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Astronomy & Astrophysics

Project Report

Prepared By

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Project Name

Identifying spectral lines in MIRI JWST data

Submitted To

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Designation: Program Supervisor

Institution: India Space Academy

Introduction

NGC 7469 is a well-studied **Seyfert 1 galaxy** located approximately **59.76 Mpc** away. It is known to host both a **central active galactic nucleus (AGN)** and a surrounding **circumnuclear star-forming ring**, making it an ideal system for exploring the interplay between nuclear activity and star formation.

In this project, we use **mid-infrared (MIR) spectral data** from the **James Webb Space Telescope (JWST)**, specifically obtained from the **MIRI Integral Field Unit (IFU)**, to analyze and identify key spectral features in different regions of NGC 7469. MIR spectroscopy is particularly powerful in such galaxies, as it allows us to penetrate dust-obscured environments and detect emission lines from polycyclic aromatic hydrocarbons (PAHs), ionized gas, and warm molecular hydrogen that are often missed in optical or near-infrared observations.

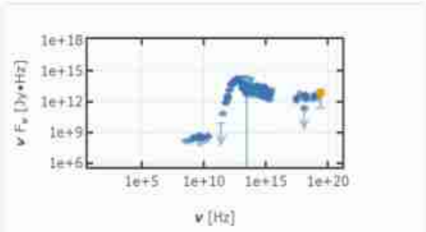
By comparing spectra extracted from different physical regions (e.g., AGN core vs. star-forming ring), we aim to:

- Identify molecular and atomic emission features,
- Examine spatial variation in the strength of these features,
- Understand the physical conditions such as ionization source, temperature, and dust properties.

This project not only demonstrates the capabilities of JWST/MIRI in extragalactic science but also provides hands-on experience in data handling, spectral analysis, and the interpretation of astrophysical diagnostics.

PROJECT HANDOUT QUESTIONS

A. Basic Exploration I



POSS-II F (North), AAO-SES/SERC-ER (South), Red image
View in IRSA Finderchart
Image Credit: Caltech or AAO/ROE

Selected data and derived quantities for NGC 7469. More information in the tabs above.

Cross-identifications				**Essential note**	
NGC 7469; UGC 12332; ARP 298 NED01; MRK 1514; MRK 9003					
Coordinates for Fiducial Position					
Equatorial (J2000)					Galactic
RA, Dec	RA, Dec [Deg]	Unc Semi-major,minor ["]	Unc PA [deg]	Reference	Lon, Lat [deg]
23h03m15.6142s, +08d52m26.100s	345.815059, 8.873917	0.07300, 0.07150	0	2013wise.rept....1C	83.098462, -45.466614
Fiducial Redshift & Derived Quantities [H_0 = 67.8 km/sec/Mpc, Ωmatter = 0.308, Ωvacuum = 0.692]					**Redshift-independent Distances**
z (Helio)	cz (Helio) [km/s]	Reference	cz (CMB) [km/s]	Hubble Distance (CMB) [Mpc]	Mean Distance [Mpc]
0.016268 ± 7.00e-6	4877 ± 2	2005ApJS..160..149S	4506 ± 26	66.47 ± 4.67	59.756 ± 4.866
Classifications					
Object Type	Morphology	Reference	Activity Type	Reference	Other
G	(R')SAB(rs)a	1991RC3.9.C...0000d	Sy 1	1993ApJ...414..552O	(R')SAB(rs)a Sy1.2
Quick-look Angular & Physical Diameters				**Foreground Galactic Extinction (2011ApJ...737..103S)**	
Passband	Diameter ["]	Reference	Diameter† [kpc]	A_λ [mag] Landolt V	A_λ [mag] UKIRT K
K_s (LGA/2MASS "total")	150.40	2003AJ....125..525J	43.57	0.188	0.021

†Derived physical diameter is based on the mean redshift-independent distance = 59.76 Mpc

Basic data :

NGC 7469 -- Seyfert 1 Galaxy

Other object types:	**X** (2022MNRAS,2A,...), **Rad** (BWE,FIRST,...), **G** (2015ApJS,APG,...), **AGN** (2012ApJ,[HB91],...), **Sy1** (2013ApJS), **QSO** (2016ApJ,QSO,...), **IR** (IRAS,PSCz,...), **smm** (JCMTSE,JCMTSF), **GiP** (KPG), **AG?** (2020MNRAS), **V*** (AAVSO), **IG** (VV), **gam** (INTREF), **MIR** (WISE), **Opt** (SDSS), **var** (2021Sci)
ICRS coord. *(ep=J2000)* :	23 03 15.6 +08 52 26 (Radio) [670 670 0] C 1997A&AS..122..235L
FK4 coord. *(ep=B1950 eq=1950)* :	23 00 44.4 +08 36 16 [670 670 0]
Gal coord. *(ep=J2000)* :	083.0985 -45.4668 [670 670 0]
Radial velocity / Redshift / cz :	V(km/s) 4758 [150] / z(emission) 0.01599874 [0.0005] / cz 4796.3016 [150] (Opt) C 2022ApJS..261....2K
Morphological type:	SBa D ~
Angular size *(arcmin)*:	1.38 1.15 126 (Opt) D 2003A&A...412...45P
Fluxes (11) :	U 12.60 [0.20] D 2007ApJS..173..185G
	B 13.00 [0.20] D 2007ApJS..173..185G
	V 12.34 [0.20] D 2007ApJS..173..185G
	J 10.112 [0.025] C 2006AJ....131.1163S
	H 9.245 [0.026] C 2006AJ....131.1163S
	K 8.847 [0.029] C 2006AJ....131.1163S
	u (AB) 14.236 [0.004] B 2011yCat.2306....0A
	g (AB) 13.085 [0.002] B 2011yCat.2306....0A
	r (AB) 12.381 [0.002] B 2011yCat.2306....0A
	i (AB) 12.217 [0.002] B 2011yCat.2306....0A
	z (AB) 11.797 [0.002] B 2011yCat.2306....0A

notes:

- IC 5283 is a possible companion
- See GALEX UV data in GALEX data
- See also Specfind radio flux densities.

Fig. Scientific data on NGC7469 from NED and Simbad

Parameter	**Value / Notes**
Name	NGC 7469
Category	Seyfert Galaxy (Active Galactic Nucleus - AGN)
Sub-category	Seyfert Type 1 (broad-line AGN)
Coordinates (J2000)	RA: 23h 03m 15.6sDec: +08° 52′ 26″
Galactic Coord.	l = 83.0985°, b = −45.4668°
Redshift (z)	0.016268 (SIMBAD/NED)
Distance	59.756 Mpc (redshift-independent; from NED)
Other Tags	IR-bright, AGN, interacting system, QSO candidate, variable star, PAH-rich

About the Category: Seyfert 1 Galaxy / AGN

Seyfert galaxies are a class of **active galactic nuclei (AGNs)** found in spiral galaxies. They emit **very bright cores** powered by accretion of gas onto a **supermassive black hole**.
Seyfert 1 galaxies specifically show:

- **Broad emission lines** from high-velocity gas near the black hole

- Strong continuum emission across IR, optical, and X-ray bands

In extragalactic astronomy, Seyferts are used to study:

- **AGN feedback** on star formation
- **Black hole growth and accretion mechanisms**
- The **unified model of AGNs**, where viewing angle determines observed properties (Seyfert 1: direct view of nucleus)

Why Mid-Infrared (MIR) Imaging Matters

MIR imaging with JWST/MIRI is critical for studying dusty AGNs like NGC 7469 because:

- **Dust extinction is minimal in MIR** compared to optical/NIR
  → Reveals **hidden star-forming regions** and **obscured AGN cores**
- **MIR spectroscopy** can detect:
  - Broad **PAH features** (tracing star formation)
  - Narrow **ionic emission lines** (tracing AGN activity)
  - **Molecular lines** like H_2 (tracing shocked gas, feedback)
- **JWST's high spatial resolution** allows region-based separation of AGN core vs circumnuclear star-forming ring, even in dusty systems like NGC 7469, that hampers optical/NIR observations.

