面分光による
SMGs overdensityからの
Proto-Cluster 探索

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Presentation Table

1.Introduction
   Galaxy Evolution
   Sub-Millimetre Galaxies (SMGs)
   Proto-Clusters
2.Data
3.Analysis
4.Result
5.Discussion
   Discussion-6.1
   Discussion-1.1/1.2
   Discussion-34.1/34.2
6.Conclusion
7.Future Work/Proposals

Presentation Table

1.Introduction

銀河の活動性に対するシナリオ

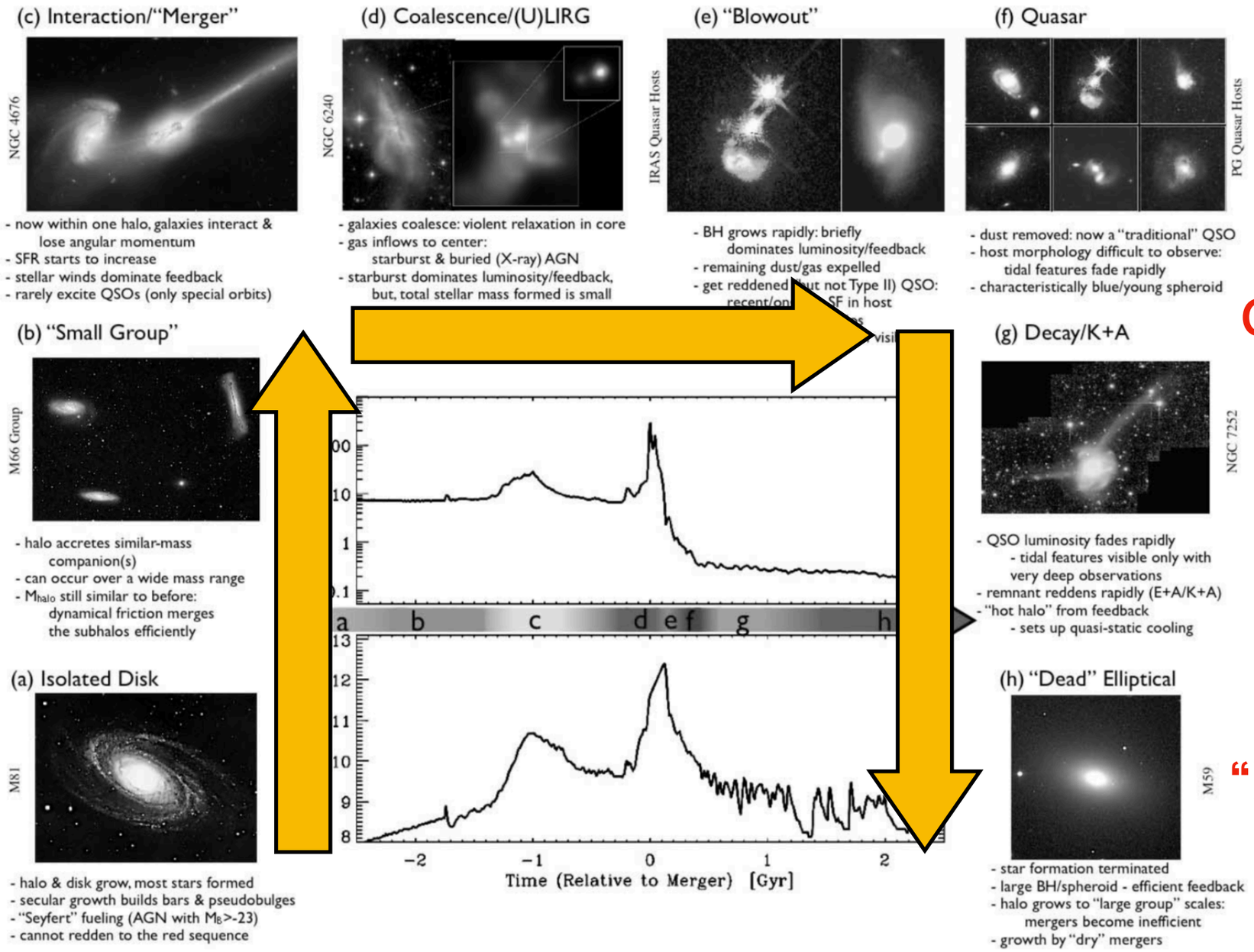
Starburst

(Dry) Merger

Quenching

Birth

"Dead"



