Resolving a dusty, star-forming SHiZELS galaxy at z = 2.2 with HST, ALMA and SINFONI on kiloparsec scales

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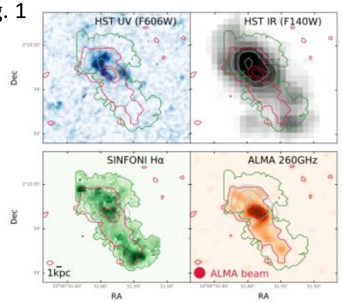
We present ~ 0.15″ spatial resolution imaging of SHiZELS-14, a massive ($M_* \sim 10^{11}\,\mathrm{M_\odot}$), dusty, star-forming galaxy at $z = 2.24$. Our rest-frame ~ 1kpc-scale, matched-resolution data comprise four different widely used tracers of star formation: the Hα emission line (from SINFONI/VLT), rest-frame UV continuum (from *HST* F606W imaging), the rest-frame far-infrared (from ALMA), and the radio continuum (from JVLA). Although originally identified by its modest Hα emission line flux, SHiZELS-14 appears to be a vigorously star-forming (SFR ~ $1000\,\mathrm{M_\odot yr^{-1}}$) example of a submillimeter galaxy, probably undergoing a merger. SHiZELS-14 displays a compact, dusty central starburst, as well as extended emission in Hα and the rest-frame optical and FIR. The UV emission is spatially offset from the peak of the dust continuum emission, and appears to trace holes in the dust distribution. We find that the dust attenuation varies across the spatial extent of the galaxy, reaching a peak of at least $A_{\mathrm{H}\alpha} \sim 5$ in the most dusty regions, although the extinction in the central starburst is likely to be much higher. Global star-formation rates inferred using standard calibrations for the different tracers vary from ~ 10 – $1000\,\mathrm{M_\odot yr^{-1}}$, and are particularly discrepant in the galaxy's dusty centre. This galaxy highlights the biased view of the evolution of star-forming galaxies provided by shorter wavelength data.

SMG : High-SFR, Compact CO & dust, High-Mass
→ z~2のProgenitor of massive quiescent?
UV, optical, FIRなどで見える構造が違う
→ SMG-likeなz=2.24の銀河を多波長で観測

SHiZELS-14

- HiZELS(NB Hα emitter survey)よりNGSの制限などから20天体をVLT/SINFONIでrest-optical分光
  → SINFONI-HiZELS = SHiZELS
- 最も明るく、空間的に広がって、活発な天体

Fig. 1



観測

Resolved : Hα(SINFONI), rest-UV(HST), rest-FIR(ALMA), radio(JVLA)
Others : COSMOS optical/IR imaging, Spitzer & Herschel

Table 1

Basic property	Measurement	Reference
RA (J2000)	10:00:51.6	Swinbank+12
Dec (J2000)	+02:33:34.5	Swinbank+12
$z_{\mathrm{H}\alpha}$	2.2418	Swinbank+12
Derived property	**Measurement**	**Reference**
$\log_{10} M_{*,\mathrm{SED}}/\mathrm{M_\odot}$	11.2 ± 0.1	This paper
$\log_{10} M_{\mathrm{gas}}/\mathrm{M_\odot}$	10.1 ± 0.4	Swinbank+12
$\log_{10} M_{\mathrm{dust}}/\mathrm{M_\odot}$	8.9 ± 0.1	This paper
$\log_{10} L_{\mathrm{TIR}}/\mathrm{L_\odot}$	12.85 ± 0.01	This paper
$\mathrm{SFR_{SED}}/\mathrm{M_\odot yr^{-1}}$	690 ± 30	This paper
$R_{e,\mathrm{H}\alpha}$/kpc	4.6 ± 0.4	Swinbank+12
$R^{\mathrm{maj}}_{e,\mathrm{opt}}$/kpc	4.6 ± 0.2	This paper
$R^{\mathrm{maj}}_{e,\mathrm{FIR}}$/kpc	4.5 ± 0.2	This paper
A_V	1.9 ± 0.1	This paper

Globalな性質 : StellarとダストのSED fitting

ダストだけのフィッティングも実施

- 2成分ダスト : T_{warm}=64K, T_{cold}=28K
  1成分ダスト : T=32K ← 100um PACSが説明つかず
- $\log(M_{dust}/M_{sun})$=9.0, $\log(L_{TIR}/L_{sun})$=12.81
- 様々な星形成率 → ダスト減光に敏感なSFRは低い
- AGNの超硬はない(No Xray, No [NII]/Hα excess, No mid-infrared excess, IR-radio relation)

