CHEMISTRY AT THE EXTREME: THE UNUSUAL MOLECULAR AND ISOTOPIC CONTENT OF PLANETARY NEBULAE

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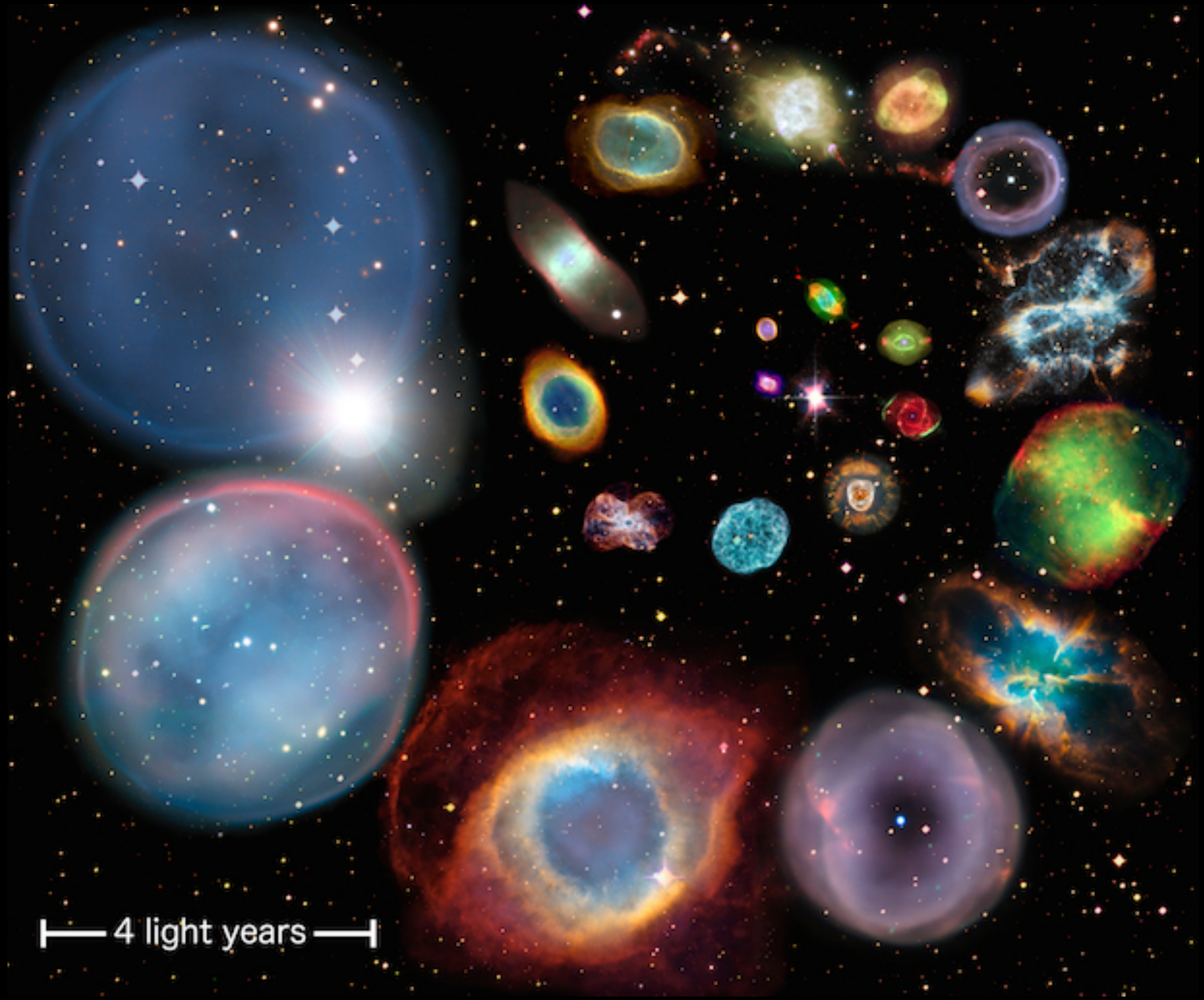
Oral Presentation #320.2 (Wednesday at 2:50 EDT)