Hopkins+2008

1.Introduction

銀河の活動性に対するシナリオ

Sub-Millimetre Galaxies

・sub-mm bandで検出

・高い星形成率(SFR) ~1000Msolar

・”dusty” starburst galaxy

Starburst

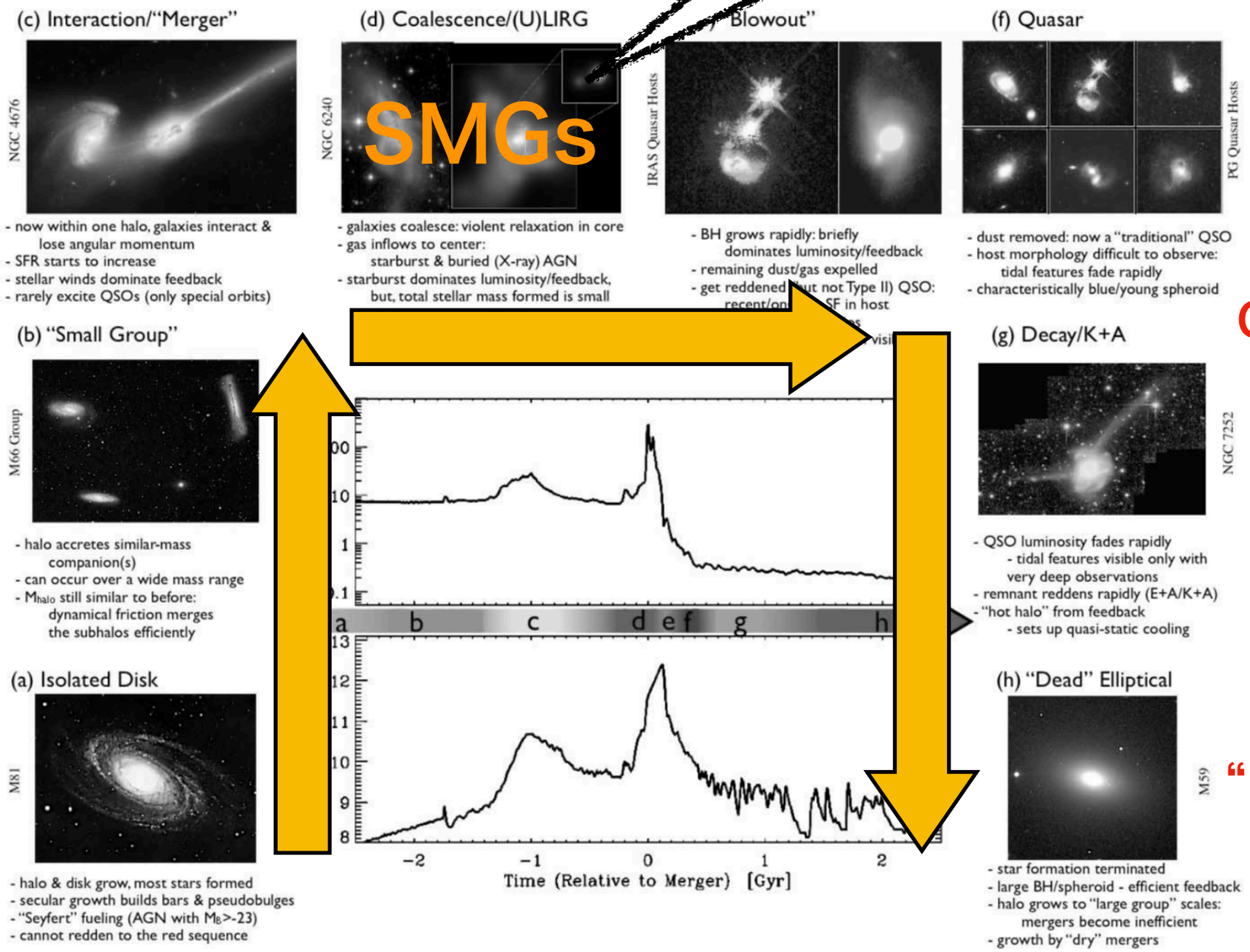
SMGs

(Dry) Merger

Quenching

Birth

“Dead”



Hopkins+2018

1.Introduction

cluster：銀河が集まっているところ。重力的に束縛されている。

scale~6Mpc　(total) Mass~10^14-15 Msolar

特徴：cluster外の領域よりもelliptical galaxyが多い。

Proto-cluster：clusterの前身？

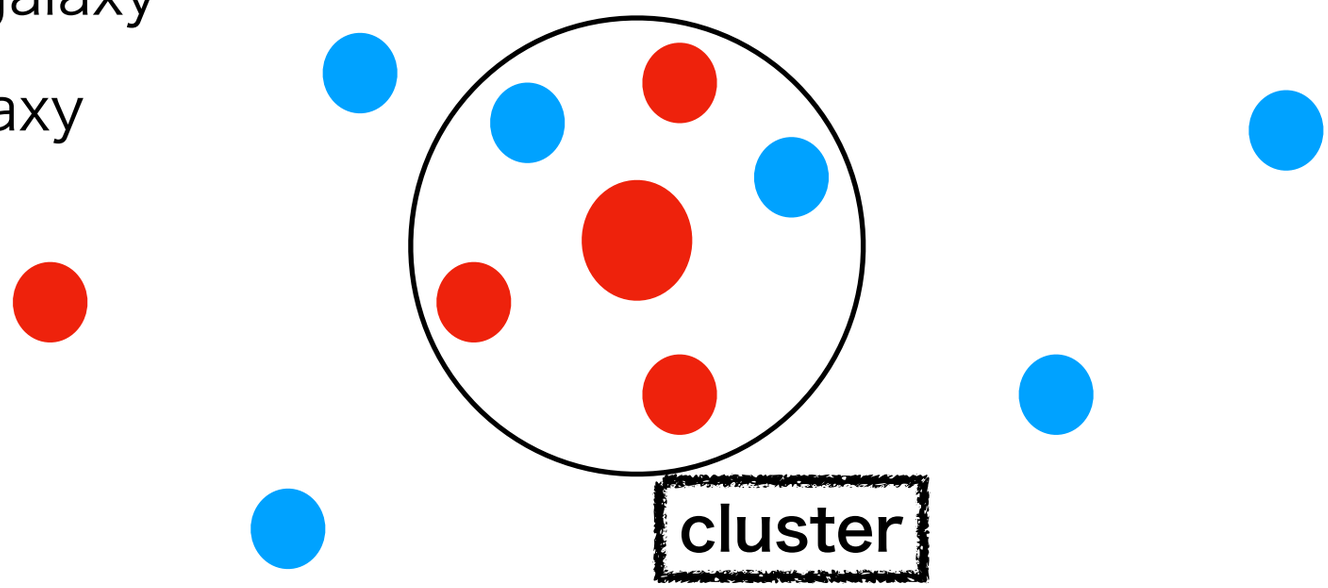
scale 6~10Mpc　(total) Mass ~ ？

Proto-clusterを探す理由は?