Fig. 4

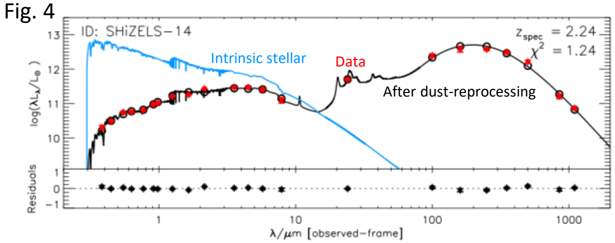


Fig. 5

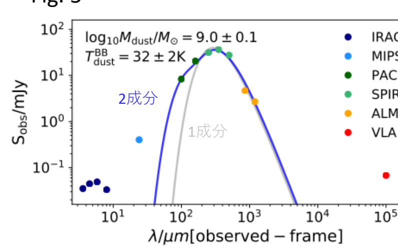


Table 2

Waveband (Instrument)	Formula for $\log_{10}(\mathrm{SFR/M_\odot yr^{-1}})$	$\mathrm{SFR/M_\odot yr^{-1}}$
SFRs from individual tracers		
$\mathrm{TIR_{8-1000\mu m}}$ (dust SED fit)	$\log_{10}(L_{\mathrm{TIR}}/\mathrm{erg\,s^{-1}}) - 43.41$	**950 ± 50**
Radio (1.4 GHz, VLA, Bell 2003 conversion)	$\log_{10}(L_{1.4\mathrm{GHz,rest}}/\mathrm{erg\,s^{-1}\,Hz^{-1}}) - 28.43$	1180 ± 100
Radio (1.4 GHz, VLA, Kennicutt & Evans 2012)	$\log_{10}(L_{1.4\mathrm{GHz,rest}}/\mathrm{erg\,s^{-1}\,Hz^{-1}}) - 28.2$	2010 ± 170
Hα (SINFONI/VLT)	$\log_{10}(L_{\mathrm{H}\alpha}/\mathrm{erg\,s^{-1}}) - 41.27$	33 ± 2
"	$L_{\mathrm{H}\alpha}$ corrected using 1 mag dust extinction	83 ± 5
"	$L_{\mathrm{H}\alpha}$ corrected using M_*-dependent dust extinction of Garn et al. (2010), $\log_{10} M_*/\mathrm{M_\odot} = 11.2$	180 ± 10
"	$L_{\mathrm{H}\alpha}$ corrected using $A_{\mathrm{H}\alpha} = 1.6 \pm 0.1$, derived from scaled A_V	140 ± 20
"	$L_{\mathrm{H}\alpha}$ corrected using $A_{\mathrm{H}\alpha} = 3.7 \pm 0.1$, derived from scaled A_V & preferential extinction of birth clouds	1000 ± 100
FUV (*HST* F606W)	$\log_{10}(\nu L_\nu/\mathrm{erg\,s^{-1}}) - 43.17$	13 ± 1
"	corrected using A_{1600} derived from β, with $\beta = -0.5 \pm 0.1$	300^{+70}_{-50}
"	corrected using $A_{\mathrm{UV}} = 4.3 \pm 0.2$, derived from scaled A_V	680 ± 130
SFRs from combinations of tracers		
FUV + TIR	$L_{\nu,\mathrm{corr}} = L_{\nu,\mathrm{obs}} + 0.27L_{\mathrm{TIR}}$, L_ν – SFR conversion above	440 ± 20
Hα + TIR	$L_{\mathrm{H}\alpha,\mathrm{corr}} = L_{\mathrm{H}\alpha,\mathrm{obs}} + 0.0024L_{\mathrm{TIR}}$, $L_{\mathrm{H}\alpha}$ – SFR conversion above	330 ± 20
FUV + radio	$L_{\mathrm{FUV,corr}} = L_{\mathrm{FUV,obs}} + 4.2 \times 10^{14} L_{1.4\mathrm{GHz}}$	990 ± 80
SFRs from SED fitting		
MAGPHYS		690 ± 30
BAGPIPES		660 ± 60

ResolvedなSFR

- 短い波長のSFRが全体にわたって低い
- ダスト補正すると中心部でずれる
  → 中心で強い減光

Fig. 6

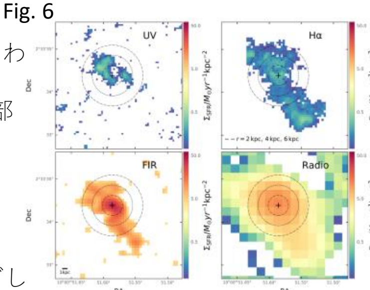
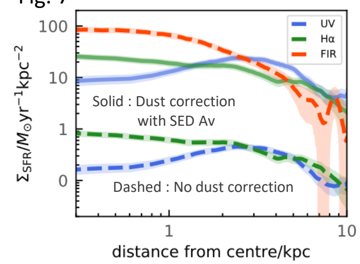


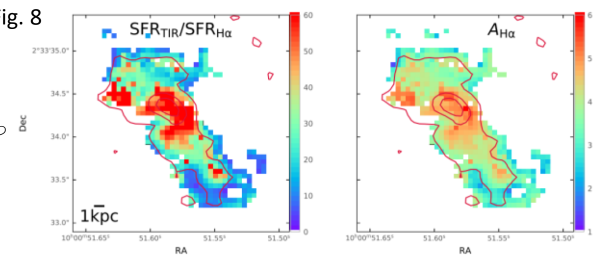
Fig. 7



Resolvedなダスト減光推定

- $SFR_{TIR}=SFR_{H\alpha}\times10^{0.4A_{H\alpha}}$
- SEDのAvをスケーリングした値(3.7mag)より大きい値も。最大で~5mag。

Fig. 8



ResolvedなUV分布

- $SFR_{UV}=SFR_{H\alpha}$とFig.8のAv mapでHαから推定されるUV分布を作る
  → 観測を再現できない
  → 直近の星形成はUVでは隠され、より長いtimescaleの星形成が見えている
  (Stellar massのpeakはUVと一致)

SMGの中での立ち位置

- Rest-FIRでより広いディスク構造
- 星形成が広がっていて、Hα輝線からdispersion dominated

→ on-going merger (mid-stage?)
↔ 他のSMGはlate-stageも含む様々なstage

Fig. 9