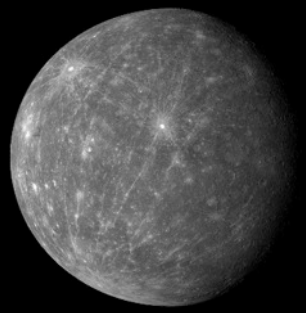
nperature Spectroscopy: Application of Laser lectance of the poles of the Moon and Mercury

Siegler, Paul Lucey, Myriam Lemelin Greg Neumann,
Greenhagen, Paul Hayne, David Paige, Pierre Williams

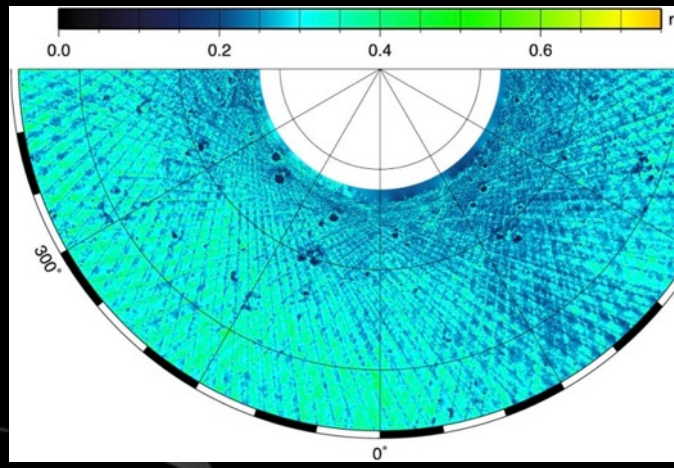
nperature Spectroscopy: Application of Laser lectance of the poles of the Moon and Mercury



Siegler, Paul Lucey, Myriam Lemelin Greg Neumann,
Greenhagen, Paul Hayne, David Paige, Pierre Williams

Outline

1) MLA (laser altimeter) evidence for ice on Mercu
2) New data from Mercury and the Moon
3) Surface brightening model
   "Thermal spectroscopy"
4) What do we see in the LOLA data?
5) How does this compare
   to Mercury? To LAMP?



Big Questions:

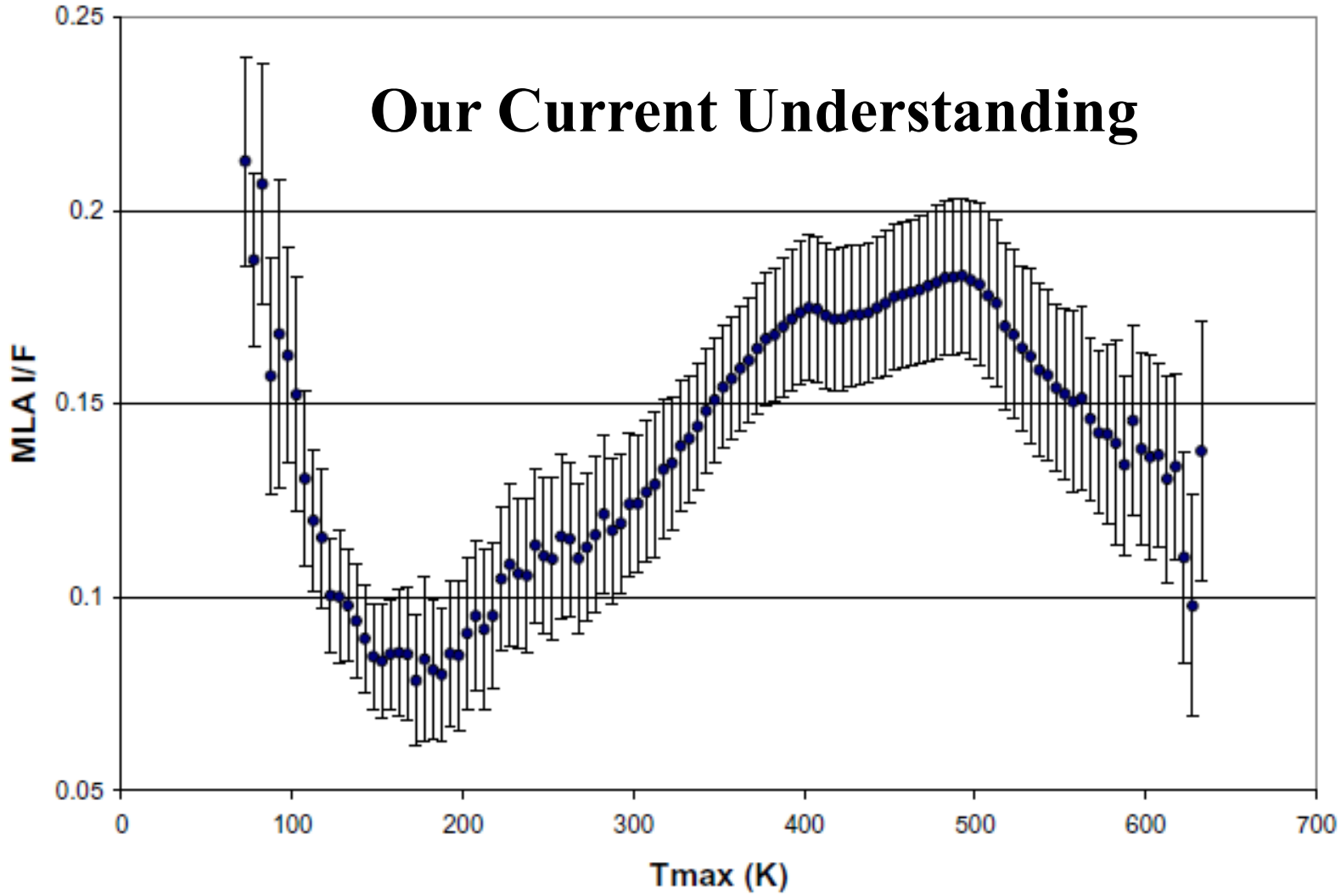
Do we see any similar laser reflectance features on the Moon?

And are they the same ones?

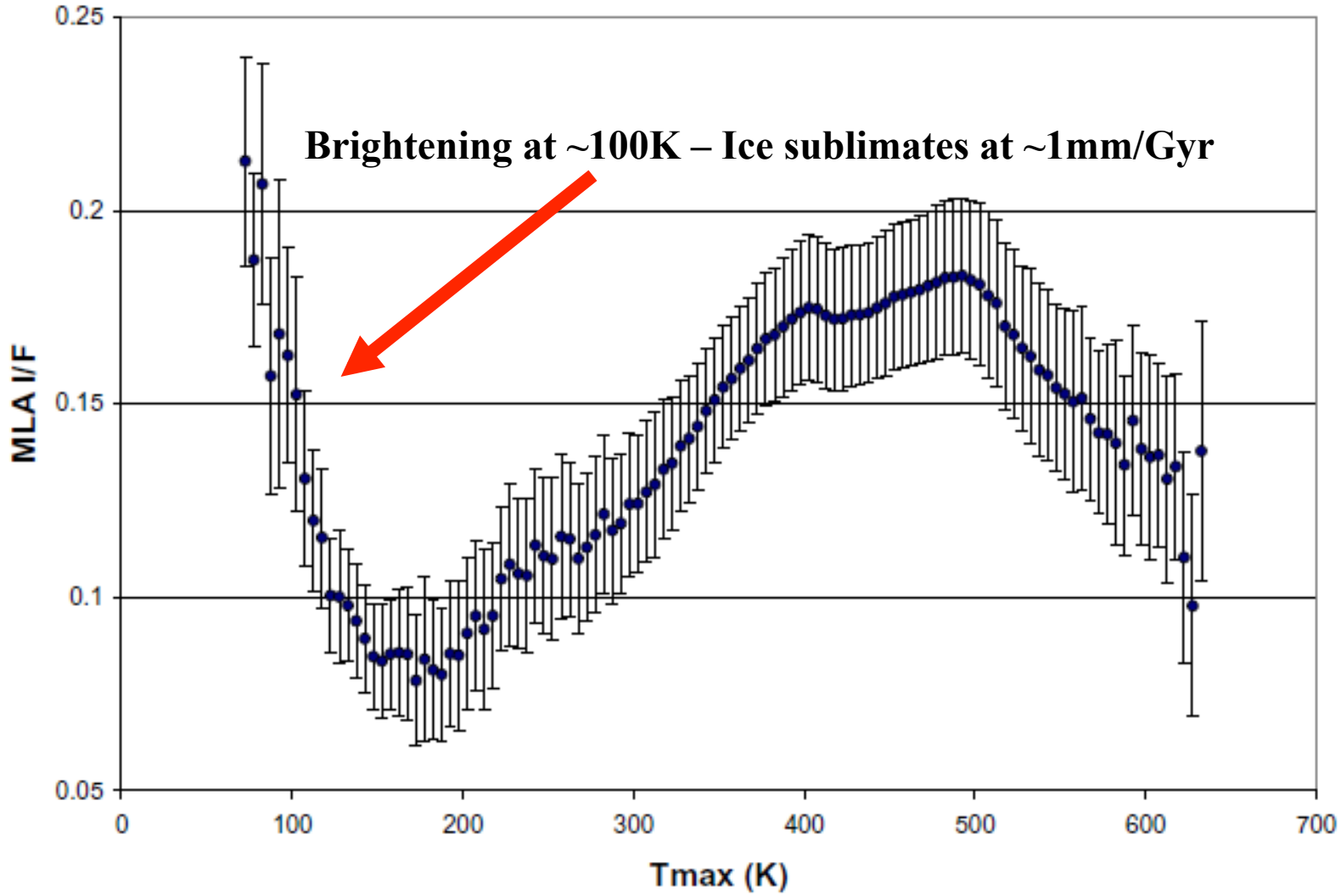
Do these point at specific volatiles?

What does this tell us about the origin and age of the volatiles on both bodies?

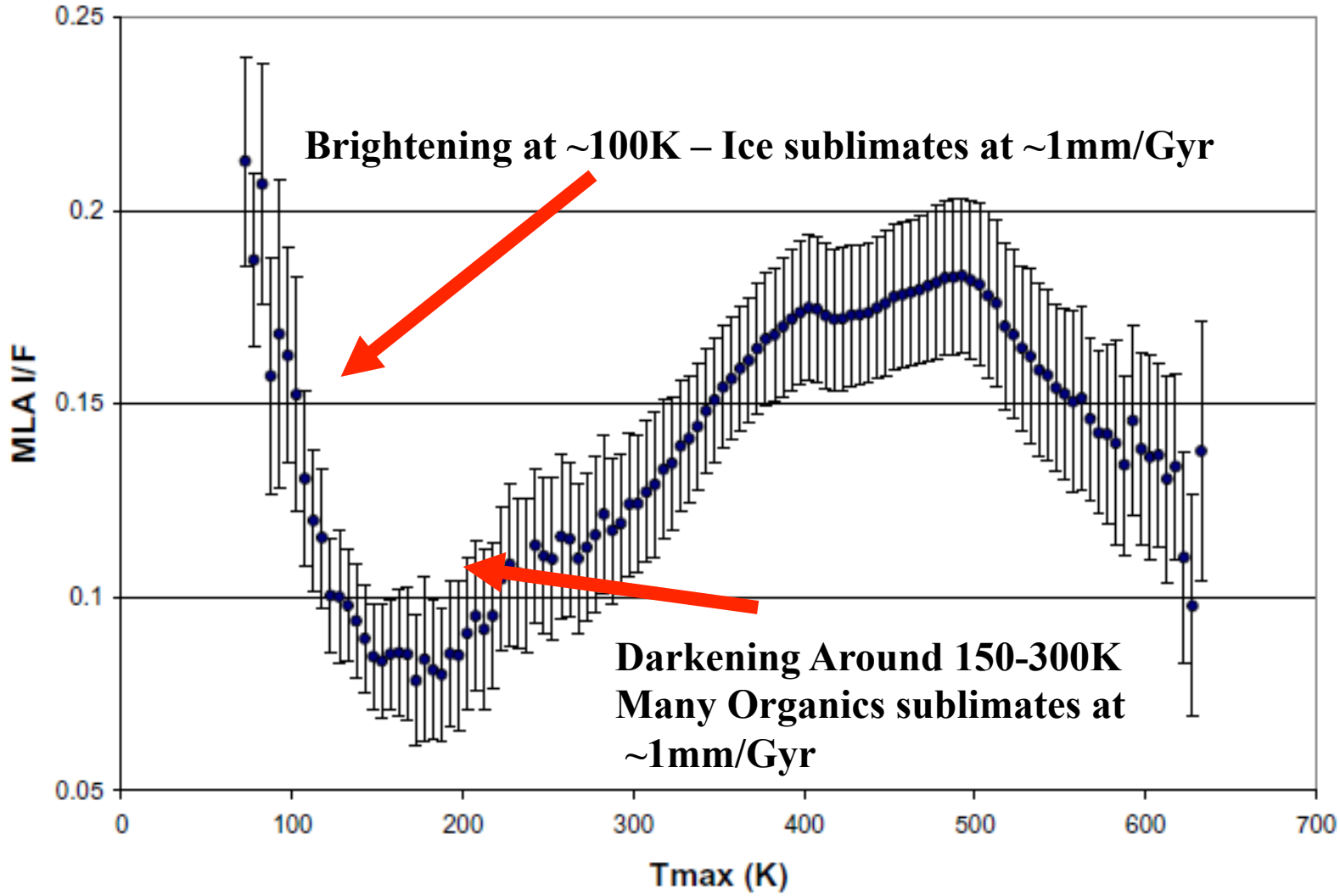
Mercury

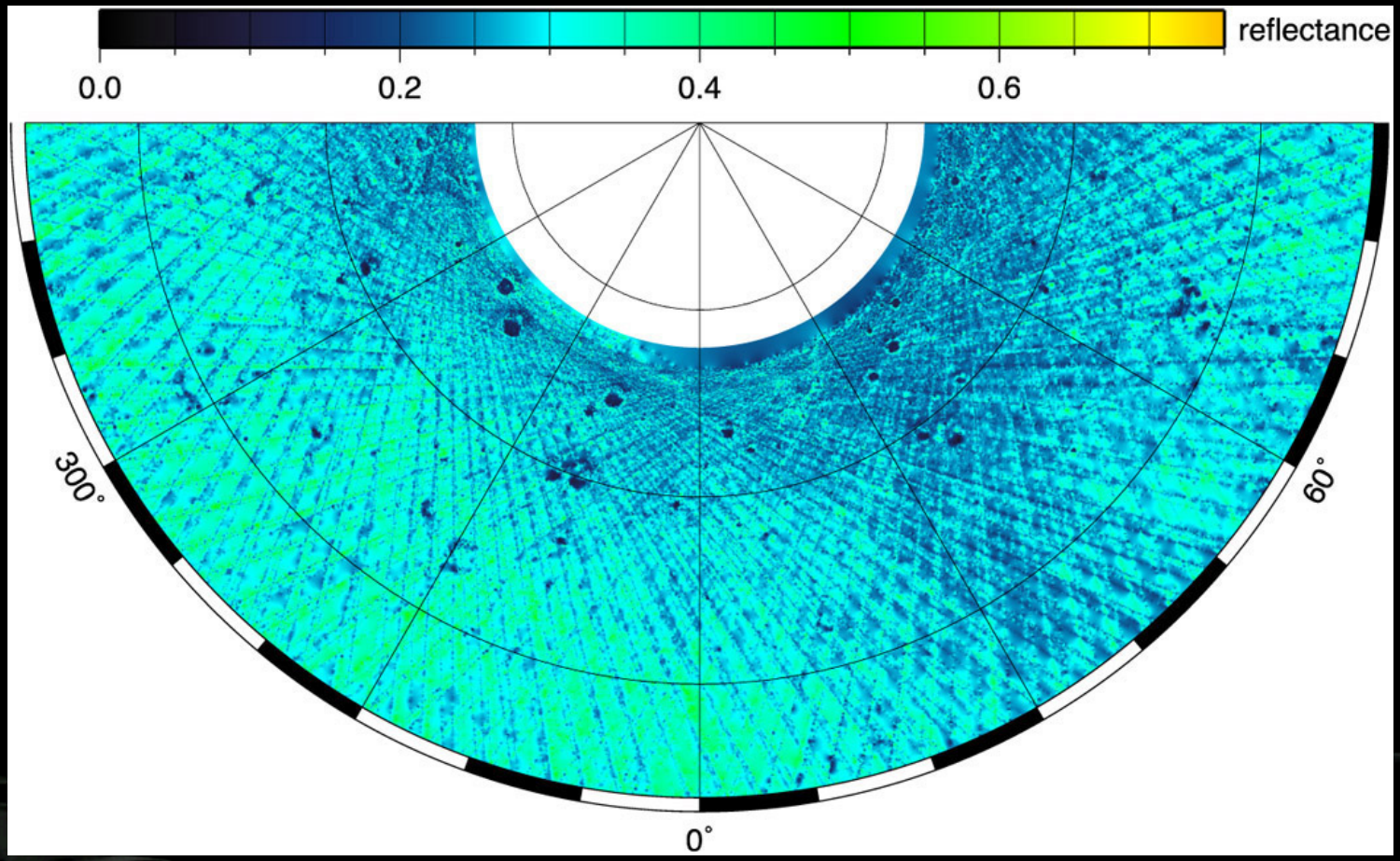

Our Current Understanding
MLA I/F
0.25
0.2
0.15
0.1
0.05
0
100
200
300
400
500
600
700
Tmax (K)

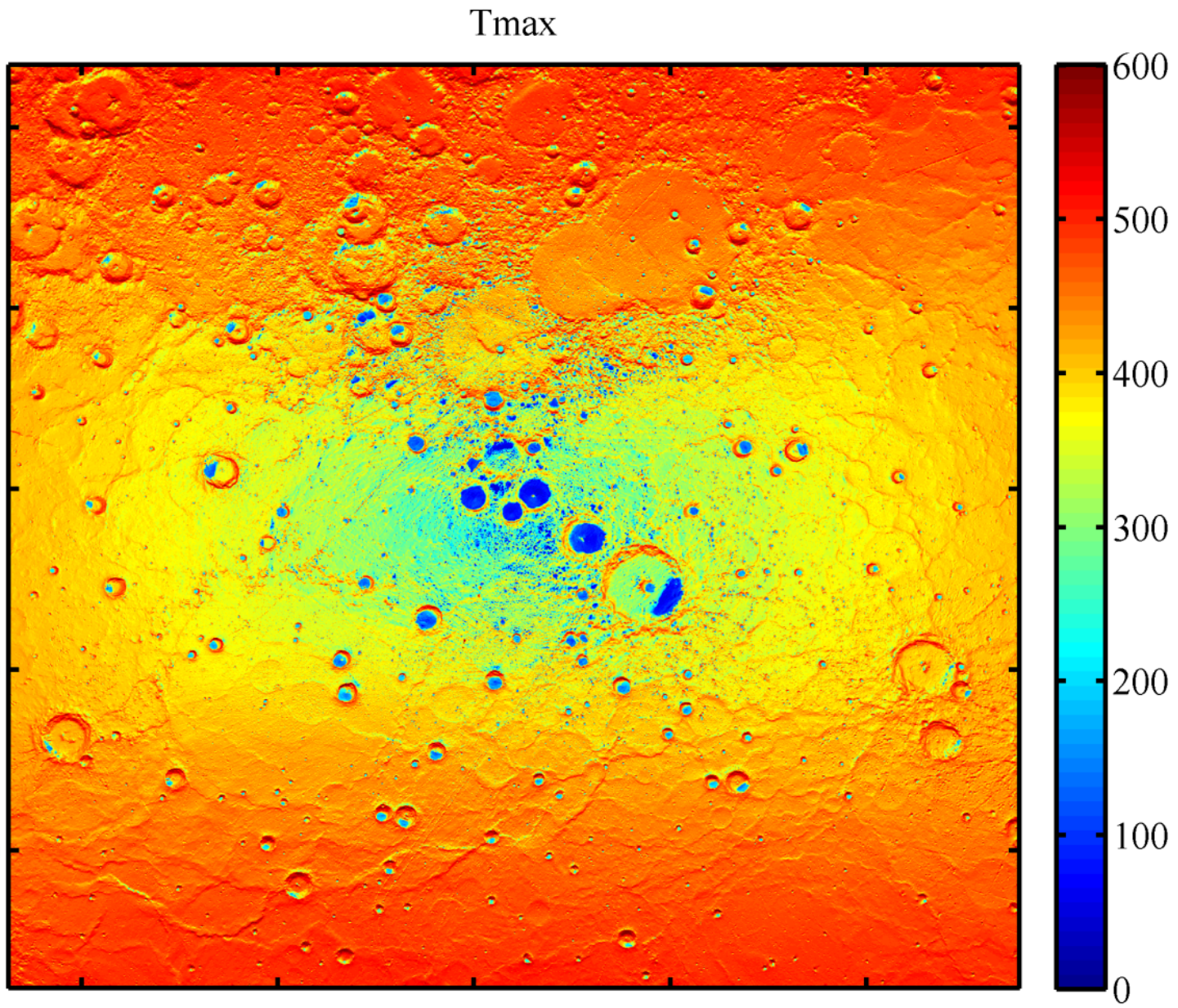
Mercury


Brightening at ~100K – Ice sublimates at ~1mm/Gyr
MLA I/F
0.25
0.2
0.15
0.1
0.05
0
100
200
300
400
500
600
700
Tmax (K)

