SORTIE Ion Velocity Meter First Light:

Open Source Instrument Data Processing Case Study

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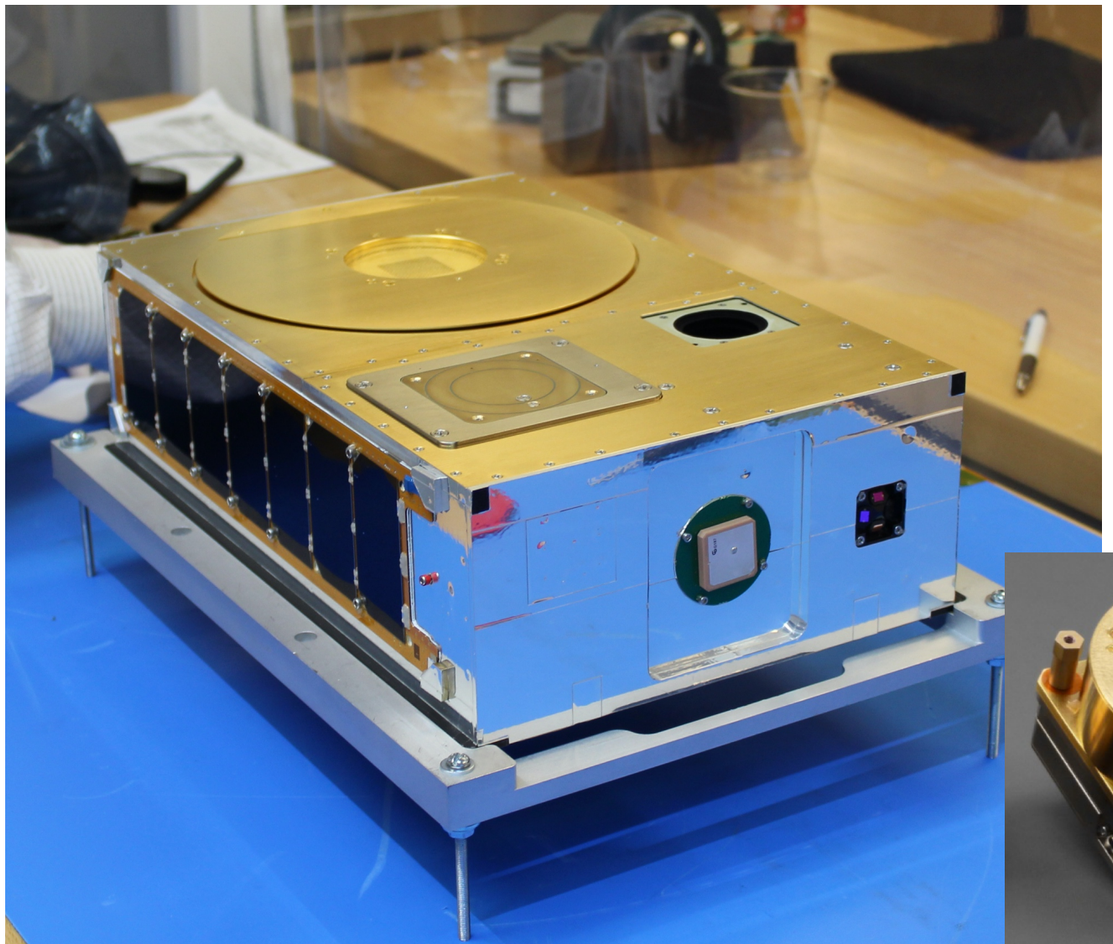
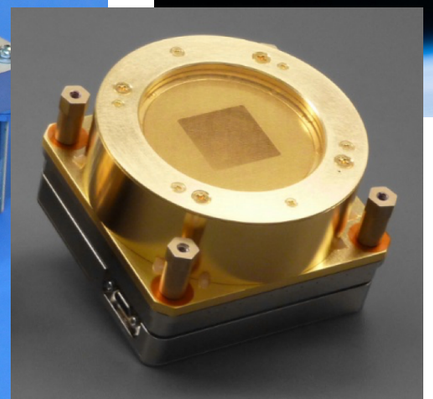
ASTRA and Air Force Research Lab

SORTIE Spacecraft

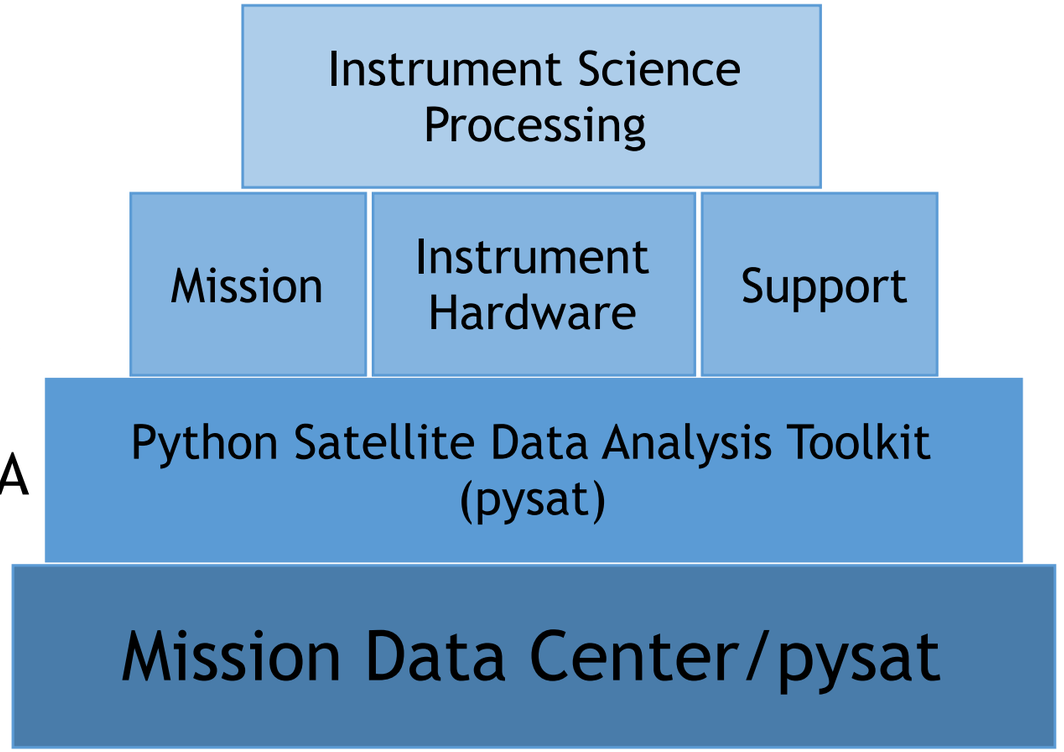
- ISS Deployed
- CubeSat Ion Velocity Meter-IVM
- CubeSat Planar Langmuir Probe





