The GALEX Observations of Planetary Nebulae.

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Abstract

We present the first ultraviolet (UV) photometric observations of planetary nebulae (PNe) using observations made by Galaxy Evolution Explorer (GALEX). We found about 112 PNe observed by GALEX. We have determined the angular diameter of PNe in NUV and also in FUV for whichever source detection exists considering a 3σ emissione level above the background. Of the PNe, 20% are elliptical, 7% are bipolar and rest are circular in UV. The emission lines contributing to GALEX FUV flux are strong OV, C IV, and He II while the emission line contributing to the NUV flux are C III] and He II.

Introduction to planetary nebulae

- PNe are the end product of the stars of masses between 0.8 M⊙ and 8 M⊙. A planetary nebula (PN) consists of a hot, luminous central star and an expanding glowing shell of gas and dust.
- More than 3000 PNe have been detected in the Milky Way which are catalogued by **Parker et al. (2006)** and **Acker et al. (1992)**.
- The central star of most of the PNe (CSPNe) is very hot object which is bright in UV and hence, the UV observations explore the properties of these objects.

Angular sizes of PNe

- The angular size of PN is one of the most important observational entity, which is used in determining nebular distance and masses of the PN.
- Several methods such as direct measurements at the 10% level of the peak surface brightness, Gaussian deconvolution, second-moment deconvolution, etc., have been employed to measure the angular dimension of PNe that are observed by varoius techniques **(Tylenda et al. 2003, van Hoof et al. 2000)**.
- We have measured the angular diameter of 112 PNe which were detected by GALEX survey.

GALEX Obervation

- GALEX has covered 75% of the sky in two UV bands, FUV and NUV, simultaneously, with spatial resolution of **4.2″** and **5.3″**, respectively **(Morrissey et al. 2007)**.
- We have downloaded all the GALEX GR7 data from MAST archive.
- We searched the GALEX data base using the Vizier catalogue of galactic PNe by **Acker et al. (1992)** and the MASH catalogue of PNe by **Parker (2006)**. We detected a total of 112 PNe in GALEX database.
- Most of these objects are from AIS survey except a few, which are from MIS survey of GALEX. However, 39 of the PNe in the list have both the FUV and NUV detections. We have shown all the 112 PNe in an Aitoff projection in Galactic coordinates in figure 1.

IUE Spectra of a PN

We found several of the PNe in our GALEX detected have IUE spectra. We have obtained the low dispersion spectrum from SWP01741 and LWR01635 for PN G358.3-21.6, which is a high excition PN. Since GALEX and IUE have almost the similar wavelenth coverage, we have shown the filter response curves of the GALEX FUV and NUV filters on the combined IUE (SWP01741 + LWR01635) spectra (figure 2). The prominent emission lines seen in the spectrum are H I, O V, C IV, He II, CIII], He II, [Mg V], and O III. The emission lines contributing to GALEX FUV flux are strong OV, C IV, and He II while the emission line contributing to the NUV flux are C III] and He II.

