VV655 and NGC 4418: Implication of an interaction for the evolution of a LIRG

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Abstract

Context. VV 655, a dwarf irregular galaxy with HI tidal debris, is a companion to the lenticular luminous infrared galaxy (LIRG) NGC 4418. NGC 4418 stands out among nearby LIRGs due to its dense central concentration of molecular gas and the dusty, bi-polar structures along its minor axis suggestive of a wind driven by a central starburst and possible nuclear activity.
Aims. We seek to understand the consequences of the ongoing minor interaction between VV 655 and NGC 4418 for the evolution of the LIRG. Specifically, we consider the origin of the gas supply responsible for the unusual nuclear properties of NGC 4418.
Methods. We investigate the structural, kinematic, and chemical properties of VV 655 and NGC 4418 by analyzing archival imaging data and optical spectroscopic observations from the SDSS-III and new spectra from SALT-RSS. We characterize their gas-phase metal abundances and spatially resolved, ionized gas kinematics to better understand whether gas transfer between VV 655 and NGC 4418 resulted in the highly obscured nucleus of the LIRG.
Results. The gas-phase metallicity in NGC 4418 significantly exceeds that in VV 655. No kinematic disturbances in the ionized gas are observed along the minor axis of NGC 4418, but we see evidence for ionized gas outflows from VV 655 that may increase the cross-section for gas stripping in grazing collisions. A faint, asymmetric outer arm is detected in NGC 4418 of the type normally associated with galaxy-galaxy interactions.
Conclusions. The simplest model suggests that the minor interaction between VV 655 and NGC 4418 produced the unusual nuclear properties of the LIRG via tidal torquing of the interstellar medium of NGC 4418 rather than through a significant gas transfer event. In addition to inducing a central concentration of gas in NGC 4418, this interaction also produced an enhanced star formation rate and an outer tidal arm in the LIRG. The VV 655-NGC 4418 system offers an example of the potential for minor collisions to alter the evolutionary pathways of giant galaxies.

VV655(gas-rich dwarf irregular) & NGC4418(lenticular LIRG) system
→ minor merger
NGC4418のunusual nuclear properties
- 高密度分子ガス($n(H_2)=10^5$-$10^7 cm^{-3}$, ~$10^8 M_\odot$)
- post-starburst stellar population
- highly obscured AGN

→ VV655との相互作用によるgas transfer or tidal torquingが原因？

Data

Spectroscopy
- SDSS-III spec.: single-fiber
- SALT/RSS: long-slit

Imaging & Photometry
- GALEX, KiDS, Spitzer

Table1とimgingより...
- VV655はgas-richで dpletion timeも~Hubble time
- NGC4418のAsymmetric arm-like structure ← minor interactionによる

Fig.1

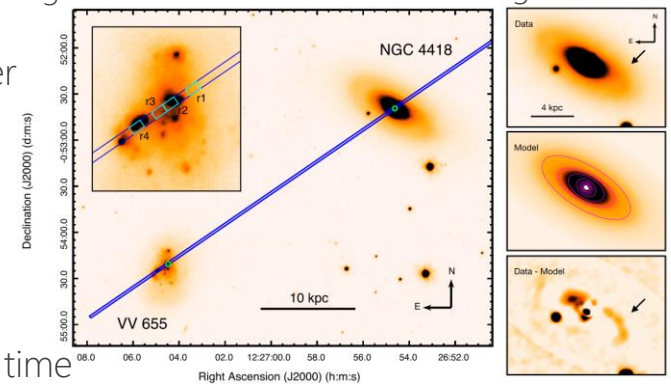
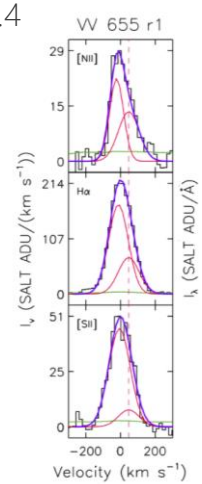


Fig.3

Fig.4



Chemical abundance

- VV655 << NGC4418(空間的な変化なし)

Ionized gas kinematics in NGC4418

- VV655からのHI tidal debirsと関連するような乱れはない

→ 以上2つから、直近のgas transferはなさそう

Galactic outflow from VV655?

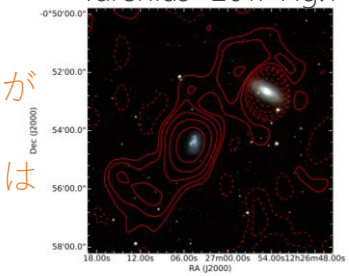
- r1, r3領域で[NII]6583にvelocity wing → outflow
  → escape velocityには達していない

先行研究

- ~100-400Myr前にclose passage (Varenius+2017)
- Arm構造は< 1 Gyrの年齢 (Helmi+2003)
- starburst(10Myr)+post-starburst(300-400Myr) (Ohyama+2019)

~100-400Myr前の接近による
tidal torqueでNGC4418自身のdiskが
中心に流れ込み、中心集中
当時NGC4418から流れ込んだgasは
十分にchemical enrichされている

Varenius+2017 Fig.1



(b) HI moment 0

Table.1

Observed Property	Measured	VV 655 Physical	Measured	NGC 4418 Physical	Notes
RA (J2000)	12h27m04.56s		12h26m54.62s		a
Decl. (J2000)	-00d54m23.2s		-00d52m39.4s		a
Redshift	2202 km s^{-1}	34 Mpc	2106 km s^{-1}	34 Mpc	b
Far-UV Mag.	16.8	4×10^{42}erg s^{-1}	...	...	c
3.6 μm Mag.	12.5	2.4×10^9 $L_\odot$	9.9	2.7×10^{10} $L_\odot$	d
HI Mass	1×10^9 $M_\odot$	M(HI)/M_* ≈ 1/2	...	...	e
$R_P(r)$	18″	3.0 kpc	27″	4.3 kpc	f
v_{rot}	20 km s^{-1}	30-90 km s^{-1}	130 km s^{-1}	150 km s^{-1}	g
SFR		~ 0.1 $M_\odot$ yr^{-1}		~ 3.2 $M_\odot$ yr^{-1}	h

Table.2

Galaxy	[OIII].λ5007/Hα	[NII].λ6583/Hα	[SII].λ6716/Hα	[SII].λ6716/[SII].λ6731	Notes
			SDSS-III		
VV 655	0.62 ± 0.01	0.098 ± 0.004	0.150 ± 0.005	1.43 ± 0.07	a
NGC 4418	0.17 ± 0.04	0.95 ± 0.05	0.47 ± 0.04	1.2 ± 0.1	a
			SALT-RSS		
VV 655 (r1; Diffuse)	...	0.121 ± 0.007	0.230 ± 0.007	1.52 ± 0.08	
VV 655 (r2: SF)	...	0.100 ± 0.002	0.170 ± 0.003	1.43 ± 0.04	
VV 655 (r3; Diffuse)	...	0.105 ± 0.003	0.163 ± 0.003	1.35 ± 0.04	
VV 655 (r4: SF)	...	0.091 ± 0.001	0.158 ± 0.001	1.43 ± 0.02	
NGC 4418 (Nucleus)	...	1.27 ± 0.08	0.42 ± 0.06	1.1 ± 0.2	b
NGC 4418 (R = 7.5″)	...	0.7 ± 0.1	0.45 ± 0.09	1.0 ± 0.3	b