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The Planetary Spectrum Generator (PSG):

An accurate online radiative transfer suite for atmospheres, comets, small bodies and exoplanets

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Planetary Spectrum Generator: An accurate online radiative transfer suite for atmospheres, comets, small bodies and exoplanets

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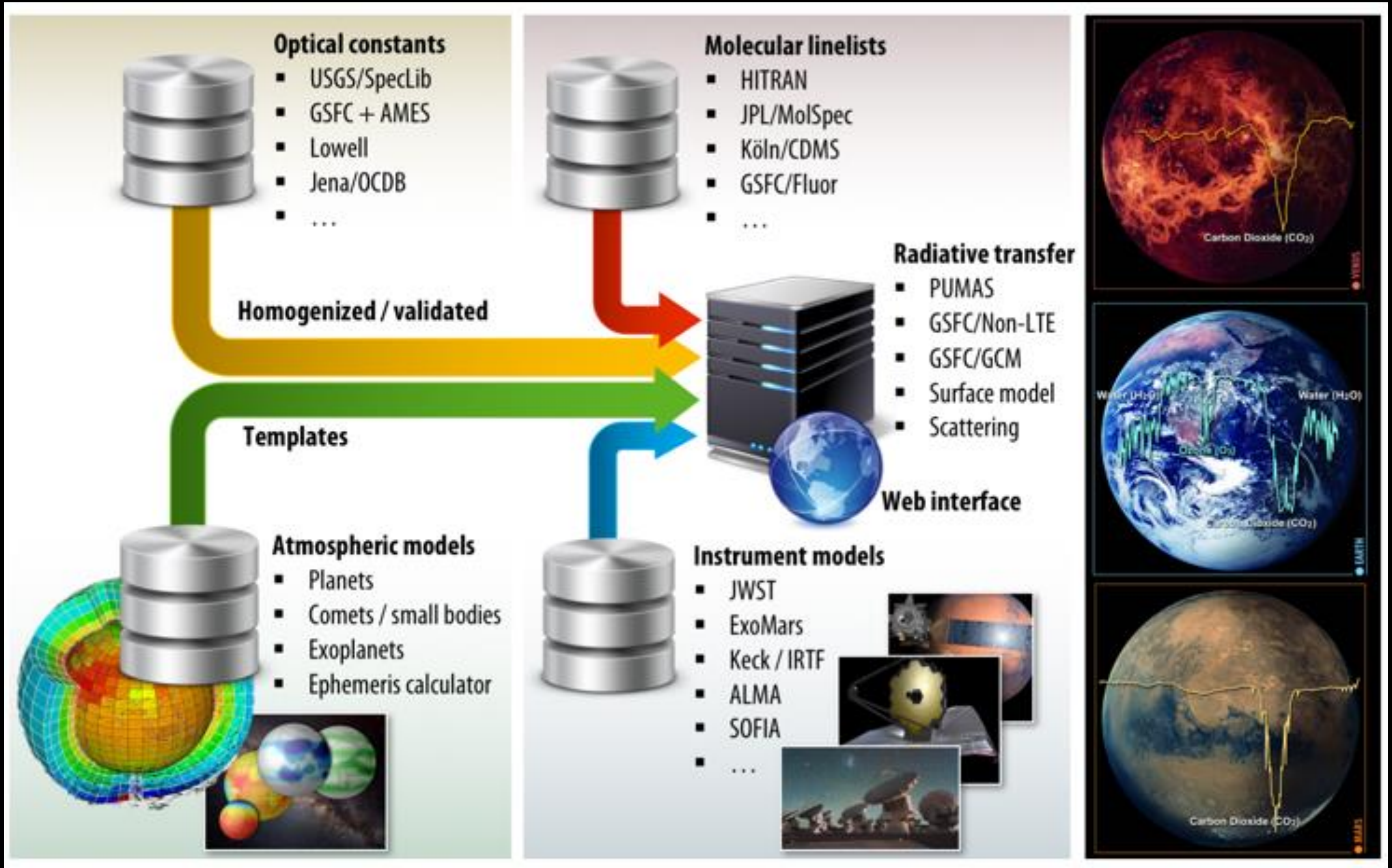
ABSTRACT

