Ghostly and beautiful "planetary nebulae" finally get more accurate distances

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NGC 3242

Credit: Adam Block (NOAO/AURA/NSF)

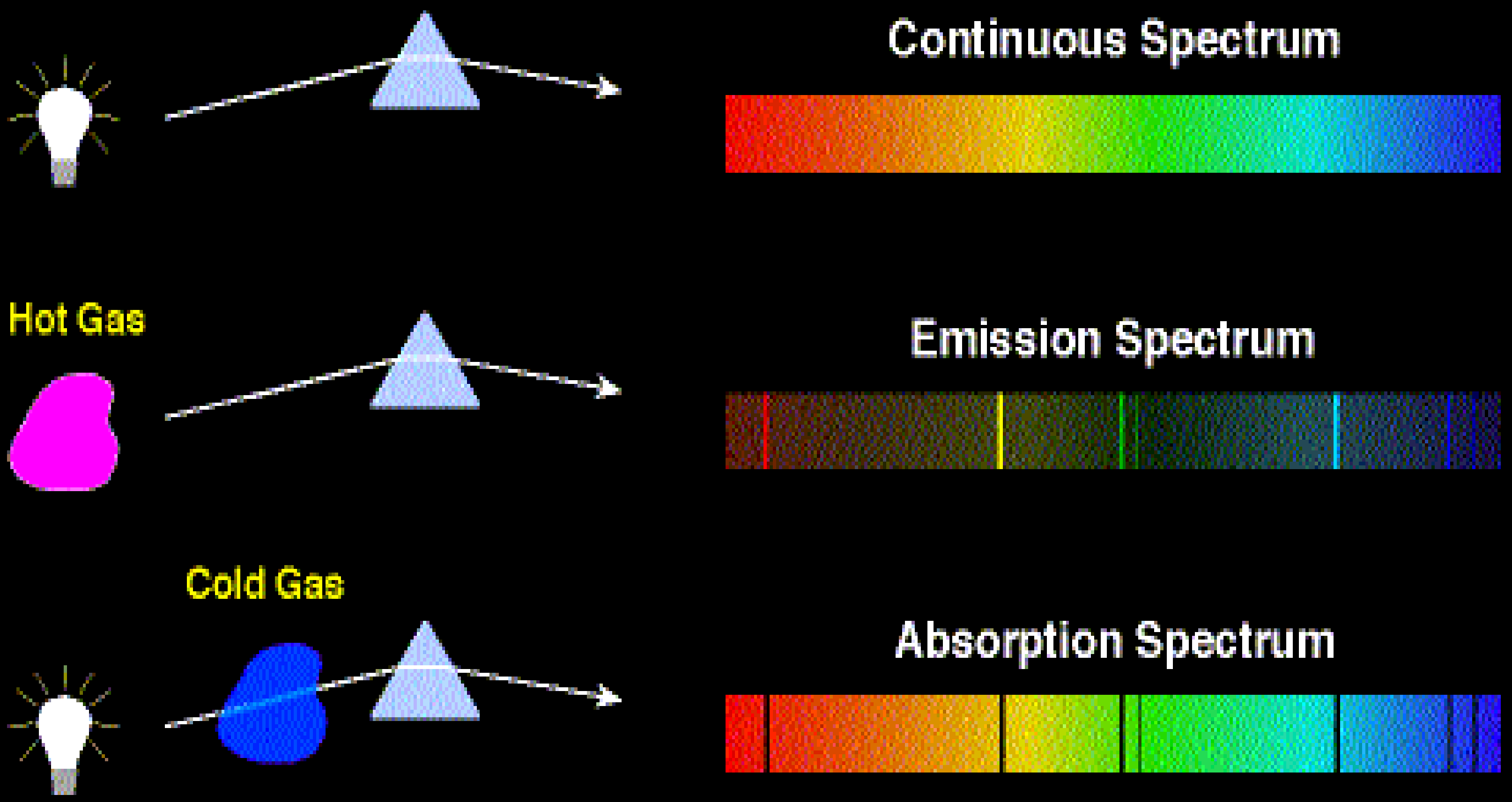
Image credits: B. Balick, R. Sahai, A. Hajian, M. Meixner, P. Harrington, K. Borkowski et al. (STScI/AURA/NASA/ESA/NOAO), G Mellema et al. (HST, ESA, NASA), A. Block (NOAO/AURA/NSF), G. Jacoby (WIYN/NOAO/NSF), D. Malin (AAO) and A. Zijlstra (IPHAS).

What is a planetary nebula?

