Neutron-capture Emission Lines in Planetary Nebulae from EMIR Spectra

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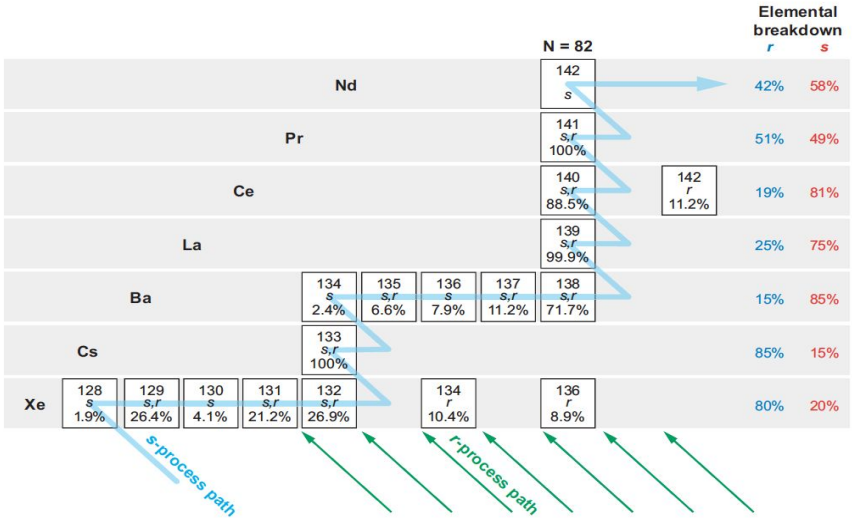
The s-process

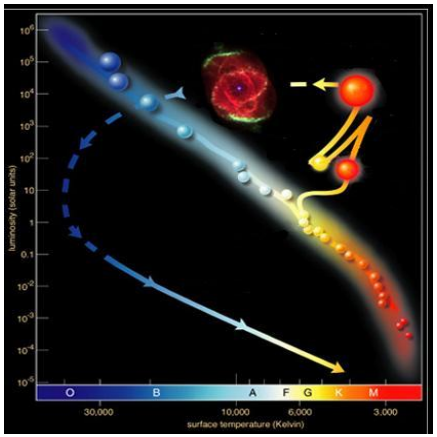
Half of the heavy elements (Z>30) present in the Universe are formed in slow neutron-capture nucleosynthesis (*s-process)* during the AGB phase

Nebular spectroscopy gives us an excellent opportunity to test theoretical nucleosynthesis models in AGB stars

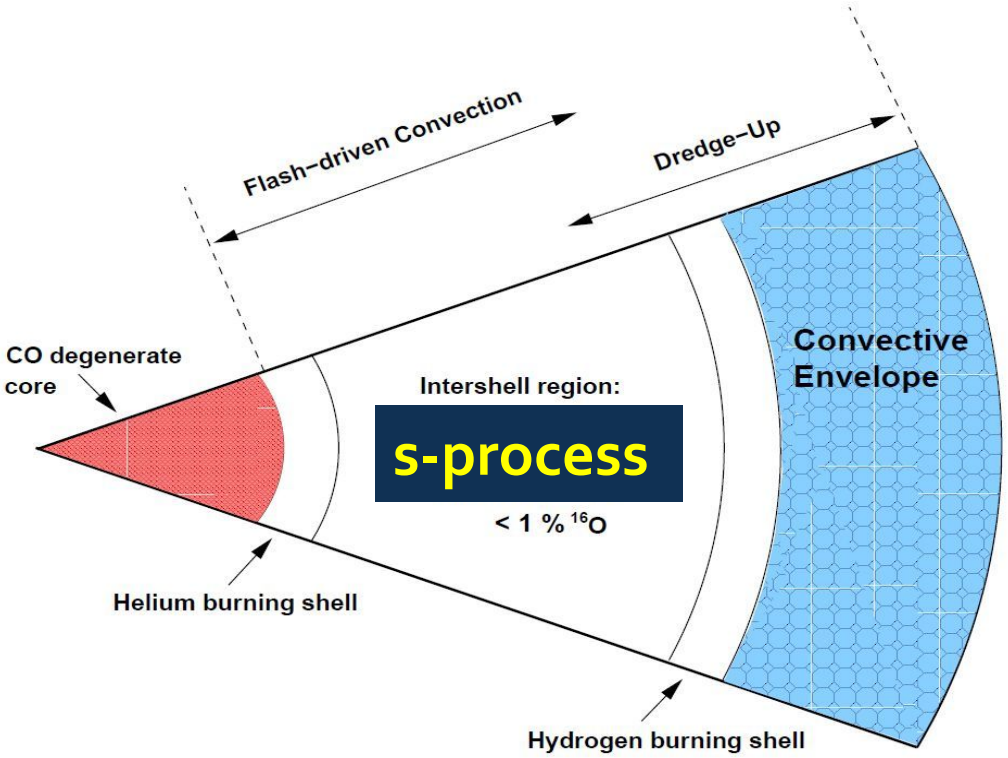
s-element abundances are useful to study the evolution of low-to intermediate AGB stars

