import libraries

```
import numpy as np
import warnings
import matplotlib.pyplot as plt
from astropy.io import fits
from astropy.wcs import WCS
from regions import Regions
import pandas as pd
import plotly.graph_objects as go

warnings.filterwarnings("ignore", category=UserWarning, append=True)
```

Redshift and Region File

```
z = 0.016268
reg_path = "data/region_file"
regions = Regions.read(reg_path, format='ds9')
```

File Group Dictionary

```
channels = {
    "ch1": [
        './data/jw01328-c1006_t014_miri_ch1-short_s3d.fits',
        './data/jw01328-c1006_t014_miri_ch1-medium_s3d.fits',
        './data/jw01328-c1006_t014_miri_ch1-long_s3d.fits'
    ],
    "ch2": [
        './data/jw01328-c1006_t014_miri_ch2-short_s3d.fits',
        './data/jw01328-c1006_t014_miri_ch2-medium_s3d.fits',
        './data/jw01328-c1006_t014_miri_ch2-long_s3d.fits'
    ],
    "ch3": [
        './data/jw01328-c1006_t014_miri_ch3-short_s3d.fits',
        './data/jw01328-c1006_t014_miri_ch3-medium_s3d.fits',
        './data/jw01328-c1006_t014_miri_ch3-long_s3d.fits'
    ],
    "ch4": [
        './data/jw01328-c1006_t014_miri_ch4-short_s3d.fits',
        './data/jw01328-c1006_t014_miri_ch4-medium_s3d.fits',
        './data/jw01328-c1006_t014_miri_ch4-long_s3d.fits'
    ]
}
```

Function to Process Region

```
def process_region(region_index, file_group, label):
    region = regions[region_index]
```

```
    spectrum_all = []
    spectrum_all_err = []
    wavelength_all = []

    for file_path in file_group:
        spectrum = []
        spectrum_err = []

        with fits.open(file_path) as hdul:
            data = hdul[1].data
            data[data < 0] = np.nan
            data_err = hdul[2].data
            header = hdul[1].header
            wcs = WCS(header)
            mask = region.to_pixel(wcs.celestial).to_mask()
            num_channels, ny, nx = data.shape

            for i in range(num_channels):
                masked_data = np.array(mask.multiply(data[i, :, :]),
dtype=float)
                masked_data_err =
np.array(mask.multiply(data_err[i, :, :]), dtype=float)
                avg_intensity = np.nanmean(masked_data)
                avg_intensity_err =
np.sqrt(np.nanmean(masked_data_err**2))
                if np.isnan(avg_intensity): avg_intensity = 0
                if np.isnan(avg_intensity_err): avg_intensity_err = 0
                spectrum.append(avg_intensity)
                spectrum_err.append(avg_intensity_err)

            crval3 = header['CRVAL3']
            cdelt3 = header['CDELT3']
            crpix3 = header['CRPIX3']
            wavelength = (np.arange(num_channels) - (crpix3 - 1)) *
cdelt3 + crval3
            wavelength /= (1 + z)

            wavelength_all.extend(wavelength)
            spectrum_all.extend(spectrum)
            spectrum_all_err.extend(spectrum_err)

    df = pd.DataFrame({
        'Wavelength_microns': wavelength_all,
        'Intensity_MJy_sr': spectrum_all,
        'Uncertainty': spectrum_all_err
    })
    df.to_csv(f'extracted_spectrum_{label}.csv', index=False)

    plt.figure(figsize=(15, 8))
    plt.errorbar(wavelength_all, spectrum_all, yerr=spectrum_all_err,
```

```
color='blue', ecolor='black')
    plt.xlabel('Wavelength (microns)')
    plt.ylabel('Average Intensity (MJy/sr)')
    plt.grid(True)
    plt.title(f'NGC 7469 Spectrum - {label}')
    plt.savefig(f'spectrum_plot_{label}.png', dpi=300)
    plt.show()

    fig = go.Figure(layout=dict(width=800, height=500,
template='plotly_white'))
    fig.add_trace(go.Scatter(
        x=wavelength_all,
        y=spectrum_all,
        mode='lines',
        line=dict(color='#1f77b4', width=1.5),
        name='Spectrum'
    ))

    spectrum_all = np.array(spectrum_all)
    spectrum_all_err = np.array(spectrum_all_err)
    wavelength_all = np.array(wavelength_all)

    fig.add_trace(go.Scatter(
        x=np.concatenate([wavelength_all, wavelength_all[::-1]]),
        y=np.concatenate([spectrum_all + spectrum_all_err,
(spectrum_all - spectrum_all_err)[::-1]]),
        fill='toself',
        fillcolor='rgba(31, 119, 180, 0.2)',
        line=dict(color='rgba(255,255,255,0)'),
        hoverinfo='skip',
        name='Uncertainty'
    ))

    features = {
        'PAHs': {'PAH 7.7': 7.7, 'PAH 8.6': 8.6, 'PAH 11.3': 11.3},
        'Neon': {'[Ne VI]': 7.65},
        'Other': {'[Ar III]': 8.991, '[S IV]': 10.51},
        'H₂': {'S(3)': 9.66, 'S(4)': 8.03}
    }

    colors = {
        'PAHs': '#FF7F0E',
        'Neon': '#D62728',
        'Other': '#9467BD',
        'H₂': '#8C564B'
    }

    for category, lines in features.items():
        for name, wl in lines.items():
            fig.add_vline(
```

```
                x=wl,
                line=dict(color=colors[category], width=1.5,
dash='dot'),
                annotation=dict(text=name, yanchor='bottom',
font=dict(size=10, color=colors[category]), yshift=10)
            )

    for wl in [7.7, 8.6, 11.3]:
        fig.add_vrect(x0=wl-0.15, x1=wl+0.15,
fillcolor=colors['PAHs'], opacity=0.1, line_width=0)

    fig.update_layout(
        title=f'<b>NGC 7469 JWST/MIRI Spectrum - {label}</b>',
        xaxis_title='<b>Wavelength (μm)</b>',
        yaxis_title='<b>Intensity (MJy/sr)</b>',
        hovermode='x unified',
        margin=dict(l=50, r=50, b=50, t=80),
    )

    fig.write_html(f'interactive_spectrum_{label}.html')
    fig.show()
```

Run for Region 0 and Region 1, Per Channel

```
for ch, files in channels.items():
    process_region(0, files, f'region0_{ch}')
    process_region(1, files, f'region1_{ch}')
```

```
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to
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Set DATE-AVG to '2022-07-04T03:54:53.948' from MJD-AVG.