IVM Processing Software

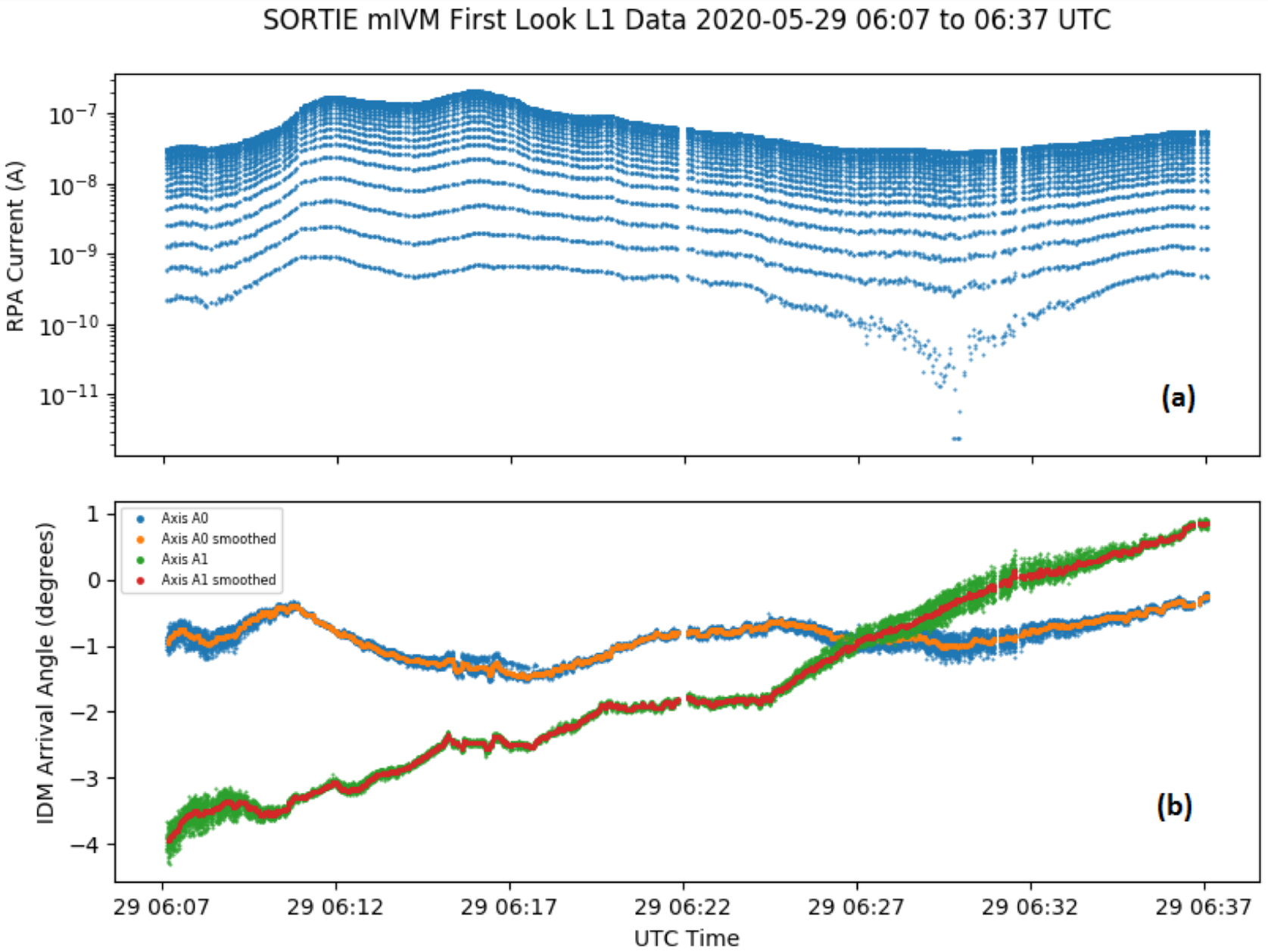
- IVM core processing software built on top of pysat as well as mission, instrument, and other support packages
- pysat provides for a generalized data processing environment that abstracts away tedious file and data handling responsibilities
  - Handles coupling of core IVM software to unique processing environments (UC-Berkeley, CDAAC at UCAR, UTD)
  - to_netcdf4 method creates files suitable for NASA archive
    - used to create ICON IVM files
  - Pysat can function as its own data center
- Design enables the same core IVM software to be used across ICON, COSMIC-2 and SORTIE missions
  - pysat is generating operational instrument processing heritage at 9 satellite-data-years/year