Heavy elements can also be processed in explosive events such as Supernovae or neutron star mergers through the rapid neutron-capture nucleosynthesis (the r-process)



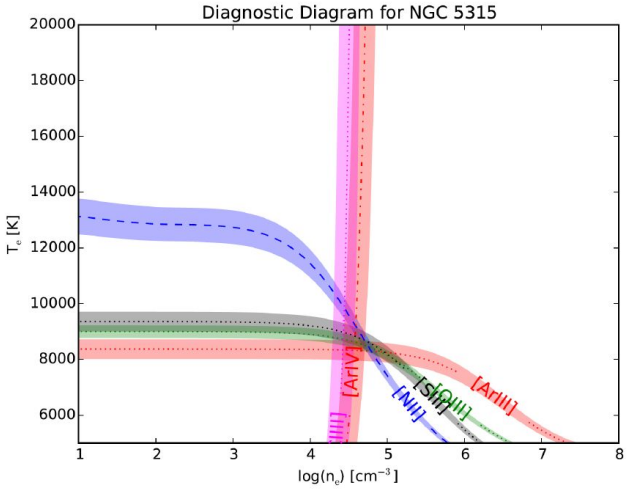


The s-process



The Data Analysis

Madonna et al. (2017)



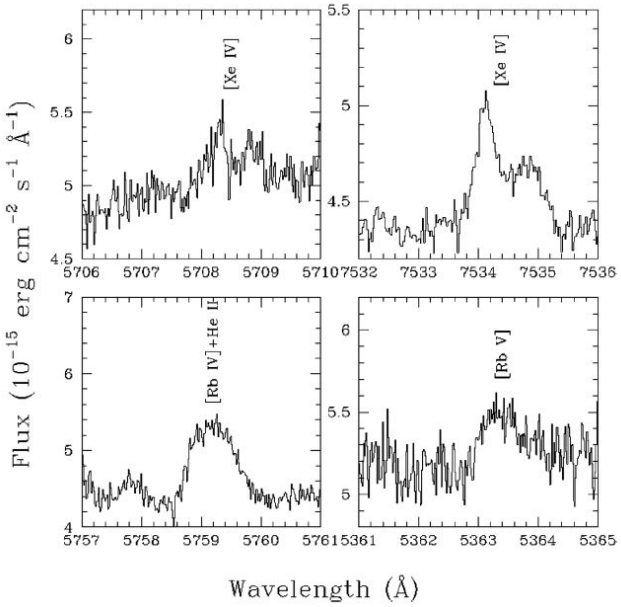
We use PyNeb (Luridiana et al. 2015): python-based package

