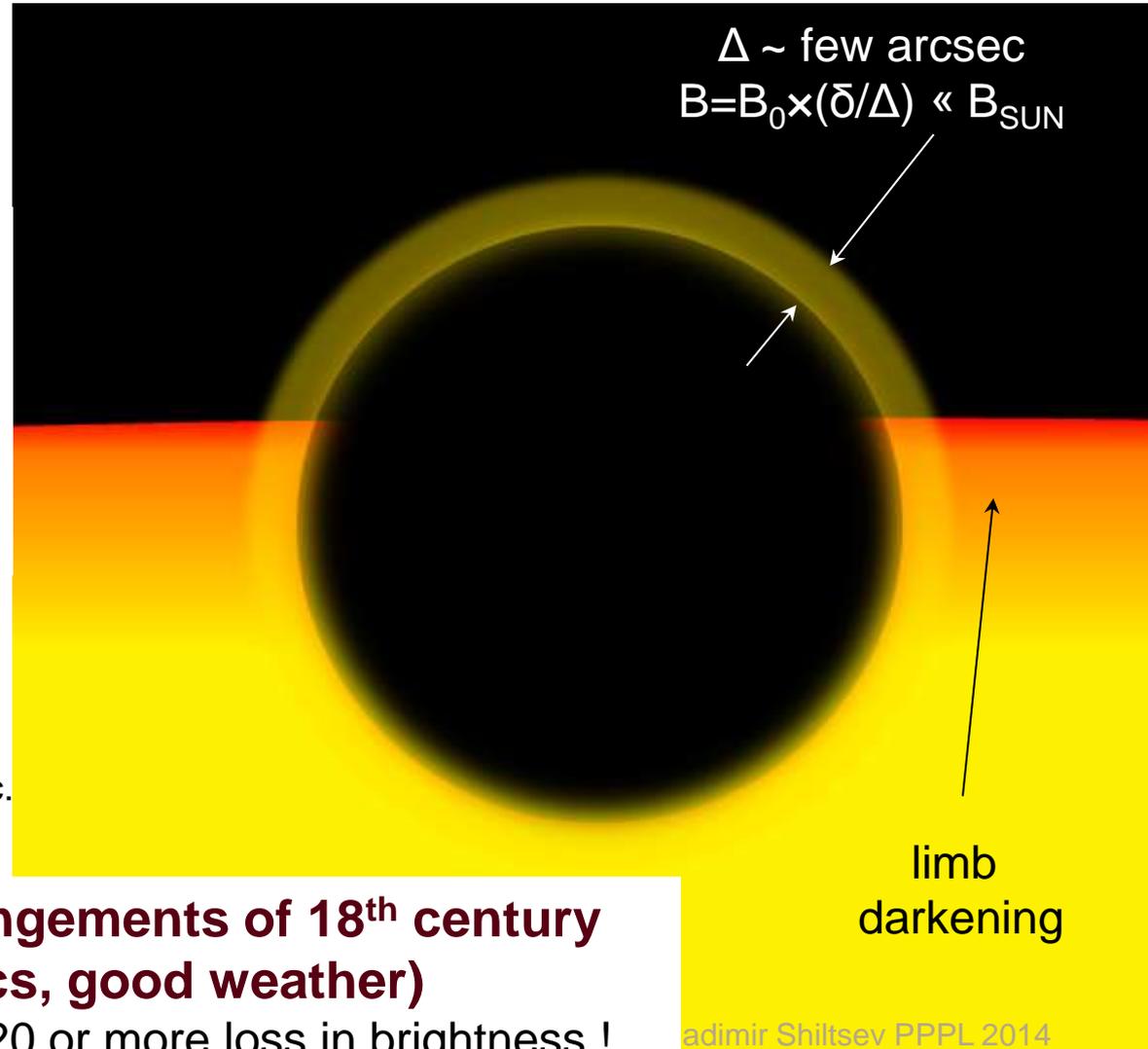
Diffraction on aperture

$$\Delta \approx 140''/D[\text{mm}]$$

- $\sim 3$ - $4''$  for Lomonosov telesc.
- $>70$ mm unique in 18<sup>th</sup> c.