Current Support Packages

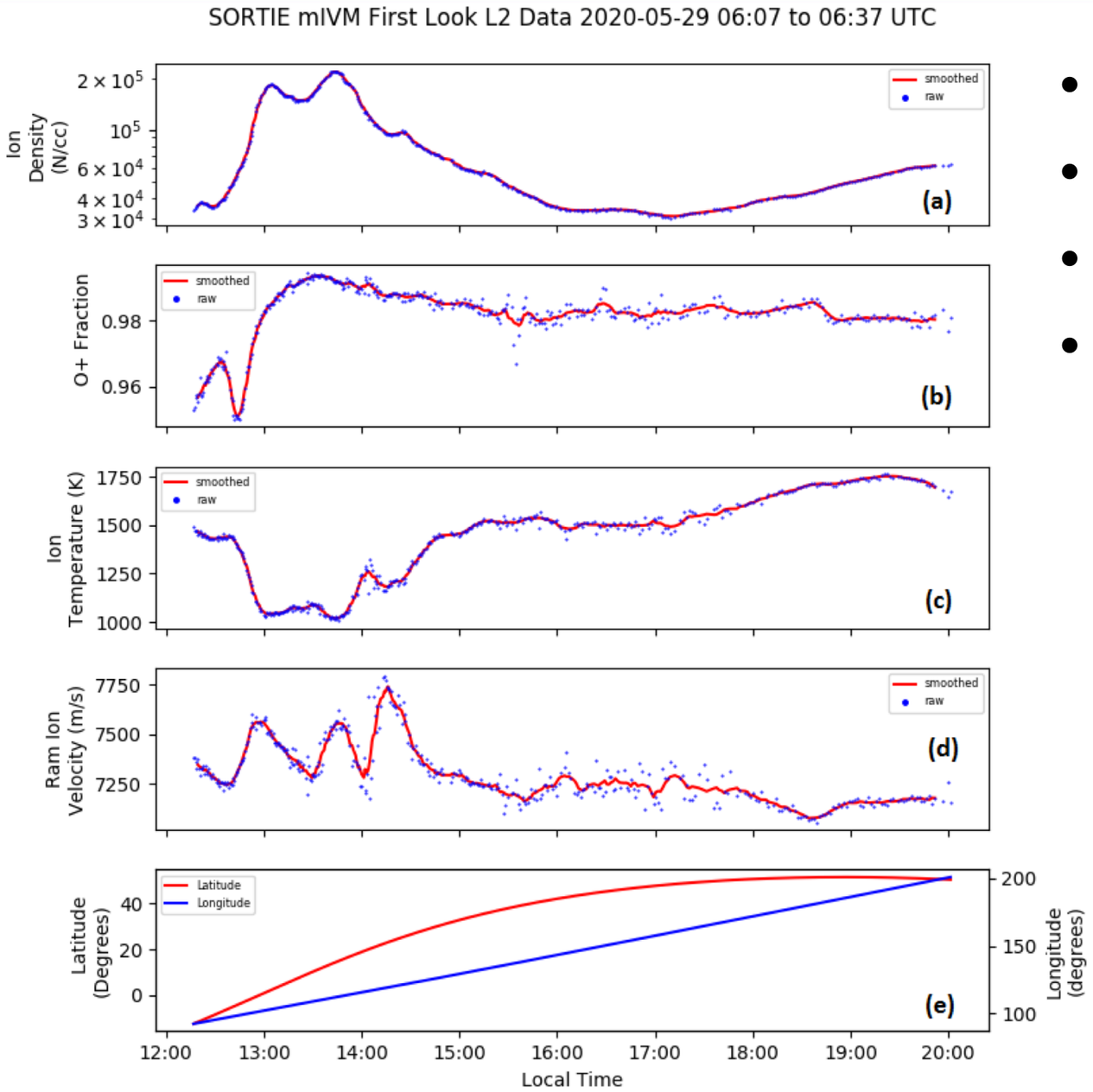
- Apexpy
  - Magnetic coordinate location information
- OMMBV
  - Magnetic basis vectors and field-line scaling of electric fields and ion drifts
- IGRF reference code
- Packages in development (incomplete descriptions)
  - pysatMissions
    - Orbits and coupling to empirical models via sgp4, pyglow, and others
  - pysatModels
    - Coupling to numerical models (TIEGCM, SAMI, etc.)

Level-1 Data



- First demonstration of single aperture IVM
- Measurements over energy are robust across whole data segment
  - Currents as low as a few pA
- Arrival angles and smoothed signal
  - ~8.5 m/s std-dev raw signal (~ 3 m/s smoothed)