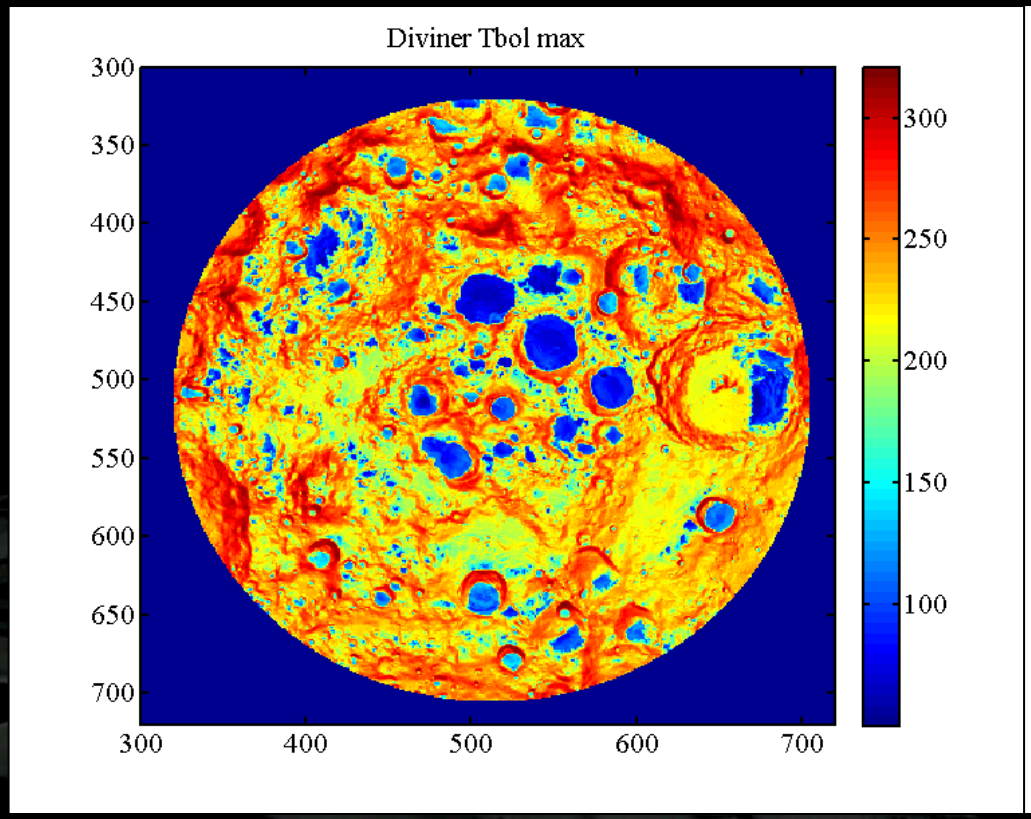
Mercury

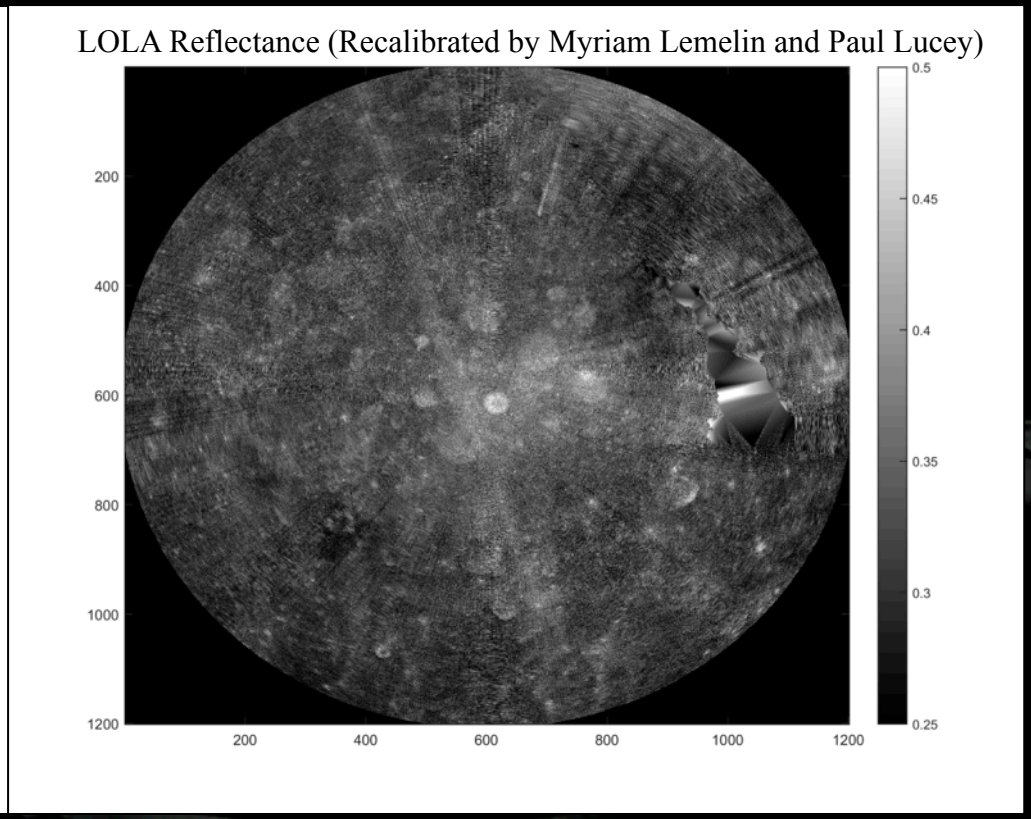

Brightening at ~100K – Ice sublimates at ~1mm/Gyr
Darkening Around 150-300K
Many Organics sublimates at
~1mm/Gyr
MLA I/F
Tmax (K)
0.25
0.2
0.15
0.1
0.05
0
100
200
300
400
500
600
700

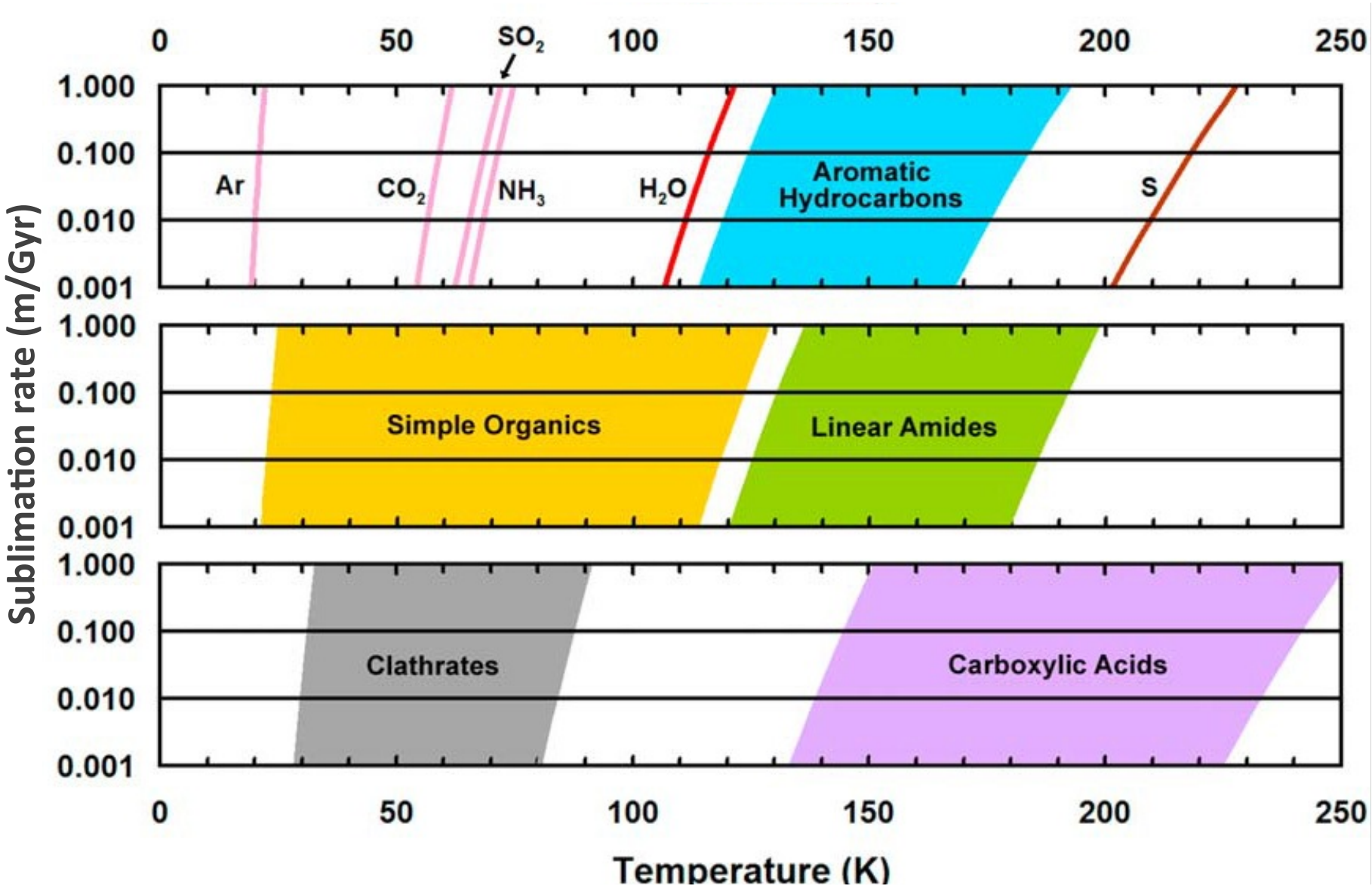

reflectance
0.0
0.2
0.4
0.6
300°
60°
0°


Tmax
600
500
400
300
200
100
0

With new temperatures
and new LOLA Reflectance
can we learn more about composition
and areal coverage of these materials?

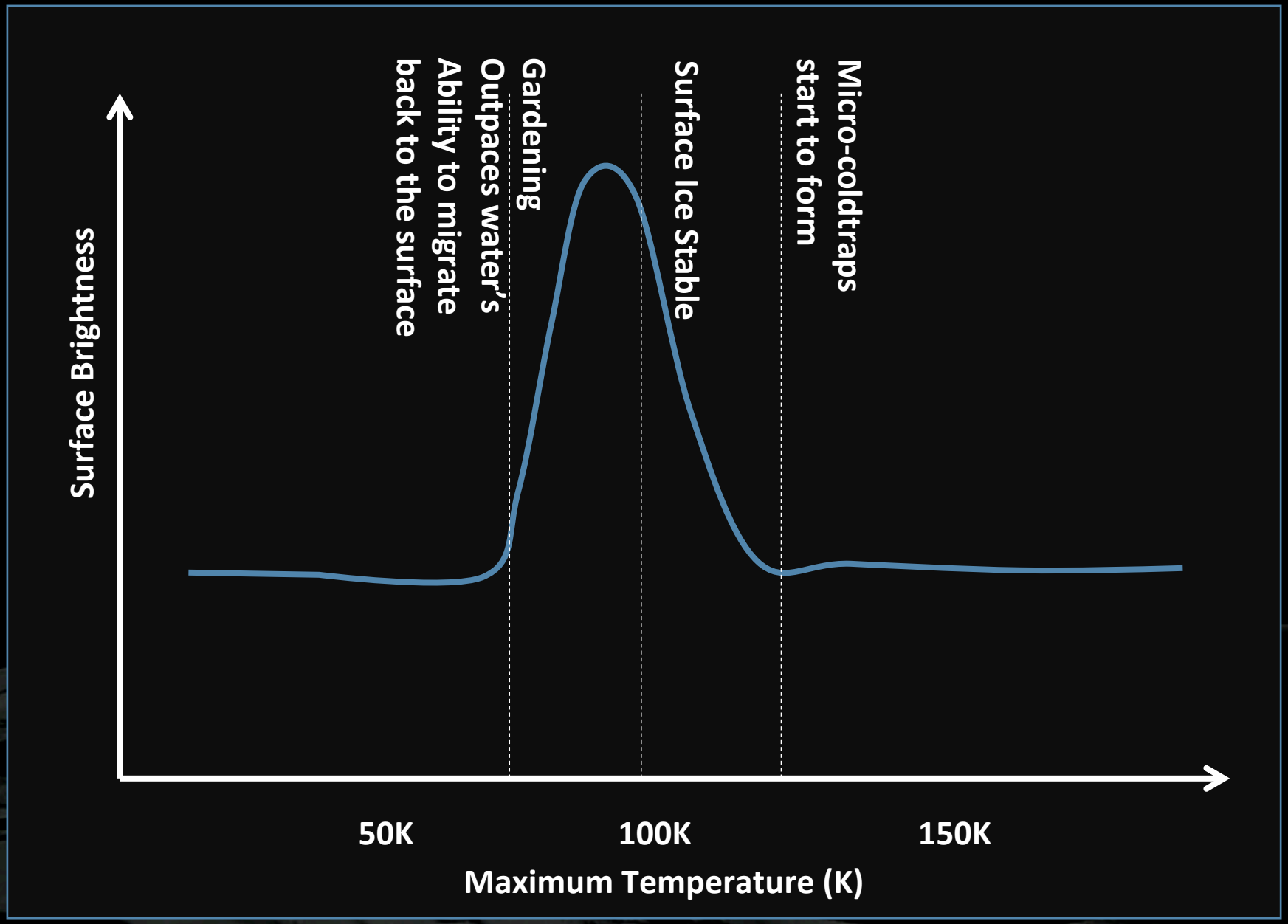




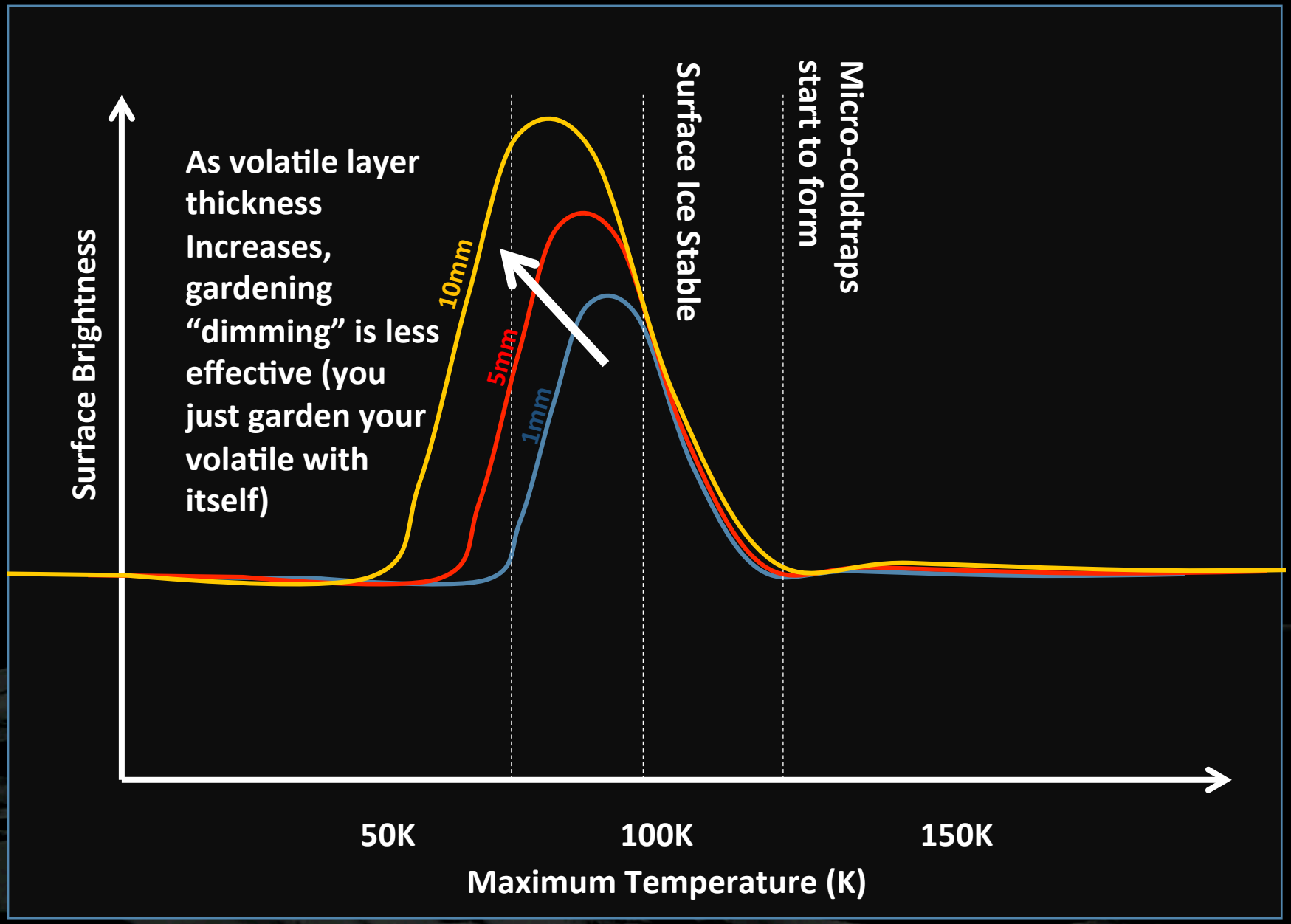


Zhang and Paige, 2010

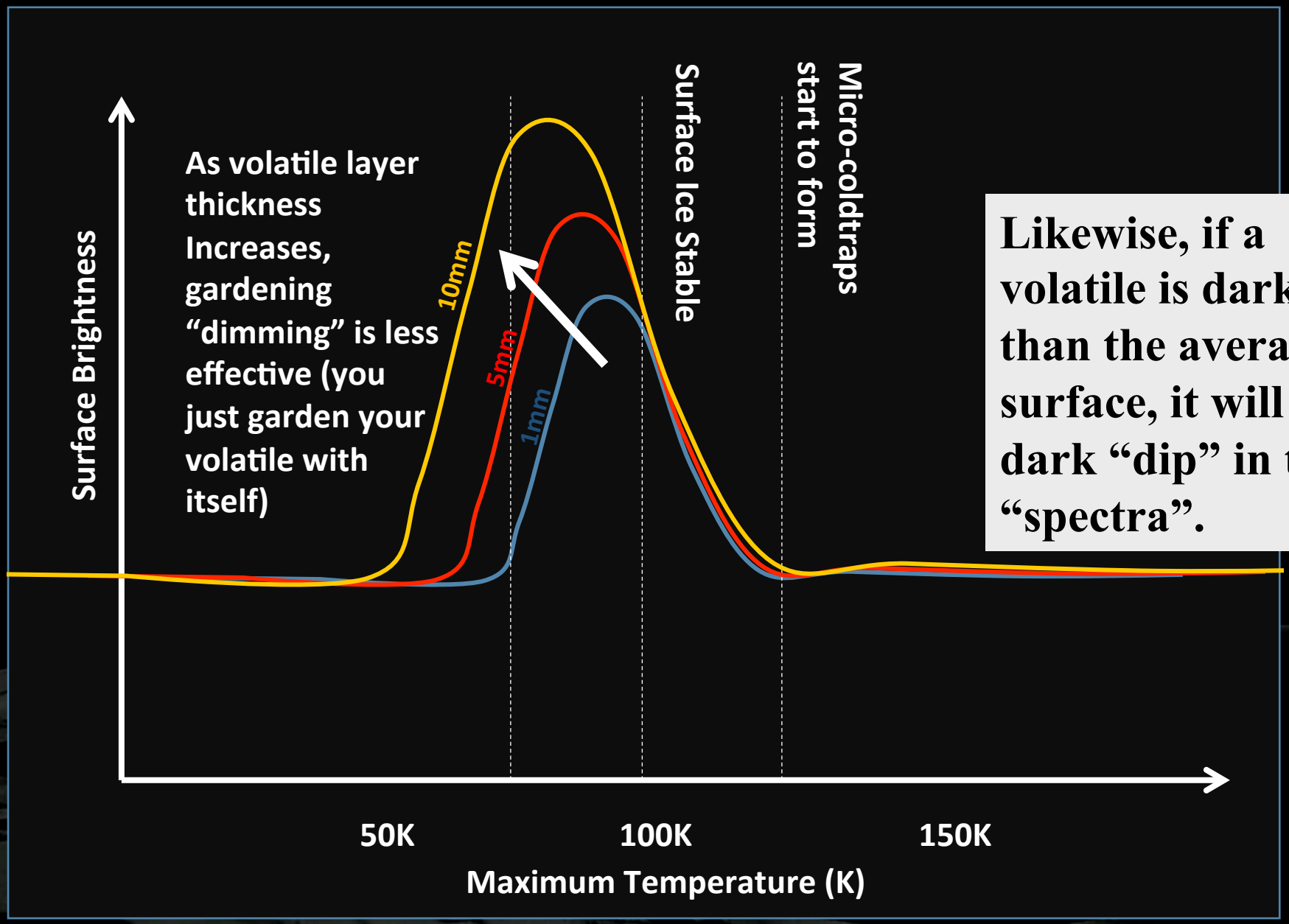
Expectations of balance between surface frost stability and gardening