今日見られるようなclusterの特徴を説明する！

: Elliptical galaxy

: Spiral galaxy



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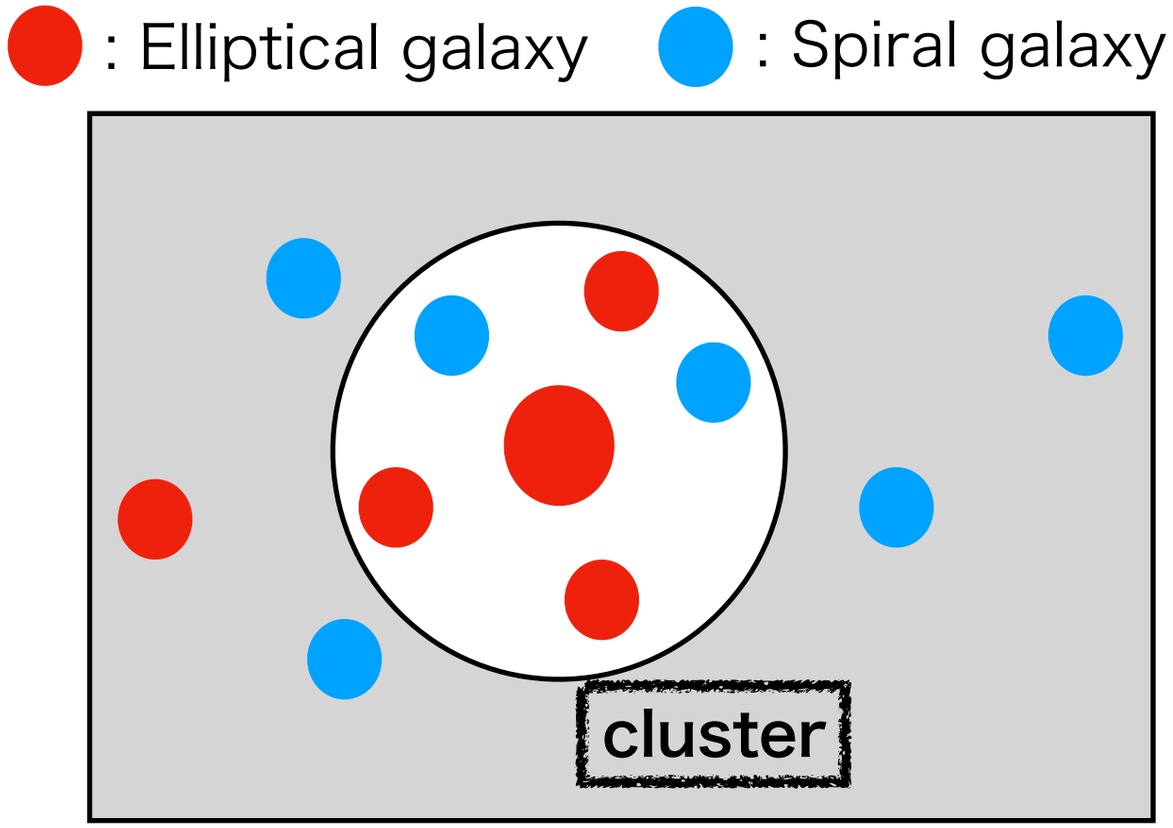