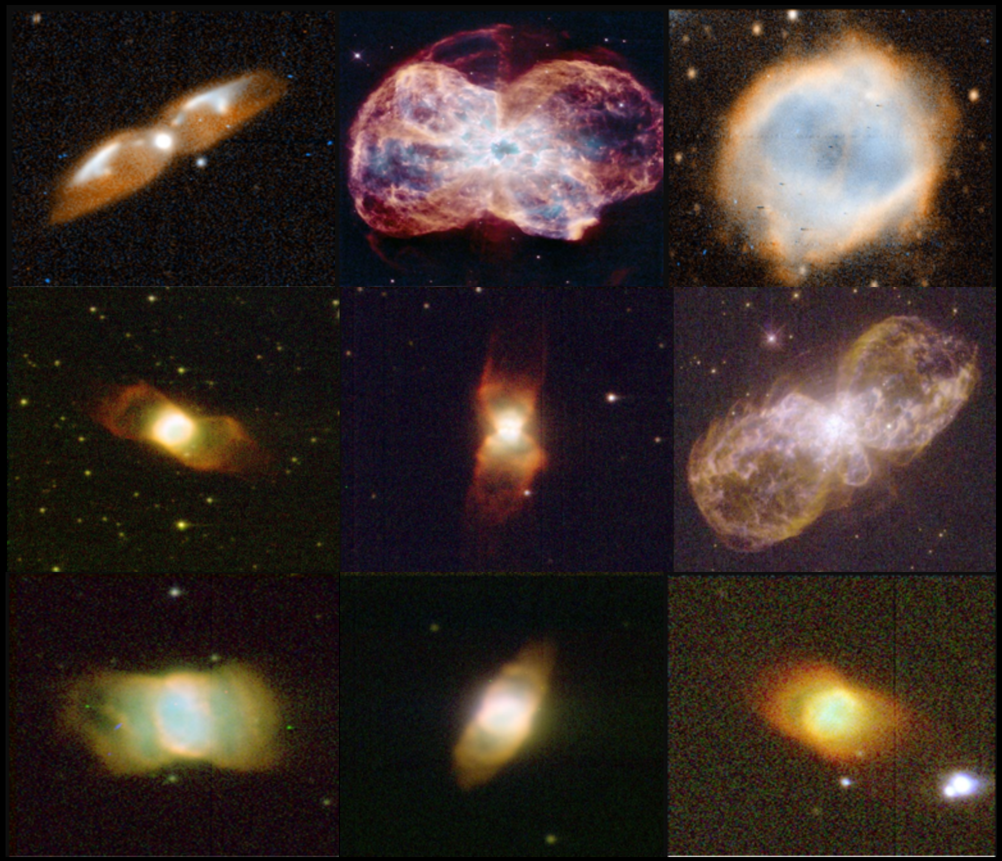
PLANETARY NEBULAE: THE LAST GASPS OF DYING STARS



- Planetary nebulae mark the final stage of Sun-like stars.
- The star's outer layers are ejected and flow away from the remnant core.
- This material mixes with the surrounding space.
- It may later be incorporated into new stellar systems.