Expectations of balance between surface frost stability and gardening

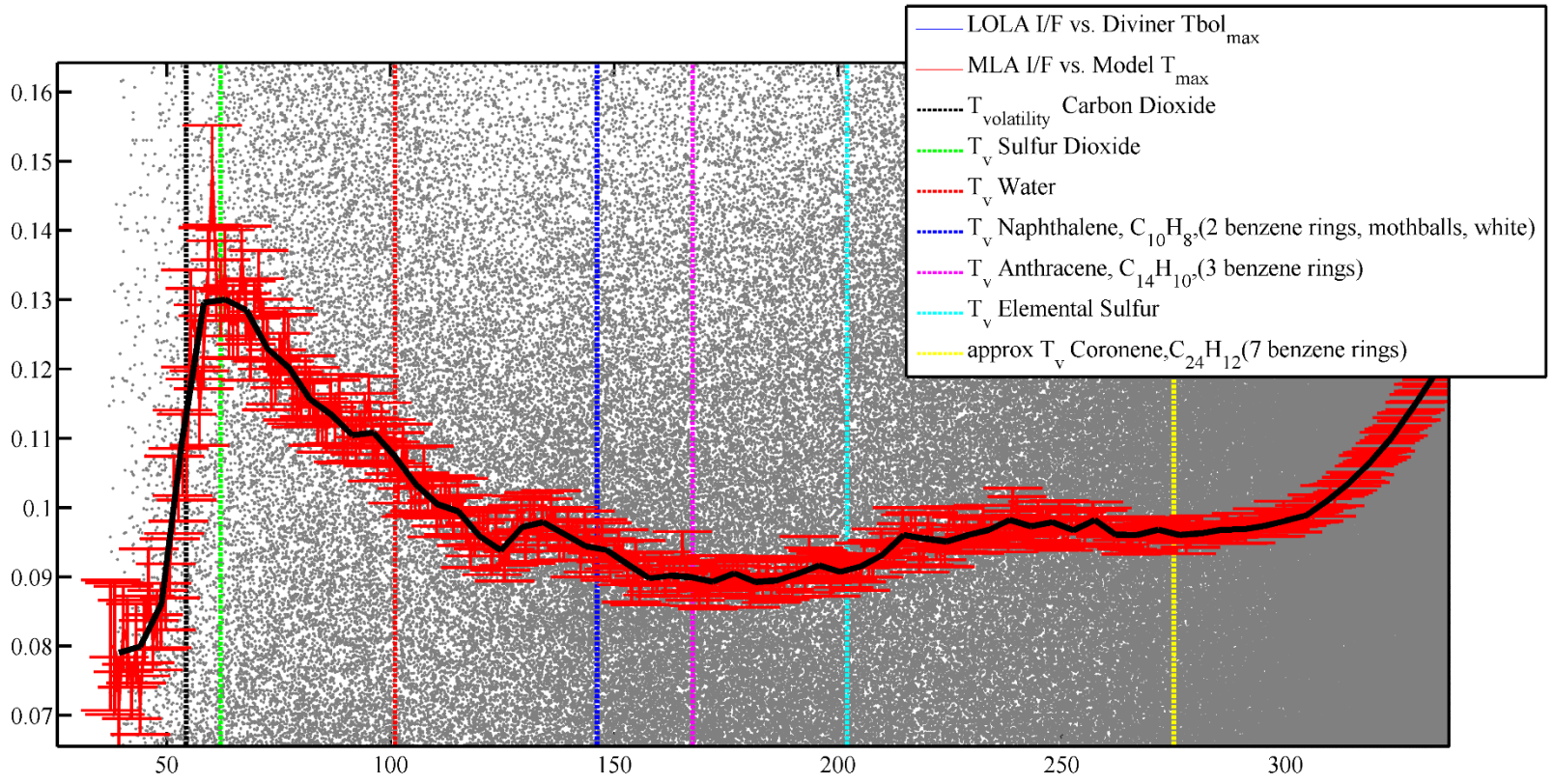


Expectations of balance between surface frost stability and gardening

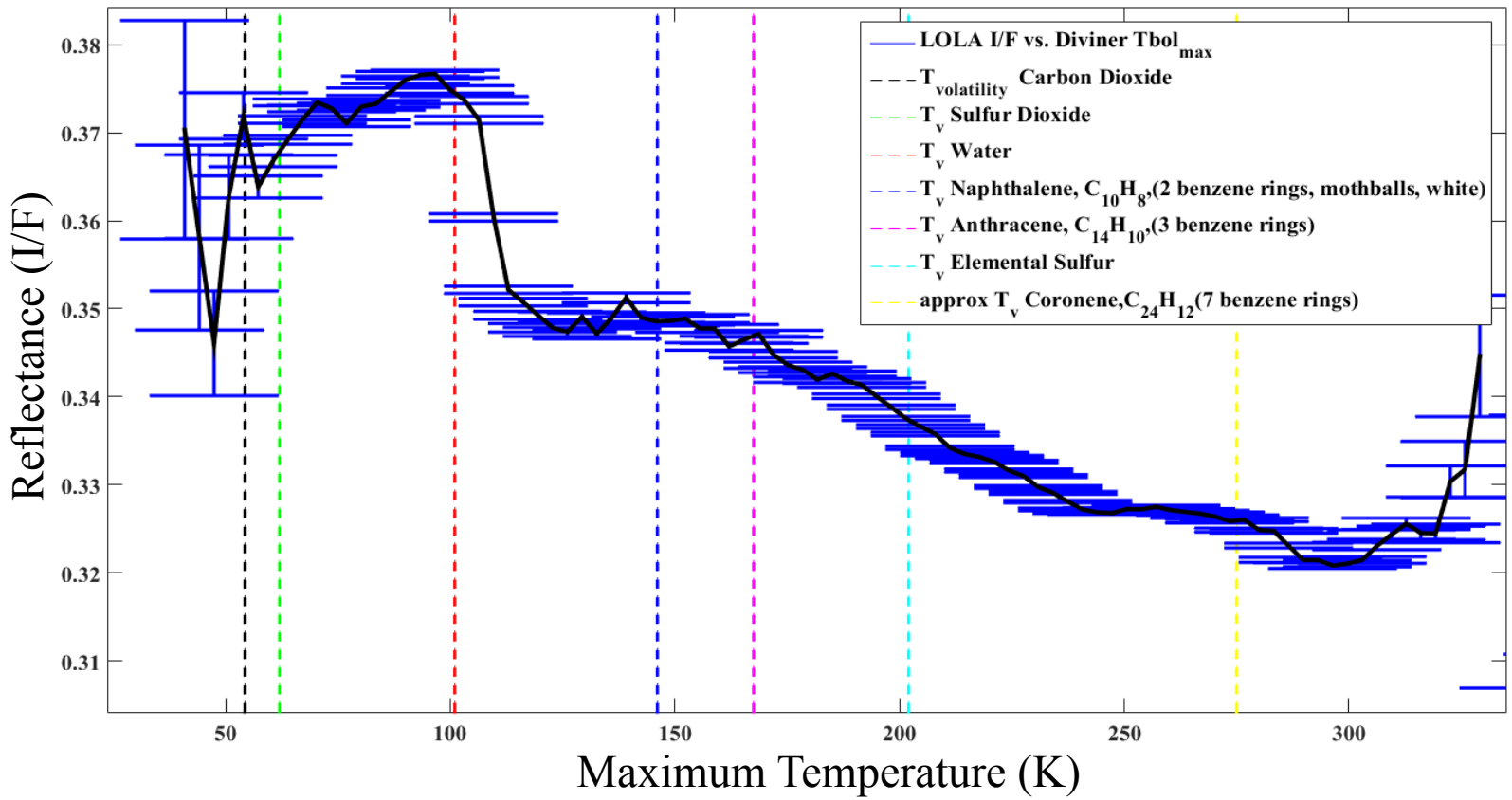


Likewise, if a volatile is darker than the average surface, it will cause dark "dip" in the "spectra".

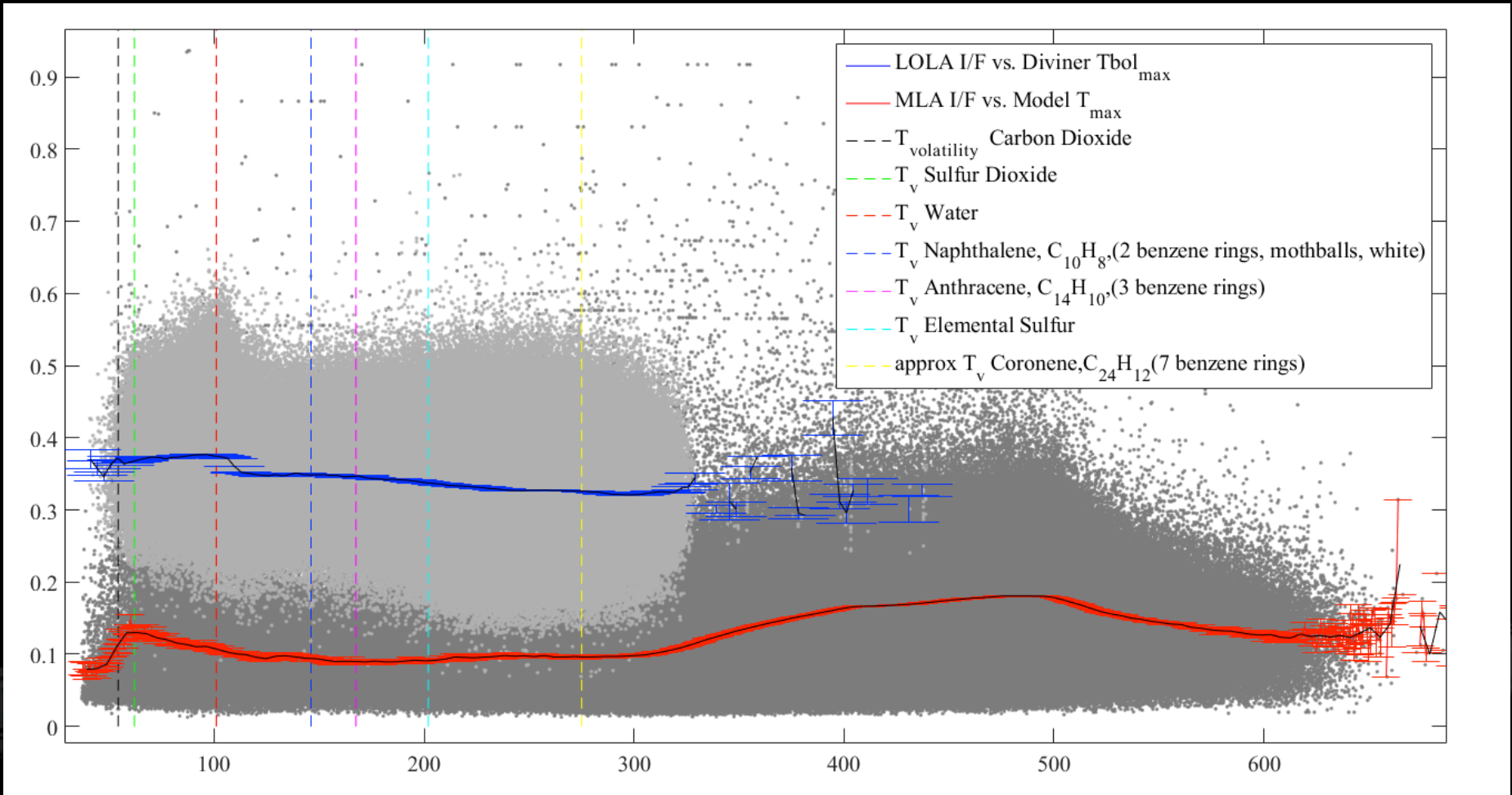
The Mercury
MLA reflectance vs Temperature



The Moon
LOLA reflectance vs Temperature

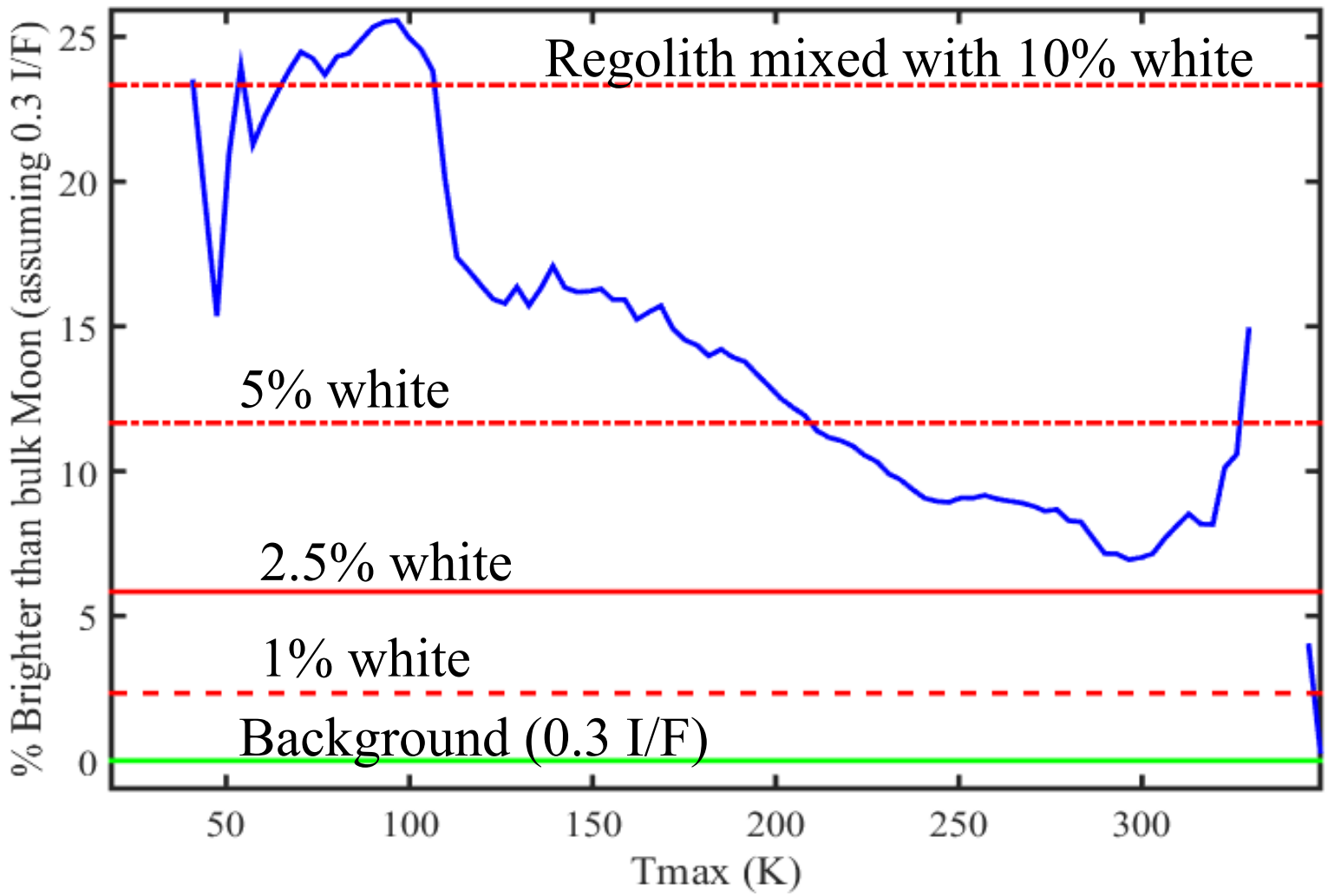


The Moon and Mercury
LOLA and MLA reflectance vs Temperature

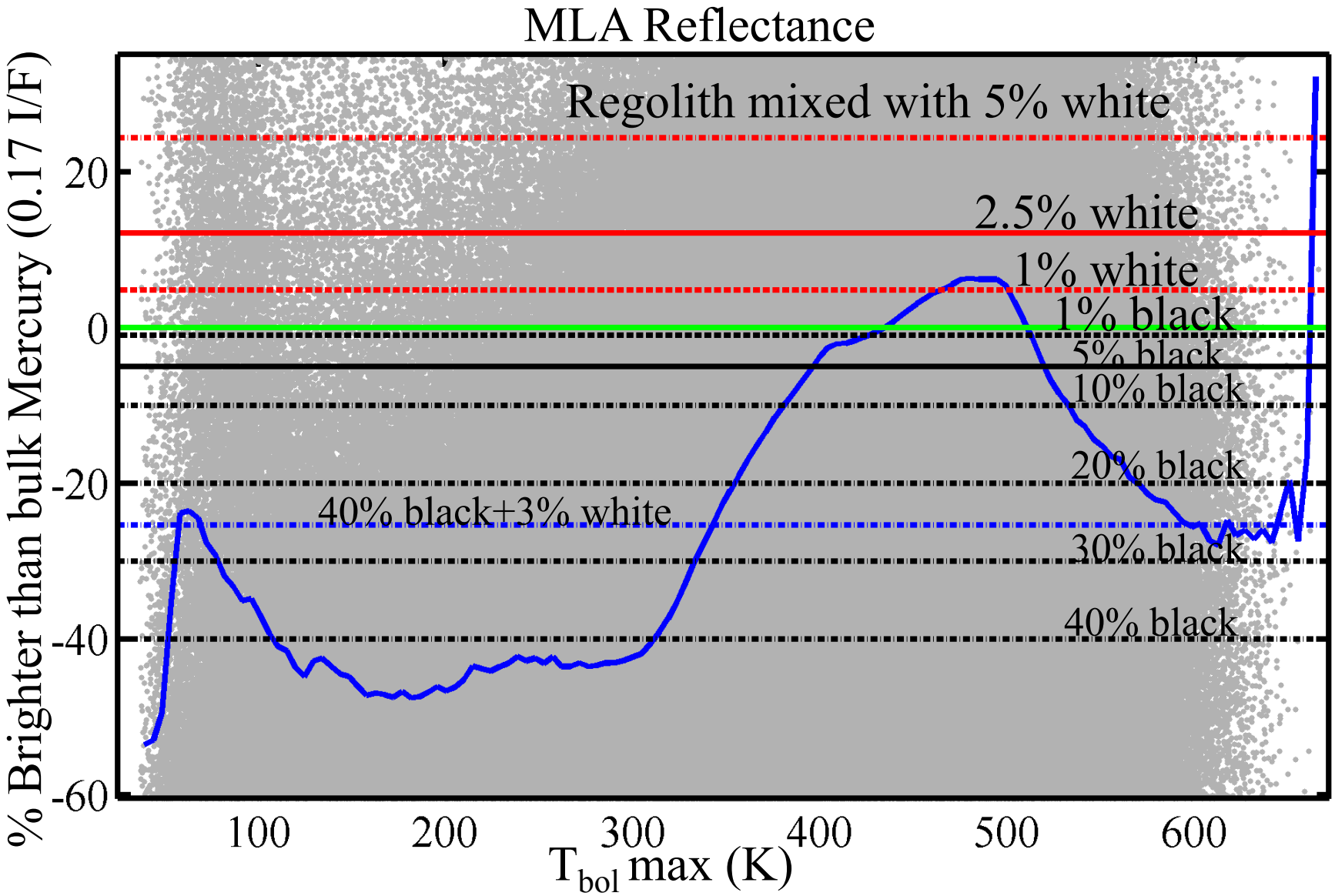


Take Home:
Mercury is DARK and shows greater Contrast than the Moon

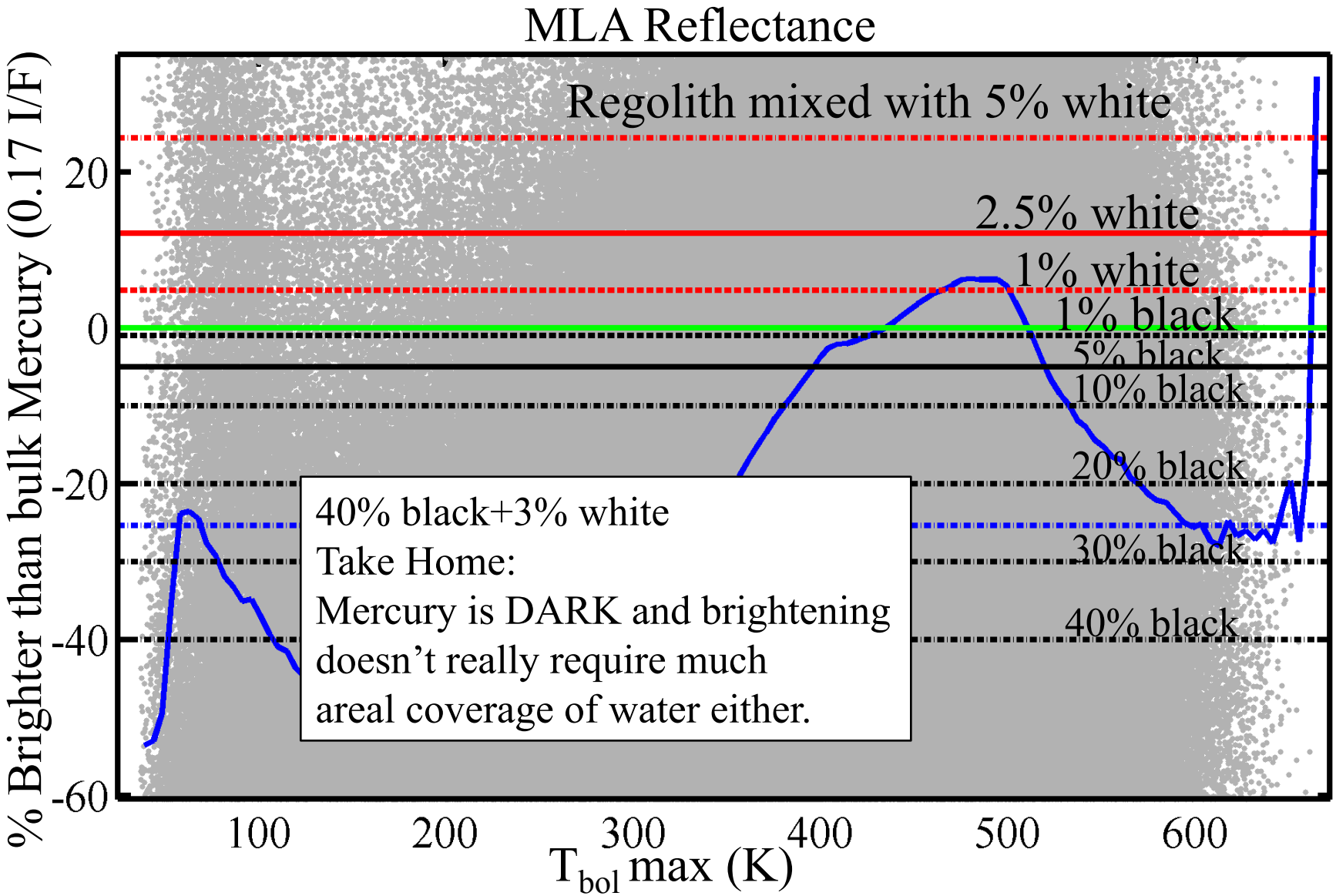
What does this mean in terms of actual brightening/darkening?

