Advanced: Exploring Nebulae Through Filters

Title: Exploring Nebulae: A Deep Dive into Cosmic Clouds

Duration: ~2 hours

Grade Level: 6th Grade to High School (Advanced Users)

Objectives:

- Observe and analyze different types of nebulae using the remote telescope.
- Understand the characteristics and compositions of nebulae through filter use.
- Foster scientific inquiry by comparing observations across various filters.
- Encourage students to explore astrophysical concepts through direct observation.

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1. Introduction and Objectives (10 minutes)

- **Welcome and Overview**
    - Introduce instructors and outline the session's focus on nebulae.
    - Highlight the hands-on observation of nebulae using different filters.
- **Setting the Stage**
    - Discuss the significance of nebulae in the universe.
    - Present the goal: to observe and compare nebulae across different filters to infer their compositions.

2. Understanding Nebulae (15 minutes)

- **Types of Nebulae and Examples**
    - **Emission Nebulae:** Orion Nebula (M42)
    - **Reflection Nebulae:** Witch Head Nebula (IC 2118)
    - **Planetary Nebulae:** dumbbell nebula(M27)
    - **Dark Nebulae:** Horsehead Nebula (Barnard 33)
- **Characteristics of Each Type**
    - Explain how each type interacts with light differently.
    - Discuss the role of elements like hydrogen, helium, and dust.

3. Introduction to Filters (10 minutes)

- **Understanding Filters**
    - **Luminance (L):** Captures brightness.

    - **Red, Green, Blue (RGB):** Captures colors, and reveals composition.
    - **Sulfur II (S), Hydrogen-alpha (H), Oxygen III (O):** Narrowband filters targeting specific emission lines.
- **Purpose of Using Filters**
    - Enhance certain features of nebulae.
    - Identify elemental compositions based on emitted wavelengths.

4. Observing Nebulae Through the Telescope (60 min)

- **Selecting Targets**
    - Divide students into groups, each assigned a different nebula type.
- **Hands-On Observation**
    - **Activity:** Use the telescope to observe assigned nebulae through various filters (LRGBSHO).
        - For example, viewing the Orion Nebula through a Hydrogen-alpha filter to see areas of active star formation.
- **Comparative Analysis**
    - Observe how the appearance of each nebula changes with different filters.
    - Encourage students to note differences in brightness, detail, and structure.
- **Data Recording**
    - Provide observation sheets for students to log:
        - Nebula name
        - Filter used
        - Notable features observed

5. Group Discussion and Interpretation (40 minutes)

Discussion and Analyzing Results

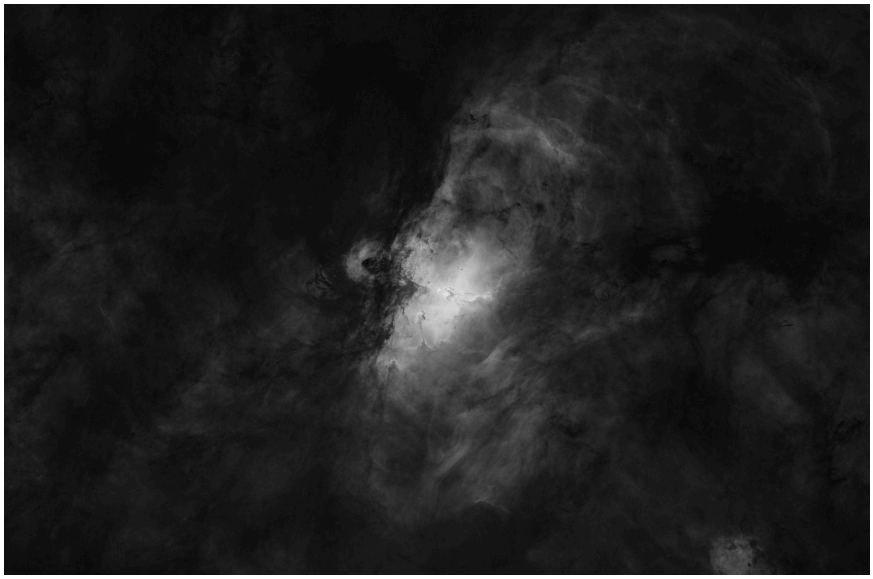
- **Introduction to Spectral Lines and Emission**
    - Atoms and Light:
        - Explain that atoms emit or absorb light at specific wavelengths called spectral lines.
        - Different elements have unique spectral signatures.
    - Ionization and Recombination:
        - Describe how high-energy photons ionize atoms.
        - When electrons recombine with ions, they emit photons at characteristic wavelengths.
- **Understanding Filters and Corresponding Wavelengths**
    - Hydrogen-alpha (Hα) Filter:
        - Passes light at 656.3 nm, emitted by hydrogen atoms.
        - Highlights ionized hydrogen regions, indicating star formation.
    - Oxygen III (OIII) Filter:
        - Passes light at 500.7 nm, from doubly ionized oxygen.

