Report of the Heliophysics Activities of the IAU Working Group on Solar Eclipses

Jay Pasachoff
Williams College–Hopkins Observatory
Williamstown, Massachusetts

NSF NATIONAL GEOGRAPHIC NASA SIGMA XI THE SCIENTIFIC RESEARCH SOCIETY Williams

I report on the solar-physics coordination and scientific activities relevant to heliophysics of the IAU Working Group on Solar Eclipses of Divisions C and E (Sun and Heliosphere) over the last triennium and with plans for the next triennium. Since the previous IAU General Assembly, we had total solar eclipses in Indonesia/Pacific in 2016 and in the United States 2017, the latter especially with major international participation from groups headed by members of the Working Group and from others.

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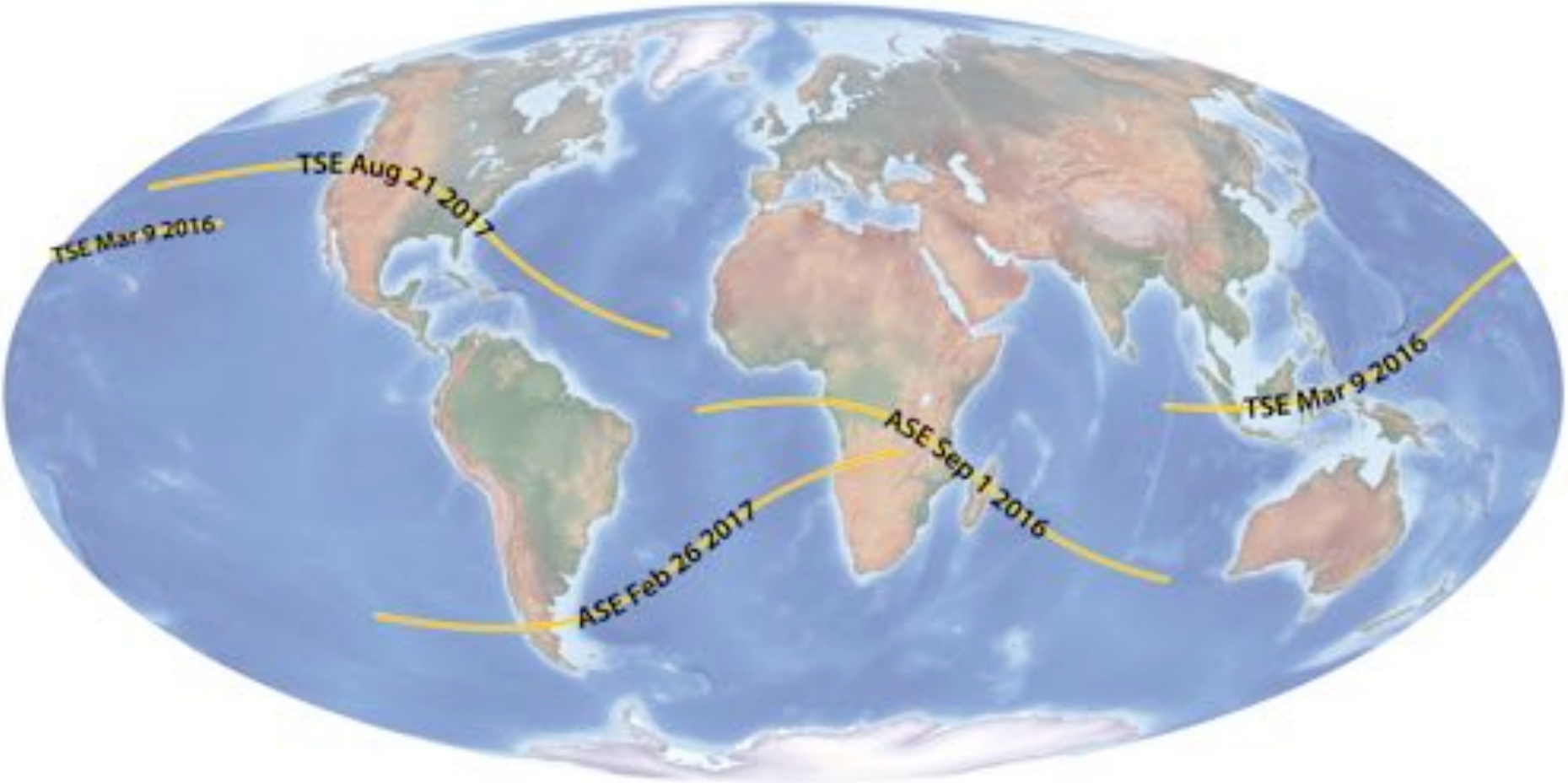
IAU Working Group on Solar Eclipses

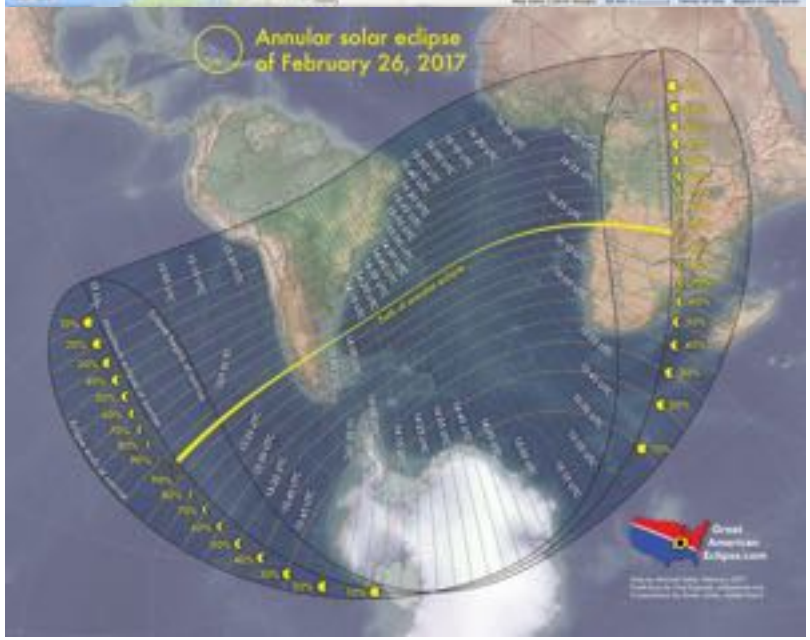
- Jay Pasachoff (USA, Chair), Iraida Kim (Russia), Hiroki Kurokawa (Japan), Jagdev Singh (India), Vojtech Rusin (Slovakia), Yoichiro Hanaoka (Japan), Zhongquan Qu (China), Beatriz Garcia (Argentina), Patricio Rojo (Chile)
- Xavier Jubier (France), Fred Espenak (US), Jay Anderson (Canada), Glenn Schneider (US), Michael Gill (UK), Michael Zeiler (USA), Bill Kramer (USA), and Ralph Chou (Canada).


TSE Aug 21 2017
TSE Mar 9 2016
TSE Mar 9 2016
ASE Sep 1 2016
ASE Feb 26 2017

March 8/9, 2016

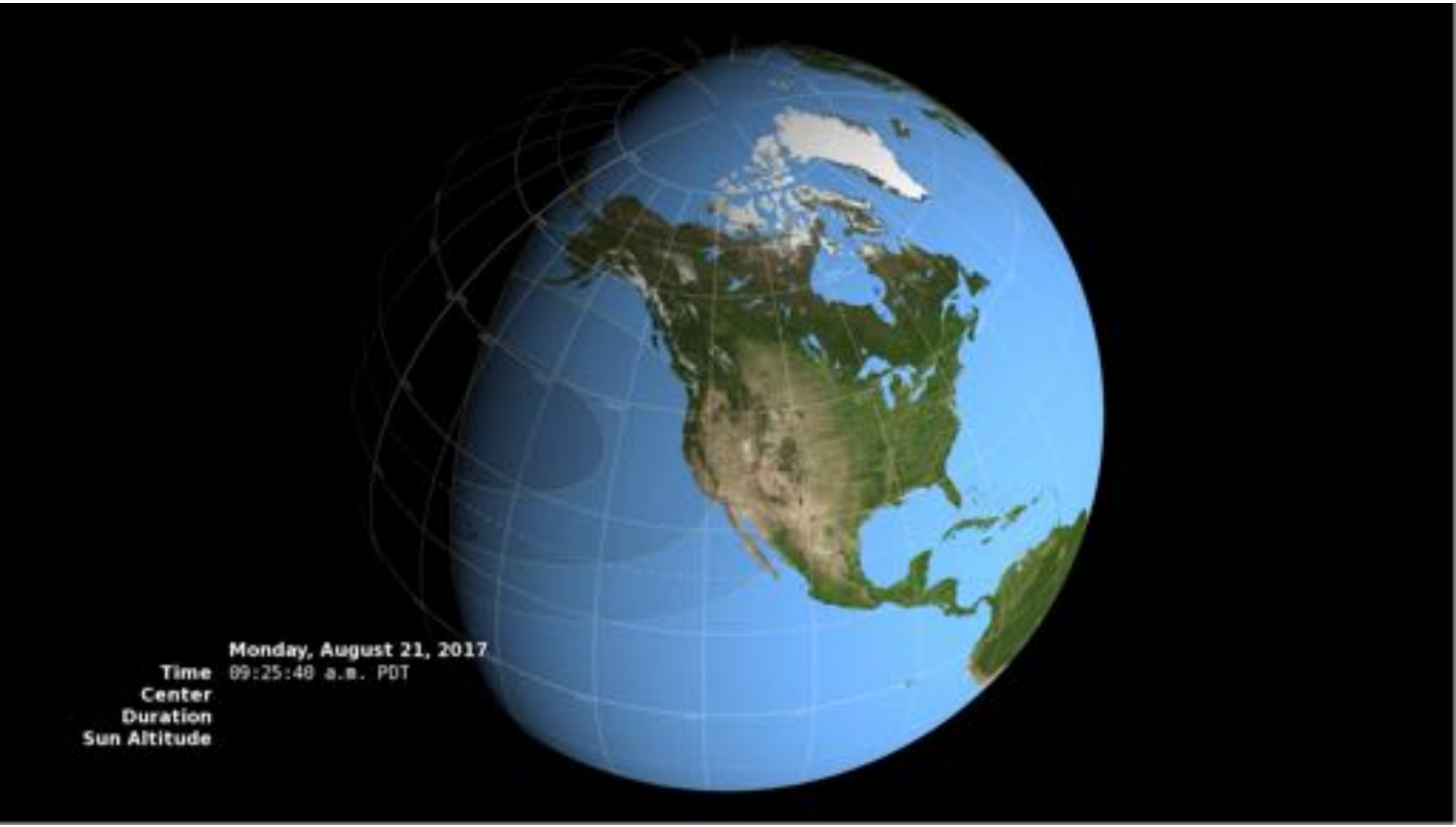
- Since the previous IAU General Assembly, we had total solar eclipses in Indonesia/Pacific in 2016 and in the one in the United States in 2017, the latter especially with major international participation from groups headed by members of the Working Group and from others. There were annular eclipses that crossed Africa and Indian Ocean islands such as Réunion in 2016 and that crossed Chile and Argentina, reaching Africa, in 2017.

