Interacting galaxies hiding into one, revealed by MaNGA

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Given their prominent role in galaxy evolution, it is of paramount importance to unveil galaxy interactions and merger events and to investigate the underlying mechanisms. The use of high-resolution data makes it easier to identify merging systems, but it can still be challenging when the morphology does not show any clear galaxy-pair or gas bridge. Characterising the origin of puzzling kinematic features can help to reveal complicated systems. Here, we present a merging galaxy, MaNGA 1-114955, in which we highlighted the superimposition of two distinct rotating discs along the line of sight. These counter-rotating objects both lie on the star-forming main sequence but display perturbed stellar velocity dispersions. The main galaxy presents off-centred star formation as well as off-centred high-metallicity regions supporting the scenario of recent starbursts, while the secondary galaxy hosts a central starburst which coincides with an extended radio emission, in excess with respect to star formation expectations. Stellar mass as well as dynamical mass estimates agree towards a mass ratio within the visible radius of 9:1 for these interacting galaxies. We suggest we are observing a pre-coalescence stage of a merger. The primary galaxy has accreted gas through a past first pericentre passage about 1 Gyr ago, and more recently from the secondary gas-rich galaxy, which exhibits an underlying active galactic nucleus (AGN). Our results demonstrate how a galaxy can hide another one and the relevance of a multi-component approach to study ambiguous systems. We anticipate our method to be efficient at unveiling the mechanisms taking place in a sub-sample of galaxies observed by the Mapping Nearby Galaxies at Apache Point Observatory (MaNGA) survey, all exhibiting kinematic features of puzzling origin in their gas emission lines.

MaNGA 1-114955:
見た目だけではmergerと判断できないが、運動学的に一般的でない特徴をもつ

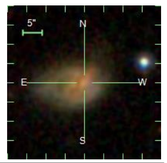

Table 1. Information about MaNGA-ID 1-114955.

r.a. (J2000)	dec. (J2000)	redshift	morphology	inclination (°)	$M_\star$ ($M_\odot$)	SFR_{SED} ($M_\odot\,yr^{-1}$)	SFR ($M_\odot\,yr^{-1}$)
22h10m24.5s	+11d42m47s	0.09228	interacting	44	1.59×10^{11}	13.3	10.6

輝線が明らかにdouble-peak (Fig. 1)
- double-peak galaxies catalogue (Maschmann et al. 2020)
SDSSやMaNGAのpipelineだとsingle gaussianを仮定しているのでfittingに失敗する
→ MaNGA dataに対してdouble-gaussianによるfittingを適用

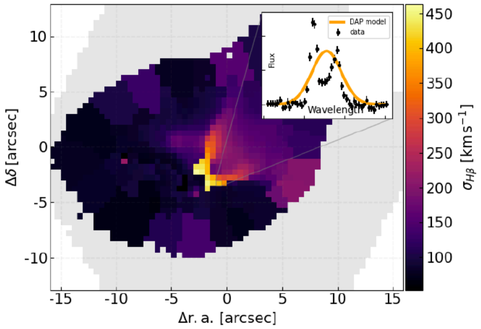

Fig. 1. Velocity dispersion of the Hβ emission line derived by the MaNGA DAP. The MaNGA field of view is represented as a grey footprint. The included panel shows a portion of the continuum-subtracted spectrum from one spaxel where the model (in green) does not manage to fit the spectral features.

right: (original) - (smooth image)
clumpやdust laneが見える

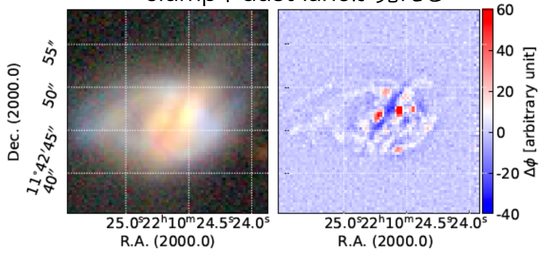

Fig. 5. Morphology. **Left:** Composite image (*g*, *r*, *z* bands) from the Legacy survey (Dey et al. 2019). **Right:** Difference between the Mega-Cam r band filter image and its smoothed version.

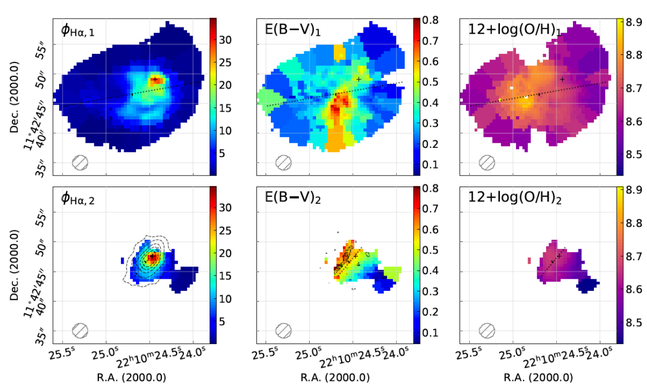

Fig. 2. Gas properties derived from our multi-component approach. The first (resp. second) row shows the maps for the first (resp. second) component detected in MaNGA data. The first column presents the Hα extinction-corrected flux (in erg s^{-1} Å^{-1} cm^{-2} per spaxel), the second displays the extinction computed from the Balmer decrement and the last column shows the oxygen gas phase abundance derived using the O_3N_2 calibrator. The black crosses refer to the position of the extinction-corrected Hα flux peak for the represented component. The MaNGA PSF is displayed as a hatched grey circle in the bottom-left corner of the panels.