Level-2 Data

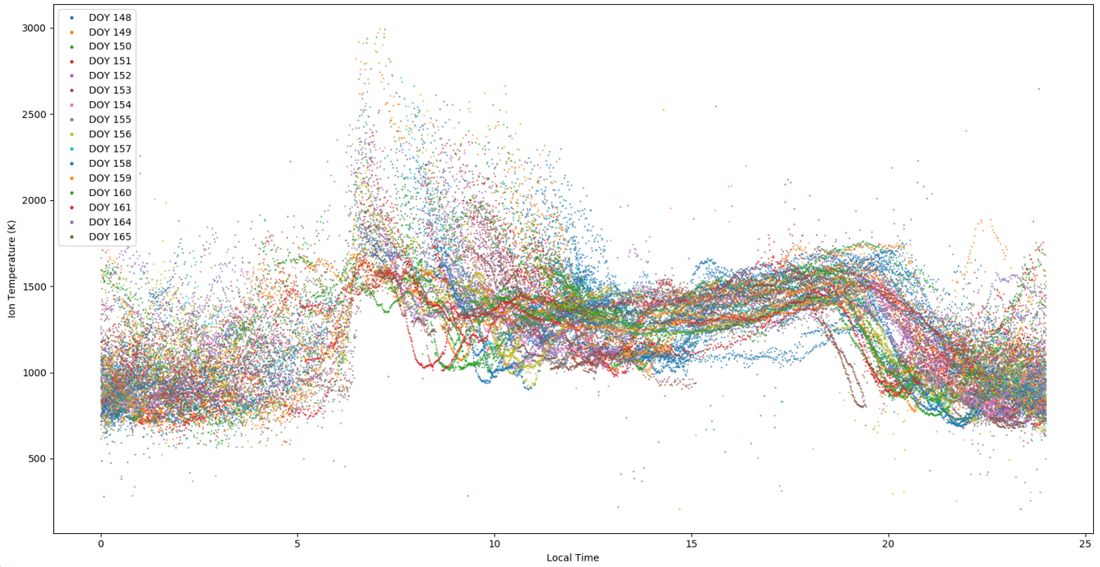


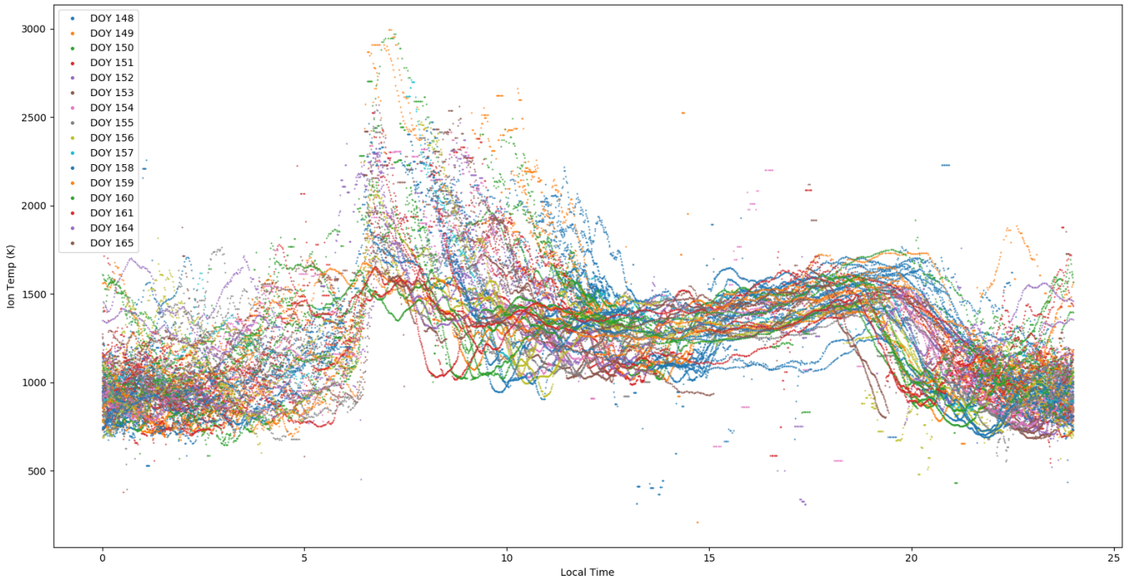
- Circular orbit ~420 km
- O+ composition std-dev < 0.2%
- Ion Temp std-dev ~18K
- Ram Ion Drift std-dev ~40 m/s
  - 30 - 50 m/s at 1-Hz depending upon O+ composition
    - 12-13 LT (96%) vs 16-17 LT (98%)
    - Error model for CubeSat IVM incomplete
  - Performance determined by hardware + software and is evolving

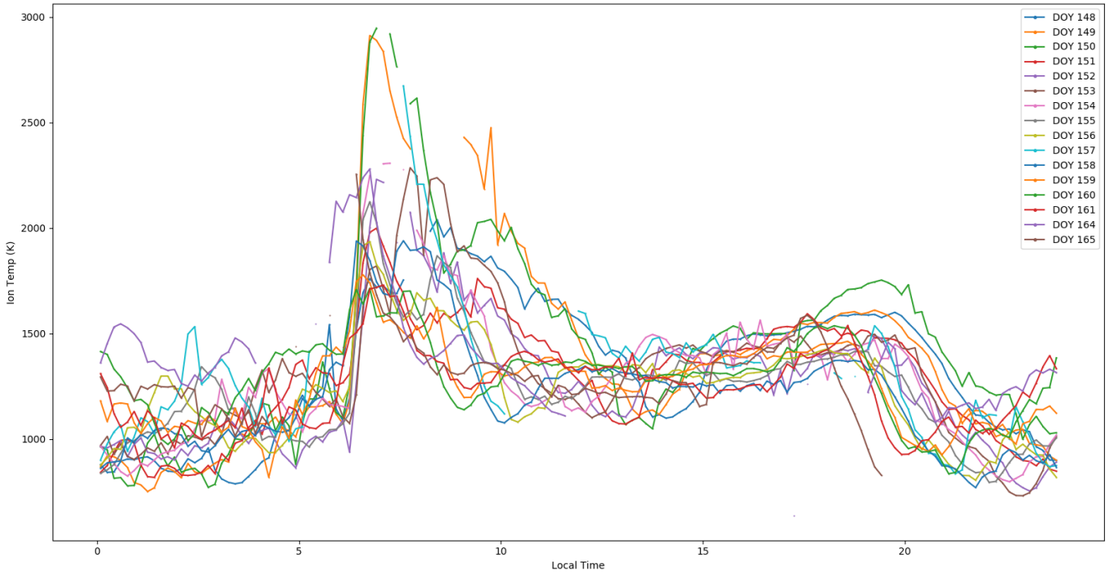
Mission Results - Ion Temperature

Ion Temp

- Raw Data
- 30s Rolling Average
  - Local Times binned and used to form day-averages (per LT bin) – one average local time day per calendar day

