# Scientific Applications of Planetary Laser Altimeter Radiometry

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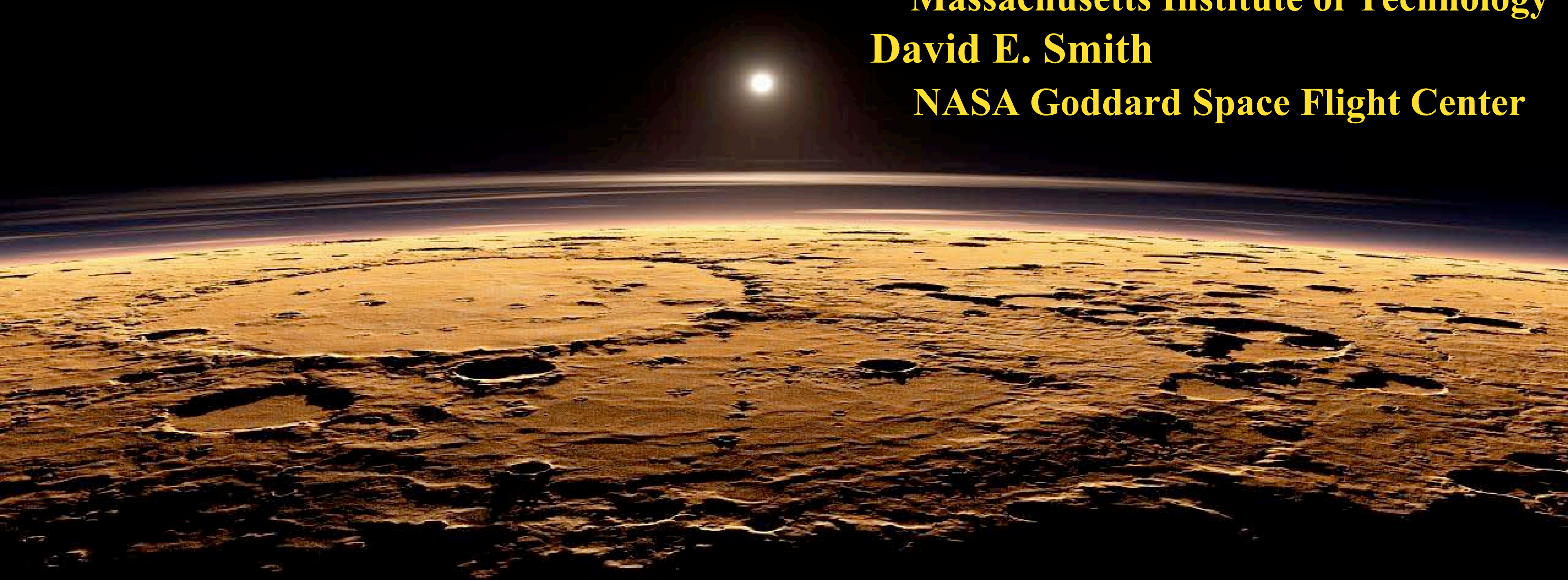

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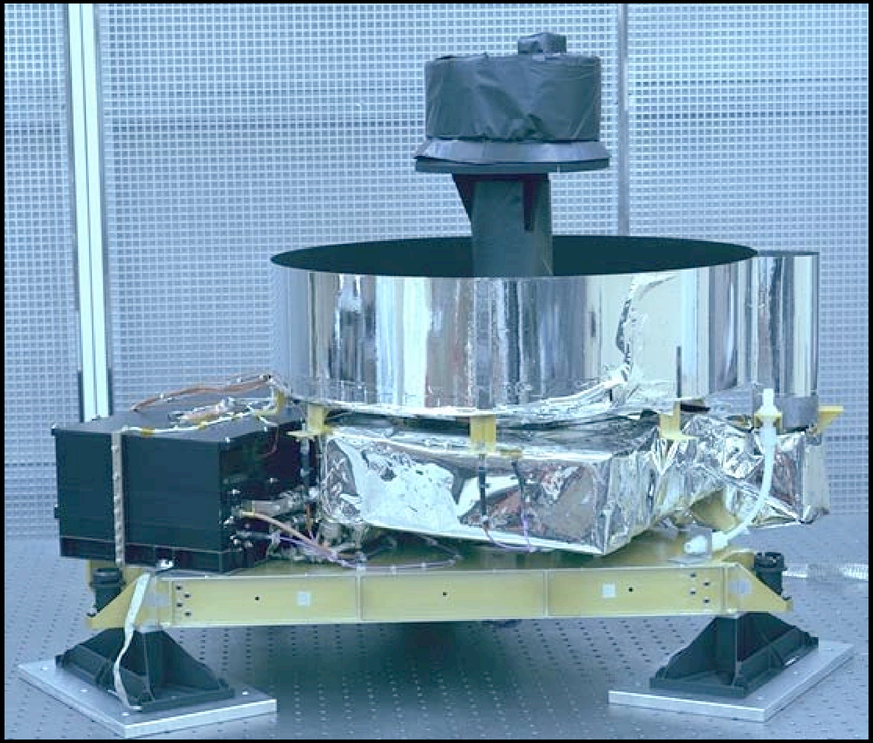
Laser altimeters in addition to providing topographic data of planetary bodies are sometimes able to provide a measurement of the radiance of the object at the wavelength of the laser/detector. At Mars the laser altimeter on the Mars Global Surveyor spacecraft had an adjustable threshold for the detector so that return signals would be kept within a specified dynamic range. The threshold was adjusted according to the strength of the previous return and thus the variation in threshold became an approximate measure of the reflectance of Mars at 1064 nm over the illuminated laser spot on the saurface of Mars, approximately 165 meters in diameter. This method we refer to as the active radiometry mode. After the laser ceased to operate in June 2001, and in between laser firings when the laser was operating, the detector measured the radiance of the solar illuminated surface at 1064 nm over the detector field of view of approximately 385 meters. This mode is referred to as the passive radiometry mode. In the active mode the instrument acquired radiometry at 1 Hz, with a S/N of about 10; in the passive mode the instrument acquired radiometry at 8 Hz with a S/N of about 100. We now have nearly 3 Mars-years (over 5 Earth-years) of high resolution passive radiometry of Mars at 1064 ±1 nm for spatial footprints of under 400 meters. These observations are being used to study the intrinsic brightness of Mars and to monitor the changes in the polar icecaps due to the seasonal exchange of $CO_2$ between the atmosphere and the surface. Fig 1 shows the two polar regions of Mars at the same time of year (Ls =260) when the sun is just below the equator and moving northwards. Note the difference in radiance of the two regions and the lack of symmetry of the south polar icecap.