We have developed an online radiative-transfer suite (https://psg.gsfc.nasa.gov) applicable to a broad range of planetary objects (e.g., planets, moons, comets, asteroids, TNOs, KBOs, exoplanets). The Planetary Spectrum Generator (PSG) can synthesize planetary spectra (atmospheres and surfaces) for a broad range of wavelengths (UV/Vis/near-IR/IR/far-IR/THz/sub-mm/Radio) from any observatory (e.g., JWST, ALMA, Keck, SOFIA), any orbiter (e.g., ExoMars, Juno), or any lander (e.g., MSL). This is achieved by combining several state-of-the-art radiative transfer models, spectroscopic databases and planetary databases (i.e., climatological and orbital). PSG has a 3D (three-dimensional) orbital calculator for most bodies in the solar system, and all confirmed exoplanets, while the radiative-transfer models can ingest billions of spectral signatures for hundreds of species from several spectroscopic repositories. It integrates the latest radiative-transfer and scattering methods in order to compute high resolution spectra via line-by-line calculations, and utilizes the efficient correlated-k method at moderate resolutions, while for computing cometary spectra, PSG handles non-LTE and LTE excitation processes. PSG includes a realistic noise calculator that integrates several telescope/instrument configurations (e.g., interferometry, coronagraphs) and detector technologies (e.g., CCD, heterodyne detectors, bolometers). Such an integration of advanced spectroscopic methods into an online tool can greatly serve the planetary community, ultimately enabling the retrieval of planetary parameters from remote sensing data, efficient mission planning strategies, interpretation of current and future planetary data, calibration of spectroscopic data, and development of new instrument/spacecraft concepts.

Planetary Spectrum Generator (PSG)
Villanueva+2018, psg.gsfc.nasa.gov



Planetary Spectrum Generator

This site provides an interface to Goddard's Planetary Spectrum Generator (PSG), which can be used to generate high-resolution spectra of planetary bodies (e.g., planets, moons, comets, exoplanets). The spectroscopic suite can be also accessed remotely via the Application Program Interface (API). When requiring help on a specific input parameter, please click on the ⓘ icon.

Calculation template ⓘ	Load	Select template
Target and geometry ⓘ	Change	Target: Mars for date (2016/01/24 01:00 UT); geometry: Observatory from 1.4532 AU.
Atmosphere and surface ⓘ	Change	Surface pressure: 4.971 mbar; Molecular weight: 43.34 g/mol; Atmospheric profile: None; Gases: CO2,H2O; Surface temperature: 270.77 K; Albedo: 0.2762; Emissivity: 0.7238.
Instrument parameters ⓘ	Change	Wavelength range 2700-2740 cm with a resolution of 70000 RP. Molecular radiative-transfer enabled. Continuum flux module enabled.

Help | Reset | Download config-file | Generate Spectra

Table 1
Database of linelists handled by PSG.