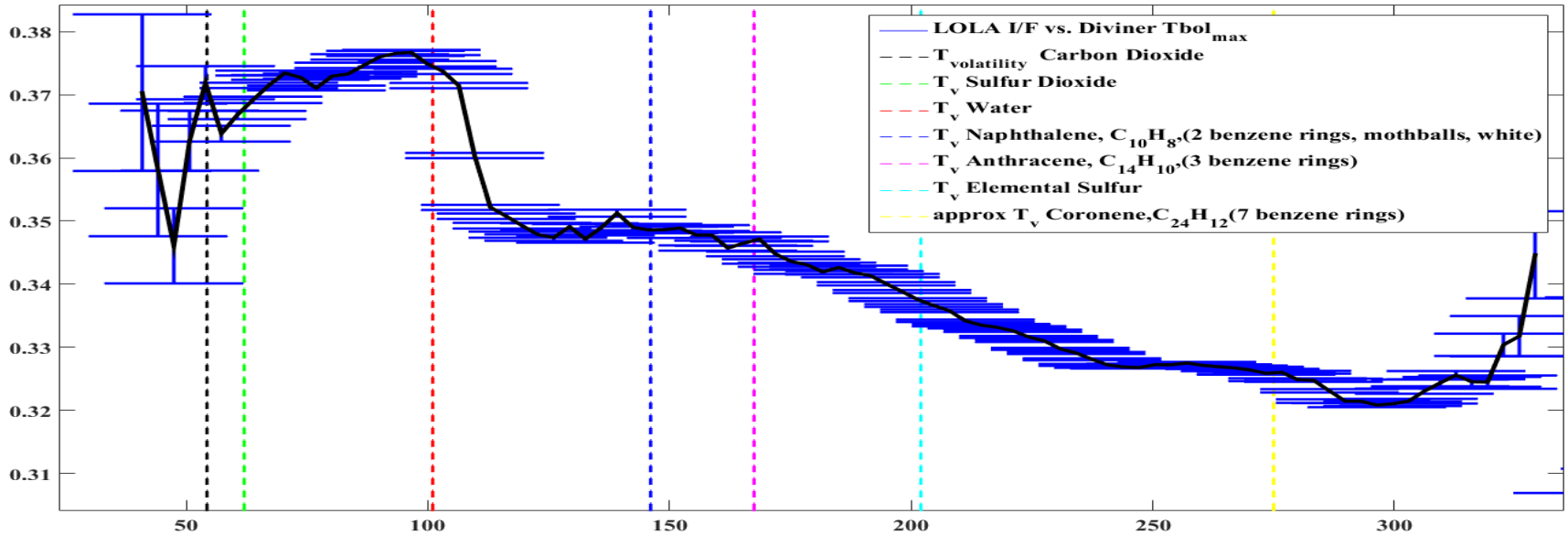


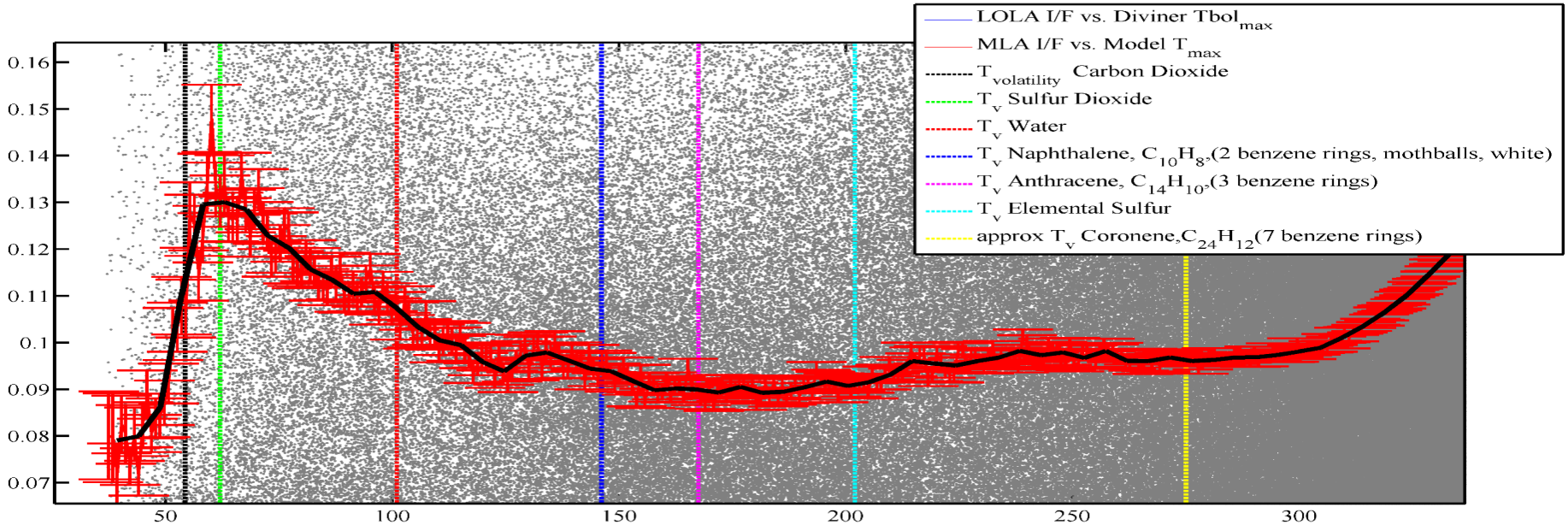
What does this mean in terms of actual brightening/darkening?

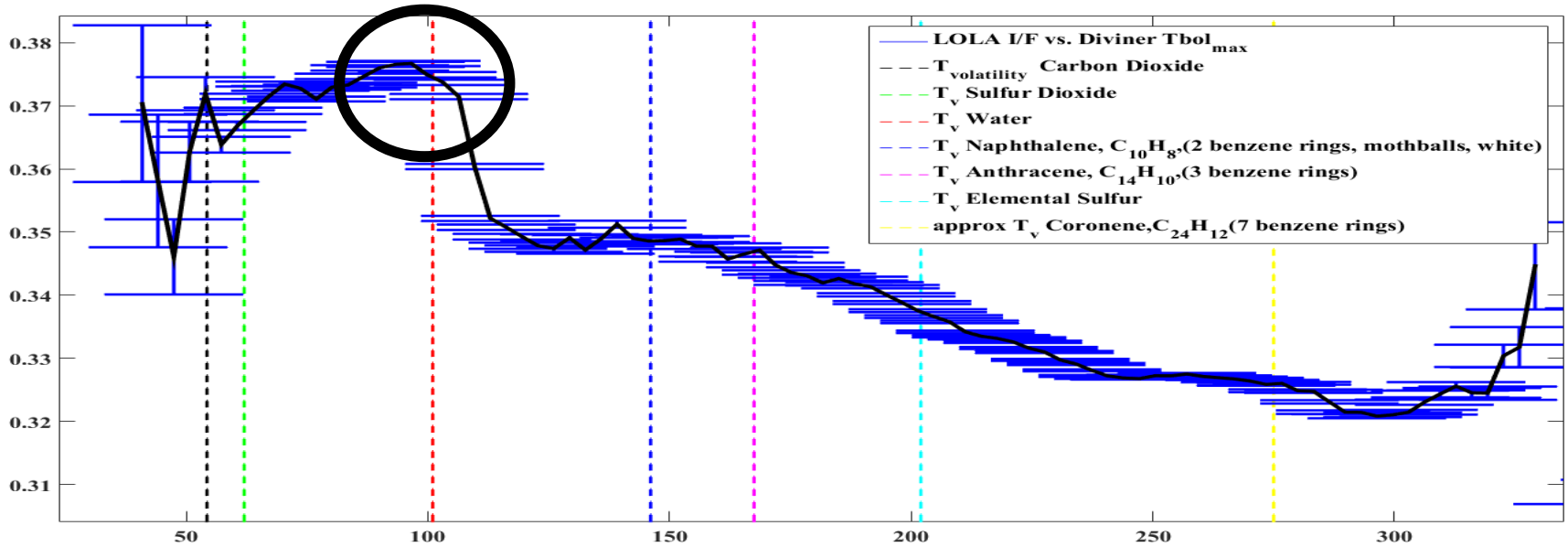


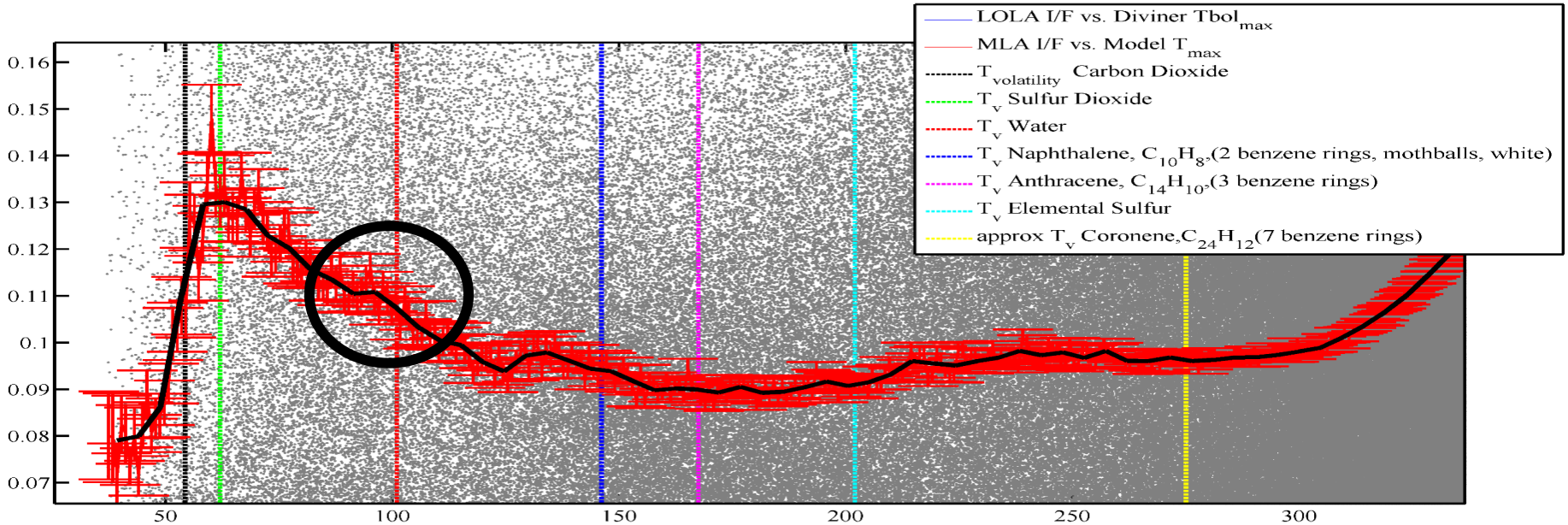
What does this mean in terms of actual brightening/darkening?

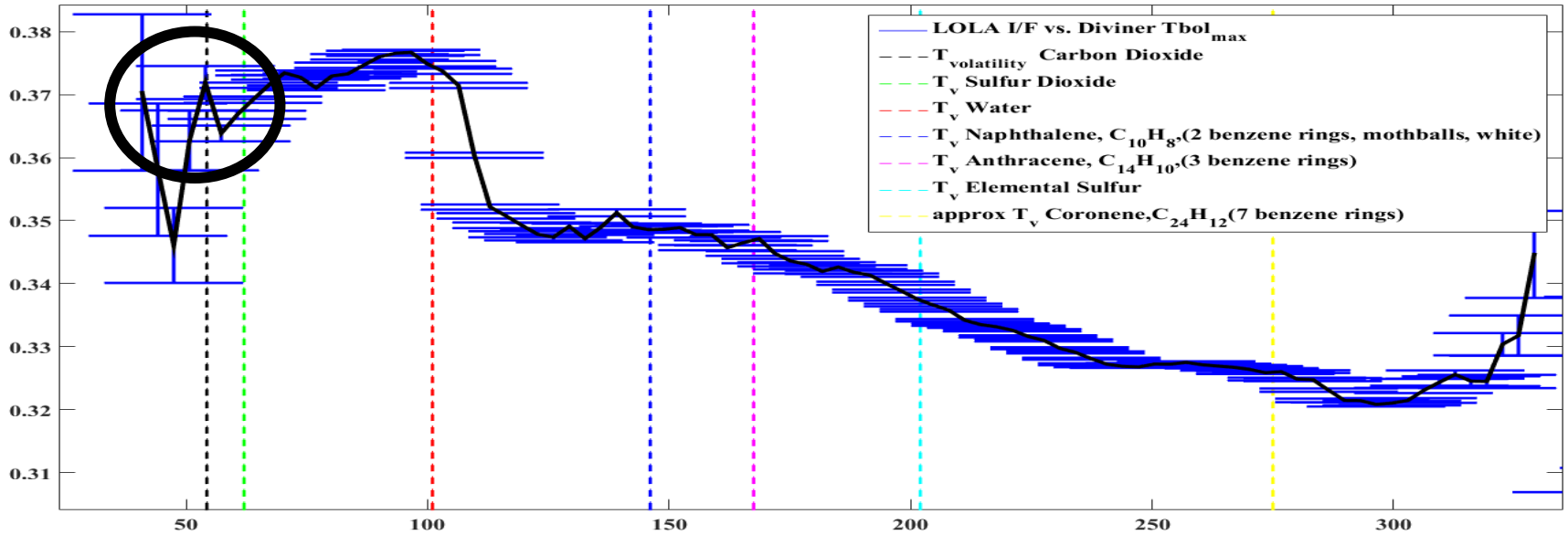


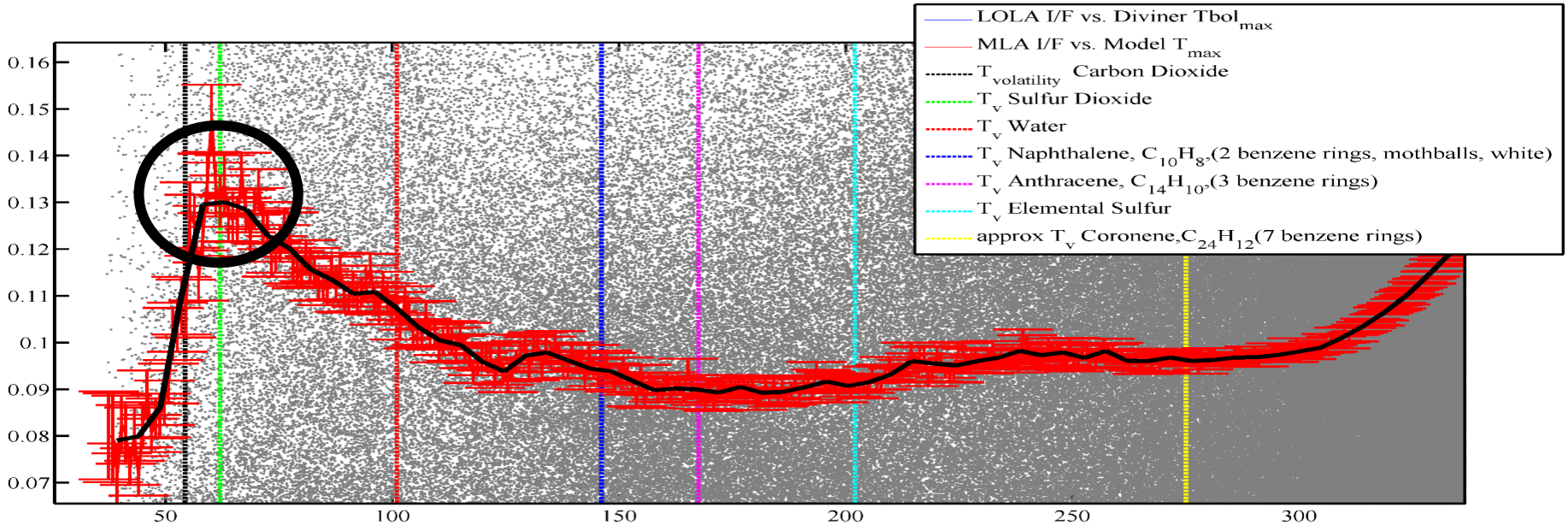

LOLA I/F vs. Diviner Tbol$_{max}$
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
50
100
150
200
250
300

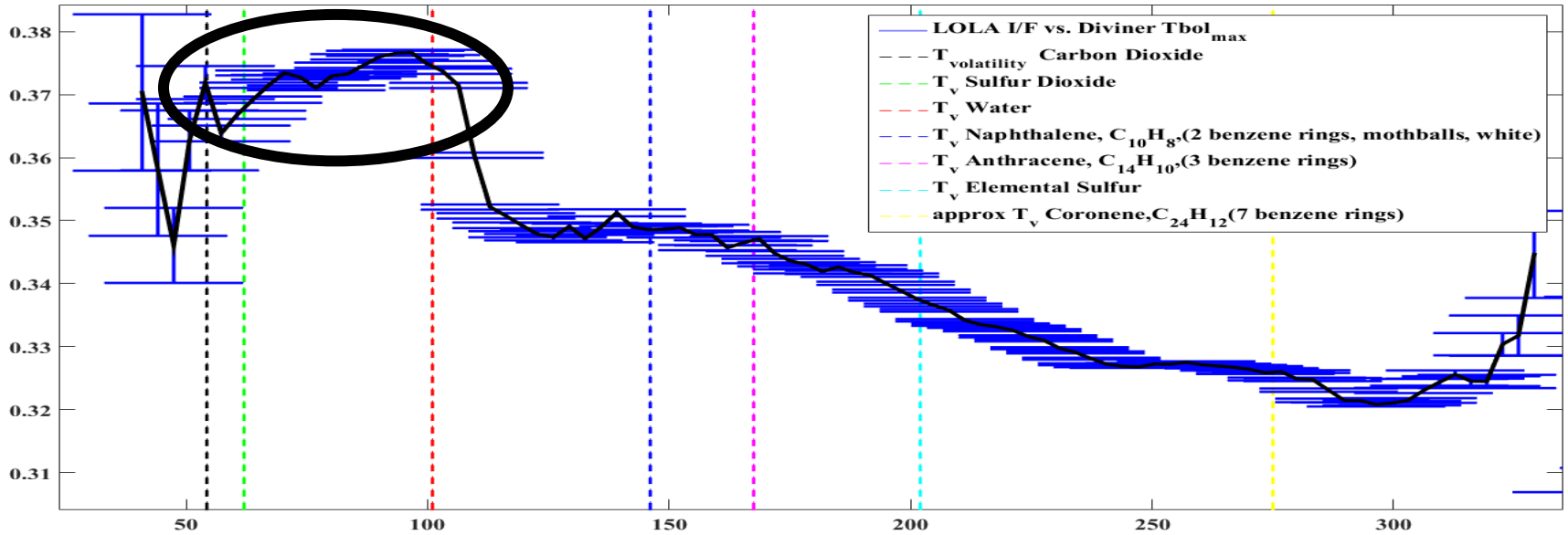

LOLA I/F vs. Diviner Tbol$_{max}$
MLA I/F vs. Model T_{max}
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
50
100
150
200
250
300

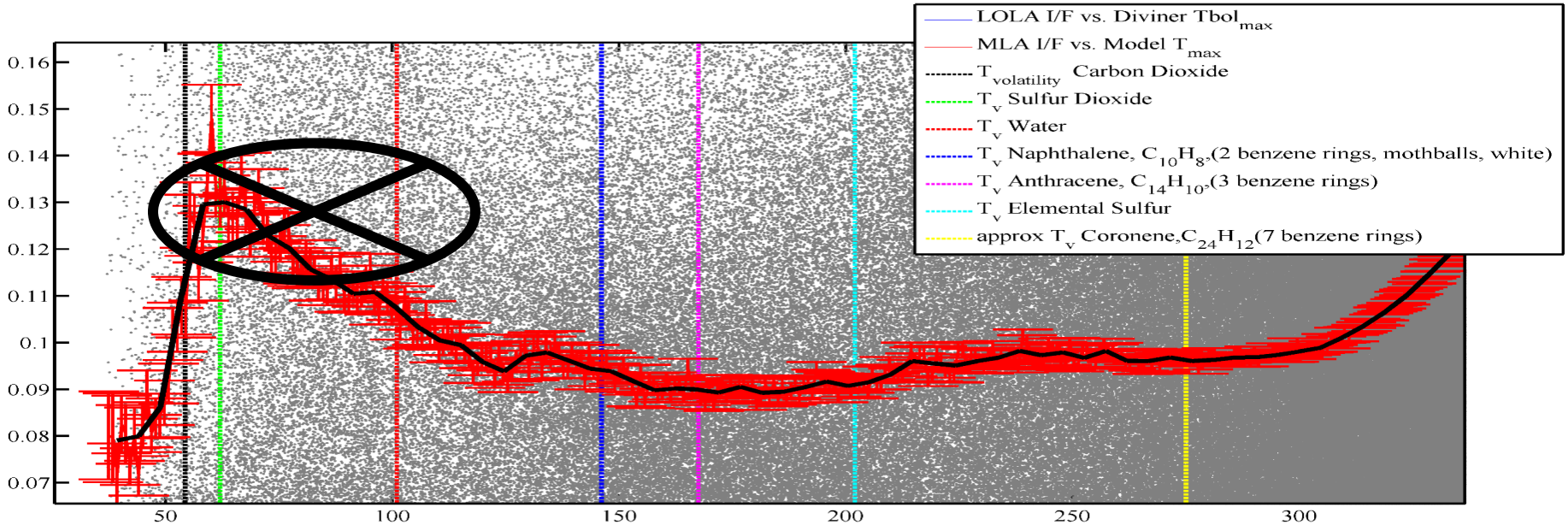

LOLA I/F vs. Diviner Tbol$_{max}$
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
50
100
150
200
250
300