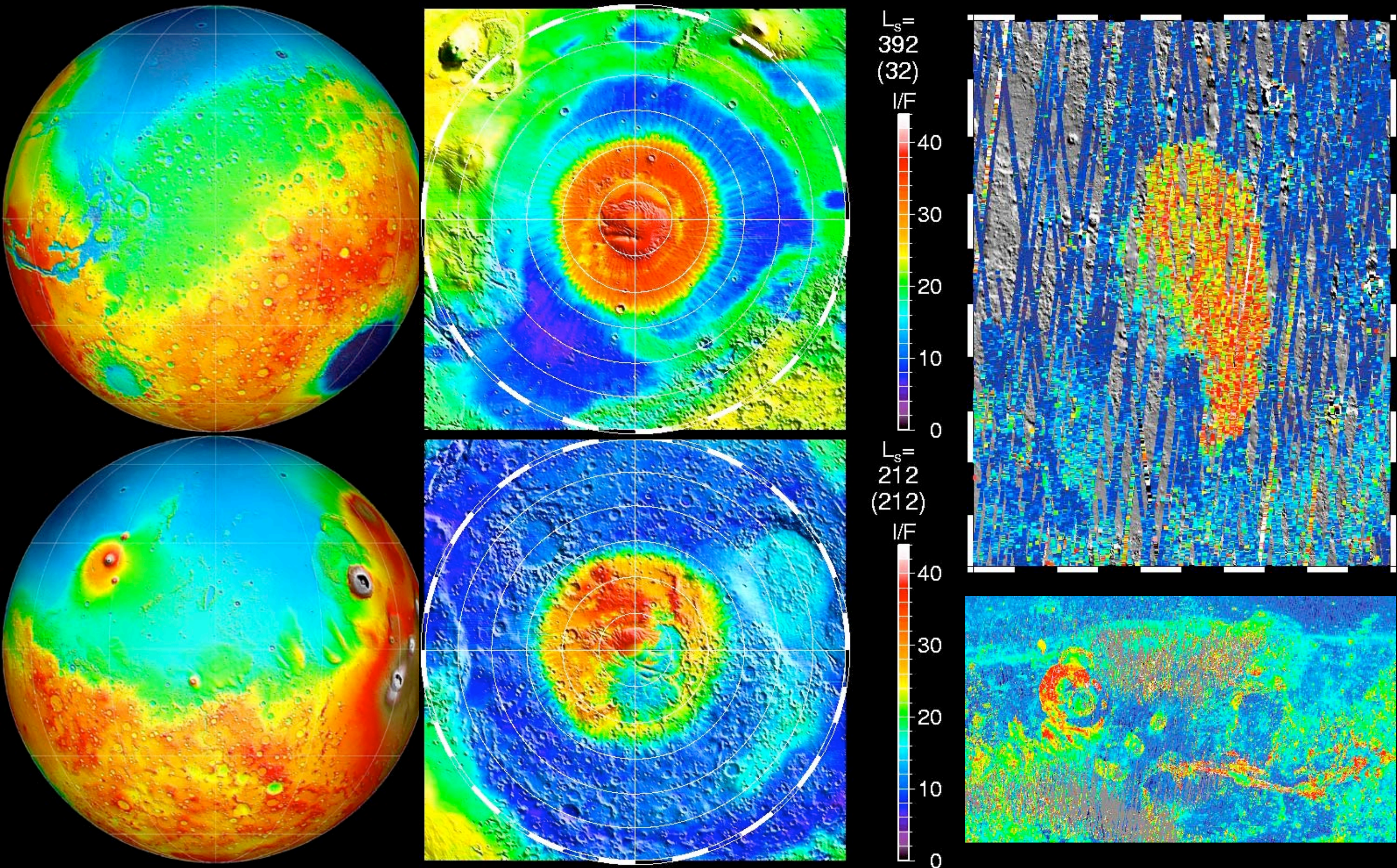
# MOLA Instrument and Mapping Parameters