	Spectroscopic capabilities
HITRAN 2016 [14]	Wavelength range: 0.3 µm to radio Number of lines: 5,399,562 Number of molecules: 50 Number of isotopologues: 126 $CO_2/H_2/He$ broadening: 13 molecules Number of CIA spectra: 554 Number of cross-section spectra: 987 Number of aerosols: 98
GSFC Fluorescence Database [28–32] (C_2H_2, C_2H_4, C_2H_6, CH_3D, CH_3OH, CH_4, CO, CO_2, H_2CO, H_2O, H_2S, HC_3N, HCN, HDO, HNC, NH_3, OCS)	Wavelength range: shorter than 10 µm Number of lines: 530,281 Based on lines (non-LTE): 2 billions Number of species: 17
GEISA 2015 [15]	Wavelength range: 0.3 µm to radio Number of lines: 5,023,277 Number of species: 52 Number of isotopologues: 118
JPL Molecular Spectroscopy [16]	Wavelength range: 2.65 µm to radio Number of lines: 888,113 Number of species: 383
CDMS Cologne Database for Molecular Spectroscopy [17]	Wavelength range: 1.81 µm to radio Number of lines: 1,612,154 Number of species: 792
Exo-Transmit Opacities database [33]	Wavelength range: 0.1–170 µm Number of spectral points: 7454 Number of temperatures: 30 (100–3000 K) Number of pressures: 13 (1E-9 to 1000 bar) Number of species: 30
The MPI-Mainz UV/VIS Spectral Atlas [34] UV cross-sections for O3 [35] UV cross-sections for CO2 [36]	Wavelength range: 0.01–1 um Number of cross-sections: 70 Number of species: 22 (e.g., H_2O, CH_4, CO_2, N_2O, O_3)

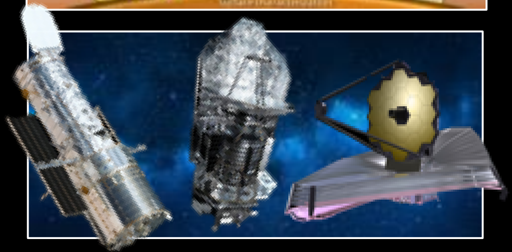
Table 2
Database of surface repositories handled by PSG.

Mars Reconnaissance Orbiter (MRO) Compact Reconnaissance Imaging Spectrometer for Mars instrument (CRISM) spectral library: repository of spectral templates applicable to Mars [62] Number of components: 31 Spectral coverage: 0.44–3.9 µm Type of parameters: reflectances (PSG type 0) Online repository: http://crismtypespectra.rsl.wustl.edu
United States Geological Survey (USGS) digital spectral library (version splib06a): repository of a wide range of materials and components [63] Number of components: 1380 Spectral coverage: most in the 0.3–3 µm range, with some reaching ~200 µm. Type of parameters: reflectances (PSG type 0) Online repository: http://speclab.cr.usgs.gov/spectral.lib06/ds231/datatable.html
Database of Optical Constants for Cosmic Dust (DOCCD): repository of optical constants for a wide range of silicates, oxides, sulfides, carbonates, carbides and carbon materials [64] Number of components: 106 Spectral coverage: most in the 2–500 µm range, with some reaching ~10,000 µm. Type of parameters: optical constants (PSG type 1) Online repository: http://www.astro.uni-jena.de/Laboratory/OCDB
Lowell Observatory Grundy's database of optical data on cryogenic ices (N_2, H_2O, CH_4) [5] Number of components: 3 Spectral coverage: 0.6–5 µm Type of parameters: alpha parameter (PSG type 2) Online repository: http://www2.lowell.edu/users/grundy/ice.html
NASA Goddard's Cosmic Ice Laboratory: optical constants for selected ices of astrobiological relevance [65] Number of components: 22 Spectral coverage: 2–20 µm and 2–333 µm Type of parameters: optical constants (PSG type 1) Online repository: http://science.gsfc.nasa.gov/691/cosmicice
NASA Ames' Database of Astrochemical Ices [66] Number of components: 6 Spectral coverage: 2–200 µm, 2–20 µm, 3–14 µm Type of parameters: optical constants (PSG type 1) Online repository: http://www.astrochem.org/db.php
HITRAN Refractive index repository [67] Number of components: 97 Spectral coverage: wide range from UV to radio Type of parameters: optical constants (PSG type 1) Online repository: http://hitran.org
Bus-DeMeo asteroid taxonomy with 25 classes based on PCA of combined visible and near-IR spectral data [68] Number of components: 25 Spectral coverage: 0.45–2.45 µm Type of parameters: reflectance spectra (PSG type 0) Online repository: http://smass.mit.edu/busdemeoclass.html

