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pyIntensityFeatures

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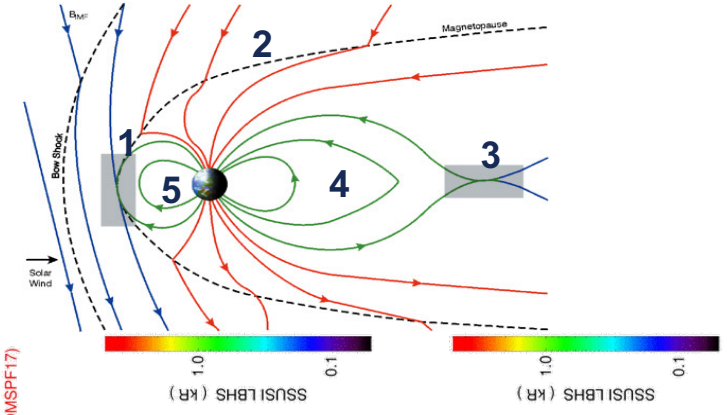
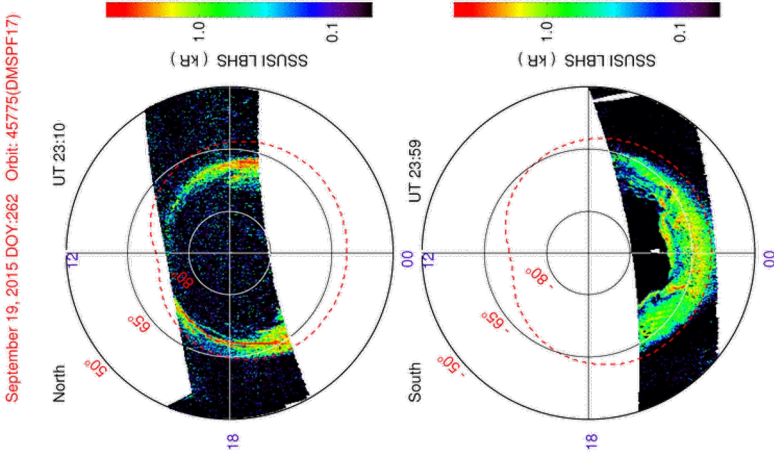
Motivation

- High latitude M-I coupling varies based on region:
  - Open field lines in the polar cap
  - Closed field lines in the auroral oval, high L-shells
  - Closed field lines below the auroral oval, low L-shells
- Gridding relative to the polar cap (Open-Closed field line Boundary, OCB) and auroral oval (Equatorward Auroral Boundary, EAB) can improve modelling and statistical studies
- Auroral boundary detections from space-based imagers are needed to improve these efforts
- Existing boundary information may not be suitable for scientific use

Top: Plasma Physics of the Local Cosmos (2004)





Bottom: JHU APL Website (accessed 5 June 2023)

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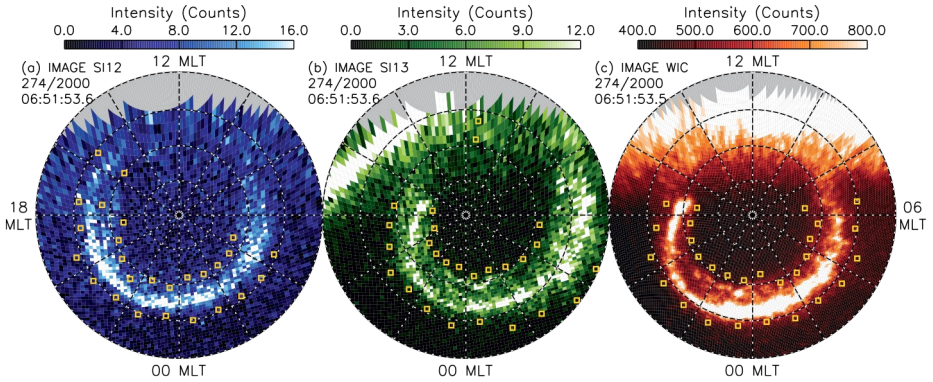
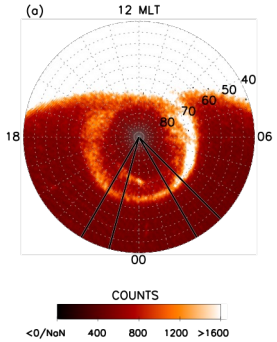
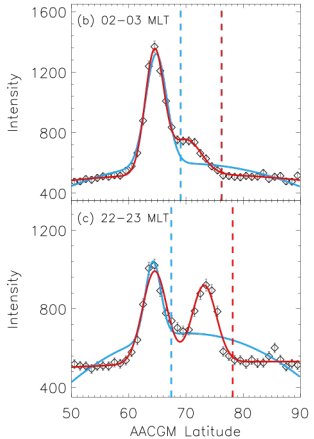
Starting Point for Auroral Luminosity Boundaries