**So, with best arrangements of 18<sup>th</sup> century  
(good optics, good weather)**

$\Delta \approx 3$ - $4'' \rightarrow$  factor of  $\sim 20$  or more loss in brightness !



# Physics Behind Seeing the Arc (III)

## The effect of very weak filter

### Effect #1 :

Apparent brightness of the arc is up

### Effect #2 :

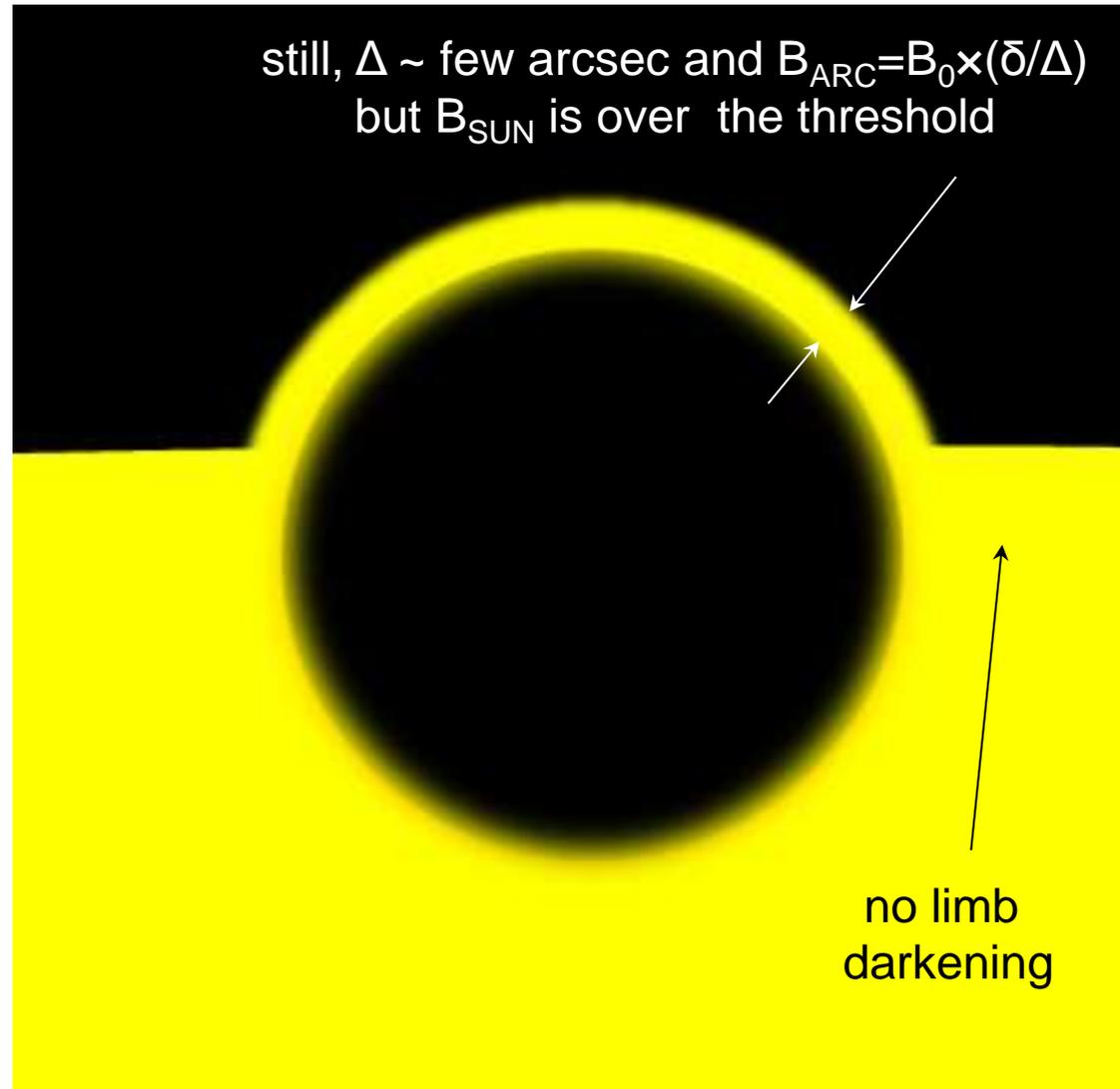
Brightness of the Sun is up to but it goes beyond the glare limit