Distribution of PNe detected by GALEX

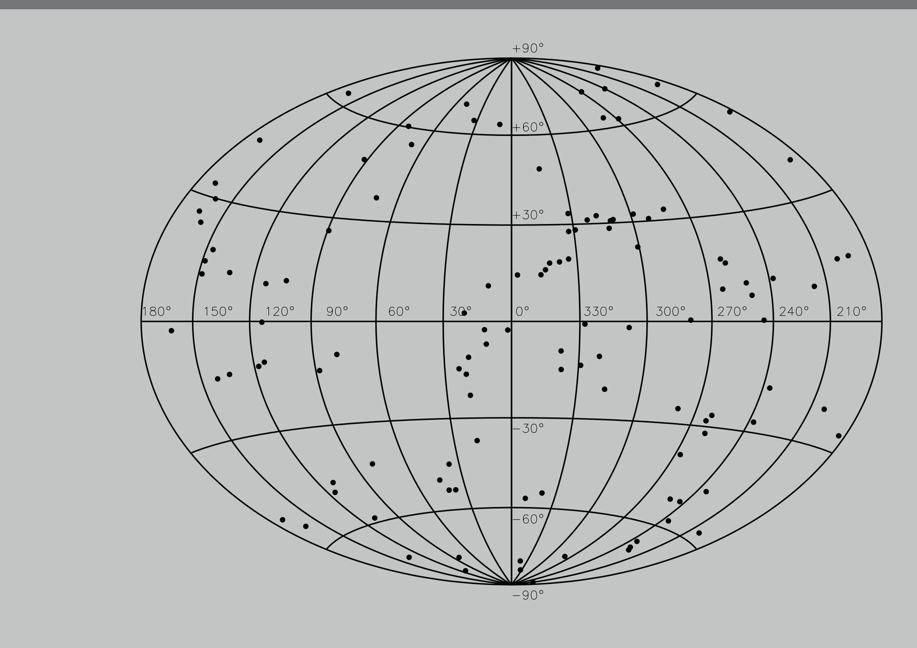

Figure 1: Distribution of PNe detected by GALEX are shown in an Aitoff projection in Galactic coordinates.

IUE spectrum of PN G358.3-21

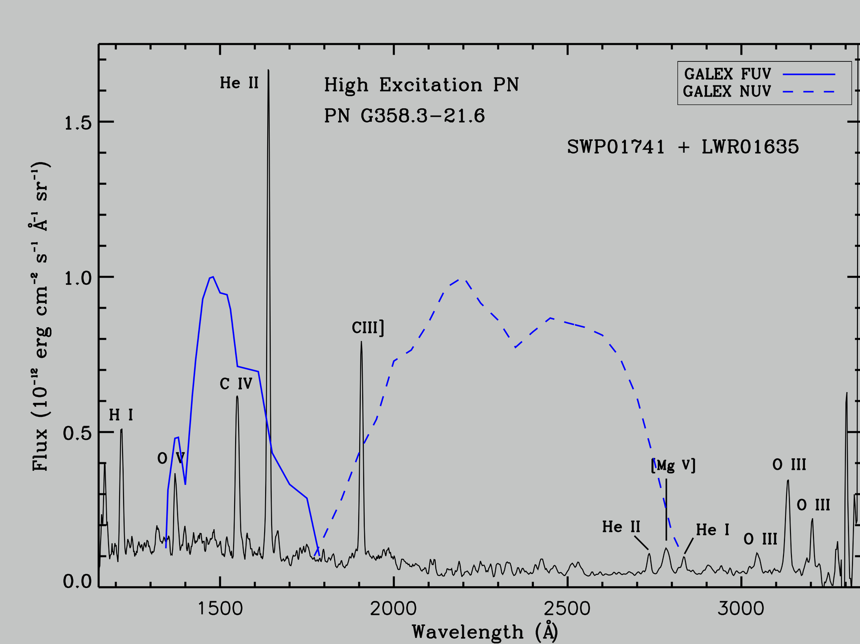

Figure 2: IUE spectrum of PN G358.3-21.6 and the spectrum is smoothed by three points. The blue solid and dashed lines are the effective area curves of GALEX FUV and NUV filters, respectively.