- IMAGE SI12, SI13, and WIC measured Ly-α, O, and LBH emission bands in the Northern hemisphere
- Chisham et al., 2022 found the polar and equatorward ALBs using the Longden et al., 2010 method
  - Used Newell DMSP boundaries to determine the offset between the ALB and precipitation boundaries
  - Fits to the offset boundaries agree well with the convection reversal boundary, providing confidence in the ALBs
- Used the IDL code developed by Longden as a base and generalize
  - Allow any number of multi-Gaussian fits
  - Added adaptive limits for partial-aurora scans
  - Added test for MLT consistency in boundary IDs







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Methodology

- Clean data as directed by the instrument team
- Identify a scan of intensity observations that contain the auroral oval in one hemisphere
- Separate the scan into MLT slices, for each slice:
  - Fit the intensity peaks (try multiple fits)
  - Identify the poleward and equatorward boundaries
  - Calculate boundary uncertainty
  - Evaluate the poleward and equatorward boundaries and select the best ones
- Evaluate the poleward and equatorward boundaries in each scan and remove outliers

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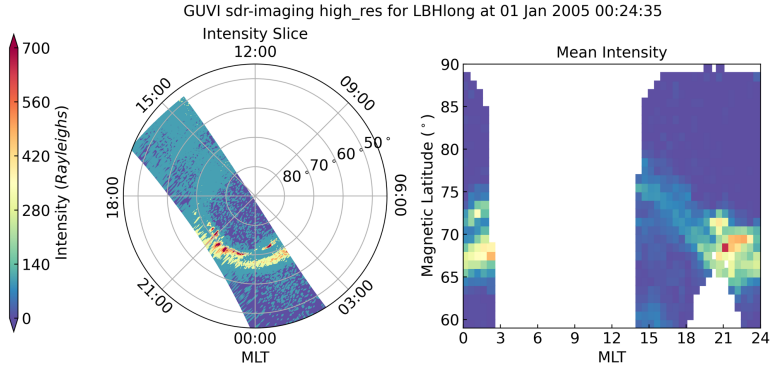
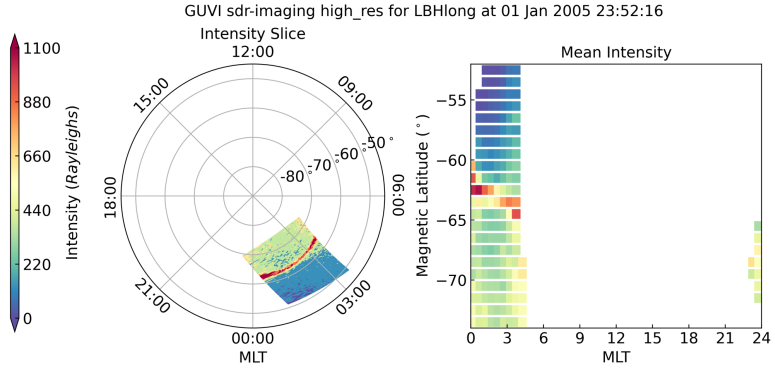
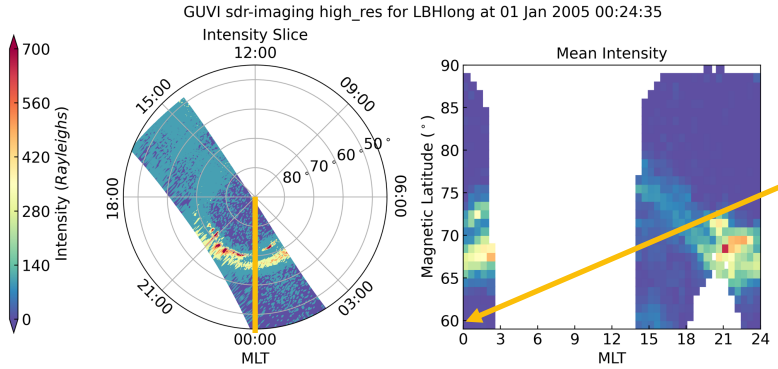
Identify and Process a Scan