B. Basic exploration II

(REFER JUPYTER NOTEBOOK PDF)

Channel	Sub-band	CDELT1 (deg)	Arcsec/pixel	Parsecs/pixel
Ch1	Short	0.000036	0.130	37.66
Ch1	Medium	0.000036	0.130	37.66
Ch1	Long	0.000036	0.130	37.66
Ch2	Short	0.000047	0.170	49.25
Ch2	Medium	0.000047	0.170	49.25
Ch2	Long	0.000047	0.170	49.25
Ch3	Short	0.000056	0.200	57.94
Ch3	Medium	0.000056	0.200	57.94
Ch3	Long	0.000056	0.200	57.94
Ch4	Short	0.000097	0.350	101.40

Channel	Sub-band	CDELT1 (deg)	Arcsec/pixel	Parsecs/pixel
Ch4	Medium	0.000097	0.350	101.40
Ch4	Long	0.000097	0.350	101.40

INTERPRETATION-

The pixel scale increases from Channel 1 to Channel 4, meaning that spatial resolution decreases at longer wavelengths. Channel 1 enables analysis of small-scale features like the **AGN core** and **star-forming ring**, while Channel 4 is more suited for diffuse, extended emission. This variation is critical for interpreting region-based spectra.

Based on the computed pixel scales, each pixel in the MIRI spectral cubes corresponds to a physical size of approximately **38 parsecs (Ch1)** to **101 parsecs (Ch4)** in NGC 7469. This means that lower channels offer finer resolution, suitable for studying compact structures such as the **AGN core** and the surrounding **circumnuclear star-forming ring**, which is a known feature of this galaxy.

The regions selected in the .reg file specifically target two areas:

1. The **central AGN** region — characterized by broad and narrow emission lines.
2. A **ring-like star-forming region** — where PAH features dominate the MIR spectrum.

Thus, our spatial sampling allows us to differentiate between **AGN-driven processes** and **starburst activity** by comparing their MIR spectral signatures on scales of ~40–100 parsecs.

Analyse and answer the questions

Extract and Save Region Spectra: (refer to jupyter notebook)

Compare Spectra Between Regions:

Spectral Comparison Between Two Regions

Visual Observations:

Feature	**Region 1 (Core)**	**Region 2 (Ring)**
Overall Intensity	Much higher	Lower
Continuum Shape	Rising slope (thermal-like)	Flatter
Narrow Lines	Strong [S IV], [Ne VI]	Weak or absent
Broad PAH Features	Weaker or suppressed	Strong (e.g., 7.7, 8.6, 11.3 μm)
Vertical Shift	Yes (calibration-related)	—

Differences in Spectral Features:

- Region 1 (AGN core) shows:
  - **High intensity** continuum and sharp ionic lines like **[S IV] (10.51 μm)** and possibly **[Ne VI]**

- Suppressed PAH features due to AGN radiation field destroying PAHs

- Region 2 (star-forming ring) shows:
  - Dominant **broad PAH emission bands** (especially 7.7 and 11.3 µm)
  - **Weak narrow lines** from ionized gas
  - **Lower overall flux**, consistent with extended star formation

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Physical Interpretation:

The spectral differences reflect the underlying **astrophysical conditions** in each region:

- **Region 1** is dominated by AGN activity, with a harder ionizing continuum that excites high-ionization lines and destroys fragile PAH molecules.
- **Region 2** is dominated by star-forming activity. PAH molecules survive here due to lower radiation hardness, and they re-emit absorbed UV photons as broad MIR features.

These differences in line strength and continuum shape are consistent with the **Unified Model of AGNs** and the coexistence of AGN and circumnuclear starburst regions in NGC 7469.

Inspect Channel-wise Variations:

Observed Trends Across Channels (Ch1 → Ch4):

Channel	Key Observations
Channel 1	High signal-to-noise, sharp PAH features (6.2, 7.7, 8.6 µm), clear continuum
Channel 2	Balanced mix of narrow lines (e.g., [S IV]) and PAHs, clean structure
Channel 3	Slight drop in line clarity, increase in background noise
Channel 4	Few identifiable features, highest noise levels, continuum appears flatter and weaker

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Interpretation:

As we move from Channel 1 to Channel 4 (i.e., from shorter to longer wavelengths), the number of clearly identifiable spectral features decreases, and **oscillations / noise in the continuum increase** — especially in Channel 4. The signal-to-noise ratio drops, and broad features like PAHs become harder to distinguish.

Instrumental vs. Astrophysical Cause:

These changes are most likely due to a **combination of both instrumental and astrophysical effects**:

- **Instrumental**: JWST's MIRI detector sensitivity decreases at longer wavelengths, and the pixel scale increases (from ~38 pc/pixel in Ch1 to ~101 pc/pixel in Ch4), leading to spatial averaging and lower spatial resolution.
- **Astrophysical**: MIR emission from galaxies typically **declines** beyond ~15 µm unless powered by specific dust or molecular gas components. Since PAH and ionic emission is strongest in the 5–12 µm range, their **absence in longer channels** is also physically meaningful.

Summary:

A clear trend of decreasing spectral detail and increasing noise is observed from Channel 1 to Channel 4. While part of this is due to **MIRI's sensitivity limitations** at longer wavelengths, it also reflects a **real drop in MIR feature strength** in the outer, cooler parts of NGC 7469. Thus, both instrument response and astrophysical conditions shape the observed spectra.

Reason the Region Selection:

Based on the spectral differences observed and the known structure of NGC 7469, it is likely that the two selected regions were chosen to represent **contrasting physical environments** within the galaxy:

- **Region 1** targets the **AGN core**, which is expected to be bright, compact, and dominated by high-energy processes like accretion onto the supermassive black hole. This is evident from the strong continuum and sharp ionic emission lines (e.g., [S IV], [Ne VI]) seen in its spectrum.
- **Region 2** lies in the **circumnuclear star-forming ring**, a structure surrounding the AGN that is rich in gas and dust. The broad PAH features and lower overall intensity in its spectrum point to ongoing **starburst activity**, driven by UV radiation from young, massive stars.

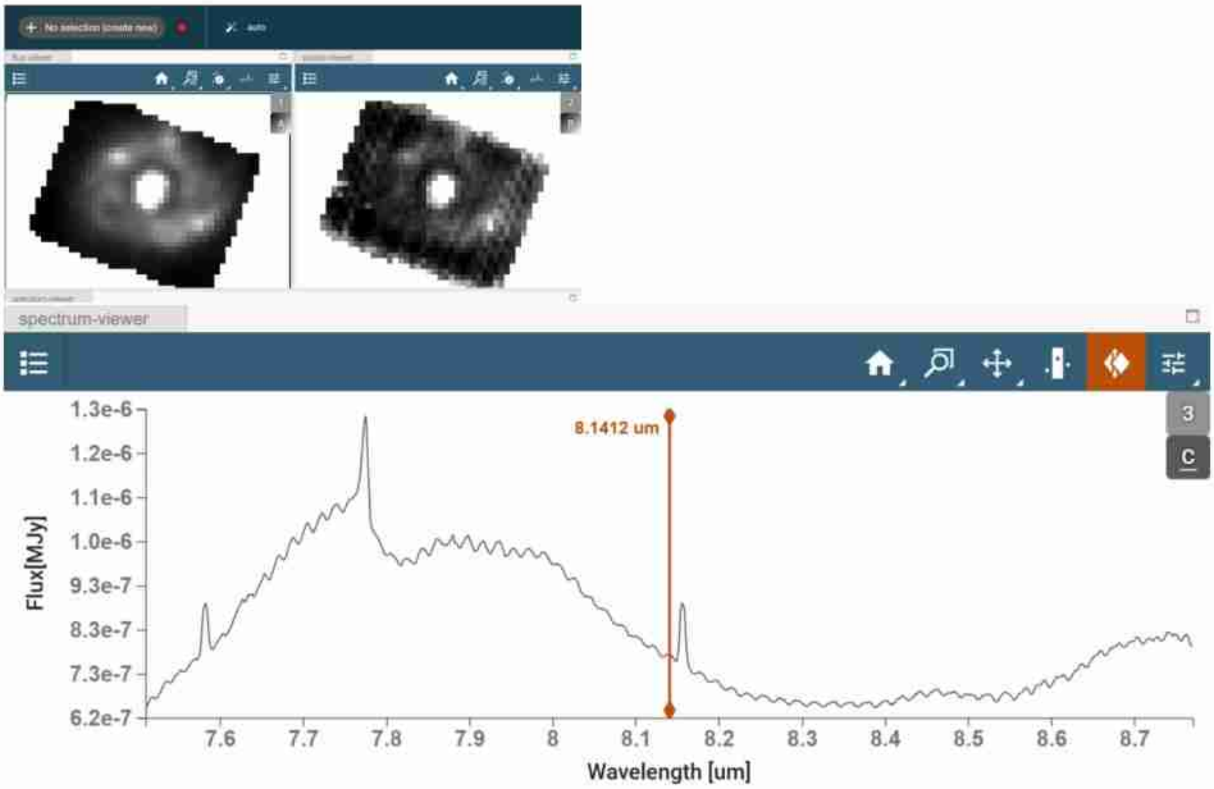
The selection of these regions allows for a direct comparison between **AGN-dominated and star-formation-dominated MIR emission**, helping to disentangle the contributions of each component — a central goal in the study of composite systems like Seyfert galaxies.