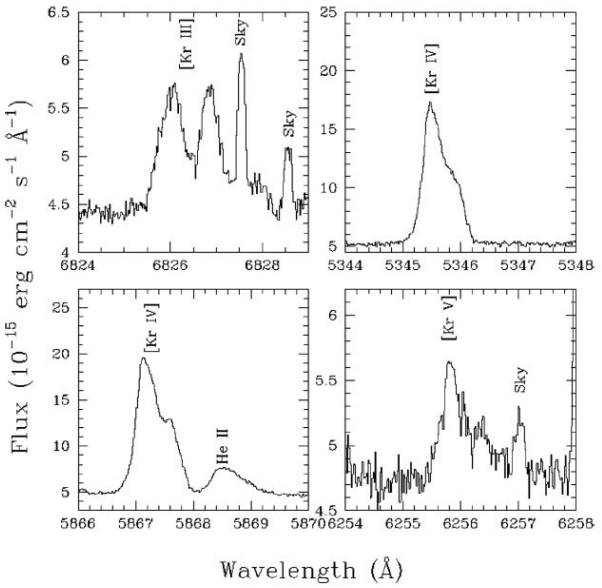
Ionic Abundances → ICFs → Elemental abundances

ICFs from Delgado-Inglada et al. 2014 for common elements (O, Ar, Cl, S…)

Optical detections of s-elements

NGC3918





García-Rojas, Madonna et al. (2015)

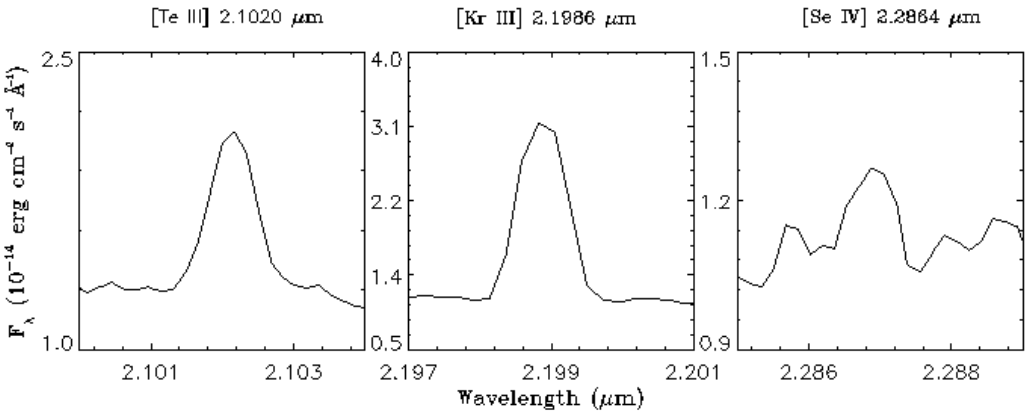
The optical range is home of multiple neutron-capture lines

Neutron-capture elements detectable in the optical and NIR range

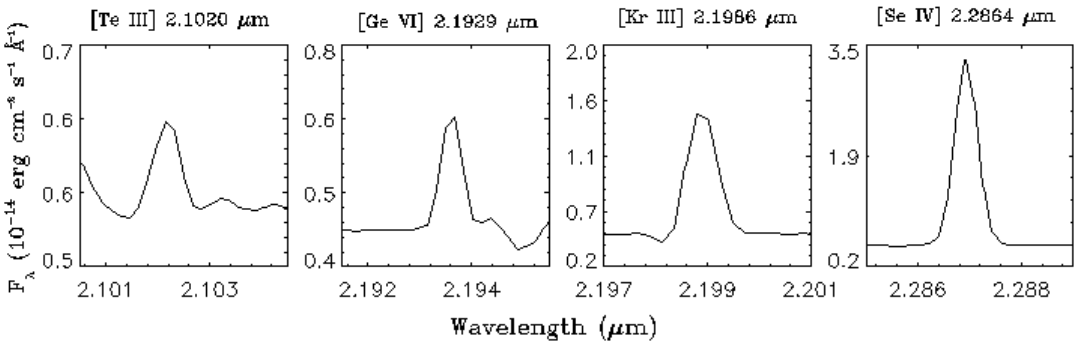
Element	Optical	NIR
Ge		Ge^{5+}
Se	Se^{2+}	Se^{2+}, Se^{3+}
Br	Br^{2+}	Br^{4+}
Kr	Kr^{2+}, Kr^{3+}, Kr^{4+}	Kr^{2+}, Kr^{5+}
Rb	Rb^{3+}, Rb^{4+}	Rb^{3+}
Cd		Cd^{3+}
Te	Te^{2+}	Te^{2+}
Xe	Xe^{2+}, Xe^{3+}, Xe^{4+}, Xe^{5+}	Xe^{2+}