- see next slide
- details on the Sun are not well seen – eg no limb darkening

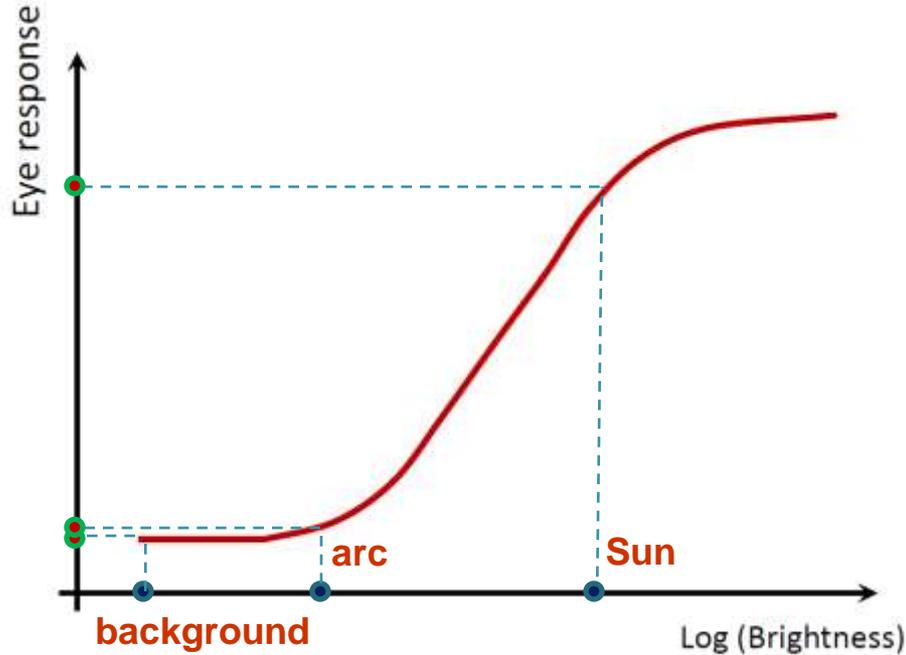
### As the result :