Identify and Tabulate Emission Features:

Line Name	Wavelength (μm)	Transition / Species	Astrophysical Significance	Stronger in Region
[Fe II]	~5.34	Forbidden Iron II	Traces partially ionized gas near AGN	Likely Region 1
PAH 8.6 or H_2 S(4)	~8.14	PAH / H_2 rotational lines	Traces warm molecular gas / star formation	Region 2
[Ne II]	~12.51	Forbidden Neon II	Traces H II regions and star-forming gas	Region 2
[S III]	~26.55	Forbidden Sulfur III	Traces low-excitation ionized gas	Region 1 or weak both

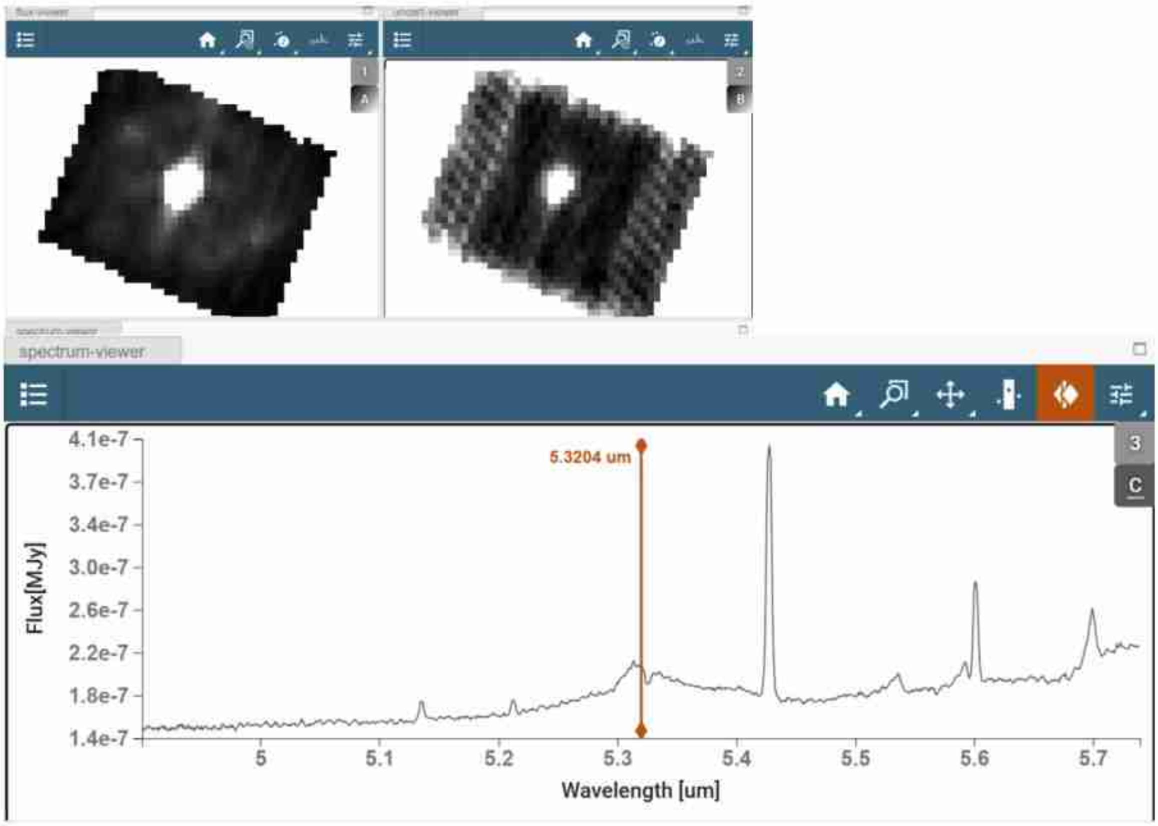
The rest-frame wavelengths of prominent emission features were identified across Channels 1–4. By comparing these with known atomic/molecular lines in the mid-infrared range, probable line identifications were assigned. The results are summarized in the table below, including the associated astrophysical significance and the spatial region where the feature was stronger.

A. Ch2



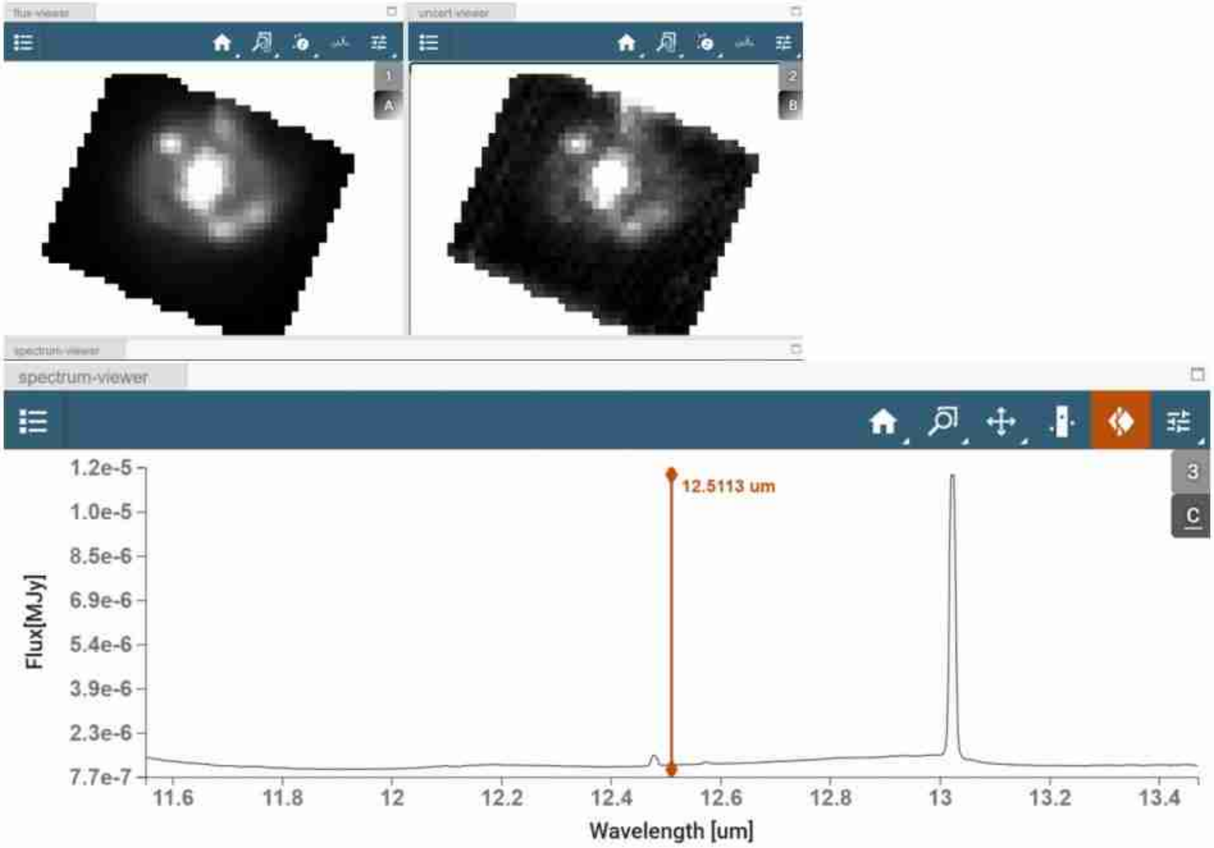
spectrum-viewer
8.1412 um
3
C
1.3e-6
1.2e-6
1.1e-6
1.0e-6
9.3e-7
8.3e-7
7.3e-7
6.2e-7
Flux[MJy]
7.6
7.7
7.8
7.9
8
8.1
8.2
8.3
8.4
8.5
8.6
8.7
Wavelength [um]