Variation of flux across a PN

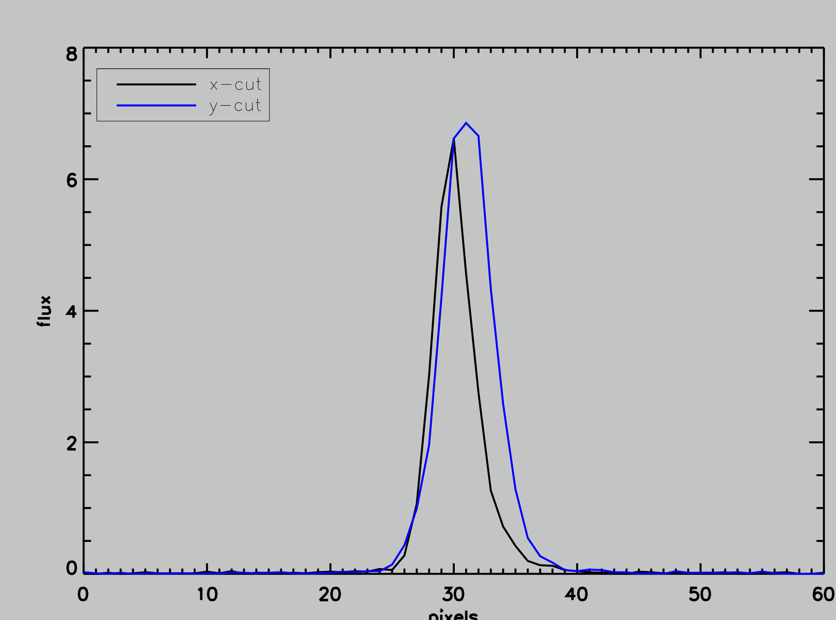

Figure 3: X and Y pixel values of a PN is shown here to know its expansion in UV.