$(B_{ARC} / B_{SUN})$  is improved

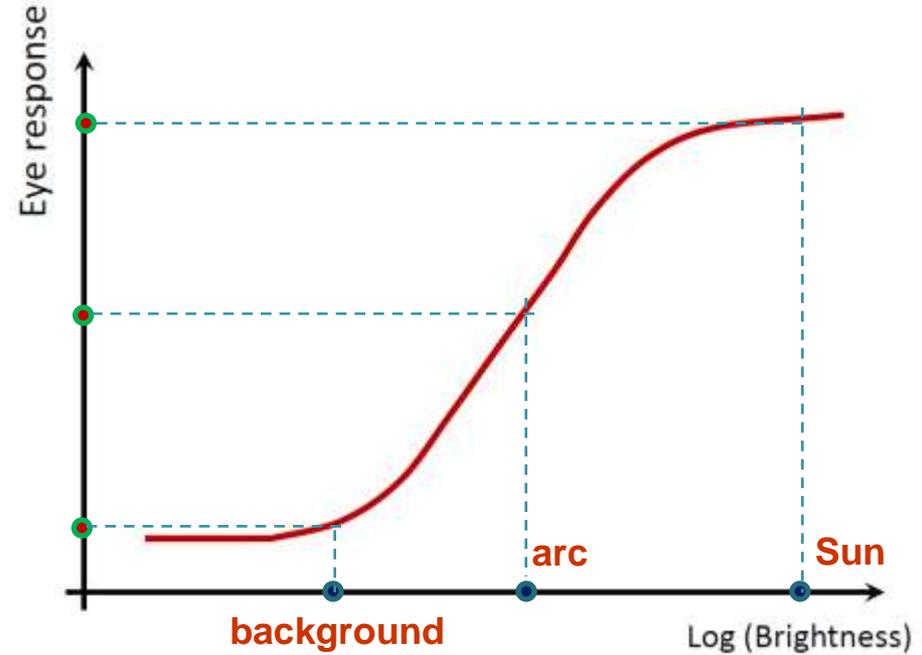
- makes it easier to see the arc



# Sun-Arc-Background in the