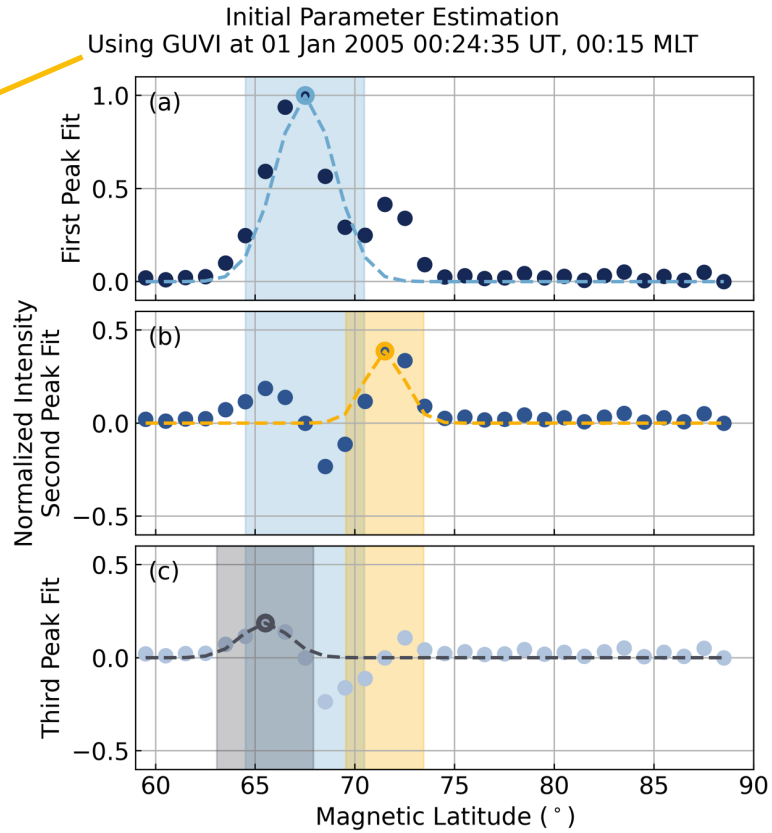




- Identify a “scan” of auroral data
  - `pyIntensityFeatures.instruments.satellites.get_auroral_slice`
  - User provides arrays of time, latitude, longitude, and intensity data
  - Optionally specifies a start time and a mask to select clean data
  - User should provide hemisphere (assumes North) and a minimum co-latitude (assumes 45˚)
  - Operates in geodetic coordinates
- Process the auroral scan to get MLT slices:
  - Create a grid in magnetic coordinates (package uses AACGMV2)
  - Get mean and standard deviation of the intensity at each magnetic latitude and local time (MLat, MLT)
  - Determine the magnetic latitude limits of the slice by finding the highest and lowest latitudes with data at all MLT