階層的構造形成＋銀河形成シナリオ＝clusterの形成シナリオ

@clusterの外側

銀河の周りに銀河が存在せず、
mergeが起きにくい

ので

spiral galaxyが多く存在

@clusterの内側

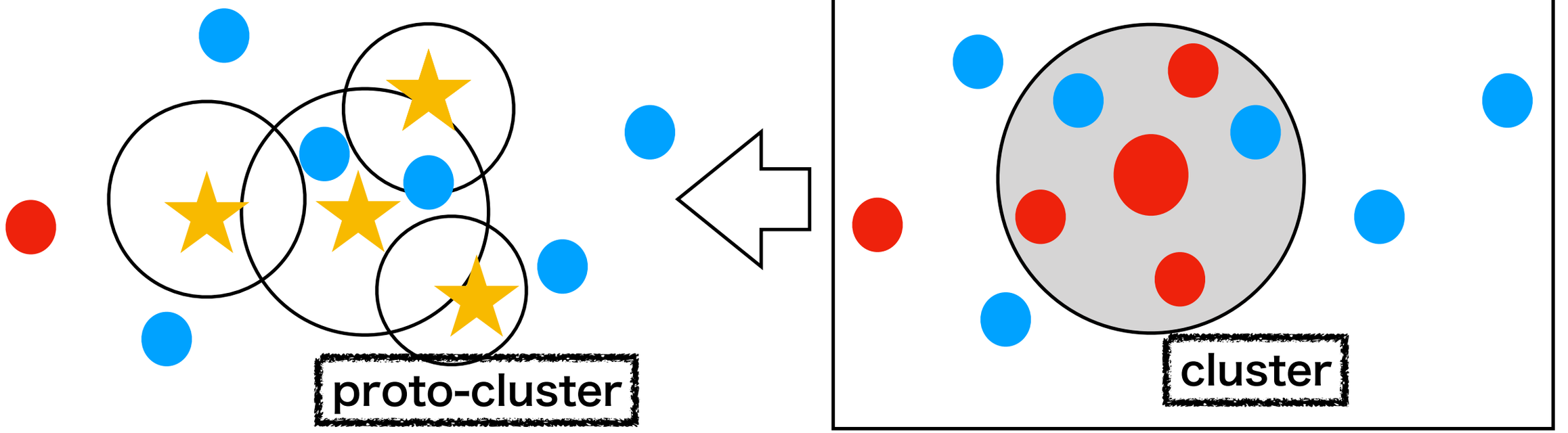
銀河が密集しているので、
margeが起きやすい

ので

elliptical galaxyが多く存在

1.Introduction

: SMGs　: Elliptical galaxy　: Spiral galaxy



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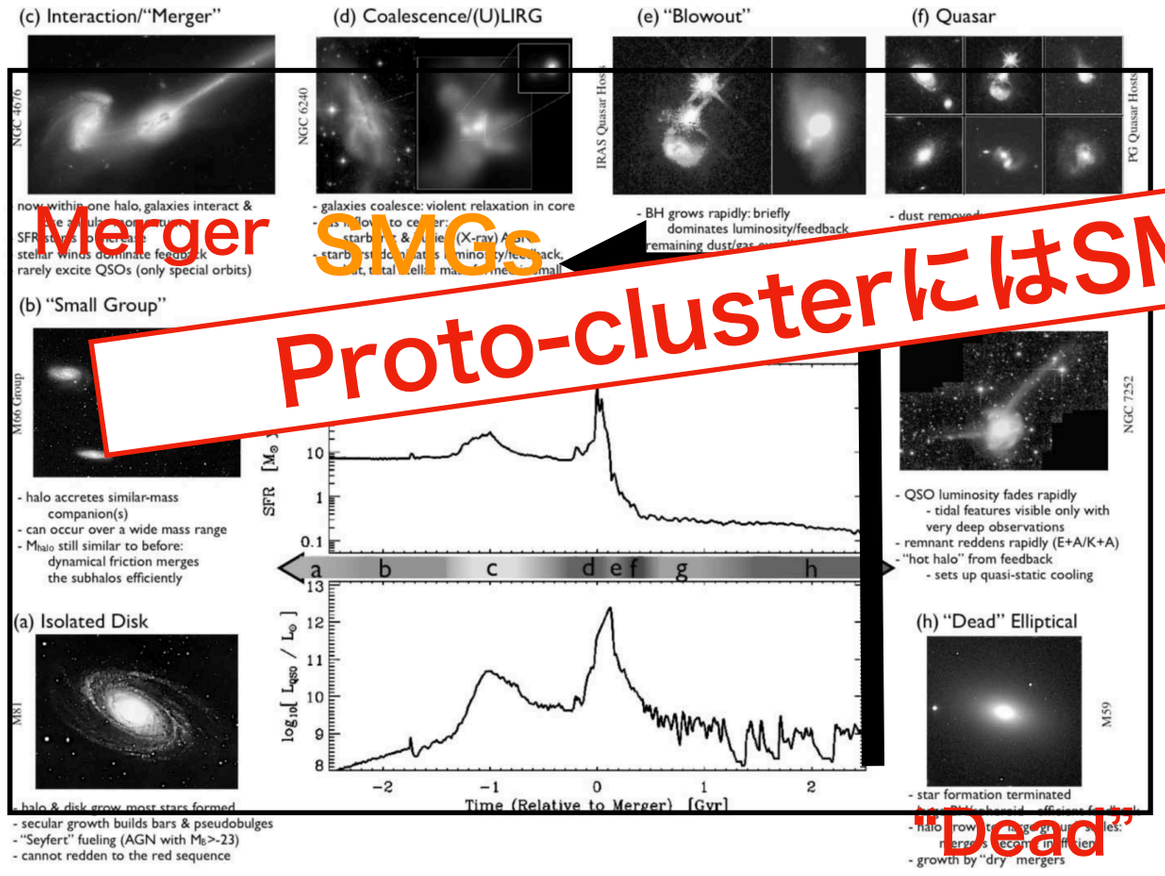


Proto-clusterにはsmgsが見られるはず！

clusterの内側

銀河が密集しているので、

margeが起きやすい

ので

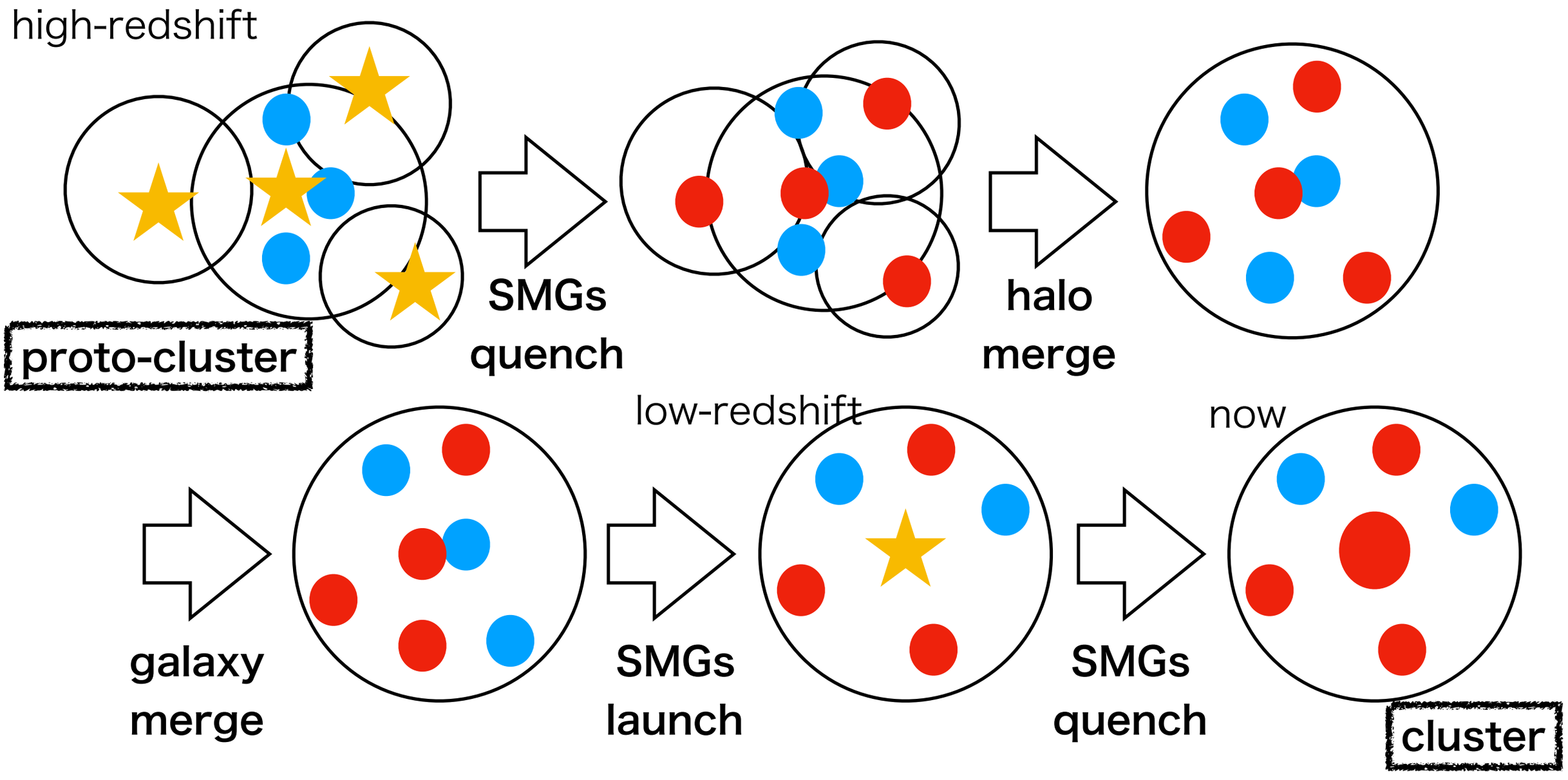
elliptical galaxyが多く存在

1.Introduction

In previous research (clustering)