Set DATE-END to '2022-07-04T04:01:02.328' from MJD-END'.
[astropy.wcs.wcs]
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```

```
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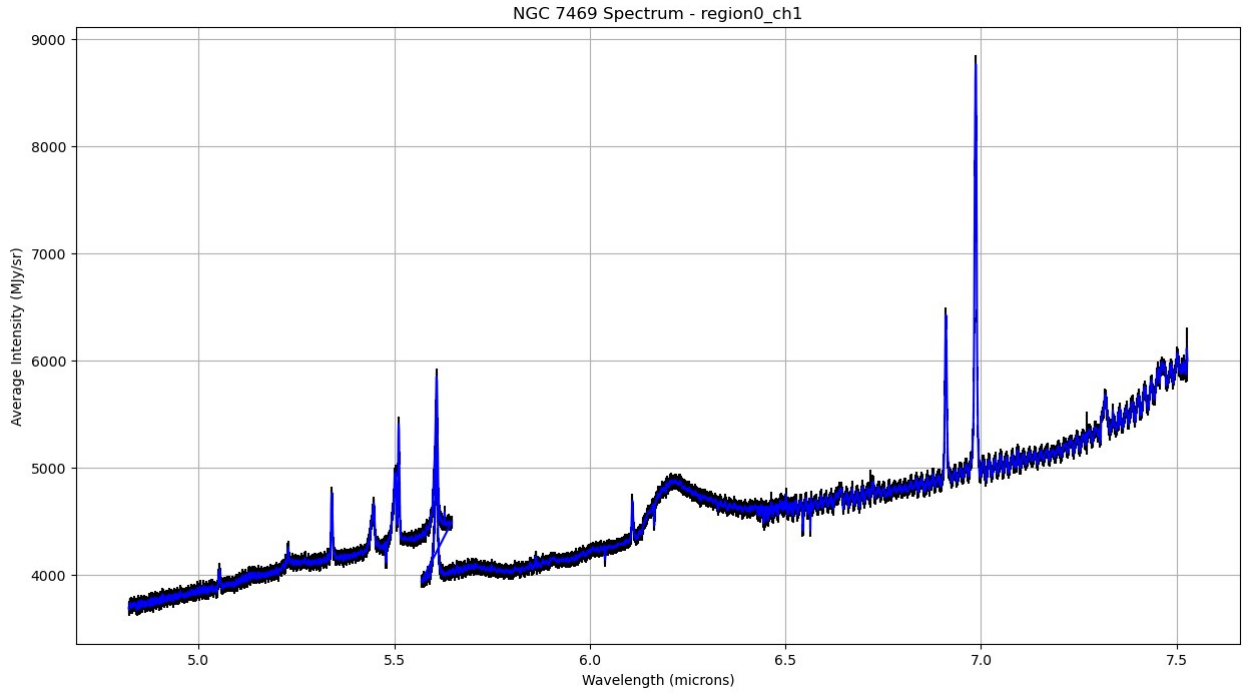

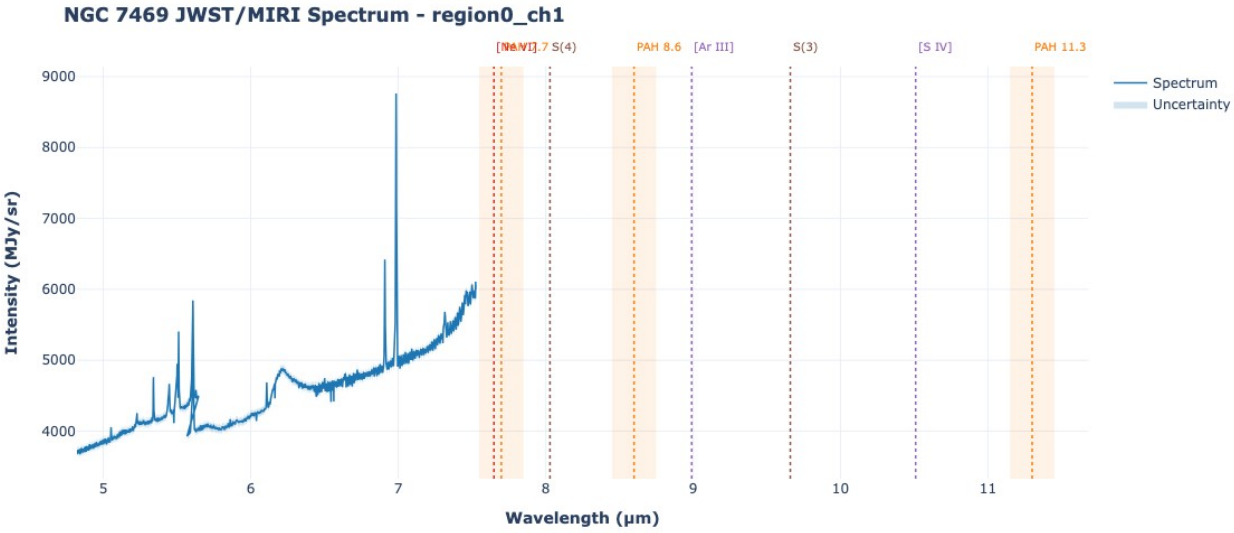


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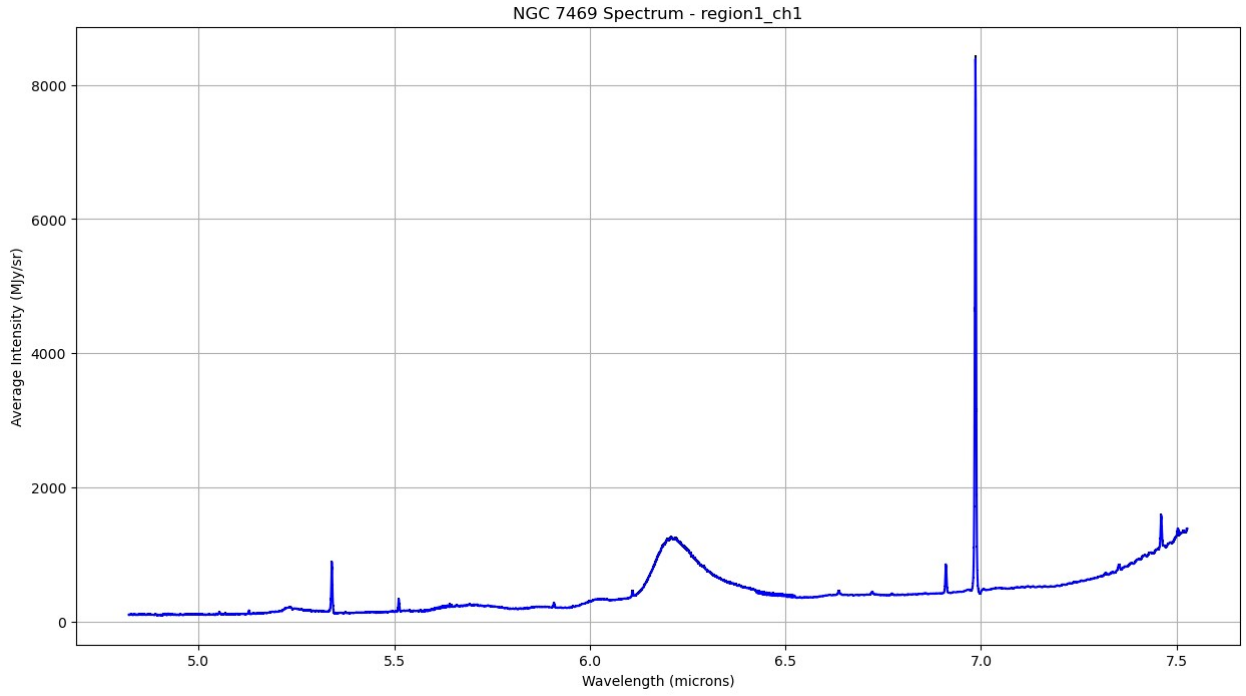

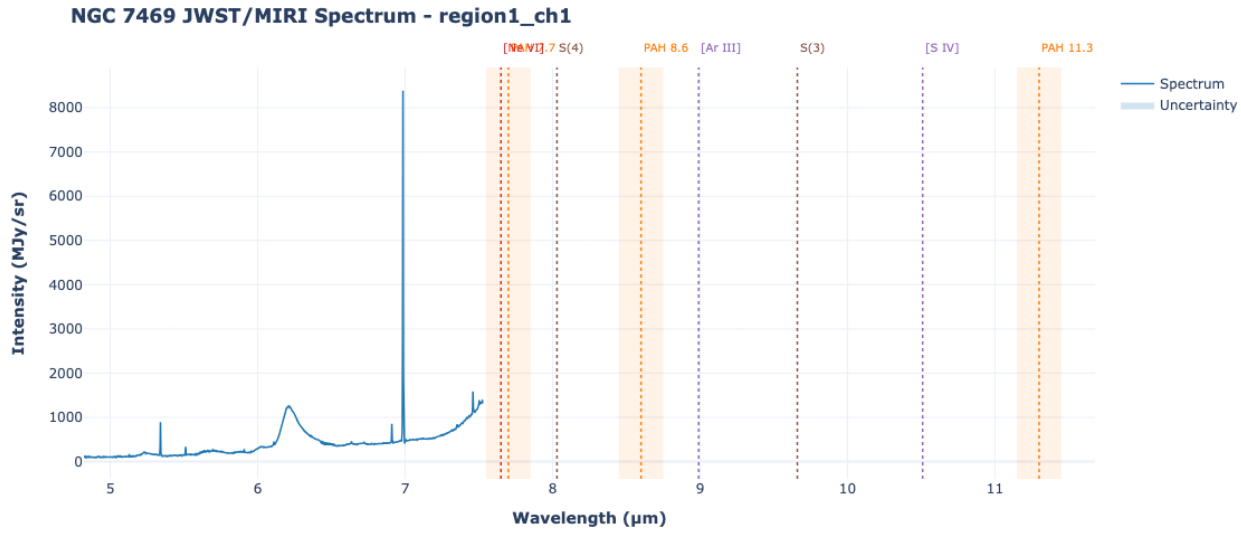