Annular eclipse of 26 February 2017



Annular eclipse of 26 February 2017


Great American Eclipse.com
Eclipse ends at sunrise
Maximum eclipse at sunrise
Eclipse begins at sunrise
0.10 eclipse magnitude
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
Northern limit of eclipse
Eclipse ends at sunset
Maximum eclipse at sunset
Eclipse begins at sunset
Path of the total solar eclipse
16:45 UT
17:00 UT
17:15 UT
17:30 UT
17:45 UT
18:00 UT
18:15 UT
18:30 UT
18:45 UT
19:00 UT
19:15 UT
19:30 UT
19:45 UT
Southern limit of eclipse
Total solar eclipse of August 21, 2017
Eclipse magnitude is the maximum fraction of the Sun's diameter occulted by the Moon
Times given are for the moment of the local greatest eclipse
18:00 UT = 11 a.m. PDT = 12 p.m. MDT = 1 p.m. CDT = 2 p.m. EDT
Map by Michael Zeiler, January 2015
Calculations by Xavier Jubier, xjubier.free.fr
Predictions by Fred Espenak, eclipsewise.com



NASA’s Goddard Space Flight Center Scientific Visualization Studio; Ernie Wright

From our observing site
campus of Willamette University
Salem, Oregon

Scientific colleagues:
Ron Dantowitz, Clay Center Observatory
Daniel Seaton ‘01, NOAA and U Colorado CIRES
Vojtech Rusin, Slovakian Academy of Sciences
John Seiradakis, Aristotle U, Thessaloniki
Aristeidis Voulgaris, Aristotle U, Thessaloniki
Marcos Peñaloza-Murillo, U de los Andes, Venezuela

Williams College undergraduates:
Erin Meadors ‘20
Cielo Perez ’19
Brendan Rousseau ‘19
Ross Yu ‘19
Declan Daly ‘20
Connor Marti ‘20
Christian Lockwood ‘20
Charles Ide ‘20

Graduate students:
Allen Davis ’14 (now Yale U)
Muzhou Lu ‘13 (now U Colorado, Boulder)
David Sliski (now U Penn)
Amy Steele ‘08 (now U Maryland)

additional alumni scientists
Duane Lee ’01 (Ph.D. Columbia)
(Vanderbilt U; newly MIT)
Marcus Freeman ‘08 (Ph.D. RIT)

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Above:
Chinese team, based at Yunnan Observatory

Above:
Williams College team

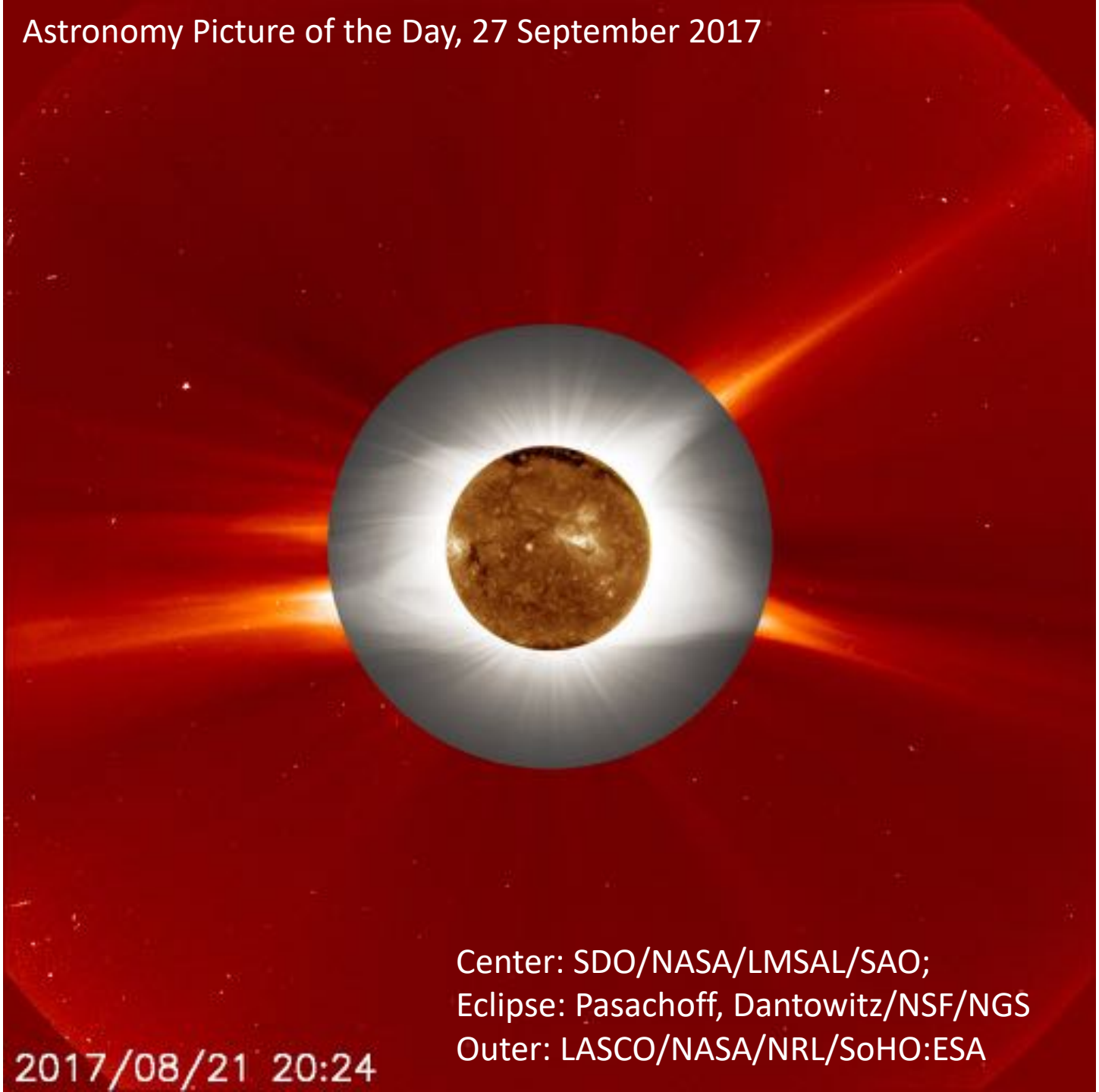
Below:
Japanese team, based at Kyoto Obs.

Alan Sliski

Our composite image from Salem with 68 individual images included

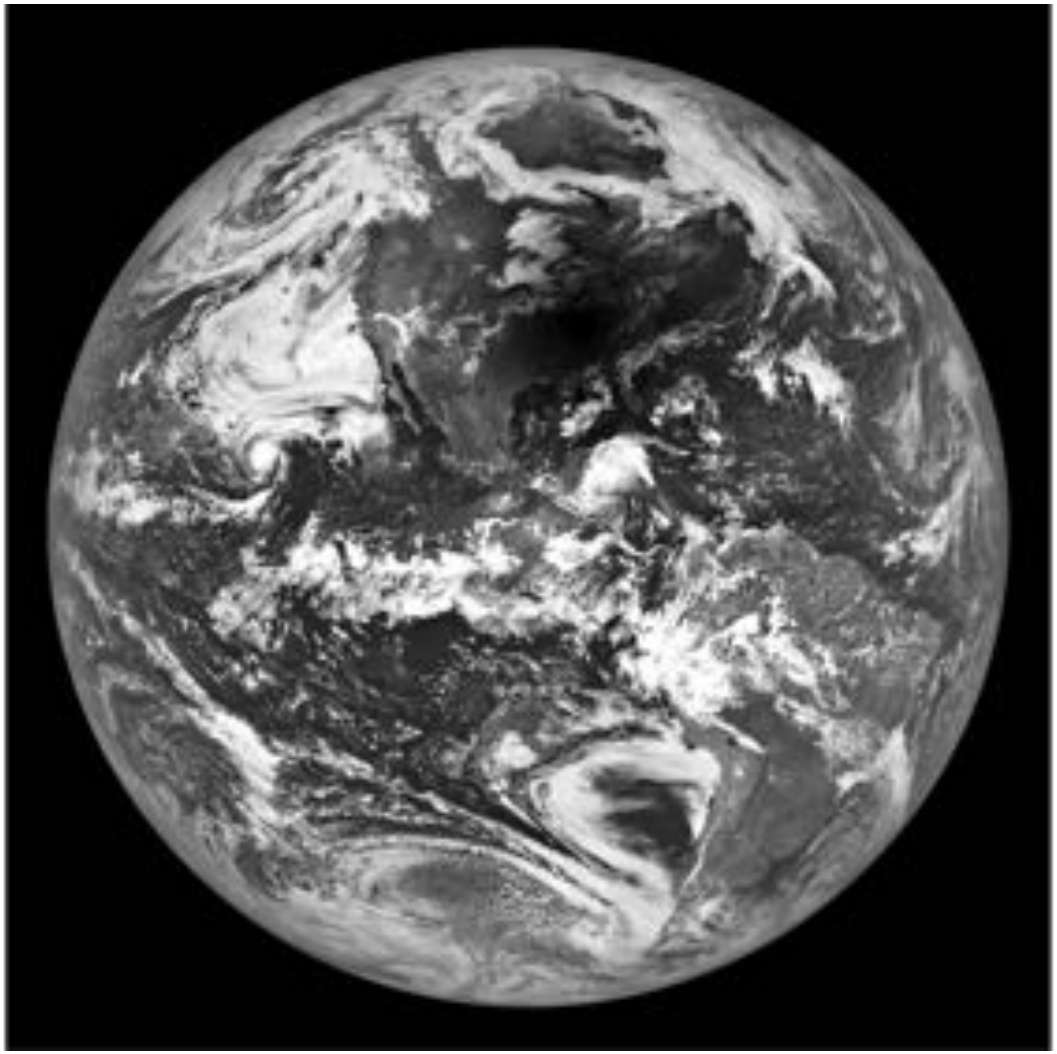
Jay Pasachoff, Vojtech Rusin, Roman Vanur, and the Williams College Solar Eclipse Expedition

Astronomy Picture of the Day, 27 September 2017



GOES-16 weather satellite
National Oceanic and Atmospheric Administration (NOAA)

