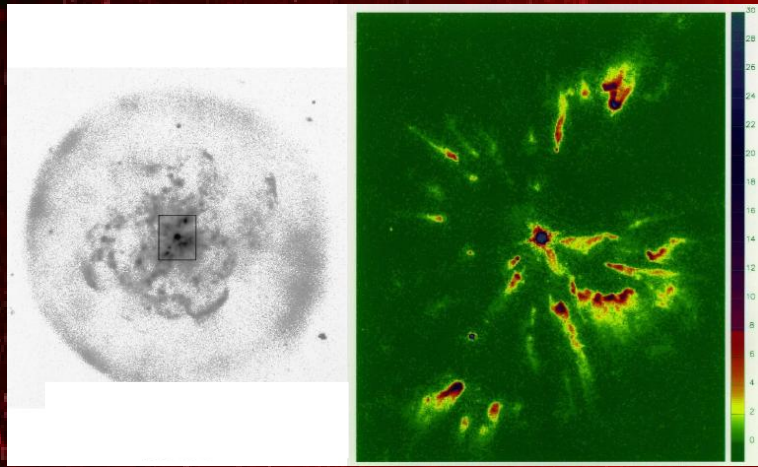


The hydrogen-deficient knot in Abell 58

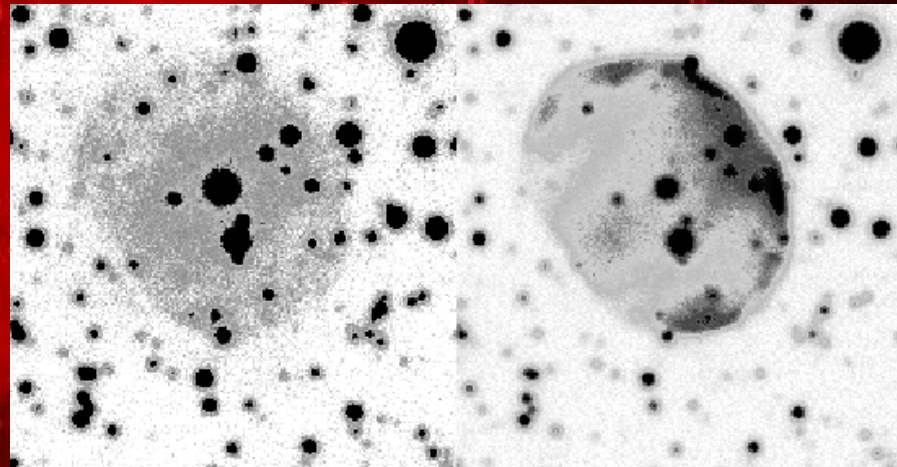
Abell 30



[O III] ground-based

[O III] Hubble Space Telescope

Abell 58



ESO NTT, [O III]

[N II]

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The hydrogen-deficient planetary nebulae

- Very small number of nebulae have visible hydrogen-deficient material in them
- Known examples are Abell 30, Abell 58, Abell 78, IRAS 15154-5258, IRAS 18333-2357
- Typical morphology – large, faint, spherical shell; inner regions knotty and higher surface brightness. Large IR excess indicates a lot of dust.
- Long-held theory of formation – final thermal pulse ejecting freshly processed material into old nebula
- Significance – evidence suggests many or all PNe contain some H-deficient material.

