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The halo of M105 and its group environment as traced by planetary nebulae populations: I. Wide-field photometric survey of planetary nebulae in the Leo I group.

Hartke, J. et al. (2020) published in A&A.

Abstract

Context. M 105 (NGC 3379) is an early-type galaxy in the Leo I group. The Leo I group is the nearest group that contains all main galaxy types and can thus be used as a benchmark to study the properties of the intra-group light (IGL) in low-mass groups.
Aims. We present a photometric survey of planetary nebulae (PNe) in the extended halo of the galaxy to characterise its PN populations and investigate the presence of an extended PN population associated with the intra-group light.
Methods. We use PNe as discrete stellar tracers of the diffuse light around M 105. These PNe were identified on the basis of their bright [O III]5007 Å emission and the absence of a broad-band continuum using automated detection techniques. We compare the PN number density profile with the galaxy surface-brightness profile decomposed into metallicity components using published photometry of the *Hubble* Space Telescope in two halo fields.
Results. We identify 226 PNe candidates within a limiting magnitude of $m_{5007,\mathrm{lim}} = 28.1$ from our Subaru-SuprimeCam imaging, covering 67.6 kpc (23 effective radii) along the major axis of M 105 and the halos of NGC 3384 and NGC 3398. We find an excess of PNe at large radii compared to the stellar surface brightness profile from broad-band surveys. This excess is related to a variation in the luminosity-specific PN number α with radius. The α-parameter value of the extended halo is more than seven times higher than that of the inner halo. We also measure an increase in the slope of the PN luminosity function at fainter magnitudes with radius.
Conclusions. We infer that the radial variation of the PN population properties is due to a diffuse population of metal-poor stars ([M/H] < -1.0) following an exponential profile, in addition to the M 105 halo. The spatial coincidence between the number density profile of these metal-poor stars and the increase in the α-parameter value with radius establishes the missing link between metallicity and the post-asymptotic giant branch phases of stellar evolution. We estimate that the total bolometric luminosity associated with the exponential IGL population is $2.04 \times 10^9\ L_\odot$ as a lower limit. The lower limit on the IGL fraction is thus 3.8%. This work sets the stage for kinematic studies of the IGL in low-mass groups.

Background

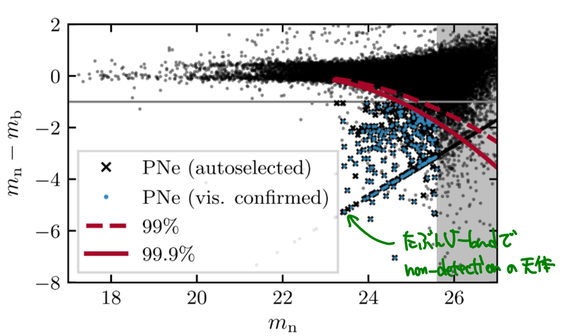
近傍にあり多様な銀河を含む low mass group

M105: Leo I group の中心にある楕円銀河 (diffuseで暗い成分) intra-group light (IGL) の研究に適している

PN: 中心質量星の進化した者. 明るく輝線天体なので単体で検出可能.
IGLの性質を調べるツールとして PN を用いる.
ここでは luminosity-specific PN number α に注目する $N_{\mathrm{PN}} = \alpha L_{\mathrm{bol}}$. (コレ)
stellar luminosity で規格化した PN の数で銀河年齢の関数
- low-mass star の割合が高いと α は大きくなる
- age が若いと PN が少ないので α は小さくなる
- mass loss の効率が変わると PN になる質量 range に影響する

Observations

観測に用いた装置は 2つ.
Subaru Suprime Cam: [O III] 5007Å & V-band
extended PN.S: slit-less spectrograph on WHT.
過去のデータも合わせて. 合計 2258 obj. の candidates を抽出



Suprime-Cam/Subaru のデータでの candidate selection. color-magnitude diagram での selection の後, 再検出で フィルタリング

Table 1. Properties of M 105 and NGC 3384 based on broad-band photometry.