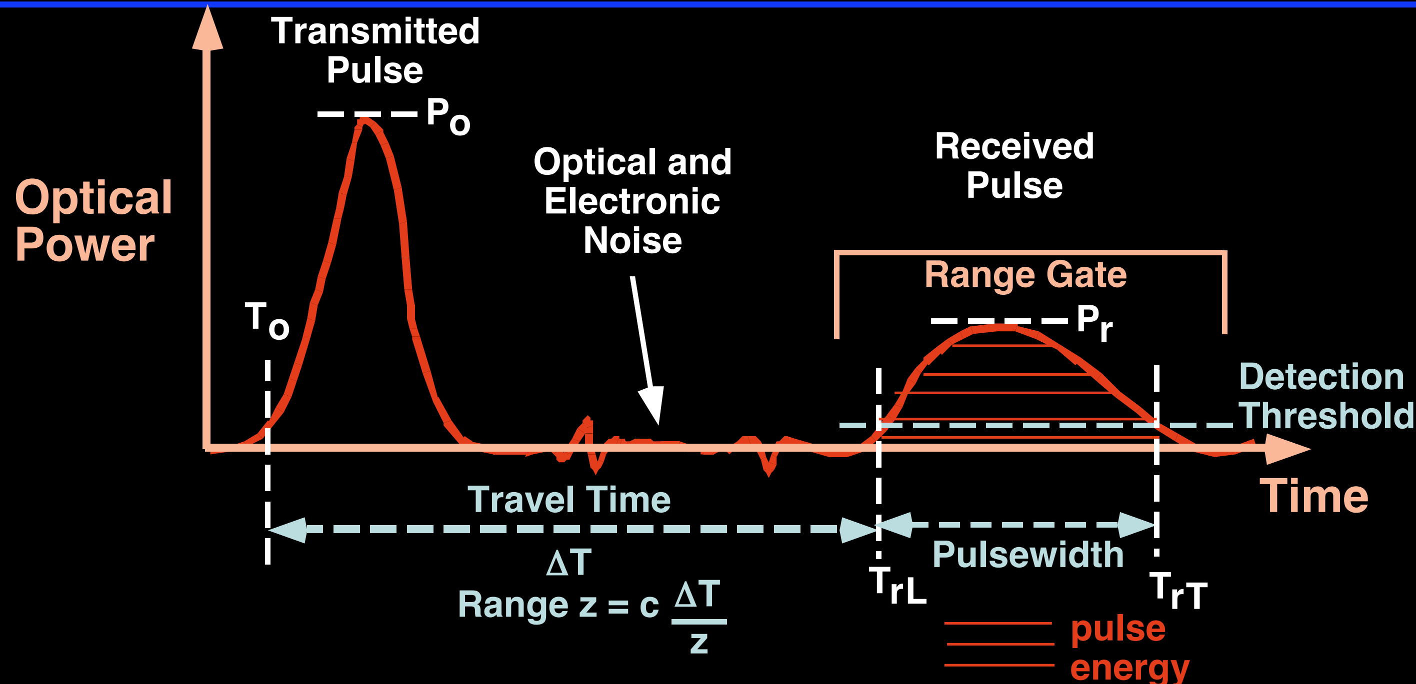
671,121,600 shots

- Wavelength: 1.064 ± 0.002 $\mu$m
- Pulsewidth: 8 nsec
- Pulse energy at start of mapping: 48 mJ
- Return pulses detected: ~99%
- Range resolution: 37.5 cm
- Pulse repetition frequency: 10 Hz
- Maximum range (hardware driven): 786 km
- Surface spot size in mapping orbit: ~168 m
- Along-track shot spacing: ~330 m
- Absolute vertical accuracy (from radial orbit error): <1 m

# Topography, 1064 nm Radiance, Surface Roughness



# Spectral Radiance from MOLA Active & Passive Radiometry




- Passive measurement capability based on dynamic detection threshold feature in receiver that adjusts for changes in background noise associated with solar illumination.

- Power in 2-nm bandwidth is converted to spectral radiance via the link equation. Units are W $m^{-2}$ $sterad^{-1}$ $nm^{-1}$ . We normalize to a constant mean solar distance, and assume $F_{solar}$= 590 W $m^{-2}$ with Lambertian scattering to yield a spectral reflectance (I/F).

# Longitude of the Sun at Mars, $L_s$

We describe seasonal variations on Mars in terms of the longitude of the sun $L_s$.