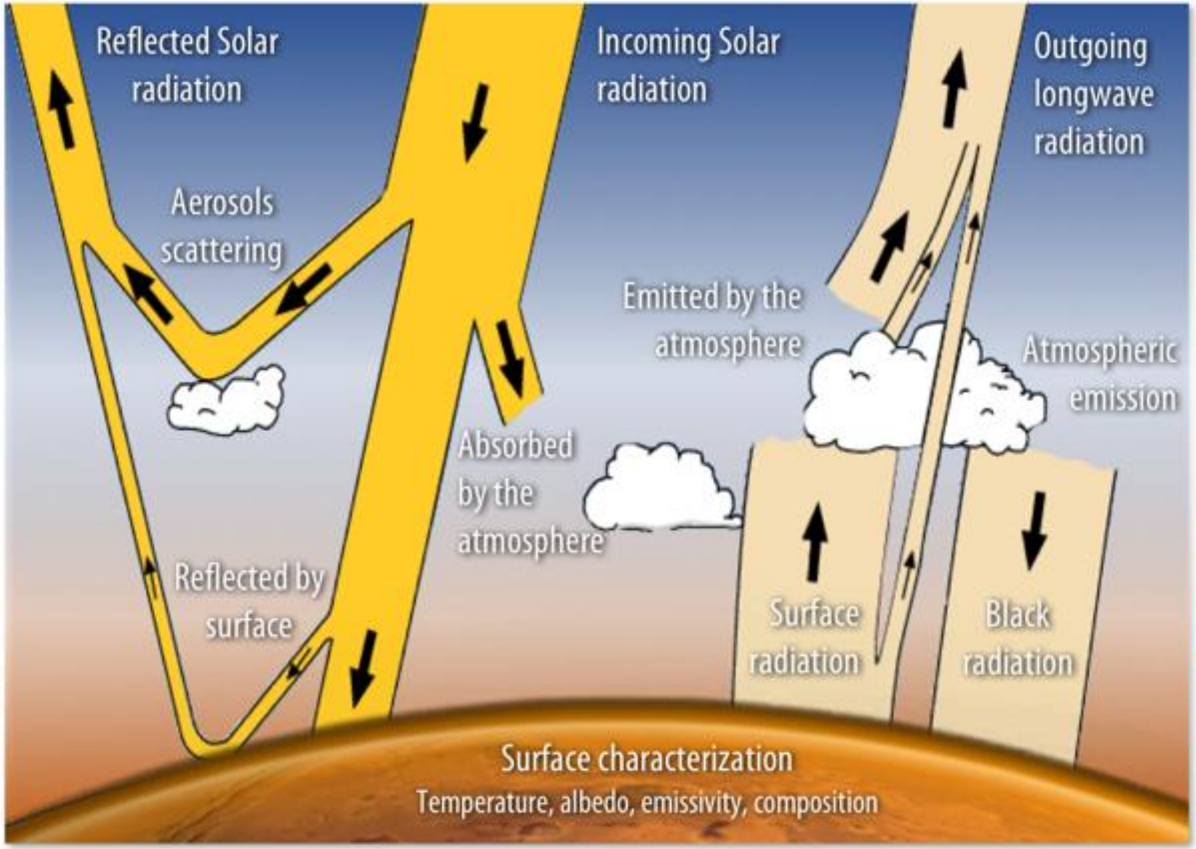
PSG synthesizes spectra of **planets**, **exoplanets** and **small-bodies** from 10 nm to 100 mm (UV/Vis/near-IR/IR/far-IR/THz/sub-mm/Radio) from any observatory (e.g., JWST, ALMA, Keck, SOFIA), any orbiter (e.g., ExoMars, Cassini, New Horizons).