Process each MLT in the Scan





- For each MLT grid point, fit the intensity and find the poleward and equatorward boundaries
- Process:
  - Identify the maximum number of intensity peaks (up to three peaks)
  - Find peak intensity and standard deviation to initialize future fitting

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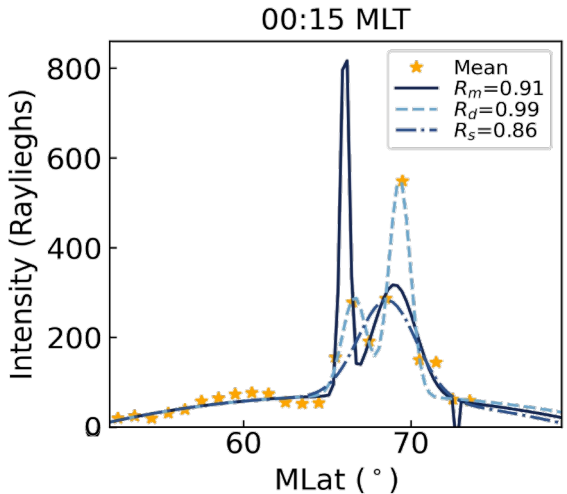
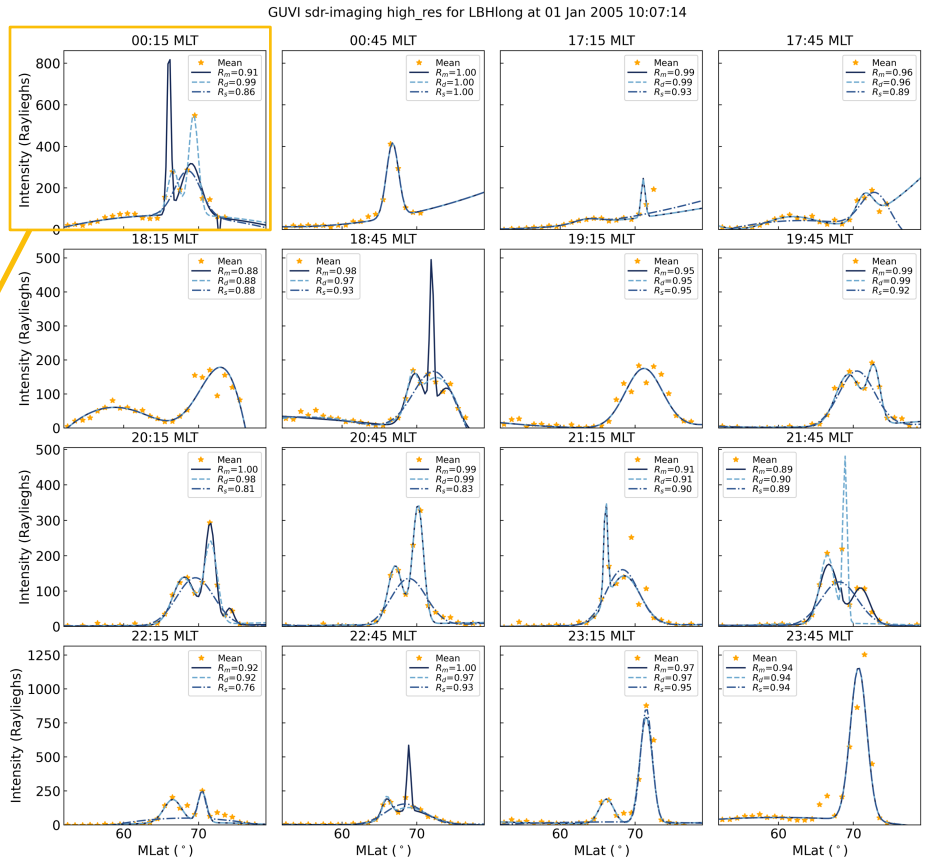
Process each MLT in the Scan