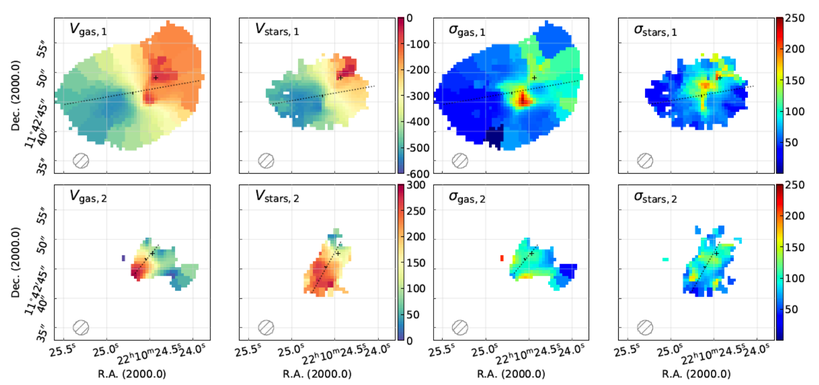

Fig. 3. Gas and star kinematics. The first row shows the maps for the first component and the second one for the second component detected in MaNGA data. The first and second columns display the respective ionised gas and stellar velocity fields (in km s^{-1}). The dotted black lines refer to the computed position angles. The third and fourth columns show the respective velocity dispersion fields (in km s^{-1}) for the gas and the stars. As above, the black crosses refer to the position of the extinction-corrected Hα flux peak for the represented component.

- 視線方向に沿って、2つの逆方向に回転する円盤成分 (ガス・星) に分離 (Fig. 2, 3)
  系の速度差は450 km s^{-1}
- 主銀河は運動の中心から外れた領域に星形成のピーク
  - 主銀河中心部は伴銀河による源光でunderestimateしているかも
- (星形成ピークとは別に) metallicityのピークも外れている
  - Balmer吸収が強い (Fig. B1)
  - ~1 Gyr前にstarburstがあったか?
- 主銀河のE(B-V)やσ mapにclampやfilament構造
  and 星形成ピークがmass-metallicity relationから外れている
  → interactionによるgas accretionの痕跡かも
  - 伴銀河の外側のgasが剥ぎ取られて供給された?
- 主銀河のmetallicity mapがアシンメトリー & 星形成mapの特徴から、
  大きなinteractionが2回あったと思われる

機械的な解析では見逃されてしまうが、実は視線方向に重なったinteractionだった
何か特別な特徴があるsystemというわけではない (たぶん)

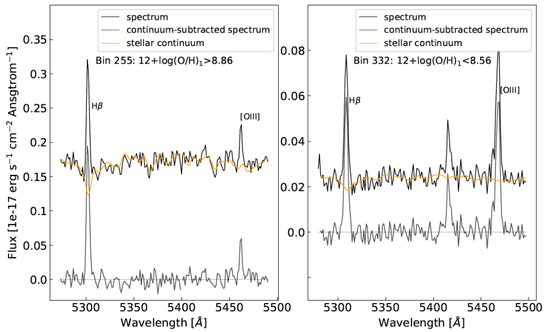

Fig. B.1. Different extracted spectra and their corresponding fits. The left panel shows the spectrum of a bin with a high gas-phase oxygen abundance and the right panel refers to a bin where the computed gas-phase oxygen abundance is low. One can see on the left panel an important Balmer absorption line below Hβ.

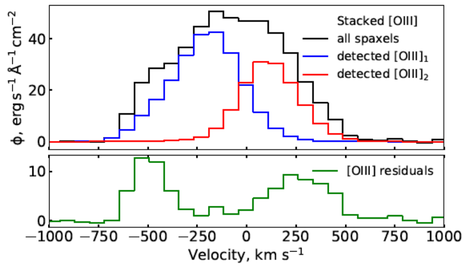

Fig. 9. Stacked ionised-gas lines. In the top (resp. bottom) panel, we

Stackするとより速度の速い成分が見える
→ outflowの兆候か

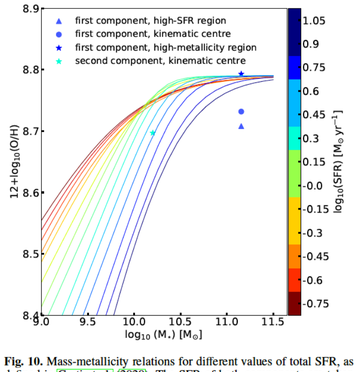

Fig. 10. Mass-metallicity relations for different values of total SFR, as defined in Curti et al. (2020). The SFR of both components are taken from Salim et al. (2016) and the stellar masses are the ones given in Sec. 4.7.1. The markers are colour-coded with the SFR of the corresponding host galaxies. For the primary galaxy, different 3-arcsec circular apertures have been considered as discussed in Sect. 4.7.4.

予想されるシステムの構造

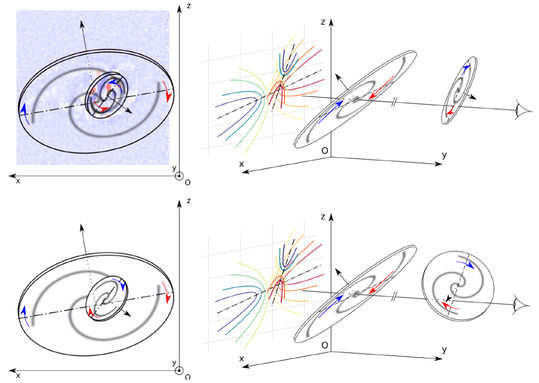

Fig. 11. Schematic illustration of the revealed merging system. **Top:** Configuration where the near-side of the secondary galaxy is on the north side. **Bottom:** Configuration where the near-side is on the south side of the major axis. Left panels show the discs as projected on the sky. Right panels show a "3D view", with a different viewing angle, for which discs can be represented with no superposition. The top-left panel includes the highlighting of a potential dust lane of Figure 5.