RECENT MASTCAM AND MAHLI VISIBLE/NEAR-INFRARED SPECTROPHOTOMETRIC OBSERVATIONS: KIMBERLEY TO HIDDEN VALLEY. J.R. Johnson[1], J.F. Bell III[2], A. Hayes[3], R. Deen[4], A. Godber[2], R.E. Arvidson[5], M. Lemmon[6], S. Kuhn[4], J. Carsten[4], M.R. Kennedy[7]. [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, jeffrey.r.johnson@jhuapl.edu, [2]Arizona State University, [3]Cornell University, [4]Jet Propulsion Laboratory/Caltech, [5]Washington University in St. Louis, [6]Texas A&M University, [7]Malin Space Science Systems, San Diego.

Introduction: The Mast Camera (Mastcam) imaging system on the Curiosity rover continued acquisition of multispectral images of the same terrain at multiple times of day at three new rover locations between sols 611 and 726, expanding on data sets previously acquired [1,2,3]. In addition, the Mars Hand Lens Imager (MAHLI) on the rover arm was used as a goniometer to acquire a multiple-viewpoint (phase angle) data set on sol 707. These data sets will be used to investigate the light scattering properties of rocks and soils along the Curiosity traverse using radiative transfer (RT) models [e.g., 4].

Data sets: Mastcam. Images were acquired by the Mastcam-34 (M-34) camera on Sols 611-620 while the rover was parked at the Kimberley region performing drill operations on the target Windjana. This data set comprised a 1-column x 2-row mosaic pointed east and a 2-column x 1-row mosaic pointed west at 8 times of day (Table 1) (**Fig. 1a**). On Sols 720-726 while the rover was assessing the drillability of the Bonanza_King target near the entrance to Hidden Valley, M-34 1-column x 2-row mosaics pointed west were acquired at 6 times of day (the east direction was blocked by the rover) (**Fig. 2a**). All data sets were acquired using filters centered at 445, 527, 751, and 1012 nm, and the images were jpeg-compressed. Each data set provided phase angle coverage from near 0° to ~125-140° for a variety of rocks and soils (including rover tracks) at each location (Table 1). Navigation Camera (Navcam) stereo images were also acquired with each data set to provide terrain measurements for computing surface normals and local incidence and emission angles used in photometric modeling [1,4].

Data sets: MAHLI. On Sol 707, the MAHLI camera was used a goniometer to acquire images at 20 arm positions, all centered at the same location within the work volume, and all from a near-constant distance of 85 cm from the surface [3] (**Fig. 3**). Although this experiment was run at only one time of day (~14:30 LTST), it provided phase angle coverage from near 0° to ~110°. The terrain included a large (~45 cm), faceted block named "Stirling" and soils near the Hidden Valley entrance. Acquisition of images from 20 different viewpoints also allowed construction of a 3D shape model of this scene (**Fig. 3c**).

Methods. Preliminary image calibration involves conversion to radiance and reflectance via use of flat field images and onboard calibration targets [2]. Color phase composites were created by using calibrated images at three phase angles but at the same wavelength. These show the spatial distribution of relative backscattering vs. forward scattering properties across the scene (**Fig. 1b, 2b**).

Future work. Sky models will be developed to compensate for the effects of diffuse skylight using Mastcam measurements of atmospheric opacity and scattering models [4,5]. Geometric registration and projection of the M-34 images will be done using terrain models generated from the Navcam stereo pairs [1] to correct local slopes and facets prior to input to RT models [e.g., 4]. Paired images from the MAHLI goniometer experiment are being used to produce stereo products (e.g., surface normals) for similar corrections. Future observations will be acquired at each rover sampling (drilling, scooping) location to provide data necessary to model and characterize the surface scattering properties of each sampling location.

