MASCS Instrument & VIRS Calibration

Rachel Klima (on behalf of the MASCS team)
JHU/APL

MASCS/VIRS Data Users’ Workshop
LPSC 2014, The Woodlands, TX
March 17, 2014
Mercury Atmospheric and Surface Composition Spectrometer (MASCS)

- The Ultraviolet and Visible Spectromterer (UVVS)
  - 115-600 nm (split into FUV, MUV, Vis)
  - Primarily designed for exosphere measurements
  - Some surface scans being conducted
  - Surface data still being validated for science quality

- Visible and Infrared Spectrograph (VIRS)
  - Surface measurements (300-1450 nm)
• Since entering orbit in March 2011, >10 million spectra have been collected (~95% surface coverage at 20 km spacing between footprints)
• Observation geometry is heavily restricted by spacecraft operational requirements. Global data at latitudes below 70°N and S are limited to incidence <70°, emission <85°, Phase ranges from 78-102°
VIRS Instrument Design

- Cassegrain Telescope (feeds both VIRS and UVVS)
- VIS detector: linear 512 element Si array
  - 300-900 nm
  - 5 nm spectral resolution
- IR detector: linear 256 element InGaAs array
  - 900-1450 nm
  - 5 nm spectral resolution
- No active detector cooling
- Shutter on VIRS entrance assembly

Figures from McClintock and Lankton, 2007, SSR
Nominal VIRS Calibration (to CDR)

• Raw DN converted to corrected counts in DN.
• Shuttered dark measurements are interleaved with observations to monitor changes in dark current with temperature or other external conditions. A polynomial is fit to the shuttered darks in each data record to interpolate the dark level at the time of each observation.
• Corrected counts are converted to radiance.
• Noise spectrum – predicted standard deviation of observation based on dark measurements as a function of temperature (noise is in DN)

\[ L = \left( \frac{(C - B_e - B_d - B_g)}{t} \right) \left( \frac{1}{S} \right) \]

L = radiance at the sensor
C = raw data value in DN,
\( B_e \) = background due to an electronic offset (in DN)
\( B_d \) = dark level (in DN)
\( B_g \) = grating-scattered light (in DN)
t = integration time (in s)
S = radiometric sensitivity measured in the laboratory in units of DN s\(^{-1}\) (W m\(^{-2}\) sr\(^{-1}\) \(\mu\)m\(^{-1}\))\(^{-1}\)
Nominal VIRS Data Calibration (to DDR)

\[
r = \frac{L}{E_{\text{Sun}}/\pi}
\]

\[
f(i, e, \alpha) = \frac{\cos i}{\cos i + \cos e} p(\alpha)
\]

\[
p(\alpha) = a_0 + a_1 \alpha
\]

\[
r'(45, 45, 90) = r(i, e, \alpha) \frac{f(45, 45, 90)}{f(i, e, \alpha)}
\]

- Radiance divided by solar spectrum to get radiance factor
- Corrected for viewing geometry and phase dependence
- Noise spectrum converted to reflectance units

L = radiance at the sensor (W m\(^{-2}\) sr\(^{-1}\) \(\mu\text{m}^{-1}\))

\(E_{\text{Sun}}\) = Solar spectrum irradiance (W m\(^{-2}\) \(\mu\text{m}^{-1}\))

\(f\) = dependence of reflectance on viewing geometry

\(i\) = incidence angle

\(e\) = emission angle

\(\alpha\) = phase angle

\(p(\alpha)\) = phase function

\(a_0 = 0.0576\)

\(a_1 = -3.52 \times 10^{-4}\)

\(r'\) = normalized reflectance
High Temperature Issues

- Temperatures were predicted to remain under ~30°C. Data calibration was anticipated to be more challenging at >10°C.
- Actual temperatures have exceeded 10°C for most of the orbital data. The bulk of data have been obtained at 10-35°C, but some reach >50°C.
High Temperature Issues