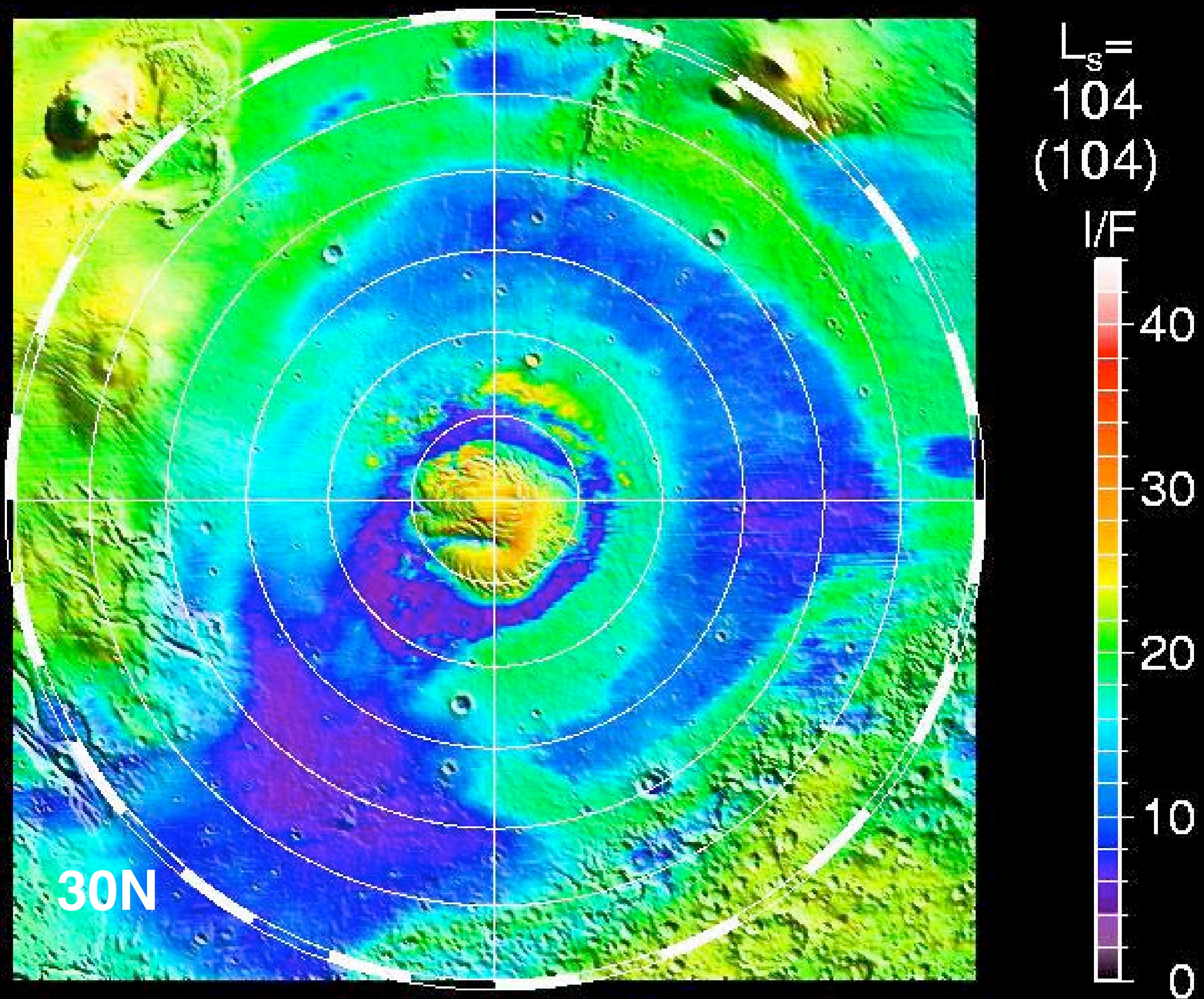
Ls = 0, beginning of N. Spring and S. Fall (sun on equator)

Ls = 90, beginning of N. Summer and S. Winter (sun at max. N. lat)

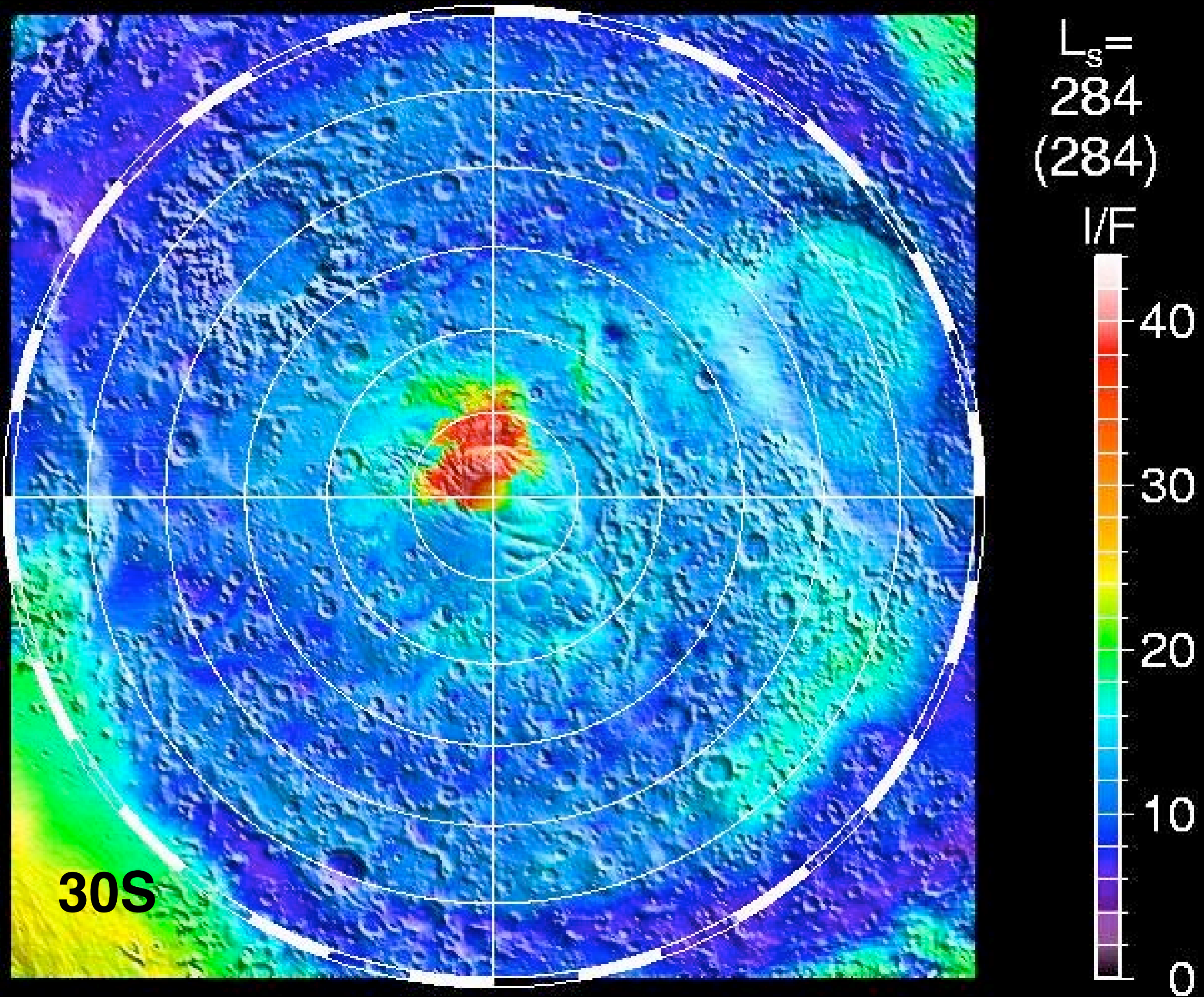
Ls = 180, end of N. Summer and S. Winter (sun on equator)