Parameter	Symbol	Value	Ref.
	M 105		
SBF distance [a]	$D_{\mathrm{M\,105}}$	10.3 Mpc	1
Effective radius	$r_{\mathrm{e,M\,105}}$	54.″8 ± 3.″5	2
Mean ellipticity	$\epsilon_{\mathrm{M\,105}}$	0.111 ± 0.005	2
Mean position angle	$\mathrm{PA}_{\mathrm{M\,105}}$	70° ± 1°	2
Mean colour	$(B-V)_{\mathrm{M\,105}}$	0.92 mag	3
Sérsic index	n	4	2
	NGC 3384		
Distance	D_{3384}	11.3 Mpc	1
Mean colour	$(B-V)_{3384}$	0.88 mag	3
		Spheroid	
Sérsic index	n	4	4
Effective radius	r_{e}	15.″2	4
Mean ellipticity	$\epsilon_{\mathrm{spheroid}}$	0.17	4
Mean position angle	$\mathrm{PA}_{\mathrm{spheroid}}$	60.°51	4
		Disc	
Disc radius	r_{d}	63.″73	4
Mean ellipticity	ϵ_{disc}	0.66	4
Mean position angle	$\mathrm{PA}_{\mathrm{disc}}$	52.°5	4
Inclination	i	70°	4

Notes. [a]This SBF distance corresponds to a distance modulus of $\mu_{\mathrm{SBF}} = 30.049$, which agrees excellently with the distance determined from TRGB magnitudes by Lee & Jang (2016), which is $\mu_{\mathrm{TRGB}} = 30.05 \pm 0.02\,(\mathrm{random}) \pm 0.12\,(\mathrm{systematic})$.
References. (1) Tonry et al. (2001); (2) Capaccioli et al. (1990); (3) Watkins et al. (2014); (4) Cortesi et al. (2013b).

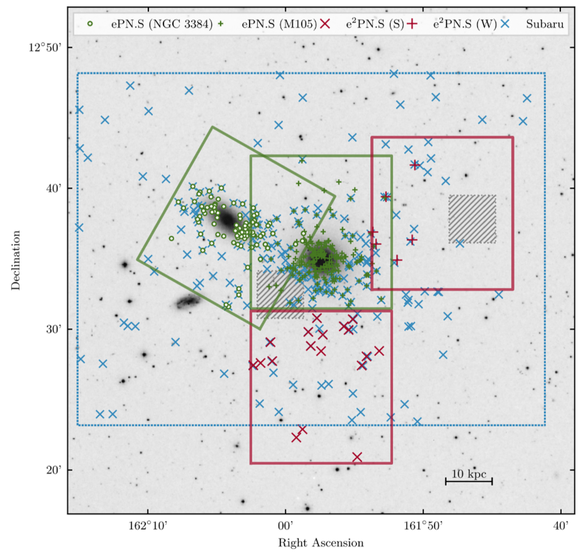
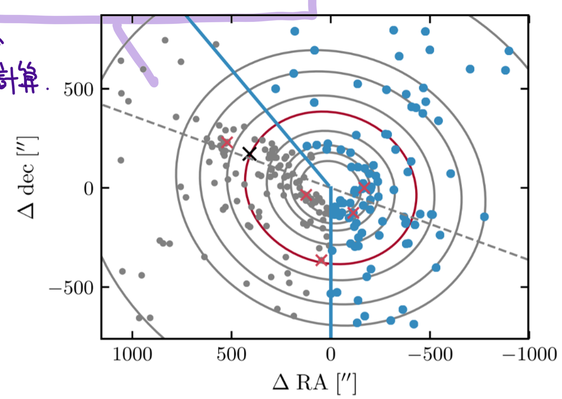


Fig. 1. DSS image of M 105. Overplotted are the PN candidates from the Subaru survey (blue crosses), PNe from the ePN.S survey (Pulsoni et al. 2018, green pluses), and the e²PN.S survey (this work, red pluses and crosses). PNe in NGC 3384 from Cortesi et al. (2013a) are denoted with green circles. The red and green rectangles denote the ePN.S and e²PN.S fields, and the dashed blue rectangle indicates the SuprimeCam footprint. The grey hatched regions indicate the two HST fields analysed in Lee & Jang (2016). The scale bar in the lower right corner denotes 10 kpc. North is up, and east is to the left.

$$\mu_{\mathrm{PN}}(r) = -2.5 \log_{10}\left(\frac{N_{\mathrm{PN,corr}}(r)}{A(r)}\right) + \mu_{\mathrm{off}},$$

(μ_{off}: αの値はここに反映される)

各円環でこの値を計算.