1. Saturation and increased noise in NIR
   Some pixels more sensitive to thermal noise than others

2. ‘Sticking’ of the shutter mechanism (affects both VIS and NIR)
   ‘Dark’ observations used to perform background subtraction are actually light, resulting in the radiance being excessively low or total dark subtraction failure

(for more info, see Klima et al., LPSC 2014, #1978, Thursday Posters)
High Temperature Issues

- Vis (Si)
- Missing Darks = Shutter Stuck Open

(Chart showing Raw Counts (DN) vs. Wavelength (nm))
MASCS/VIRS Data Record Structure
What are EDRs, CDRs, and DDRs?

Rachel Klima (on behalf of the MASCS team)
JHU/APL

MASCS/VIRS Data Users’ Workshop
LPSC 2014, The Woodlands, TX
March 17, 2014
Experiment Data Records (EDRs)

- Experiment Data Records contain the raw data and spectrum metadata.
- Important information for filtering or checking the quality of the data, including the raw spectrum data is passed through to Calibrated Data Records (CDR) and also available there.
- Important metadata includes: Dark Frequency, instrument temperature, integration time, gain, lamp on, binning, start and end pixel, spectrum number, spectrum mission elapsed time (MET). All of these are passed through to the CDRs.

22 June 2011
Calibrated Data Records (CDRs)

- Calibrated Data Records contain instrument status information necessary to filter and validate data quality
- UTC time translated from spacecraft time
- Spectra included (one row per spectrum):
  - Raw Spectrum – direct from EDR, uncompressed raw spectrum as 16-bit DN.
  - Corrected Counts – corrected for dark current and other instrument level corrections (DN/sec)
  - Calibrated Radiance – derived radiance at sensor (W m⁻² sr⁻¹ μm⁻¹).
  - Noise Spectrum – estimated noise (in DN) based on noise measured during shuttered darks as a function of temperature plus shot noise.
  - Channel Wavelengths – wavelengths for each detector element
- Spice derived geometry information (lat, lon, viewing geometry, slant range, subspacecraft lat/lon, footprint size, etc.)
- Data Quality Index (described on next slide)
Data Quality Index (in CDRs and DDRs)

19 character index of data quality. Each digit signifies quality factor of measurements.

Format: ABCD-EFGH-IJKL-MNOP
A: Dark Scan Flag, denotes shutter commanded closed for dark observation: 0 = shutter not engaged; 1 = shutter engaged.
B, C, D: Temperature 1,2, Grating Flags:
  0 = Temperature does not exceed 15 deg C threshold
  1 = Temperature exceeds 15 deg C threshold but less than 25 deg C threshold.
  2 = Temperature exceeds 25 deg C threshold but less than 40 deg C threshold
  3 = Temperature exceeds 40 deg C threshold.
E: Anomalous Pixels: Integer 0-9 = Indicates number of hot pixels found (the number of pixels with a noise spike (defined in DQI L, below).
F: Partial Data Flag: 0 = No partial data; 1 = Partial data exists.
G: Saturation Flag: 0 = No pixels saturated; 1 = Saturated pixels exist.
H: Low Signal Level Flag: 0 = Signal level not below -32768 threshold; 1 = Signal level below -32768 threshold.
I: Low VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
J: High VIS Wavelength Uncertainty Flag (not yet implemented, set to 0)
K: UVVS Operating Flag: 0 = UVVS is not scanning during readout; 1 = UVVS is scanning during readout.
L: UVVS Noise Spike Flag: 0 = No noise spike detected; 1 = Noise spike detected (A noise spike is a data value in 1 or 2 channels that exceeds 3 standard deviations of the average for a given channel in a given observation).
M: SPICE Version Epoch: Indicates what SPICE is used to determine pointing fields in CDR. ‘Predict’ SPICE may change one or more times before settling on ‘Final’ pointing solutions about 2 weeks from data acquisition.
  0 = No SPICE
  1 = Predict
  2 = Actual
N-P: Spares
Derived Data Records (DDRs)

