# Identifying mergers using non-parametric morphological classification at high redshifts

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**ABSTRACT**

We investigate the time evolution of non-parametric morphological quantities and their relationship to major mergers between $4 \geqslant z \geqslant 2$ in high-resolution cosmological zoom simulations of disk galaxies that implement kinetic wind feedback, $H_2$-based star formation, and minimal ISM pressurisation. We show that the resulting galaxies broadly match basic observed physical properties of $z \sim 2$ objects. We measure the galaxies' concentrations ($C$), asymmetries ($A$), and *Gini* ($G$) and $M_{20}$ coefficients, and correlate these with major merger events identified from the mass growth history. We find that high values of asymmetry provide the best indicator for identifying major mergers of $> 1:4$ mass ratio within our sample, with *Gini*-$M_{20}$ merger classification only as effective for face-on systems and much less effective for edge-on or randomly-oriented galaxies. The canonical asymmetry cut of $A \geqslant 0.35$, however, is only able to correctly identify major mergers $\sim 10\%$ of the time, while a higher cut of $A \geqslant 0.8$ more efficiently picks out mergers at this epoch. We further examine the temporal correlation between morphological statistics and mergers, and show that for randomly-oriented galaxies, half the galaxies with $A \geqslant 0.8$ undergo a merger within $\pm 0.2$ Gyr, whereas *Gini*-$M_{20}$ identification only identifies about a third correctly. The fraction improves further using $A \geqslant 1.5$, but about the half the mergers are missed by this stringent cut.

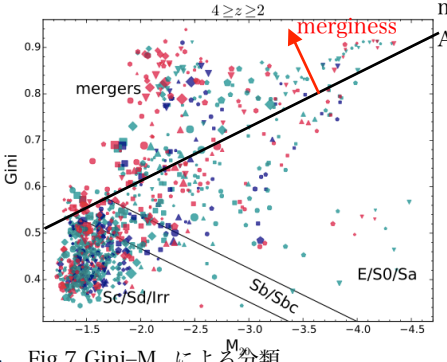



Fig.7 Gini–$M_{20}$による分類
Mergers : G > −0.14 $M_{20}$ + 0.33 (Lotz+08b)

Fig.6 Asymmetry – Merger ratio
mergerのthresholdは
A=0.35/0.8/1.5,R=0.25

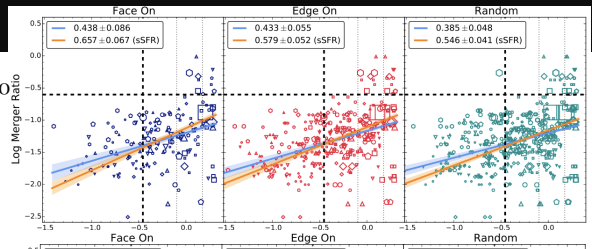
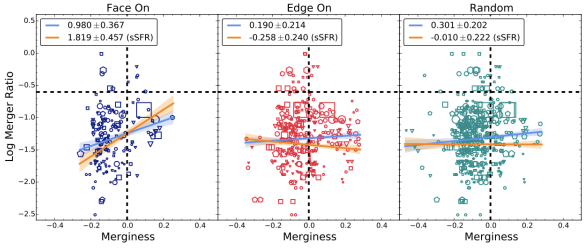



Fig.10 merginess – Merger ratio




■イントロダクション

・銀河のmerger historyをnon-parametricな指標を用いて定量的に調べる最適な方法を模索しているが、観測では遠方銀河の空間構造の評価が難しい
→ 高解像度のcosmological SPH zoom-in simulationを利用

・2≦z≦4の銀河でConcentration(C),Asymmetry(A),Gini(G),$M_{20}$によるnon-parametricな評価を行い、merger ratio: Rとの関係を調べた。

$$\mathcal{R} \equiv \frac{M_1}{M_2} = \frac{M_t - M_{(t-1)}}{M_t}, \quad C = 5\log\left(\frac{r_{80}}{r_{20}}\right), \quad A = \frac{\sum|f_0 - f_{180}|}{\sum|f_0|}, \quad Gini = \frac{1}{\bar{f}n(n-1)}\sum_i^n (2i-n-1)f_i,$$

$$M_{20} \equiv \log\left(\frac{\sum_i M_i}{M_{tot}}\right), \text{while} \sum_i f_i < 0.2 f_{tot},\ M_{tot} \equiv \sum_i^n M_i = \sum_i^n f_i\left[(x_i - x_c)^2 + (y_i - y_c)^2\right]$$