Ls = 270, end of N. Spring and S. Fall (sun at max. S. lat)

# North Pole 1064-nm Passive Radiometry
(northern summer)



# South Pole 1064-nm Passive Radiometry
(southern summer)

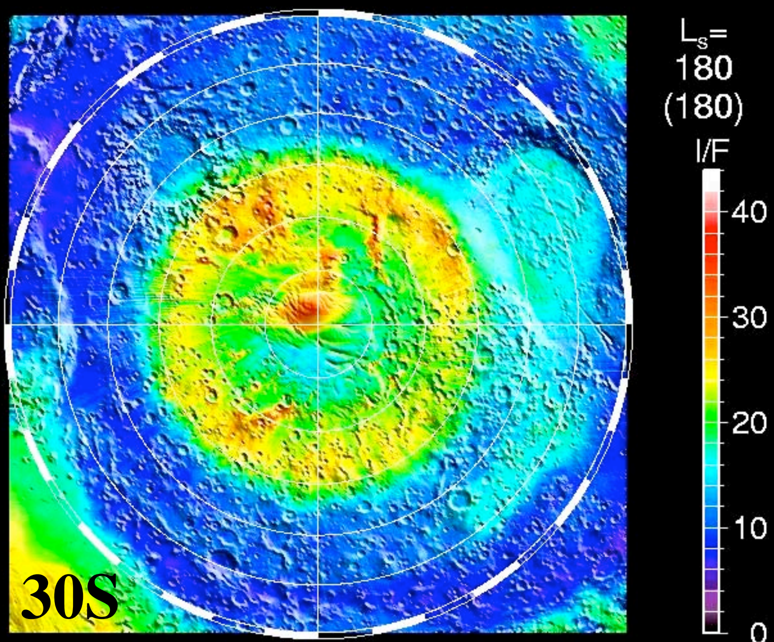


# South Polar Ice of Mars: Changes in 60 days

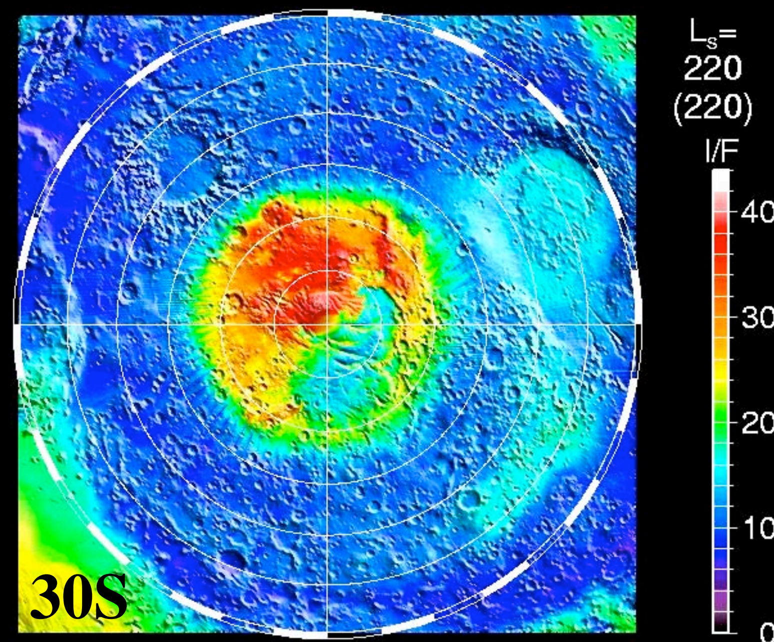
## End of winter to early Spring

The seasonal icecaps of Mars is $CO_2$;