The EMIR Data

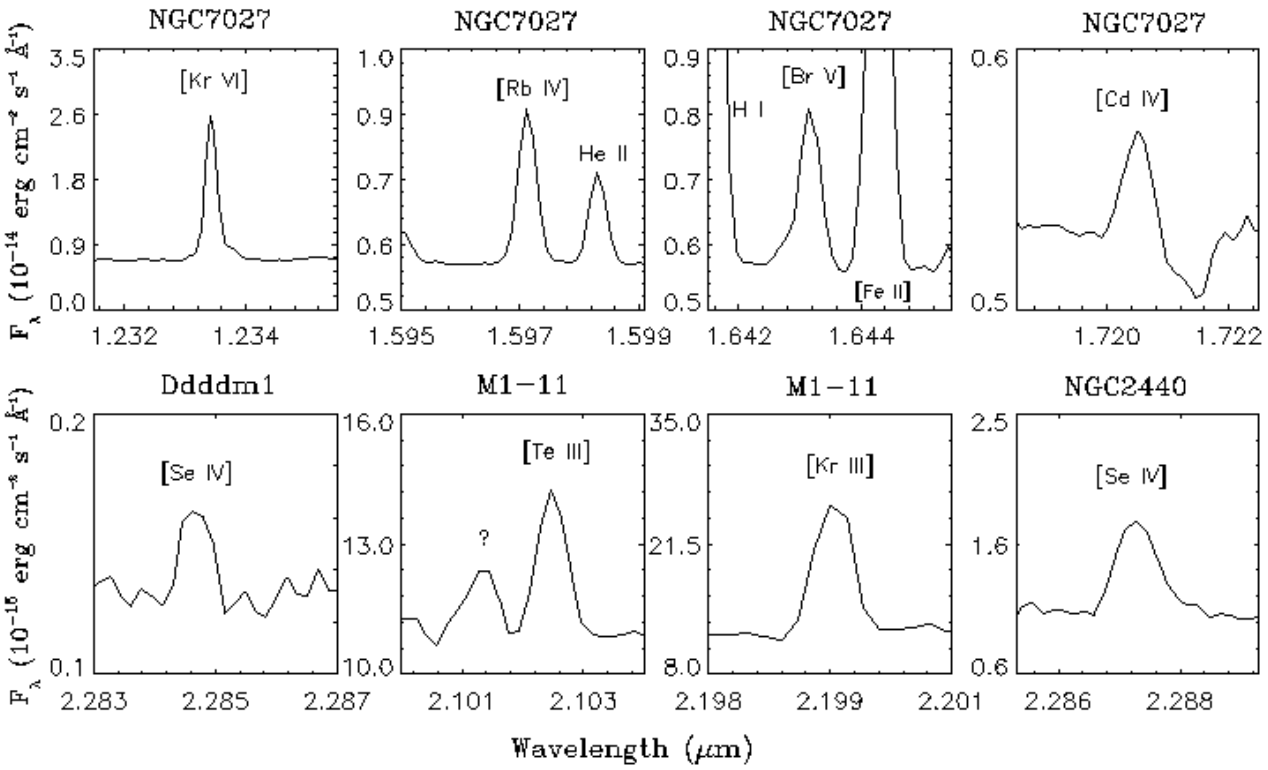
IC418



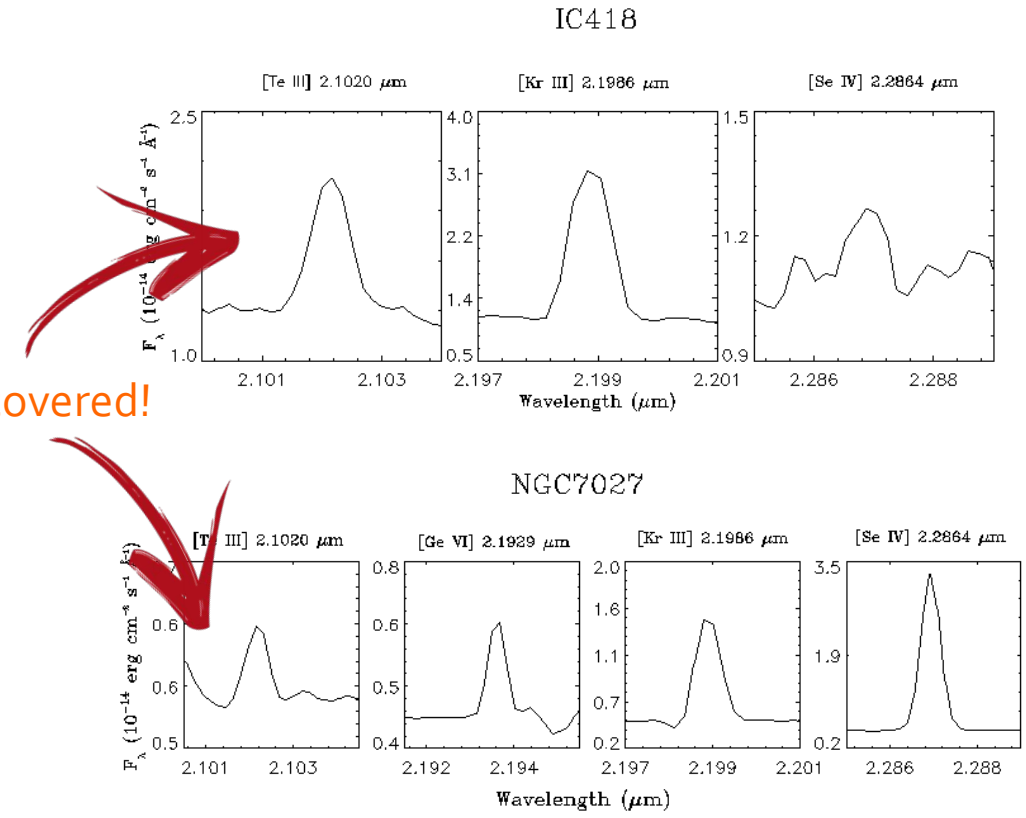
NGC7027



The EMIR Data