PSG has a 3D orbital calculator for most bodies in the Solar system, and all confirmed exoplanets. Observing geometries are: observatory, from surface, nadir, limb, occultation.

PSG radiative transfer performed with several models: line-by-line, correlated-k, multiple-scattering, non-LTE fluorescence, and surface Hapke models.



PSG includes a noise and signal-to-noise calculator for quantum and thermal detectors, at any observatory.



PUMAS

- Accurate line-by-line modeling and efficient correlated-k synthesis for moderate resolutions
- Full scattering modeling of aerosols and ices
- Rayleigh, CIA and molecular analysis from UV to radio
- Layer-by-layer analysis in spherical geometry

CEM

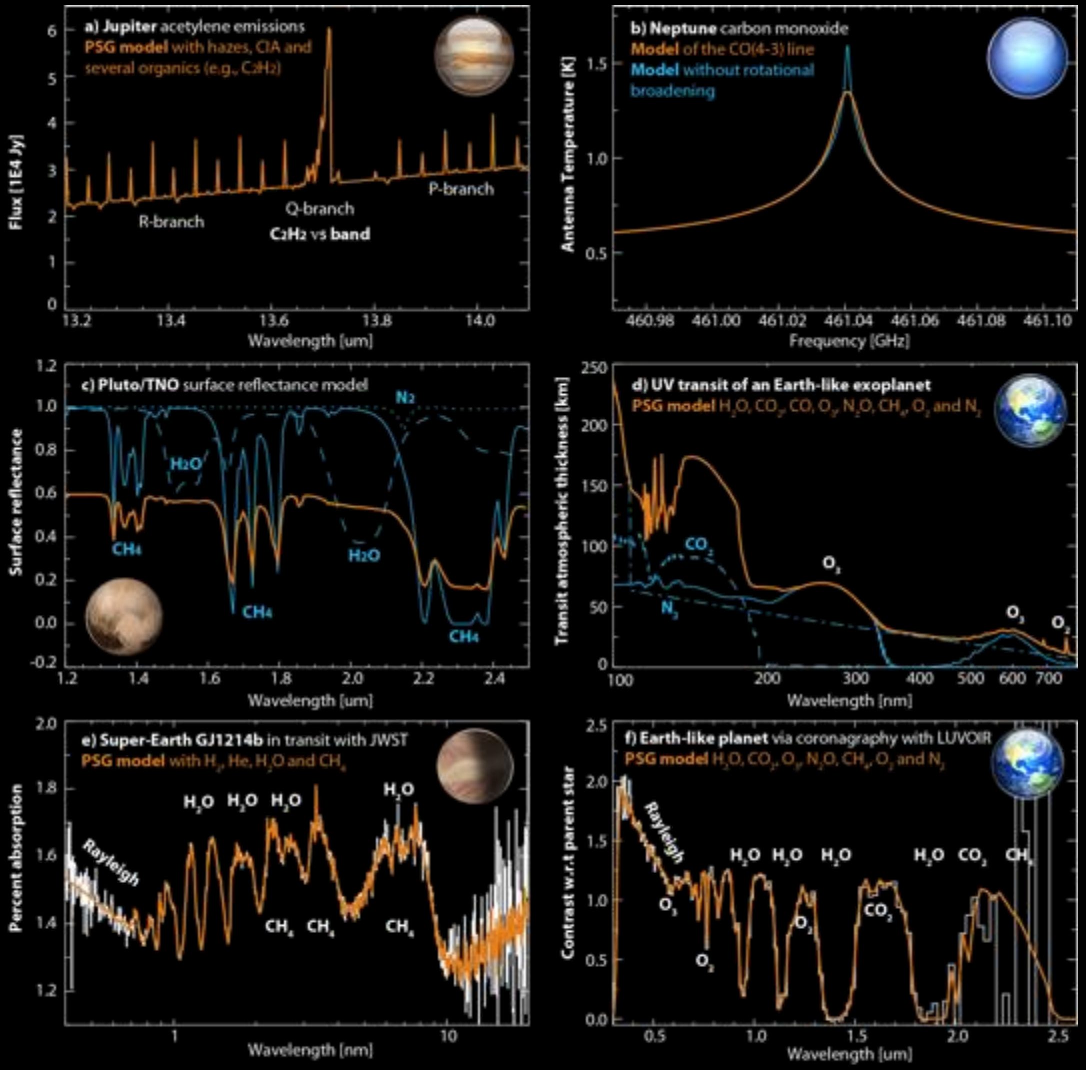
- Non-LTE fluorescence analysis of cometary coma (line-by-line) – UV to IR
- Rotational LTE excitation analysis of cometary coma - IR to Radio
- Nucleus and extended grains emission model
- Photodissociation processes and parent/daughter analysis

