Getting Started with EXES Data

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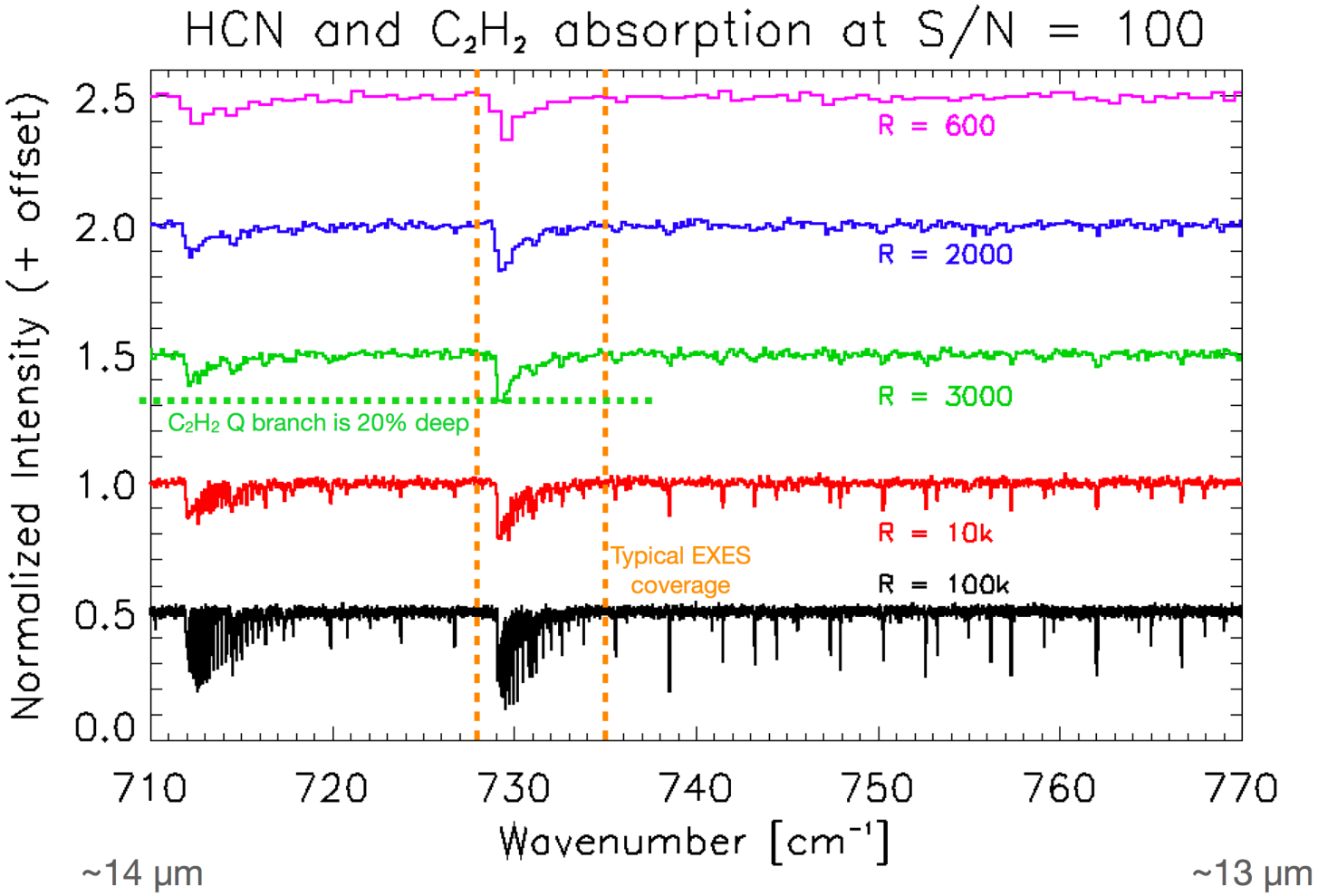
Notes: SOFIA site links migrating to IRSA

EXES at-a-glance

- Instrument paper: Richter, et al., 2018, JAI, 7,1840013
- Detector is a 1024 x 1024 pixel Si:As optimized for low background
  - Same type as MIRI
- Nodded (on or off slit) or Mapping Observations
- Multi-order high resolution mode
  - cross-dispersed with **R = 50,000 – 100,000** (depends on silt width)
  - single setting coverage of 0.8% with 4 – 40” long slit or ~4% with >1” long slit
- Single order modes:
  - Medium mode (**R ~ 8,000 to 25,000**)
  - Low mode (**R ~ 1,500 to 4,000**)

Courtesy Matt Richter, IR2022



EXES at-a-glance

- 1D products have **wavenumbers (cm^{-1})** for their x-axis
  - wavenumber **=** 10000.0/(wavelength in μm) = (frequency in GHz) / 30.0
- Y-units:
  - Flux Unit: erg s^{-1} cm^{-2} sr^{-1} $(cm^{-1})^{-1}$ or Jy/pix (*CAL*)
  - Intensity Unit: erg s^{-1} cm^{-2} $(cm^{-1})^{-1}$ or Jy
    - Some early EXES data is an “odd” Jy or Jy/pix (*COA*) state.
    - **Please contact us if you work with Cycle 4 & earlier data**
- Making synthetic spectra HITRAN online + HAPI (hitran.org; hitran.org/hapi), ExoMol (https://exomol.com/), and GEISA (https://geisa.aeris-data.fr/)
- Atmospheric correction: ATRAN (https://atran.arc.nasa.gov/cgi-bin/atran/atran.cgi) & Planetary Spectrum Generator (https://psg.gsfc.nasa.gov/index.php)
  - Steve Goldman’s Jupyter Cookbooks: https://sofia-data-analysis-cookbooks.readthedocs.io/en/latest/exes.html
  - Curtis DeWitt’s presentation at SOFIA IR School: https://www.youtube.com/watch?v=yB_J6-2jmp4