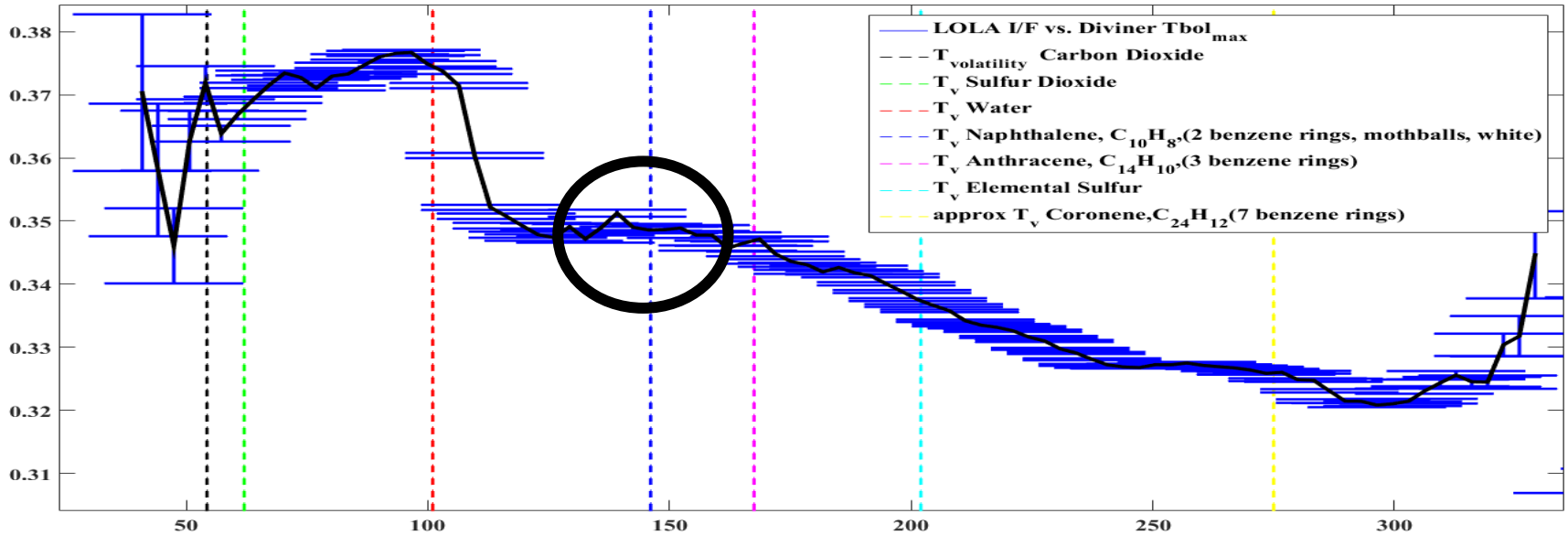

LOLA I/F vs. Diviner Tbol$_{max}$
MLA I/F vs. Model T_{max}
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
50
100
150
200
250
300

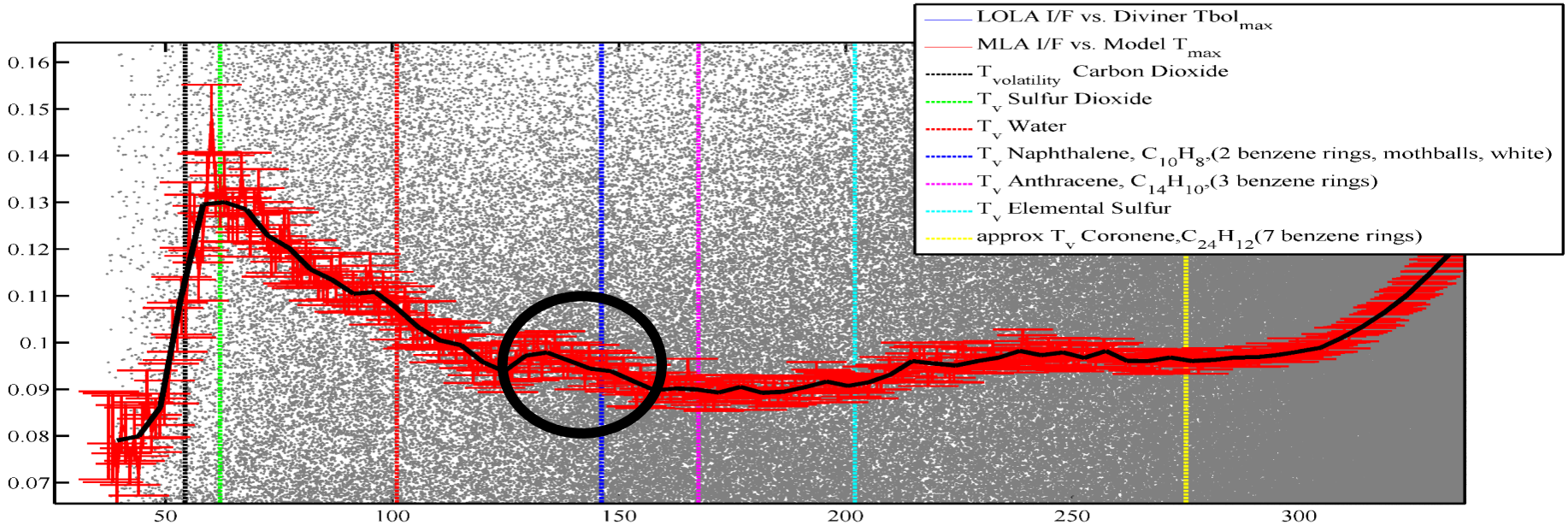

LOLA I/F vs. Diviner Tbol$_{max}$
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
50
100
150
200
250
300


LOLA I/F vs. Diviner Tbol$_{max}$
MLA I/F vs. Model T_{max}
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
50
100
150
200
250
300

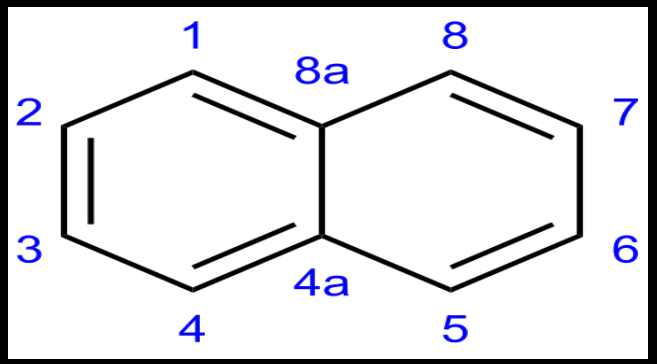

LOLA I/F vs. Diviner Tbol$_{max}$
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
50
100
150
200
250
300

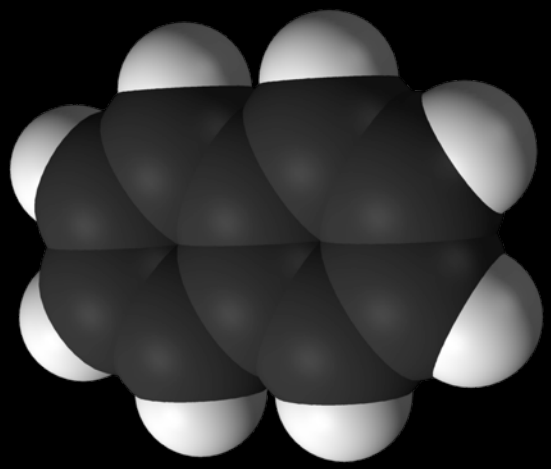

LOLA I/F vs. Diviner Tbol$_{max}$
MLA I/F vs. Model T_{max}
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
50
100
150
200
250
300


LOLA I/F vs. Diviner Tbol$_{max}$
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
50
100
150
200
250
300


LOLA I/F vs. Diviner Tbol$_{max}$
MLA I/F vs. Model T_{max}
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
50
100
150
200
250
300

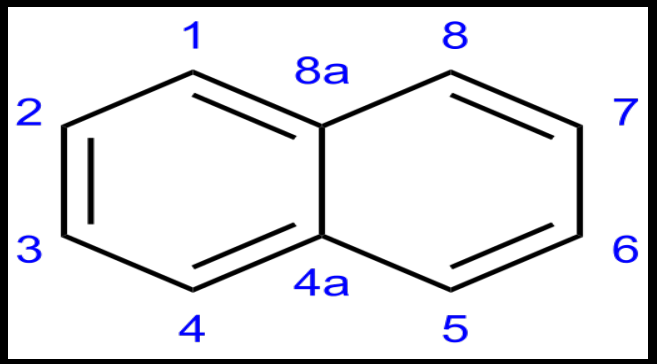
Naphthalene:
Organic Molecule
Simplest "PAH"
2 Benzene rings
White in Color

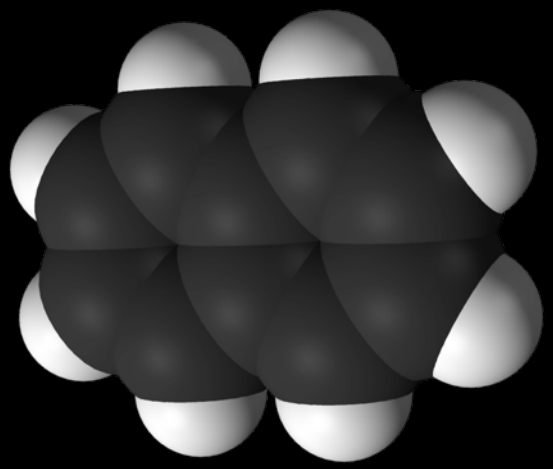




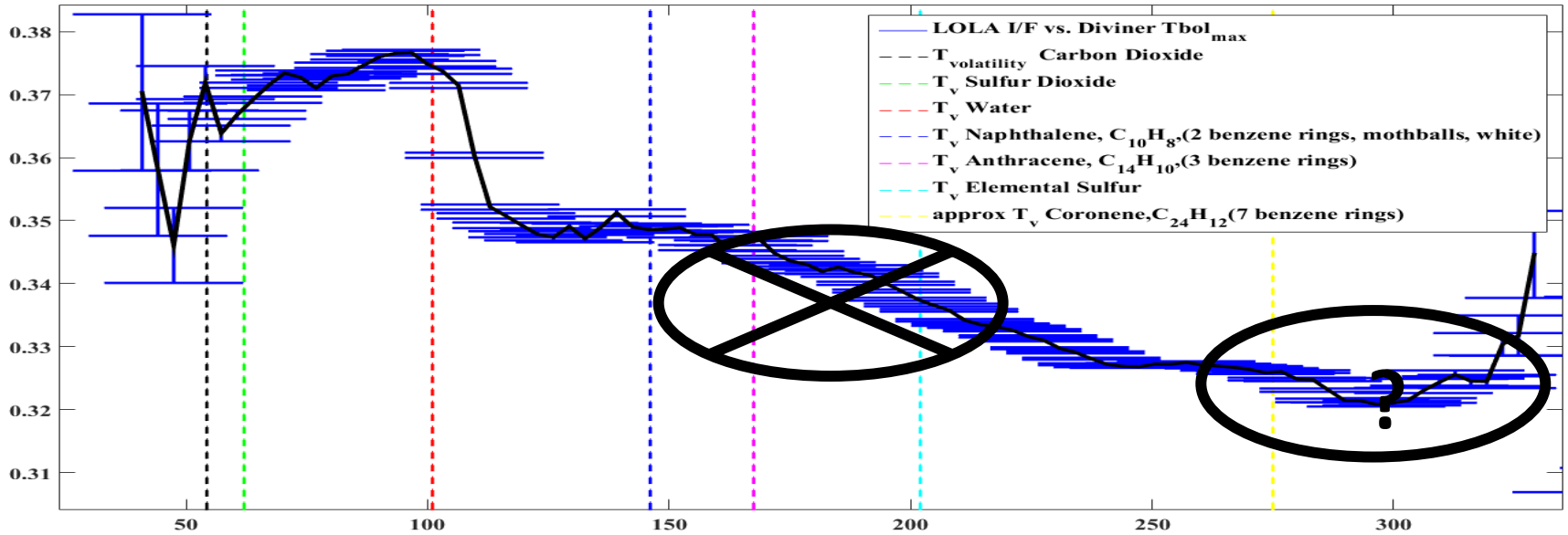
Better known
for use in…

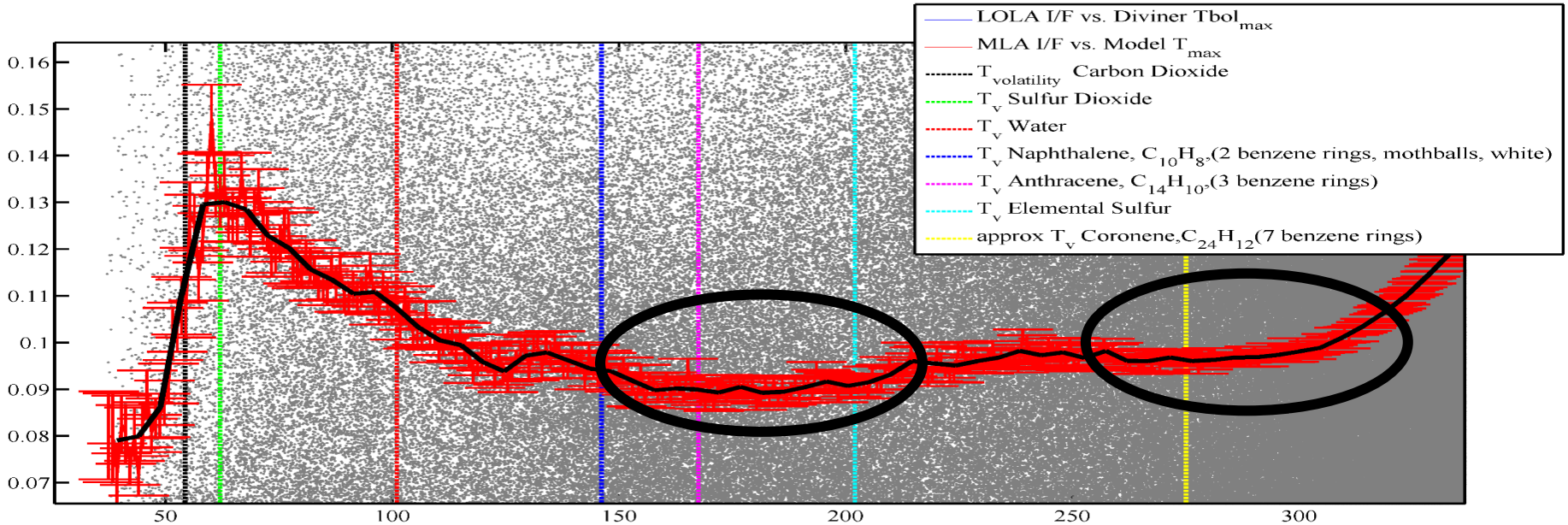
Naphthalene:
Organic Molecule
Simplest "PAH"
2 Benzene rings
White in Color





Evidence for simple organics as a lunar polar volatile


LOLA I/F vs. Diviner Tbol$_{max}$
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
50
100
150
200
250
300
?


LOLA I/F vs. Diviner Tbol$_{max}$
MLA I/F vs. Model T_{max}
$T_{volatility}$ Carbon Dioxide
T_v Sulfur Dioxide
T_v Water
T_v Naphthalene, $C_{10}H_8$,(2 benzene rings, mothballs, white)
T_v Anthracene, $C_{14}H_{10}$,(3 benzene rings)
T_v Elemental Sulfur
approx T_v Coronene,$C_{24}H_{12}$(7 benzene rings)
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
50
100
150
200
250
300

Mercury and the Moon comparison

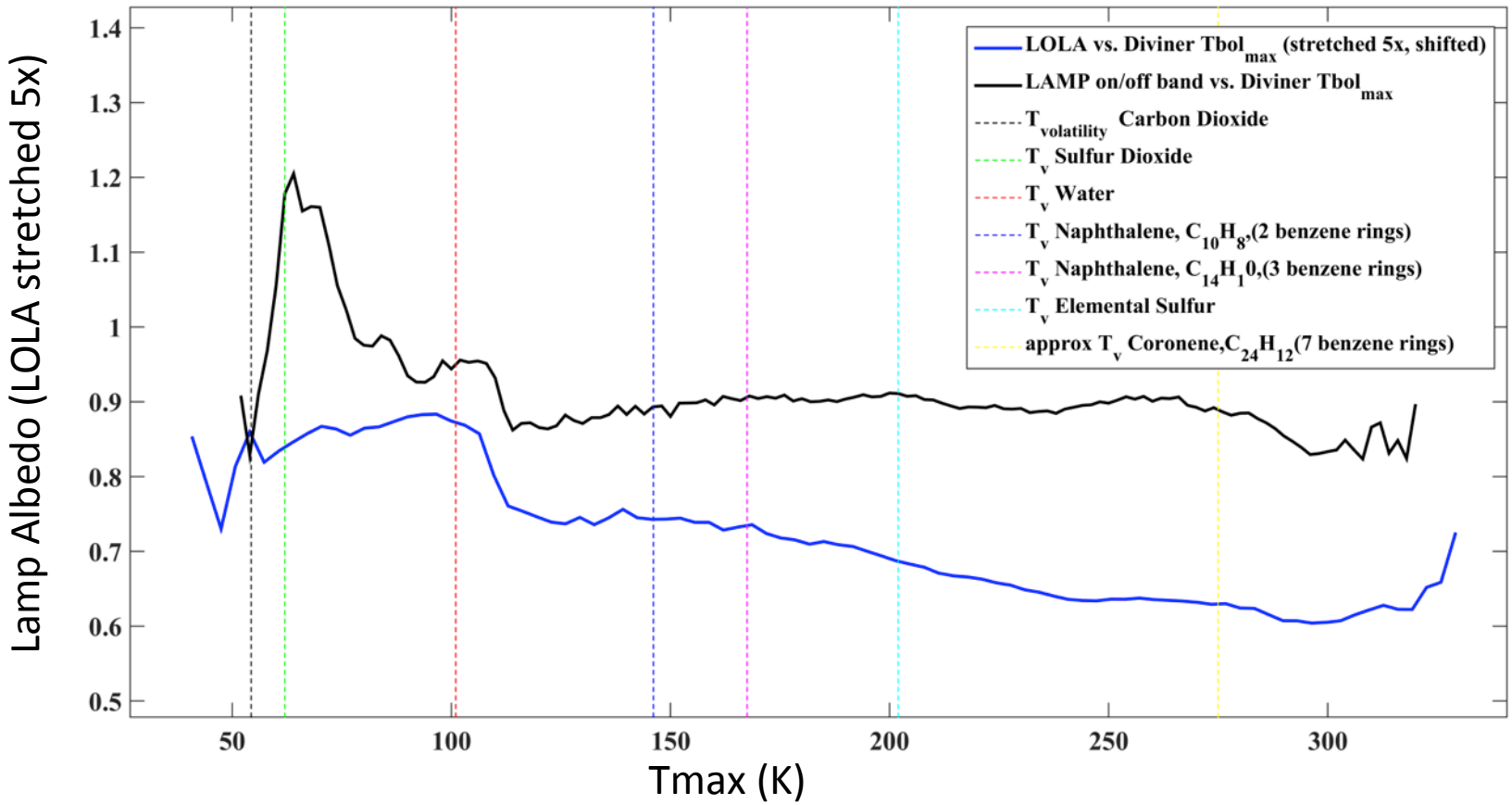
1) Both show evidence for water (brightening at 100K)

2) Both show evidence for brightening at cold temps- could be thick ice, new ice (not yet gardened), or CO_2/S

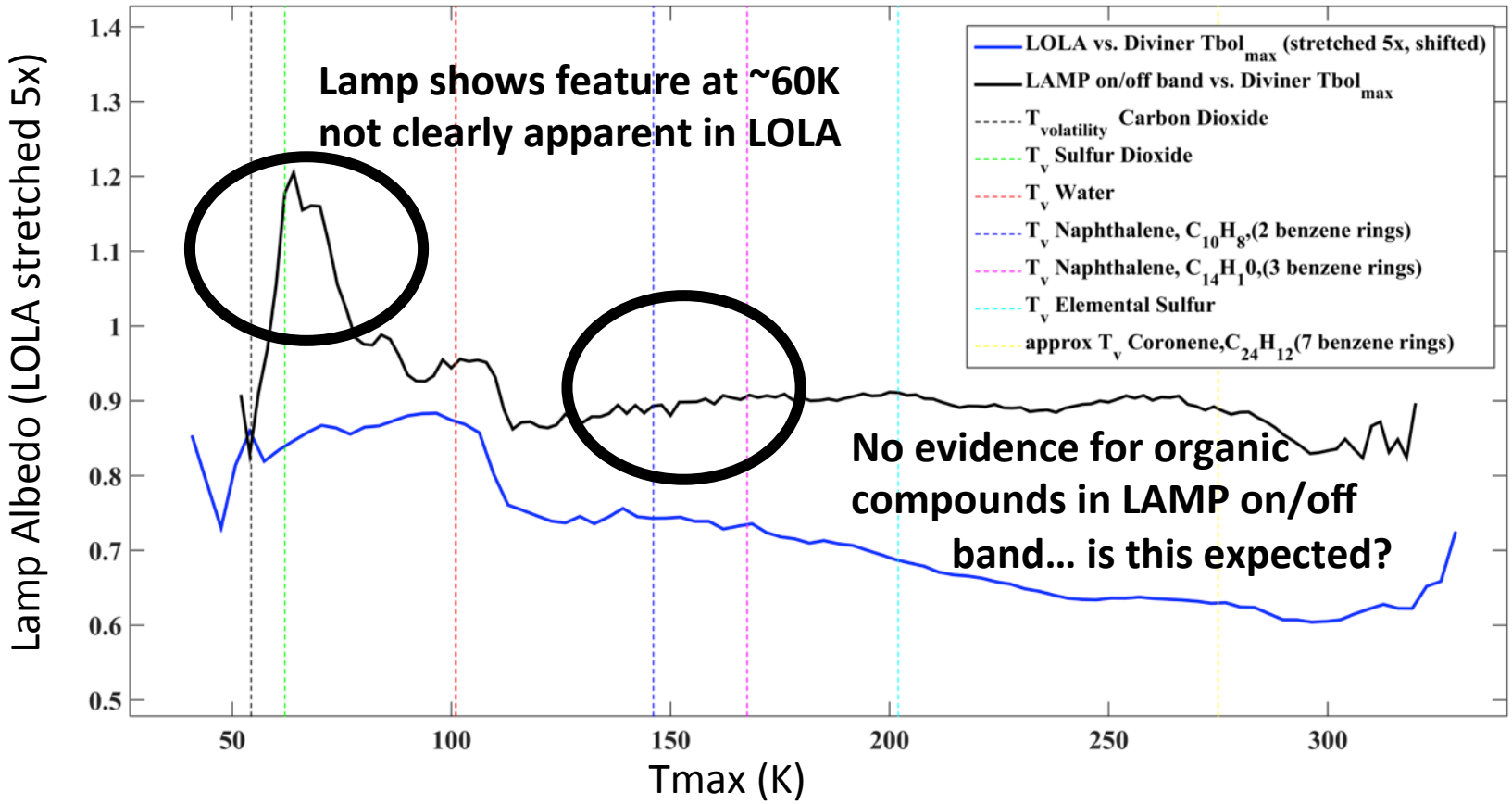
3) Both show evidence for simple organics –e.g. naphthale Organics on the Moon!