- Process (second time example):
  - Identify the maximum number of intensity peaks (up to three peaks)
  - Find peak intensity and standard deviation to initialize future fitting
  - Fit 1, 2, and 3 Gaussian peaks with a quadradic background
    - Quadradic background accounts for dayglow and noise





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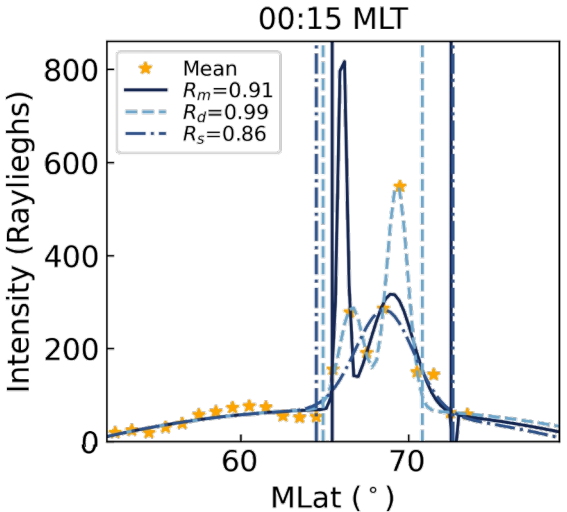
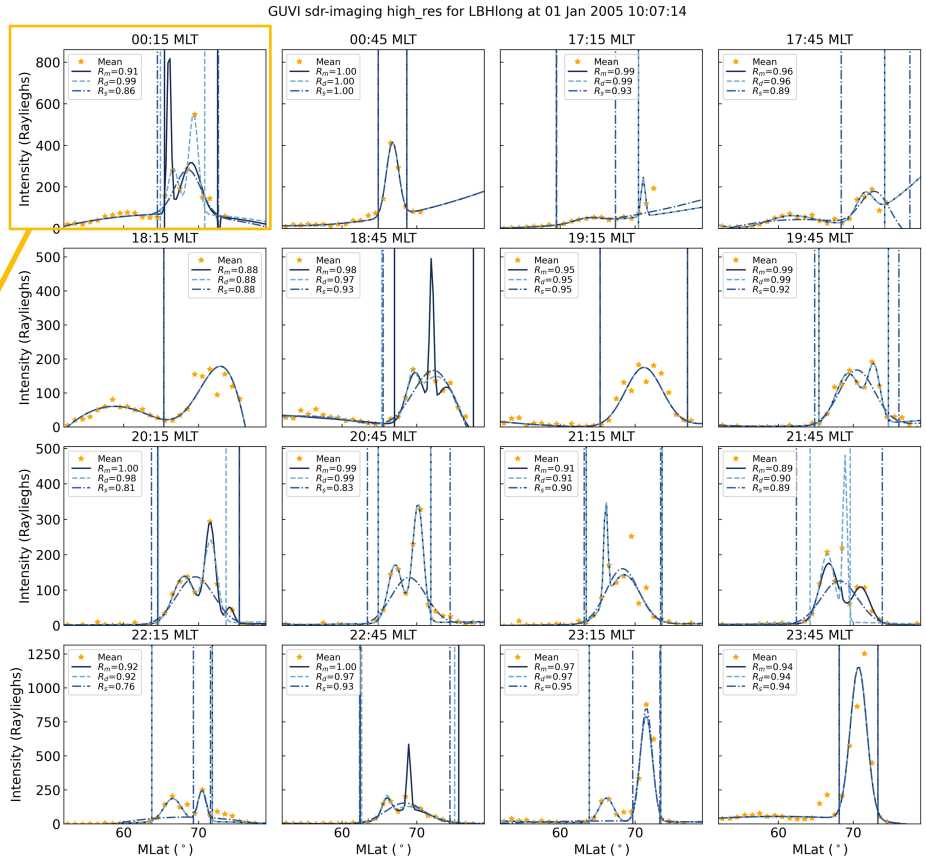
Process each MLT in the Scan