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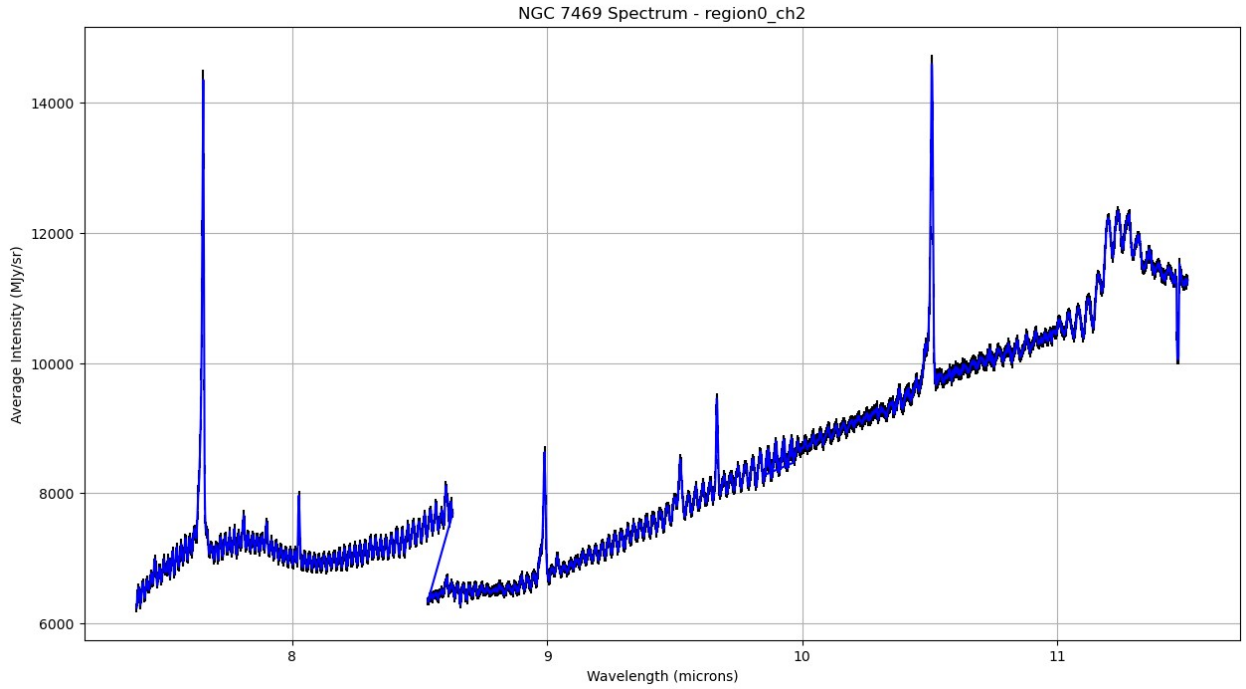

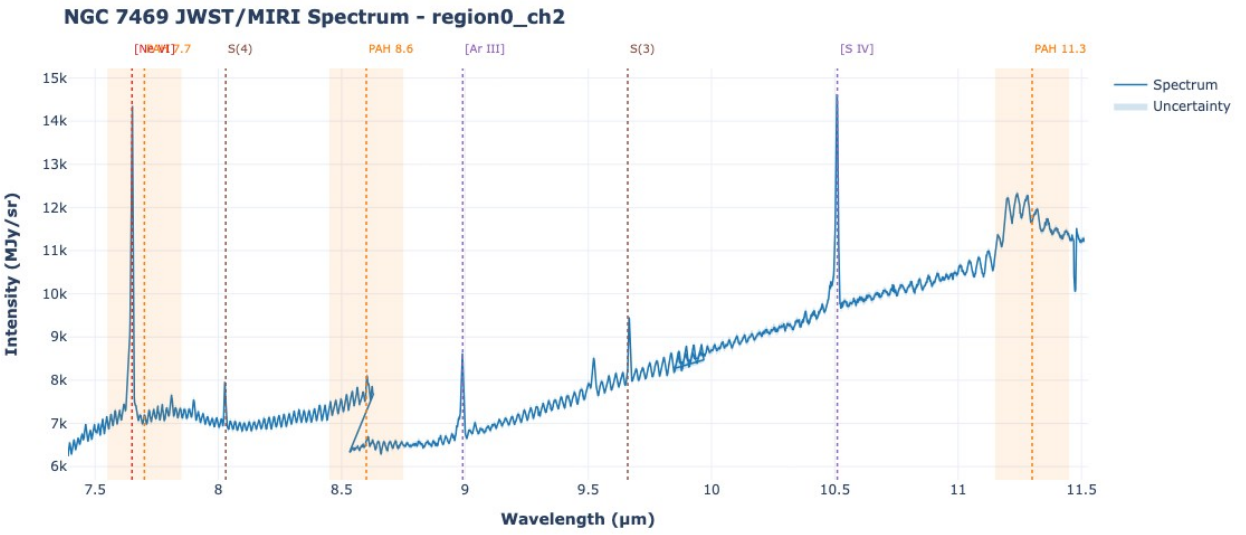


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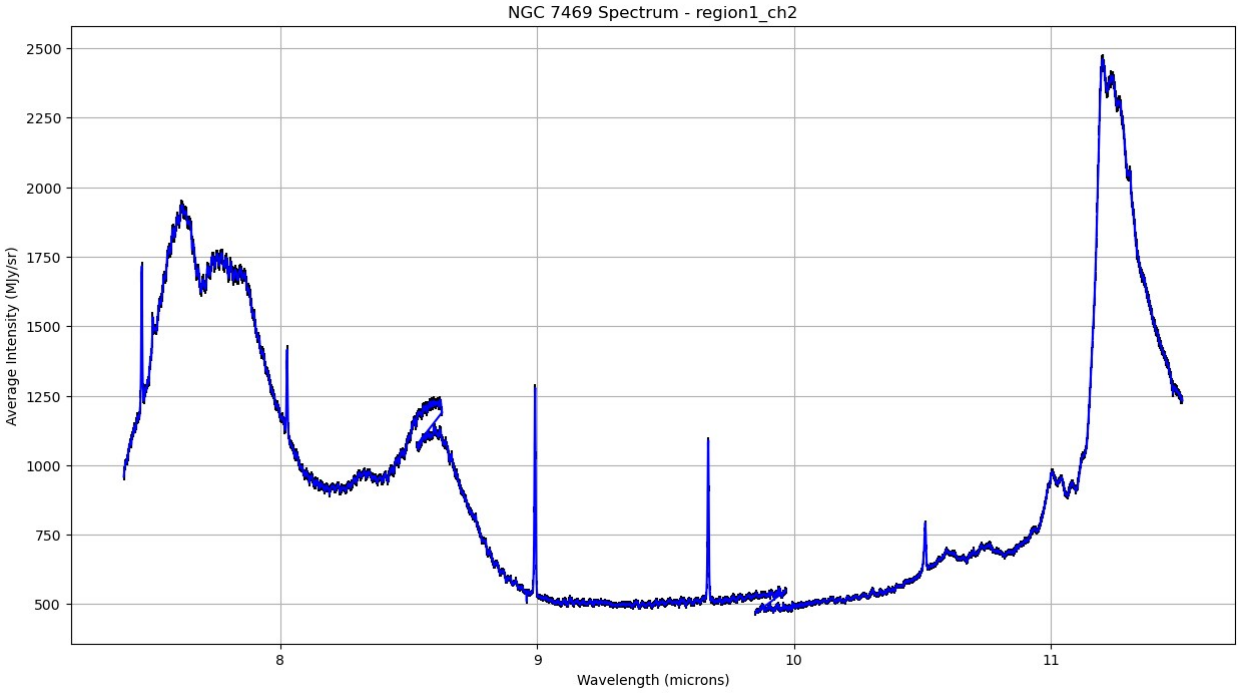

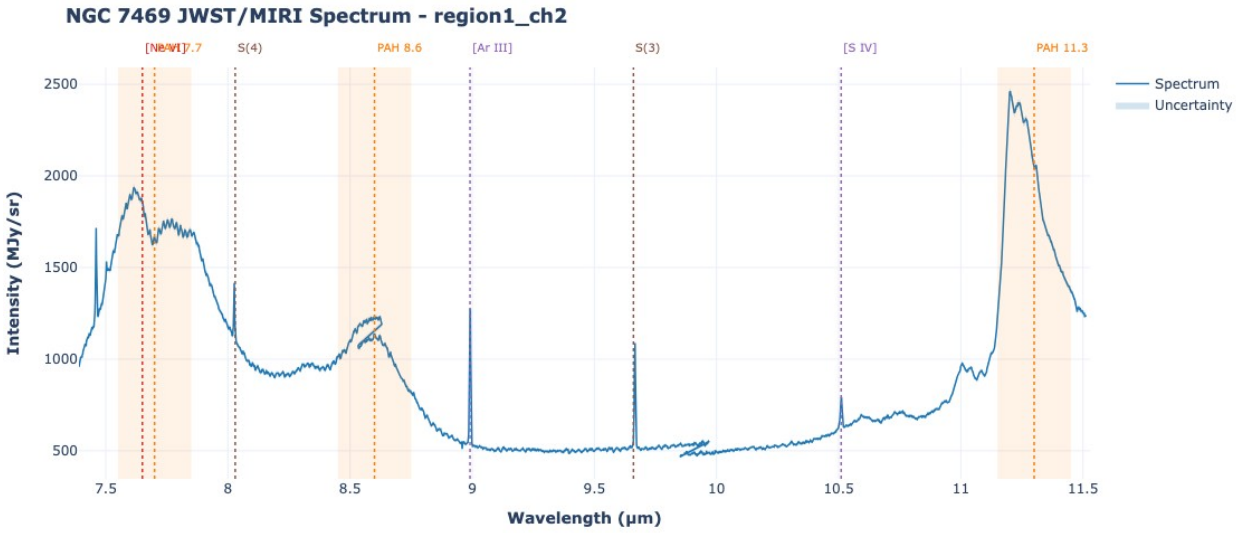


```
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to
'2022-07-04T03:48:43.551' from MJD-BEG.
Set DATE-AVG to '2022-07-04T03:54:53.308' from MJD-AVG.
Set DATE-END to '2022-07-04T04:01:01.688' from MJD-END'.