SURFACE

- Hapke surface modeling with areal mixing
- Henyey-Greenstein phase modeling
- Database with hundreds of optical constants

Planetary Spectrum Generator (PSG)

Villanueva+2018, psg.gsfc.nasa.gov



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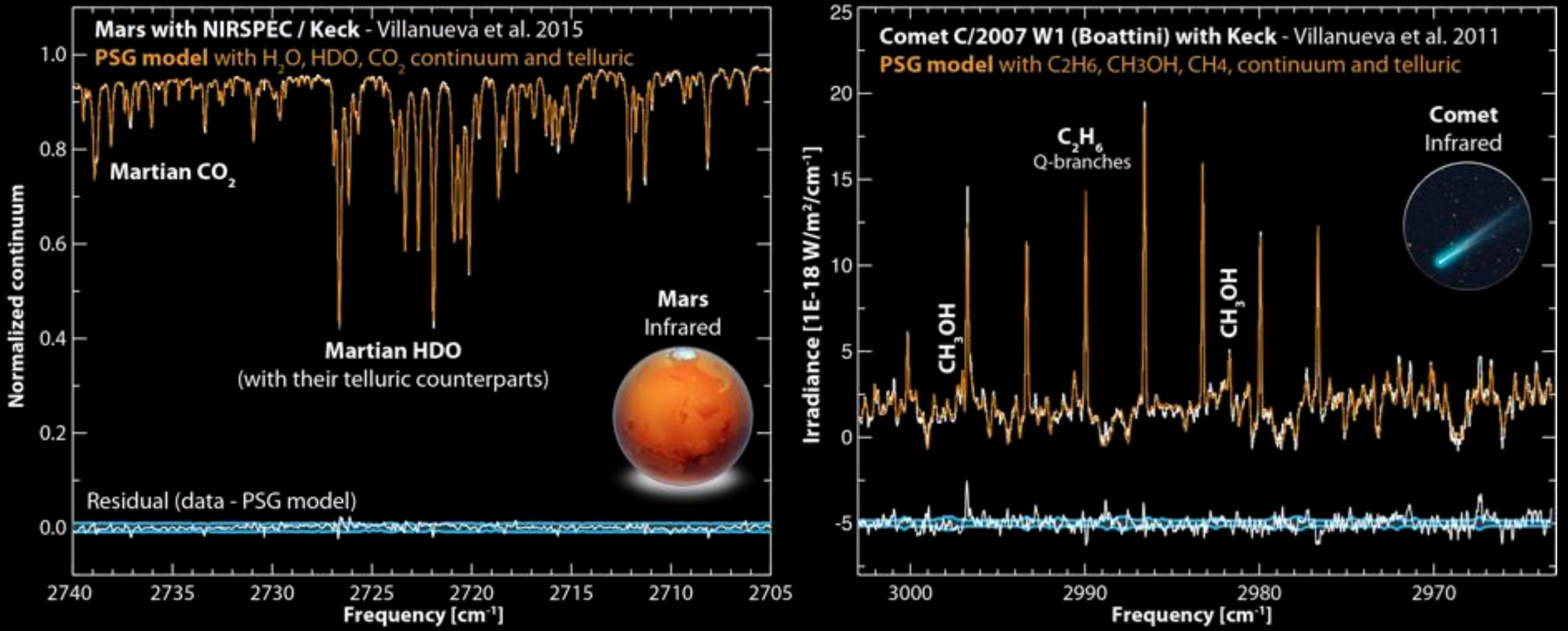

