FUTURE OBSERVATIONS OF THE MARS ATMOSPHERE BY NASA MISSIONS

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Launched November 18, 2013, the MAVEN spacecraft (Mars Atmosphere and Volatile Evolution Mission) is on its way to Mars orbit, where it will join two NASA orbiters, Mars Odyssey (ODY) and Mars Reconnaissance Orbiter (MRO), the European Space Agency (ESA) Mars Express Orbiter (MEX), and the recently launched India Space Research Organization (ISRO) Mars Orbiter Mission (MOM). Meanwhile, MER *Opportunity* and the Mars Science Laboratory (MSL) *Curiosity* rovers continue to operate on the surface of Mars.

MAVEN will start a one (Earth) year science phase in the fall of 2014, when ODY, MER, the NASA supported component of MEX, MRO and now MSL will be in extended missions. Funding for these extended missions will be based on the results of a 2014 Senior Review, which is not presently scheduled, but is expected to make its recommendations before summer 2014. In preparation for that review, the currently operating missions are considering the activities to be proposed for the period October 2014 to September 2016, including observations relevant to understanding better the Martian atmosphere and its interaction with the surface, both in the present climate and in the past. The purpose of this talk is to give an overview of present thinking about atmospheric observations by the NASA Mars missions in that 2014-2016 timeframe.

The focus of the MAVEN mission is the upper atmosphere of Mars and its interaction with the space environment. By measuring the solar energy inputs into the Martian atmosphere, characterizing the magnetic environment, measurements of bulk and trace gas constituents, including ions and isotopes, MAVEN seeks to understand atmospheric escape processes in the present climate as driven by the measured forcing functions and then to extrapolate those back into the past, using models of stellar evolution and constrained by the measured isotopic abundances. The fundamental, motivating questions is: What happened to the water in the early, more massive Mars atmosphere? There is plenty of evidence for liquid water modifying the morphology and composition of the ancient Mars surface. That water can go two places: Frozen in the crust of the planet still today or lost to space. MAVEN intends to address that loss to space by measurement and by modeling.

Upper atmosphere transport and ultimate loss is driven both by the energy inputs from the sun and by forcing from the lower atmosphere, also driven by solar radiation. Thus, observations of the lower and middle atmosphere are also of interest and can be provided (data on temperatures and aerosol distributions) by orbiter instruments and constrained by surface meteorological data (e.g., argon measurements by MER and meteorological measurements by MSL REMS and isotopic measurements by MSL SAM). Key orbiter capabilities for the lower atmosphere are the THEMIS IR and VIS imaging systems on Mars Odyssey, the Mars Color Imager (MARCI) weather camera and the Mars Climate Sounder (MCS) vertical profiler on MRO. Also on MRO, the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) will make column measurements of water vapor and carbon monoxide when viewing nadir and various species including some oxygen species when viewing every other month at the limb with high vertical resolution. MCS temperature/pressure profiles and aerosol detection extend to ~80 km with ~5 km vertical resolution. Stellar occultations by MAVEN's UV Imaging Spectrometer (UVIS) [and by Mars Express SPICAM] can help bridge the gap to higher altitudes that are the focus of the MAVEN mission.

The MAVEN remote sensing atmospheric measurements are mainly by UVIS. UVIS can also monitor the planet with global, low-resolution scans, from apoapsis. These can be compared with the daily global maps of lower atmospheric cloud phenomena produced by MARCI. MARCI observes in 2 UV and 5 visible color filters.

MAVEN also makes in situ measurements of atmospheric gases using the Neutral Gas Ion Mass Spectrometer (NGIMS). Bulk density is also derived using the spacecraft accelerometer (ACC) and attitude data. Typically, these measurements are made near the spacecraft periapsis at ~ 150 km. However, there are also five presently planned "deep dips" in which the MAVEN periapsis is lowered to ~125 km for a week or so at carefully timed points in the MAVEN mission. A distinct feature of the elliptical MAVEN orbit is that it will precess through local time, as does MEX, but unlike MRO and ODY which are in near-polar orbits at fixed local times (however, see discussion below). Figure 1 shows the variation with local time and latitude of the MAVEN periapsis during its prime science mission (November 2014 to October 2015) as presently planned, together with the current timing of the deep dips and with the local times of MRO and ODY. These would be prime times for simultaneous (co-located in local time) observations of the upper and lower atmospheres.

ODY is presently at a local time of ~4 p.m./a.m., but is deliberately drifting out to later local times to shorten the eclipses that it experiences and thereby ease the burden on its sole spacecraft battery. The ODY team has proposed to let the spacecraft drift all the way out to 6:45 a.m./p.m. so that THEMIS can view the atmosphere and surface in the post-dawn environment. With systematic coverage at these times, ODY THEMIS could provide a unique perspective on the diurnal development and evolution of atmospheric hazes, especially those in the equatorial cloud belt.

