Binary Stars in Planetary Nebulae with Gaia DR2

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Abstract: Gaia Data Release 2 was used to select a sample of 211 central stars of planetary nebulae (CSPNe) with good quality astrometric measurements, that we called it *Golden Astrometry Planetary Nebulae (GAPN).* Gaia astrometry allowed us to derive accurate distances and radii, and to calculate luminosities with the addition of self-consistent literature values for magnitudes and extinctions. The extremely accurate measurements of parallaxes and proper motions in Gaia DR2 have allowed us to search for co-moving wide binary companions in a region close to each of the nebulae in the GAPN sample. We also studied the spectral energy distribution (SED) of the binary pairs to check the consistency of spectral types and masses in order to better constrain the ages and evolutionary state of the CSPNe.

Context

- In a previous work (*González-Santamaría et al. 2019*), we used **Gaia Data Release 2** (GDR2) to select a sample of 211 central stars of planetary nebulae (CSPNe) with good quality astrometric measurements. We called it the *Golden Astrometry Planetary Nebulae (GAPN)*.

- From GDR2 astrometry we were able to estimate the **distances** to these PNe. Then, together with literature data, we could derive other properties as nebular radii or CS luminosities.

- Such information was used to plot the position of the stars in a HR diagram and to study their **evolutionary status** in comparison with CSPNe evolutionary tracks.

Methodology

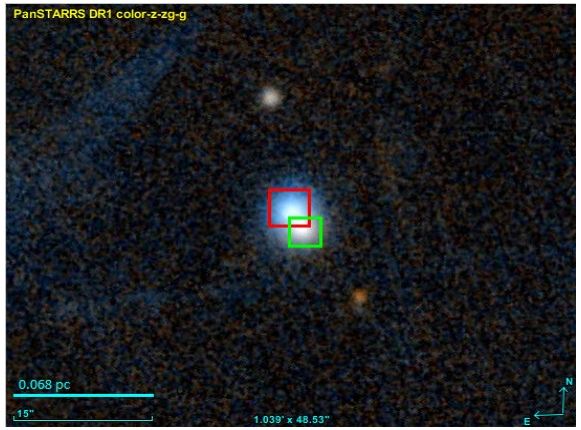
- The extremely precise measurements of **parallaxes** and **proper motions** in Gaia DR2 has allowed us to search for co-moving stars in a region around each CS of the GAPN sample.

- We selected those objects with similar parallaxes and proper motions as the CS, limiting our search to a region around **15,000 AU** of each CS to minimize accidental detections, and only considering stars with good parallax and proper motions data (with errors below 30% in DR2).

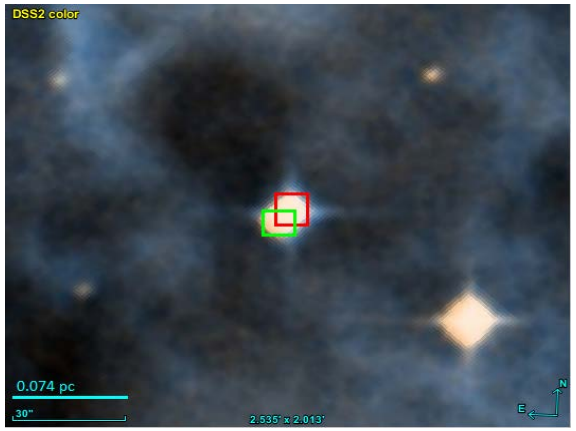
- We also did a study to estimate the **probability** of each match of being by chance, obtaining a very low values. It consists on obtaining the probability distribution of the astrometric parameters around the area of each nebulae, and then estimate the probability for a random object to have the same parameters as the CS.

Results

- We found wide **binary systems** as CSs in **8** PNe of our GAPN sample. One of them could even be a triple system.
- We have determined some astrometric parameters of these binary systems, as **positions**, **proper motions** or angular and physical **separations**.
- We also analyzed the **spectral energy distribution (SED)** of the companion stars to estimate their **temperatures** and **luminosities**.
- Then, together with *PARSEC* isochrones in Gaia DR2 passbands, we were able to derive some of their **masses** and **ages**. This task is in process yet…



Abell 33



NGC 246

Object	G	$G_{BP} - G_{RP}$	$A(V)$	T_{eff} (kK)	$log(L/L_{\odot})$	$Mass_i$ ($M_{\odot}$)	Age_{evo} (Myr)	log(g)
Abell 24 (CS)	17.41	-0.61	0.195	137.0	1.703	>3.00	437	-
Abell 24 (B)	15.67	1.08	0.195	5.1	-0.545	0.761	1800	2.0
Abell 33 (CS)	15.96	-0.37	0.003	100.0	2.04	1.131	6907	-
Abell 33 (B)	16.67	-	0.003	4.6	-0.787	0.676	4935	2.5
Abell 34 (CS)	16.42	-0.60	0.126	98.0	2.079	1.001	9244	-
Abell 34 (B)	14.85	0.88	0.126	5.9	0.102	0.908	9400	2.5
NGC 246 (CS)	11.81	-0.65	0.062	150	3.688	1.493	2460	-
NGC 246 (B)	14.19	0.93	0.062	4.7	-0.241	0.846	3300	3.5
NGC 3699 (CS)	17.60	-0.17	1.357	-	-	-	-	-
NGC 3699 (B)	16.54	1.10	1.357	6.6	0.227	1.161	200	3.5
NGC 6853 (CS)	14.03	-0.59	0.14	135.0	2.44	1.494	2452	-
NGC 6853 (B)	16.12	1.30	0.14	3.6	-1.127	0.587	1100	3.5
NGC 6853 (C)	18.99	-	0.14	3.3	-1.860	0.347	8785	-0.5
PHR J1129-6012 (CS)	17.26	1.06	-	-	-	-	-	-
PHR J1129-6012 (B)	17.12	1.06	-	4.9	-0.019	0.857	9900	5.0
PN SB 36 (CS)	15.25	1.23	-	-	-	-	-	-
PN SB 36 (B)	14.62	0.93	-	5.5	0.277	0.955	>10000	0.0

Impact and prospects for the future

- The presence of binary stars in PNe allow us to better understand the **formation** and **evolution** of this late stellar evolutionary phase. It can also shed some light on its relationship with the aspherical **morphologies** of PNe.

- In the near future, with the launching of **Gaia DR3**, it is expected to be more cuantity of astrometric data and with more accuracy. This will allow us to detect more binary systems associated to PNe.