- Process (second time example):
  - Fit 1, 2, and 3 Gaussian peaks with a quadradic background
  - Find the poleward and equatorward boundaries for each fit
    - The boundary is the location 2σ from the most poleward/equatorward peak





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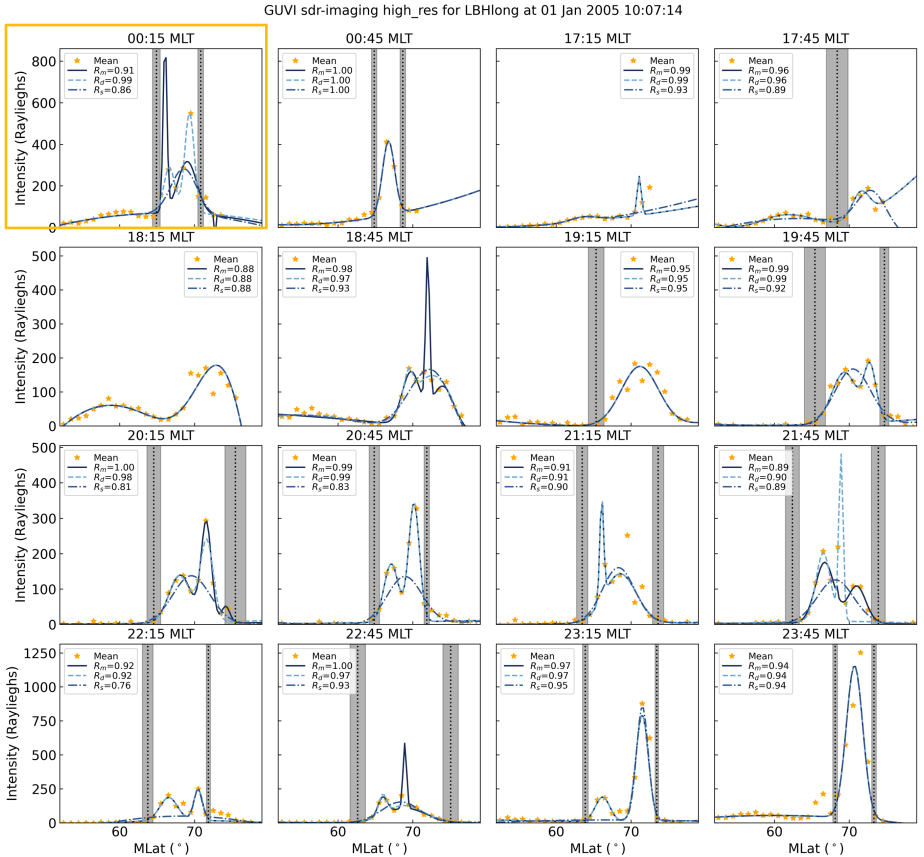
Process each MLT in the Scan

- Process (second time example):
  - Find the poleward and equatorward boundaries for each fit
  - Calculate boundary uncertainty using the uncertainties of the mean and standard deviation of the Gaussian peaks, as well as the covariance of the fitting
    - Recommend that user also accounts for the grid size in their final boundary uncertainties
  - Choose the best poleward and equatorward boundaries separately, based on their fit's Pearson correlation coefficient and the boundary uncertainty
  - Reject boundaries based on the background intensity, boundary uncertainty, location relative to a latitude limit