        - Reveals high-energy regions in planetary nebulae and supernova remnants.
    - Sulfur II (SII) Filter:
        - Passes light at 672.4 nm, emitted by ionized sulfur.
        - Indicates shock-heated gas in nebulae.
    - Luminance and RGB Filters:
        - Capture broad ranges of the spectrum for brightness and color information.
- **Discussing Observations Across Different Filters**
    - Group Presentations:
        - Each group shares images of their nebula through different filters.
        - Compare how the nebula's appearance changes with each filter.

Analyzing results

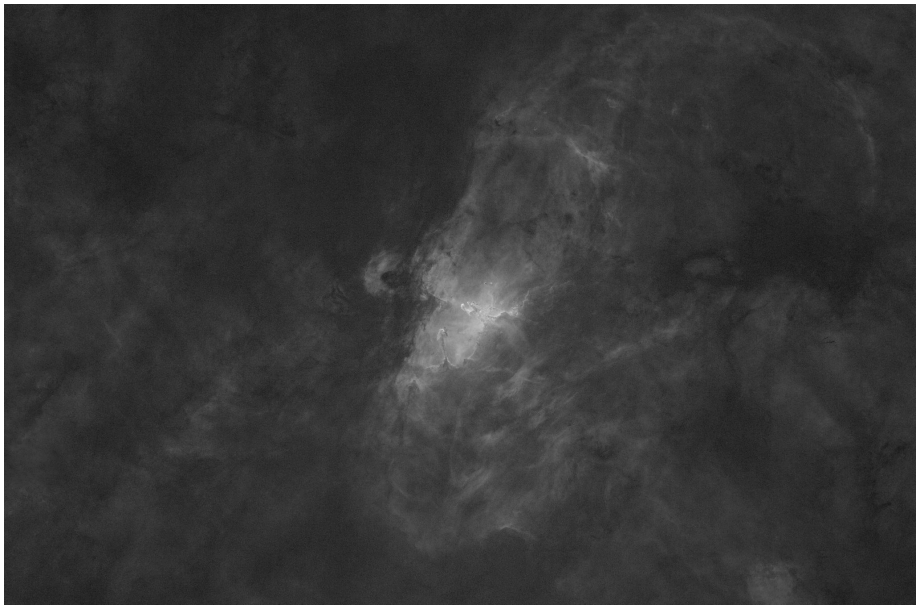
A. Emission Nebulae

- **Example:** Orion Nebula (M42), M8, M16
- **Expected Observations by Filter:**
    - **Hydrogen-alpha (Hα) Filter**
        - **Observation:** The nebula appears very bright with intricate structures.
        - **Explanation:** The nebula rich in ionized hydrogen gas emitting strongly at 656.3 nm.
        - **Composition Insight:** Strong Hα emission indicates active star formation regions where young, hot stars ionize surrounding hydrogen (NASA, 2020).