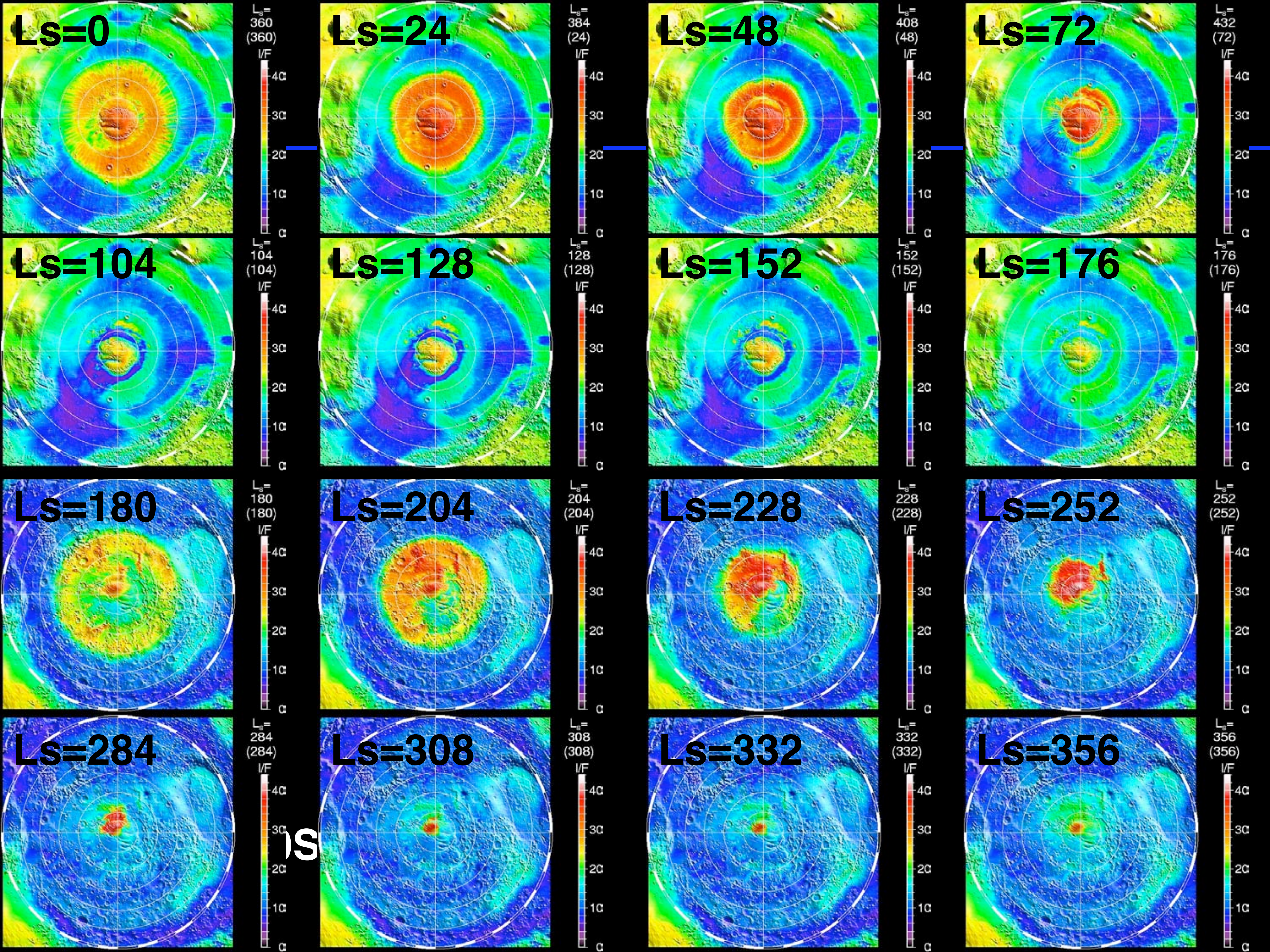
the permanent icecaps are $H_2O$



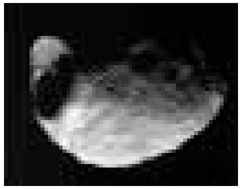

Cap extends to nearly lat 55S at the end of southern winter



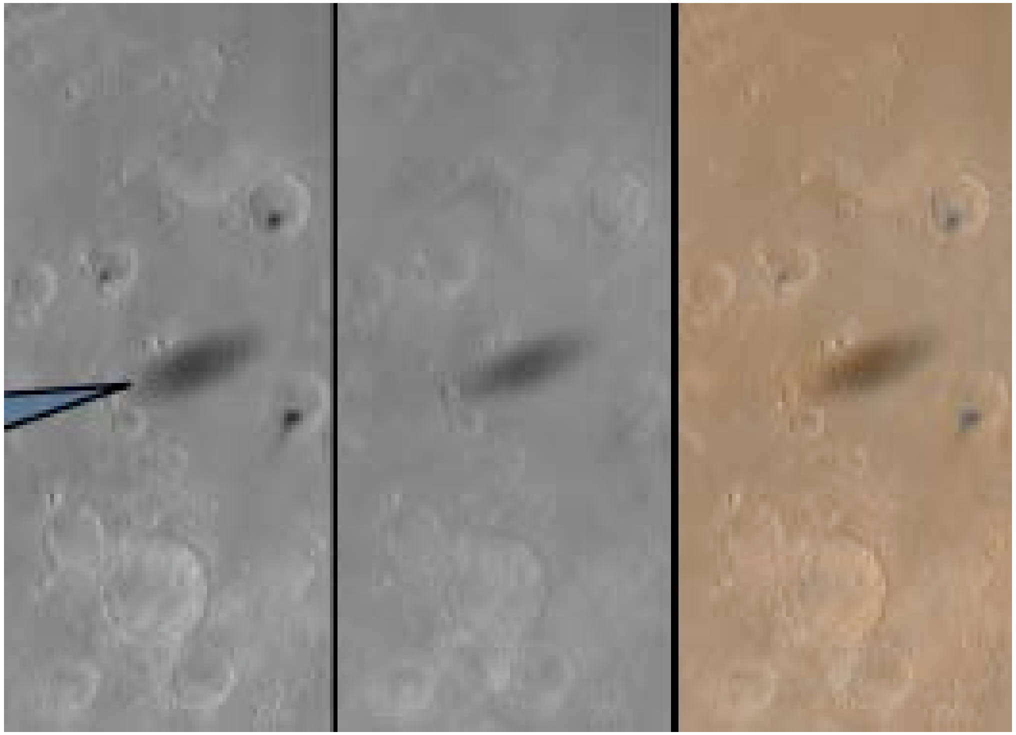

Cap has decreased to lat 65S at the end of southern winter, but appears brighter and irregular


Ls=0
Ls=24
Ls=48
Ls=72
Ls=104
Ls=128
Ls=152
Ls=176
Ls=180
Ls=204
Ls=228
Ls=252
Ls=284
Ls=308
Ls=332
Ls=356
Ls= 360 (360)
Ls= 384 (24)
Ls= 408 (48)
Ls= 432 (72)
Ls= 104 (104)
Ls= 128 (128)
Ls= 152 (152)
Ls= 176 (176)
Ls= 180 (180)
Ls= 204 (204)
Ls= 228 (228)
Ls= 252 (252)
Ls= 284 (284)
Ls= 308 (308)
Ls= 332 (332)
Ls= 356 (356)
I/F
40
30
20
10
0

# Shadow Observations of Phobos



Images of the shadow of Phobos on the surface of Mars taken by the MOC camera on MGS.  These are observed regularly.