Lunar Reconnaissance Orbiter



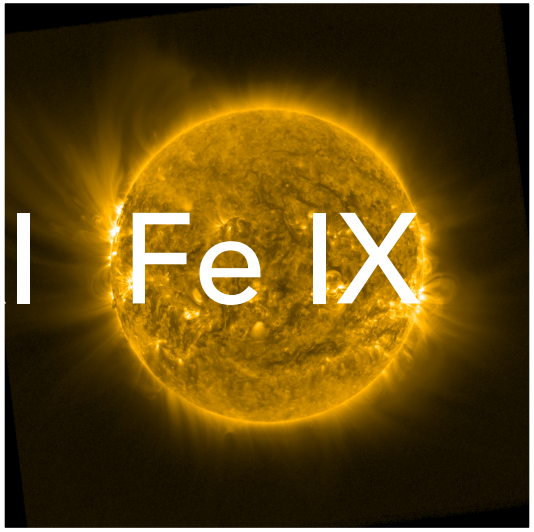
NASA / GSFC / Arizona State Univ. / LRO

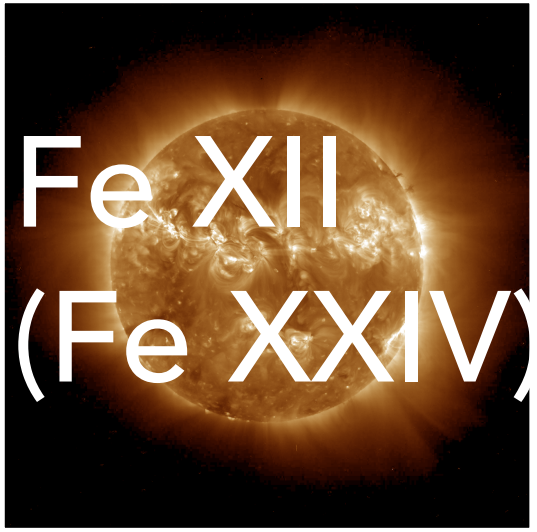
International Space Station eclipse view
(NASA/ESA)

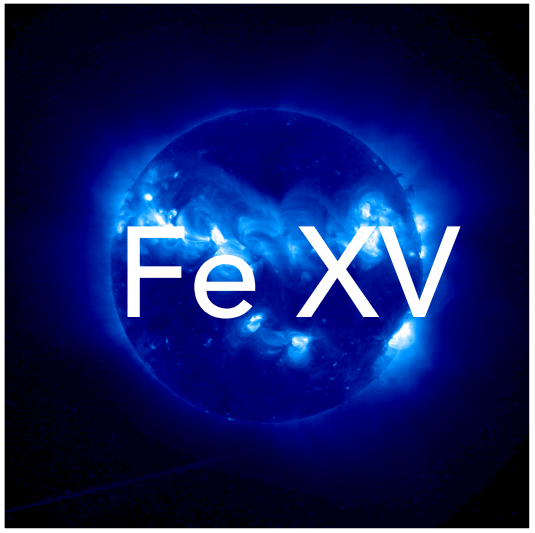
The Solar Ultraviolet Imager on GOES-16

GOES-R/SUVI

Spectral Response

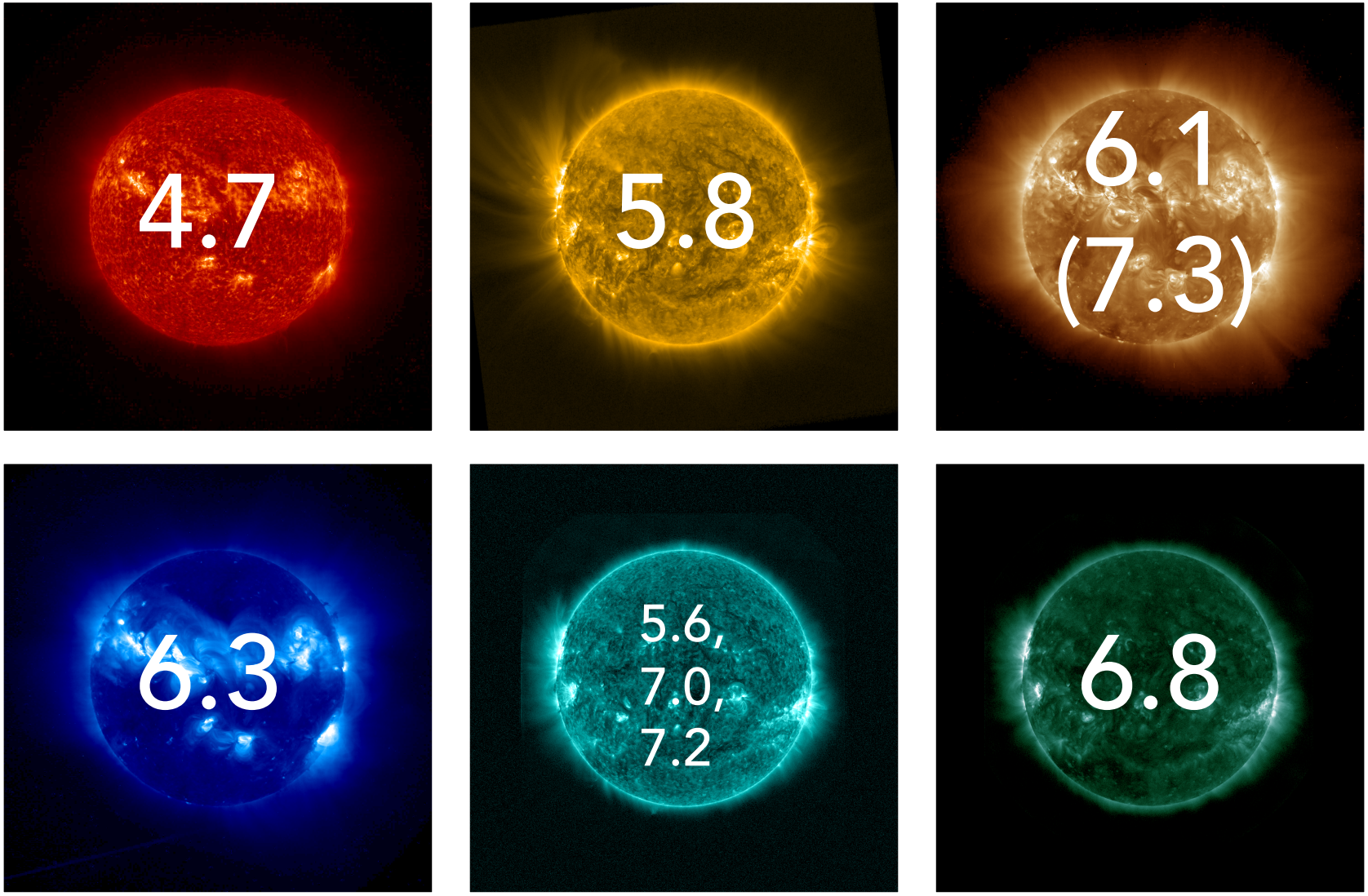


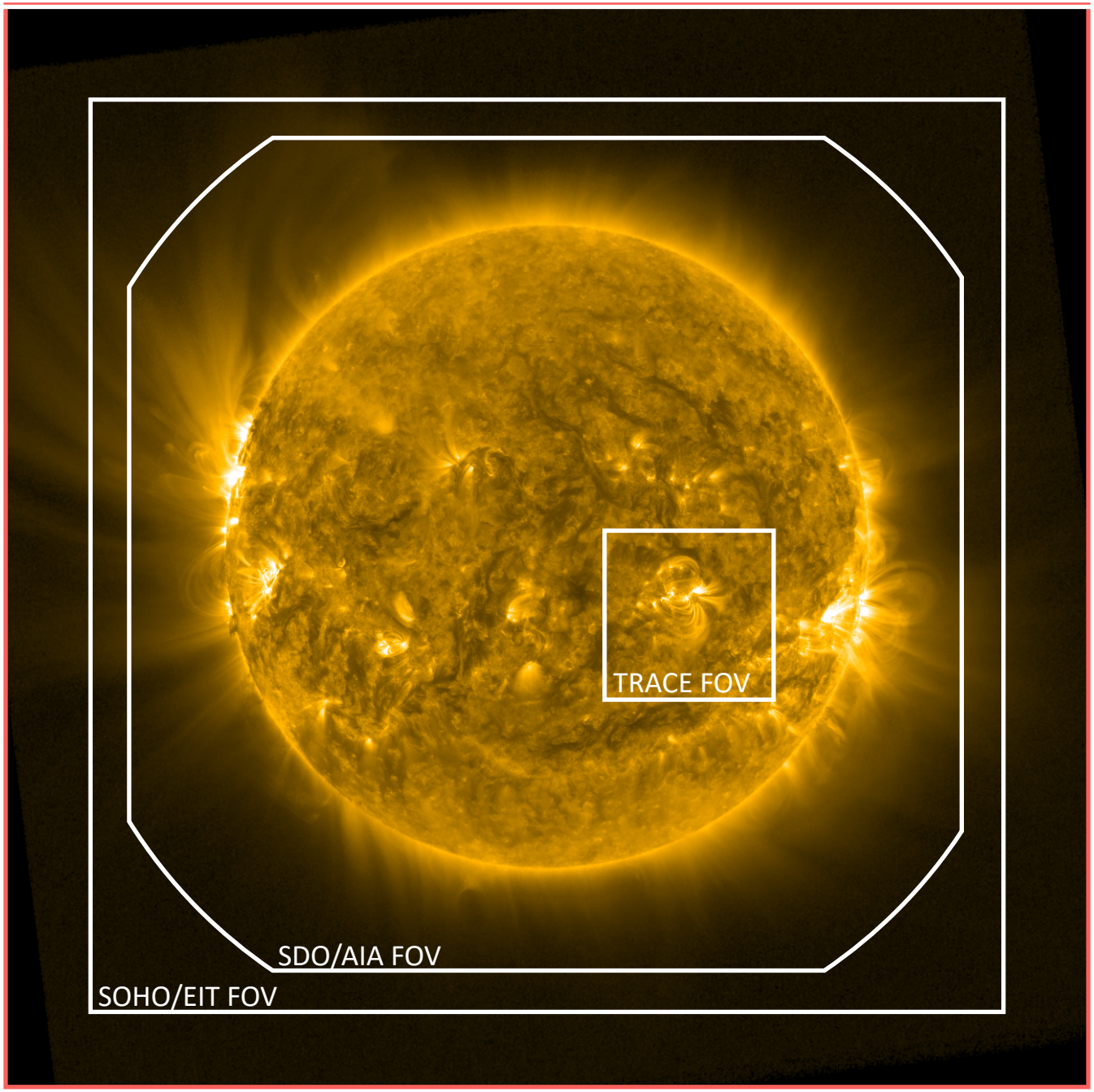




GOES-R/SUVI

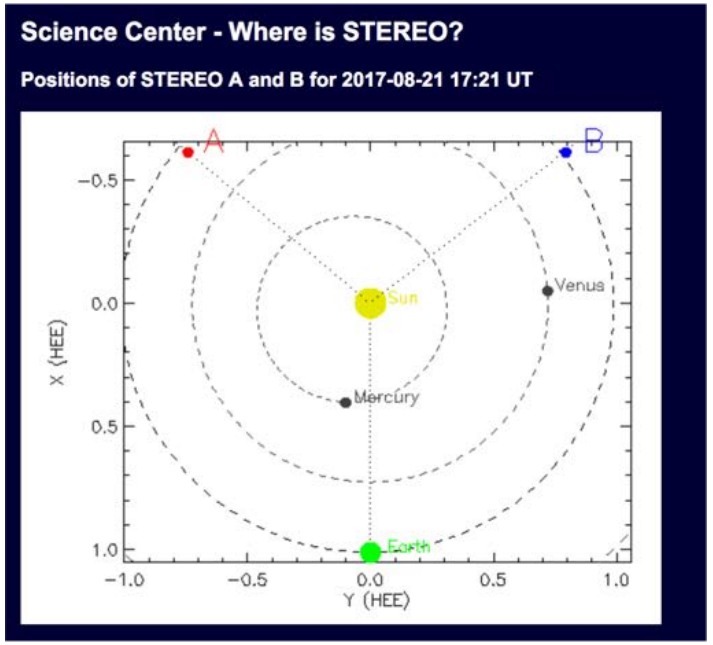
Temperature Response (Log_{10} T)