Results & Discussion

PN の数の radial profile ... 10× effective radius あたりから有限の excess
➡ 単一の stellar population & α では説明できない

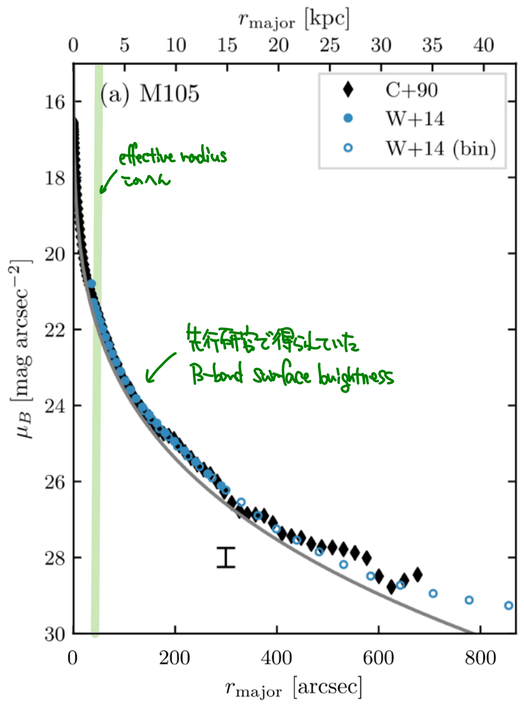
Case 1: Sérsic profile + X (constant, exponential)
➡ 一応説明できるけど, constant population model が最適 (= unphysical)

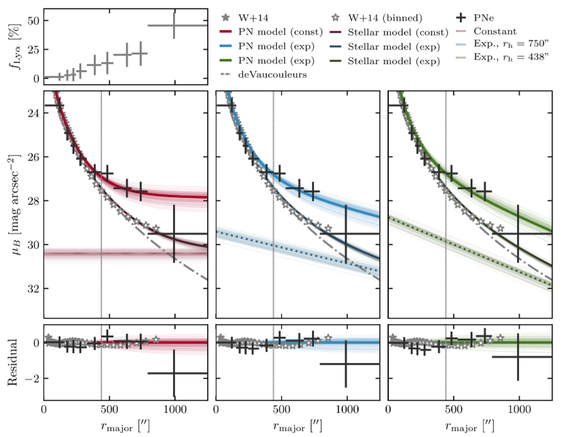
Case 2: metal poor/rich populations (double Sérsic)
➡ あまりうまく fit できなかった (metal-poorな population だと想定)

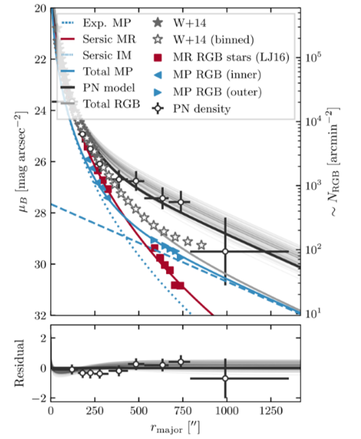
Case 3: metal rich/intermediate (double Sérsic) + exponential
➡ うまく fit できた, exponential 成分は inner に比べて α が 7倍

外側の PN で luminosity function の傾きが steep ... old & metal-poor な population と consistent

② この population の起源は?
① star formation from pristine gas before reionization / ② mergers & accretion (ETG formation と consistent?)
Halo or IGL? 今のところどちらも判断ない, kinematics と Paper II で議論予定.







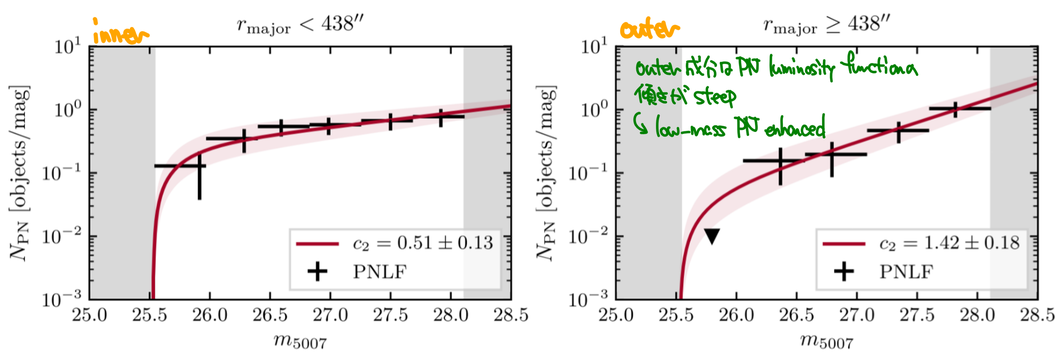


Fig. 13. Radial variation of the PNLF in M 105. *Left*: observed PNLF in the inner halo (black crosses) and best-fit generalised PNLF with $c_2 = 0.51 \pm 0.12$ (red line and shaded region). *Right*: observed PNLF in the outer halo (black crosses) and best-fit generalised PNLF with $c_2 = 1.42 \pm 0.18$ (red line and shaded region).