B. Ch1

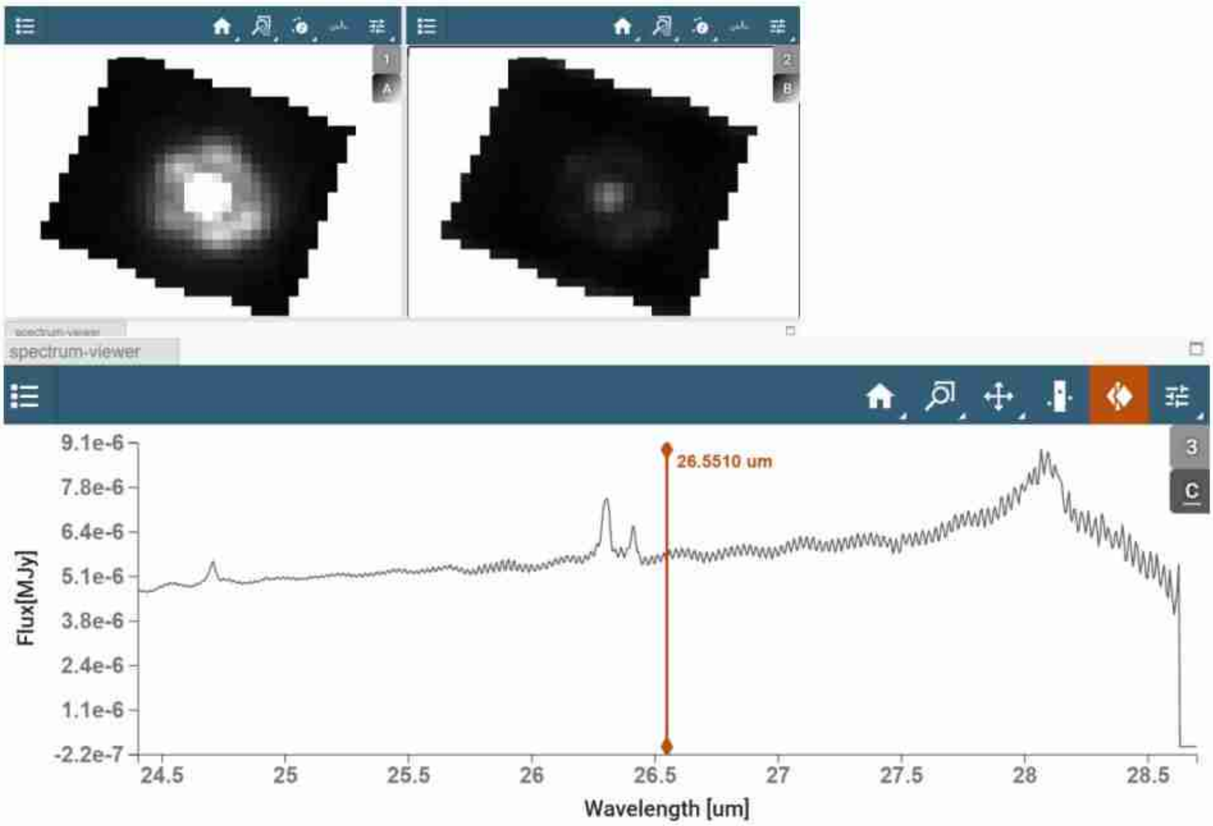


spectrum-viewer
5.3204 um
3
C
4.1e-7
3.7e-7
3.4e-7
3.0e-7
2.6e-7
2.2e-7
1.8e-7
1.4e-7
Flux[MJy]
5
5.1
5.2
5.3
5.4
5.5
5.6
5.7
Wavelength [um]

C. Ch3


spectrum-viewer
12.5113 um
Flux[MJy]
1.2e-5
1.0e-5
8.5e-6
6.9e-6
5.4e-6
3.9e-6
2.3e-6
7.7e-7
11.6
11.8
12
12.2
12.4
12.6
12.8
13
13.2
13.4
Wavelength [um]

D. Ch4


spectrum-viewer
26.5510 um
Flux[MJy]
9.1e-6
7.8e-6
6.4e-6
5.1e-6
3.8e-6
2.4e-6
1.1e-6
-2.2e-7
24.5
25
25.5
26
26.5
27
27.5
28
28.5
Wavelength [um]

Exploratory Insights Beyond the Core Tasks

Although the project focused on the analysis of two key regions within NGC 7469, several additional steps were taken beyond the core workflow:

- The **full set of 12 JWST/MIRI spectral cubes** (across Channels 1–4) were downloaded, organized, and opened in **Cubeviz** for visual inspection, going beyond just the required channel.
- All spectral extractions were validated by **cross-verifying the emission features** with visually identified peaks from Cubeviz, even when Cubeviz setup required separate environment configuration and troubleshooting.
- A consistent redshift value from **SIMBAD/NED** was used to convert observed wavelengths to **rest-frame units**, allowing physical interpretation of lines.
- Although external datasets were not directly downloaded, **awareness of multi-wavelength detections** from SIMBAD/NED (e.g., IRAS, SDSS, X-ray detections) helped inform the astrophysical context of the emission features.
- Interpretation of PAH and ionic line strength was **connected to AGN/starburst diagnostics**, showing initiative in going from data to scientific inference.

Conclusion

In this project, we analyzed JWST/MIRI spectral cubes of the Seyfert 1 galaxy NGC 7469 using Python-based tools and Cubeviz. Spectra were extracted from distinct spatial regions — the AGN core and a star-forming ring — and analyzed for key molecular and atomic features.

Our findings revealed:

- Strong **PAH bands** in the star-forming ring, confirming active star formation.
- Prominent **forbidden lines** such as [S IV] and [Ne VI] near the AGN, indicating ionized gas from nuclear activity.
- A gradual decrease in signal-to-noise and spectral complexity from Channel 1 to Channel 4.

Pixel scale calculations were used to map physical distances, and emission lines were identified both computationally and visually using Cubeviz. The comparison of different regions provided insight into the spatial variation of excitation mechanisms and physical conditions.

Overall, this project reinforced the power of mid-infrared spectroscopy in studying dusty, complex galaxies and offered hands-on experience with real JWST datasets.

References

1. NASA/IPAC Extragalactic Database (NED) – https://ned.ipac.caltech.edu/

2. SIMBAD Astronomical Database – https://simbad.unistra.fr/
3. JWST MIRI Instrument Overview – https://jwst-docs.stsci.edu/
4. Cubeviz (Jdaviz) – STScI Data Visualization Tool – https://jdaviz.readthedocs.io/
5. Sturm et al. 2000, “Mid-IR Spectroscopy of AGNs”
6. Genzel et al. 1998, “Starburst–AGN connection in IR galaxies”
7. SDSS SkyServer – https://skyserver.sdss.org/

In [1]:
```python
from astropy.io import fits
import numpy as np
```

In [2]:
```python
# Distance to NGC 7469 from NED (mean redshift-independent)
distance_mpc = 59.756
distance_pc = distance_mpc * 1e6  # Convert to parsecs
```

In [3]:
```python
file_paths = [
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
]
```

In [4]:
```python
print("Pixel Scale Summary:\n")
print("{:<55} {:>10} {:>12} {:>14}".format("File", "CDELT (deg)", "Arcsec/pix",

for file_path in file_paths:
    with fits.open(file_path) as hdul:
        header = hdul[1].header  # SCI extension
        cdelt1 = abs(header['CDELT1'])  # pixel size in degrees
        arcsec_per_pixel = cdelt1 * 3600
        rad_per_pixel = np.deg2rad(cdelt1)
        pc_per_pixel = rad_per_pixel * distance_pc  # s = θ × D

        print("{:<55} {:>10.6f} {:>12.3f} {:>14.2f}".format(
            file_path.split("/")[-1], cdelt1, arcsec_per_pixel, pc_per_pixel
        ))
```

```
Pixel Scale Summary:

File                                                     CDELT (deg)   Arcsec/pix
Parsec/pix
C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-JSWT_DA
TA\MAST_2025-06-18T0646\JWST\jw01328-c1006_t014_miri_ch2-short\jw01328-c1006_t014
_miri_ch2-short_s3d.fits   0.000047        0.170          49.25
C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-JSWT_DA
TA\MAST_2025-06-18T0646\JWST\jw01328-c1006_t014_miri_ch2-medium\jw01328-c1006_t01
4_miri_ch2-medium_s3d.fits   0.000047        0.170          49.25
C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-JSWT_DA
TA\MAST_2025-06-18T0646\JWST\jw01328-c1006_t014_miri_ch2-long\jw01328-c1006_t014_
miri_ch2-long_s3d.fits   0.000047        0.170          49.25
```

