HEMISPHERICAL PLUTO AND CHARON COLOR COMPOSITION FROM NEW HORIZONS. K. Ennico[1], A. Parker[2], C.A.J. Howett[2], C.B. Olkin[2], J.R., Spencer[2], W.M. Grundy[3], D.E. Reuter[4], D.P. Cruikshank[1], R.P. Binzel[5], M.W. Buie[2], S.A. Stern[2], H.A. Weaver[6], L.A. Young[2], and the New Horizons Surface Composition Theme Team, [1]NASA Ames Research Center, Moffett Field, CA 94035 (Kimberly.Ennico@nasa.gov), [2]Southwest Research Institute, [3]Lowell Observatory, [4]NASA Goddard, [5]MIT, [6]Johns Hopkins University Applied Physics Lab.

Introduction: New Horizons flew by Pluto and its moons on July 14, 2015 [1]. In the days prior to the closest approach (C/A), panchromatic and color observations of Pluto and Charon were made covering a fully complete range of longitudes. Although only a fraction of this "late-approach" data series has been transmitted to the ground, the results indicate Pluto's latitudinal coloring trends seen on the encounter hemisphere continues on the far side. Charon's red pole is visible from a multitude of longitudes and its colors are uniform with longitude at lower latitudes.

New Horizons Color Camera: The New Horizons Ralph [2] instrument's Multispectral Visible Imaging Camera (MVIC) has seven CCDs, of which four are color: blue (400 to 550 nm), red (540 to 700 nm), near-IR (780 to 975 nm) and methane (860 to 910 nm). Those four CCDs operate in time delay integration (TDI) mode, and are read out as New Horizons scans the target across the MVIC fields of view. The instantaneous field of view (IFOV) of a single MVIC pixel is 20x20 μrad with a 5.7 deg total FOV in the direction orthogonal to the scan. This large FOV was chosen to match Pluto's size as seen from New Horizons near close approach. The color TDI rate, normally 52 Hz, provides an effective 0.6 second integration time.

Color Observations on Approach: Both Pluto and Charon were observed by MVIC as early as April 9, 2015, as part of a series to measure the time variability of Pluto's surface through multiple Pluto rotations (6.4 days). In these data sets, Pluto and Charon are not resolved and aperture photometry can be use to determine their color light curves [3]. By June 25, 2015, Pluto and Charon were resolved by MVIC, with initial diameters of ~6 and 3 pixels, respectively. From June 25-July 3, color images of Pluto and Charon were taken daily. There was a loss of data on July 4-6 due to recovery from a spacecraft anomaly. Approach color data sets resumed July 7, with 2-3 visits per day. The last time the far-encounter hemisphere (East Long. 0°) observed by MVIC was July 10, when Pluto and Charon were ~28 and 14 pixels, respectively, in diameter.

Encounter-Hemisphere Colors: Pluto's close-approach or Encounter Hemisphere (EH), longitude ~180°, had been chosen in part because of its bright CO-rich spot discovered by prior visible Hubble imagery [4,5] and ground based NIR spectra [6]. New Horizons discovered that this bright spot, now known as the heart-shaped Tombaugh Regio (informal name), is superimposed on terrain with a range of colors that follow a latitudinal distribution [Fig. 1]. Dark equatorial regions (e.g. Chuthulu) are very red, bordered in the north by brighter, less red terrains. Moving north of +20° latitude, the terrain becomes bluer. Interspersed with the blue northern terrain, above +60°, a distinctive yellower area is observed. Fig. 1's MVIC observation has a pixel scale 740 meters/pixel and was taken 50 minutes prior to Pluto C/A, from a range 38,130 km.