Image credit: ESA/Hubble & NASA, ESO, Ivan Bojicic, David Frew, Quentin Parker

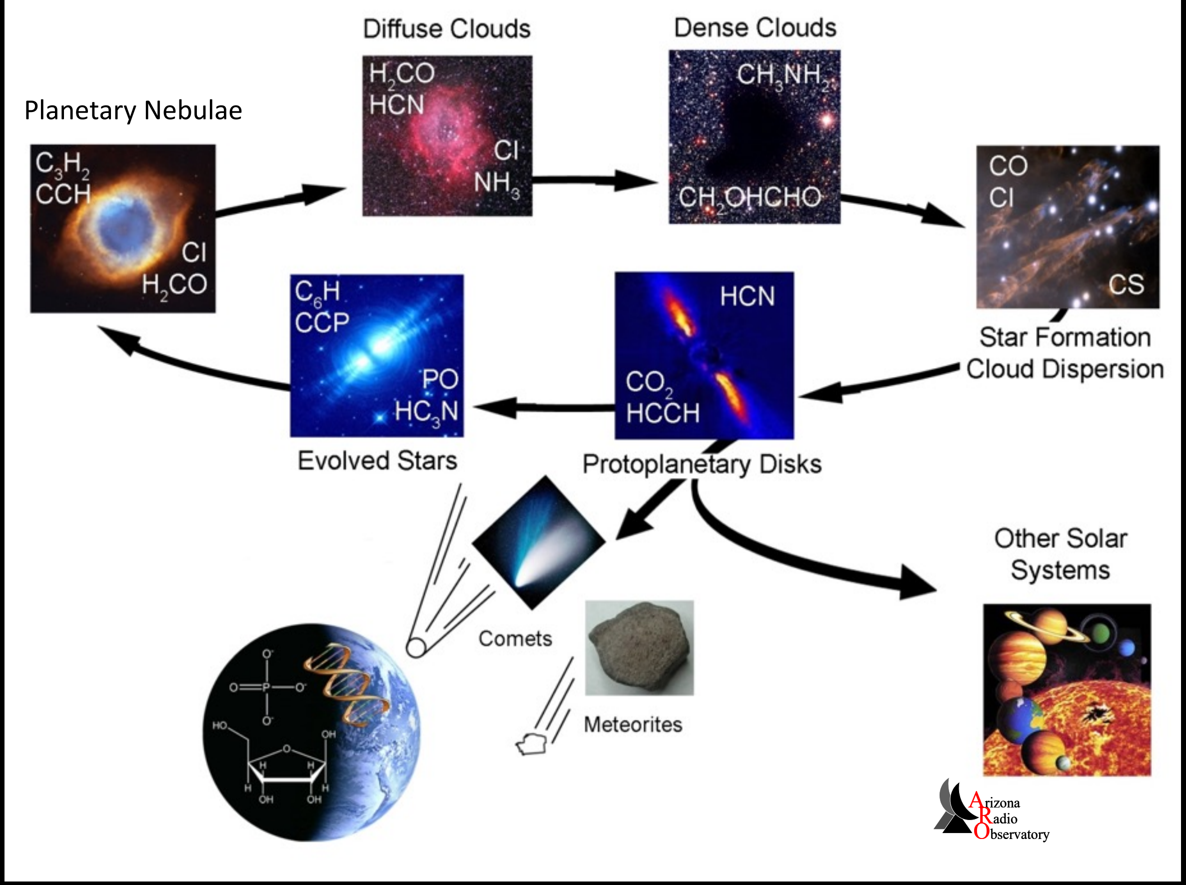
THE SURPRISING MOLECULAR INVENTORY OF PLANETARY NEBULAE



- The hot remnant core emits high-energy radiation.
- These energetic photons should destroy any remnant molecules.
- Instead, observations of over 25 planetary nebulae have revealed a wealth of molecules!

Image credit: Planetary Nebula Image Catalog and references therein

MOLECULAR POLLUTION OF THE INTERSTELLAR MEDIUM



- Planetary nebulae are **full** of molecules!
- These molecules can pollute the surrounding interstellar medium.
- This can explain the molecular abundances measured in diffuse gas!