Example Ha image of M16 that we took

- **Sulfur II (SII) Filter**
  - **Observation:** Structures are visible but fainter compared to Hα.
  - **Explanation:** SII emission highlights regions where sulfur is ionized, often present in star-forming areas.
  - **Composition Insight:** Presence of ionized sulfur suggests complex chemical processes occurring in the nebula.



Example Sii image of M16

- **Oxygen III (OIII) Filter**
  - **Observation:** Certain areas of the nebula appear bright.
  - **Explanation:** OIII emission comes from doubly ionized oxygen, indicating high-energy environments.

        - **Composition Insight:** OIII regions often correlate with the hottest and most energetic areas.

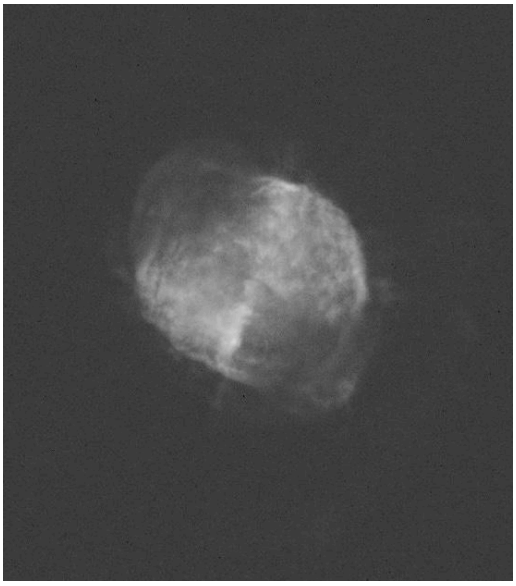
Example of an Oiii image of M16

    - **Luminance (L) Filter**
        - **Observation:** Captures overall brightness and fine details.
        - **Explanation:** Combines light from all wavelengths, providing a sharp image.
        - **Composition Insight:** Highlights the nebula's structure but doesn't specify elemental composition.
    - **RGB Filters**
        - **Observation:** The nebula shows a reddish hue due to dominant Hα emission.
        - **Explanation:** Red channel captures Hα emission; combining RGB reconstructs true-color images.
        - **Composition Insight:** The red color indicates the abundance of hydrogen gas.

B. Planetary Nebulae

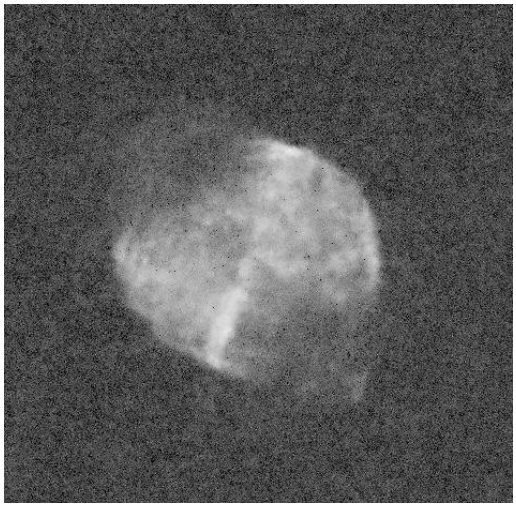
- **Example:** Ring Nebula (M57), Dumbbell Nebula (M27), Crab Nebula (M1)
- **Expected Observations by Filter:**
    - **Hydrogen-alpha (Hα) Filter**
        - **Observation:** The Dumbbell Nebula appears as a bright, well-defined structure with intricate details.
        - **Explanation:** Emission from ionized hydrogen in the nebula's shell.

- **Composition Insight:** Indicates hydrogen gas expelled from the dying star.