GOES FOV

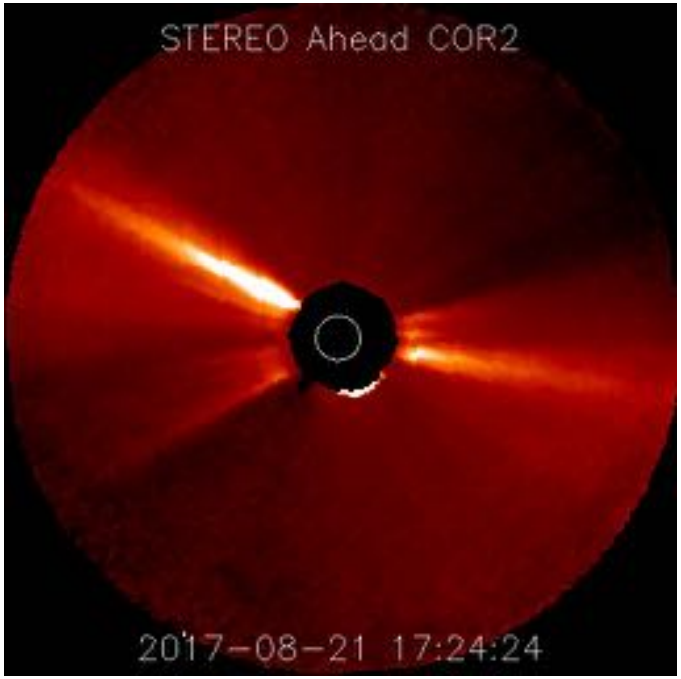
STEREO A COR2 Observations during Eclipse



View of corona from farside - Shows small ejection

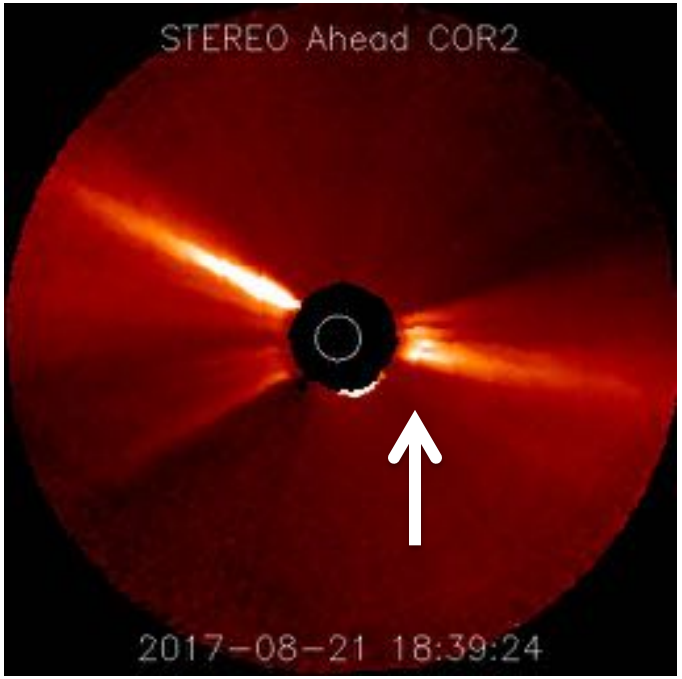
(showing space weather beacon data - high res available later via Stereo Science Center)

West Coast 17:24 UT



White circle shows size of Sun

East Coast 18:39 UT



Courtesy P. Liewer

Important notice about STEREO Behind

STEREO Instruments

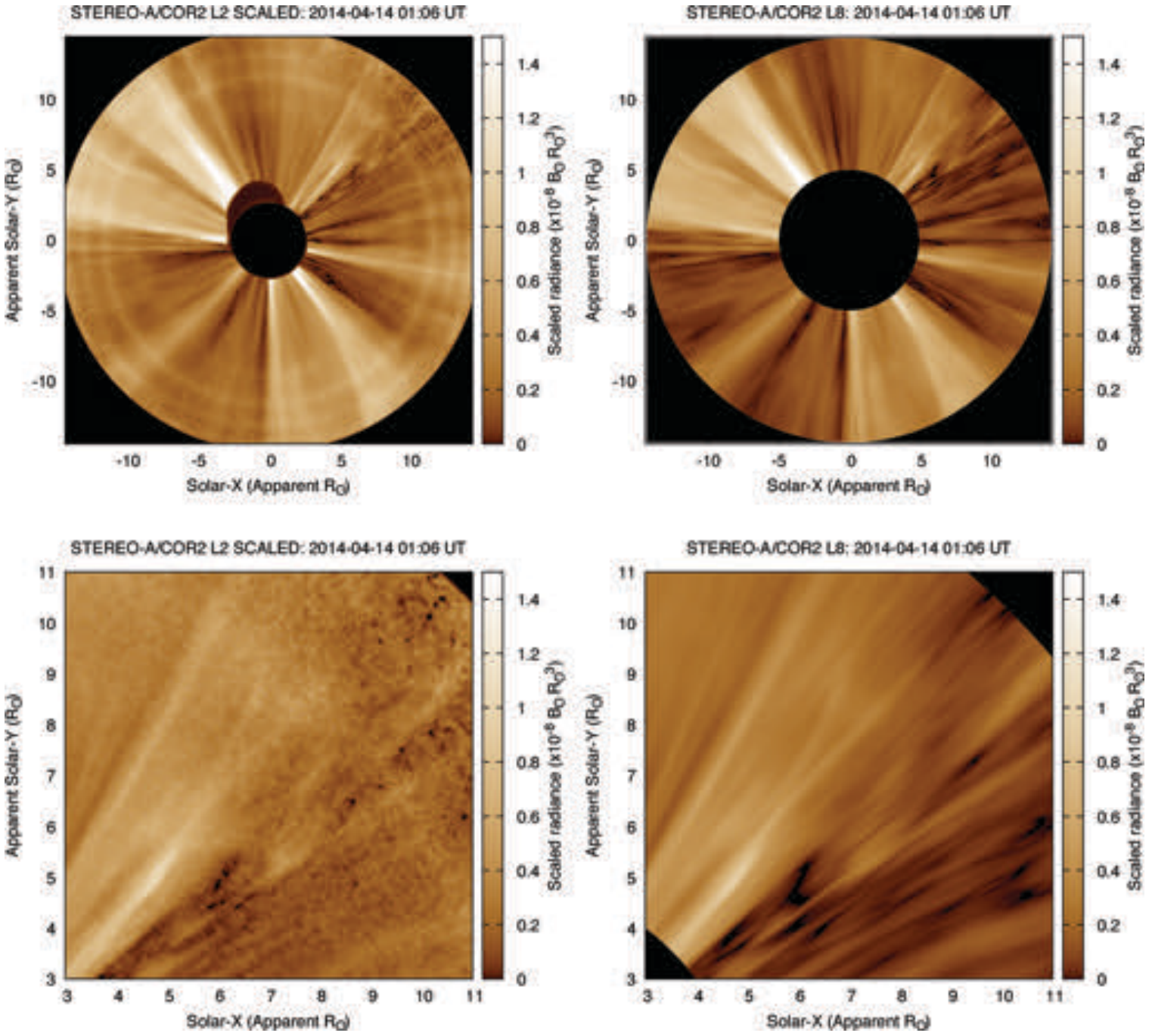
» Additional Instrument Resources

» The following four instrument packages are mounted on each of the two STEREO spacecraft:

SUN EARTH CONNECTION CORONAL AND HELIOSPHERIC INVESTIGATION (SECCHI)

Comprised of four instruments: an extreme ultraviolet imager, two white-light coronagraphs and a heliospheric imager. These instruments study the 3-D evolution of CME's from birth at the Sun's surface through the corona and interplanetary medium to its eventual impact at Earth. Principal Investigator: Dr. Russell Howard, Naval Research Laboratory, Washington, D.C.

- SECCHI EUVI: Extreme UltraViolet Imager (LMSAL)
- SECCHI COR1: Inner Coronagraph (GSFC)
- SECCHI COR2: Outer Coronagraph (NRL)
- SECCHI HI: Heliospheric Imager
- Sungrazing Comets



Craig DeForest et al., 20 July 2018 *Astrophys. J.; Image Courtesy of NASA/SwRI/STEREO*

Re: Fr. Angelo Secchi

- Organized by Dr. Ileana Chinnici,

Research Astronomer

INAF-Osservatorio Astronomico di Palermo

Palermo (Italy)

- The meeting *The legacy of Angelo Secchi 200 years after his birth* will be in Rome, 3-5 September 2018

200 years after the birth of Father Angelo Secchi, many of the scientific topics in the various fields of astrophysics, meteorology, earth sciences can be backdated to his work. He was undoubtedly among the first scientists of his time to use and promote photography and spectroscopy as new innovative tools applied to the study of stars. The spectral classification of stars he envisioned is followed to these days. His interests in our own Sun have opened modern research on solar activity, on stellar atmospheres and on stellar evolution and paved the way to most of the current frontiers in the field. In many other disciplines his key contributions have produced similar long-lasting imprints that extend to this day.

The present International Conference is organized to celebrate the man and his legacy in these fields of research. A few of the modern topics that can be traced back to Secchi's pioneering work have been selected, choosing them among the most active and innovative at the present time. In each session, an introductory talk dedicated to the man and his work is followed by contributions focused on key aspects of the current state-of-the-art science.

A 200 anni dalla nascita del gesuita Angelo Secchi una gran parte delle tematiche scientifiche che riguardano i diversi campi dell'astrofisica, della meteorologia, delle scienze della terra, può essere ricondotta al suo lavoro. Secchi è stato fra i primi scienziati del suo tempo a usare e a promuovere l'uso di fotografia e spettroscopia per studiare le stelle in maniera innovativa. La classificazione spettrale delle stelle che aveva concepito è praticata a tutt'oggi. I suoi interessi per il nostro Sole hanno dato il via alla ricerca moderna sull'attività solare, sulle atmosfere stellari e sull'evoluzione delle stelle e hanno aperto la strada alla maggior parte delle ricerche di frontiera. L'impronta dei suoi studi si vede ancora oggi in molte altre discipline.