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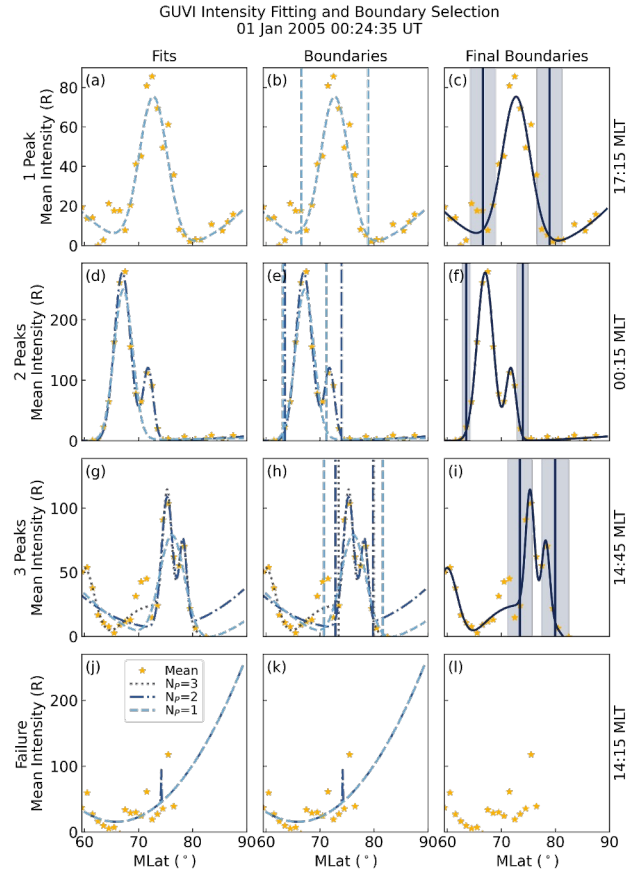
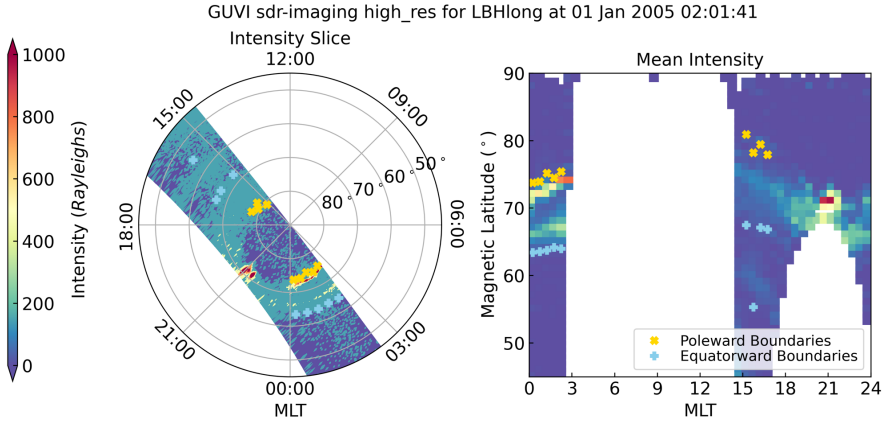
Process each MLT in the Scan

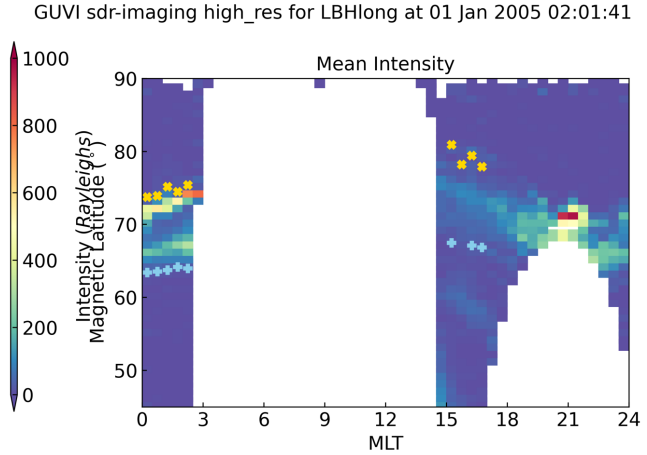
- Process (first time example):
  - Find the poleward and equatorward boundaries for each fit
  - Calculate boundary uncertainty using the uncertainties of the mean and standard deviation of the Gaussian peaks, as well as the covariance of the fitting
    - Recommend that user also accounts for the grid size in their final boundary uncertainties
  - Choose the best poleward and equatorward boundaries separately, based on their fit's Pearson correlation coefficient and the boundary uncertainty
  - Reject boundaries based on the background intensity, boundary uncertainty, location relative to a latitude limit