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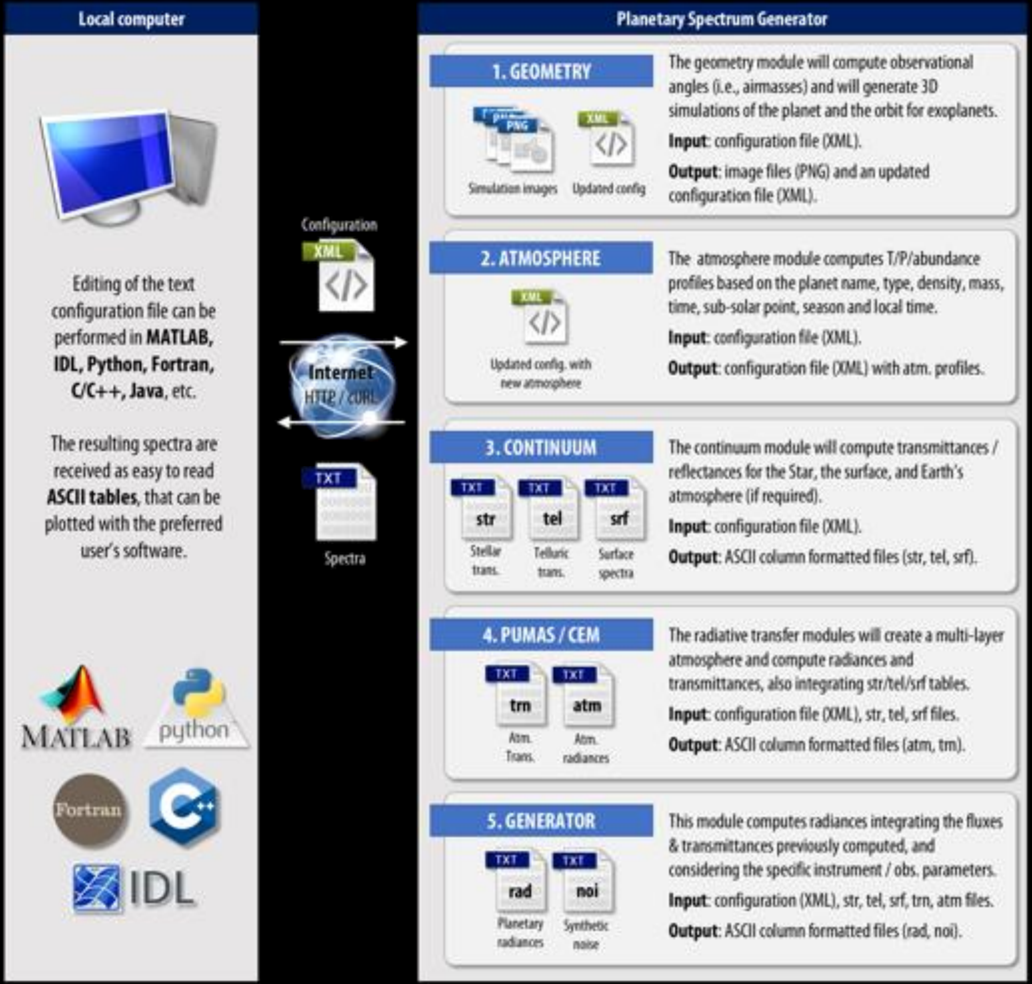

Demo

https://psg.gsfc.nasa.gov