Image credit: Lucy Ziurys

ISOTOPIC ANOMALIES IN PLANETARY NEBULAE

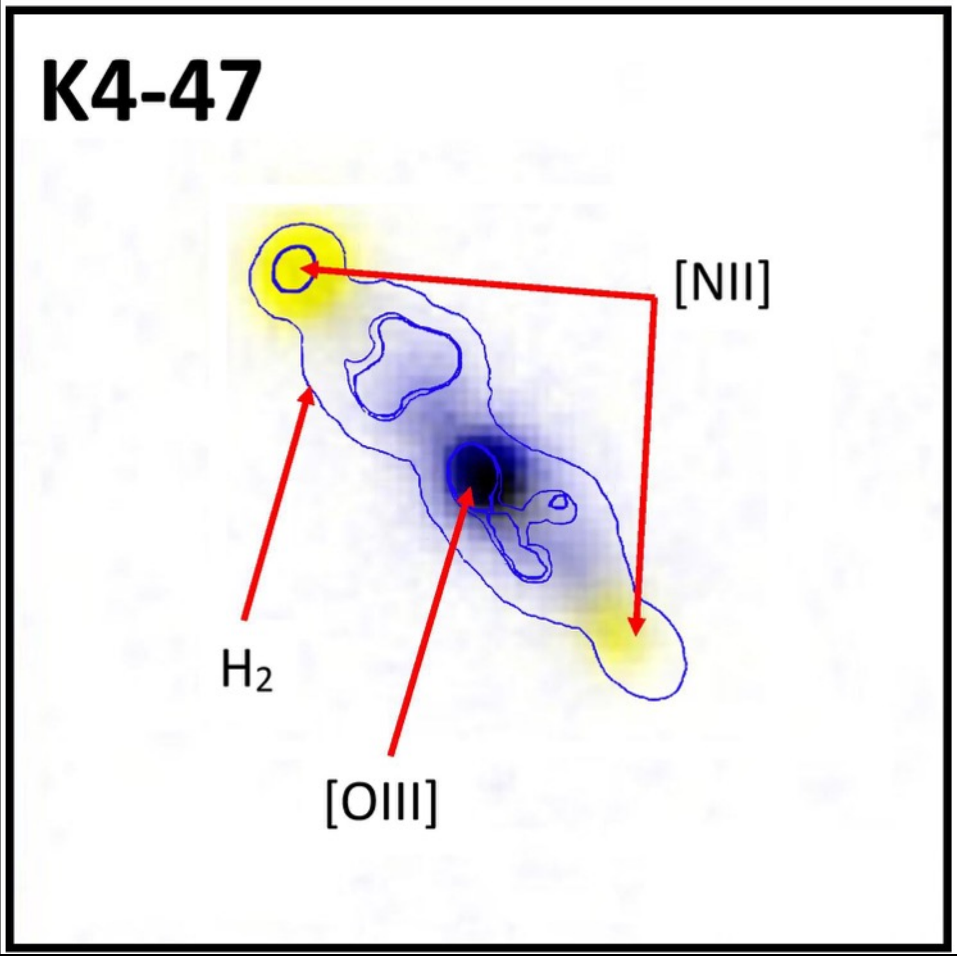


Image credit: Schmidt et al. 2018, *Nature*, 564, 378

- Many planetary nebulae exhibit surprising ^{13}C enrichment.
- K4-47 (left) demonstrates hugely elevated amounts of ^{15}N and ^{17}O – **higher than anywhere else in the universe!**
- This extreme enrichment is not predicted by models of dying stars.

CLUES TO AN EXPLOSIVE PAST

- Extreme isotopic enrichment suggests an explosive process.
- A violent helium shell flash may create ^{13}C, ^{15}N, and ^{17}O and eject them.
- This energetic event can explain the typical "hourglass" or "cloverleaf" shapes many nebulae exhibit.

Image credit: ESA/Hubble & NASA (top)/ESA & Garrelt Mellema (bottom)

