



18000 - Planetary Nebulae in Star Clusters: Testing Membership with High-Precision Proper Motions

Cycle: 33, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

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VISITS

<i>Visit</i>	<i>Targets used in Visit</i>	<i>Configurations used in Visit</i>	<i>Orbits Used</i>	<i>Last Orbit Planner Run</i>	<i>OP Current with Visit?</i>
01	(1) BMP-J1613-5406	WFC3/UVIS	1	13-Aug-2025 09:00:29.0	yes

1 Total Orbits Used

ABSTRACT

Planetary nebulae (PNe) mark the rapid transition of low- to intermediate-mass stars from the AGB to the white-dwarf (WD) cooling sequence. PNe provide information on nucleosynthesis, mixing, mass loss, and the relation between a star's initial mass and that of its WD remnant. Even the very existence of a PN shows that its central star will not end life as a core-collapse supernova (CCSN).

Unfortunately, for the vast majority of PNe, the masses and compositions of their progenitor stars are unknown. The only exception is in the case of a PN belonging to a star cluster. We propose to use precise astrometry, made possible by high-resolution HST imaging, to measure proper motions (PMs) of the central stars of three PNe that are candidate cluster members, and verify that the PMs agree with those of the clusters. Two of the PNe may belong to young open clusters, and one to an ancient globular cluster (GC). One of the open clusters, NGC 6067, is only 90 Myr old, implying

an unusually high progenitor mass of 5.6 Msun (and a firm lower mass limit for CCSN progenitors). Another PN is a possible member of the GC Pal 6. Single-star evolution theory does not predict the existence of PNe in GCs, so that interacting-binary scenarios are needed--if the PN can be shown to be a cluster member.

For two of our targets, there are archival first-epoch HST images available. In these cases, a one-orbit second-epoch observation will allow determinations of extremely precise PMs, and thus stringent tests of membership. For the PN candidate in NGC 6067, we propose first-epoch WFC3 images in Cycle 31, and a second epoch in Cycle 33, making it possible to confirm its unusually massive progenitor.

OBSERVING DESCRIPTION

We propose WFC3/UVIS imaging of the central stars of three PNe that are candidate members of three star clusters. Two of the clusters are open clusters, and one is a globular cluster. The aim is to measure precise proper motions (PMs) of the central stars, and of cluster members, in order to test whether the PNe are physical members of the clusters.

1. BMP J1613 in NGC 6067. There are no archival HST images of this target. We will obtain one orbit of imaging in Cycle 31, and a second one-orbit visit in Cycle 33.

Bellini et al. (2014), Sahu et al. (2017, 2022), Libralato et al. (2019), and other authors, have demonstrated an astrometric precision of better than 0.02 pixel (± 0.8 mas) per exposure can be achieved with WFC3/UVIS for well-exposed stellar images. WFC3 is increasingly affected by CTE. However, a correction algorithm, developed by Anderson (2021), can improve the precision to about 0.01 pixel if we place the target near the amplifier edge on the CCD. The uncertainty reduces to about ± 0.14 mas at a single epoch by combining 8 dithered exposures (possible during a one-orbit visit using subarrays). Thus the PM uncertainty over a 2-year interval would be ± 0.10 masyr. Hence it is readily possible with WFC3 astrometry to exceed the precision of the Gaia PM for this faint star by more than an order of magnitude (see the error bars in Fig. 2). This will provide an acid test of the PNN's cluster membership.

We will use the F606W (wide V) filter. This filter gives the best count rate for the central star. The F606W filter has an extremely well-characterised PSF for precision astrometry (e.g., Sahu et al. 2022 and references therein). (Note that our source is too faint, and the surrounding field too crowded, to use the technique of spatial-scanning astrometry developed by Riess et al. 2014.)

For the central star of BMP J1613, the WFC3 Exposure Time Calculator indicates that a SNR=100 exposure takes 60 sec. We will use a dither-box pattern, and obtain 8 exposures of 60 sec each. The orbit will be filled out with a single 60-sec exposure in F814W, in order to measure the colour of the central star to help constrain its effective temperature and reddening (and increase the archival value of our data). All exposures will be pre-flashed, to further mitigate effects of CTE (e.g., Kuhn & Bajaj 2021).

