Pixon goes to Mars: Improved Spatial Resolution of Mars Odyssey Epithermal Neutron Data

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Introduction: When cosmic rays strike the atmosphere and the surface of Mars, they generate neutrons from nuclei present in the top layer of the regolith by various nuclear reactions. The neutrons lose energy by interacting with the surrounding nuclei and their flux leaking from the planet subsurface is thus an indication of the elemental composition of the top layer of the regolith: different elastic and inelastic scattering cross sections produce different amounts of moderation and capture. For instance, hydrogen is especially effective at moderating neutrons because its mass is nearly the same as the mass of the neutron. Neutrons are traditionally divided into three different energy bands: fast, epithermal and thermal.

The Mars Odyssey mission transports a collection of three instruments whose main aim is to determine the elemental composition of top layers of the martian surface. Among them, the Neutron Spectrometer has produced a wealth of data which has allowed a comprehensive study of the overall distribution of hydrogen on the surface of Mars [1]. In brief, deposits ranging between 20% and 100% water-equivalent by mass are found poleward of ± 55° latitude, and less rich, but significant, found at the near-equatorial latitudes. However, the Mars Odyssey Neutron Spectrometer (MONS) has a FWHM of ∼ 550 km. Hence, if one wants to associate Water Equivalent Hydrogen (WEH) with geologic features and with mineralogy observed independently this instrumental smearing needs to be properly understood and removed. Usually, in presence of noise, this is an ill posed problem which requires the use of a statistical approach [2, 3].

An exciting prospect is to obtain more accurate WEH for certain locales where hydrous minerals have been found. This can, perhaps, help to constrain the real extent or the original volume of surface water needed to create evaporated deposits or other sedimentary units. Another rather interesting potential development is to study the distribution of subsurface water ice at lower latitudes. Although water ice is not stable at such latitudes recent impact craters have exposed permafrost at around 45° latitude.

Pixon image reconstruction methods: In the presence of both some experimental noise, N, and instrumental blurring, B, the measure data, D, can be related to the input image, I, via

$$D = B * I + N, \tag{1}$$

where $*$ denotes the convolution operator. The main goal of an image reconstruction algorithm is to choose a reconstruction, I', that both avoids spurious complexity and produces a residual field,

$$R = D - B * I' \tag{2}$$

that is statistically equivalent to the anticipated experimental noise. The pixon reconstruction [2, 3], with the scale of this smoothing set by the local information content in the data. Thus, each pixon, which can be thought of as a set of spatially correlated pixels, contains the same information content. The reconstruction therefore looks smooth in this pixon basis and the image entropy is maximised.

A variant of this algorithm has been successfully applied in planetary sciences. Namely in the reconstruction of hydrogen maps in the vicinity of the lunar poles [4, 5, 6].

Epithermal Neutron Data: Epithermal neutron data using MONS between February 2002 and December 2006 have been employed (hereafter referred as *old data*). Currently, we are also using a new dataset which includes the latest MONS time series and has been drawn applying a stricter data reduction.

Very Preliminary Results and Conclusion: In figure 1 we present the epithermal flux from the Neutron Spectrometer for the *old data*. Low epithermal flux is indicative of high hydrogen concentration [7]. The identification of large quantities of hydrogen in the top meter of the regolith is very apparent in both polar neighborhoods in all maps. By applying a specially developed pixon image reconstruction algorithm to the MONS epithermal *old data* set we have increased the “dynamical range” of the count rates and have im-

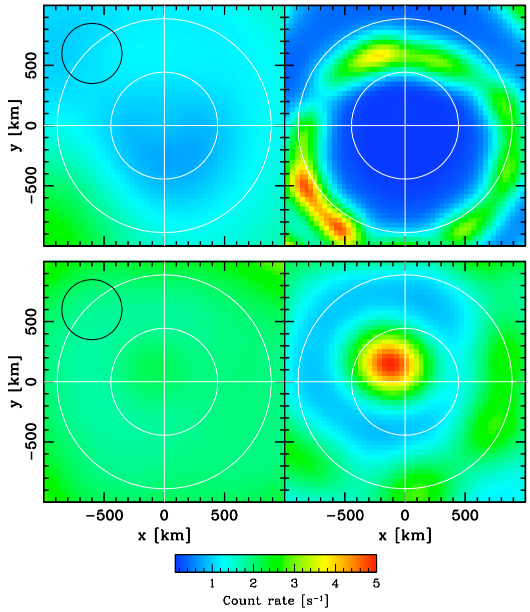

Figure 1: Epithermal count rate maps for the Martian north pole (top row) and south pole (bottom row) MONS *old data*. From the left to right, the columns show the data binned in 25× 25 km^2 flat mesh boxes and the pixon reconstructions. Also shown, with a black circle in the corner of the left hand panel is the effective size of the Odyssey response function. The spherical surface has been represented in the panels such that the distance from the image centre represents the arc length to the pole. The white circles represent latitudes ± 85° and ± 80° latitude. The colour scheme is the same in all panels and is shown at the bottom.

proved upon the sharpness of the left hand maps: for the same colour scheme some of the features which are barely apparent in the binned data are well delineated in the pixon reconstructions on length scales which are smaller than the MONS response function.

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