Eye



Regular (strong) filter



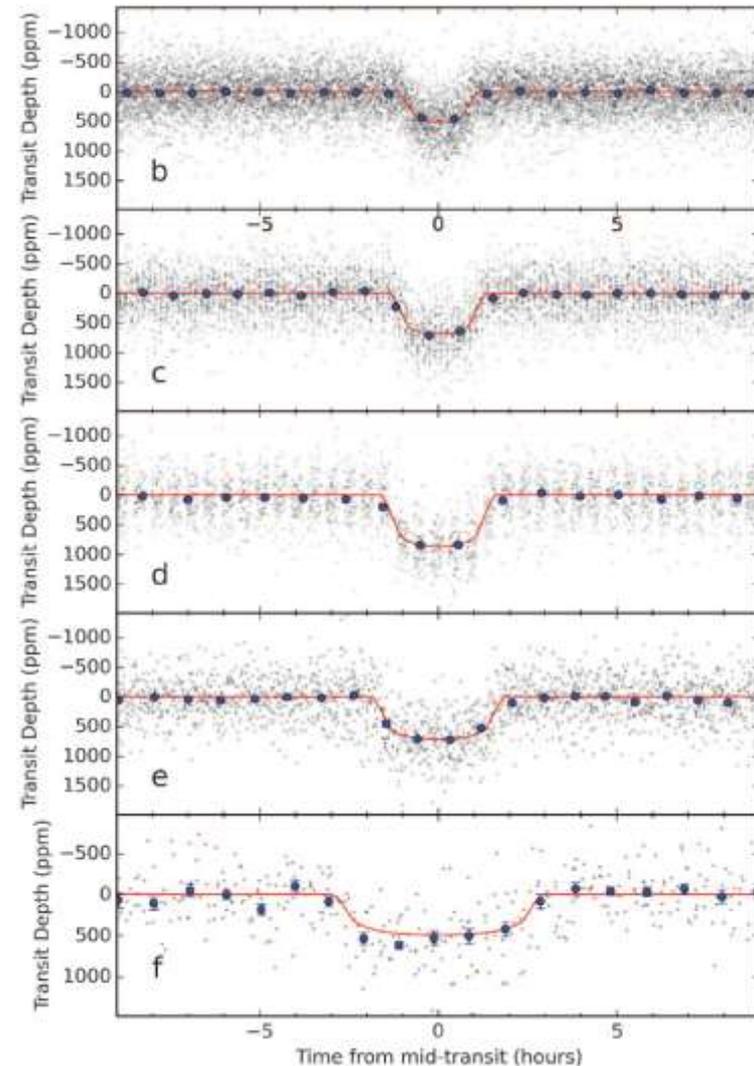
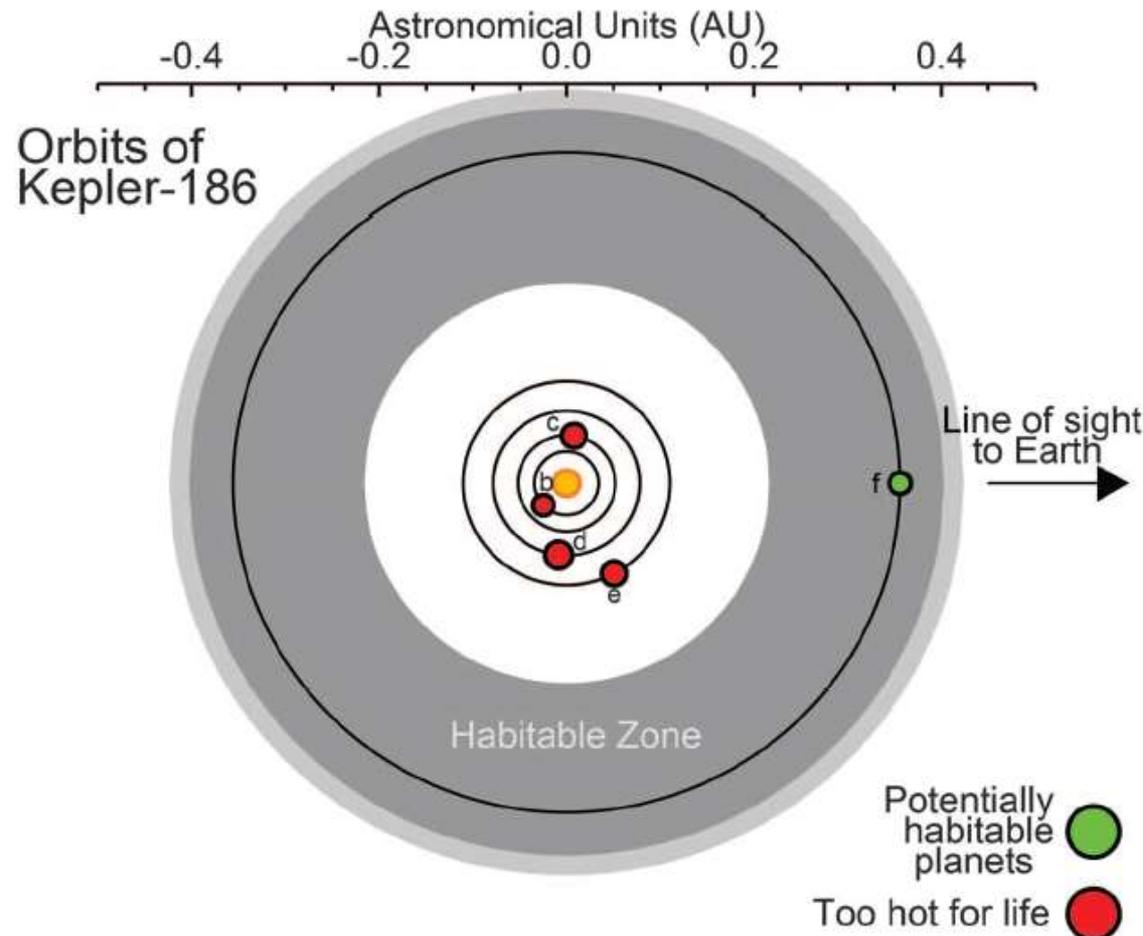
Ultimately weak filter