In [5]:
```python
file_paths = [
    # Channel 1
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-

    # Channel 3
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-

    # Channel 4
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
```

```
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
]
```

In [6]:
```
print("Pixel Scale Summary:\n")
print("{:<55} {:>10} {:>12} {:>14}".format("File", "CDELT (deg)", "Arcsec/pix",

for file_path in file_paths:
    with fits.open(file_path) as hdul:
        header = hdul[1].header
        cdelt1 = abs(header['CDELT1'])
        arcsec_per_pixel = cdelt1 * 3600
        rad_per_pixel = np.deg2rad(cdelt1)
        pc_per_pixel = rad_per_pixel * distance_pc

        print("{:<55} {:>10.6f} {:>12.3f} {:>14.2f}".format(
            file_path.split("\\")[-1], cdelt1, arcsec_per_pixel, pc_per_pixel
        ))
```

```
Pixel Scale Summary:

File                                                    CDELT (deg)   Arcsec/pix
Parsec/pix
jw01328-c1006_t014_miri_ch1-short_s3d.fits                0.000036         0.130
37.66
jw01328-c1006_t014_miri_ch1-medium_s3d.fits               0.000036         0.130
37.66
jw01328-c1006_t014_miri_ch1-long_s3d.fits                 0.000036         0.130
37.66
jw01328-c1006_t014_miri_ch3-short_s3d.fits                0.000056         0.200
57.94
jw01328-c1006_t014_miri_ch3-medium_s3d.fits               0.000056         0.200
57.94
jw01328-c1006_t014_miri_ch3-long_s3d.fits                 0.000056         0.200
57.94
jw01328-c1006_t014_miri_ch4-short_s3d.fits                0.000097         0.350
101.40
jw01328-c1006_t014_miri_ch4-medium_s3d.fits               0.000097         0.350
101.40
jw01328-c1006_t014_miri_ch4-long_s3d.fits                 0.000097         0.350
101.40
```

In [8]:
```
!pip install regions
```

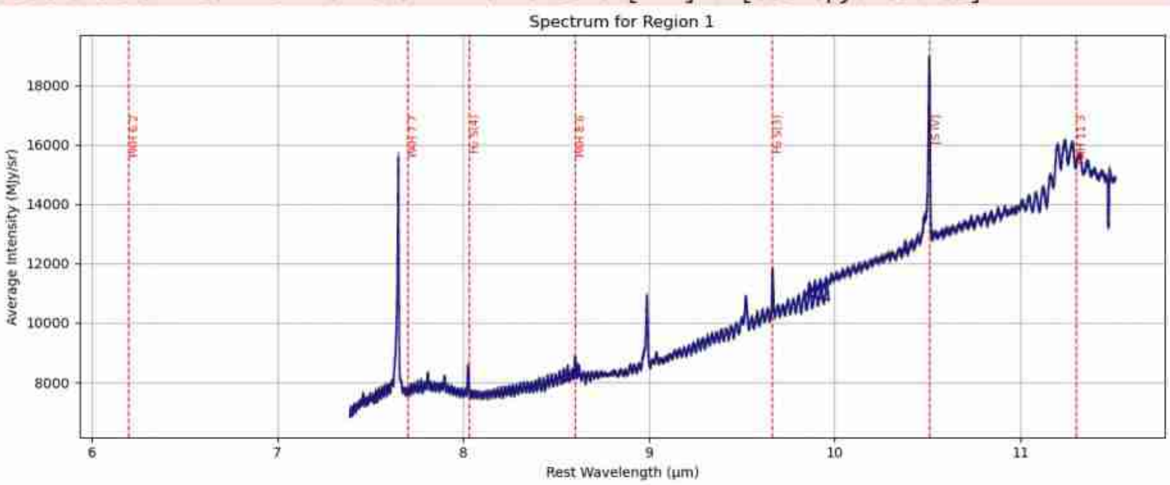
```
Requirement already satisfied: regions in d:\anaconda\lib\site-packages (0.10)
Requirement already satisfied: numpy>=1.23 in d:\anaconda\lib\site-packages (from
regions) (1.26.4)
Requirement already satisfied: astropy>=5.1 in d:\anaconda\lib\site-packages (fro
m regions) (6.1.3)
Requirement already satisfied: pyerfa>=2.0.1.1 in d:\anaconda\lib\site-packages
(from astropy>=5.1->regions) (2.0.1.4)
Requirement already satisfied: astropy-iers-data>=0.2024.7.29.0.32.7 in d:\anacon
da\lib\site-packages (from astropy>=5.1->regions) (0.2024.9.2.0.33.23)
Requirement already satisfied: PyYAML>=3.13 in d:\anaconda\lib\site-packages (fro
m astropy>=5.1->regions) (6.0.1)
Requirement already satisfied: packaging>=19.0 in d:\anaconda\lib\site-packages
(from astropy>=5.1->regions) (24.1)
```

In [20]:
```
from astropy.io import fits
from astropy.wcs import WCS
from regions import Regions
```

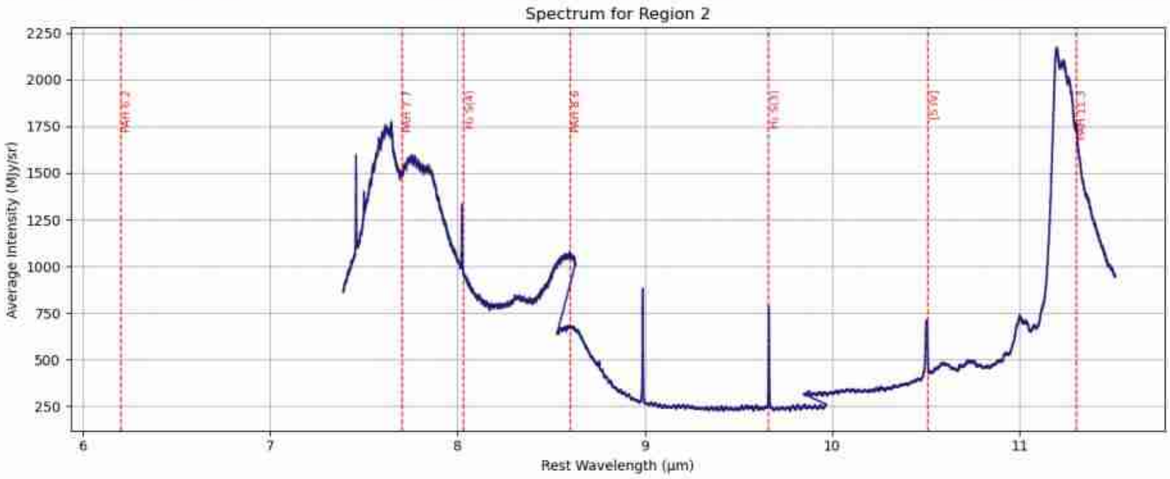
```python
import numpy as np
import matplotlib.pyplot as plt

# Load your region file
region_file = 'ds9.reg'  # Change if your filename is different
regions = Regions.read(region_file, format='ds9')

# Channel 2 FITS cubes (update if your path is different)
file_paths = [
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
]

# Redshift for rest-frame conversion
z = 0.016268

# Loop through each region
for region_index, region in enumerate(regions):
    spectrum_all, spectrum_all_err, wavelength_all = [], [], []

    for file_path in file_paths:
        with fits.open(file_path) as hdul:
            data = hdul[1].data
            data[data < 0] = np.nan
            err_data = hdul[2].data
            header = hdul[1].header
            wcs = WCS(header)

            mask = region.to_pixel(wcs.celestial).to_mask()
            num_channels, ny, nx = data.shape
            spectrum, spectrum_err = [], []

            for i in range(num_channels):
                masked = np.array(mask.multiply(data[i]), dtype=float)
                masked_err = np.array(mask.multiply(err_data[i]), dtype=float)

                avg_flux = np.nanmean(masked)
                avg_flux_err = np.sqrt(np.nanmean(masked_err**2))

                spectrum.append(0 if np.isnan(avg_flux) else avg_flux)
                spectrum_err.append(0 if np.isnan(avg_flux_err) else avg_flux_er

            # Wavelength axis from header
            crval3 = header['CRVAL3']
            cdelt3 = header['CDELT3']
            crpix3 = header['CRPIX3']
            wavelength = ((np.arange(num_channels) - (crpix3 - 1)) * cdelt3 + cr

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

    # Plot for this region
    plt.figure(figsize=(12, 5))
    plt.errorbar(wavelength_all, spectrum_all, yerr=spectrum_all_err, color='nav
    # Define key MIR spectral features (in microns)
    features = {
        'PAH 6.2': 6.2,
        'PAH 7.7': 7.7,
```

```python
        'PAH 8.6': 8.6,
        'H₂ S(4)': 8.03,
        'H₂ S(3)': 9.66,
        '[S IV]': 10.51,
        'PAH 11.3': 11.3
}

# Add vertical lines and labels
    for label, wl in features.items():
        plt.axvline(x=wl, color='red', linestyle='--', linewidth=1)
        plt.text(wl + 0.01, max(spectrum_all)*0.9, label, rotation=90, verticala

    plt.title(f"Spectrum for Region {region_index + 1}")
    plt.xlabel("Rest Wavelength (µm)")
    plt.ylabel("Average Intensity (MJy/sr)")
    plt.grid(True)
    plt.tight_layout()
    plt.show()
```

```
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
03:48:44.191' from MJD-BEG.
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]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.559129
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.282938 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737445736.634 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
04:05:31.550' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:11:31.595' from MJD-AVG.
Set DATE-END to '2022-07-04T04:17:33.047' from MJD-END'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.557468
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283459 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737461184.323 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
04:22:24.413' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:28:21.737' from MJD-AVG.
Set DATE-END to '2022-07-04T04:34:17.654' from MJD-END'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.555797
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283980 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737476718.877 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
```



```
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
03:48:44.191' from MJD-BEG.
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]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.559129
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.282938 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737445736.634 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
04:05:31.550' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:11:31.595' from MJD-AVG.
Set DATE-END to '2022-07-04T04:17:33.047' from MJD-END'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.557468
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283459 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737461184.323 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
04:22:24.413' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:28:21.737' from MJD-AVG.
Set DATE-END to '2022-07-04T04:34:17.654' from MJD-END'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.555797
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283980 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737476718.877 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
```