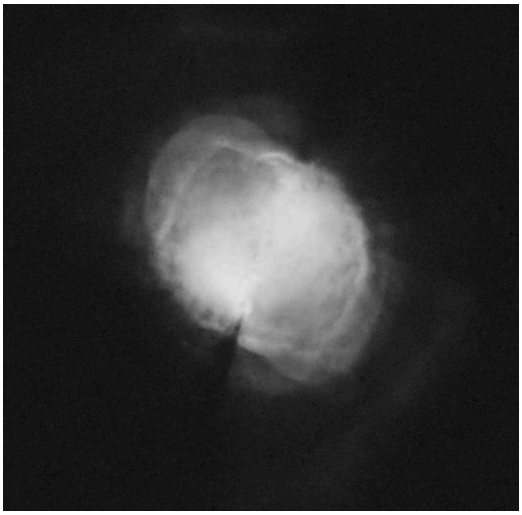


Example images we took, 300s exposure

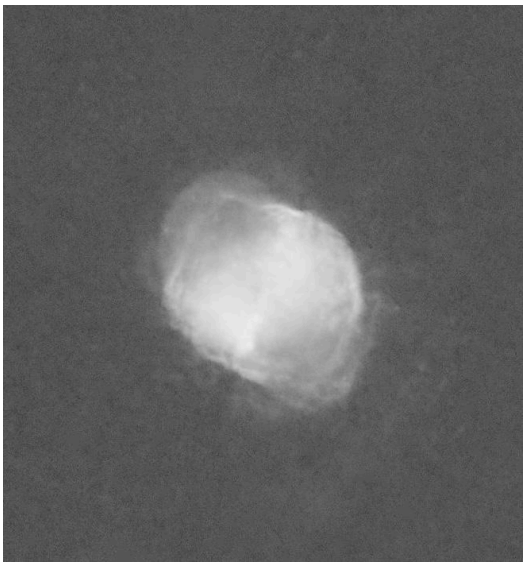
- **Sulfur II (SII) Filter**
  - **Observation:** The nebula appears brighter but less detailed compared to the Hα filter but still reveals the nebula's outline
  - **Explanation:** SII emission highlights regions with ionized sulfur.
  - **Composition Insight:** Suggests the presence of heavier elements like sulfur, pointing to nucleosynthesis processes in the progenitor star.



- **Oxygen III (OIII) Filter**
  - **Observation:** The Dumbbell Nebula is very bright in the OIII filter, often brighter than in Hα
  - **Explanation:** Strong OIII emission due to high-energy photons from the central white dwarf ionizing oxygen atoms.
  - **Composition Insight:** The abundance of doubly ionized oxygen indicates the high temperature of the central star (Kaler, 2019).



- **Luminance (L) Filter**
  - **Observation:** Detailed structure of the nebula is captured.
  - **Explanation:** Records overall brightness, showing the nebula's shape.
  - **Composition Insight:** Does not provide specific elemental information but reveals structural details.



C. Reflection Nebulae

- **Example:** Witch Head Nebula (IC 2118), M78, M45
- **Expected Observations by Filter:**
    - **Hydrogen-alpha (Hα) Filter**
        - **Observation:** Nebula appears faint or nearly invisible.
        - **Explanation:** Reflection nebulae do not emit significant Hα light.
        - **Composition Insight:** Lack of ionized hydrogen emission suggests the nebula reflects light rather than emitting it.
    - **Sulfur II (SII) Filter**
        - **Observation:** Minimal to no features observed.
        - **Explanation:** SII emission is negligible in reflection nebulae.
        - **Composition Insight:** Indicates low levels of ionized sulfur.
    - **Oxygen III (OIII) Filter**
        - **Observation:** Nebula remains faint.
        - **Explanation:** OIII emission is not prominent.
        - **Composition Insight:** Suggests minimal presence of doubly ionized oxygen.
    - **Luminance (L) Filter**
        - **Observation:** Nebula is visible with good contrast.
        - **Explanation:** Reflects starlight, so overall brightness is captured.
        - **Composition Insight:** Highlights dust particles scattering light.
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D. Dark Nebulae

- **Example:** Horsehead Nebula (Barnard 33)
- **Expected Observations by Filter:**
    - **Hydrogen-alpha (Hα) Filter**
        - **Observation:** Dark silhouette against a bright Hα background.
        - **Explanation:** The nebula absorbs and blocks Hα emission from the emission nebula behind it.
        - **Composition Insight:** Dense clouds of dust and gas obscure light, indicating regions rich in material that could form stars.
    - **Sulfur II (SII) Filter**
        - **Observation:** Similar dark silhouette as in Hα.
        - **Explanation:** Blocks SII emission from behind.
        - **Composition Insight:** Confirms the nebula's opacity to various wavelengths.
    - **Oxygen III (OIII) Filter**
        - **Observation:** The nebula remains dark against any OIII background emission.
        - **Explanation:** Continues to absorb light across different emission lines.

        - **Composition Insight:** Suggests the nebula's composition is effective at absorbing multiple wavelengths.
    - **Luminance (L) Filter**
        - **Observation:** Prominent dark shape against a brighter background.
        - **Explanation:** Captures the nebula's silhouette due to absorption of starlight.
        - **Composition Insight:** Highlights the density and thickness of the dust clouds.

- **Relating Observations to Nebula Composition**
    - **Elemental Identification:**
        - **Hydrogen:**
            - Dominant in emission nebulae.
            - Hα emissions show ionized hydrogen regions.
        - **Oxygen:**
            - Present in planetary nebulae.
            - OIII emissions indicate doubly ionized oxygen.
        - **Sulfur:**
            - Found in areas with intense radiation.
            - SII emissions point to shock-heated regions.
    - **Physical Processes:**
        - **Star Formation:**
            - Hα regions indicate where new stars are forming.
            - Gravity pulls gas and dust together, initiating fusion.
        - **Stellar Death:**
            - Planetary nebulae form from dying stars shedding outer layers.
            - OIII emissions come from hot gas illuminated by the central star.
        - **Supernova Remnants:**
            - Result from massive stars exploding.
            - SII emissions highlight shock waves heating surrounding gas.
- **Connecting Observations to Astrophysical Concepts**
    - **Emission vs. Reflection:**
        - Emission nebulae glow due to ionized gas.
        - Reflection nebulae shine by reflecting starlight.
    - **Spectral Analysis:**
        - Filters isolate specific wavelengths to identify elements.
        - Similar to how astronomers analyze light to determine composition.
    - **Life Cycle of Stars:**
        - Nebulae play roles in both star birth and death.
        - Observations help understand stellar evolution.
- **Encouraging Critical Thinking**
    - **Comparative Analysis:**

        - Compare different nebulae and filter observations.
        - Identify patterns and differences.
    - **Hypothesis Formation:**
        - Predict observations in unviewed filters based on known compositions.
        - Discuss why certain emissions are stronger in some nebulae.
    - **Question Prompts:**
        - "Why does the Orion Nebula appear brighter in Hα than OIII?"
        - "What does strong OIII emission tell us about a planetary nebula?"
        - "How do our observations inform us about the processes occurring within these nebulae?"
- **Visual Aids and Spectral Diagrams**
    - **Spectral Lines:**
        - Show diagrams of hydrogen, oxygen, and sulfur emission lines.
        - Illustrate how filters correspond to these lines.
    - **Elemental Maps:**
        - Overlay images from different filters to create elemental maps.
        - Visualize the distribution of elements within nebulae.

7. Encouraging Further Exploration (10 minutes)

- **Opportunities for Extended Learning**
    - Inform students that they can contact AstroLink directly for further telescope use.
    - Provide information on how to access additional resources or schedule observation time.
- **Astrophotography Interest**
    - Mention that students interested in astrophotography can reach out for guidance.
    - Provide examples of advanced projects they can undertake, like variable star light curve creation notably T CrB currently, or asteroid hunting.

8. Conclusion and Q&A (10 minutes)

- **Recap Key Learnings**
    - Summarize the types of nebulae observed and insights gained from filter use.
- **Open Discussion**
    - Encourage students to share what surprised them or questions they have.
- **Next Steps**
    - Provide information on upcoming sessions or clubs focused on astronomy.

NASA Science Mission Directorate. (2020). *How Do Stars Form and Evolve?* Retrieved from NASA

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