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HUBBLE SPACE TELESCOPE OBSERVATIONS OF MARS; Philip B. James, University of Toledo, Toledo, OH; Todd Clancy and Steve Lee, LASP, University of Colorado, Boulder, CO; Ralph Kahn and Richard Zurek, Jet Propulsion Laboratory, Pasadena, CA; Leonard Martin, Lowell Observatory, Flagstaff, AZ; and Robert Singer, University of Arizona, Tucson, AZ.

Mars is relatively well known for an astronomical object having been visited by several spacecraft which have observed the planet from orbit and from the surface for a considerable length of time. Mars is like the earth in that it has an active atmosphere; the strong interactions between the atmosphere and surface of Mars make the planet quite variable in appearance on daily, seasonal, and interannual scales. So, despite the scrutiny of the red planet by spacecraft, more frequent, synoptic monitoring, such as that provided by terrestrial weather satellites, is needed to understand meteorology and air surface interactions on Mars.

Martian dust storms are a good example of such variable phenomena which are still only poorly understood. Small dust and sand storms were observed frequently on the martian surface by orbiting spacecraft, and both Mariner 9 and Viking witnessed a relatively rare global dust storm event in which dust spreads from growth centers in the southern hemisphere to cover essentially the entire planet. It is known that these spectacular events, which have no parallel elsewhere in the solar system, do not occur every (martian) year; and there is some evidence that their occurrence is variable on even longer timescales. Because of the effects that such events could have on manned or unmanned surface mission to Mars, the ability to understand and forecast these events is a highly desirable companion to renewed exploration.

The best record for studying the occurrence of duststorms and other variable phenomena has come from earth based astronomy. However, because the distance to Mars from Earth varies dramatically with time, the earth based record has been confined to times near oppositions, which occur every 26 months, when Mars is closest to Earth and can be studied in detail. For most of its orbital journey around the sun the angular size of Mars is too small for studying the planet from Earth. As a result, the available data on dust storms and other time variable phenomena are modulated by the opposition cycle, and a given season can only be viewed every fifteen years.

As originally designed, Hubble Space Telescope afforded the possibility of resolving features as small as 100 kilometers on the martian surface even when it is at the far point of its orbit; this is actually better than the resolution which can generally be obtained from Earth during the opposition periods. And, at oppositions, much better resolutions of roughly 20-30 kilometers, comparable to the set of Viking approach pictures, would be possible. Hubble Space Telescope is therefore ideally suited for monitoring seasonal changes on the red planet. In practice, HST observations are constrained by the pointing constraint which prohibits pointing the telescope within 50^0 of the sun; for Mars, the period of possible observation is reduced to slightly over one half of the 687 day martian year.

This current project on Hubble Space Telescope was originally approved for a period of three years, commencing in late November of 1990 which coincided with a martian opposition. The seven scientists involved in this project have all been extensively involved in research related to variable features in the atmosphere and on the surface of Mars. The objectives of the proposed research include, in addition to study of martian dust storms: use of images obtained through different filters to study the spectral reflectance of regions on the martian surface in order to identify regional differences in surface composition and to record changes in surface "color" which have occurred since the Viking approach maps produced in the mid-Seventies; use of ultraviolet images obtained with the Planetary Camera and ultraviolet spectra obtained with the Faint Object Spectrograph to measure the amount of ozone in the planet's atmosphere as a function of location on the planet and to deduce the humidity of the atmosphere of Mars, which controls the amount of ozone; use of images to study changes in the albedo (relative reflectance) of the surface of Mars which are related to the movement and deposition of dust by the atmosphere; and use of Planetary Camera images to study martian clouds and to measure the opacity of the atmosphere. These goals were to be achieved using roughly monthly sequences designed to monitor the planet. In some cases, especially near the oppositions, several frequency filters were used to permit monitoring of color changes; when the angular size of the planet is smaller, red and blue filters will be used to discriminate between surface details, which stand out most in red, and atmospheric phenomena, which appear brighter in blue.

The General Observer Program of Hubble Space Telescope was postponed to provide the time required to deal with the various difficulties encountered by HST after launch. However, because of the time sensitive nature of the Mars observations (the 1990 opposition was in late November, and the next opposition, which is in January, 1993, will not be nearly as good), the Director approved the execution of the GO program as proposed. This program is therefore the first approved GO program to be executed. Experience with WFPC images of Saturn which were acquired in the fall led to the expectation that much of the resolution degradation caused by the spherical aberration present in the Hubble optical system could be eliminated through various deconvolution techniques. The Mars images, because of the large number of pixels and because of the complex surface details, presented a challenge to the deconvolution process, though the large signal to noise ratio possible for the bright target presented by Mars was a definite advantage. The Richardson-Lucy technique has been used on the WFPC images of Mars; though the estimation of surface resolution is somewhat subjective, we estimate that this deconvolution technique has restored the resolution to within approximately a factor of two of that originally anticipated.

The images which have so far been reduced and analyzed show the face of Mars which features some of the most prominent surface markings on the planet. The largest dark albedo feature, Syrtis Major, was originally recognized by Huygens in the Seventeenth Century; it was used to derive the roughly 24 hour 40 minute rotation period of the planet. Syrtis is located on a large, regional slope from Arabia on the west to the Isidis Basin on the east; the low albedo of the region may be due to scouring of bright dust from its surface by regional winds. The bright feature to the south of Syrtis is the Hellas basin. This feature is the remnant of a huge impact on the planet roughly three and one half billion years ago which produced a basin roughly 800 kilometers in diameter and as much as four kilometers in depth. This basin is often seen to be heavily clouded or to have its surface covered with frost; at this date in late summer, its surface is uncharacteristically visible. Hellas is often the source for planetary dust storms, although none were identified in these images. The bright area to the west of Syrtis major is Arabia, which is elevated above the volcanic plains which surround it; the high albedo of Arabia and other bright areas is thought to be the result of a thin layer of dust deposited on the surface. Because of the prominent surface markings and because the region is known to generate many duststorms, this face of the planet will be monitored fairly continuously during the observing program.

Another feature in the images which attracts immediate notice is the bright, bluish north polar hood. This cloud canopy generally covers the north polar cap of Mars during fall and winter. It is meteorologically one of the most active regions of Mars; the periphery of the hood is characterized by baroclinic weather systems which are similar in structure to those found in terrestrial mid-latitudes. Details seen in the images suggest that such structures can be monitored using HST sequences. The clouds in the south may be the harbinger of a similar hood in the south. This season is particularly difficult to image from earth, and the existence of a south polar hood is controversial. HST images will be able to resolve this question.

Analyses of the data obtained so far are very preliminary because most of the time has been invested in calibration and deconvolution of the images. Preliminary examination of the images suggests that the data will allow the participating scientist to achieve the goals stated above. The first phase of the observing program has certainly reinforced the opinion, stated above, that Hubble Space Telescope is ideally suited to planetary observations.