Consider all MLT in the Scan

- Process (first time example):
  - Choose the best poleward and equatorward boundaries based on their fit's Pearson correlation coefficient and the boundary uncertainty
  - Reject boundaries based on the background intensity, boundary uncertainty, location relative to a latitude limit
  - Identify outliers in 5 hr MLT bins using the Interquartile Range (IQR)
    - For full-auroral imagers, such as POLAR or IMAGE, consider using the entire MLT range





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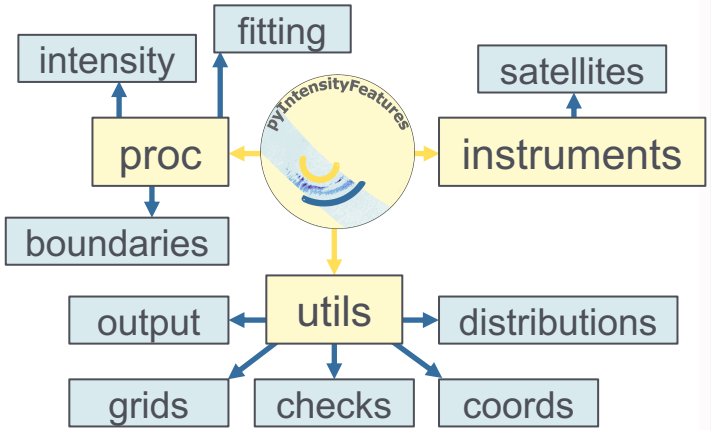
pyIntensityFeatures Usage

- Class-based user interface combines all steps needed to perform ALB identification and output data into a netCDF file
- Function access in sub-modules allows users to experiment with the best constraints for their data set




```
alb = pyIntensityFeatures.AuroralBounds({}, "time", "glat", "glon",
                                        "intensity", 110.0)
print(alb)

Auroral Boundary object
=======================
Instrument Data: {}

Data Variables
--------------
Time: time
Geo Lon: glat
Geo Lat: glon
Intensity: intensity
Transpose: {'glat': False, 'glon': False, 'intensity': False}

Coordinate Attributes
---------------------
Hemisphere: 1
Altitude: 110.00 km
Optional coords: {'hemisphere': 1}
Start time: None
End time: None

Instrument Functions
--------------------
Slicing: functools.partial(<function get_auroral_slice at 0x1391d1550>)
Cleaning: None
```

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pyIntensityFeatures Future

- Ground-based observations (All-Sky Imagers) may also be worth incorporating
- Similar algorithms may be useful for identifying other intensity features in observations
  - New classes allow vetted identification algorithms to be added to the main package
  - Potential extensions include:
    - Travelling Ionospheric Disturbances (TIDs)
    - Equatorial Ionization Anomaly (EIA)
    - Equatorial Plasma Bubbles (EPBs)

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Summary

- Find `pyIntensityFeatures` on GitHub
  - https://github.com/aburrell/pyIntensityFeatures
- Documentation available on ReadTheDocs with examples for using main class and functions
  - https://pyintensityfeatures.readthedocs.io/en/latest/?badge=latest
- Publication in JGR: Space Physics goes over more details of the algorithm
  - Burrell, A. G., Chisham, G., Longden, N., Fritz, B., & Zawdie, K. A. (2025). Automated identification of auroral luminosity boundaries using pyIntensityFeatures. Journal of Geophysical Research: Space Physics, 130, e2025JA034230, doi:10.1029/2025JA034230.

Acknowledgements

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