• Temperatures, dark frequency, integration time, spacecraft time from EDR; UTC, Data Quality Index, Spice derived geometry from CDR

• Spectra included (one row per spectrum):
  – IoF Spectrum – reflectance at sensor (no correction for viewing geometry)
  – Photom IoF Spectrum – reflectance at sensor corrected to a viewing geometry of 45,45, 90 (see slide 6 and Izenberg et al., 2014)
  – IoF Noise Spectrum – noise spectrum propagated through to reflectance units
  – Photom IoF Noise Spectrum – noise spectrum propagated through to normalized reflectance units
  – Channel Wavelengths – wavelengths for each detector element
Derived Analysis Products (DAPs)

1. An image file containing the mosaic of MASCS/VIRS reflectance @750nm,
2. An image file containing the interpolated mosaic of MASCS/VIRS reflectance @750nm,
3. An image file containing the incidence angle of MASCS/VIRS observations used in mosaic,
4. An image file containing the emission angle of MASCS/VIRS observations used in mosaic,
5. An image file containing the phase angle of MASCS/VIRS observations used in mosaic,
6. An image file containing the area of MASCS/VIRS observations used in mosaic,
7. An image file containing the CDR Date of MASCS/VIRS observations used in mosaic,
8. An image file containing the CDR Time of MASCS/VIRS observations used in mosaic,
9. An image file containing the spectrum number of MASCS/VIRS observations used in mosaic.

22 June 2011
Interpolated 750 nm Reflectance Map
Accessing MASCs/VIRS Data Directly: Downloading from PDS and Reading Structures into IDL

Rachel Klima (on behalf of the MASCs team)
JHU/APL

MASCS/VIRS Data Users’ Workshop
LPSC 2014, The Woodlands, TX
March 17, 2014
How To Get
MESSENGER MASCSS VIRS Data
from the Planetary Data System

PDS Geosciences Node
For the MASCSS VIRS Workshop
Click **Mercury** to go to the MESSENGER page.
Click MASCS Archive.
Two ways to find MASCS data:

A. Follow links directly to raw and derived archives online.

B. Use the Mercury Orbital Data Explorer search tools to select data products.
Method A: Direct links to data online

The MASCS derived data archive is in volume messmas_2001.

Data products are in the data directory. Click down the data directory tree to choose product type, mission phase, VIRS data, observation date, and sensor.
Method A: Direct links to data online, continued

Every data file (.dat) comes with a PDS label (.lbl) that describes it. You’ll need both files. Right-click to download.

If you want more than just a few files, it will be easier to get them with FTP. You can use any FTP client. We recommend Filezilla (filezilla-project.org) because it allows easy drag-and-drop downloading. See next page for an example...
Method A: Direct links to data online, continued


To get the FTP address, put ftp:// in front of the link in your browser window, and use that link in your FTP software.

This example uses Filezilla FTP software.
Other files you might need

Look inside the PDS label. There may be a line like `^STRUCTURE = “VIRSVD.FMT”`. Structure files describe the format of the data table. You’ll find them in the LABEL directory of the archive.

```bash
pds-geosciences.wustl.edu - /messenger/messe_v_h-mascas-3-virs-cdr-caldata-v1/messmas_2001/label/

[To Parent Directory]
7/11/2013 9:22 AM 1382 labinfo.txt
9/7/2012 1:38 PM 9674 uvvshdrc.fmt
6/18/2013 1:50 PM 24349 uvvsscic.fmt
1/10/2013 8:27 AM 12376 uvvsscid.fmt
12/7/2012 1:12 PM 26470 virsnc.fmt
12/11/2012 10:37 PM 18161 virsnd.fmt
12/17/2012 7:53 AM 26462 virsvc.fmt
12/10/2012 12:42 PM 18248 virsvd.fmt
```
Other files you might need

Documentation is found in the DOCUMENT directory. Each document comes in a PDF version and a plain text version, with a label that describes both. The SIS (Software Interface Specification) is the primary document.
Now for Method B, using the Mercury Orbital Data Explorer.