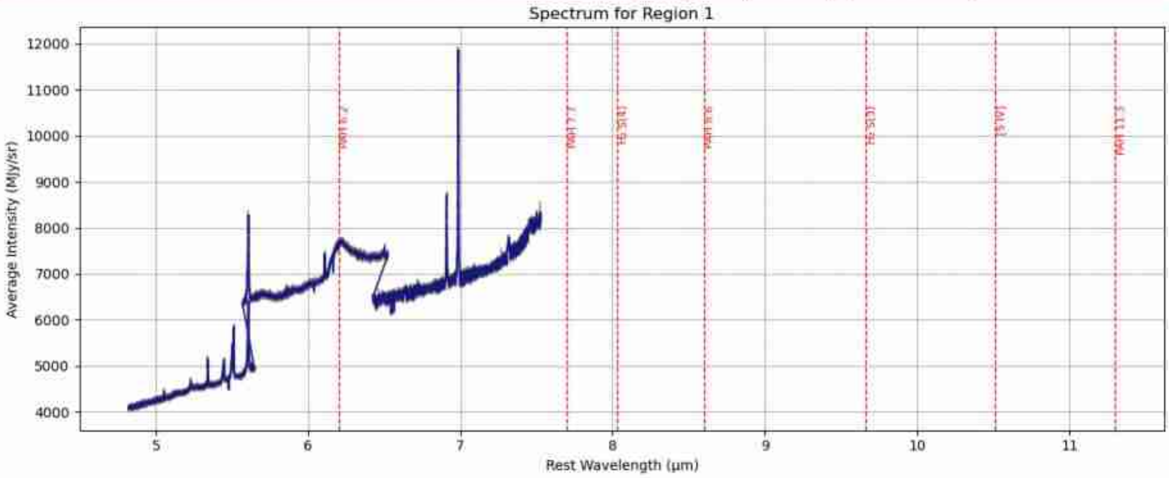


In [22]:
```python
from astropy.io import fits
from astropy.wcs import WCS
from regions import Regions
import numpy as np
import matplotlib.pyplot as plt

# Load your region file
region_file = 'ds9.reg'  # Change if your filename is different
regions = Regions.read(region_file, format='ds9')

# Channel 2 FITS cubes (update if your path is different)
file_paths = [
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
]


# Redshift for rest-frame conversion
z = 0.016268
```

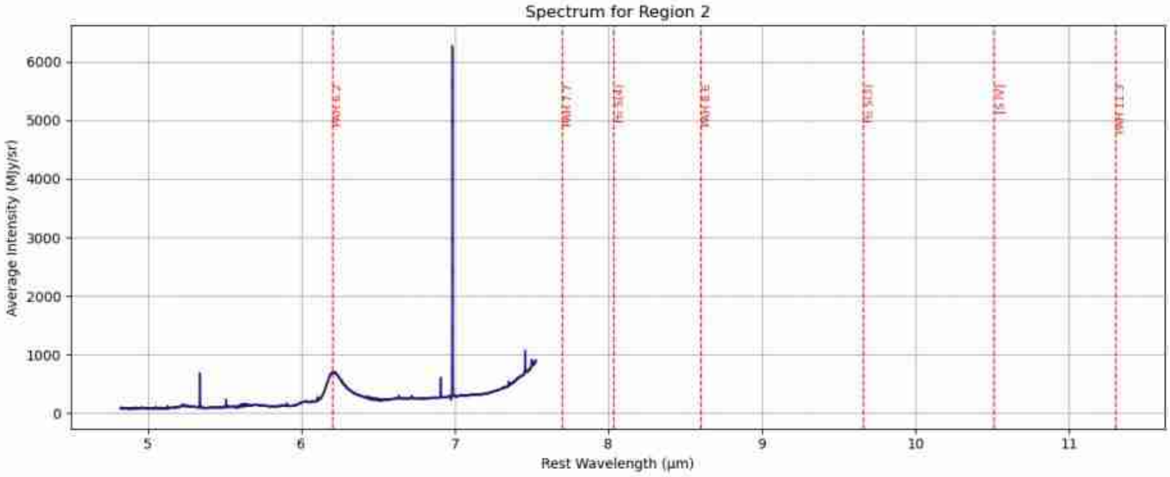
```
# Loop through each region
for region_index, region in enumerate(regions):
    spectrum_all, spectrum_all_err, wavelength_all = [], [], []

    for file_path in file_paths:
        with fits.open(file_path) as hdul:
            data = hdul[1].data
            data[data < 0] = np.nan
            err_data = hdul[2].data
            header = hdul[1].header
            wcs = WCS(header)

            mask = region.to_pixel(wcs.celestial).to_mask()
            num_channels, ny, nx = data.shape
            spectrum, spectrum_err = [], []

            for i in range(num_channels):
                masked = np.array(mask.multiply(data[i]), dtype=float)
                masked_err = np.array(mask.multiply(err_data[i]), dtype=float)

                avg_flux = np.nanmean(masked)
                avg_flux_err = np.sqrt(np.nanmean(masked_err**2))

                spectrum.append(0 if np.isnan(avg_flux) else avg_flux)
                spectrum_err.append(0 if np.isnan(avg_flux_err) else avg_flux_er

            # Wavelength axis from header
            crval3 = header['CRVAL3']
            cdelt3 = header['CDELT3']
            crpix3 = header['CRPIX3']
            wavelength = ((np.arange(num_channels) - (crpix3 - 1)) * cdelt3 + cr

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

    # Plot for this region
    plt.figure(figsize=(12, 5))
    plt.errorbar(wavelength_all, spectrum_all, yerr=spectrum_all_err, color='nav
    # Define key MIR spectral features (in microns)
    features = {
        'PAH 6.2': 6.2,
        'PAH 7.7': 7.7,
        'PAH 8.6': 8.6,
        'H₂ S(4)': 8.03,
        'H₂ S(3)': 9.66,
        '[S IV]': 10.51,
        'PAH 11.3': 11.3
}

# Add vertical lines and labels
    for label, wl in features.items():
        plt.axvline(x=wl, color='red', linestyle='--', linewidth=1)
        plt.text(wl + 0.01, max(spectrum_all)*0.9, label, rotation=90, verticala

    plt.title(f"Spectrum for Region {region_index + 1}")
    plt.xlabel("Rest Wavelength (µm)")
    plt.ylabel("Average Intensity (MJy/sr)")
    plt.grid(True)
```

```
    plt.tight_layout()
    plt.show()
```

```
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
03:48:44.191' from MJD-BEG.
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]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.559129
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.282938 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737445736.634 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
04:05:31.550' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:11:31.595' from MJD-AVG.
Set DATE-END to '2022-07-04T04:17:33.047' from MJD-END'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.557468
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283459 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737461184.323 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
04:22:24.413' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:28:21.737' from MJD-AVG.
Set DATE-END to '2022-07-04T04:34:17.654' from MJD-END'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.555797
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283980 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737476718.877 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
```



```
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
03:48:44.191' from MJD-BEG.
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]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.559129
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.282938 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737445736.634 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
04:05:31.550' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:11:31.595' from MJD-AVG.
Set DATE-END to '2022-07-04T04:17:33.047' from MJD-END'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.557468
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283459 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737461184.323 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
04:22:24.413' from MJD-BEG.
Set DATE-AVG to '2022-07-04T04:28:21.737' from MJD-AVG.
Set DATE-END to '2022-07-04T04:34:17.654' from MJD-END'. [astropy.wcs.wcs]
WARNING: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to   -72.555797
from OBSGEO-[XYZ].
Set OBSGEO-B to   -38.283980 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737476718.877 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
```