High redshift SMGs → **Cluster**

Low redshift SMGs → **Ellipticals in cluster center**



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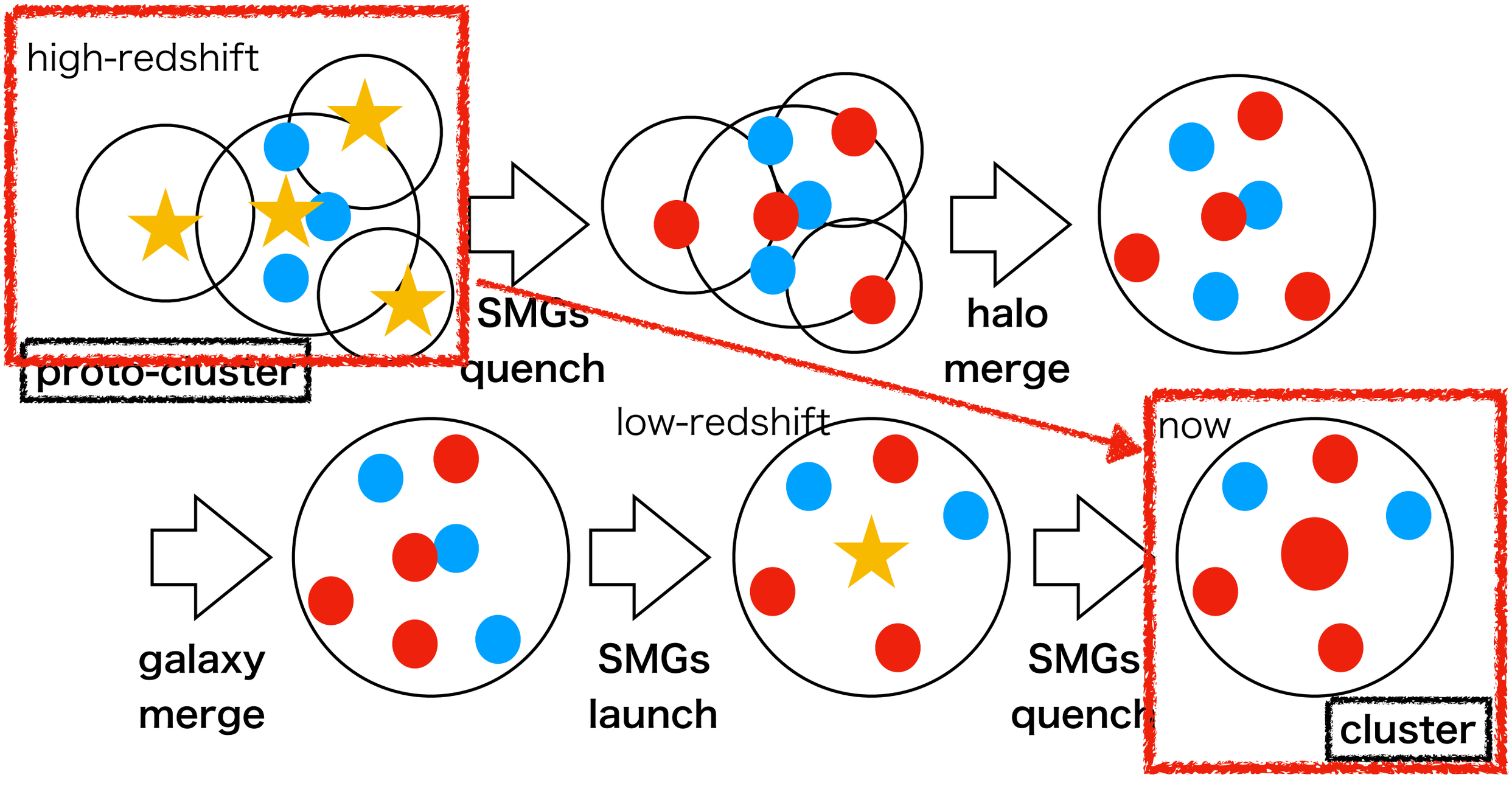

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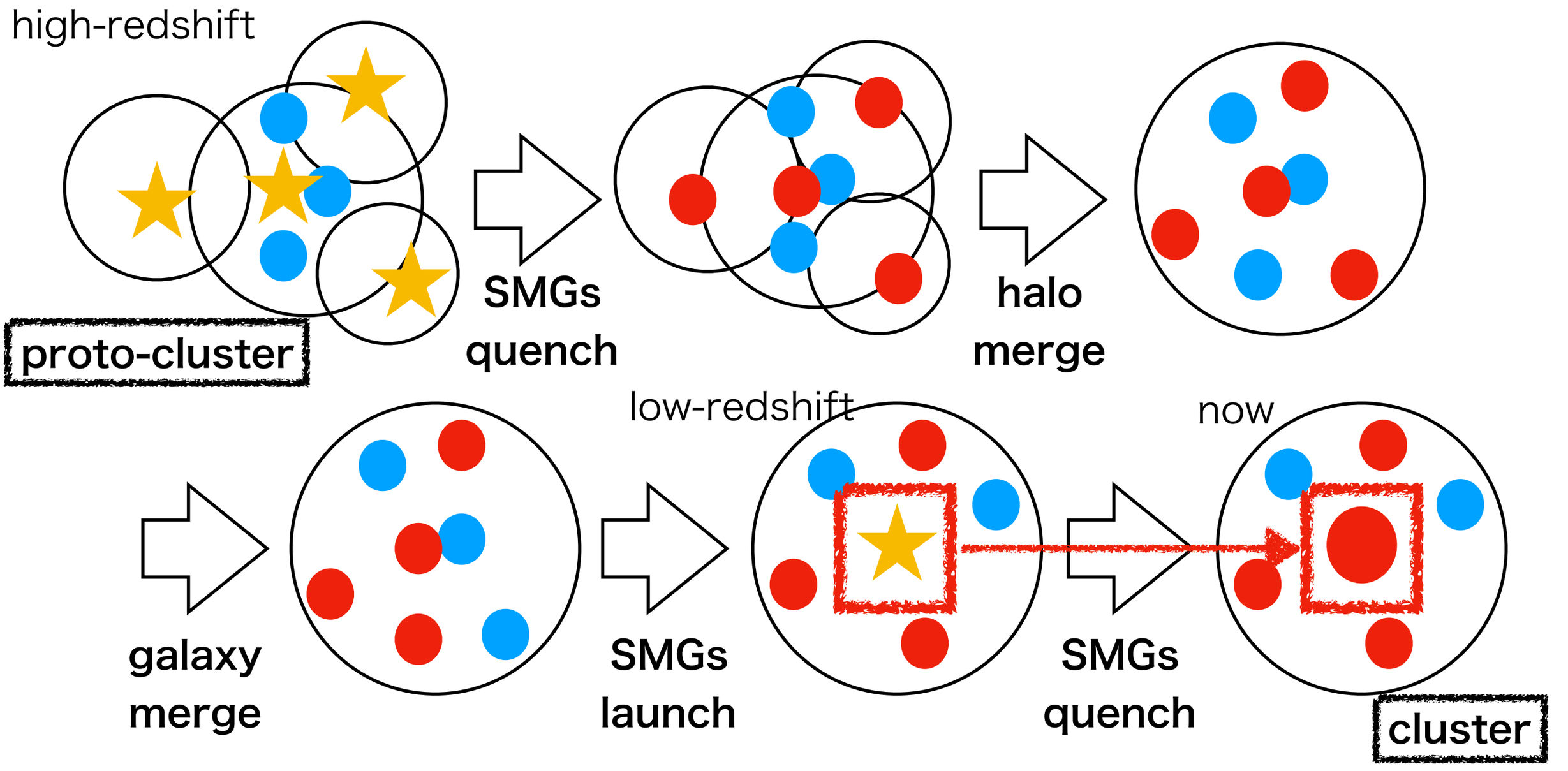