Previous work – Abell 30

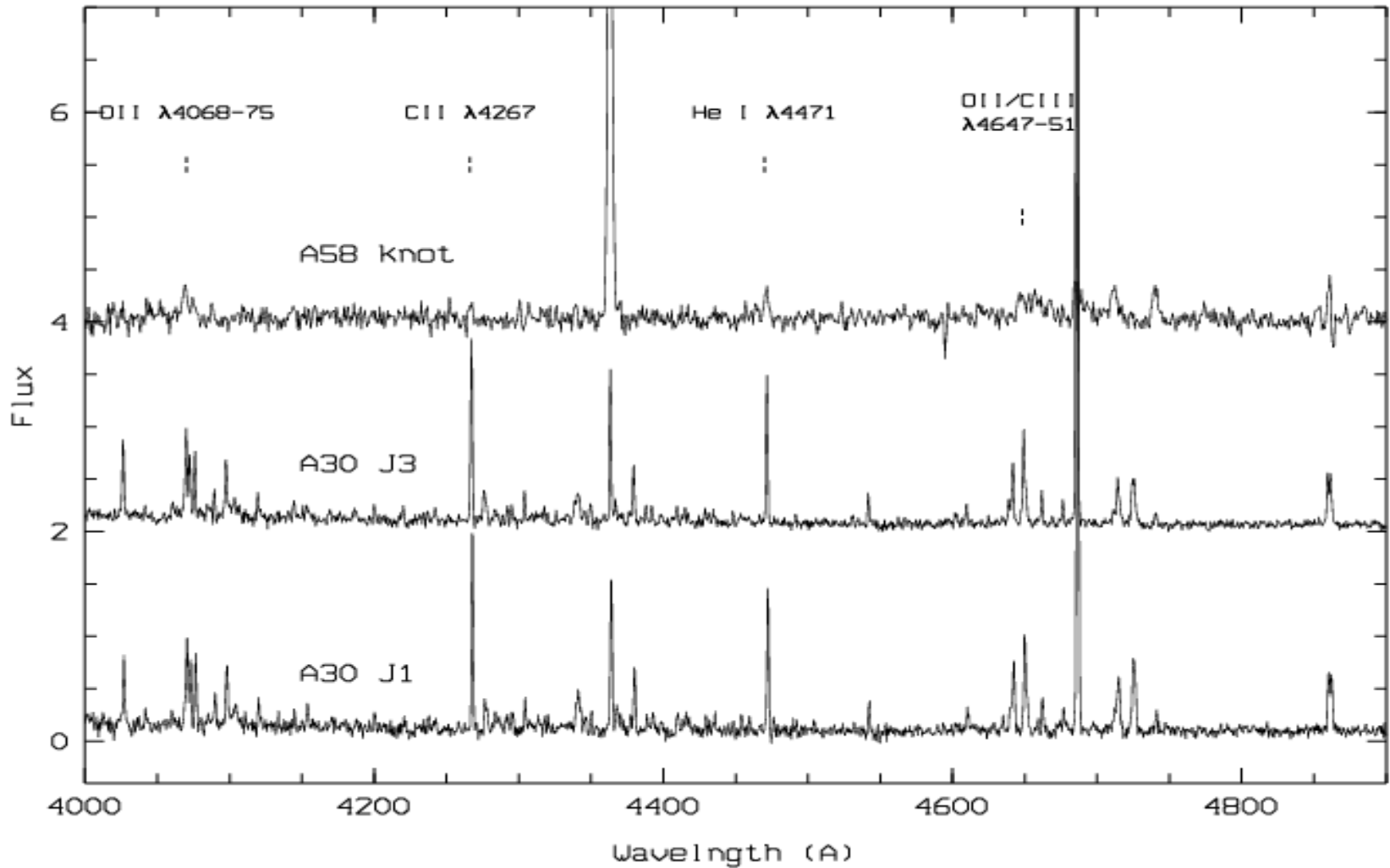
- Long slit spectroscopy of knots J1 and J3 revealed material at very low temperatures
 - Helium line ratios: 4500K (J1) 8850K (J3)
 - O II recombination lines: 500K (J1) 2500K (J3)
- Abundances from collisionally excited lines (CELs) higher than recombination line (ORL) values by x700
- C/O ratio < 1 in both knots
- Collimation of knots is difficult to explain in single-star scenario; C/O < 1 is contrary to predictions of born-again theory
- So, what is happening? Is Abell 30 a unique case or do the other H-deficient nebulae show similar phenomena?

Abell 58 / V 605 Aql

- Old, large, faint shell, discovered by Abell in 1966
- Central star experienced nova-like event in 1917, peaked in brightness in 1919 and remained bright until 1923.
- CS only seen in scattered light. Surface abundances H:He:C:O = 0:54:40:5 (Clayton et al. 2006)
- Knot at the centre of A58 presumed to have formed in 1919. Kinematic studies suggest it is one side of a collimated outflow, the receding side being completely hidden by dust (Pollacco et al. 1992)

Abell 58 / V 605 Aql

New observations, long slit spectroscopy from WHT/ISIS



Abell 58 / V 605 Aql

Standard temperature diagnostics:

$$[\text{O III}] (4959+5007)/4363 \Rightarrow 23,300 \text{ K}$$

$$[\text{N II}] (6548+6584)/5754 \Rightarrow 16,400\text{K}$$

Recombination line diagnostics:

$$\text{He } 5876/4471 \Rightarrow 3,240 \text{ K}$$

$$\text{O II } 4075/4089 \Rightarrow 770\text{K}$$

$$\text{O II } 4649/4089 \Rightarrow <100\text{K}$$

Density

$$\text{CEL diagnostics} \Rightarrow 2000\text{cm}^{-3}$$

Abell 58 / V 605 Aql

Empirical abundance analysis

| | He | C | N | O | Ne |
|------|-------|-------|------|-------|------|
| CELs | - | - | 9.07 | 9.90 | 9.87 |
| ORLs | 12.56 | 10.79 | - | 12.31 | - |