Proposal 18000 (STScI Edit Number: 0, Created: Wednesday, August 13, 2025, 8:00:30AM Eastern Standard Time) - Overview

The surrounding field will provide the astrometric frame. Gaia DR3 indicates that, for example, there are about three dozen stars in a 81×81 arcsec field centred on the target, with magnitudes in the range $17 < G < 18$. These bright stars will be well-exposed but not saturated in the WFC3 frames, providing a robust frame of stars with well-known PMs (including a handful of cluster members). This will allow us to determine the PM of the central star to high precision, and calibrated to the Gaia absolute frame.

2. PHR J1315 in AL 1 and JaFu 1 in Pal 3. For both of these targets, there are archival first-epoch HST frames. During Cycle 31, we will obtain the second-epoch frames for PM determination, one orbit each for the two targets. We will use WFC3/UVIS imaging essentially identical to that just described for BMPJ1613, but using the same filters as in the first-epoch frames.

Total request: Three orbits in Cycle 31, one orbit in Cycle 33.

Proposal 18000 - BMPJ1613 (01) - Planetary Nebulae in Star Clusters: Testing Membership with High-Precision Proper Motions

Visit	Proposal 18000, BMPJ1613 (01), implementation										Wed Aug 13 13:00:30 GMT 2025
	Diagnostic Status: Warning										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: SCHED 30%; ORIENT 177.65D TO 187.65 D; ORIENT 90.65D TO 94.65 D; ORIENT 357.65D TO 7.65 D; ORIENT 267.65D TO 277.65 D; AFTER 20-FEB-2026										
Diagnostics	(Exposure 1 (BMPJ1613 (01))) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser										
	(Exposure 2 (BMPJ1613 (01))) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser										
	(Exposure 3 (BMPJ1613 (01))) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser										
	(Exposure 4 (BMPJ1613 (01))) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser										
	(Exposure 5 (BMPJ1613 (01))) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser										
	(Exposure 6 (BMPJ1613 (01))) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser										
	(Exposure 7 (BMPJ1613 (01))) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser										
	(Exposure 8 (BMPJ1613 (01))) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser										
	(Exposure 9 (BMPJ1613 (01))) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser										
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous					
	(1)	BMP-J1613-5406	RA: 16 13 2.0384 (243.2584933d) Dec: -54 06 32.28 (-54.10897d) Equinox: J2000	Epoch of Position: 2000.0	V=20.2+/-0.5	Reference Frame: ICRS					
	Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. Coords are from Gaia DR3.										
	Category=STAR Description=[CIRCUMSTELLAR MATTER, EJECTA, PLANETARY NEBULA CENTRAL STAR]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	
	1		(1) BMP-J1613-5406	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	CR-SPLIT=NO; FLASH=40	POS TARG 10.40,9.00		150 Secs (150 Secs) [==>]	[1]	
	2		(1) BMP-J1613-5406	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	CR-SPLIT=NO; FLASH=40	SAME POS AS 1		120 Secs (120 Secs) [==>]	[1]	
	3		(1) BMP-J1613-5406	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	CR-SPLIT=NO; FLASH=40	POS TARG 14.35,9.00		120 Secs (120 Secs) [==>]	[1]	
	4		(1) BMP-J1613-5406	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	CR-SPLIT=NO; FLASH=40	POS TARG 12.86,12.09		120 Secs (120 Secs) [==>]	[1]	
	5		(1) BMP-J1613-5406	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	CR-SPLIT=NO; FLASH=40	POS TARG 9.51,12.85		120 Secs (120 Secs) [==>]	[1]	
	6		(1) BMP-J1613-5406	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	CR-SPLIT=NO; FLASH=40	POS TARG 6.83,10.70		120 Secs (120 Secs) [==>]	[1]	
	7		(1) BMP-J1613-5406	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	CR-SPLIT=NO; FLASH=40	POS TARG 6.85,7.27		120 Secs (120 Secs) [==>]	[1]	
	8		(1) BMP-J1613-5406	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	CR-SPLIT=NO; FLASH=40	POS TARG 9.54,5.14		120 Secs (120 Secs) [==>]	[1]	
	9		(1) BMP-J1613-5406	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	CR-SPLIT=NO; FLASH=40	POS TARG 12.89,5.93		120 Secs (120 Secs) [==>]	[1]	