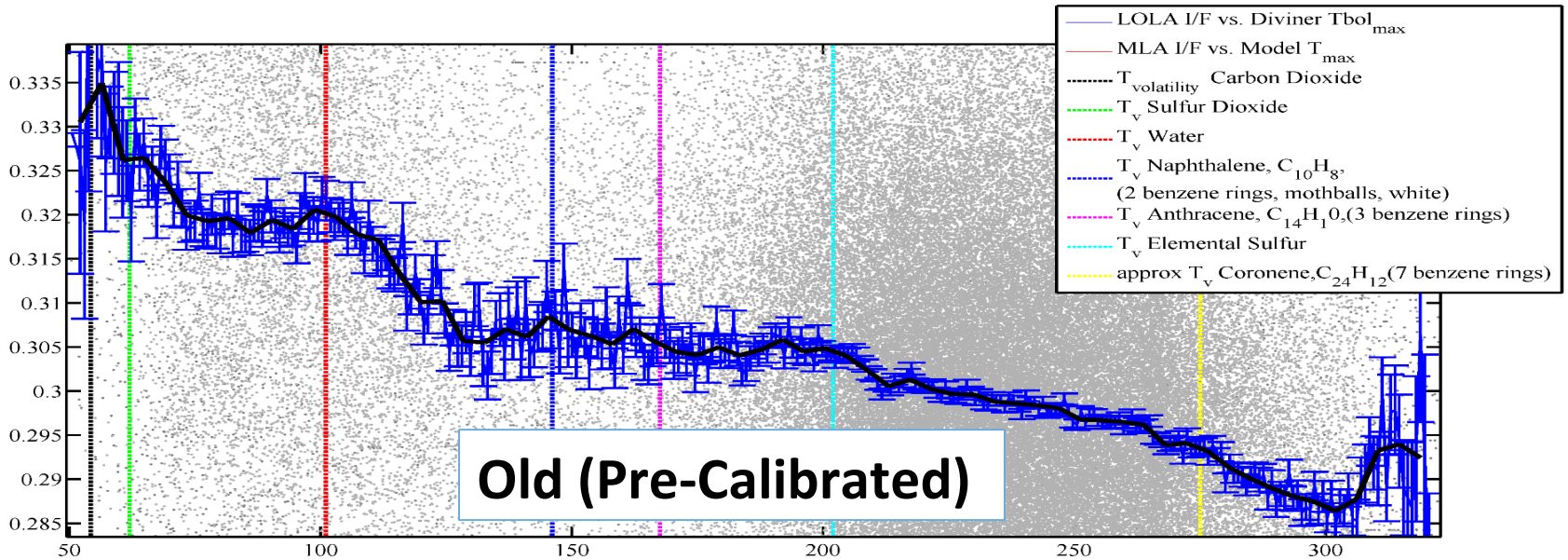
4) Only Mercury shows darkening at 160-300K, complex organic or Sulfur (Due to supply? Volcanism? Magnetic field? Endogenic vs. Exogenic)

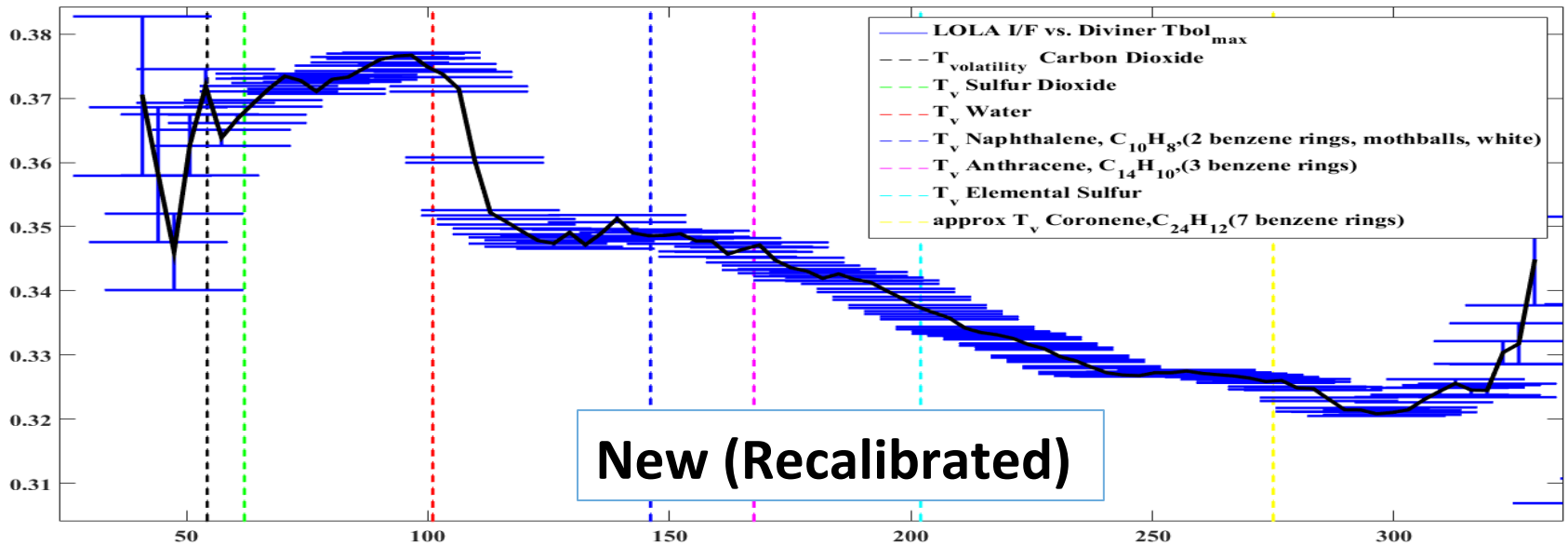
Comparison with LAMP on/off band (from Paul Hayne)



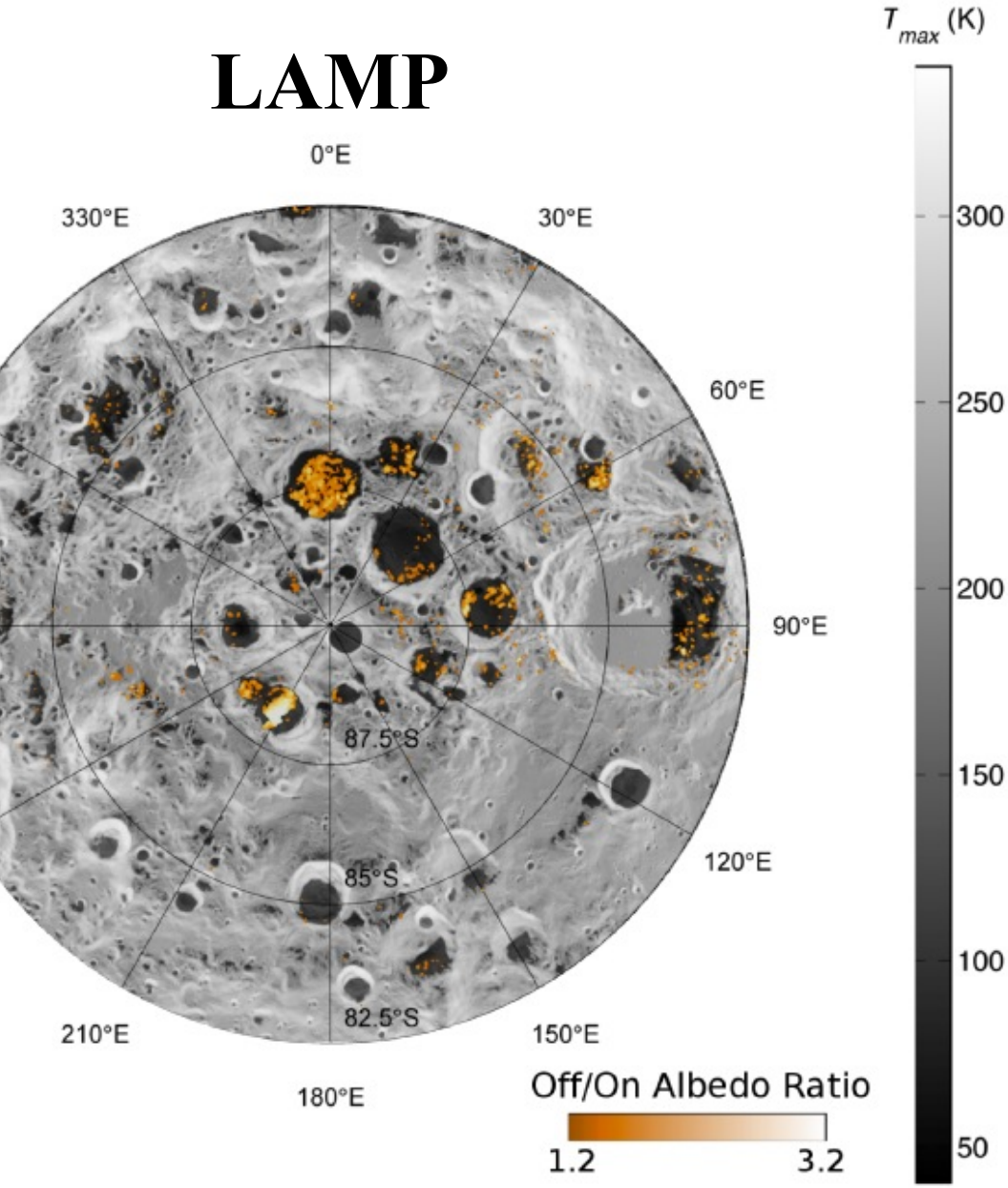
Comparison with LAMP on/off band (from Paul Hayne)



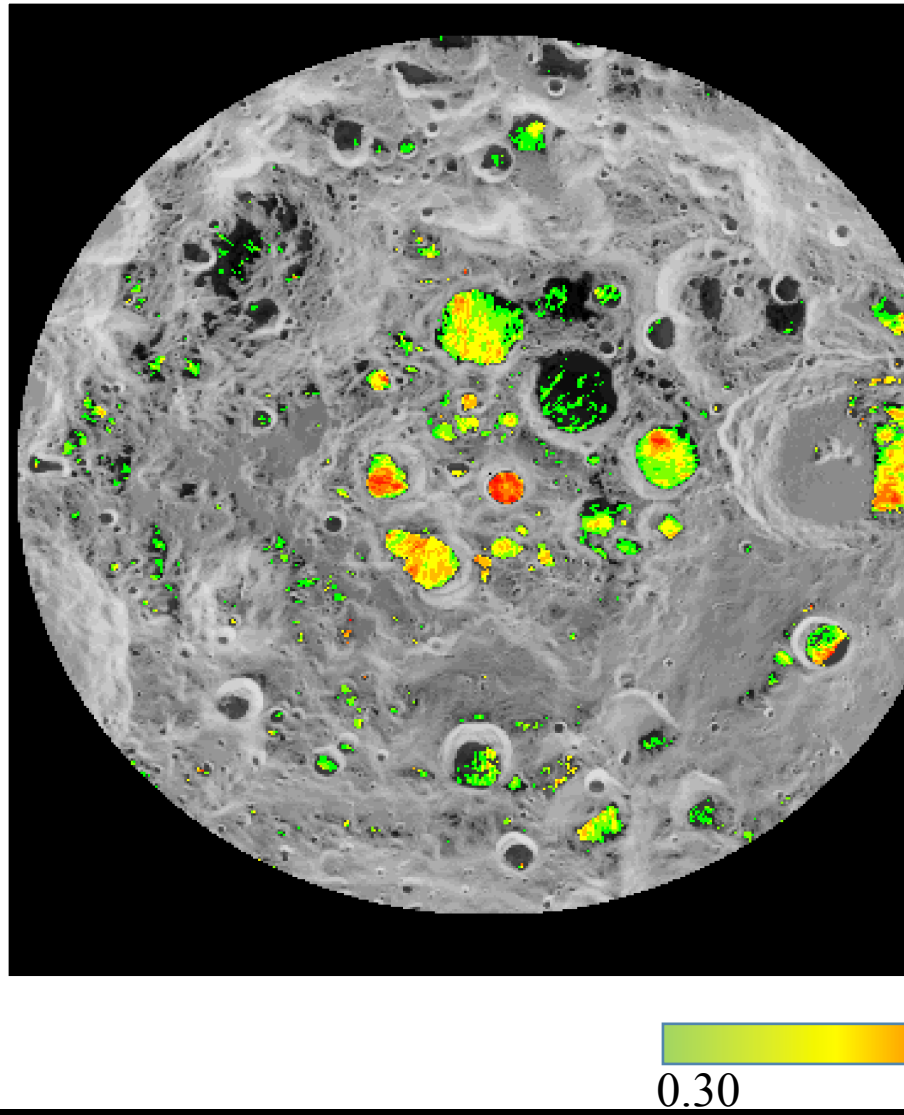

LOLA I/F vs. Diviner Tbol$_{max}$
MLA I/F vs. Model T$_{max}$
T$_{volatility}$ Carbon Dioxide
T$_v$ Sulfur Dioxide
T$_v$ Water
T$_v$ Naphthalene, C$_{10}$H$_8$, (2 benzene rings, mothballs, white)
T$_v$ Anthracene, C$_{14}$H$_1$0,(3 benzene rings)
T$_v$ Elemental Sulfur
approx T$_v$ Coronene,C$_{24}$H$_{12}$(7 benzene rings)
Old (Pre-Calibrated)
0.335
0.33
0.325
0.32
0.315
0.31
0.305
0.3
0.295
0.29
0.285
50
100
150
200
250
300


LOLA I/F vs. Diviner Tbol$_{max}$
T$_{volatility}$ Carbon Dioxide
T$_v$ Sulfur Dioxide
T$_v$ Water
T$_v$ Naphthalene, C$_{10}$H$_8$,(2 benzene rings, mothballs, white)
T$_v$ Anthracene, C$_{14}$H$_{10}$,(3 benzene rings)
T$_v$ Elemental Sulfur
approx T$_v$ Coronene,C$_{24}$H$_{12}$(7 benzene rings)
New (Recalibrated)
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
50
100
150
200
250
300