Remarkable EMIR Results: the discovery of new emission lines

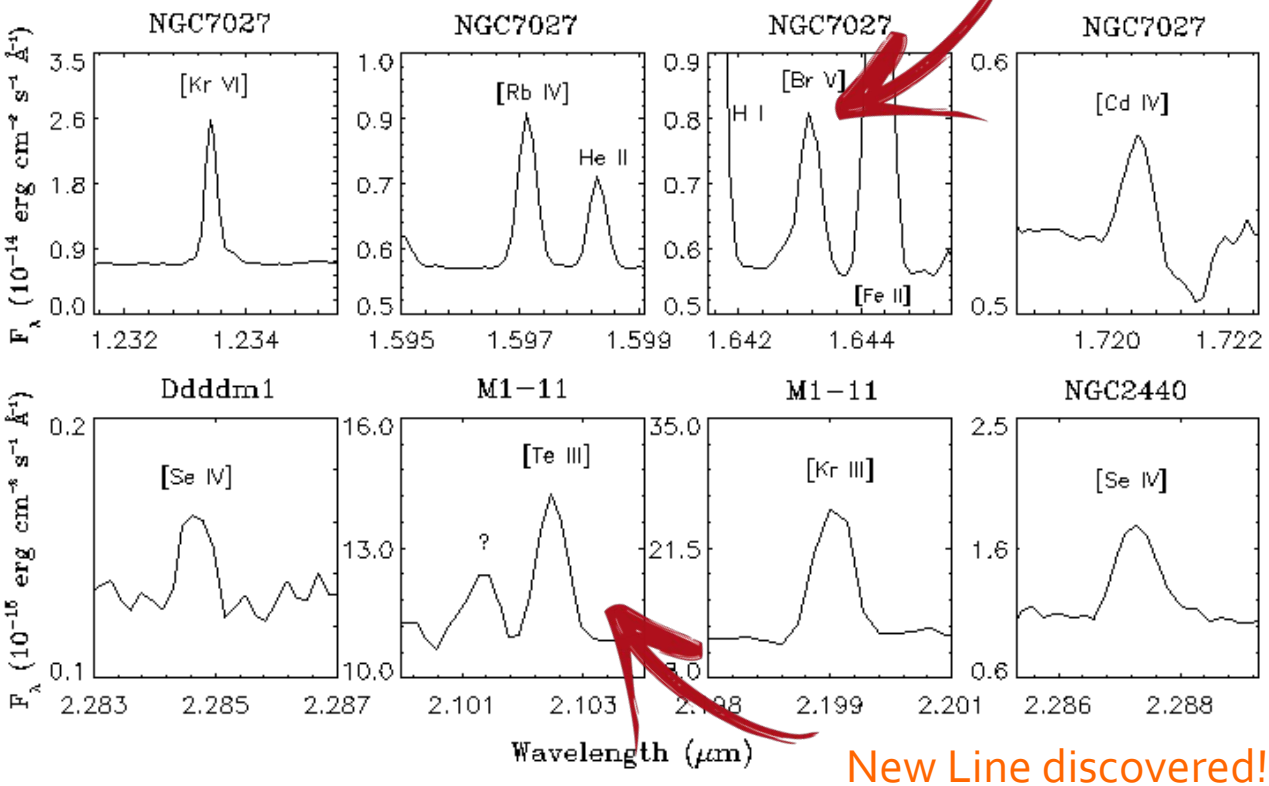


New Lines discovered!

Madonna et al. (in prep.)