In summary, continued observations by MRO and ODY will add to a rich record of the Mars climate. With similar observations proposed for the same time period as the MAVEN prime science phase and with the additional twist of systematic post-dawn observations, there will be much for the Mars atmosphere and climate modelers and researchers to work with from these capable missions.

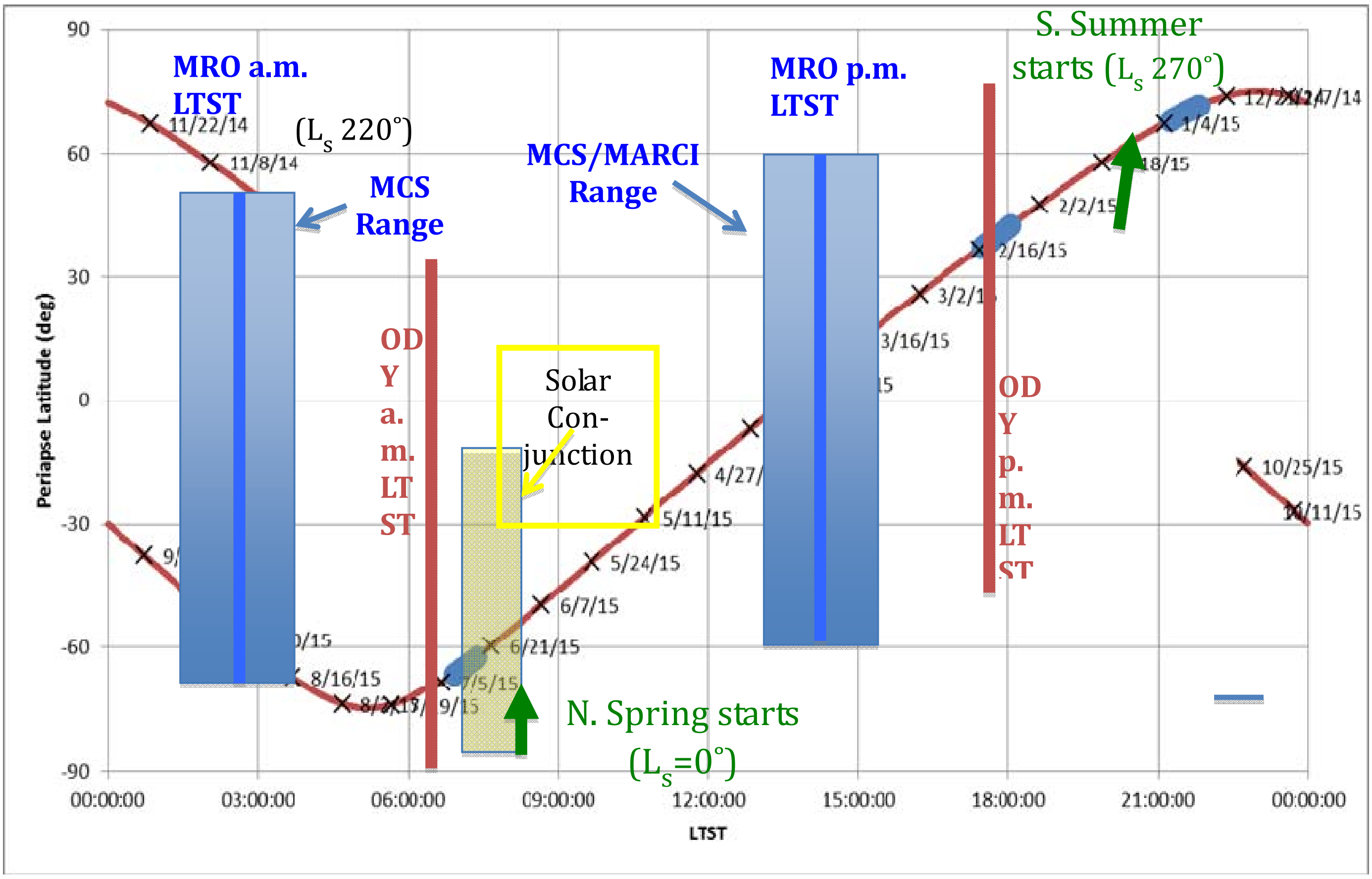

Figure 1: Variation of MAVEN periapsis in latitude (vertical axis) and local true solar time (LTST, horizontal axis) during the MAVEN prime science mission. The blue ovals are the current plans for the "deep dip" campaigns, where periapsis is lowered from ~150 km to ~125 km to enable *in situ* measurement at the lower altitudes. Also shown are the LTST (solid bars) for the ODY and MRO orbits. The shaded rectangles for MRO indicate the range of local times that can be viewed by MRO MCS, as it can look to the side limb for atmospheric profiling.