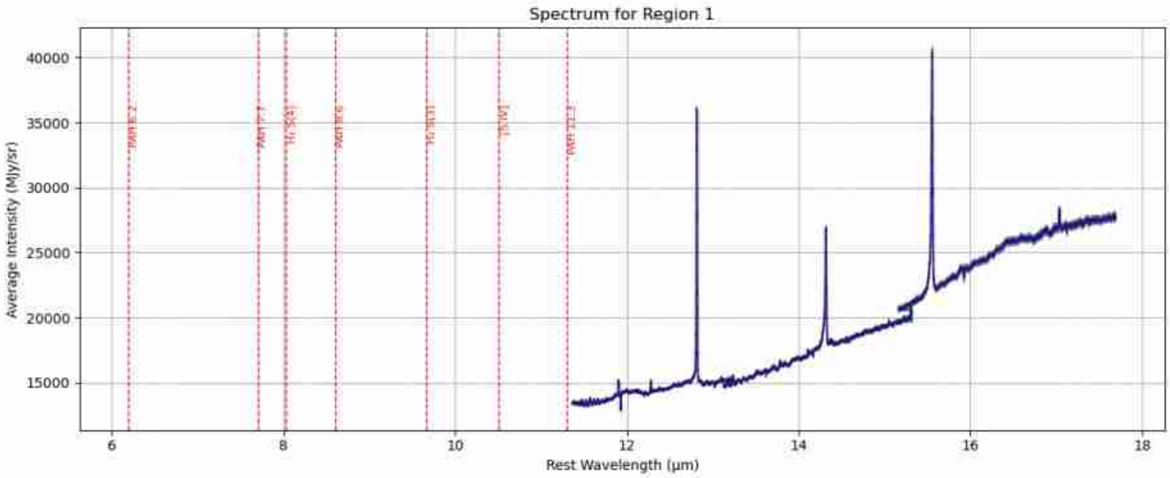


In [24]:
```python
from astropy.io import fits
from astropy.wcs import WCS
from regions import Regions
import numpy as np
import matplotlib.pyplot as plt

# Load your region file
region_file = 'ds9.reg'  # Change if your filename is different
regions = Regions.read(region_file, format='ds9')

# Channel 2 FITS cubes (update if your path is different)
file_paths = [
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
]



# Redshift for rest-frame conversion
```

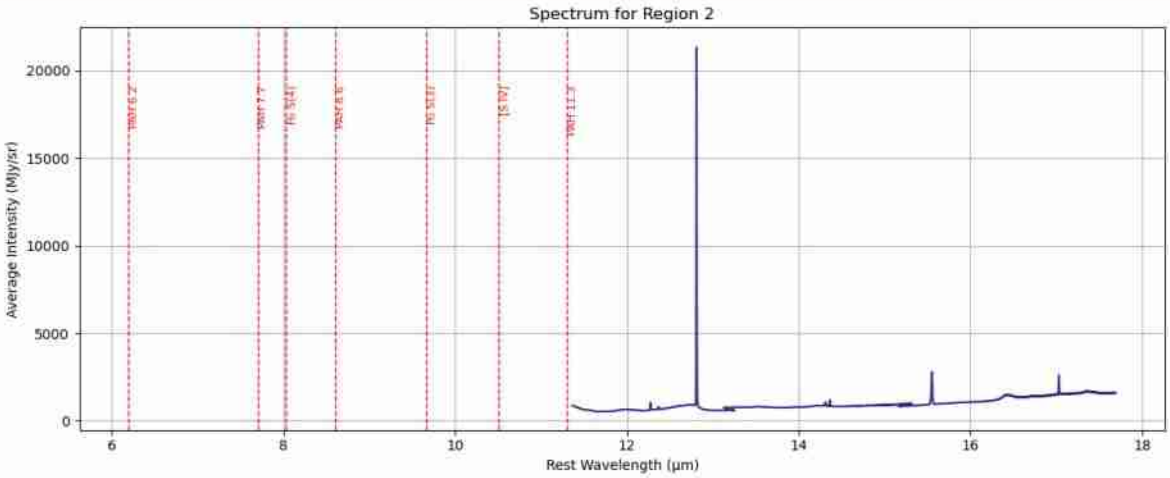
```python
z = 0.016268

# Loop through each region
for region_index, region in enumerate(regions):
    spectrum_all, spectrum_all_err, wavelength_all = [], [], []

    for file_path in file_paths:
        with fits.open(file_path) as hdul:
            data = hdul[1].data
            data[data < 0] = np.nan
            err_data = hdul[2].data
            header = hdul[1].header
            wcs = WCS(header)

            mask = region.to_pixel(wcs.celestial).to_mask()
            num_channels, ny, nx = data.shape
            spectrum, spectrum_err = [], []

            for i in range(num_channels):
                masked = np.array(mask.multiply(data[i]), dtype=float)
                masked_err = np.array(mask.multiply(err_data[i]), dtype=float)

                avg_flux = np.nanmean(masked)
                avg_flux_err = np.sqrt(np.nanmean(masked_err**2))

                spectrum.append(0 if np.isnan(avg_flux) else avg_flux)
                spectrum_err.append(0 if np.isnan(avg_flux_err) else avg_flux_er

            # Wavelength axis from header
            crval3 = header['CRVAL3']
            cdelt3 = header['CDELT3']
            crpix3 = header['CRPIX3']
            wavelength = ((np.arange(num_channels) - (crpix3 - 1)) * cdelt3 + cr

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

    # Plot for this region
    plt.figure(figsize=(12, 5))
    plt.errorbar(wavelength_all, spectrum_all, yerr=spectrum_all_err, color='nav
    # Define key MIR spectral features (in microns)
    features = {
        'PAH 6.2': 6.2,
        'PAH 7.7': 7.7,
        'PAH 8.6': 8.6,
        'H₂ S(4)': 8.03,
        'H₂ S(3)': 9.66,
        '[S IV]': 10.51,
        'PAH 11.3': 11.3
}

# Add vertical lines and labels
    for label, wl in features.items():
        plt.axvline(x=wl, color='red', linestyle='--', linewidth=1)
        plt.text(wl + 0.01, max(spectrum_all)*0.9, label, rotation=90, verticala

    plt.title(f"Spectrum for Region {region_index + 1}")
    plt.xlabel("Rest Wavelength (μm)")
    plt.ylabel("Average Intensity (MJy/sr)")
```

```
    plt.grid(True)
    plt.tight_layout()
    plt.show()
```

```
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
03:48:43.551' 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 '2022-07-04T
04:05:30.910' 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 '2022-07-04T
04:22:23.837' 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]
```



```
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
03:48:43.551' 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 '2022-07-04T
04:05:30.910' 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 '2022-07-04T
04:22:23.837' 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]
```



