SETTING UP A NEW VENUS IMAGE ANALYSIS PACKAGE CALLED VENIM.

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Introduction: VENIM (Venus Imaging package) is a Python package that focuses on investigations of Venus images, particularly cloud tracking on Venus's dayside and nightside. There is a legacy of feature-tracking work on Venus [1, 2, 3, 4]. The main drivers for VENIM are to improve two key aspects of cloud tracking studies: registration of Venus's disk (errors in the sub-pixel registration of Venus's disk are often the largest source of cloud velocity errors) and image pre-processing to enhance detection of feature motion, especially in small, low contrast sub-regions. In addition, VENIM includes some convenience functions that perform standard tasks like flat-field and bias correction, image stacking, robust rejection of bad pixels, cosmic rays and detector artifacts, and translation from detector (x,y) coordinates to (lat,lon) coordinates on Venus. VENIM's initial targets will be Akatsuki, IRTF and Venus Express data sets.

Registration: VENIM treats the problem of disk registration as one of limb identification. For nightside images (typically obtained in the 1.74 or 2.3 micron windows), locating the limb can be a challenge: flux counts may be low and variable. VENIM has two methods for limb identification: a radial gradient method and an iterative limb modeling search method.

Cloud Tracking Tracking clouds on Venus faces the dual challenges of low-contrast fields and features that are often elongated in the E-W direction. As a result, cross-correlation techniques often have spurious peaks that indicate incorrect motions and poor feature-tracking resolution along the elongated axes. Some image preprocessing has been shown to improve cross-correlation feature tracking, including high-pass filtering of images and comparing the gradients of image pairs instead of the images themselves. VENIM includes routines to cross-correlate the gradients of image pairs, see for example Fig.1.

Routines We expect that some of VENIM's routines will be specific to individual instruments (e.g., removing scattered light in Akatsuki IR2 images or masking a diagonal flaw in the IRTF/SpeX GuidDog array).

Dissemination VENIM is intended to be an open repository to which the entire Venus community can contribute. We will disseminate the package via a GitHub repository, including documentation and example Jupyter notebooks. The package will also have automatically run tests to ensure software quality.

References: [1] Moissl, R, Khatuntsev, I, Limaye, SS, et al. *J. Geophys. Res.*, 114:1531 (2009). doi:10.1029/2008JE003117. [2] Luz, D, Berry, DL, and Roos-Serote, M. *New Astron.*, 13:224–232 (2008). doi:10.1016/j.newast.2007.09.001. [3] Ogohara, K, Kouyama, T, Yamamoto, H, et al. *Icarus*, 217:661–668 (2012). doi:10.1016/j.icarus.2011.05.017. [4] Ikegawa, S and Horinouchi, T. *Icarus*, 271:98–119 (2016). doi:10.1016/j.icarus.2016.01.018.

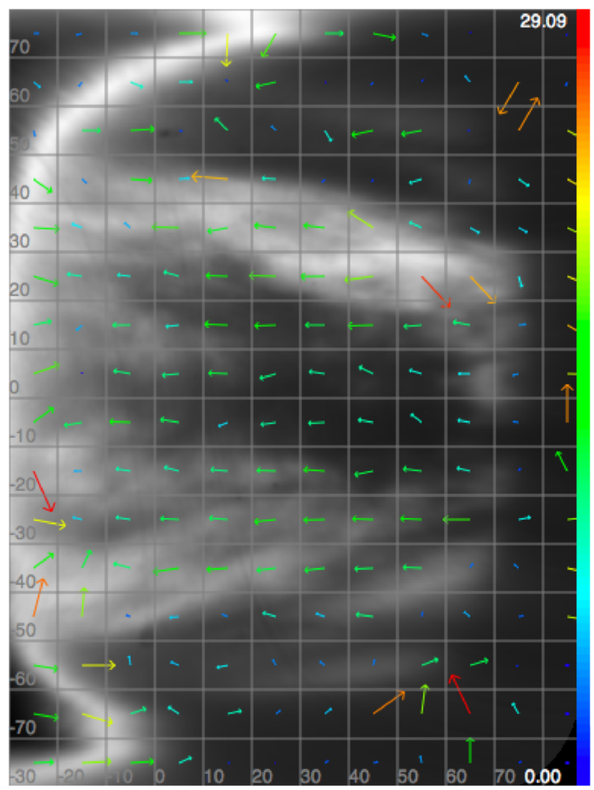

Figure 1: Example flow field for 4-JUL-2004 (left), calculated from pairs of projected images.