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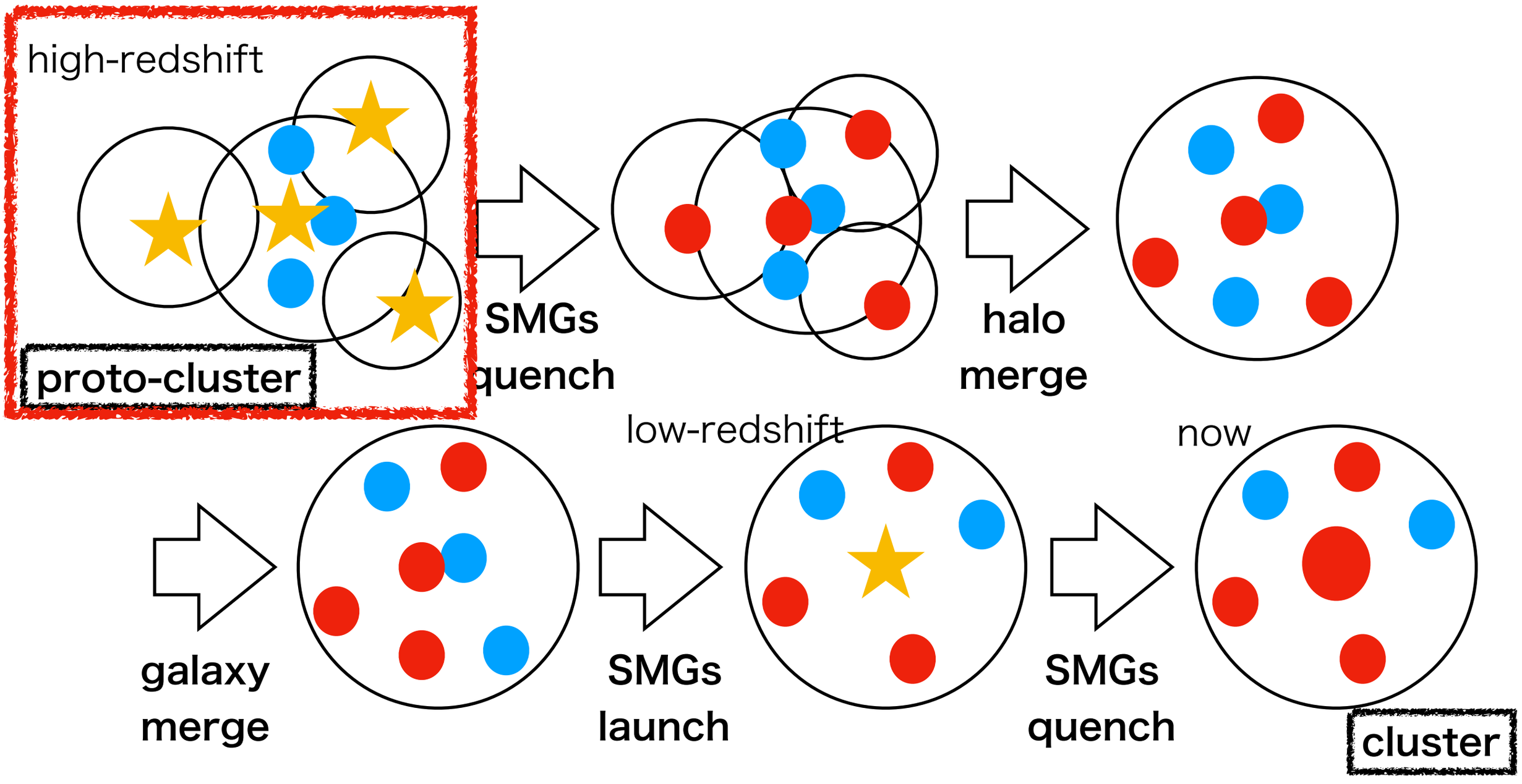