- C/O measured from ORLs is 0.06. Born-again theory predicts carbon-rich knots.
- ORL abunds hugely exceed CEL values.
 $\text{adf}(\text{O}/\text{H}) = 257$.
- cf. A30: $\text{adf}(\text{O}^{2+}/\text{H}^+) = \sim 700$.
- Hf 2-2: $\text{adf}(\text{O}^{2+}/\text{H}^+) = 80$
- NGC 1501: $\text{adf}(\text{O}^{2+}/\text{H}^+) = 32$

Abell 58 / V 605 Aql

Comparison with Abell 30 – similarities and differences

Similarities:

Nebular morphology, low temperature plasma present, very high $\text{adf}(\text{O}^{2+})$, $\text{C/O} < 1$

Differences:

Knot expanding at $\sim 200 \text{kms}^{-1}$ – A30 knots $< 20 \text{kms}^{-1}$
N/O (from CELs) is \sim solar in A58, more like average PN value in A30
Excitation much lower in A58 than in A30

Abell 58 / V 605 Aql

Comparison with V4334 Sgr (Sakurai's object)

Similarities

Nova-like events followed similar course. RCB-type spectrum near maximum brightness.

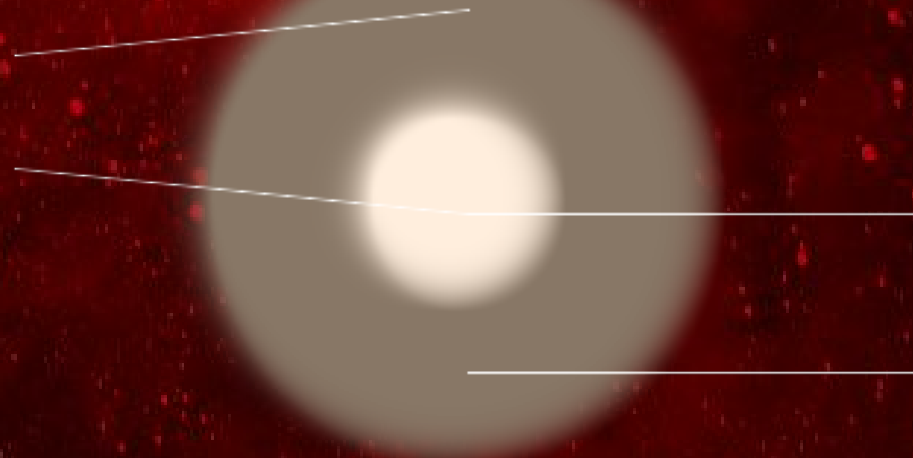
Differences:

Material ejected in Sakurai's object is expanding at 1000kms^{-1} – A58 is 200kms^{-1} . Moving away from star at several hundred kms^{-1} – A58 knot moves at 40kms^{-1} . Abundances in Sakurai's object ejecta not known. Are they carbon- or oxygen-rich?

Abell 58 / V 605 Aql

- *MOCASSIN* allows fully self-consistent modelling of arbitrary distributions of dust and gas with varying abundances
- Dust heating dominates thermal balance across knot.
- Modelling demonstrates plausibility of cold H-deficient core and hot outer envelope concept

Helium ORL emission has contributions from both the core and the knot



Heavy element recombination lines come from the core

CEL emission comes from the hot outer shell

Abell 58 / V 605 Aql

Conclusions:

- Central knot of Abell 58 is oxygen-rich, as are the knots of Abell 30
- O/H from recombination lines is 250 times higher than O/H from collisionally excited lines
- O II recombination line ratios imply very low temperatures
- Modelling supports concept of cold (<5000K) extremely H-deficient core surrounded by hot envelope

Abell 58 / V 605 Aql

Open questions

- Can a VLTP produce O-rich ejecta?
- Do the five H-deficient nebulae share a common formation mechanism?
- Are they related to classical novae rather than VLTPs?
- If H-deficient material exists in all PNe, as suggested by numerous large studies, does it have a similar origin to these H-deficient knots?