NUV images of a few PNe

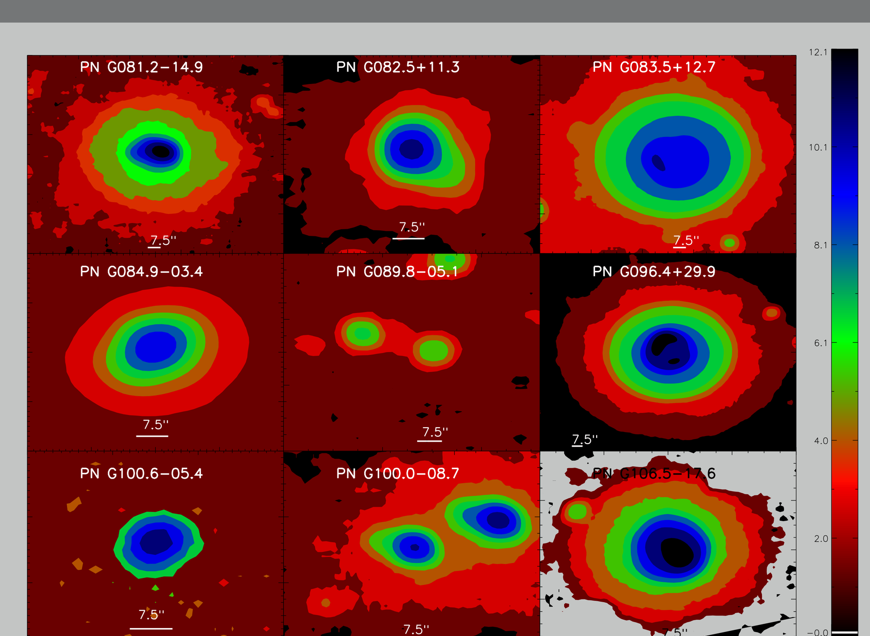

Figure 4

FUV images of a few PNe

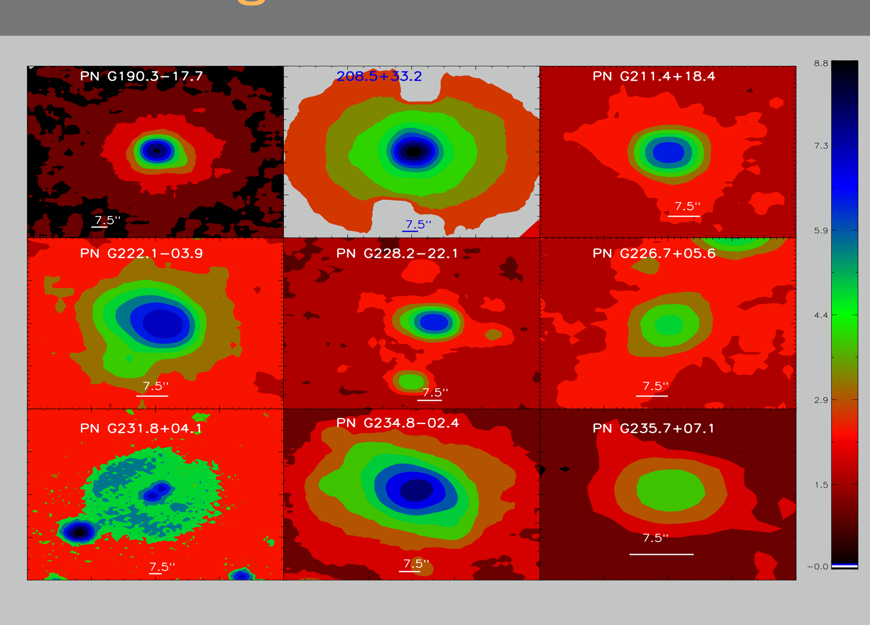

Figure 5

UV details of a few PNe

Table: 1: Measurements of sizes of a few PNe.

PNG No.	Ra (J2000) hr min sec	Dec (J2000) deg min sec	NUV (AB mag)	NUV_{err}	FUV (AB mag)	FUV_{err}	NUV size (arcsec)	FUV size (arcsec)	V size (arcsec)
005.2-18.6	19 14 23.37	-32 34 17.63	17.59	0.03	17.21	0.04	11.22x12.07	8.50x9.18	4.98
012.5-09.8	18 50 26.01	-22 34 22.45	17.18	0.03	17.07	0.04	12.92x15.82	14.79x12.75	3.6
013.3+32.7	16 21 4.47	0 -16 9.92	13.76	0.00	13.45	0.00	27.89x30.10	24.15x29.76	3
028.0+10.2	18 6 0.72	0 22 39.13	17.39	0.03	16.87	0.03	14.45x16.83	16.83x14.28	36
032.1+07.0	18 24 44.50	2 29 28.35	18.91	0.07	19.11	0.11	8.50x8.50	8.1x6.8	2.82
032.9+07.8	18 23 21.69	3 36 28.71	19.05	0.08	19.40	0.14	12.07x11.73	6.97x6.46	4.98
044.3+10.4	18 34 2.61	14 49 20.51	17.31	0.03	16.56	0.03	14.79x18.19	14.62x12.92	13.5
059.7-18.7	20 50 2.15	13 33 28.93	14.51	0.01	13.80	0.01	22.96x21.25	20.91x15.64	127.38
061.9+41.3	16 40 18.20	38 42 20.56	14.44	0.01	14.18	0.01	27.55x27.89	20.24x24.32	1.08
066.7-28.2	21 36 52.93	12 47 20.97	12.77	0.00	12.02	0.00	96.59x105.10	40.81x44.72	94.8
072.7-17.1	21 16 52.31	24 8 51.49	15.73	0.01	15.17	0.02	20.40x17.85	15.81x16.15	830.4
081.2-14.9	21 35 29.48	31 41 46.74	12.66	0.00	12.06	0.00	70.23x75.17	59.86x62.07	106.98
096.4+29.9	17 58 33.66	66 37 58.15	19.33	0.12	11.11	0.00	115.30x115.98	101.70x102.04	38.22
107.6-13.3	23 22 58.00	46 53 58.25	14.19	0.01	13.81	0.01	30.44x32.14	24.82x30.61	27.42
120.0+09.8	0 13 1.16	72 31 19.76	12.53	0.01	12.79	0.01	68.19x73.64	18.0x18.0	36.42
153.7+22.8	6 43 55.37	61 47 22.67	17.78	0.03	17.24	0.03	13.09x13.43	13.26x13.09	141
165.5-06.5	4 39 47.90	36 45 43.37	19.03	0.06	18.95	0.09	9.69x9.69	8.67x8.84	15
165.5-15.2	4 9 17.11	30 46 33.35	12.78	0.01	13.05	0.006	39.58x37.58	30.10x24.48	100.8
167.4-09.1	4 36 37.27	33 39 30.33	18.22	0.04	18.02	0.06	13.94x10.20	8.67x7.99	2.22
70.3+15.8	6 34 7.30	44 46 37.93	15.46	0.01	14.58	0.01	31.29x32.65	28.57x33.84	22
190.3-17.7	5 5 34.30	10 42 22.26	13.81	0.01	13.64	0.01	23.97x25.34	22.10x20.40	7.2
211.4+18.4	7 55 11.29	9 33 9.62	15.99	0.01	15.48	0.01	17.00x18.53	17.68x18.53	94
228.2-22.1	5 55 6.58	-22 54 2.19	15.85	0.01	15.31	0.02	20.74x19.38	16.83x16.32	132
239.6+13.9	8 33 23.44	-16 8 57.42	13.28	0.01	12.41	0.006	57.99x59.01	64.45x58.33	34.38
243.8-37.1	5 3 1.64	-39 45 43.83	14.11	0.01	13.44	0.01	26.53x29.76	28.40x25.0	23
255.8+10.9	9 5 5.37	-30 33 13.19	15.27	0.01	14.55	0.01	19.21x20.74	16.32x16.83	964.8
270.1+24.8	10 34 30.64	-29 11 14.16	14.86	0.01	14.38	0.01	23.46x20.91	27.72x21.42	54
286.8-29.5	5 57 1.94	-75 40 22.46	14.57	0.01	14.11	0.01	40.64x35.54	25.85x25.68	46
340.4-14.1	18 0 59.43	-52 44 20.17	16.21	0.01	16.22	0.02	26.87x27.89	25.00x30.78	16.2
341.6+13.7	16 1 20.91	-34 32 37.87	15.24	0.02	13.58	0.01	10.88x13.43	15.0x15.0	33.78
358.3-21.6	19 17 23.37	-39 36 45.79	13.87	0.01	13.50	0.01	11.73x14.79	19.0x19.0	7.02