■方法

・SPH zoom-inシミュレーション上で
HST F160Wフィルタを用いた仮想的な観測

・6つのhalo中に形成された７つのmassive galaxyをそれぞれ144回観測

Table 1. Simulated Galaxy Sample at $z = 2$

| Name | Symbol | $M_{\rm halo}$ | $M_*$ | SFR | $f_{gas}$ |
|---|---|---|---|---|---|
| G1 | ■ | $1.91 \times 10^{11}$ | $3.57 \times 10^{9}$ | 4.93 | 0.54 |
| G2 | ● | $1.98 \times 10^{11}$ | $7.77 \times 10^{9}$ | 9.96 | 0.47 |
| G3 | ▲ | $3.35 \times 10^{11}$ | $9.49 \times 10^{9}$ | 8.77 | 0.57 |
| G4 | ◆ | $4.85 \times 10^{11}$ | $1.80 \times 10^{10}$ | 2.51 | 0.44 |
| G5 | ⬢ | $9.55 \times 10^{11}$ | $4.05 \times 10^{10}$ | 19.93 | 0.39 |
| G6 | ⬟ | $1.15 \times 10^{12}$ | $5.58 \times 10^{10}$ | 37.50 | 0.21 |
| G7 | ▼ | $1.03 \times 10^{12}$ | $6.64 \times 10^{10}$ | 59.04 | 0.28 |

■結果

・merger ratioとの相関
　・Asymmetry(A)はmerger ratio(R)に強く相関するが、C,G,$M_{20}$ではその傾向はなかった
　・'merginess' を用いても相関は見られなかったが、face-onの場合は弱い相関があった

・Asymmetryによるmergerの識別
　・A≧0.35では、robustにmergerを識別できることがわかった。
　・例えば、A≧0.8では9/10のmergerを識別し、誤ってmergerに含めてしまう割合は〜50%。
　・A≧1.5では誤判断は減るが、半数程度のmergerしか識別できなくなる

・mergerを識別するパラメータの時間依存性を調べた
　・merginessはface-onではややmergerを判別することがあるが、randomな方向を向いている場合では上手く判別できない

・Aによりmergerを正しく判別する確率は、Δtとthreshold値とともに増加する

Fig.12
Asymmetryとmerger ratio(破線)の時間進化

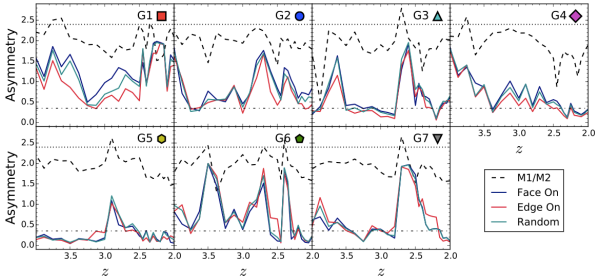



Fig.14 Asymmetryを用いてmergerを判別できている割合

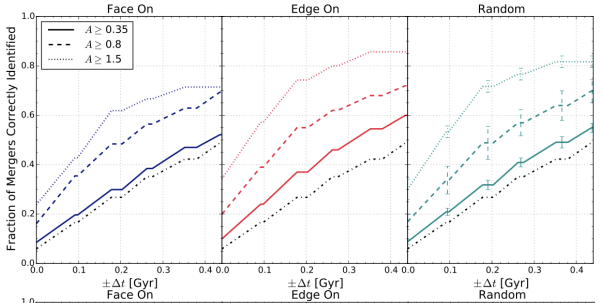
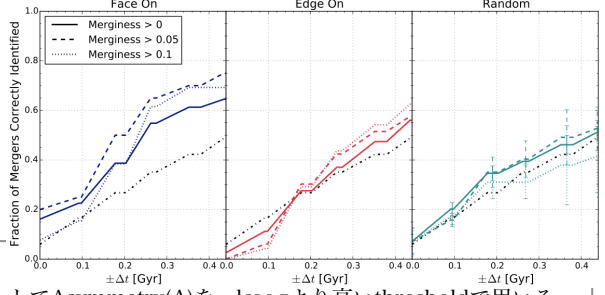



Fig.15 merginessを用いてmergerを判別できている割合




■結論

・z=2–4のmergerを識別する方法としてAsymmetry(A)を、low-zより高いthresholdで用いるのが最適であることがわかった