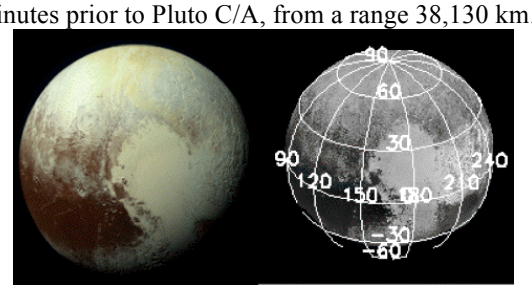

***Fig 1**. (a) MVIC color image of Pluto. (b) Geometry using a panchromatic LORRI basemap.*

Late-Approach Pluto Color Data Sets: MVIC color observations from July 7-14, 2015 provide us with higher resolution hemispheric study of Pluto and Charon over a range of longitudes. Enhanced color images, created using MVIC's NIR, red and blue filters, for observations with sub-observer longitudes of 182° (EH), 223°, 250°, 0°, 56°, and 112°, are shown in Fig. 2 with details in Table 1. The images are rescaled, as the original images were taken when Pluto was between 165 to 18 MVIC pixels in diameter. Calibration to I/F has been applied to each color channel and for the Fig. 2 (e,f) images, maximum entropy deconvolution has been applied to match the varying filter PSFs.

	Obs Date (2015)/Time (UTC)	km/ pix	Pluto SubObs Lon/Lat	Charon SubObs Lon/Lat
(a)	Jul 13th 21:07:43	14.5	182,42	2,42
(b)	Jul 13th 03:37:27	31.9	222,43	42,43
(c)	Jul 12th 16:51:03	42.6	248,43	67,43
(d)	Jul 10th 16:54:28	90.2	0,43	180,43
(e)	Jul 9th 16:55:29	114	56,43	237,43
(f)	Jul 8th 17:06:14	138	112,43	292,43

***Table 1**. Six observations studied are a subset of a larger series, which has not yet been downloaded.*

Pluto Colors: We determined the blue/red color ratio means and standard deviations averaged over 20° longitude bins for the six data sets. Four latitude regions are shown: +30° to +50°, and -10° to +10° (equatorial) in Fig. 3 and +70° to +90° (polar) and

+50° to +70° (e.g. Terra regions) in Fig. 4. The equatorial band shows the largest blue-red color variations. The red (i.e. low blue/red ratio) Chulthu region (40° to 150° East Lon.) is clearly seen in 10° to +10° latitude subset. The comparison of the polar and the +50° to +70° region shows that this latitudinal banding does encircle the planet. For these plots, only data within ±60° of the sub-observer (spacecraft) point are considered, to avoid points near the limb. Improvements on the latitude/longitude error estimates are planned.

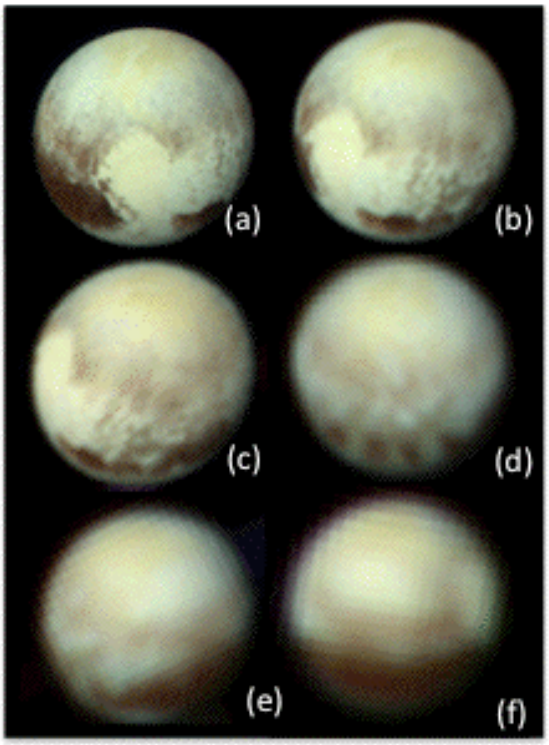

Fig 2. *Six examples of Pluto on late-approach. Geometries are summarized in Table 1.*

Late-Approach Charon Color Data Sets: Charon was observed within the same MVIC FOV as Pluto. In all these data sets, Charon remains mainly neutral, with a distinct red northern polar cap. Fig. 5 shows Charon for datasets (a), (c), and (d). Fig. 6 are two filter ratios averaged over 5° latitude annuli for dataset (a).