Table 1. *Mastcam image sequences used in this work.*

Sol	Sequences (mcam0*)	LTST (avg)	Phase angle (avg °)
611	2571,2573	11:27	66,78
611	2578,2580	14:32	24,118
614	2589,2591	12:30	51,91
614	2592,2593	13:56	30,109
615	2599,2621	15:33	10,131
617	2639,2641	16:16	6,141
620	2649,2651	08:31	105,47
620	2655,2656	09:10	97,52
720	3058	11:22	57
720	3060	12:33	74
720	3062	13:52	94
720	3064	15:11	114
720	3066	15:56	125
726	3098	08:41	16

LTST=Local True Solar Time

References: [1] Johnson, J.R. et al., LPSC, abs. #1371, 2013; [2] Bell et al., LPSC abs. #1417, 2013; [3] Johnson, J.R., et al. 8th Intern. Conf. on Mars, abs. #1073, 2014; Edgett, K. et al. (2012) Space Sci. Rev. 170, 259-317 [4] Johnson et al., JGR., 2005JE002494, 2006; Johnson et al., JGR, 2006JE002762, 2006; Johnson et al., Icarus, 248, 25-71, 2015 [5] Lemmon, M.T., et al., Icarus, 2014; 8th Intern. Conf. on Mars, abs. #1338.

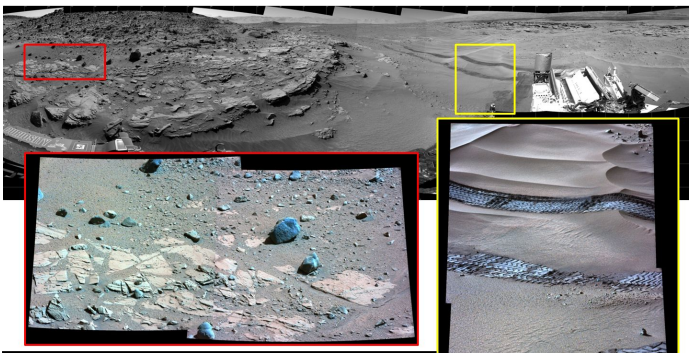


Fig. 1a. Navcam mosaic from Sol 610 (Kimberley region) showing locations of west (red) and east (yellow) false-color M34 image mosaics (RGB as 751, 527, 445 nm) acquired at ~11:30 LTST, Sol 611 (mcam02573) and ~08:30 LTST, Sol 620 (mcam02649), respectively.

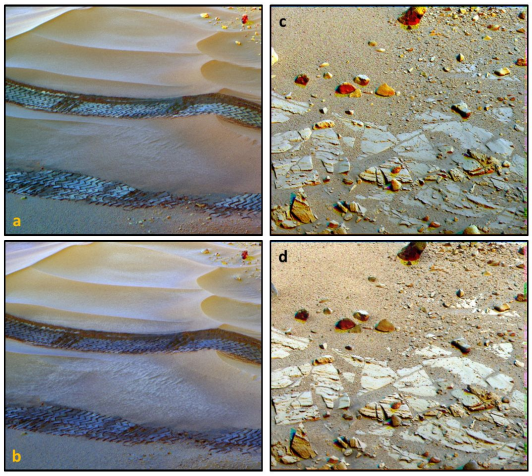
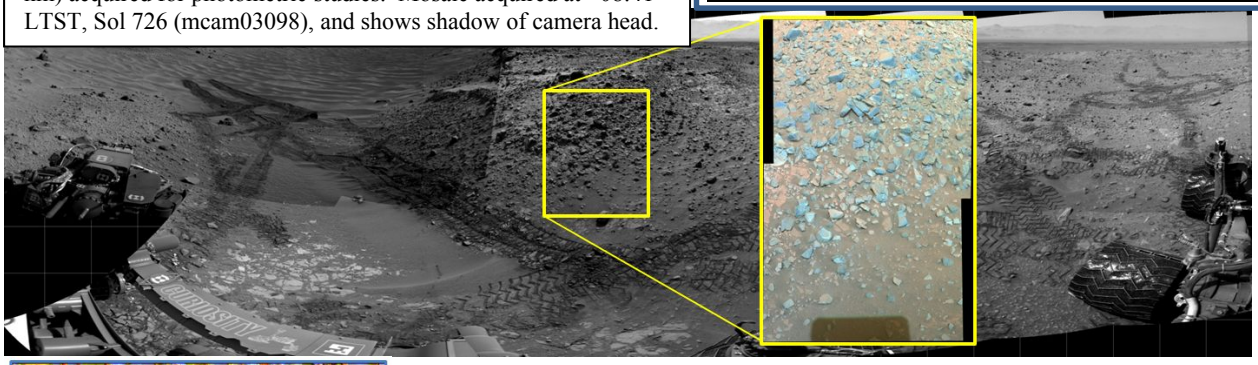