Two ways to find MASCS data:

A. Follow links directly to raw and derived archives online.

B. Use the Mercury Orbital Data Explorer search tools to select data products.
Method B: Using the Mercury Orbital Data Explorer

Choose Data Product Search.
Method B: Using the Mercury Orbital Data Explorer, continued

Open the **Select Data Sets** pulldown.

Click the checkboxes next to MASCS VIRS data sets.
Further down the page, enter your desired search criteria.

For example, to search a specific area, first open **Find by Product Location**, and then enter latitude-longitude limits.

When ready, choose **View Results in Table**.
Method B: Using the Mercury Orbital Data Explorer, continued

Click a Product ID to see more information on the right side of the screen

Check the products to be downloaded

Click **Update Cart** to add checked products to your shopping cart

When ready, click **Download**.
Method B: Using the Mercury Orbital Data Explorer, continued

Open View Products Selected for Download to see what’s in the shopping cart.

Check one of the Download Options to include additional files in the cart.

When ready, click at the bottom of the page.
Method B: Using the Mercury Orbital Data Explorer, continued

Enter your email address to be notified when your order is ready to download.

Then click Submit Request.
Other Useful Tools

**Mercury Footprint Coverage Explorer** shows product coverage maps in various formats.

**MESSENGER Quickmap** allows map-based searches and downloads.

**MASCS CDR and DDR Readers** help read data into IDL.
For More Information

Visit the PDS Geosciences Node booth at LPSC to talk with PDS representatives and get a hands-on demonstration.

Questions after LPSC? Try the Geosciences Node Forums for data users and data providers, at http://geoweb.rsl.wustl.edu/community/.

If you can’t find the answer on the forums, send an email to geosci@wunder.wustl.edu.
IDL Reader Files (CDR and DDR)

- Available at [http://pds-geosciences.wustl.edu/missions/messenger/mascas_software.htm](http://pds-geosciences.wustl.edu/missions/messenger/mascas_software.htm)
- Not officially part of PDS delivery (not reviewed and support not guaranteed)
- Reads MASCS data into an IDL structure that can be used in programs or to plot data
- Use `show_dqi.pro` to read data quality index into proper format

22 June 2011
IDL Readers – Required Files

• CDR Readers
  – init_mascs_cdr_templates_6.pro
  – read_masc_cdr_6.pro
  – read_uvvs_cdr_hdr_6.pro
  – read_uvvs_cdr_sci_6.pro
  – read_virs_nir_cdr_6.pro
  – read_virs_vis_cdr_6.pro
IDL Readers – Required Files

- DDR Readers
  - init_mascos_ddr_templates.pro
  - read_mascos_ddr.pro
  - read_uvvs_ddr.pro
  - read_uvvs_surf_ddr.pro
  - read_uvvs_surf_hdr.pro
  - read_virs_nir_ddr.pro
  - read_virs_vis_ddr.pro
MASCS/VIRS Data Access
Using Quickmap

Noam Izenberg (on behalf of the MASCS team)
JHU/APL

MASCS/VIRS Data Users’ Workshop
LPSC 2014, The Woodlands, TX
March 17, 2014
MASCS VIRS Data Access Using Quickmap

Noam Izenberg for the MASCS team
JHU/APL
noam.izenberg@jhuapl.edu
Mission News

March 7, 2014
Eleventh MESSENGER Planetary Data System Release is the Largest Yet

The Planetary Data System (PDS), which archives and distributes data from all of NASA's planetary missions, today released its eleventh batch of data collected by the MESSENGER mission. With this release, images and measurements are now available to the public for the fifth full Mercury solar day of MESSENGER orbital operations. [more]