[astropy.wcs.wcs]
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Set OBSGEO-B to   -38.282938 from OBSGEO-[XYZ].
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WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to
'2022-07-04T04:05:30.910' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:11:30.971' from MJD-AVG.
Set DATE-END to '2022-07-04T04:17:32.407' from MJD-END'.
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WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to
'2022-07-04T04:22:23.837' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:28:21.114' from MJD-AVG.
Set DATE-END to '2022-07-04T04:34:17.014' from MJD-END'.
[astropy.wcs.wcs]
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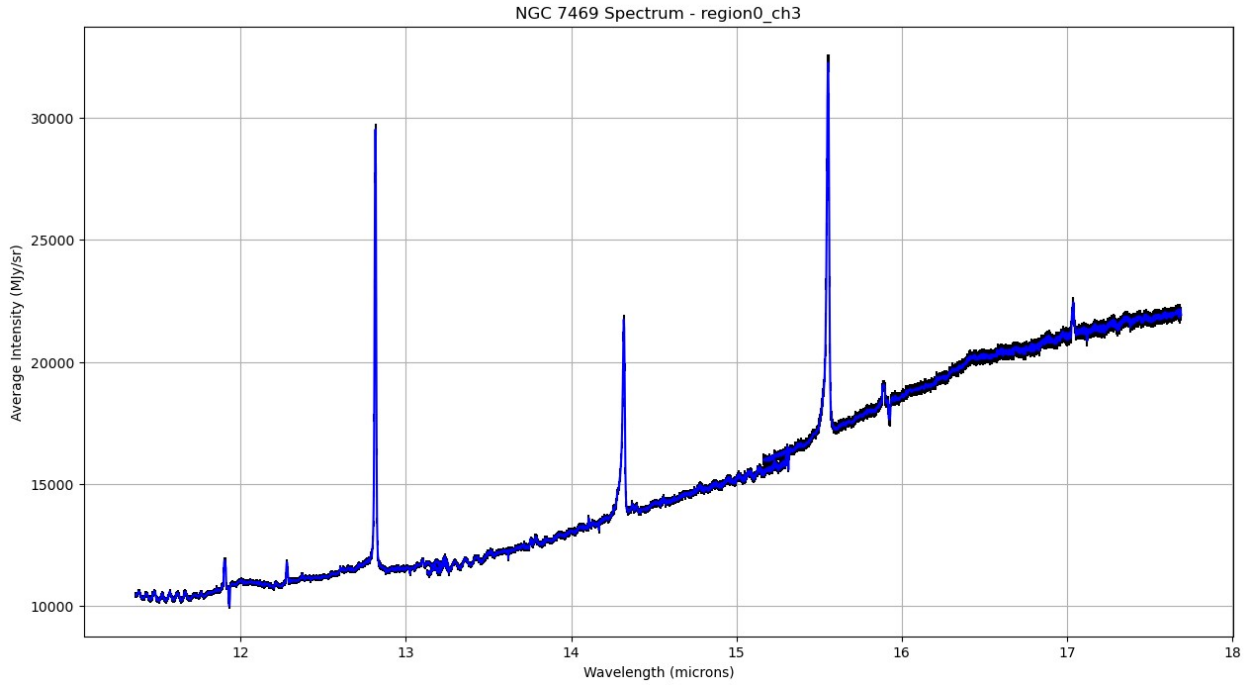

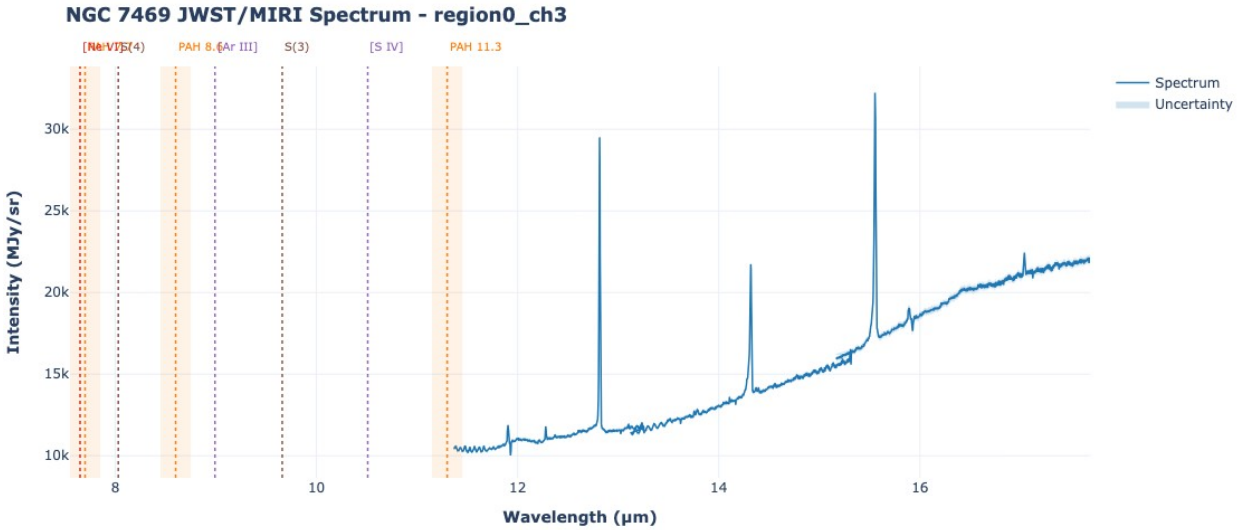