La Conferenza Internazionale intende celebrare Secchi uomo e il suo lavoro scientifico in diversi campi della ricerca più attuale e innovativa, tra quelli che si possono far risalire al suo lavoro pionieristico. In ogni sessione, una conferenza introduttiva è dedicata all'uomo e al suo lavoro; quelle successive sono focalizzate su aspetti chiave della ricerca oggi all'avanguardia

Please confirm your attendance

Organizing Secretariat
c/o Accademia Nazionale delle Scienze detta dei XL
Via L. Spallanzani 7 - 00161 Roma
tel.-fax. +39 6 44250056
info@bicentenarioangelosecchi.it
www.bicentenarioangelosecchi.it

International Conference

THE LEGACY OF ANGELO SECCHI SJ 200 YEARS AFTER HIS BIRTH

Rome, September 3-5, 2018
Biblioteca Casanatense
Via di Sant'Ignazio 52

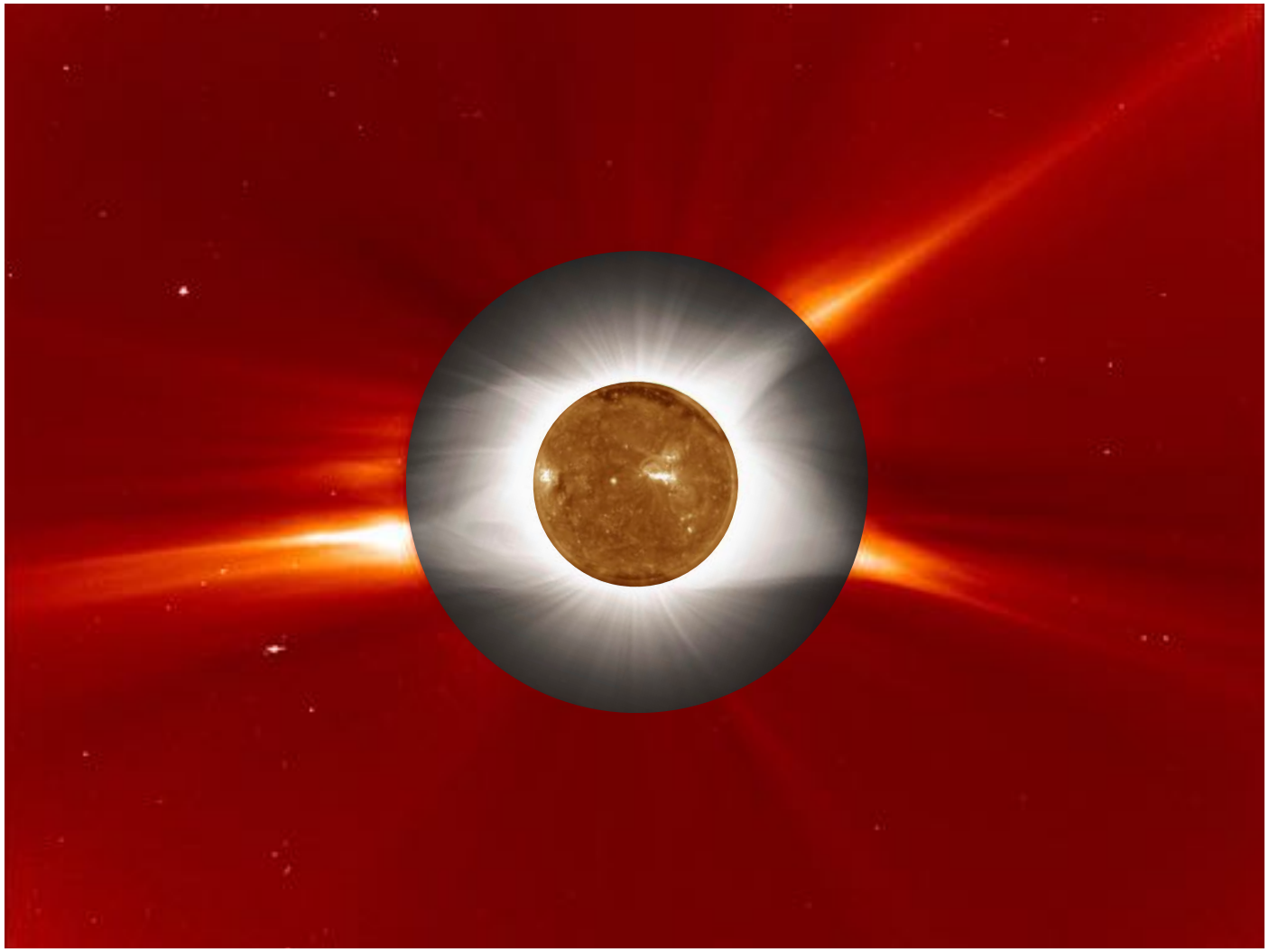
- my talk: “Secchi’s Solar Physics”
- International Conference: *The Legacy of Angelo Secchi SJ 200 Years After His Birth*
- September 3-5th at the Biblioteca Casanatense
- Comitato Nazionale per le Celebrazioni del Bicentenario della Nascita di Angelo Secchi, c/o Accademia Nazionale delle Scienze detta dei XL

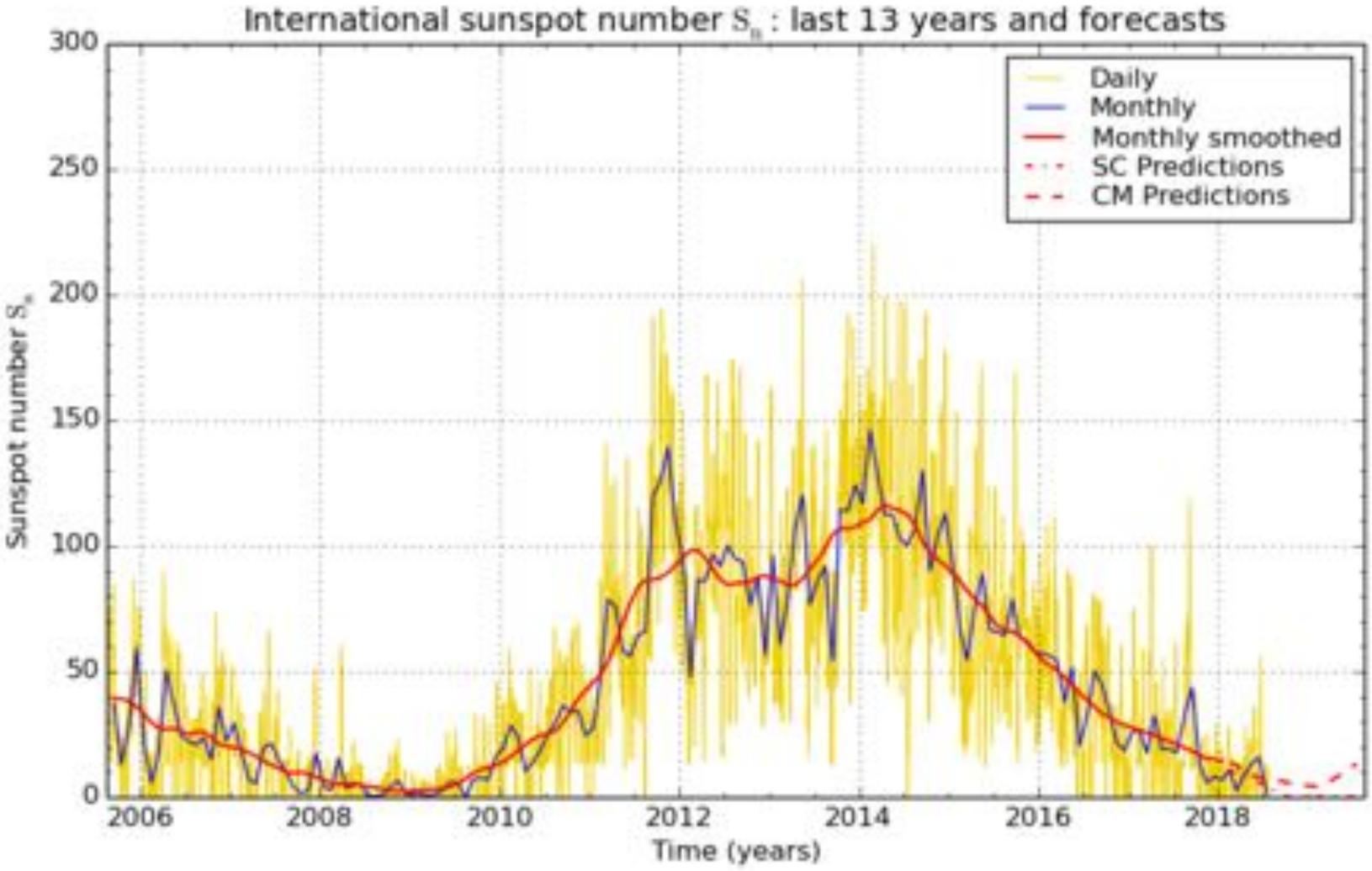
Composites with SUVI (Solar Ultraviolet Imager) on GOES-16