Featured Images

- March 12, 2014
  High-resolution Hollows

- March 10, 2014
  The New Three-Color Mosaic

- March 7, 2014
  Odin Planitia

High-resolution Targeted Mosaics, Available In QuickMap
Global Overview I

- MDIS basemap
Global Overview II

- VIRS Footprint map
Global Overview III

- VIRS 750nm Mosaic (DAP PDS11)
• VIRS 750nm Interpolated Mosaic (DAP PDS11)
Global Overview V

- **VIRS Color Mosaic**
  - Red = 575nm Reflectance
  - Green = 415 nm / 750 nm
  - Blue = 310 nm / 390 nm
Global Overview VI

- VIRS Interpolated Color Mosaic
- MDIS basemap
Regional Ib

- Search by feature name
• VIRS Footprint map
• VIRS Color Mosaic
Regional IV

- VIRS Interpolated Color Mosaic
Regional V

- MDIS Color Mosaic
Local I

- MDIS basemap
• VIRS Footprint map
Local III

- VIRS Color Mosaic
• Region of Interest
• Region of Interest
Local VI

- Individual Spectra
### Local VII

#### Individual Spectra view
- Radiance, reflectance plots
- DDR/CDR source
- CSV Downlink
- Viewing Geometry
- Spectrum, time
- CDR source name
- Detector temps

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLADH810</td>
<td>334917624000000</td>
</tr>
<tr>
<td>BS_pEmiAvg</td>
<td>20.8958954860000001</td>
</tr>
<tr>
<td>BS_plncAvg</td>
<td>56.9495862019999995</td>
</tr>
<tr>
<td>BS_pPhaAvg</td>
<td>77.8386039579999993</td>
</tr>
<tr>
<td>area</td>
<td>1.28846377172561</td>
</tr>
<tr>
<td>SPENUM</td>
<td>864</td>
</tr>
<tr>
<td>SPEMET</td>
<td>249588057.5000000000000</td>
</tr>
<tr>
<td>SPEUTC</td>
<td>12187T15:03:11</td>
</tr>
<tr>
<td>BIN</td>
<td>1</td>
</tr>
<tr>
<td>DARK</td>
<td>0</td>
</tr>
<tr>
<td>VIS310</td>
<td>11.26200001000000000</td>
</tr>
<tr>
<td>VIS390</td>
<td>32.7710000899999997</td>
</tr>
<tr>
<td>VIS415</td>
<td>56.48950000000000000</td>
</tr>
<tr>
<td>VIS575</td>
<td>83.750497000000006</td>
</tr>
<tr>
<td>VIS750</td>
<td>72.794002500000005</td>
</tr>
<tr>
<td>NIR950</td>
<td>62.20899959999999999</td>
</tr>
<tr>
<td>CDRFILE</td>
<td>VIRSC_OB2_12187_144509.DAT</td>
</tr>
<tr>
<td>VIS_TEMP</td>
<td>9.26600000000000000</td>
</tr>
<tr>
<td>NIR_TEMP</td>
<td>11.61999999999999999</td>
</tr>
<tr>
<td>VIS750_RFL</td>
<td>0.08972170000000000</td>
</tr>
<tr>
<td>CDRDate</td>
<td>12187</td>
</tr>
<tr>
<td>CDRTIME</td>
<td>144509</td>
</tr>
<tr>
<td>mcr_metric</td>
<td>2.52884306900000000</td>
</tr>
</tbody>
</table>

---

**Note:** The data and figures are from a VIRS spectrum @ UTC 2012-03-05 15:05:11 and 2012-07-09 15:03:11.
Local VIII

- Linked parameter descriptions
Local IX

- QuickSpectra-Retriever
Local X

- QuickSpectra-Retriever
Specify the search region (depicted as yellow box below)

Current Projection: Equidistant Cylindrical

Center
Latitude 26.12207  Longitude 58.28739  Size 5 sq. km

Match results:
- Any (any portion of the search region could be touched)
- All (the whole search region must be covered)