EXES Pipeline Products

- Commissioning to OC4M (January 2017)
  - First version of EXES Pipeline in IDL
- OC5C (March 2017) to OC9O (May 2022)
  - Mixed bag of IDL pipelines
  - Currently re-processing everything with new Python pipeline
    - Improved wavelength calibration
    - ATRAN -> PSG for telluric model
    - Flux units: Jy/pixel & Jy
      - **OC6L & OC6S: completed**
      - **OC5C & OC7K: in progress**
      - OC5F, OC9G, OC9K, OC9O, OC8N to follow

SOFIA @ IRSA -- https://irsa.ipac.caltech.edu/applications/sofia/?__action=layout.showDropDown&

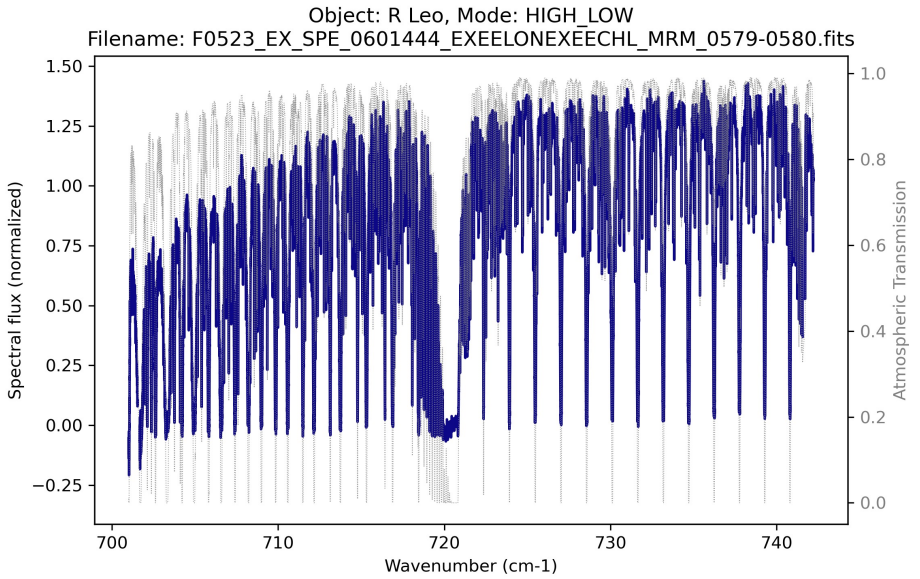
EXES Pipeline Products

- In-flight observations
  - *sci*, *dark*, *flat*
  - Raw values/counts
  - EXES' counts down (e.g. brighter means lower values)
- IDL processed
  - 2D: *RAW*, *WVM*, *FLT*, *UND*, *COA*
  - 1D: *SPC*, *CMB*, *MRD*
- Python processed
  - 2D: *RDC*, *FLT*, *UND*, *CCR*, *COA*, *CAL*, *SPM*, *COM*, *MRM*
  - 1D: *SPC*, *CMB*, *MRD*
  - Latest manual at: https://www.sofia.usra.edu/data/data-pipelines

EXES Pipeline Products

M82 [Ne II] Medium Mode Map (AOR ID: 75_0017_22)

- Maps:
  - *UND* (commissioning to OC4M) or *CCR* (OC5C to OC9O) or *CAL*
  - No WCS (**contact us for help with working with FPI frames**)
- Nodded observations:
  - *COA* or *CAL*
  - *SPM* or *SPC*
  - *COM* or *CMB*
  - *MRM* or *MRD*



R Leo MRD/MRM preview (AOR ID: 06_0144_4)

Resources

- Making synthetic spectra HITRAN online + HAPI (hitran.org; hitran.org/hapi), ExoMol (https://exomol.com/), and GEISA (https://geisa.aeris-data.fr/)

- Astropy's specutils (https://specutils.readthedocs.io/en/stable/index.html)

- Atmospheric correction: ATRAN (https://atran.arc.nasa.gov/cgi-bin/atran/atran.cgi) & Planetary Spectrum Generator (https://psg.gsfc.nasa.gov/index.php)
  - Curtis DeWitt's presentation at SOFIA IR School: https://www.youtube.com/watch?v=yB_J6-2jmp4

Jupyter Notebooks

- Steve Goldman's SOFIA Cookbooks: https://sofia-data-analysis-cookbooks.readthedocs.io/en/latest/exes.html
  - Curtis and I working on converting IDL routines into additional notebooks

- Colette Salyk's (Vassar College) spectools-ir (https://github.com/csalyk/spectools_ir; DOI: 10.5281/zenodo.5818682)