Last column represents the optical diameter of PNe arcsec.

Measurement of size of PNe

We have determined the angular sizes of the PNe in NUV and FUV for whichever sources the detection exists. Initially we used the direct measurements at the 10% level of the peak surface brightness but the GALEX images are very deep and the nebular emission extends beyond 10% contour. So, we measured the actual dimension of the nebula considering a 3σ emission level above the background.

Result and Discusion

- IUE spectra shows that the emission lines contributing to GALEX FUV flux are strong OV, C IV, and He II while the emission line contributing to the NUV flux are C III] and He II.
- x-cut and y-cut across the PN is shown in figure 3. The peak corresponds the intensity of the central star.
- PN morphology in UV is different from that in optical as the UV traces the hot gases in the inner region of nebulae.
- The NUV and FUV morphology of a few of the PNe is shown in figure 4 & 5.
- We found most of the PNe are circular, with 20% are elliptical and 7% are bipolar.
- The NUV and FUV size of the PNe (table 1) are different, the NUV size are larger than the FUV size proving that FUV extension is less than NUV.
- The bipolar morphology is the result of the interaction of a close binary.
- We aim to measure the UV integrated flux and distance of the PNe from the UV morphology.

References

[1] Acker A., Marcout J., Ochsenbein F., Stenholm B., & Tylenda, R. 1992, Strasbourg-ESO catalogue of galactic planetary nebulae (Garching: European Southern Observatory)

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About The Conference

The Conference :
"33rd Meeting of Astronomical Society of India"
From February 17 - 20, 2015, at NCRA-TIFR, Pune, India