# Relevance to Nowadays

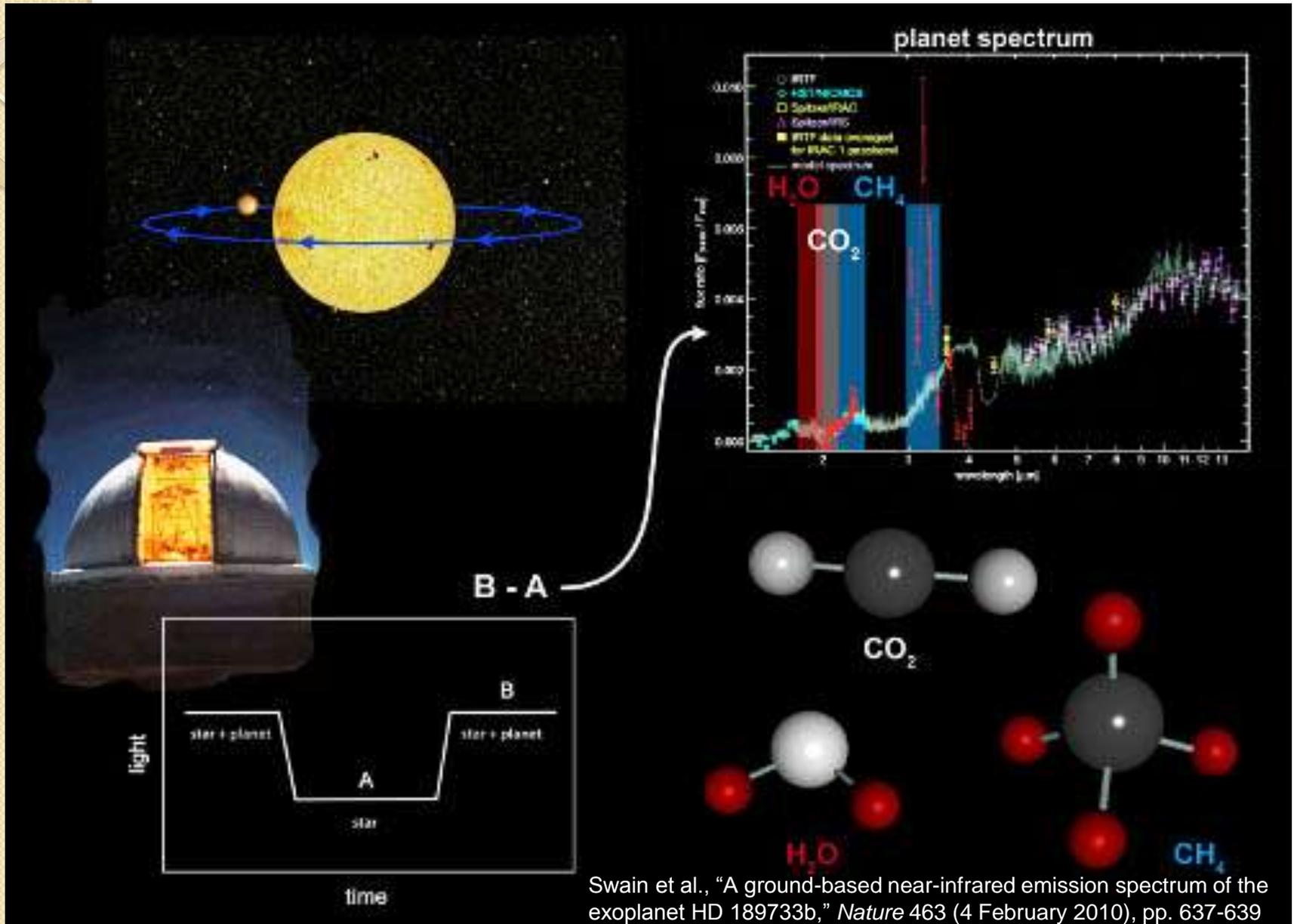
- (Great story about Lomonosov)
- Better appreciation of old masters – ingenuity of great scientists of 18<sup>th</sup> century (Dollond, Lomonosov)
- Transits of exoplanets - “hot topic” now:
  - Search for exoplanets (~1800 & growing)
  - Understanding their atmospheres

# Kepler 186f: 1.1 AU, ~Earth's size and mass

- Can study exoplanets' atmosphere at transit
- Cool star "Sun-like"



# Exoplanet Atmosphere Studies



Swain et al., "A ground-based near-infrared emission spectrum of the exoplanet HD 189733b," *Nature* 463 (4 February 2010), pp. 637-639

# Couple Words Through Centuries

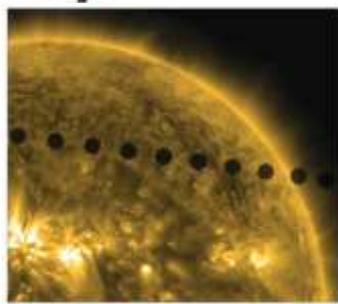
- “...After reading here about the great atmosphere around the aforementioned planet, one can say: we can then presume that because of its vapor updrafts, clouds gather, rains fall, flowing streams gather into the rivers, and the rivers flow into the seas, different types of plants grow everywhere on which animals feed.... Some people ask if there are humans like us living on the other planets, then what faith are they? Have they been preached the gospel? Are they baptized into the faith of Christ? “
- “..The Creator has given two books to the mankind. In one [He] has shown His majesty, in another - His will. The first one is this visible world, established by Him so that a man looking at the vastness, beauty and elegance of its buildings, acknowledges divine omnipotence, as much as he can understand. The second book is the Holy Scripture... For the book of creation of the visible world, the interpreters are physicists, mathematicians, astronomers and other expounders of the divine infusions into the nature - much like the prophets, apostles and teachers of the church in the Scripture“