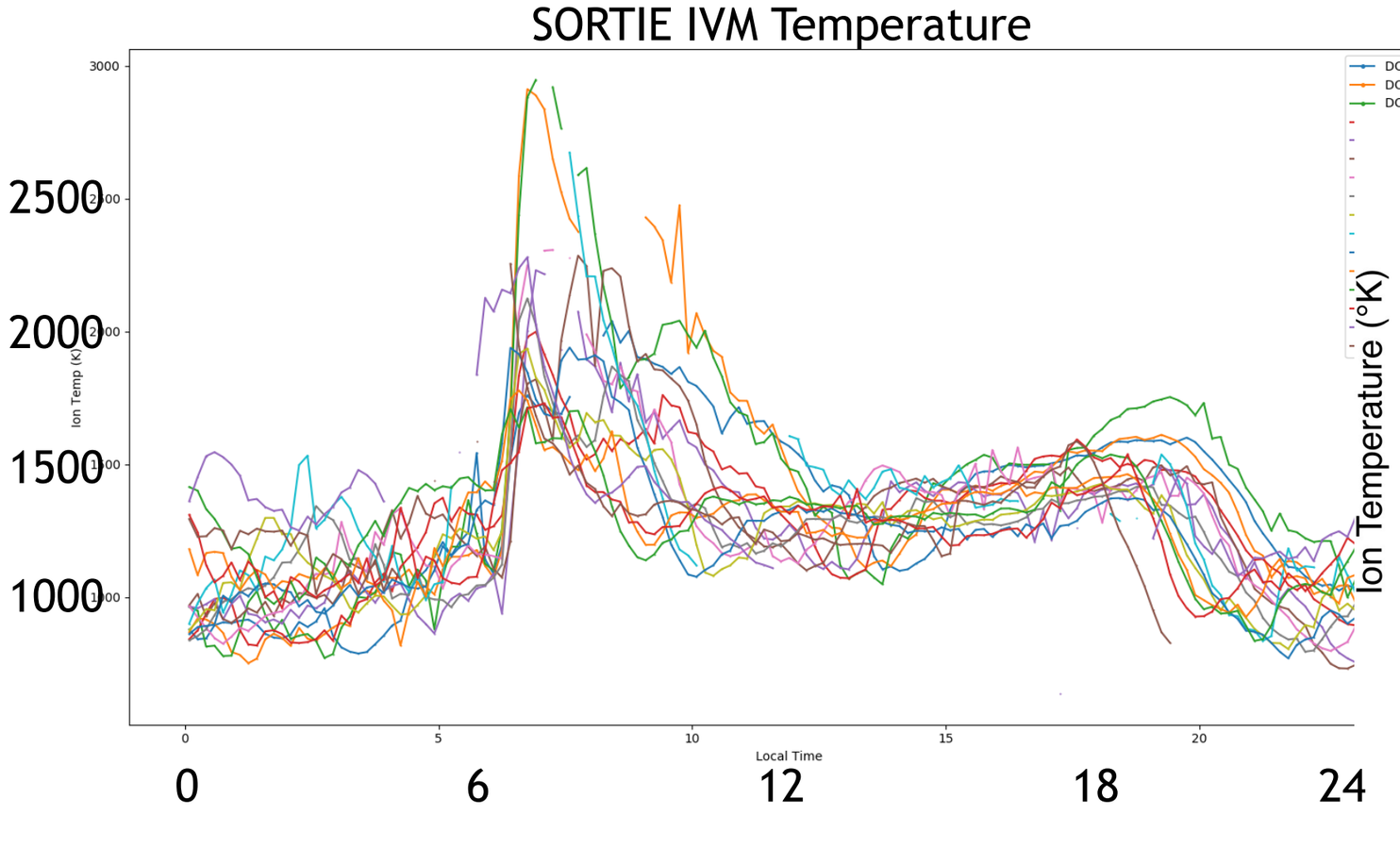


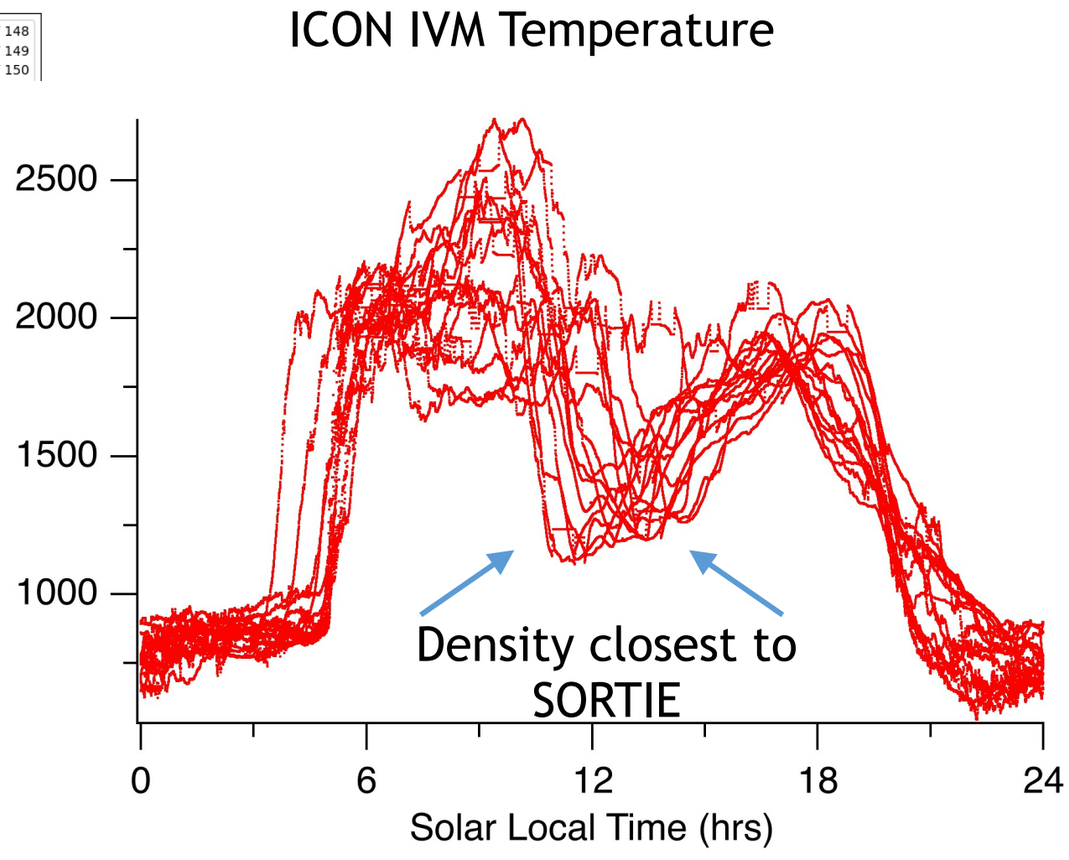




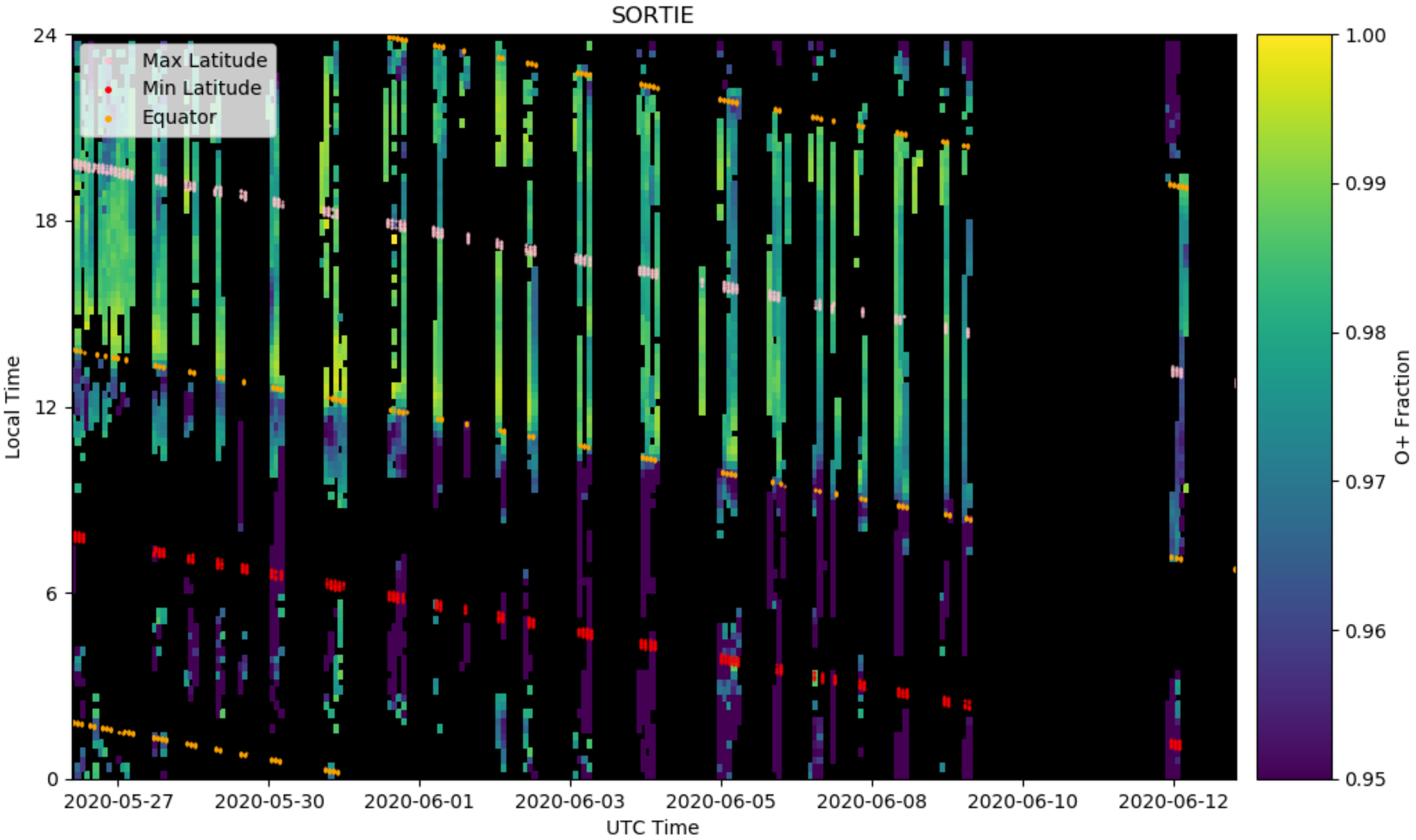
Ion Temperature - Comparison to ICON

- Different orbits between platforms, though SORTIE IVM is clearly producing geophysical temperatures
  - Single day for ICON (curve per orbit) multiple days for SORTIE (curve per day)