- A *planetary nebula* is a shell of ionized gas around a hot central star, formed as an average-mass star (like our Sun) sheds its outer atmosphere as it dies.
- Planetary nebulae exist for only about 20,000 years, which is actually a tiny fraction of the total lifetime of the star.
- The newly exposed core of the star has a typical surface temperature of 100,000 ℃. This is hot enough to *ionize* the surrounding gas, causing it to glow.
- The ionizing star eventually shrinks and fades, turning into a 'white dwarf'.
- Planetary nebulae expand and fade as they age.
- Planetary nebulae show a wide variety of interesting shapes, ranging from spherical and elliptical, to bipolar forms (recall previous slide).
- The *spectrum* of the planetary nebula is dominated by emission lines from hydrogen, helium, oxygen, nitrogen and neon (see next two slides).

Background: types of *spectra*

A prism or grating can be used to spread light into a 'rainbow' of component colours. This is called a *spectrum* (plural *spectra*)

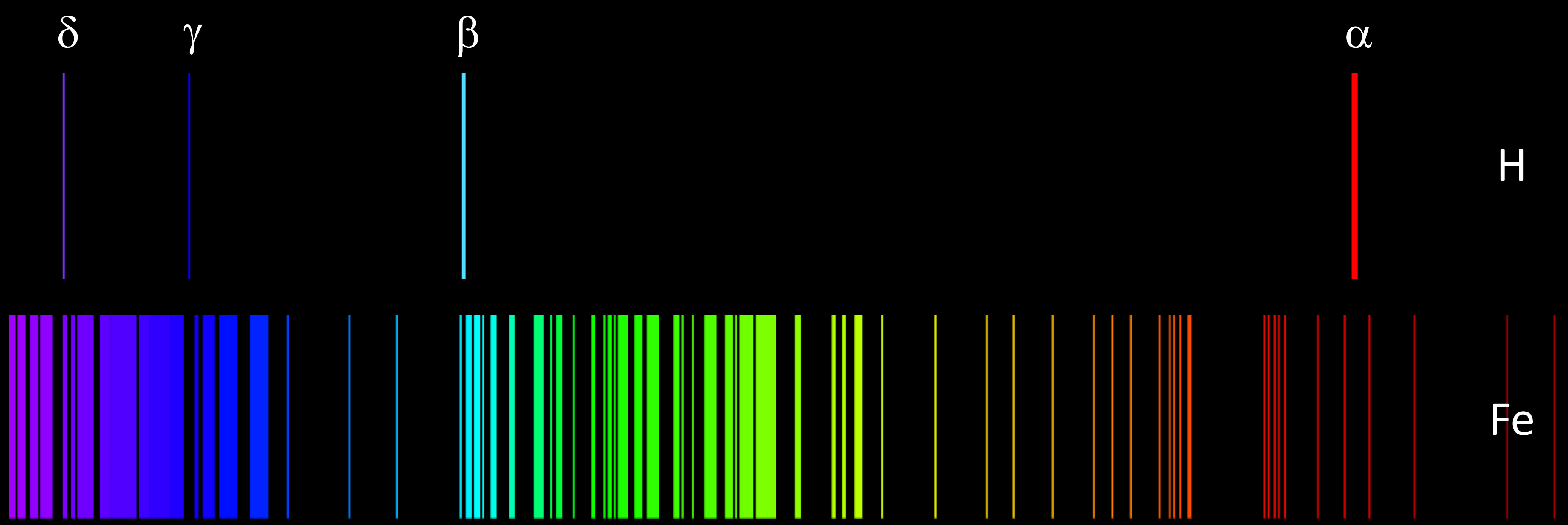


Credit: University of Tennessee

Emission Spectra

Each chemical element has a unique spectrum, just like a “bar code”

The brightest emission lines in a planetary nebula spectrum include those from hydrogen (H).



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Planetary nebulae are valuable tools in astronomy

- Planetary nebulae help astronomers to understand how stars evolve and die.
- We get a better understanding of the nuclear processes acting in old stars, which produce new elements like carbon and nitrogen.
- Along with gas, dust is also produced, which is rich in organic compounds.
- Planetary nebulae allow us to better understand how chemical elements are recycled back into the Galaxy. The gas and dust can form a new generation of stars.
- By observing these nebulae we can better quantify the amounts of these products being returned to our Galaxy.
- But we need an *accurate* census of planetary nebulae in order to do this… so we need to measure their distances!
- We are still not sure if our own Sun will make a planetary nebula when it dies...

The Distance Problem

- We cannot generate a census without knowing their distances. Most planetary nebulae are fairly remote.
- PNe are not ‘standard candles’, nor ‘standard rulers’.
- Most Galactic planetary nebulae in the Milky Way were too distant for a trigonometric parallax, cf. the recently launched GAIA satellite.
- But PNe do *decrease* in surface brightness (flux per unit area) as they expand (radius *increases*).
- Previous statistical distance scales had large uncertainties, especially for the very largest nebulae.