Note: For faster results limit search region to capture a small amount of obs

FOUND 6 OBSERVATIONS with positive metric, ordered from best (lower value) to worst (higher value)
The following table can be sorted by clicking the header of the various columns
Clicking on each observation footprint allows to access additional metadata and VIRS/MDIS comparison plot
Individual spectra can be selected to be included in the charts at the bottom and 'redraw plots' clicked to redraw with the given parameters
<table>
<thead>
<tr>
<th>Source Locator</th>
<th>Incidence angle (avg. on sphere)</th>
<th>Emission angle (avg. on sphere)</th>
<th>Phase angle (avg. on sphere)</th>
<th>VIS Temp.</th>
<th>NIR Temp.</th>
<th>Area (sqkm)</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIRSVC_ORB_12012_050451 [DAT] [LBL]</td>
<td>56.556</td>
<td>22.859</td>
<td>77.826</td>
<td>14.238</td>
<td>16.980</td>
<td>1.584</td>
<td>3.118</td>
</tr>
<tr>
<td>VIRSNC_ORB_12012_050451 [DAT] [LBL]</td>
<td>56.579</td>
<td>22.836</td>
<td>77.827</td>
<td>14.240</td>
<td>16.981</td>
<td>1.584</td>
<td>3.120</td>
</tr>
<tr>
<td>VIRSVC_ORB_12012_050451 [DAT] [LBL]</td>
<td>56.533</td>
<td>22.882</td>
<td>77.826</td>
<td>14.236</td>
<td>16.979</td>
<td>1.585</td>
<td>3.120</td>
</tr>
<tr>
<td>VIRSVC_O2_12187_144509 [DAT] [LBL]</td>
<td>58.090</td>
<td>20.645</td>
<td>77.805</td>
<td>9.489</td>
<td>11.765</td>
<td>1.858</td>
<td>3.756</td>
</tr>
<tr>
<td>VIRSVC_O2_12187_144509 [DAT] [LBL]</td>
<td>58.065</td>
<td>20.571</td>
<td>77.806</td>
<td>9.477</td>
<td>11.751</td>
<td>2.004</td>
<td>4.047</td>
</tr>
<tr>
<td>Source Locator</td>
<td>Incidence Angle</td>
<td>Emission Angle</td>
<td>Phase Angle</td>
<td>VIS Temp.</td>
<td>NIR Temp.</td>
<td>Area (sqkm)</td>
<td>Metric</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------</td>
<td>----------------</td>
<td>-------------</td>
<td>-----------</td>
<td>-----------</td>
<td>-------------</td>
<td>--------</td>
</tr>
<tr>
<td>VIRSVC_ORB_12012_050451</td>
<td>56.556</td>
<td>22.859</td>
<td>77.826</td>
<td>14.238</td>
<td>16.980</td>
<td>1.584</td>
<td>3.118</td>
</tr>
<tr>
<td>VIRSVC_ORB_12012_050451</td>
<td>56.579</td>
<td>22.836</td>
<td>77.827</td>
<td>14.240</td>
<td>16.981</td>
<td>1.584</td>
<td>3.120</td>
</tr>
<tr>
<td>VIRSVC_ORB_12012_050451</td>
<td>56.533</td>
<td>22.882</td>
<td>77.826</td>
<td>14.236</td>
<td>16.979</td>
<td>1.585</td>
<td>3.120</td>
</tr>
<tr>
<td>VIRSVC_OB2_12187_144509</td>
<td>58.090</td>
<td>20.645</td>
<td>77.805</td>
<td>9.489</td>
<td>11.765</td>
<td>1.858</td>
<td>3.756</td>
</tr>
<tr>
<td>VIRSVC_OB2_12187_144509</td>
<td>58.065</td>
<td>20.571</td>
<td>77.806</td>
<td>9.477</td>
<td>11.751</td>
<td>2.004</td>
<td>4.047</td>
</tr>
</tbody>
</table>

Observations at (lon, lat) = (58.28739, 26.12207)
The following plot shows the spectra listed on the table above, as well as their average (in green).
The following plot shows the spectra listed on the table above, as well as their average (in green).