Remarkable EMIR Results: the discovery of new emission lines

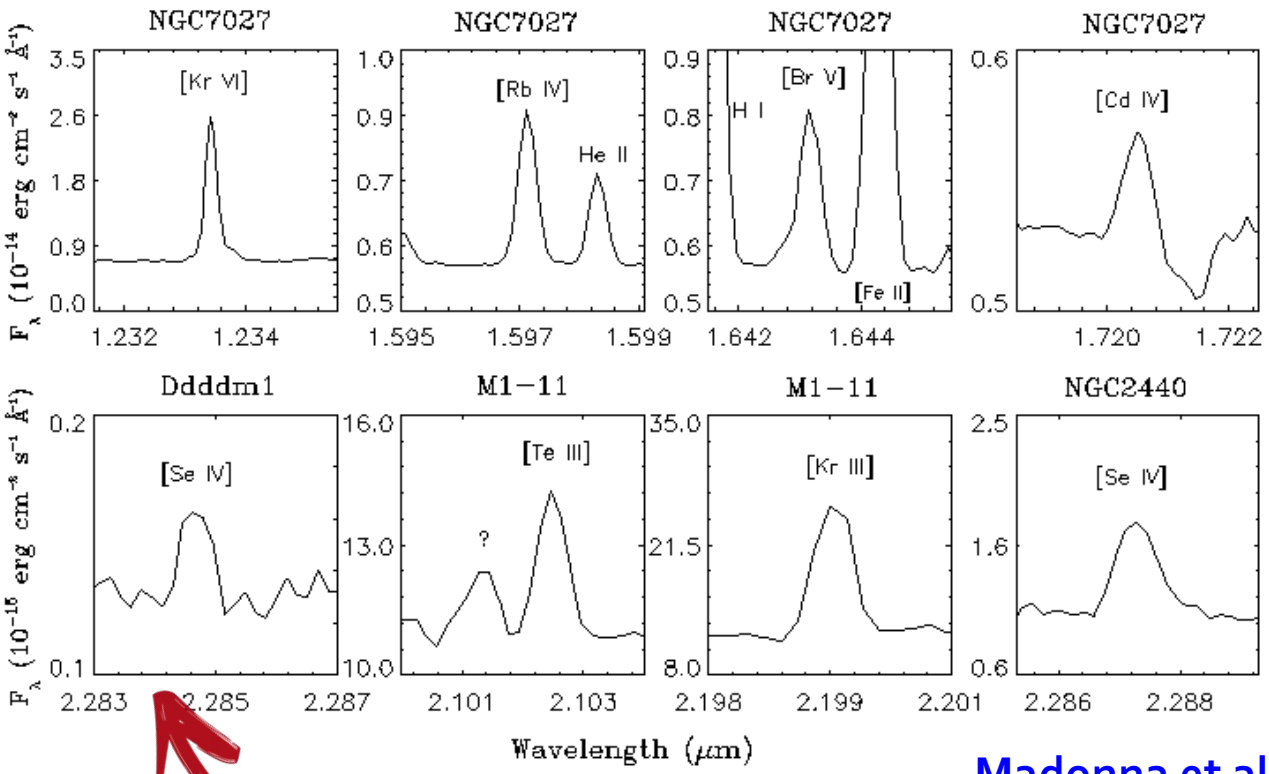
New Line discovered!



New Line discovered!

Madonna et al. (in prep.)

Remarkable EMIR Results: detection in a Halo PN



Madonna et al. (in prep.)