Interpretation: Coloring on Pluto is likely to result from hydrocarbons called tholins that are products of photolysis and radiolysis [7]. The distinct northern regions on Pluto could be consistent with an accumulating layer of tholins, produced in Pluto's atmosphere and gradually settling out. If so, MVIC color imagery suggests this activity has occurred at all longitudes. The colors of the equatorial dark-regions on Pluto's sub-Charon hemisphere appear not as red the Chuthulu Regio (40° to 150°). Charon, with the exception of its red pole, remains spectrally neutral at the resolutions of this data set.

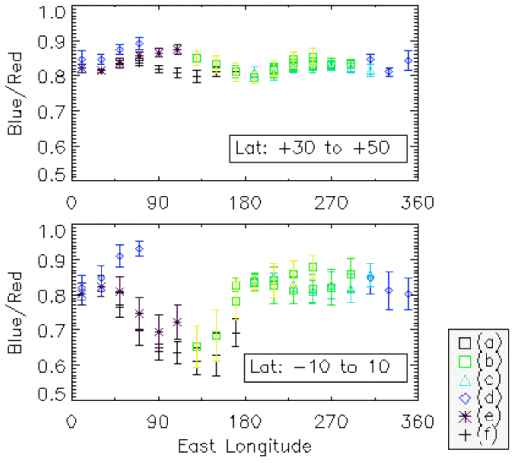

Fig 3. *Pluto's blue-red I/F ratio for two latitude regions. Point types/colors correspond to Table 1.*

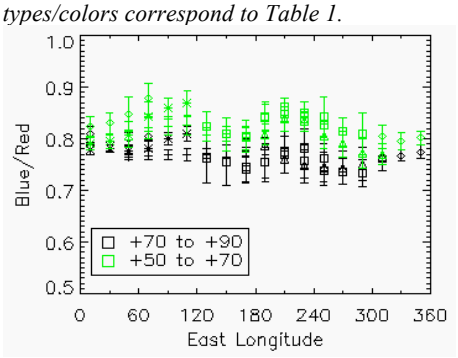

Fig 4. *Pluto's N. region blue to red I/F. Pole (black) remains a distinct color, redder than +50° to +70° (green), at all longitudes. Point types match described in Fig 3's legend.*

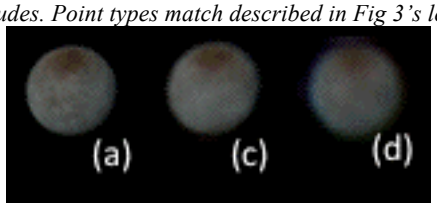

Fig 5. *Three Charon late-approach color composites. Geometries are summarized in Table 1.*

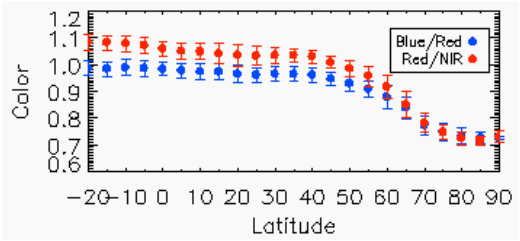

Fig 6. *Charon mean color ratios as function of latitude for set (a) showing the distinctly different color of its north pole.*

References: [1] Stern, S.A. et al (2015) Science, 350, 6258. [2] Reuter, D. et al (2008) Space Sci.Rev. 140, 129. [3] Ennico, K. et al. (2015) DPS #47, id.#200.08. [4] Stern, S.A. et al. (1997) AJ, 113:827S. [5] Buie, M. et al. (2010) AJ, 139:1128–1143. [6] Grundy, W. & Buie, M. (2001) Icarus 153,248–263. [7] Cruikshank, D. et al. (2015), Icarus 246, 82–92.