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Set DATE-END to '2022-07-04T04:34:17.014' from MJD-END'.
[astropy.wcs.wcs]
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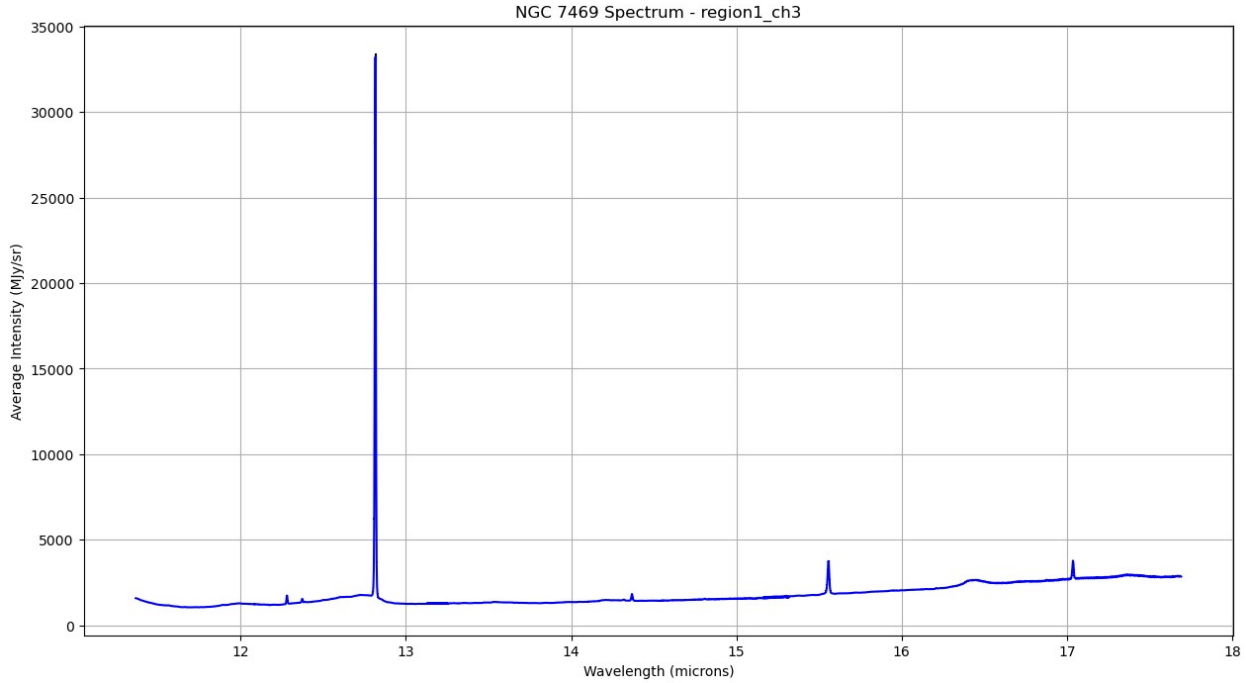

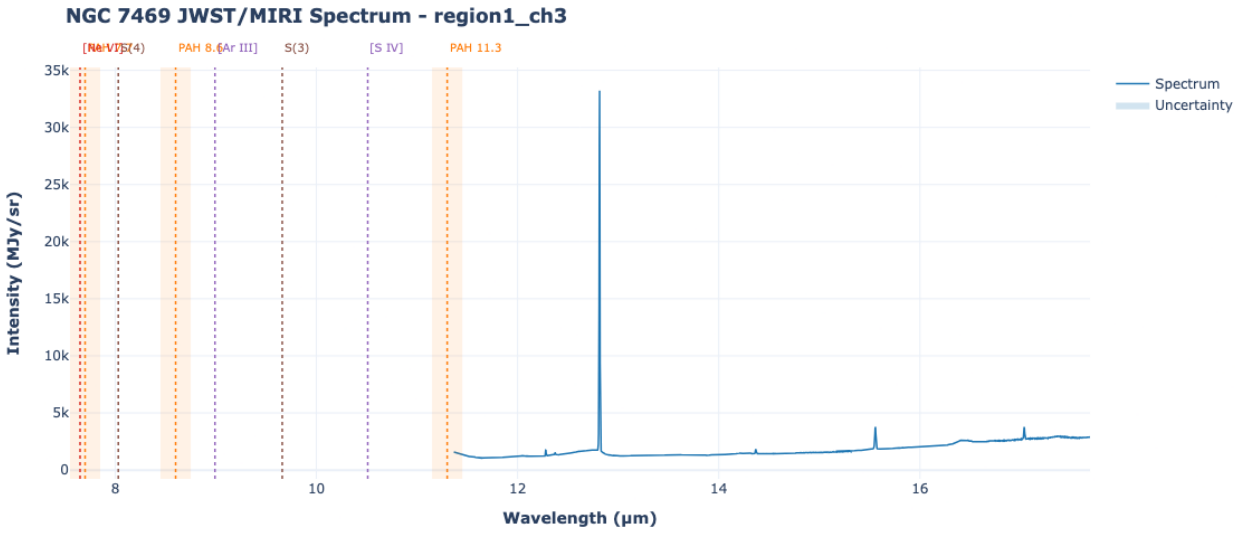


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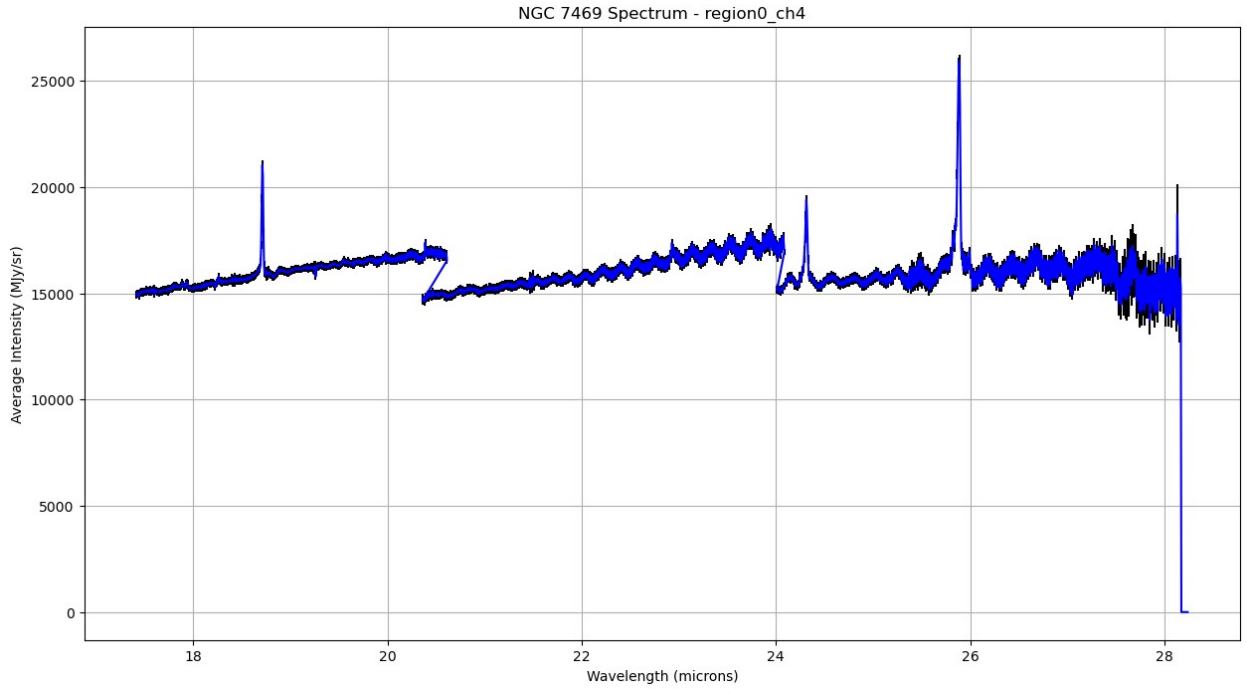
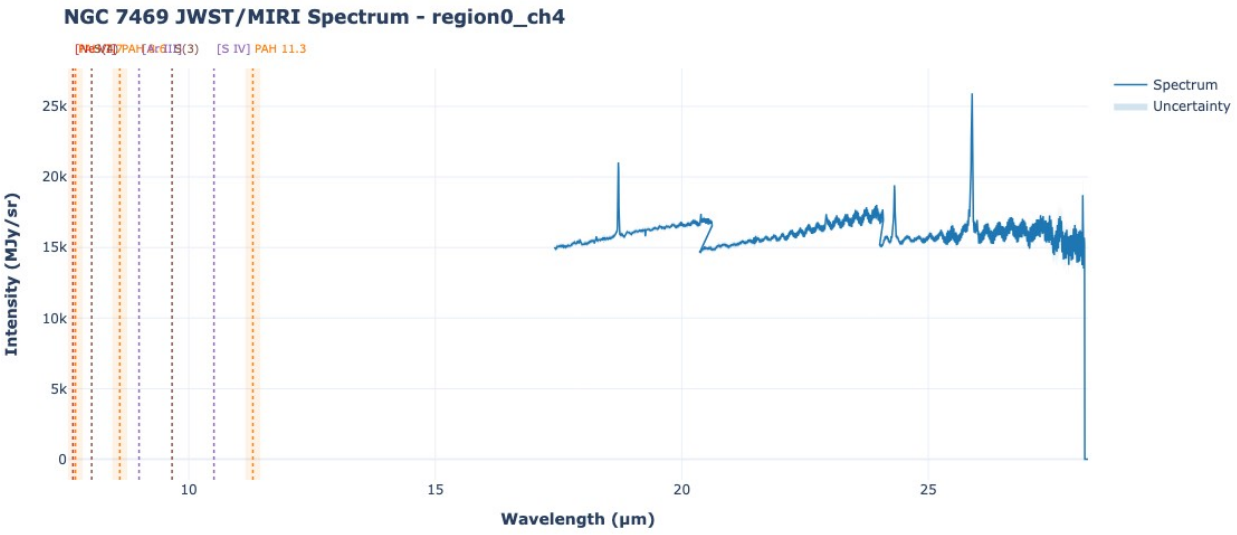
'2022-07-04T04:05:30.910' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:11:30.971' from MJD-AVG.
Set DATE-END to '2022-07-04T04:17:32.407' from MJD-END'.
[astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to
-72.557469 from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283458 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737461174.508 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to
'2022-07-04T04:22:23.837' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:28:21.114' from MJD-AVG.