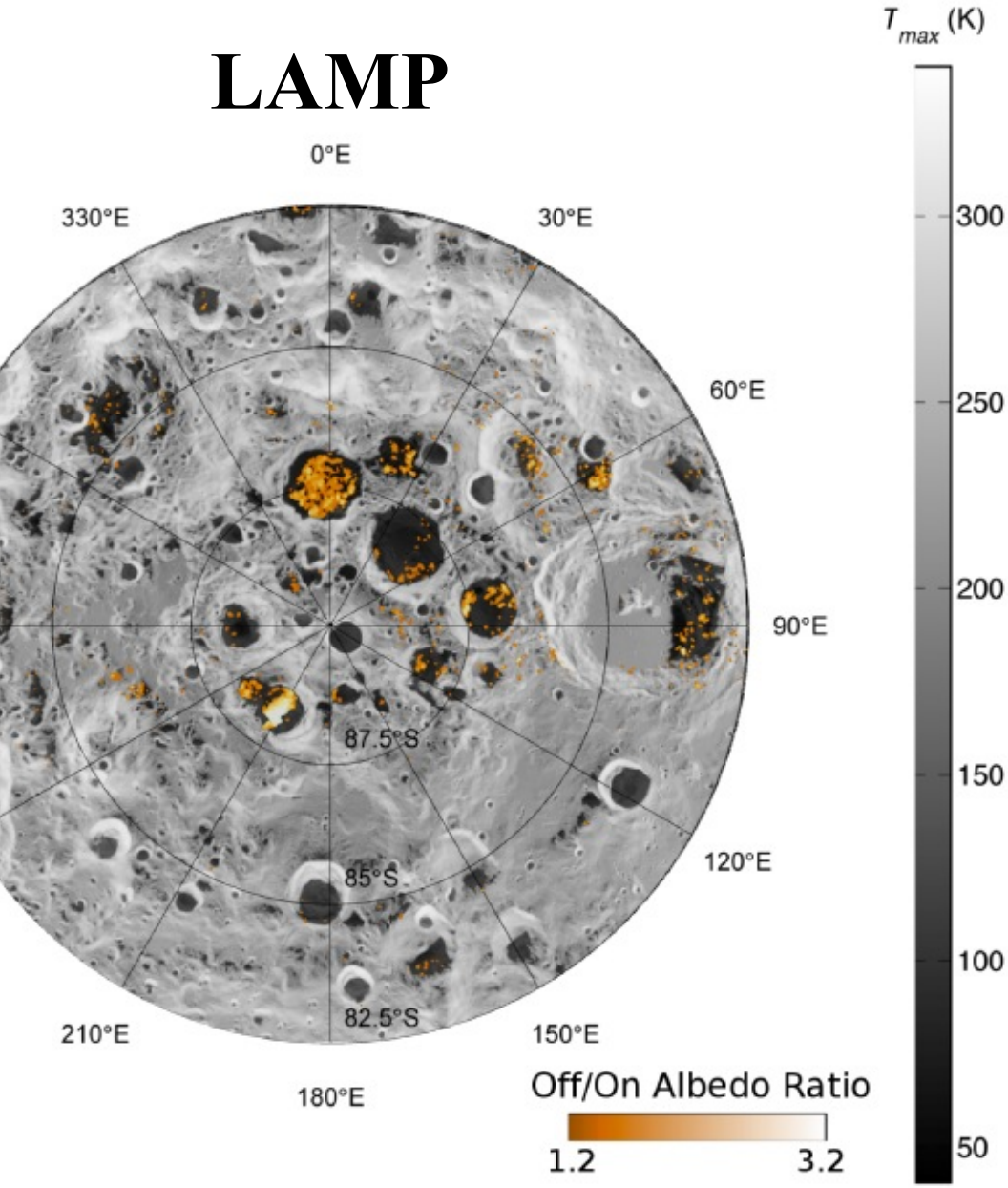
LAMP



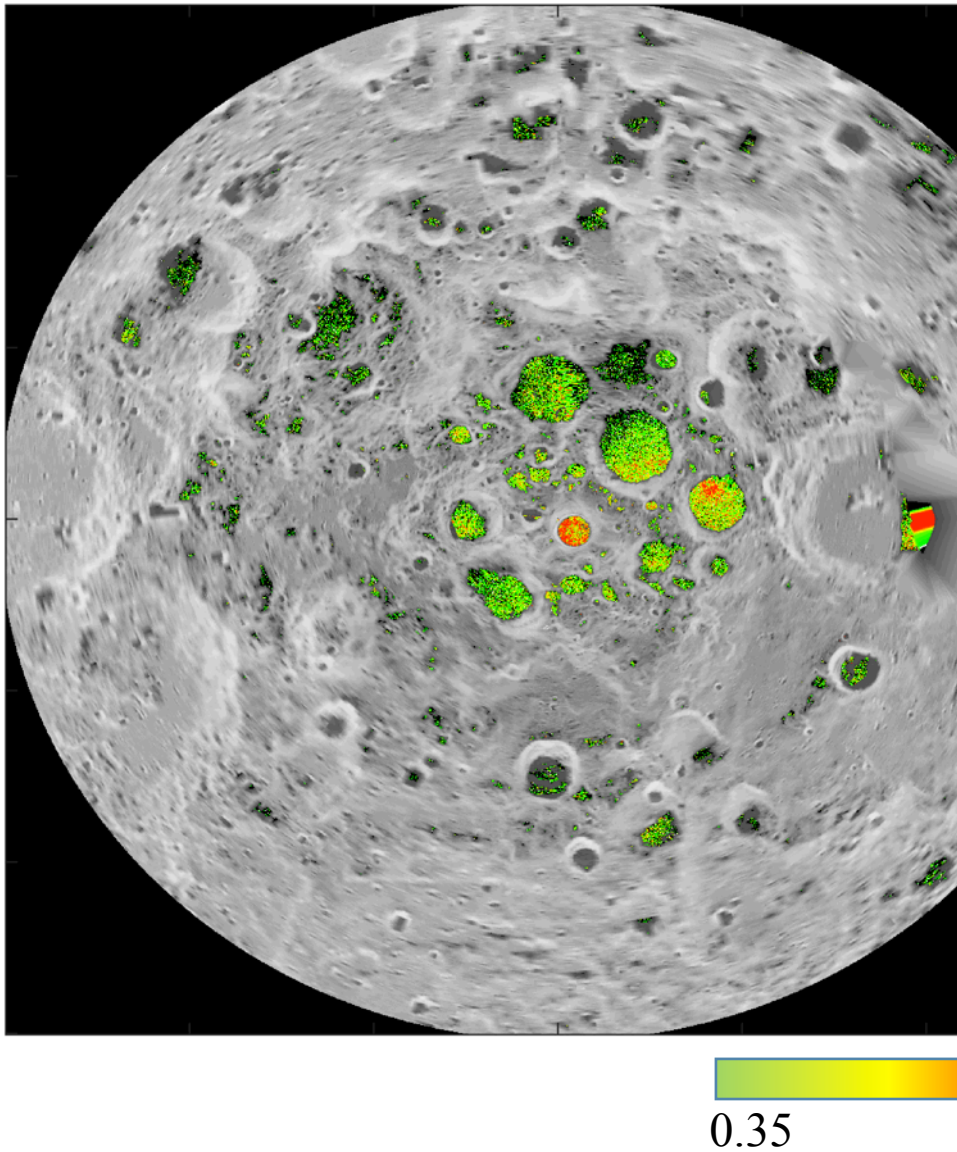
LOLA Pre-Calibrated



LAMP

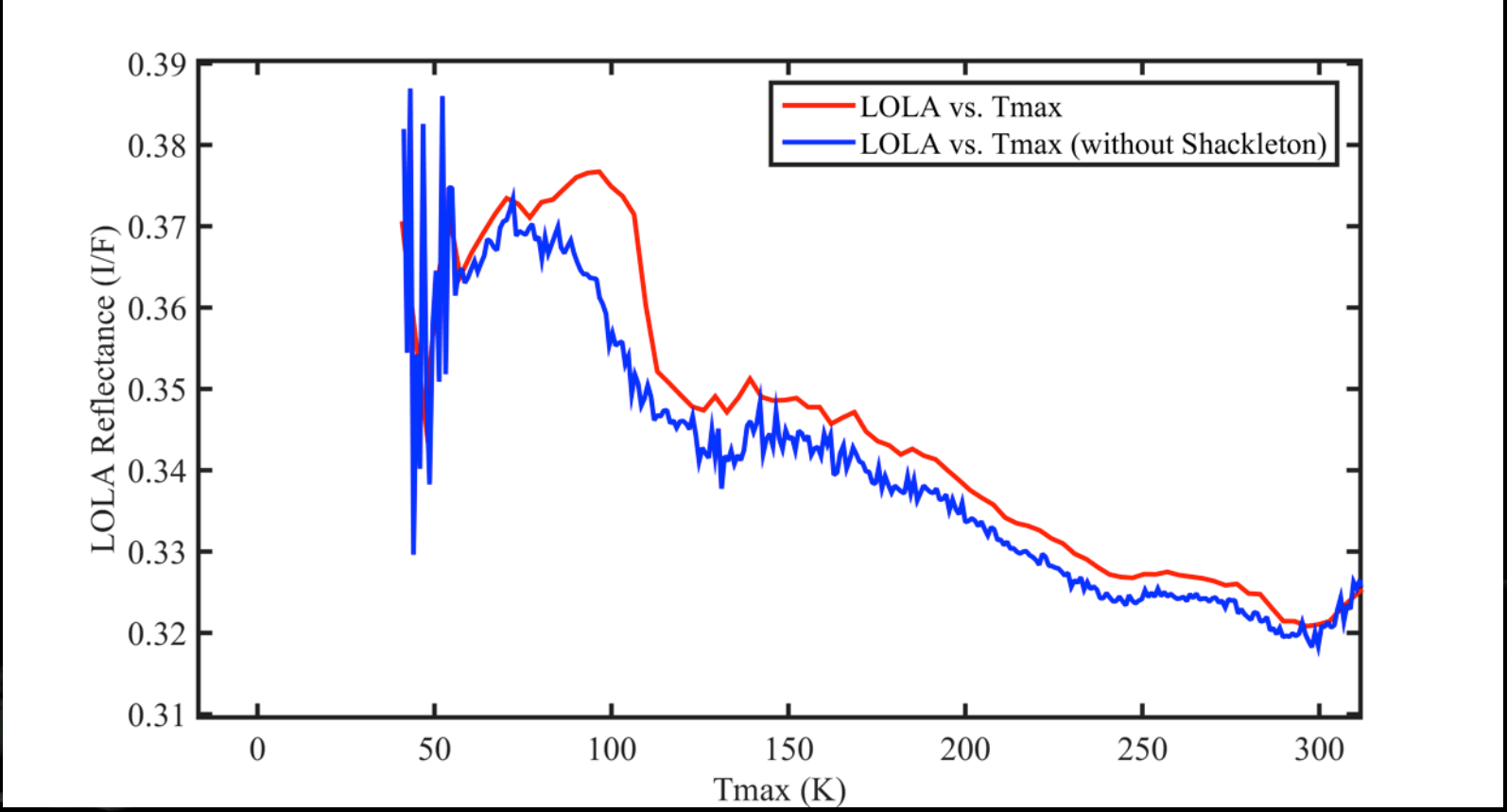


LOLA Recalibrated



“Its just Shackleton”…

No, its still there



	MLA	LOLA	LAMP On/ Off ratio
Water (100 K peak)	YES	YES	YES
~50-60 K Peak	YES	Maybe	YES
Dip between Water and 50K peak	NO	Maybe	YES
Plausible simple bright organics	YES	YES	NO
160-300 K darkening (Complex organic or Sulfur compound)	YES	Maybe	NO

Summary

1) Both show evidence for water (brightening at 100K)

2) Both show evidence for brightening at cold temps

3) Possible simple organics on both Mercury and the Moon

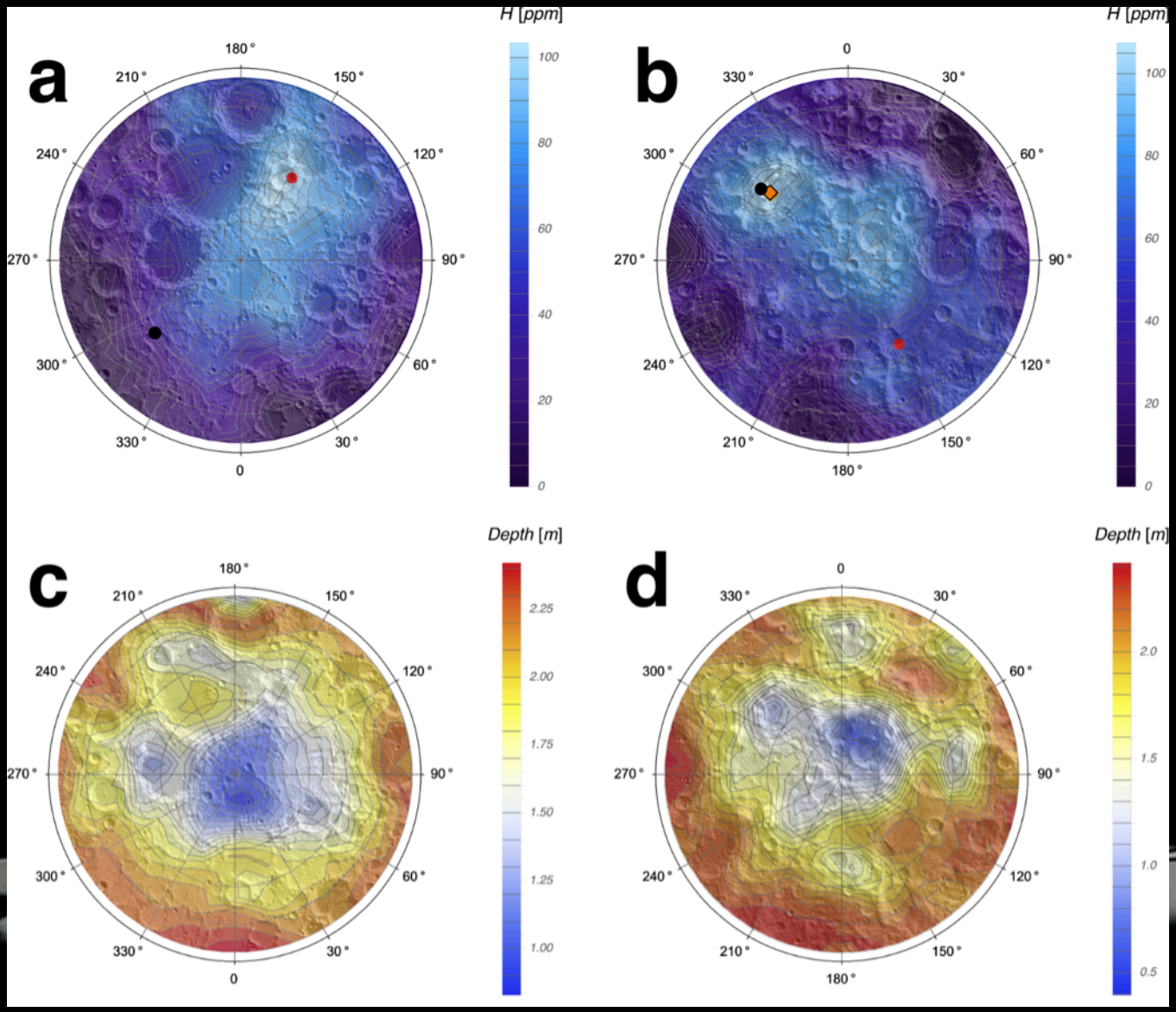
4) Only Mercury shows darkening at 160-300K, complex org. or Sulfur (due to supply? Volcanism? Magnetic field

5) LAMP on/off data doesn't show organics… is this expected?

vertisement for
nes Keane's poster

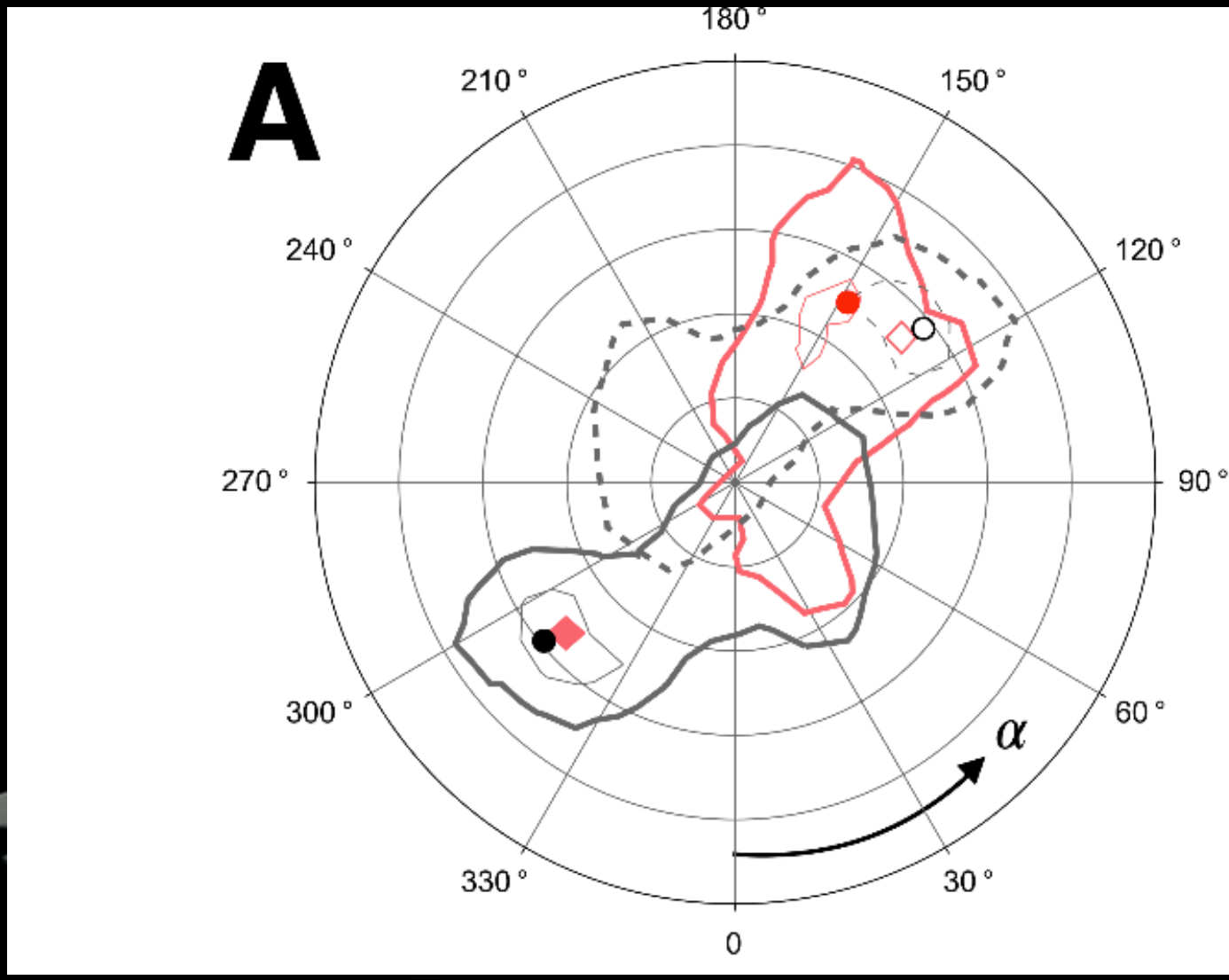
Problem:

Epithermal Neutron
ibution (from Lunar
pector, though
orted by LEND)
ld map ground ice
would be expected
orrelate with the
mal environment…
t doesn't.



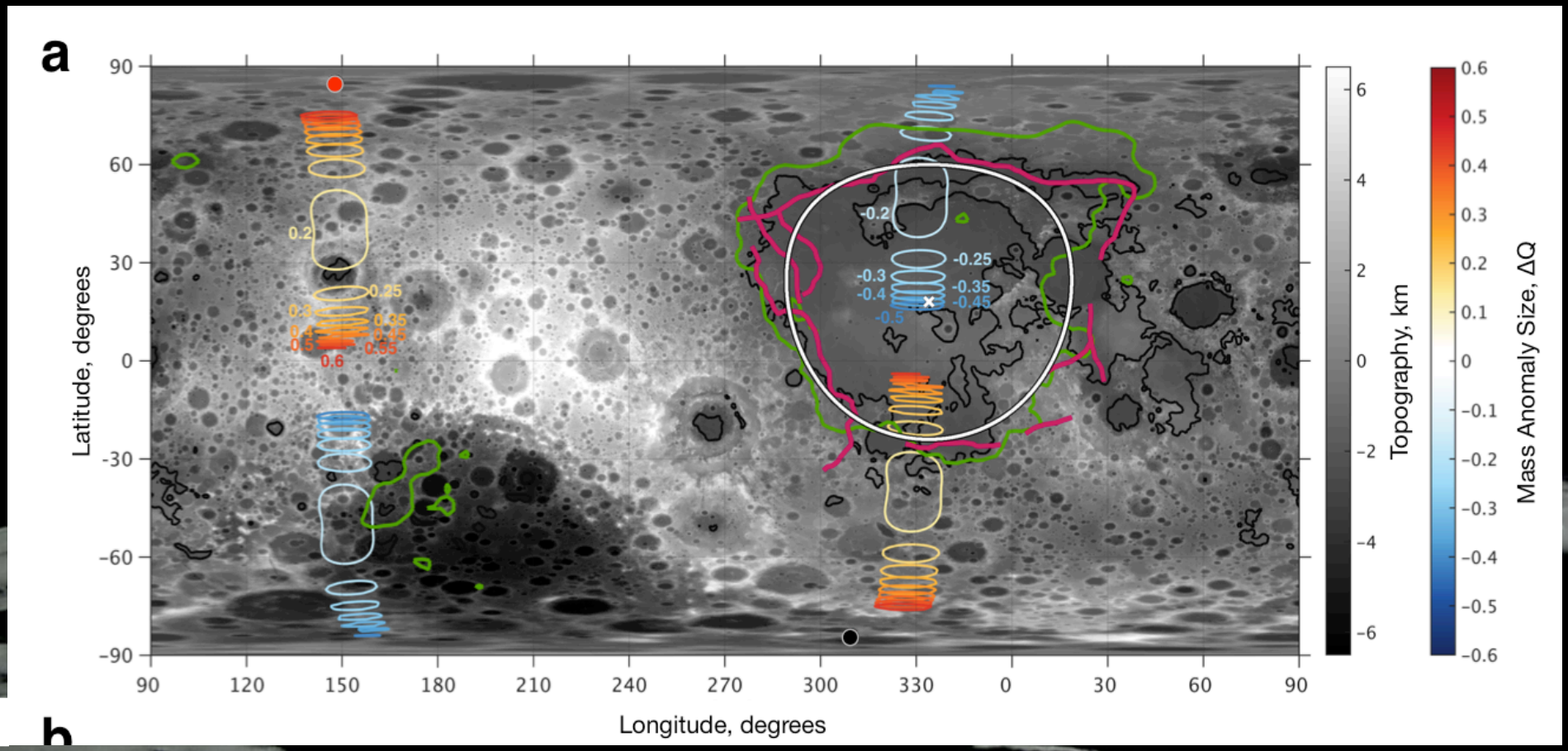
vertisement for
nes Keane's poster

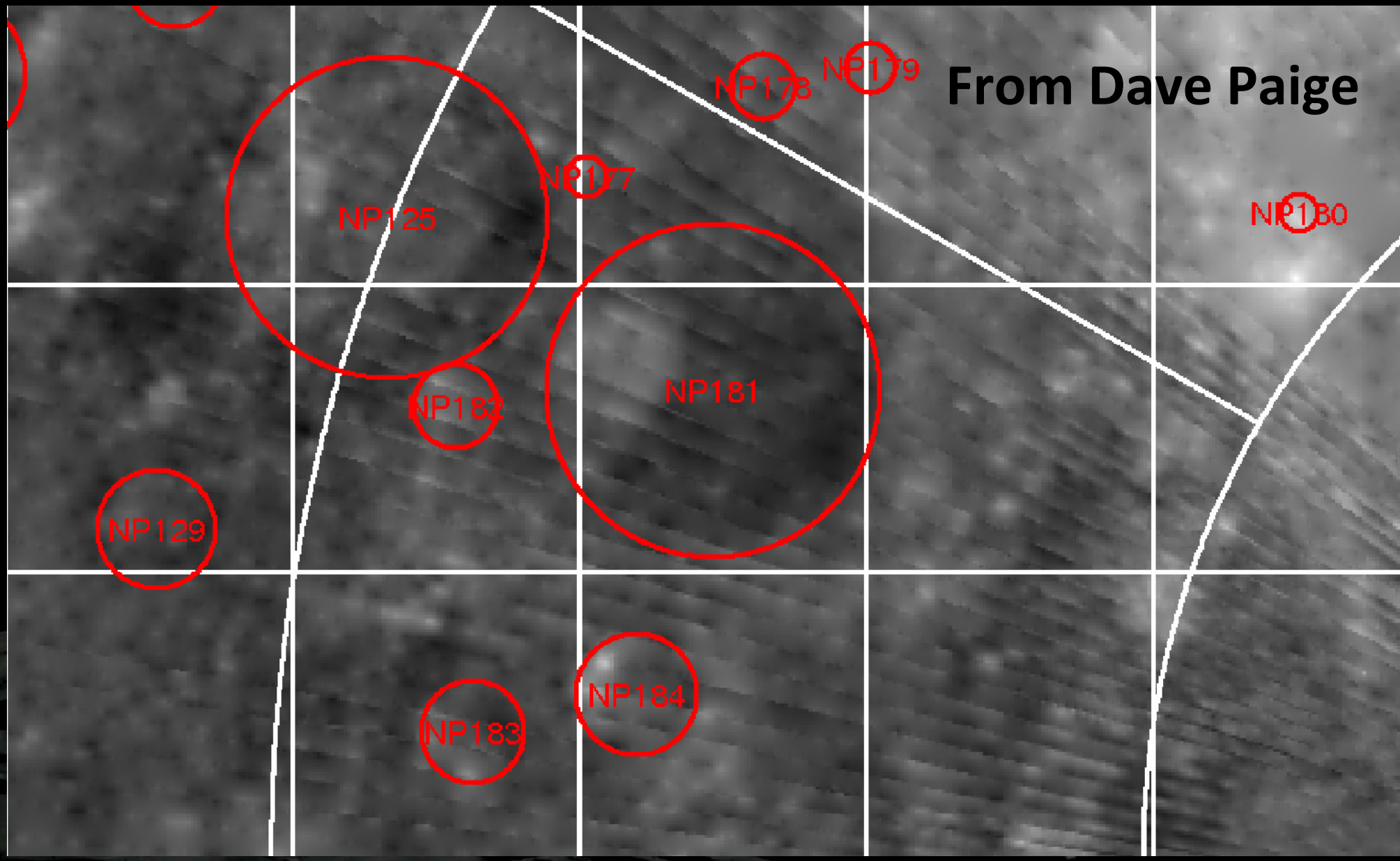
Observation:
Polar hydrogen
osits are opposite
ach other. This is best
ained by True Polar
der of the Moon's
axis.