Fig 1b. Phase color composites acquired at same wavelength but different phase angles (g): Portion of east mosaic, with red (g~10°), green (g~51°), blue (g~105°) at (***a***) 445 nm and (***b***) 751 nm; Portion of west mosaic, with red (g~52°), green (g~78°), blue (g~109°) at (***c***) 445 nm and (***d***) 751 nm. Blue colors more forward scattering (tracks) than reds (sands, rocks).

Fig. 2a. Navcam mosaic of Bonanza_King area (Sol 722) showing location of false-color M34 image mosaics (RGB as 751, 527, 445 nm) acquired for photometric studies. Mosaic acquired at ~08:41 LTST, Sol 726 (mcam03098), and shows shadow of camera head.



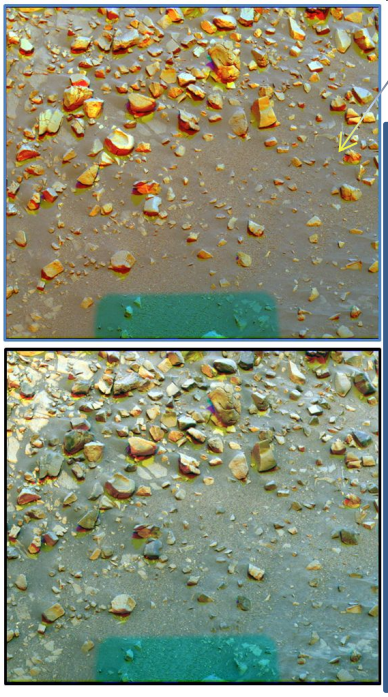


Fig 2b. Phase color composites of lower frame of Fig. 2a mosaic, acquired at same wavelength but different phase angles (g): red (g~11°), green (g~63°), blue (g~100°) at (*top*) 445 nm and (*bottom*) 751 nm.

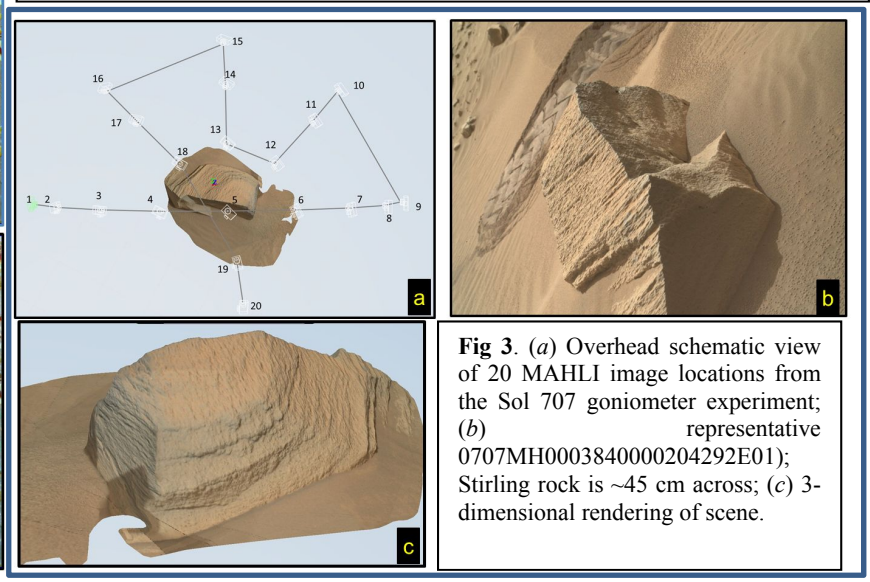


Fig 3. (*a*) Overhead schematic view of 20 MAHLI image locations from the Sol 707 goniometer experiment; (*b*) representative 0707MH0003840000204292E01); Stirling rock is ~45 cm across; (*c*) 3-dimensional rendering of scene.