DUST GRAINS: COSMIC ROSETTA STONES

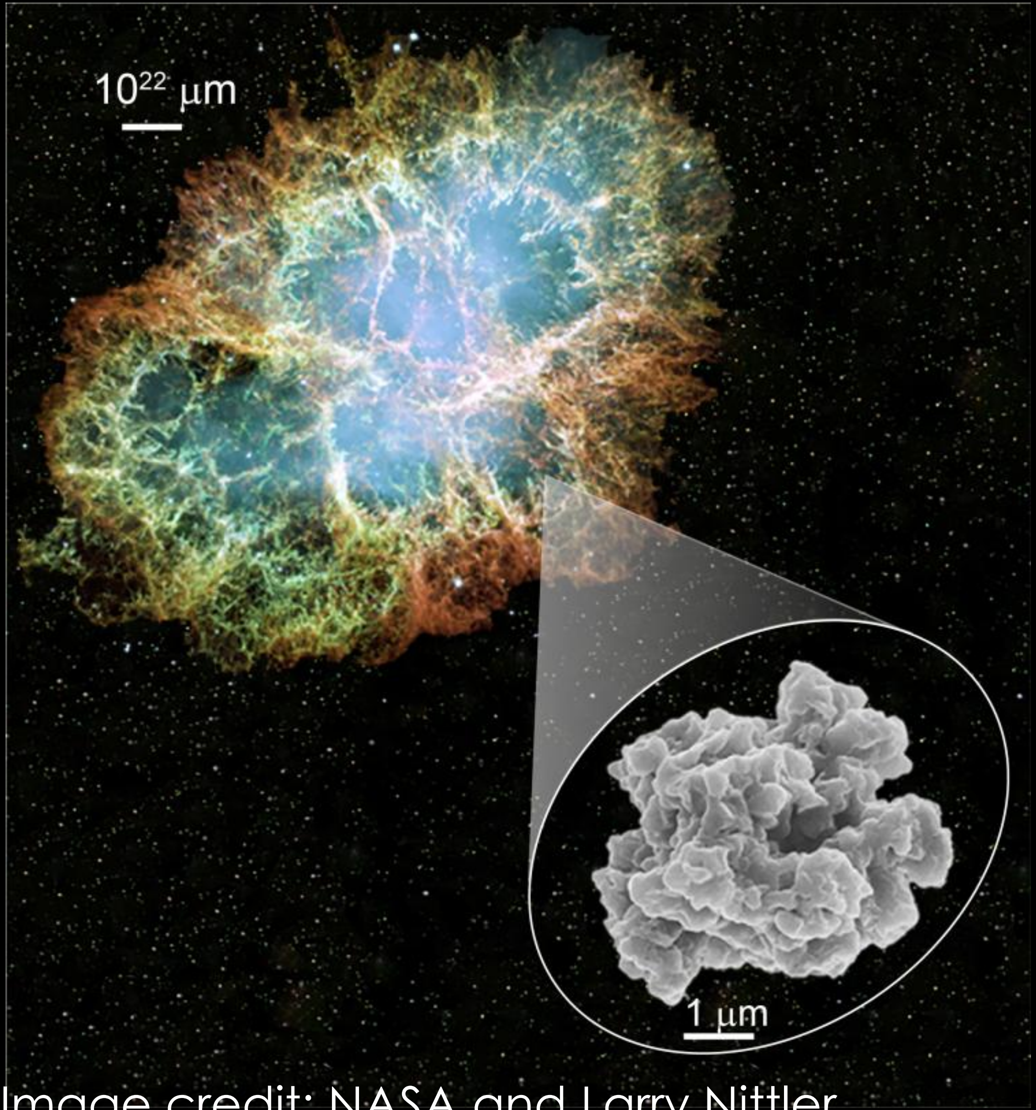


Image credit: NASA and Larry Nittler

- Dust grains are produced in dying stars.
- Some of these grains have been incorporated into meteorites.
- Isotopic ratios measured in these grains provide a window to their history.