1.Introduction

overview of high-z Proto-cluster

Name (1)	z (2)	N_{spec} (3)	δ (4)	Sample (5)	Window size (6)	dz (7)	σ_V (8)	M_h (9)	Reference (10)
				Protocluster with $N_{spec} \geqslant 10$					
z66OD	6.59	12	14.3 ± 2.1	LAE	$\pi \times 4.2^2$	0.1	670 ± 200	5.4×10^{14}	This work
HSC-z7PCC26	6.54	14	$6.8^{+6.1}_{-3.7}$	LAE	$\pi \times 4.2^2$	0.1	572	8.4×10^{14}	C17,19,Hi18
SDF	6.01	10	16 ± 7	LBG	6×6	~0.05	647 ± 124	$(2–4) \times 10^{14}$	To12,14
z57OD	5.69	44	11.5 ± 1.6	LAE	$\pi \times 4.2^2$	0.1	1280 ± 220	4.8×10^{14}	O05,J18,This work
SPT2349-56	4.31	14	>1000	SMG	$\pi \times 0.16^2$	0.1	408^{+82}_{-56}	1.16×10^{13}	M18
TNJ1338-1942	4.11	37	$3.7^{+1.0}_{-0.8}$	LAE/LBG	$7 \times 7(\times 2)$	0.049	265 ± 65	$(6–9) \times 10^{14}$	V02,05,07,M04, Z05,Ov08
DRC-protocluster	4.00	10	~5.5–11.0	SMG	0.61×0.730	...	794	$(3.2–4.4) \times 10^{13}$	O18
PC217.96+32.3	3.79	65	14 ± 7	LAE	$\pi \times 1.2^2$	0.035	350 ± 40	$(0.6–1.3) \times 10^{15}$	Lee14,D16,S19
D4GD01	3.67	11	...	LBG	$\pi \times 1.8^2$	~1	352 ± 140	...	To16
ClJ0227-0421	3.29	19	10.5 ± 2.8	Spec	$\pi \times 6.2^2$	0.09	995 ± 343	$(1.9–3.3) \times 10^{14}$	Lem14
TNJ2009-3040	3.16	>11	$0.7^{+0.8}_{-0.6}$	LAE	7×7	0.049	515 ± 90	...	V07
MRC0316-257	3.13	31	$2.3^{+0.5}_{-0.4}$	LAE	7×7	0.049	640 ± 195	$(3–5) \times 10^{14}$	V05,07
SSA22FLD	3.09	>15	$3.6^{+1.4}_{-1.2}$	LBG/ LAE/SMG	11.5×9	0.034	...	$(1.0–1.4) \times 10^{15}$	S98,00,M05,Y12,U17,18
MRC0943-242	2.92	28	$2.2^{+0.9}_{-0.7}$	LAE	7×7	0.056	715 ± 105	$(4–5) \times 10^{14}$	V07
P2Q1	2.90	12	12 ± 2	Spec	7×8	0.016	270 ± 80	8.1×10^{14}	C14
MRC0052-241	2.86	37	$2.0^{+0.5}_{-0.4}$	LAE	7×7	0.054	980 ± 120	$(3–4) \times 10^{14}$	V07
HS1549	2.85	26	~5	LBG/SMG	...	0.060	...	...	M13,Lac18
PCL1002	2.45								D15,Ch15,Ca15
HS1700FLD	2.30								S05,Lac18
PKS1138-262	2.16			HAE/SMG					K00,04a,04b,P00,02, V07,K13,Z18
				Protocluster with $N_{spec} < 10$					
A2744z8OD	8.38	1	132^{+66}_{-51}	LBG	$\pi \times 0.1^2$	~1	...	9×10^{13}	I16,L17
Borg	~8	0	~4.5	LBG	2.1×2.3	~1	...	$>2 \times 10^{14}$	Tr12
BDF	7.04	3							
HSC-z7PCC4	6.58	1							
CFHQSJ2329-0301	6.43	0							
HSC-z6PCC4	5.72	4							
HSC-z6PCC5	5.69	2							
COSMOSAzTEC03	5.30	4							
TNJ0924-2201	5.19	6							
SDF	4.86	0							
PClJ1001+0220	4.57	9							
6C0140+326	4.41	0	8 ± 5	LAE	10×10	~0.04	...	$(0.8–2.9) \times 10^{14}$	K11
D4UD01	3.24	5	...	LBG	$\pi \times 1.6^2$	~1	61 ± 105	...	To16
D1UD01	3.13	5	...	LBG	$\pi \times 1.6^2$	~1	235 ± 75	...	To16
LABd05	2.7	0	~2	LAE	28×11	0.165	...	...	P08
USS1558-003	2.53	0	...	HAE	7×4	0.041	...	...	H12
4C23.56	2.48	3	$4.3^{+5.3}_{-2.6}$	HAE/SMG	7×4	0.035	...	...	T11,Z18
J2143-4423	2.38	0	5.8 ± 2.5	LAE	44×44	0.044	...	...	P04
4C10.48	2.35	0	11^{+2}_{-2}	HAE	2.5×2.5	0.046	...	...	H11
BoötesJ1430+3522	2.3	0	2.7 ± 1.1	LAE	$\pi \times 5^2$	0.0037	...	1.51×10^{15}	B17