The Hα *S-r* relation: method

The solution to the distance problem is simple and elegant, with three parameters to be measured for each nebula:

1. The size of the object on the sky, taken from the latest high-resolution surveys;
2. An accurate measurement of how bright the object is in the red hydrogen-alpha emission line;
3. The amount of dimming toward the nebula, by making an estimate of the so-called interstellar reddening.

From these values we calculate the Hα surface brightness, from which we can estimate the *true radius* of the nebula.

Combining this number with the angular size of the nebula allows its distance to be determined via trigonometry.

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The Hα surface brightness–radius relation: a robust statistical distance indicator for planetary nebulae

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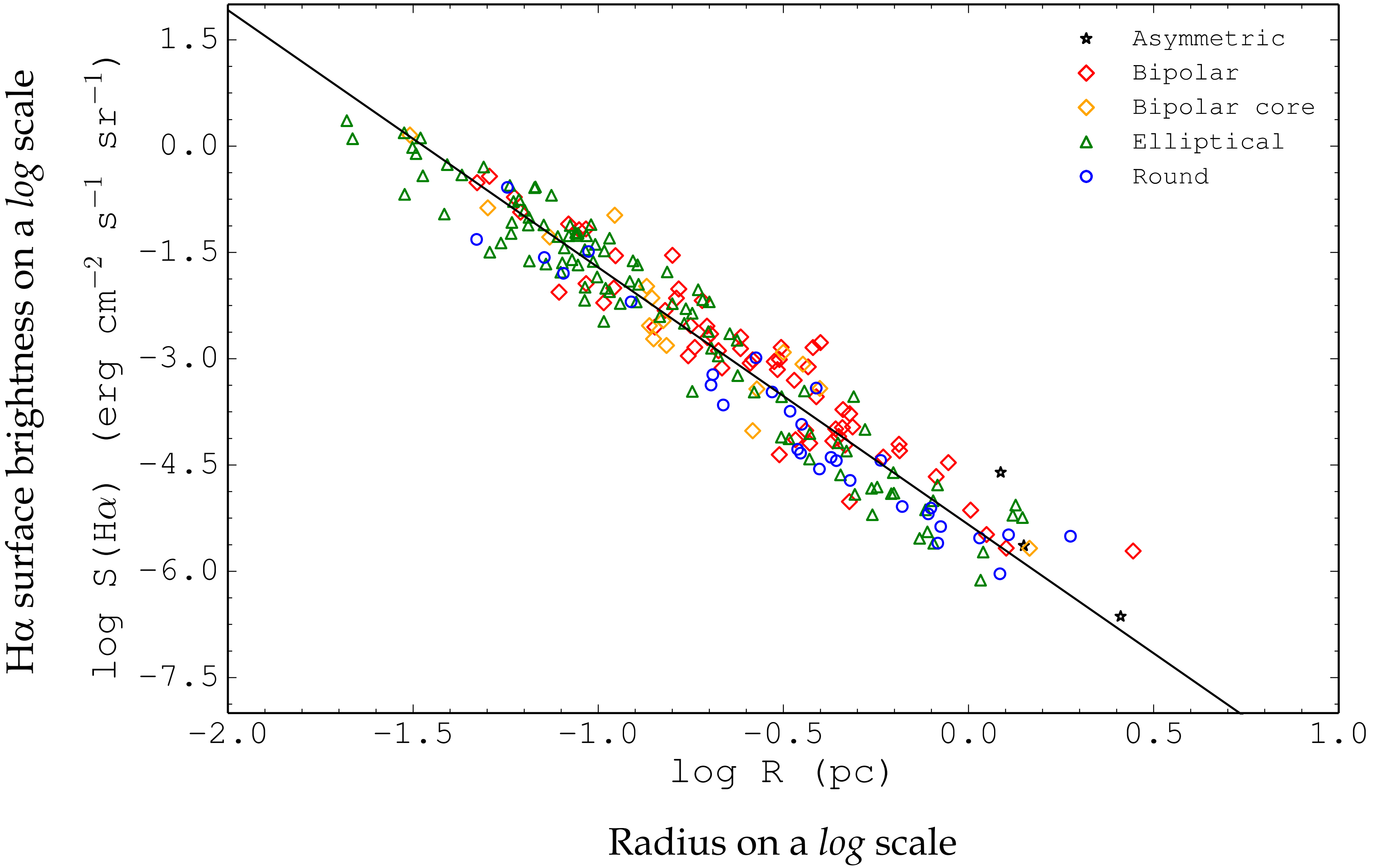
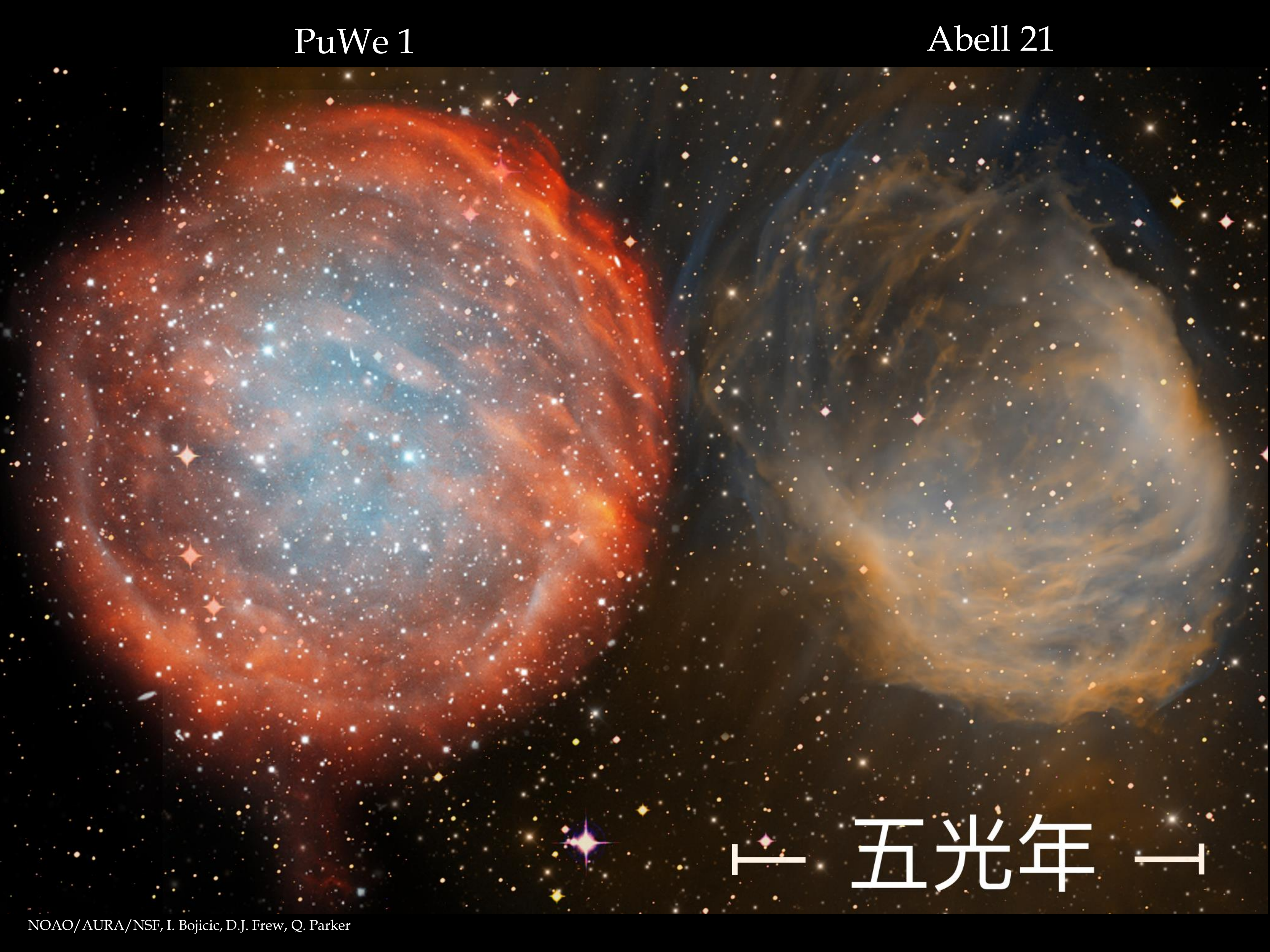
The Hα *S-r* relation



The Hα *S-r* relation: summary

- This is not the first statistical distance scale developed, but is the first to measure brightness in hydrogen-alpha (Hα) emission.
- We used the best quality input data yet obtained.
- Unlike radio methods, we can measure accurate fluxes for the very largest and faintest planetary nebulae using Hα.
- Since these very large planetary nebulae are the most common, measuring good distances to them is crucial.
- While direct distance measurements will soon come from the Gaia space mission (http://sci.esa.int/gaia/), not all planetary nebulae can be measured this way, so our technique will be needed for many years to come.
- Our method has been robustly calibrated using more than 300 planetary nebulae whose accurate distances have been determined independently.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Q & A

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