FROM PLANETARY NEBULAE TO PLANETS

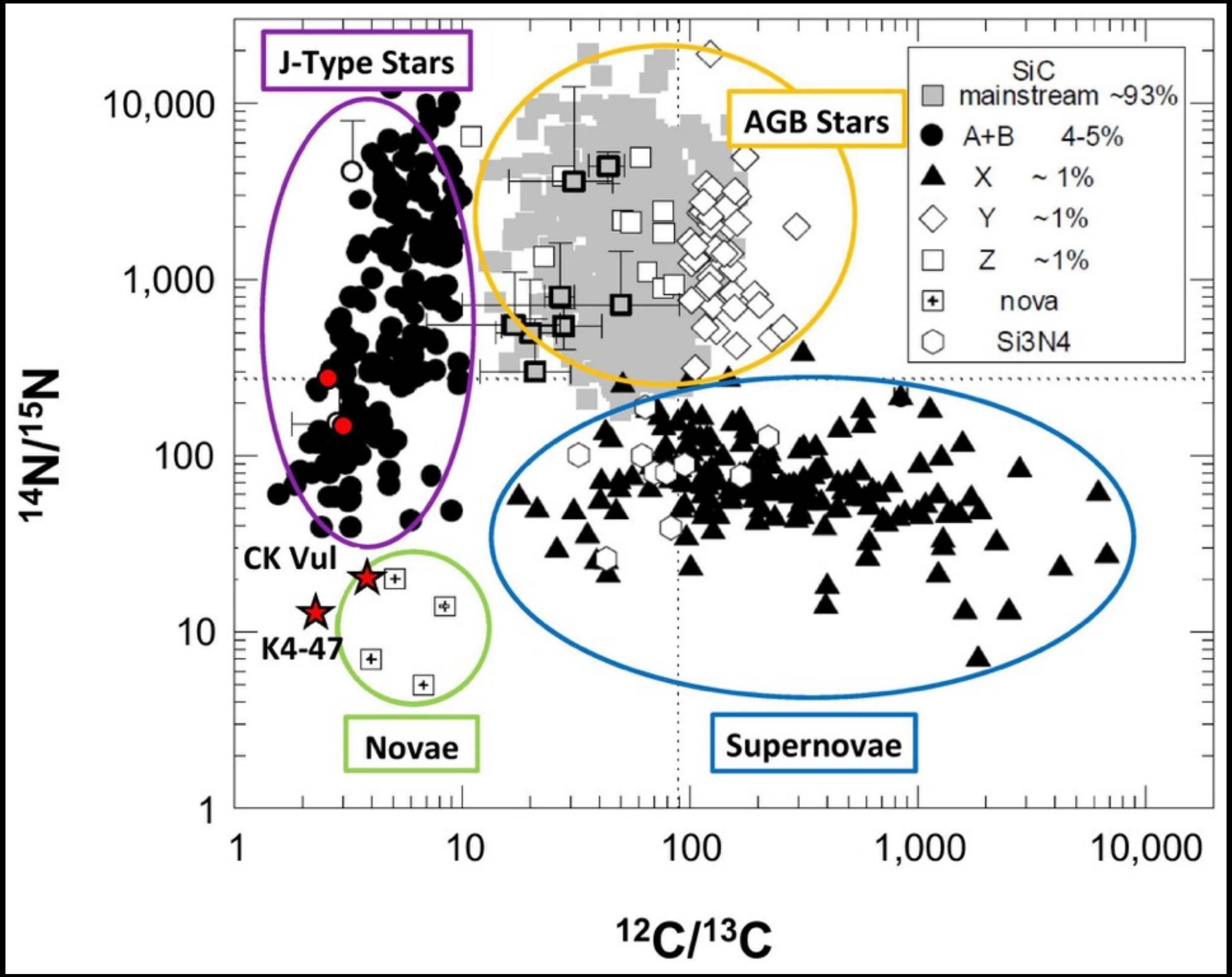


Image credit: Schmidt et al. 2018, *Nature*, 564, 378

- "Nova" grains exhibit low $^{12}C/^{13}C$, $^{14}N/^{15}N$, and $^{16}O/^{17}O$ ratios.
- Models have difficulty replicating these ratios.
- K4-47's isotopic ratios match those of nova grains remarkably well.
- Nova grains may originate from planetary nebulae like K4-47!

CONCLUSIONS

- Against all odds, planetary nebulae are full of molecules!
- These molecules may pollute the interstellar medium from which new stellar systems form.
- Extreme isotopic ratios measured in numerous planetary nebulae indicate an explosive origin.
- These extreme ratios match those of atypical dust grains, suggesting planetary nebulae are their true birthplaces.