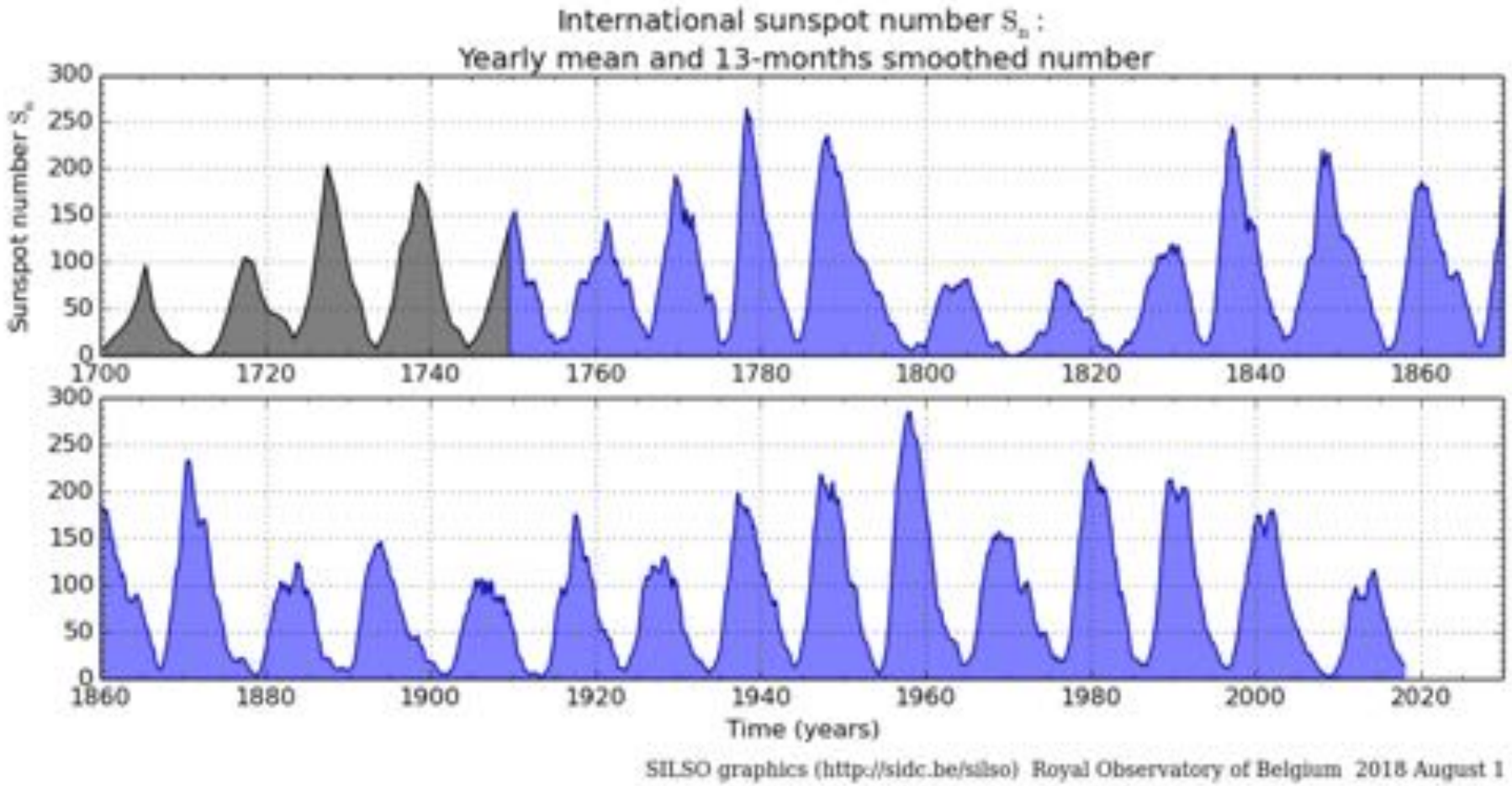
center: SUVI (Dan Seaton, NOAA/CIRES-UColorado), 195 Å

eclipse: Pasachoff/Dantowitz/NSF/NGS

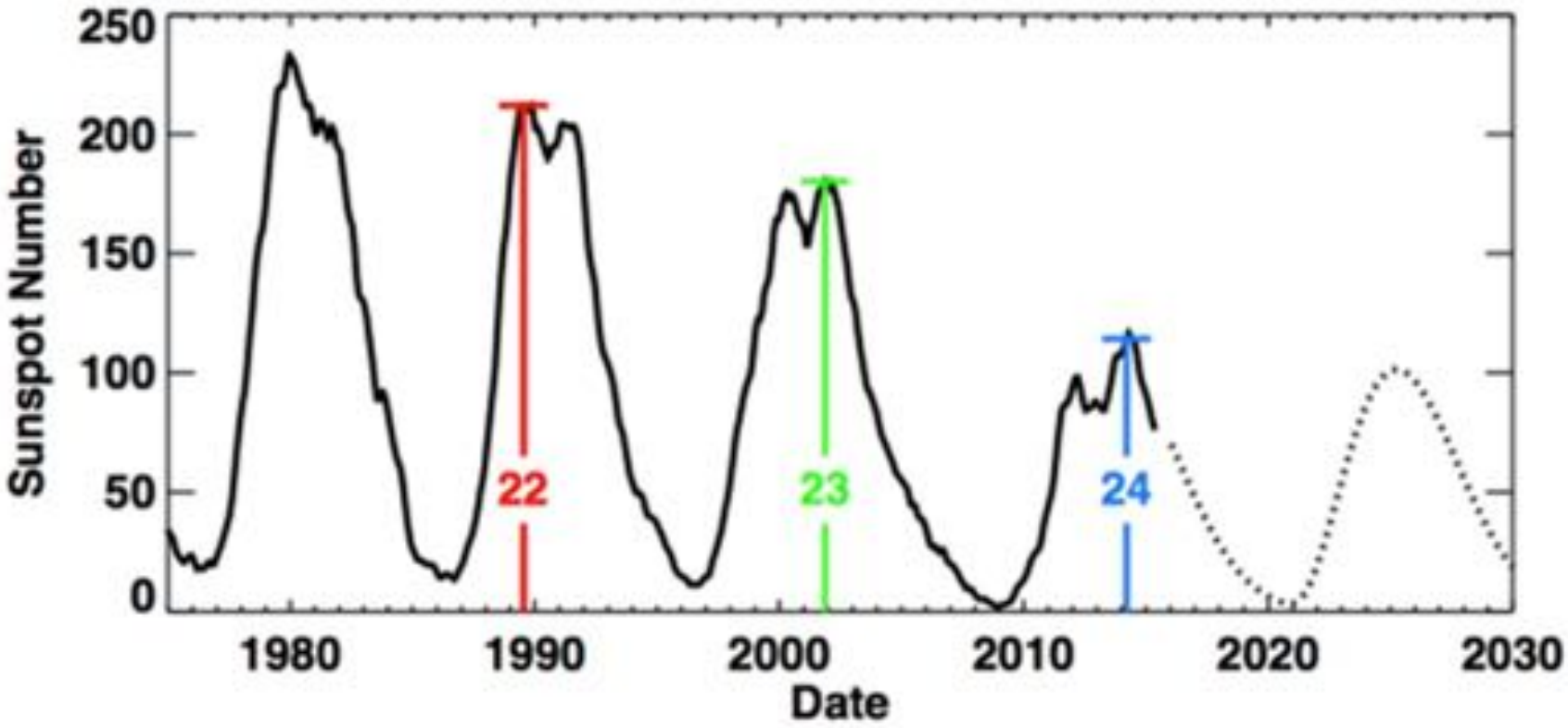
outer: Outer: LASCO/NASA/NRL/SoHO:ESA




International sunspot number S_n : last 13 years and forecasts
Daily
Monthly
Monthly smoothed
SC Predictions
CM Predictions
Sunspot number S_n
Time (years)
0
50
100
150
200
250
300
2006
2008
2010
2012
2014
2016
2018
SILSO graphics (http://sidc.be/silso) Royal Observatory of Belgium 2018 August 1


International sunspot number S_n :
Yearly mean and 13-months smoothed number
Sunspot number S_n
300
250
200
150
100
50
0
1700
1720
1740
1760
1780
1800
1820
1840
1860
1860
1880
1900
1920
1940
1960
1980
2000
2020
Time (years)
SILSO graphics (http://sidc.be/silso) Royal Observatory of Belgium 2018 August 1

Prediction by David Hathaway

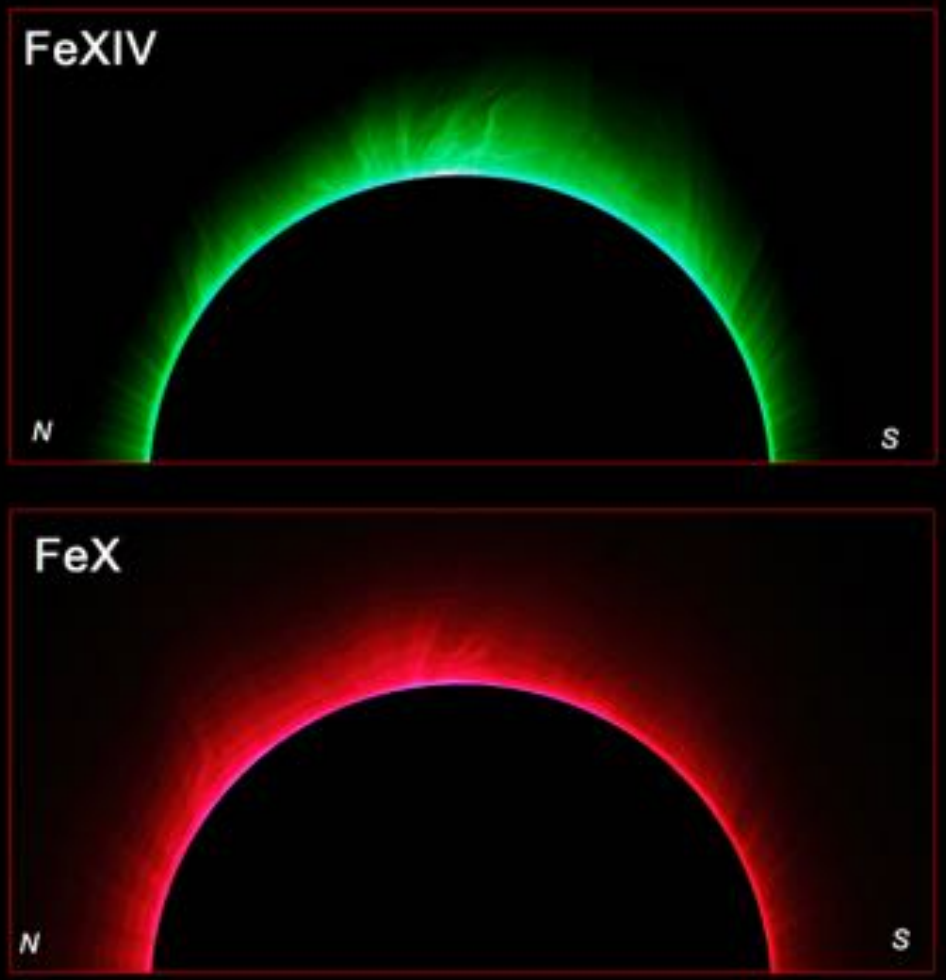


30 July 2018

TOTAL SOLAR ECLIPSE 21TH AUGUST 2017 (Salem, OR)