VIRS spectra (Reflectance) @ lon=58.287 lat=26.122 (5x5 sqkm)
Nabokov Example I

• MDIS basemap
• VIRS Color – crowded with many spectra, hard to select one with accuracy. Use QuickSpectra
Nabokov Example III

- Probe spot and select small area (1x1 km)
Area filled with footprints, not all of high value
Nabokov Example V

<table>
<thead>
<tr>
<th>ortho. preview (20x20 sqkm)</th>
<th>source locator</th>
<th>Incidence angle (avg. on sphere)</th>
<th>Emission angle (avg. on sphere)</th>
<th>Phase angle (avg. on sphere)</th>
<th>VIS Temp.</th>
<th>NIR Temp.</th>
<th>area (sqkm)</th>
<th>metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS: VIRSVC_CRB_11232_215320</td>
<td>[DAT] [LBL]</td>
<td>23.610</td>
<td>64.967</td>
<td>88.242</td>
<td>28.499</td>
<td>29.506</td>
<td>12.119</td>
<td>31.258</td>
</tr>
<tr>
<td>NR: VIRSVC_CRB_11232_216320</td>
<td>[DAT] [LBL]</td>
<td>23.617</td>
<td>64.851</td>
<td>88.231</td>
<td>28.498</td>
<td>29.480</td>
<td>12.645</td>
<td>32.595</td>
</tr>
<tr>
<td>INSPECT SPECTRUM AS [CSV]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIS: VIRSVC_CRB_11232_215320</td>
<td>[DAT] [LBL]</td>
<td>23.626</td>
<td>64.927</td>
<td>88.229</td>
<td>28.462</td>
<td>29.474</td>
<td>13.210</td>
<td>34.038</td>
</tr>
<tr>
<td>NR: VIRSVC_CRB_11232_216320</td>
<td>[DAT] [LBL]</td>
<td>23.626</td>
<td>64.927</td>
<td>88.229</td>
<td>28.462</td>
<td>29.474</td>
<td>13.210</td>
<td>34.038</td>
</tr>
<tr>
<td>INSPECT SPECTRUM AS [CSV]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIS: VIRSVC_CRB_11232_215320</td>
<td>[DAT] [LBL]</td>
<td>23.630</td>
<td>64.923</td>
<td>88.219</td>
<td>28.504</td>
<td>29.453</td>
<td>13.399</td>
<td>34.509</td>
</tr>
<tr>
<td>NR: VIRSVC_CRB_11232_216320</td>
<td>[DAT] [LBL]</td>
<td>23.630</td>
<td>64.923</td>
<td>88.219</td>
<td>28.504</td>
<td>29.453</td>
<td>13.399</td>
<td>34.509</td>
</tr>
<tr>
<td>INSPECT SPECTRUM AS [CSV]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Individual spectra spectra that touch target area
• Excluding footprints you don’t want from average
The following plot shows the spectra listed on the table above, as well as their average (in green).

- Radiance
Nabokov Example VIII

The following plot shows the spectra listed on the table above, as well as their average (in green).

- Shows only selected spectra and their average.
Do Science With VIRS!

• Planned, not yet implemented:
  – ROI multiple spectrum downloading (currently all bulk data access is via PDS)
• Questions, feedback
• Contact
  – noam.izenberg@jhuapl.edu
  – rachel.klima@jhuapl.edu

Key References:
• McClintock and Lankton (2007) *Space Science Reviews* 131, 481-521
• Holsclaw et al. (2010) *Icarus* 209, 179-194
• Izenberg et al. (2014) *Icarus* 228, 364-374
• Klima et al. (2014) *LPSC 45* #1978 on Thursday, March 20