Stars and Nebulae

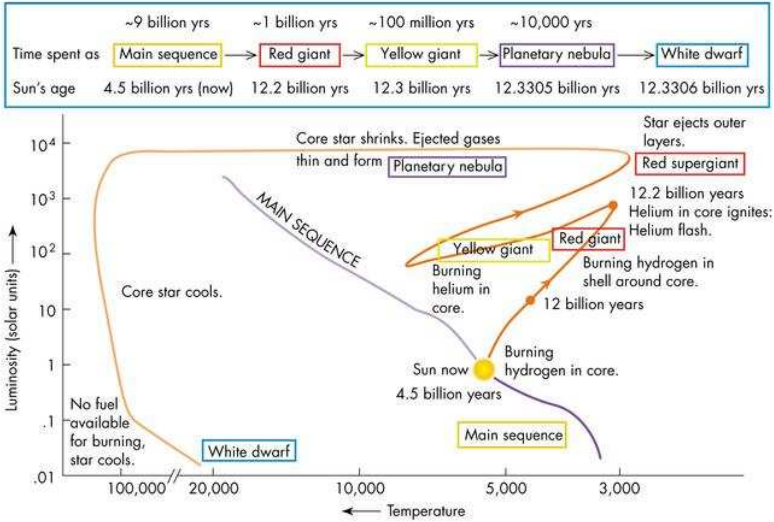
- In the core of the star, **the temperature and densities** are high enough to sustain nuclear fusion reactions, and the energy produced by these reactions works its way to the surface and radiates into space as heat and light.
- When the fuel for the fusion reactions is depleted, the structure of the star changes.
- **The process of building up heavier elements from lighter ones by nuclear reactions, and adjusting the internal structure to balance gravity and pressure, is called stellar evolution.**
- Observations allow us to find the luminosity of the star, or the rate at which it radiates energy as heat and light.

Stellar Evolution

Stars are not static objects. As a star consumes fuel in its nuclear reactions, its structure and composition changes, affecting its color and luminosity.

The H-R diagram not only shows us the colors and luminosities of many stars, it shows these stars at different stages in their evolutionary histories.

Hertzsprung-Russell (H-R) diagram



Nebulae

Originally, the word **nebula** referred to almost any extended astronomical object (other than planets and comets). Before astronomers knew that galaxies were distant collections of stars, galaxies were also called nebulae because of their fuzzy appearance. Today, we reserve the word nebula for extended objects consisting mostly of gas and dust.

Most nebulae can be described as diffuse nebulae, which means that they are extended and contain no well-defined boundaries.

Types of Nebulae

- **Emission nebulae** emit spectral line radiation from ionized gas (mostly ionized hydrogen).
- **Reflection nebulae** are clouds of dust that simply reflect the light of a nearby star or stars. Reflection nebulae are usually blue, because blue light scatters more easily.
- **Planetary nebula** results from the death of a star. When a star has burned the material, it can no longer sustain its own fusion reactions, the star's gravity causes it to collapse. As the star collapses, its interior heats up. The heating of the interior produces a stellar wind that blows away the outer layers of the star. When the outer layers have blown away, the remaining core remnant heats the gases, which are now far from the star, and causes them to glow. The resulting "planetary nebulae" are shells of glowing gas that surround a small core. Planetary nebulae are part of the normal stellar life cycle, but they are short-lived, lasting only about 25,000 years.

Why ?? planetary nebulae

- What's so interesting about planetary nebulae? Astronomers are drawn to study these objects because they provide opportunities to analyze material that was once a part of a shining star.
- For example, by studying the chemical composition of the nebula we can gain an understanding about the material out of which the star originally formed.
- In addition, the abundances of certain elements such as carbon and nitrogen in the nebula reveal details about the physical processes that occurred within the star during its nuclear fusion lifetime.
- Studying planetary nebulae helps us to understand how a star changes, or evolves, during its lifetime.