Set DATE-END to '2022-07-04T04:34:17.014' from MJD-END'.
[astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to
-72.555798 from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283980 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737476710.042 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
```



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WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to
'2022-07-04T03:48:43.551' from MJD-BEG.
Set DATE-AVG to '2022-07-04T03:54:53.308' from MJD-AVG.
Set DATE-END to '2022-07-04T04:01:01.688' from MJD-END'.
[astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to
-72.559130 from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.282938 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737445726.821 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to
'2022-07-04T04:05:30.910' from MJD-BEG.
```
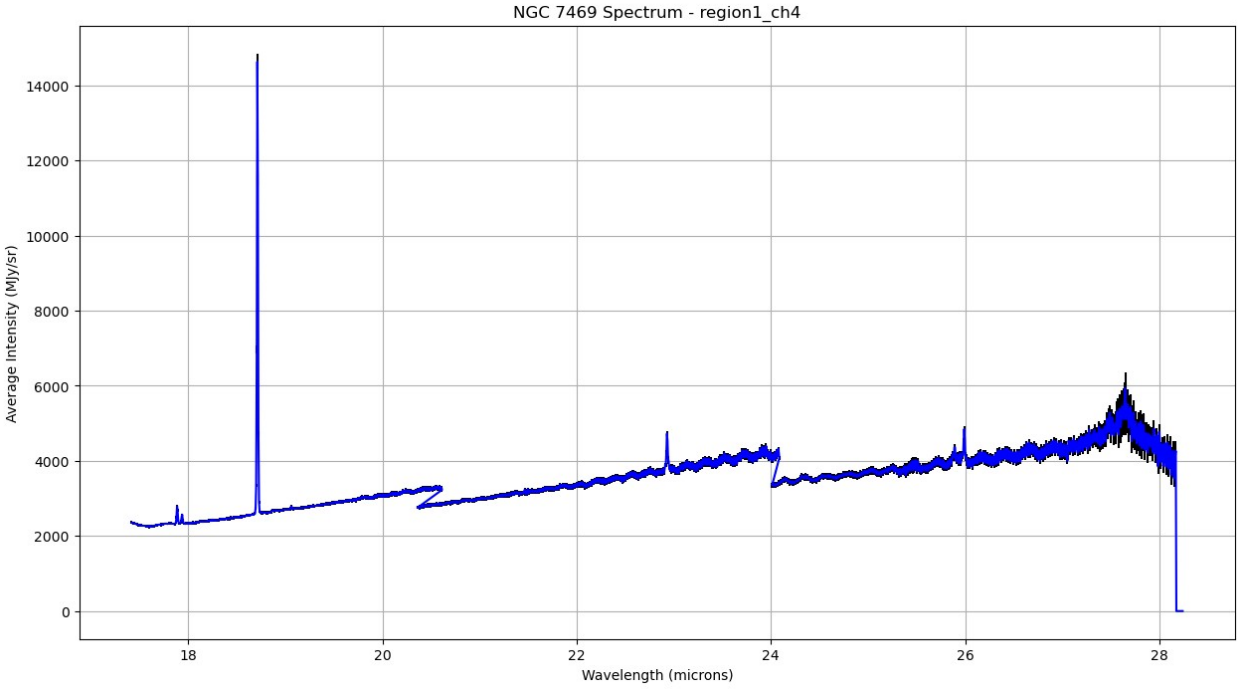
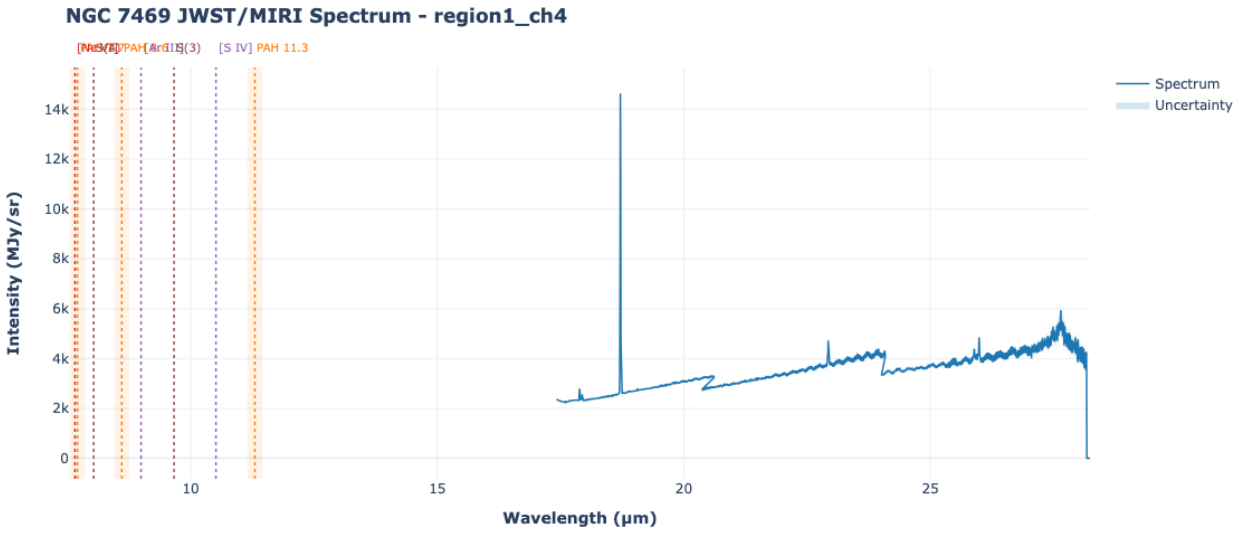

```
Set DATE-AVG to '2022-07-04T04:11:30.971' from MJD-AVG.
Set DATE-END to '2022-07-04T04:17:32.407' from MJD-END'.
[astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to
-72.557469 from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283458 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737461174.508 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to
'2022-07-04T04:22:23.837' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:28:21.114' from MJD-AVG.
Set DATE-END to '2022-07-04T04:34:17.014' from MJD-END'.
[astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to
-72.555798 from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283980 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737476710.042 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
```





Run for All Channels Combined