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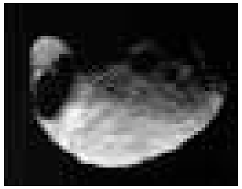
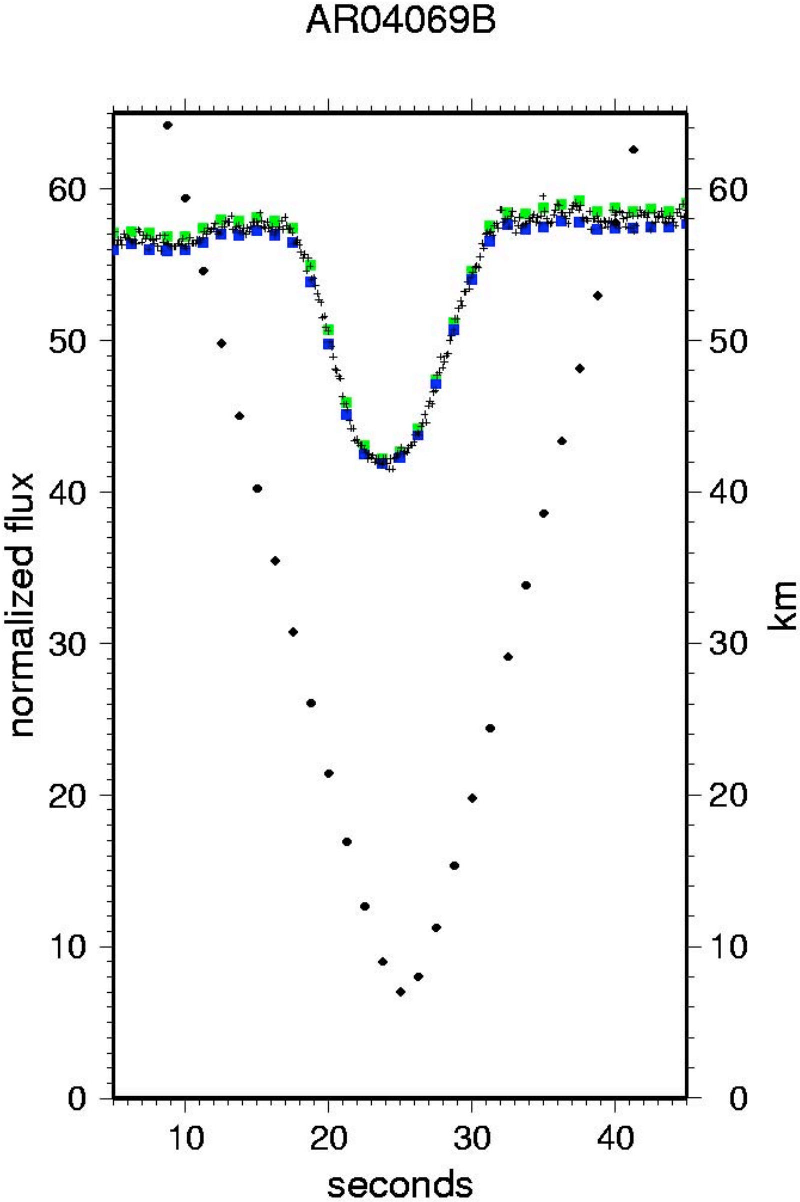


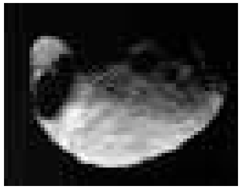
Variation in surface reflectance seen MOLA as MGS passes over shadow.

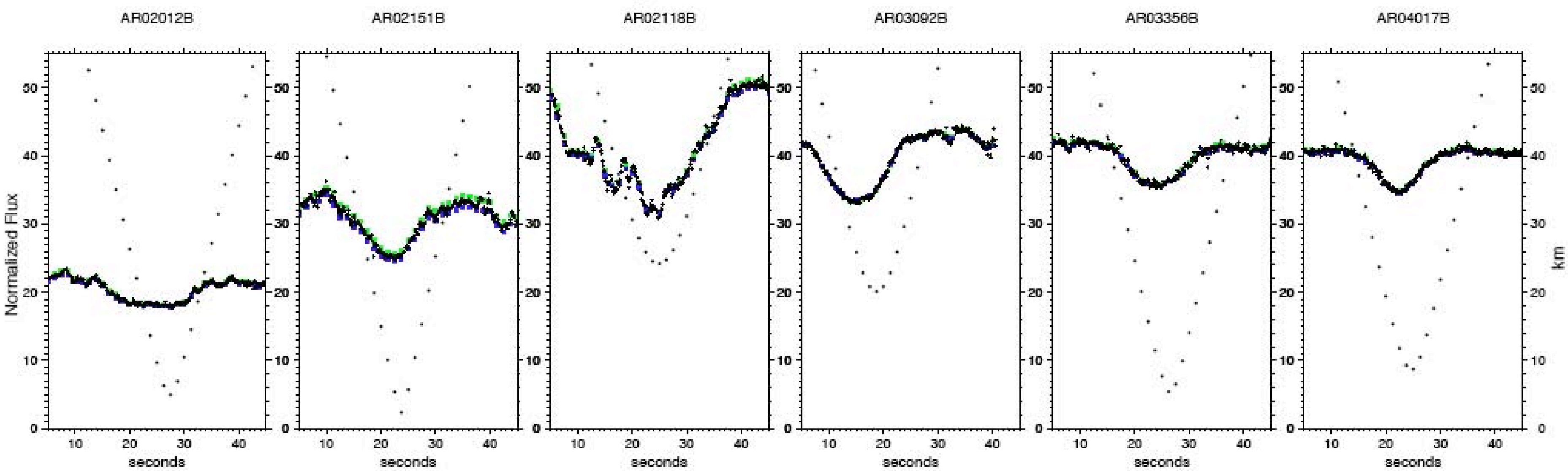
MOLA detector FOV is ~ 400 meter spot and observations are obtained at 8 Hz so spots are contiguous.