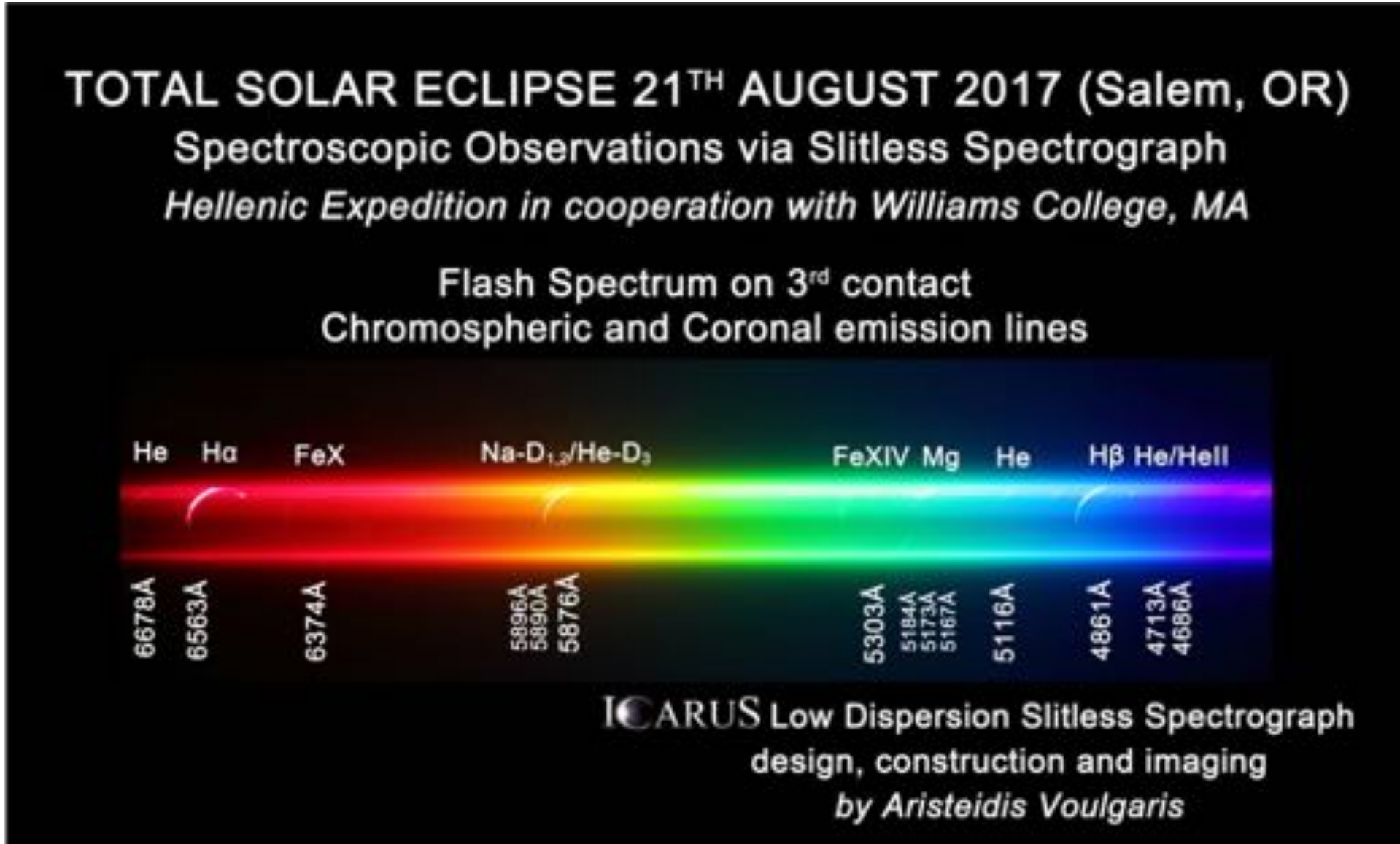
Hellenic Expedition in cooperation with Williams College, MA

FeXIV 5302.8Å and FeX 6374Å Coronal emission lines imaging via Lyot Filters

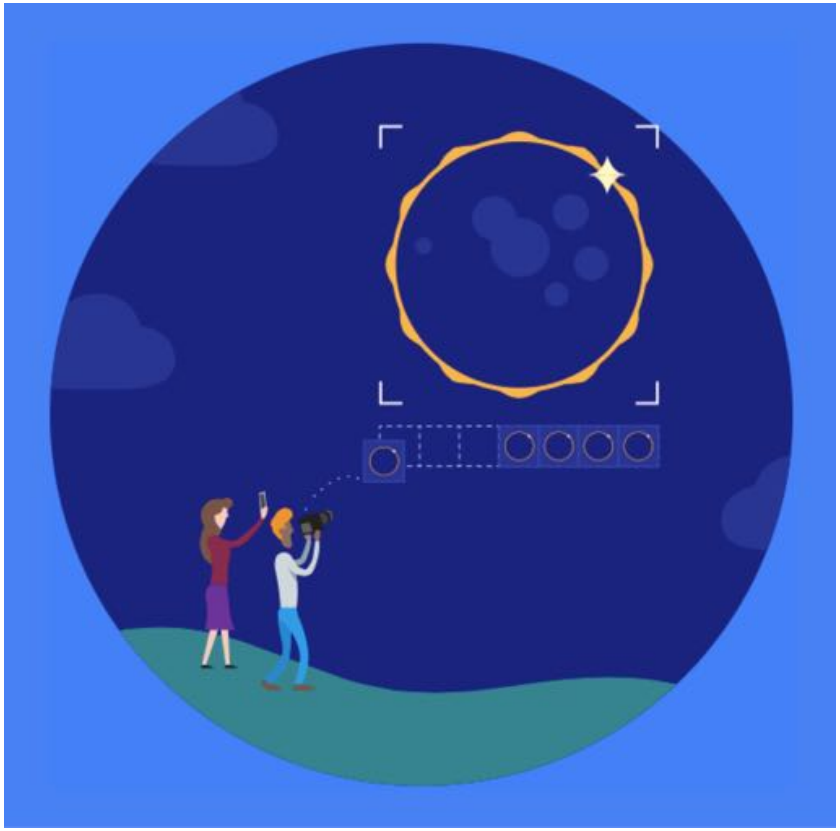


Icarus Lyot Filters, Coelostat, optical bench
design, construction and imaging
by Aristeidis Voulgaris

Aris Voulgaris, as part of the Williams College Expedition



Megamovie Success!
We have an Archive!



URL *eclipsemega.movie*

A Wyoming frame from Megamovie v.2

iphone plus 50x, Nebraska (Braxton Collier)

Also, Citizen CATE of Matt Penn (NSO) succeeded

Hudson, Hugh S., Scott W. McIntosh, Shaddia Habbal, Jay M. Pasachoff, and Laura Peticolas, 2011, "The U.S. Eclipse Megamovie in 2017: a white paper on a unique outreach event," a white paper: http://www.eclipse2017.org/2017/photo/mega_movie.htm

Composite by Christian Lockwood ‘20

NSF NATIONAL GEOGRAPHIC NASA SIGMA XI THE SCIENTIFIC RESEARCH SOCIETY Williams

Information posted at

- http://totalsolareclipse.org

Our expedition was supported in large part by grants from the Committee for Research and Exploration of the National Geographic Society and from the Solar Terrestrial Program of the Atmospheric and Geospace Sciences Division of the National Science Foundation, with additional student support from the STP/AGS of NSF, the NASA Massachusetts Space Grant Consortium, the Sigma Xi honorary scientific society, the Clare Booth Luce Foundation studentship and the Freeman Foote Expeditionary Fund at Williams College, other Williams College funds, and U. Pennsylvania funds.

Pasachoff, Jay M., and Andrew Fraknoi, 2017, "Resource Letter OSE-1 on Observing Solar Eclipses," *American Journal of Physics* **85**(7), 485-494, July.

Resource Letter OSE-1: Observing Solar Eclipses

Jay M. Pasachoff
Hopkins Observatory, Williams College, Williamstown, Massachusetts 01267 and Division of Geological and Planetary Sciences, Caltech, Pasadena, California 91125

Andrew Fraknoi
Foothill College, Los Altos Hills, California 94022

(Received 8 April 2017; accepted 22 May 2017)

This Resource Letter provides a guide to the available literature, listing selected books, articles, and online resources about scientific, cultural, and practical issues related to observing solar eclipses. It is timely, given that a total solar eclipse will cross the continental United States on August 21, 2017. The next total solar eclipse path crossing the U.S. and Canada will be on April 8, 2024. In 2023, the path of annularity of an annular eclipse will cross Mexico, the United States, and Canada, with partial phases visible throughout those countries.
[http://dx.doi.org/10.1119/1.4985062]

I. INTRODUCTION

A 60- to 71-mile-wide band of totality will cross the Continental United States on August 21, 2017, taking 90 min to span the continent with totality on the centerline ranging from about 2 min in Oregon to a maximum of 2 min 40 s in Illinois and Kentucky. The path of totality will pass through narrow paths in 12 states—Oregon, Idaho, Wyoming, Nebraska, Kansas, Missouri, Illinois, Kentucky, Tennessee, North Carolina, Georgia, and South Carolina—and clip small corners of Montana and Iowa. Since the 1918 total solar eclipse, the previous eclipse with totality that crossed the United States from coast to coast went through Bermuda, this is the first eclipse since the founding of the United States with totality entirely in the one country (Fig. 1).

The rest of the United States will see a partial eclipse, including Alaska and Hawaii; from all of Canada except the northernmost portion; from all of Mexico and Central America; and from northern South America; as well as from westernmost Africa and westernmost Europe near sunset. The solar corona is about a million times fainter than the solar photosphere, the everyday solar surface. This means

(or to look however briefly through any optical device such as a telescope or binoculars). Accordingly, it is important for eclipse-watchers to have suitable solar filters to look through at the solar crescent, or to use methods of projection such as "pinhole cameras." Images are much clearer with the new generation of "Mylar" or related filters, available very inexpensively, than with pinhole projection. For those using filter material with telescopes or binoculars, sage advice is to use the filter material on the front, Sun-facing side of the optical device, lest the concentrated solar rays burn a hole in the material if used at the exit/eyepiece.

However, it is important to note that the solar corona itself, during the minutes or seconds of totality, is about the same brightness as the full moon and equally safe to look at. Those neglecting to take off the filters for totality will not be able to see anything of the subtle, but beautiful solar phenomena an eclipse reveals. In order, these exciting phenomena are, after the last solar crescent seen through filters is extinguished, Baily's beads (the photosphere shining through the valleys on the edge of the Moon), the diamond-ring effect (the last Baily's bead shining brightly), the reddish solar chromosphere, and then—for the duration of totality—

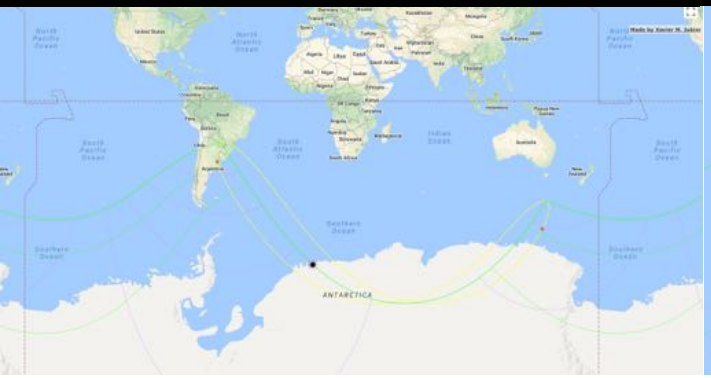
PBS NOVA
Eclipse Over America
https://nova.wistia.com/medias/py80aesc2x

Curiosity Stream
Eclipse Across America
http://curiositystream.com/eclipse

- Our Working Group's Website at http://eclipses.info provides much information, including maps and links, suitable for professional astronomers and others. After an Antarctic and Southern Africa partial eclipse in 2017, 2018 included partial eclipses in Argentina/Chile on February 15; Antarctica/Tasmania on July 13; and Arctic including northern Scandinavia and previous totality sites at Novosibirsk in Russia (site of 2008 totality) and at Svalbard (site of 2015 totality).