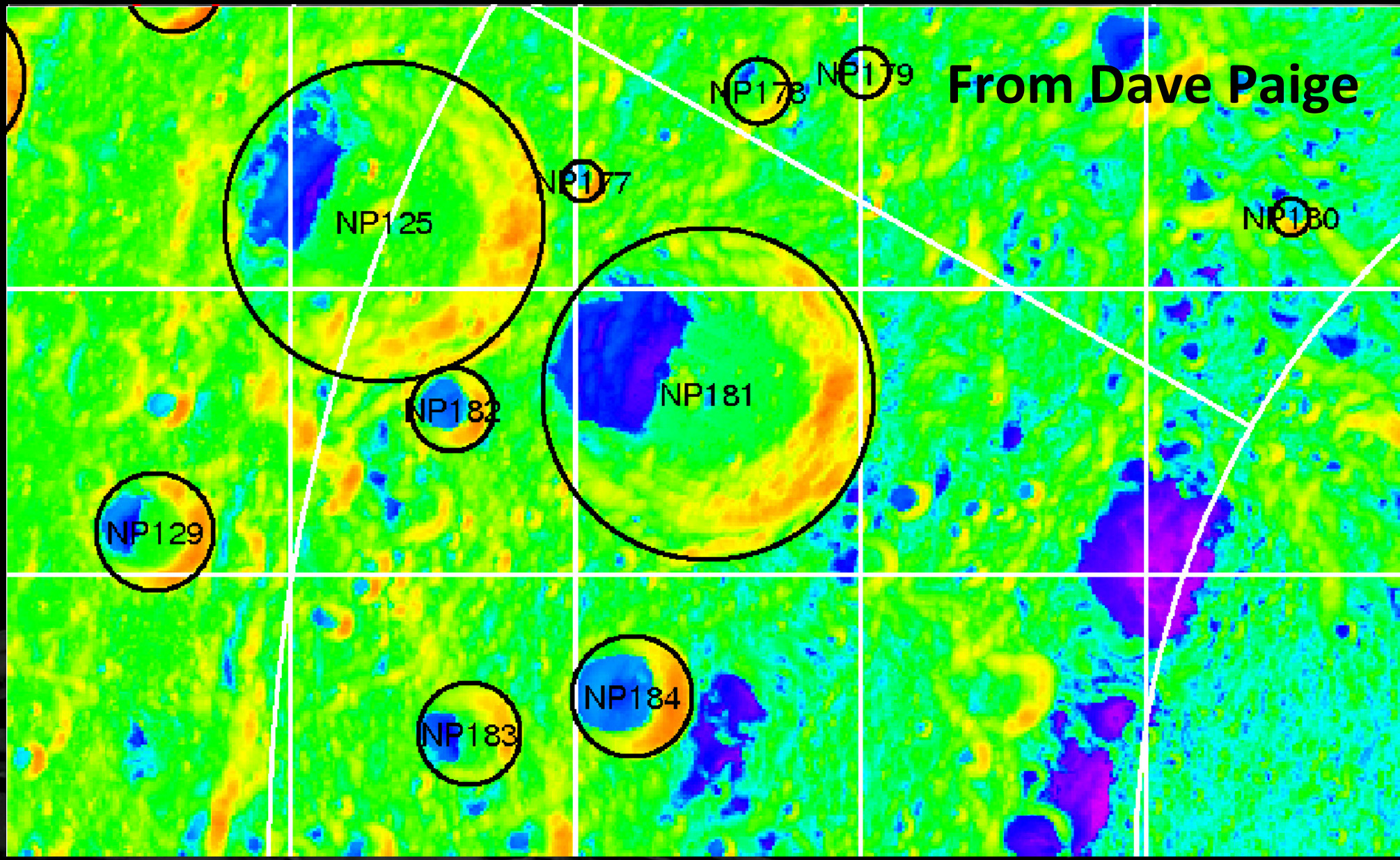


Advertisement for James Keane's poster

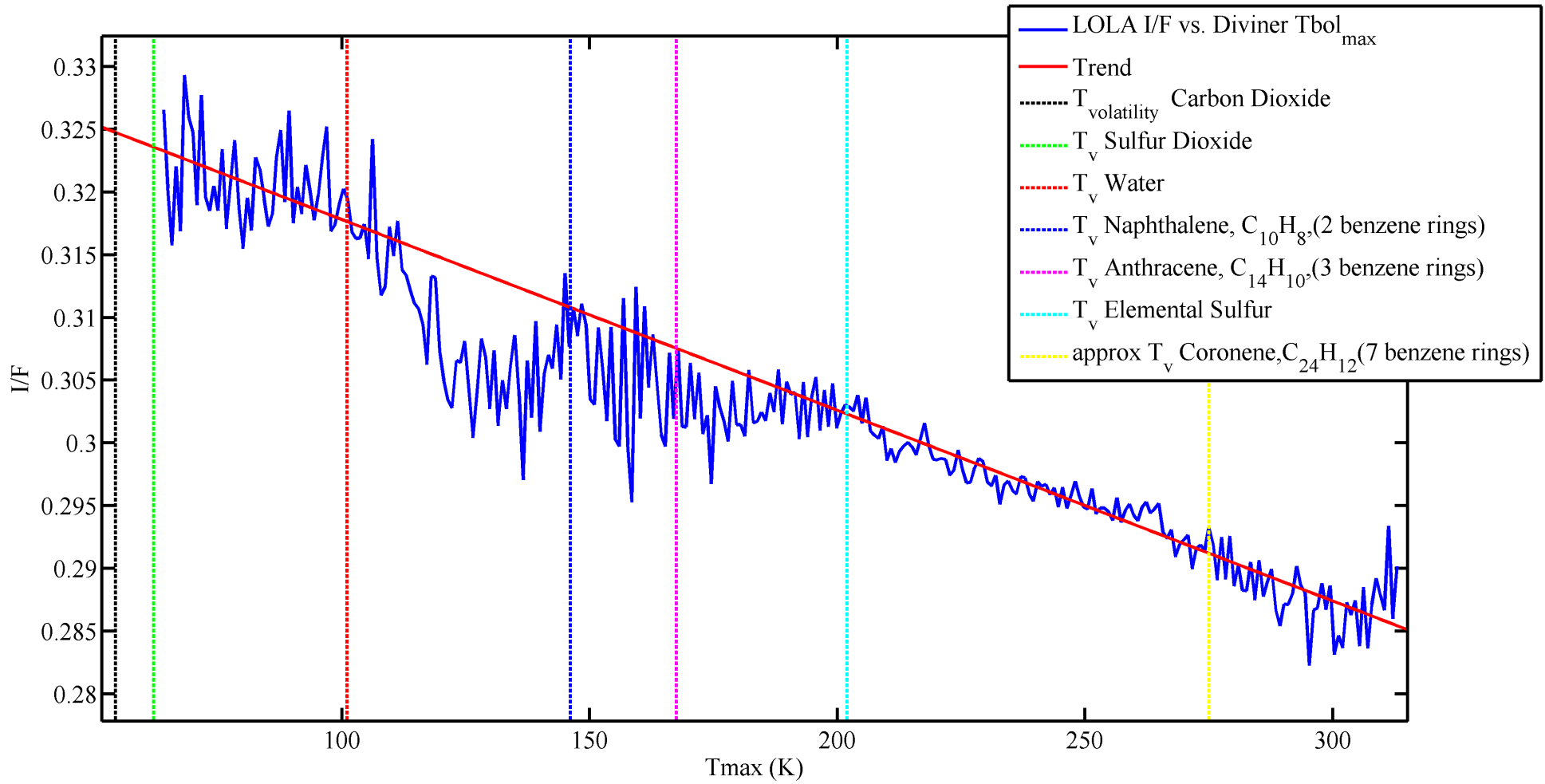
Answer: But that's crazy, it takes a huge mass anomaly to mo
pole by 5.5°… where could you hide such a mass? The PKT.



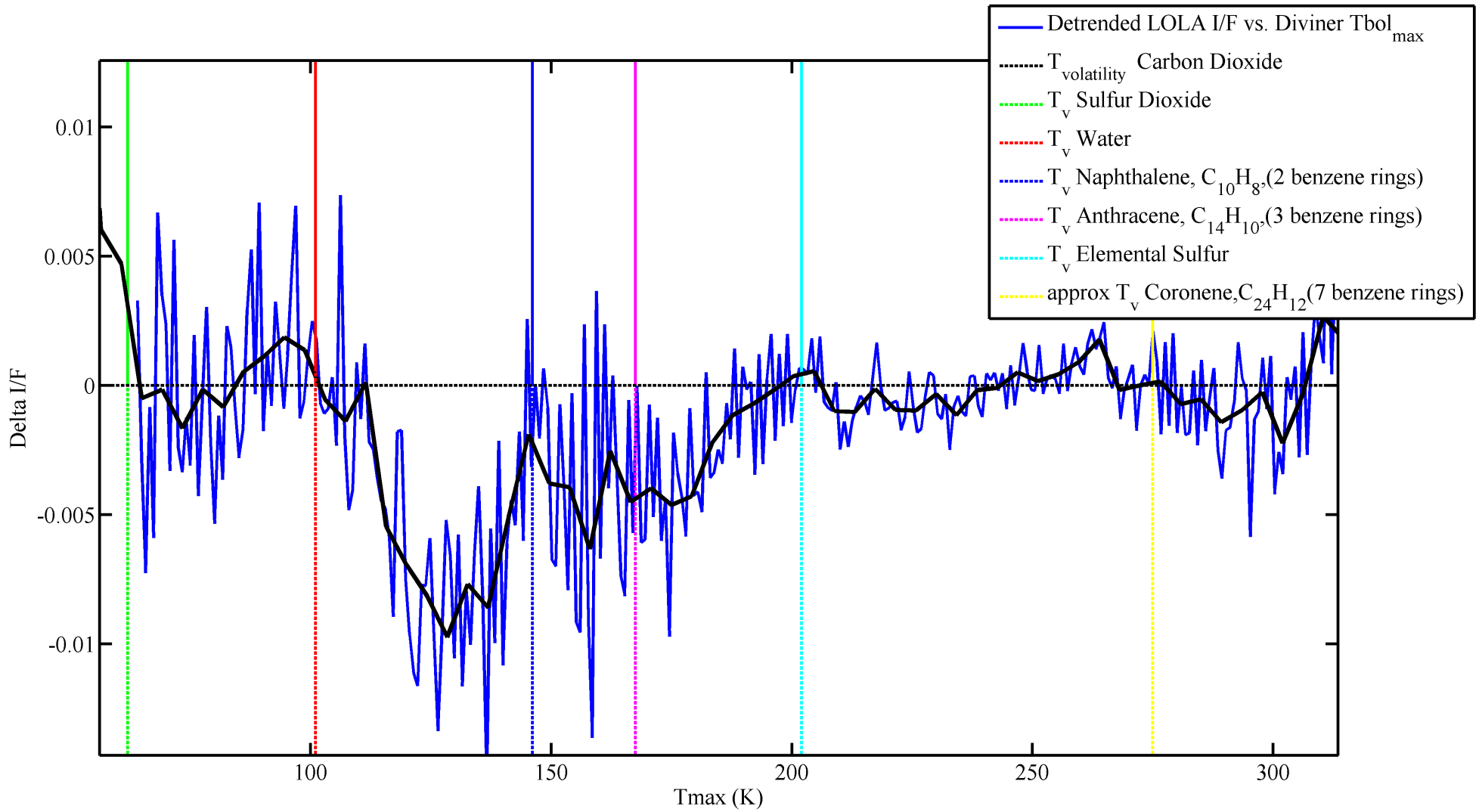

From Dave Paige
NP178
NP179
NP177
NP125
NP180
NP181
NP182
NP129
NP184
NP183

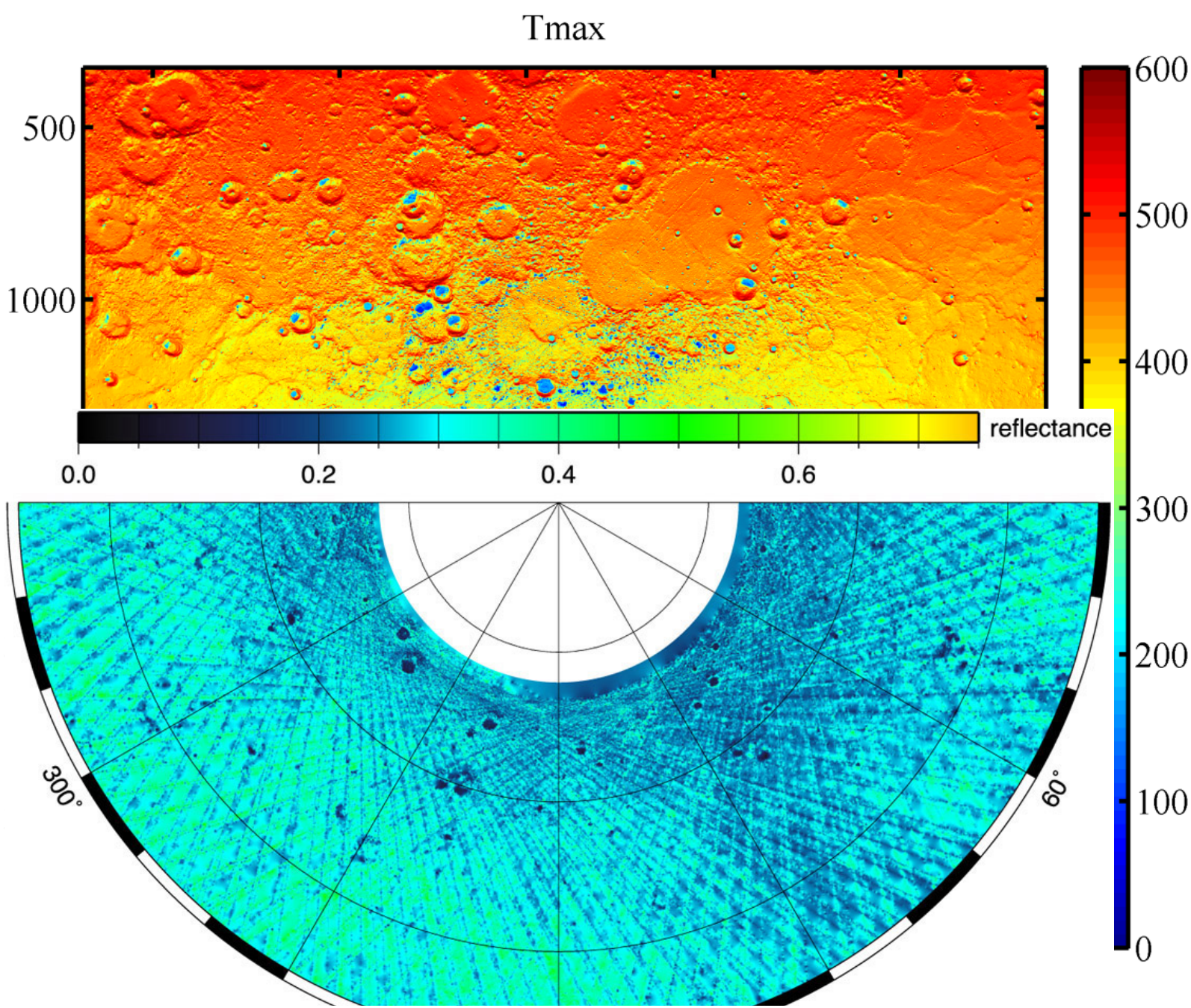

From Dave Paige
NP178
NP179
NP177
NP125
NP180
NP181
NP182
NP129
NP184
NP183

Removing Background slope

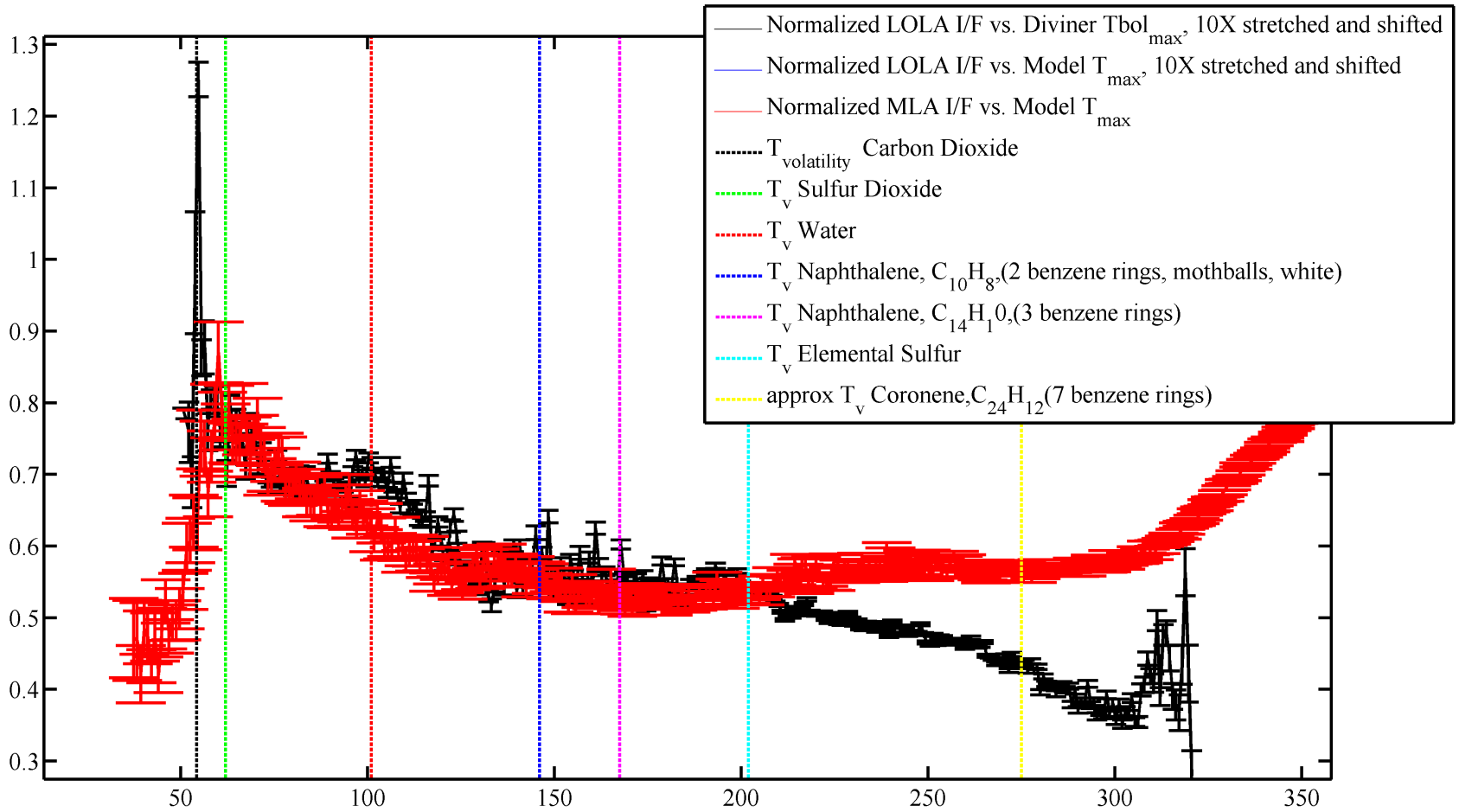
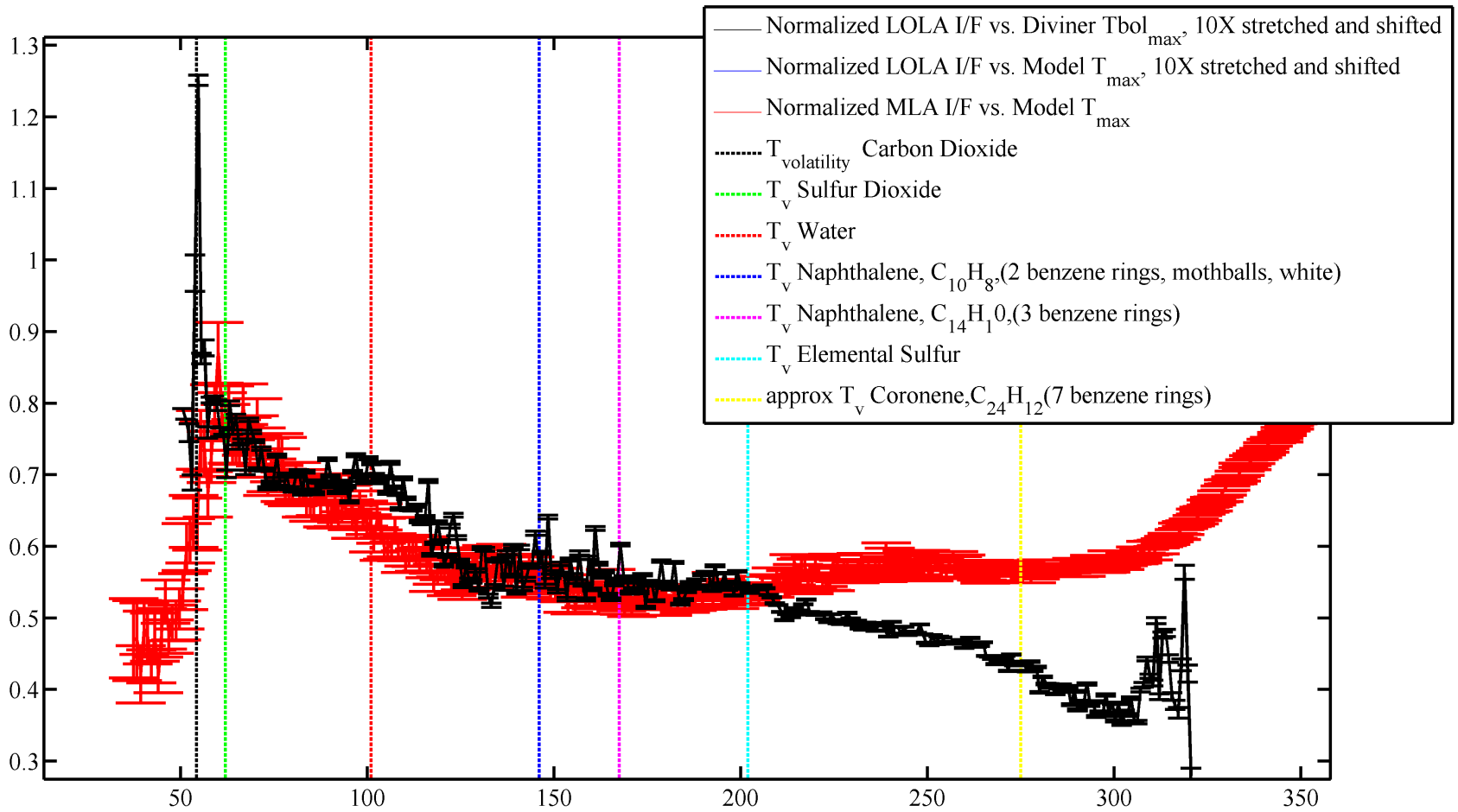


Removing Background slope




Tmax
500
1000
600
500
400
300
200
100
0
reflectance
0.0
0.2
0.4
0.6
300°
60°

The Moon and Mercury
10X LOLA and MLA reflectance vs Temperature



The Moon and Mercury
10X LOLA and MLA reflectance vs Temperature