Fig shows comparision of predicted time of time of passing through shadow and actual time indicating an error in the ephemeris of Phobos.

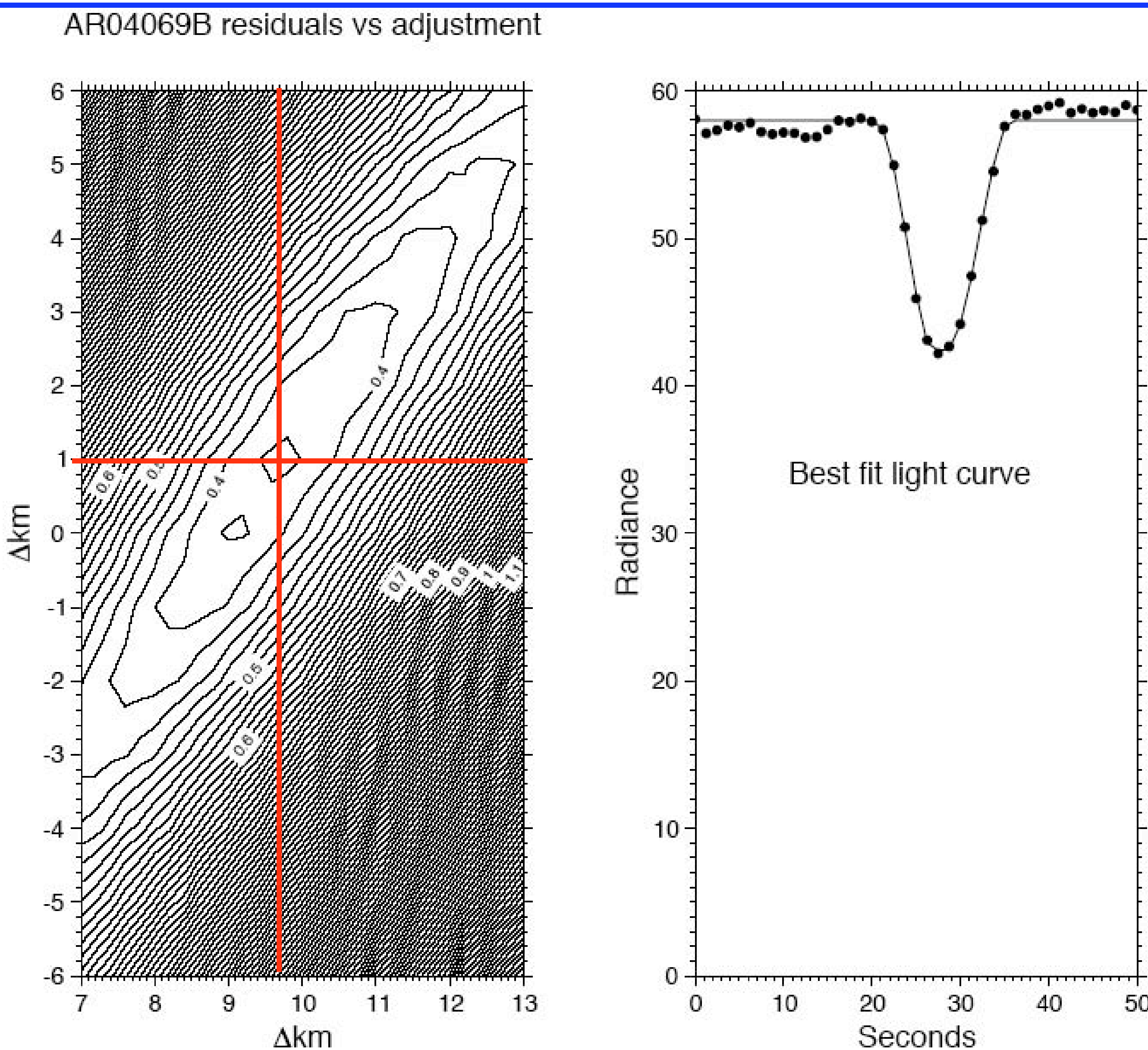


# MOLA Observations of Phobos Shadow





# Analysis of MOLA Shadow Observation




Residuals to predicted surface brightness curve show the error in the predicted shadow position in along and across track position of Phobos.

1 km and 9.6 km

# Summary and Conclusions

Radiometric brightness observations by altimneters can be a important scientific observation for certain studies.

These observations should be considered when we develop laser altimeters as potentially providing additional science.