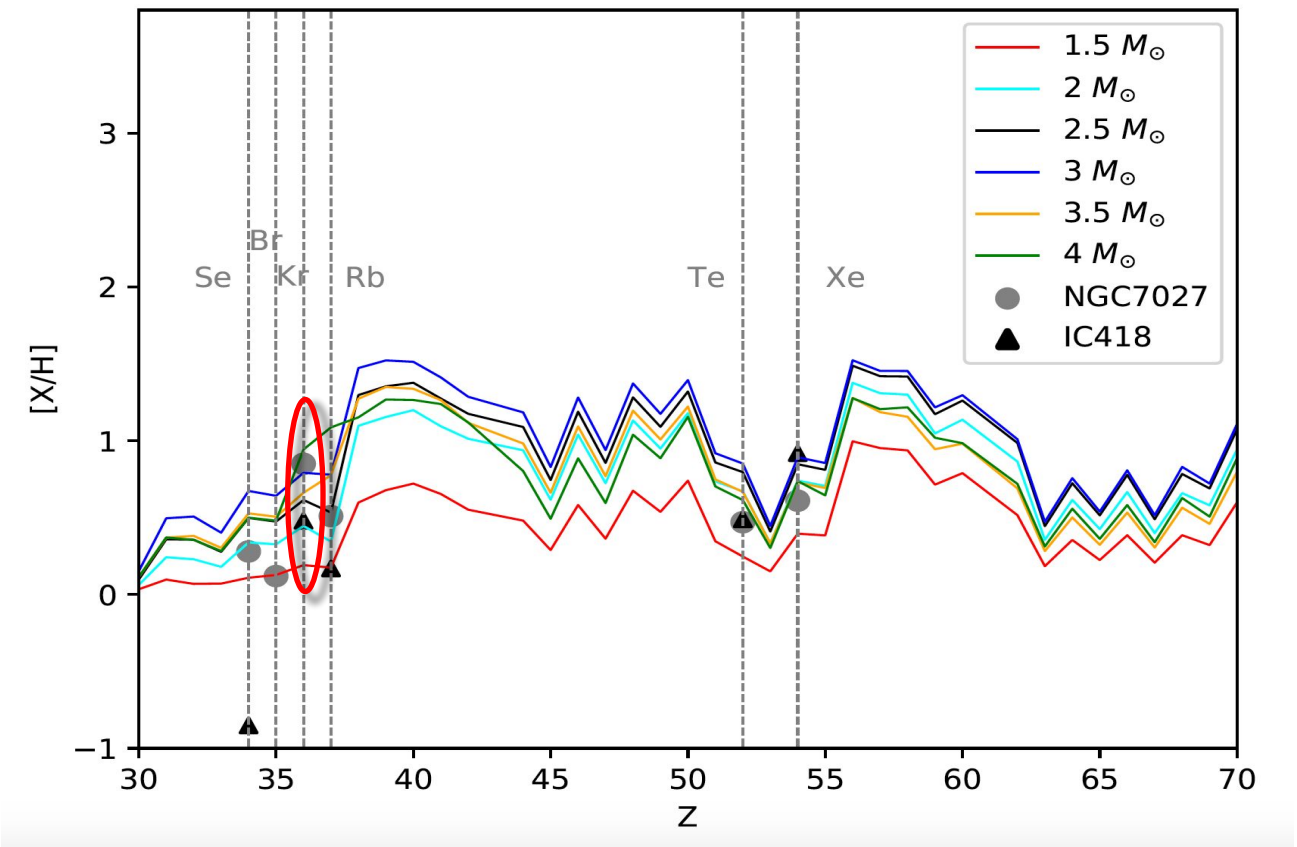
First detection > 3σ in a Halo PN

Remarkable EMIR Results: Testing New ICFs in NGC7027

Element	ICF	Abundance	[X/Ar]	Ions Used by the ICF
Se	Sterling 2015 eq. 7	3.66±0.27	0.46	Se^{2+}
Se	Sterling 2015 eq. 8	3.66±0.13	0.46	Se^{3+}
Se	Sterling 2015 eq. 9	3.57±0.21	0.37	(Se^{2+}+ Se^{3+})
Kr	Sterling 2015 eq. 1	$4.09^{+0.24}_{-0.16}$	0.96	Kr^{2+}
Kr	Sterling 2015 eq. 2	4.06±0.17	0.93	Kr^{2+}
Kr	Sterling 2015 eq. 3	4.10:	0.97	Kr^{3+}
Kr	Sterling 2015 eq. 4	4.10±0.10	0.97	(Kr^{2+}+ Kr^{3+})
Kr	Sterling 2015 eq. 5	$4.17^{+0.31}_{-0.20}$	1.04	(Kr^{3+}+ Kr^{4+})
Kr	Sterling 2015 eq. 6	4.14±0.08	1.01	(Kr^{2+}+Kr^{3+}+ Kr^{4+})

NIR Data from EMIR; Optical Data from Zhang et al. (2005)

Remarkable EMIR Results: Observations Vs Theoretical Models



Theoretical models from Karakas & Lugaro (2016)

Future Observations with EMIR

- EMIR proposal on semester 2017B: IC418, M1-11, IC2165, NGC2440, M1-12 and M1-17. We have obtained data for IC418 (H-band and K-band)
- Search for new or recently discovered lines:

  YJ band: [Se III] 1.099, um [Xe III] 1.0207 um [Kr VI] 1.2330 um
  H band: [Rb IV] 1.5974 um, [Br V] 1.6429 um, [Cd IV] 1.7204 um
  K band: [Te III] 2.1021 um, [Ge VI] 2.1929 um

- Neutron-capture elements in Halo PNe

- Further nights for EMIR observations (2018A): we aim to conduct a NIR survey of neutron-capture element detections with unprecedented accuracy