Planetary nebulae

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GALEX Obervation

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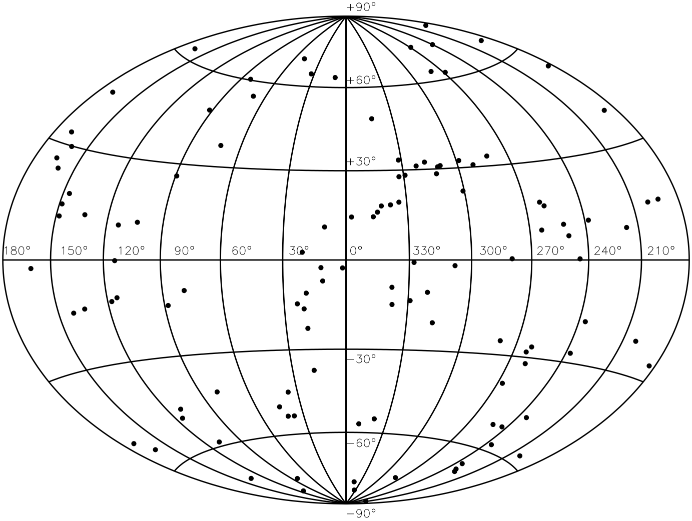
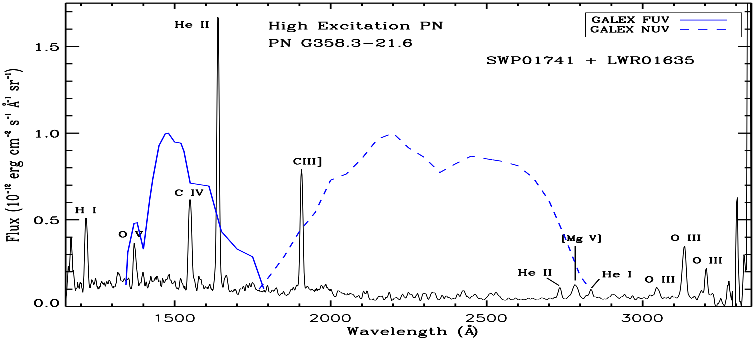
Distribution of PNe detected by GALEX

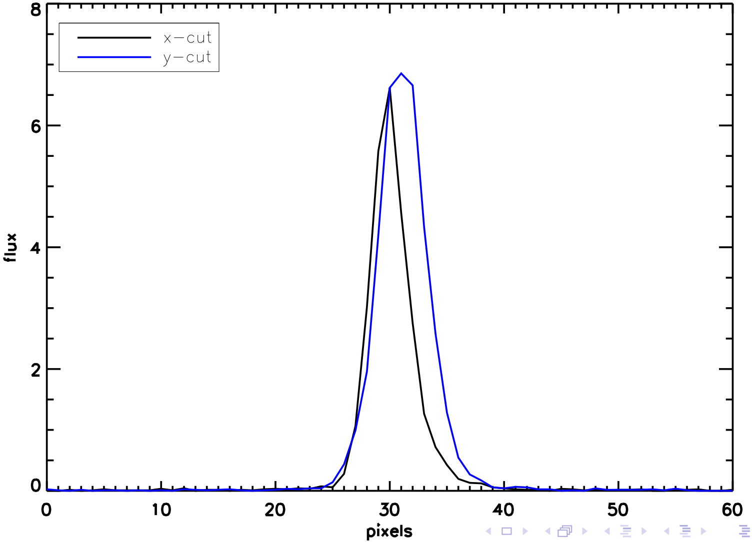


IUE Spectra of a PN



The prominent emission lines seen in the spectrum are H I, O V, C IV, He II, CIII], He II, [Mg V], and O III.The emission lines contributing to GALEX FUV flux are strong OV, C IV, and He II while the emission line contributing to the NUV flux are C III] and He II.