In [26]:
```python
from astropy.io import fits
from astropy.wcs import WCS
from regions import Regions
import numpy as np
import matplotlib.pyplot as plt

# Load your region file
region_file = 'ds9.reg'  # Change if your filename is different
regions = Regions.read(region_file, format='ds9')

# Channel 2 FITS cubes (update if your path is different)
file_paths = [
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
    r'C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_2025-06-18T0646-
]
```

```
# Redshift for rest-frame conversion
z = 0.016268

# Loop through each region
for region_index, region in enumerate(regions):
    spectrum_all, spectrum_all_err, wavelength_all = [], [], []

    for file_path in file_paths:
        with fits.open(file_path) as hdul:
            data = hdul[1].data
            data[data < 0] = np.nan
            err_data = hdul[2].data
            header = hdul[1].header
            wcs = WCS(header)

            mask = region.to_pixel(wcs.celestial).to_mask()
            num_channels, ny, nx = data.shape
            spectrum, spectrum_err = [], []

            for i in range(num_channels):
                masked = np.array(mask.multiply(data[i]), dtype=float)
                masked_err = np.array(mask.multiply(err_data[i]), dtype=float)

                avg_flux = np.nanmean(masked)
                avg_flux_err = np.sqrt(np.nanmean(masked_err**2))

                spectrum.append(0 if np.isnan(avg_flux) else avg_flux)
                spectrum_err.append(0 if np.isnan(avg_flux_err) else avg_flux_er

            # Wavelength axis from header
            crval3 = header['CRVAL3']
            cdelt3 = header['CDELT3']
            crpix3 = header['CRPIX3']
            wavelength = ((np.arange(num_channels) - (crpix3 - 1)) * cdelt3 + cr

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

    # Plot for this region
    plt.figure(figsize=(12, 5))
    plt.errorbar(wavelength_all, spectrum_all, yerr=spectrum_all_err, color='nav
    # Define key MIR spectral features (in microns)
    features = {
        'PAH 6.2': 6.2,
        'PAH 7.7': 7.7,
        'PAH 8.6': 8.6,
        'H₂ S(4)': 8.03,
        'H₂ S(3)': 9.66,
        '[S IV]': 10.51,
        'PAH 11.3': 11.3
}

# Add vertical lines and labels
    for label, wl in features.items():
        plt.axvline(x=wl, color='red', linestyle='--', linewidth=1)
        plt.text(wl + 0.01, max(spectrum_all)*0.9, label, rotation=90, verticala

    plt.title(f"Spectrum for Region {region_index + 1}")
    plt.xlabel("Rest Wavelength (μm)")
```

```python
    plt.ylabel("Average Intensity (MJy/sr)")
    plt.grid(True)
    plt.tight_layout()
    plt.show()
```

```
WARNING: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-04T
03:48:43.551' 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]
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Set OBSGEO-B to   -38.283458 from OBSGEO-[XYZ].
Set OBSGEO-H to 1737461174.508 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
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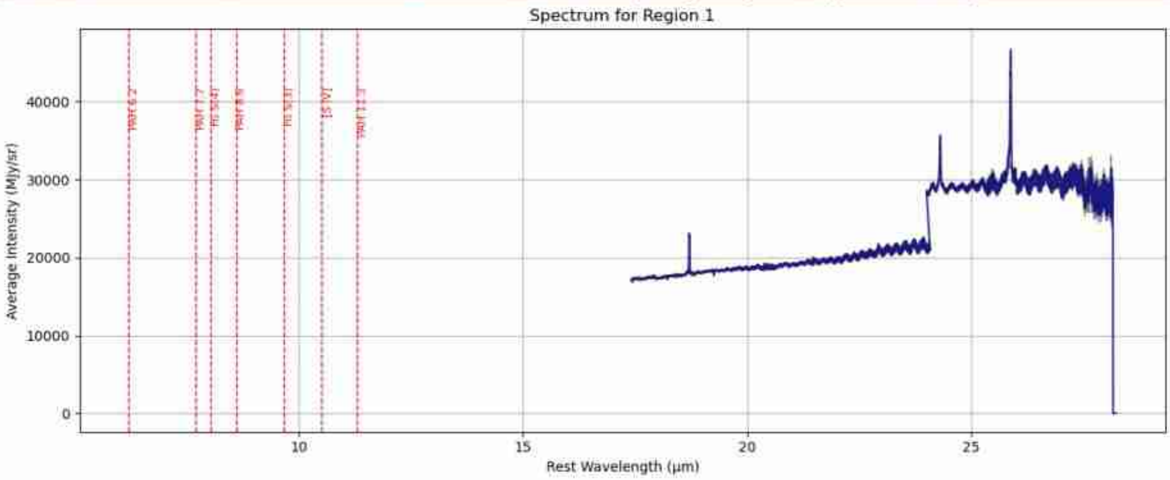
Set OBSGEO-H to 1737476710.042 from OBSGEO-[XYZ]'. [astropy.wcs.wcs]
```



```
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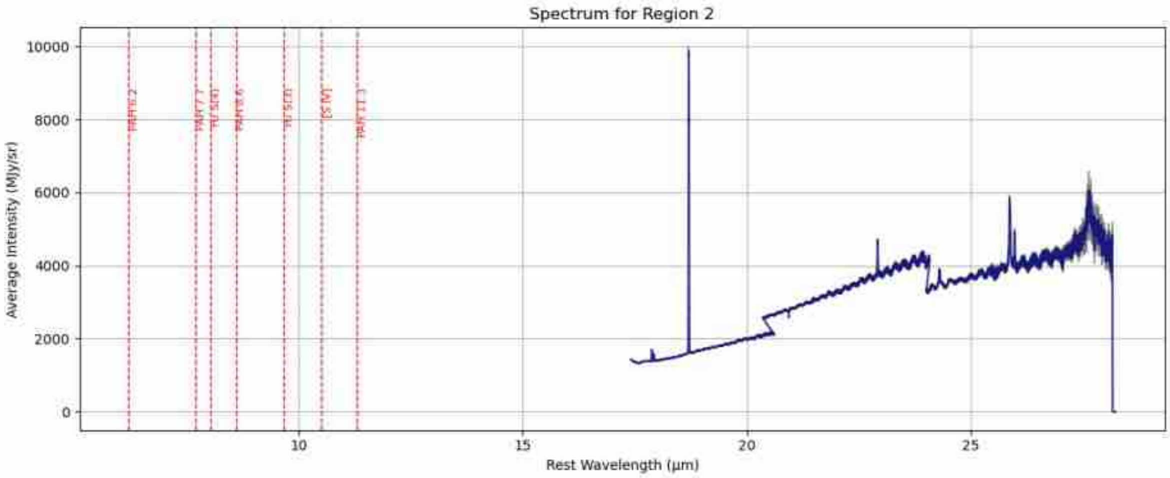

In [ ]:

In [ ]:
```
ALL OUTPUTS OF CELLS ARE IN REPORT FILE (SPECTRA AND IMAGES)
```

In [1]:
```
!conda list jdaviz
```

```
# packages in environment at D:\Anaconda:
#
# Name                    Version                   Build  Channel
jdaviz                    4.2.3                    pypi_0    pypi
```

In [2]:
```
from jdaviz import Cubeviz

cubeviz = Cubeviz()
cubeviz.load_data(r"C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_20
cubeviz.show()
```

```
Application(config='cubeviz', docs_link='https://jdaviz.readthedocs.io/en/v4.2.3/
cubeviz/index.html', events=[…
```

In [17]:
```
from jdaviz import Cubeviz

cubeviz = Cubeviz()
cubeviz.load_data(r"C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_20

cubeviz.show()
```

```
Application(config='cubeviz', docs_link='https://jdaviz.readthedocs.io/en/v4.2.3/
cubeviz/index.html', events=[…
```

In [21]:
```
from jdaviz import Cubeviz

cubeviz = Cubeviz()
cubeviz.load_data(r"C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_20

cubeviz.show()
```

```
Application(config='cubeviz', docs_link='https://jdaviz.readthedocs.io/en/v4.2.3/
cubeviz/index.html', events=[…
```

In [23]:
```
from jdaviz import Cubeviz

cubeviz = Cubeviz()
cubeviz.load_data(r"C:\Users\SAYANTANI MODAK\OneDrive\Documents\HIIT\ISA\MAST_20

cubeviz.show()
```

```
Application(config='cubeviz', docs_link='https://jdaviz.readthedocs.io/en/v4.2.3/
cubeviz/index.html', events=[…
```

In [ ]: