Discovery of Planetary Nebulae

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I. Introduction

According to CNN the world will end
Dec 21, 2012

As usual, they got it wrong

The world will end:

Dec 21,
5,000,002,012

The sun will....

II. Discovery

A. Messier's Catalog
B. Herschel names them
C. Nebular Hypothesis

Planetary Nebulae

I. Introduction
II. Discovery
III. Structure
IV. Measurements
V. Summary

A. Messier Catalog

Charles Messier (1730-1817) was hunting for comets. People kept reporting the same fuzzy blobs that were NOT comets, so from 1758-1782 he made a catalog of about 100 of these fuzzy things to "ignore".

In fact, these 110 objects are nebulae, star clusters and galaxies, which are the best things to look for in an amateur telescope!
The Summer Triangle

- Deneb
- Vega
- Altair

Cygnus
The Swan

Lyra
The Harp

M27: July 12, 1764
Dumbbell Nebula
In Vulpecula
6' in diameter

M57: July 1779
Ring Nebula
In Lyra
1' in diameter
Made of stars?

M57 Barbell Nebula
Perseus (1780)
(Not recognized as Planetary Nebula until 1918)

Perseus
The Hero

- Algol
- Pleiades

Ursa Major
The Big Bear

M97 Owl Nebula
Discovered 1781
6000 years old?

Ursa Minor
The Small Bear

B. 1781: Uranus Discovered
(accidentally!) by William Herschel using a 6 inch telescope

C. Nebular Hypothesis

- Herschel (1786) thought that “Planetary Nebulae” might be a cloud of gas coalescing into a star to be surrounded by planets (hence the name)
- “Nebular Hypothesis” had been theoretically proposed earlier (1734 Swedberg, 1755 Kant)

Herschel Classifies Nebulae

- 1785 Catalog of 1000 objects
- 1788 another 1000 objects
- 1802 another 500 objects

Classifies objects into star clusters and nebulae. The “types” were:

I. Bright Nebulae
II. Faint Nebulae
III. Very faint Nebulae
IV. Planetary Nebulae
(Uranus-like in color & shape)
V. Very large Nebulae
VI. Very compressed and rich star clusters
VII. Compressed clusters of small and large (i.e., faint and bright) stars
VIII. Coarsely scattered clusters of stars
III. The Message in the Light

A. Atomic Spectra Lines

B. Huggins & Nebulium

C. Central Stars are White dwarfs

A.1. Dark Line Spectra

• 1802 Wollaston sees lines in solar spectra
• 1814 Fraunhofer labels them A, B, C, D
• Later measures over 500 lines!

A.2. Solar spectrum

A.3. Bright Line Spectra

• 1857 Bunsen’s burner, a clean flame with no color
• 1859 Kirchhoff suggest using it to study spectra of elements in flame
• Each element has a unique set of “bright line” (emission) spectra

A.4. Kirchhoff’s Laws

B. 1786 Herschel discovers:

Ursa Major

Ursa Minor

Polaris

Draco the Dragon

H IV 37 (NGC6543) Cats’ Eye Nebula (made of stars?)
Gemini
The Twins

NGC2392 (1787)
Eskimo Nebula
(Herschel)

B.2 William & Margaret Huggins

(1864) Spectra of Cat’s Eye Nebula shows single emission line in green
• Implies it’s a gas, NOT made of stars (which would have absorption lines)
• Unknown element “Nebulium” makes greenish color

B.2 William & Margaret Huggins

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• (1926) Bowen shows Nebulium is really Oxygen & Nitrogen under extraordinary conditions

C. Central Star: White Dwarf!

1800 Friedrich von Hahn discovers central star of Ring Nebula (very faint)
• Central Stars have Hydrogen, Helium and sometimes Carbon & Oxygen lines.
• 1918 Wright identifies as type “O” [VERY HOT 125,000˚C], hence must be very very small to be so faint (magnitude m=15.3)! Not a normal star forming!

Helix Nebula, Aquarius

Discovered 1824, central star is 100,000 degrees Kelvin, m=13.4
It is the closest bright nebula to earth (700 light years)
**White Dwarfs**

- (1956) Iosif Shklovsky proposes that (red giant) stars explode and form a planetary nebula + white dwarf star
- White dwarfs would have BIG densities. A handful of this electron degenerate matter would weigh several tons on the earth!
- But are they just science fiction? To PROVE it, you must find one in a binary star system, where you can measure its mass.
- They found one orbiting Sirius!

**Hourglass & Double Helix**

- Earlier theories thought the star blew up once
- But some nebulas show 2 rings
- How can there be 2 deaths?

**“Bipolar” Planetary Nebula**

- M2_9 HST: Wings of Butterfly Nebula (Twin Jet Nebula)
- Planetary in Ophiuchus (2100 Lightyears away)
- About 1200 years old
- Neutral Oxygen (red), once ionized Nitrogen (green), twice ionized Oxygen (blue)

**2f). Preferential Ejection**

- Ejected doughnut shaped cloud of gas and dust from its equator
- Later ejected gas from entire surface, which was channeled by dust into oppositely directed streams
- Explains 2 loops!

**IV. Measurements**

A. Age of Planetary Nebula

B. Doppler and Speed

C. Size & Distance
A. Age of Planetary Nebula

- Compare measurements of size of nebula over several centuries.
- In 100 years, M27 has expanded 2".
- Today it is 5'=300" in size.
- How old is it?
  - \((300\text{"})(100\text{ yr}/2\text{"})= 15,000 \text{ years}\)

B.1. Doppler Effect with Sound

1842 Christian Doppler shows "detected" frequency \(f_d\) depends upon:

\[
f_d = f_s \left(1 + \frac{v}{c}\right)
\]

- \(f_s\): frequency of source
- \(v\): relative speed between detector and source
- \(c\): velocity of sound in medium

So if moving 10% speed of sound towards you, the frequency will be increased 10%.

B.2. Doppler Effect with Light

Amount of shift of color is proportional to speed: \(\frac{\Delta \lambda}{\lambda} = \frac{v}{c}\). A 10% shift in wavelength means 10% speed of light.

C.1. Size of Dumbbell

- (1970) Dumbbell has Doppler shift of 0.01%
- \(0.0001)c=(0.0001)(300000\text{km/s})=30 \text{ km/sec}\)
- In 1 year expands:
  \[
  \left(\frac{30 \text{km}}{\text{sec}}\right)\left(\frac{3600 \text{ sec}}{\text{hr}}\right)\left(\frac{24 \text{ hr}}{\text{day}}\right)\left(\frac{365 \text{ day}}{\text{yr}}\right) = \text{ Billion km}
  \]
- In 15,000 years has expanded to size:
  \[
  \left(15,000 \text{ yr}\right)\left(1 \text{ Billion km/year}\right) = 15 \text{ trillion km}
  \]

C.2. Distance to Dumbbell

- Recall the “parallax triangle”
- Hence if the size is 100,000 AU and makes an angle of 300", how far away is it?
  \[
  D = \frac{\text{size}}{\text{angle}} = \frac{100,000 \text{AU}}{300\text{"}} = 333 \text{ parsecs}
  \]

V. Summary

- Early confusion if “planetary nebulae” were close groups of stars or gaseous nebula.
- Then it was thought they were a star forming from a nebula.
- Expanding size and exotic white dwarf core imply its an exploded star.