*From: M.V.Lomonosov The Appearance of Venus On The Sun, Observed At The St.Petersburg Imperial Academy Of Sciences On May 26, 1761.*

# Further reading:

Comment: Robert P. Crease

## Critical Point Atmospheric tales



Historic opportunity June's transit of Venus.

**Robert P. Crease** reports on the result of four new experiments in "historical astronomy"

## Pomor Polymath: The Upbringing of Mikhail Vasilyevich Lomonosov, 1711–1730

Robert P. Crease and Vladimir Shiltsev\*

**Physics in Perspective**

Phys. Perspect. 15 (2013) 391–414

The life story of Mikhail Vasilyevich Lomonosov (1711–1765) opens a window onto Russian science, politics, language, and social advancement in the era of Peter the Great (1672–1725). We cover Lomonosov's background and upbringing, from his birth in 1711



*Solar System Research, 2013, Vol. 47, No. 6, pp. 487–490.*

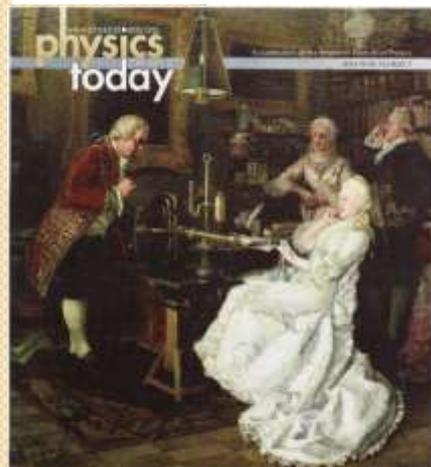


## The Venus Aureole Effect: Minimum Aperture for Visual Detection

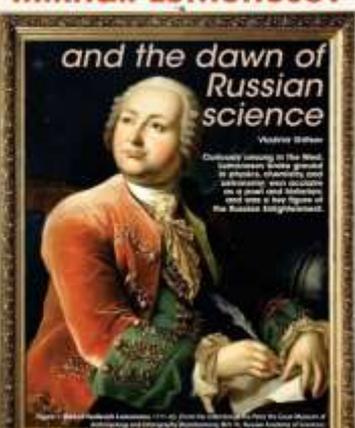
R.A. Rosenfeld ([randall.rosenfeld@utoronto.ca](mailto:randall.rosenfeld@utoronto.ca))  
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Jeff Danielson ([saskdanielson@gmail.com](mailto:saskdanielson@gmail.com))<sup>2</sup>  
Rob Sheppard ([grabhooks@hotmail.com](mailto:grabhooks@hotmail.com))<sup>2</sup>  
Paul Greenham ([paul.greenham@mail.utoronto.ca](mailto:paul.greenham@mail.utoronto.ca))<sup>3</sup>

## Critical Point Transit watching

Phys. Today **65**(2), 40 (2012)



## Mikhail Lomonosov



## Experimental Reconstruction of Lomonosov's Discovery of Venus's Atmosphere with Antique Refractors during the 2012 Transit of Venus

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<sup>c</sup> Telescope Engineering Company, Inc., Golden, CO 80401 USA

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**Abstract**—In 1761, the Russian polymath Mikhail Vasilyevich Lomonosov (1711–1765) discovered the atmosphere of Venus during its transit over the Sun's disc. In this paper we report on experimental reenactments of Lomonosov's discovery with antique refractors during the transit of Venus June 5–6, 2012. We conclude that Lomonosov's telescope was fully adequate to the task of detecting the arc of light around Venus off the Sun's disc during ingress or egress provided proper experimental techniques as described by Lomonosov in his 1761 report are employed.

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