Partial solar eclipse of February 15, 2018
viewed from Buenos Aires, Argentina
maximum of 16%

Jay M. Pasachoff



Next partial eclipses: August 11, 2018, from northern Sweden/Norway/Siberia;
January 9, 2019, from Japan/China/Korea

Partial solar eclipse of July 13, 2018
viewed from Tasmania
maximum of 10%

Next partial eclipses:
August 11, 2018, from northern Sweden/Norway;
January 9, 2019, from Japan/China/Korea

Partial solar eclipse of July 13, 2018
viewed from Tasmania

Partial solar eclipse of July 13, 2018
viewed from Tasmania
maximum of 10%

Next partial eclipses:
August 11, 2018, from northern Sweden/Norway/Siberia;
January 9, 2019, from Japan/China/Korea

Partial solar eclipse of August 11, 2018
viewed from Stockholm, Sweden
maximum of 4%

From Rob Lucas, near Abisko, northeast of Kiruna, Sweden

Next partial eclipse:
January 6, 2019, from Japan/China/Korea

Partial solar eclipse of August 11, 2018
viewed from Stockholm, Sweden
maximum of 4%

Next partial eclipse:
January 6, 2019, from Japan/China/Korea

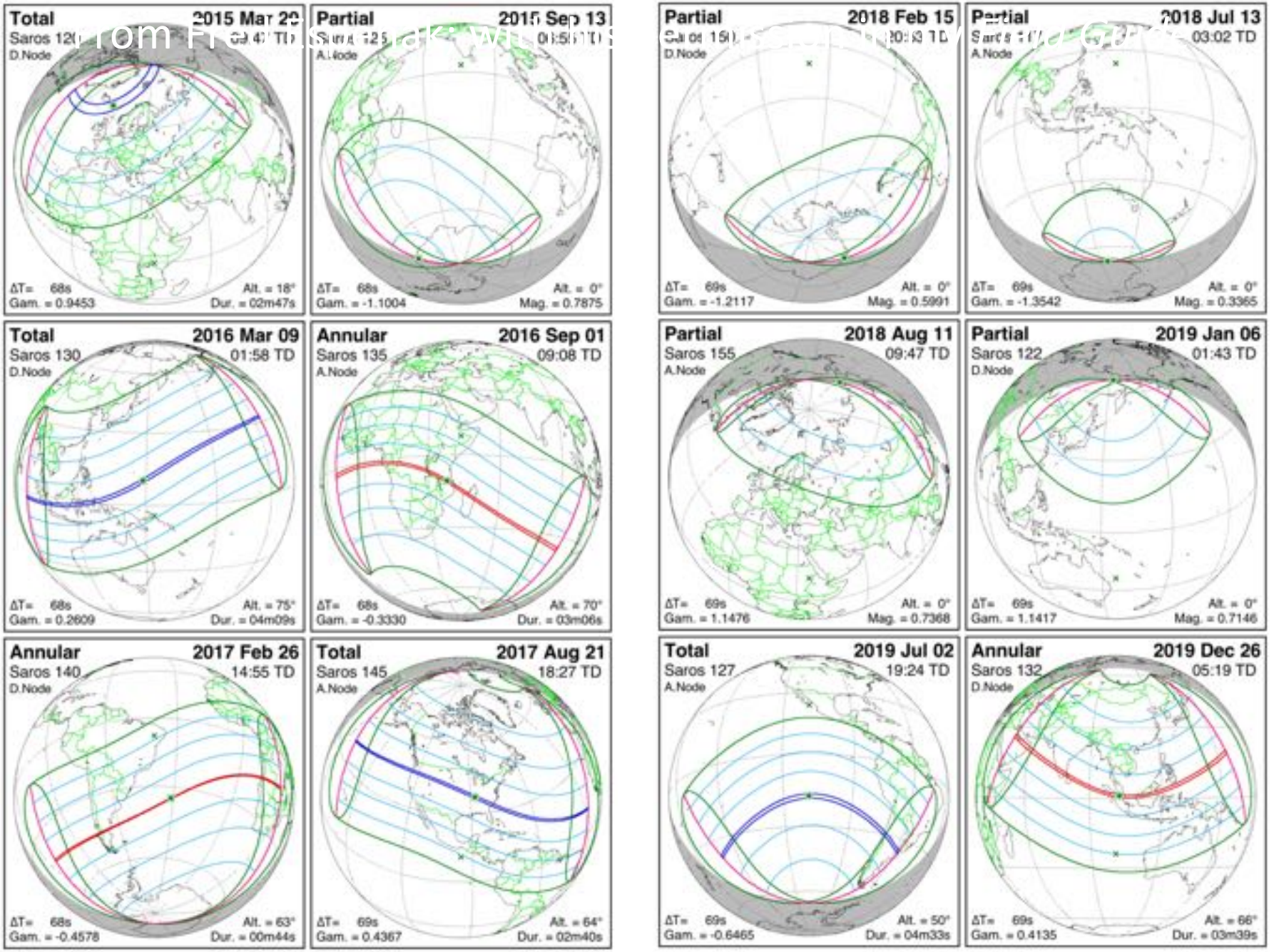
Partial solar eclipse of August 11, 2018
viewed from Stockholm, Sweden
maximum of 4%

Next partial eclipse:
January 6, 2019, from Japan/China/Korea

Partial solar eclipse of August 11, 2018
viewed from Yakutsk, Eastern Siberia, Russia, by Xavier Jubier
maximum magnitude of 65%

Next partial eclipse:
January 6, 2019, from Japan/China/Korea

- We have assisted with vouching for our scientists to obtain visas and duty-free temporary import of scientific equipment.
- The following triennium has total solar eclipses in Chile/Argentina on 2 July 2019 and on 14 December 2020; and annular eclipses on 26 December 2019, 21 June 2020, and 10 June 2021.
- It also includes a partial eclipse visible from China, Russian Siberia, Korea, and Japan on 6 January 2019.



Fred Espenak, EclipseWise.com

July 2, 2019

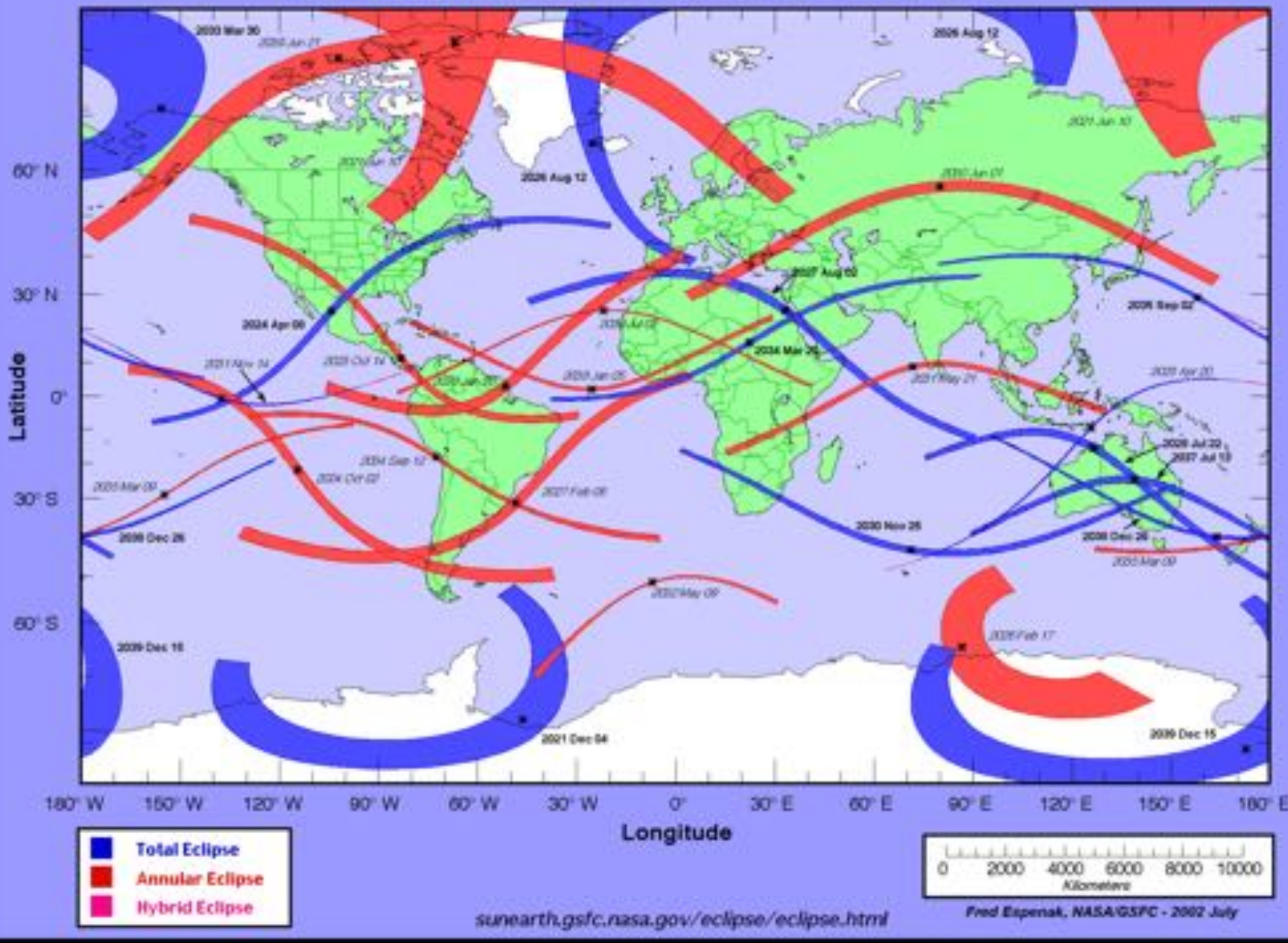
Next annular eclipse: India/Sri Lanka, December 26, 2019

Xavier Jubier map

December 14, 2020

Xavier Jubier map

Total and Annular Solar Eclipse Paths: 2021 –2040




Adam Schiff; Tina Seeger; Muzhou Lu

cupcakes by
Tina Seeger
‘16
Muzhou Lu
‘13
Adam Schiff
‘15


Partial Eclipse
Cupcakes
(because we are low on frostings)

Special Edition

"Sun-in-
H-alpha"
Cupcake

Annular Eclipse Cupcakes

"If you like it, then you (probably should) have put a ring on it." (then in your stomach)

Special Edition

- Totality/Corona Cupcake

Solar Minimum

Cupcakes

For the traditionalists

Solar Maximum

Cupcakes

Get one now, or you will have to wait another 11 years!

Special Edition

Prominence Eruption Cupcake

Coronal "Messy" Ejection

Transit of Venus

Cupcakes (because we are low on chocolate chips)

Note: ① Almost to scale

② Notice the "drop" shape of "Venus"