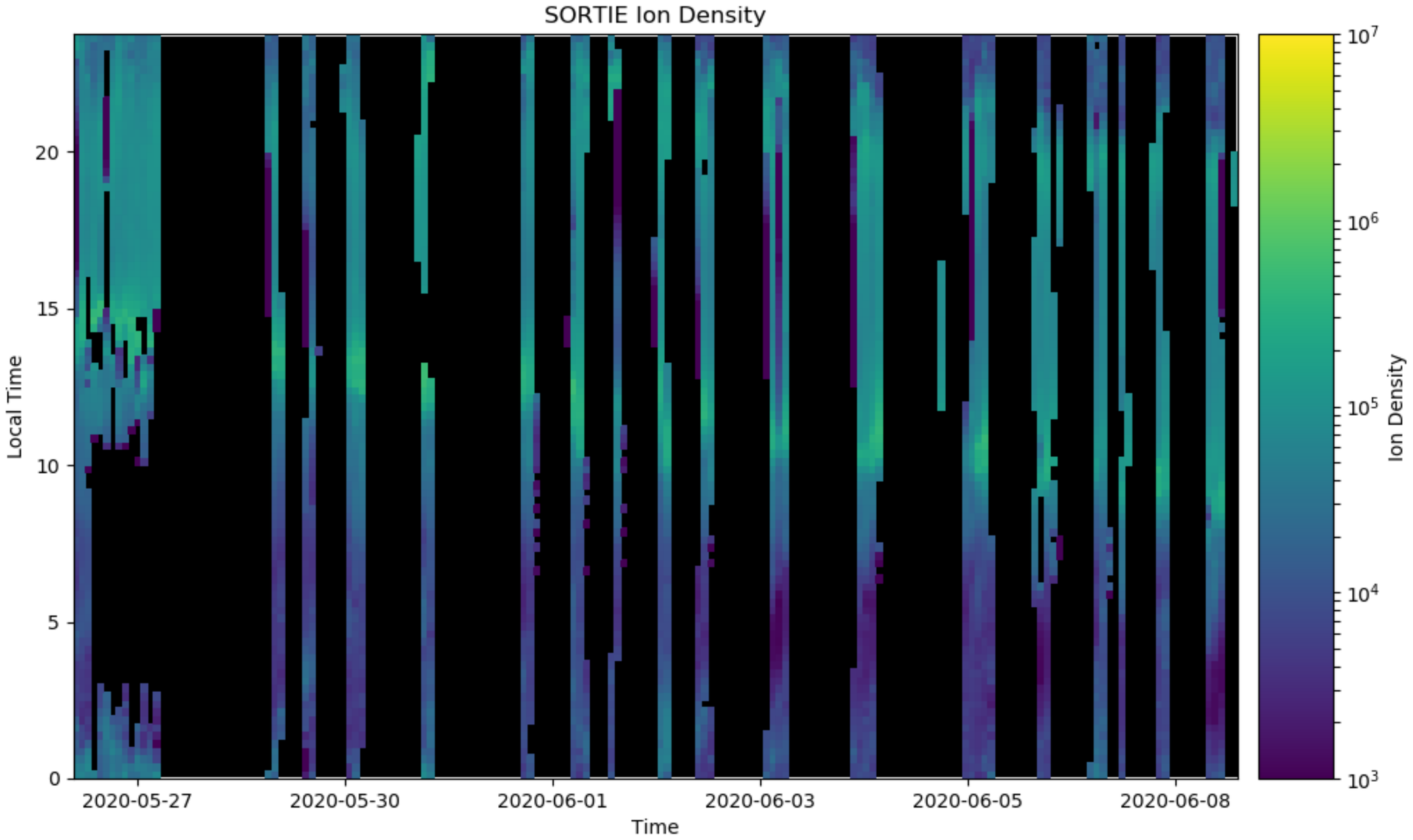




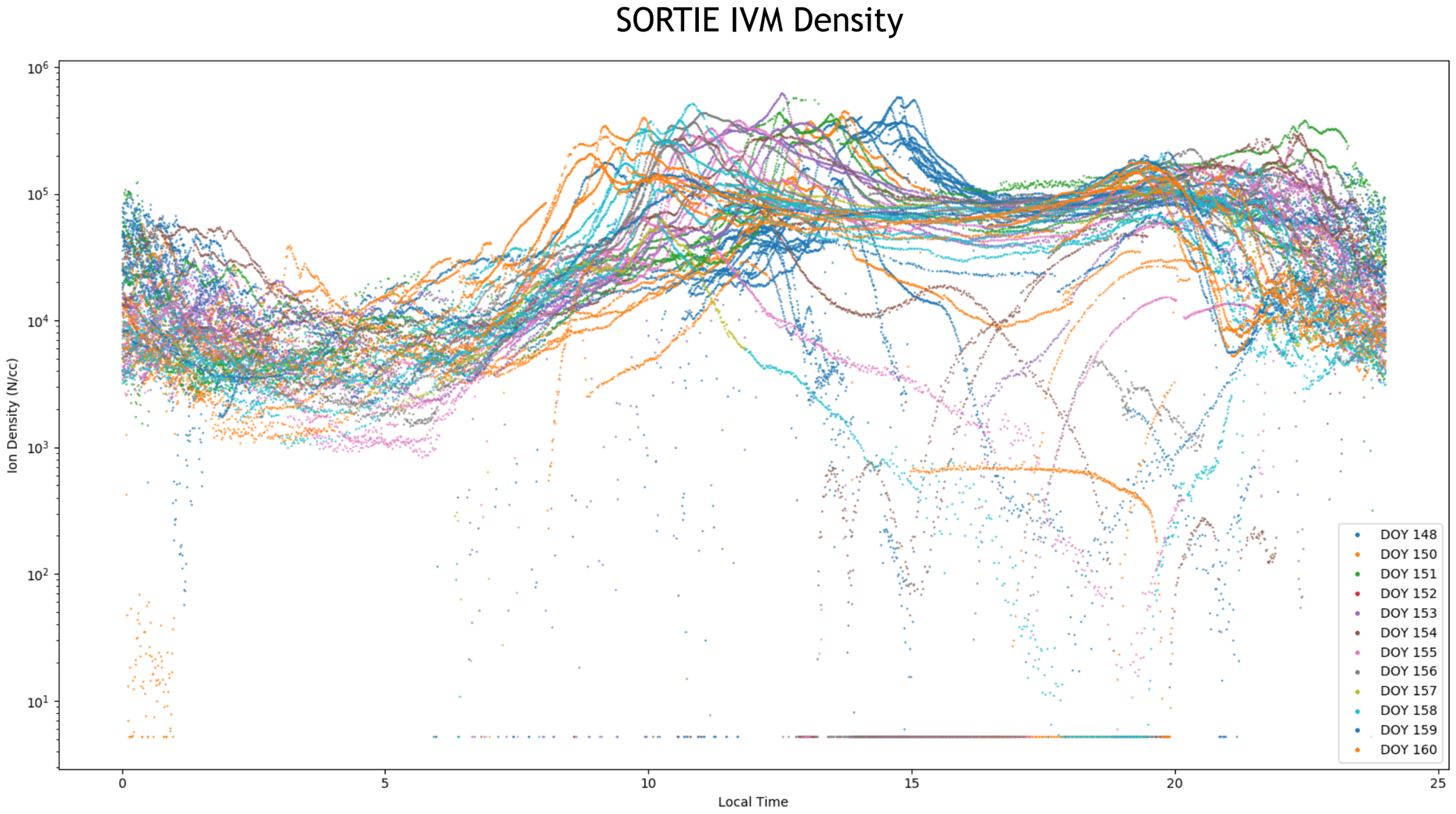
O+ Fraction Results - Full Mission



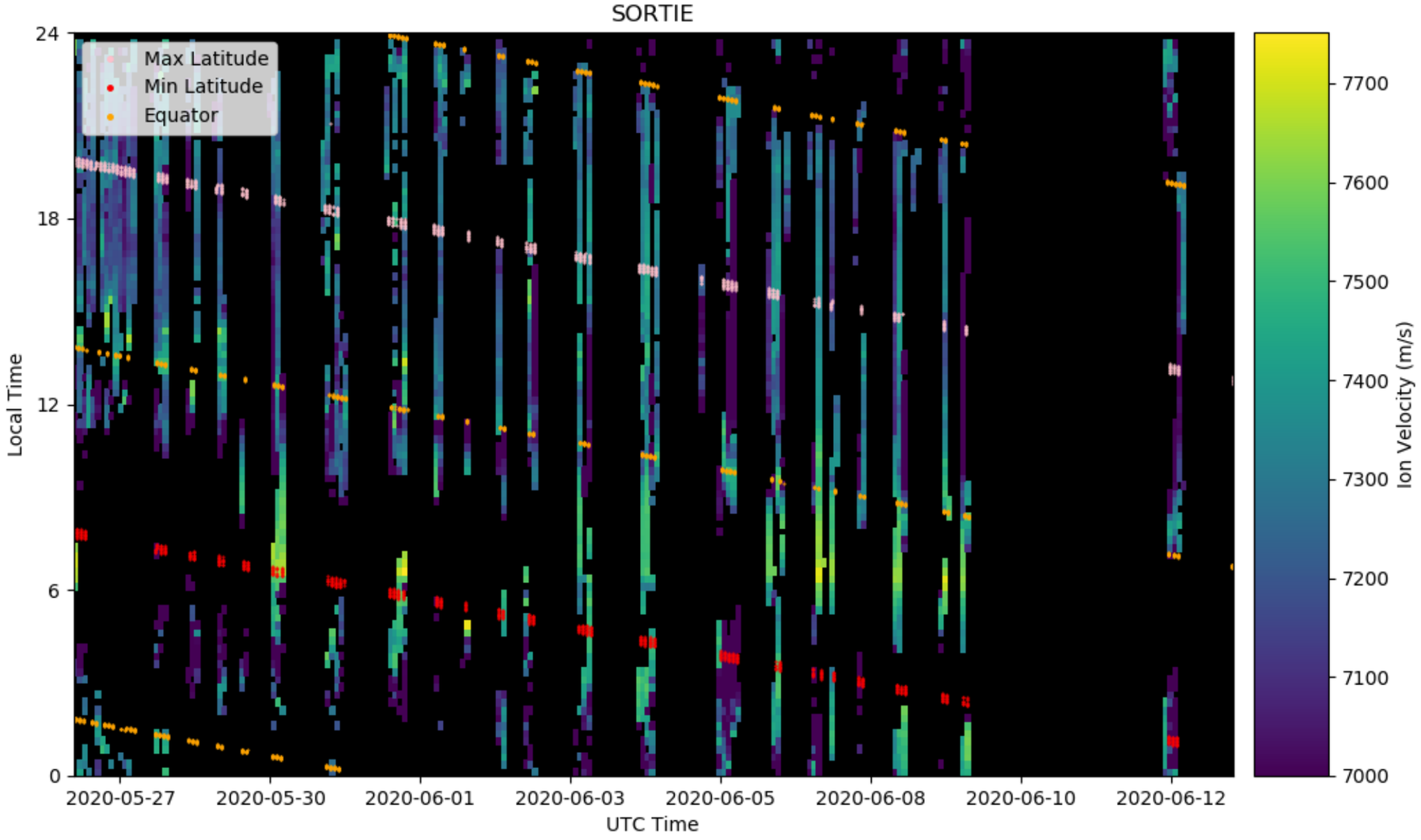
Density Results - Full Mission



Density Results - per Orbit Plots



Ram Drifts - Full Mission



Conversion of measured drifts to a geophysical basis requires incorporation of spacecraft attitude and ephemeris - in progress

Shown is total ion velocity into instrument

Summary

- SORTIE IVM first light results demonstrate that ionospheric science is possible using CubeSats
  - Results only available at CEDAR due to design flexibility provided by pysat and other packages when creating IVM software
- End-to-End processing for CubeSats and other missions already possible with open source software
  - Continued operation of ICON, COSMIC-2, and SORTIE will provide additional operational heritage for pysat and other packages
    - Experiences on these missions will be folded back into pysat
  - pysatMissions and pysatModels extends mission support to include a greater range of pre- and post-launch activities
- Use and development of open source software for science missions makes future missions easier and cheaper
  - Essential for CubeSat missions where funding, personnel, and development time may be limited
  - Every CubeSat mission that directs all required software development, from beginning to end of mission, towards open source would provide an even stronger software foundation for all subsequent CubeSat missions.

DOIs

- pysat publication (10.1029/2018JA025297) and software (10.5281/zenodo.1199703)
- OMMBV software (10.5281/zenodo.1299374)
- Apexpy publication (10.1029/2010JA015326) and software (10.5281/zenodo.1214206)
- Magnetic Basis Vector Review (10.1007/s11214-016-0275-y)
- OMMBV manuscript pending submission
- pysat and other related pysat packages may be found at github.com/pysat