Variation of flux across a PN



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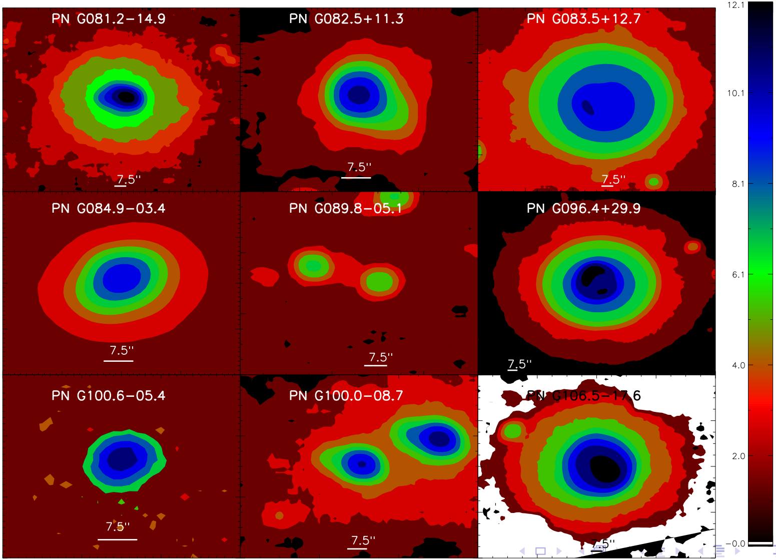
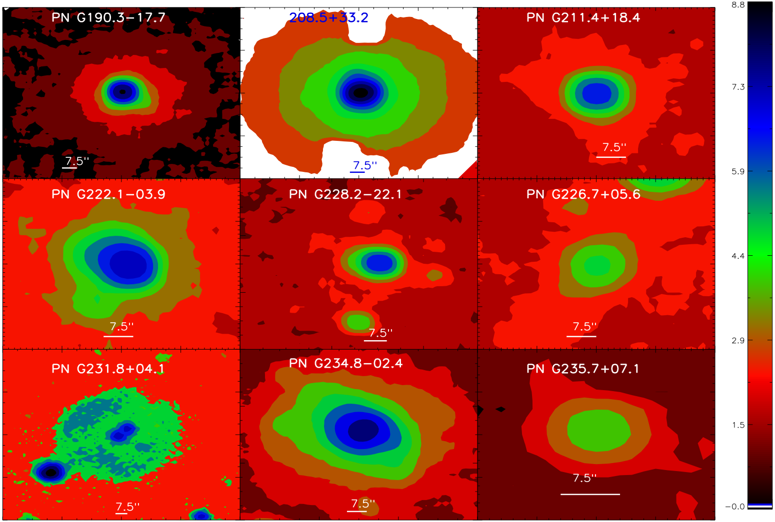
NUV images of a few PNe



FUV images of a few PNe



PNG No.	Ra (J2000) hr min sec	Dec (J2000) deg min sec	NUV (mag)	FUV (mag)	NUV size (arcsec)	FUV size (arcsec)	V size (arcsec)
005.2-18.6	19 14 23.37	-32 34 17.63	17.59	17.21	11.22x12.07	8.50x9.18	4.98
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013.3+32.7	16 21 4.47	0 -16 9.92	13.76	13.45	27.89x30.10	24.15x29.76	3
028.0+10.2	18 6 0.72	0 22 39.13	17.39	16.87	14.45x16.83	16.83x14.28	36
032.1+07.0	18 24 44.50	2 29 28.35	18.91	19.11	8.50x8.50	8.1x6.8	2.82
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243.8-37.1	5 3 1.64	-39 45 43.83	14.11	13.44	26.53x29.76	28.40x25.0	23
255.8+10.9	9 5 5.37	-30 33 13.19	15.27	14.55	19.21x20.74	16.32x16.83	964.8
270.1+24.8	10 34 30.64	-29 11 14.16	14.86	14.38	23.46x20.91	27.72x21.42	54
286.8-29.5	5 57 1.94	-75 40 22.46	14.57	14.11	40.64x35.54	25.85x25.68	46
340.4-14.1	18 0 59.43	-52 44 20.17	16.21	16.22	26.87x27.89	25.00x30.78	16.2
341.6+13.7	16 1 20.91	-34 32 37.87	15.24	13.58	10.88x13.43	15.0x15.0	33.78
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Summary & Conclusions

- IUE spectra shows that the emission lines contributing to GALEX FUV flux are strong OV, C IV, and He II while the emission line contributing to the NUV flux are C III] and He II.
- The peak corresponds the intensity of the central star.
- PN morphology in UV is different from that in optical as the UV traces the hot gases in the inner region of nebulae.
- Determined the NUV and FUV morphology of the PNe.
- We found most of the PNe are circular, with 20% are elliptical and 7% are bipolar.
- The NUV and FUV size of the PNe are different, the NUV size are larger than the FUV size proving that FUV extension is less than NUV.
- The bipolar morphology is the result of the interaction of a close binary.
- We aim to measure the UV integrated flux and distance of the PNe from the UV morphology.

THANK YOU