LAE/LBG → SMG

SMGのoverdnsityから Proto-clusterを発見！

Harikane+2019

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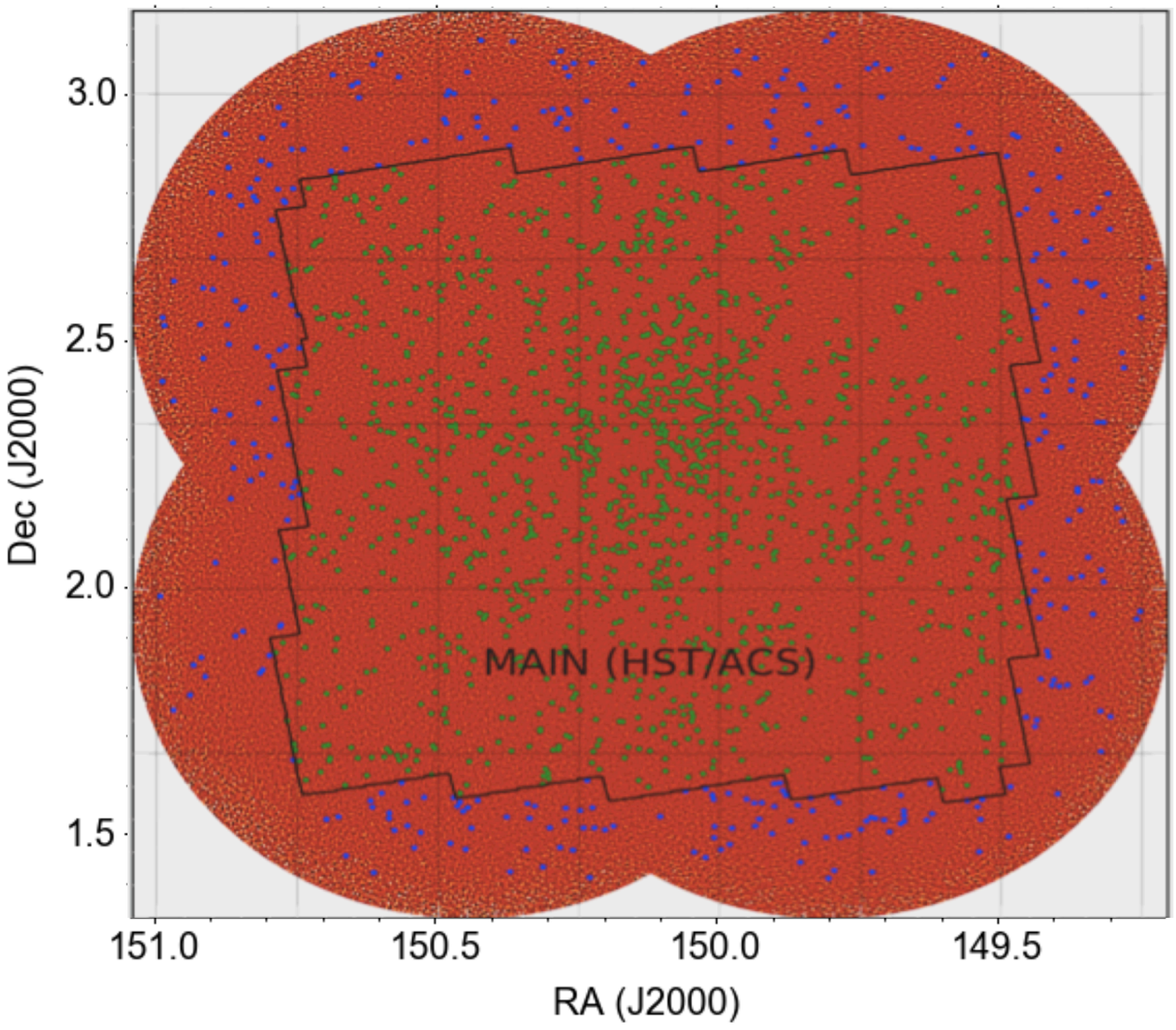
2.Data

- 領域：COSMOS (1.4×1.4deg^2)
- 元観測：SCUBA-2 (resolution~15”/1147SMGs/>4σ=4.8mJy)

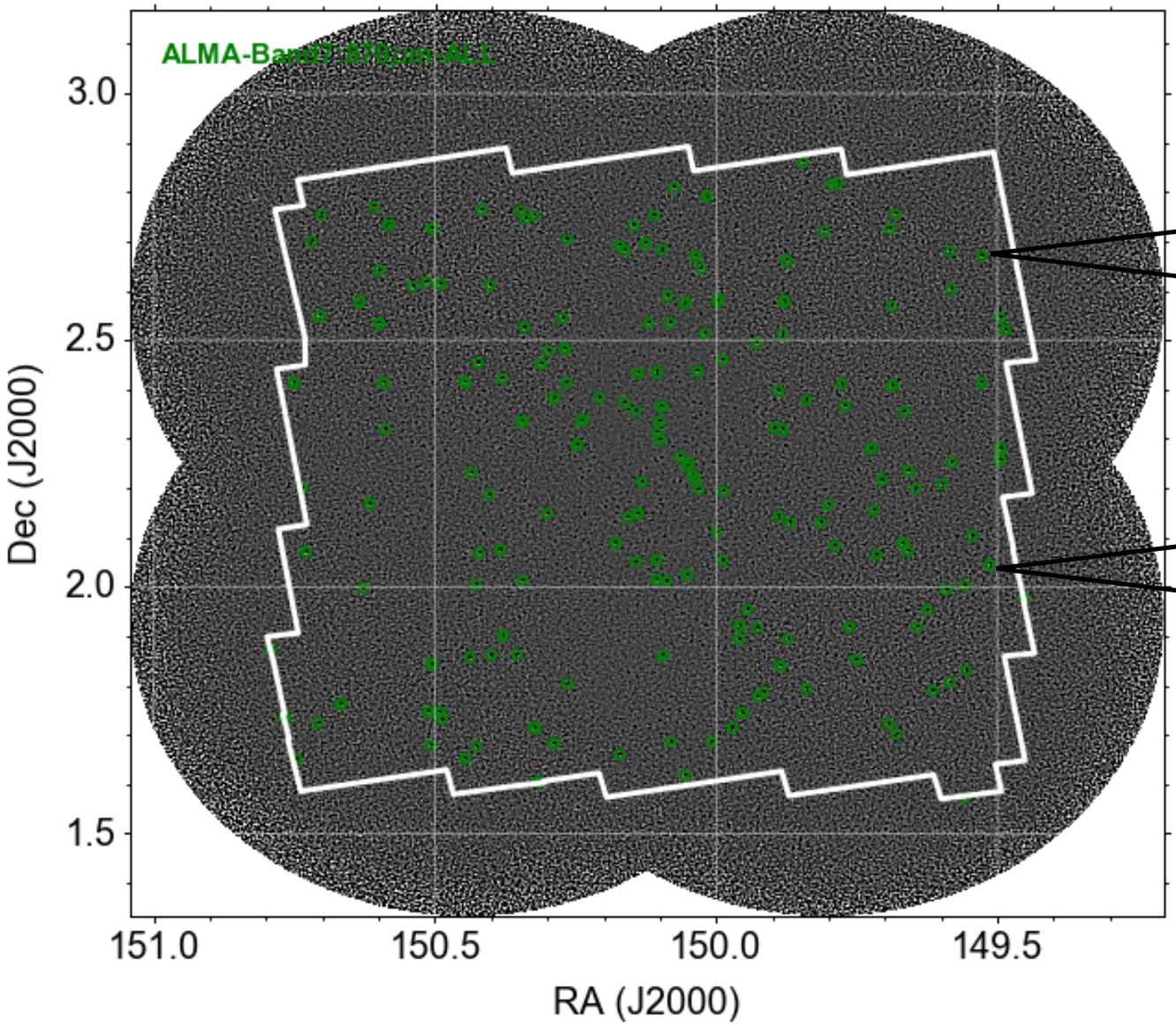
豊富な測光データ
- **SUBARU HSC U-deep**
- **UVISTA UD & Deep etc..**

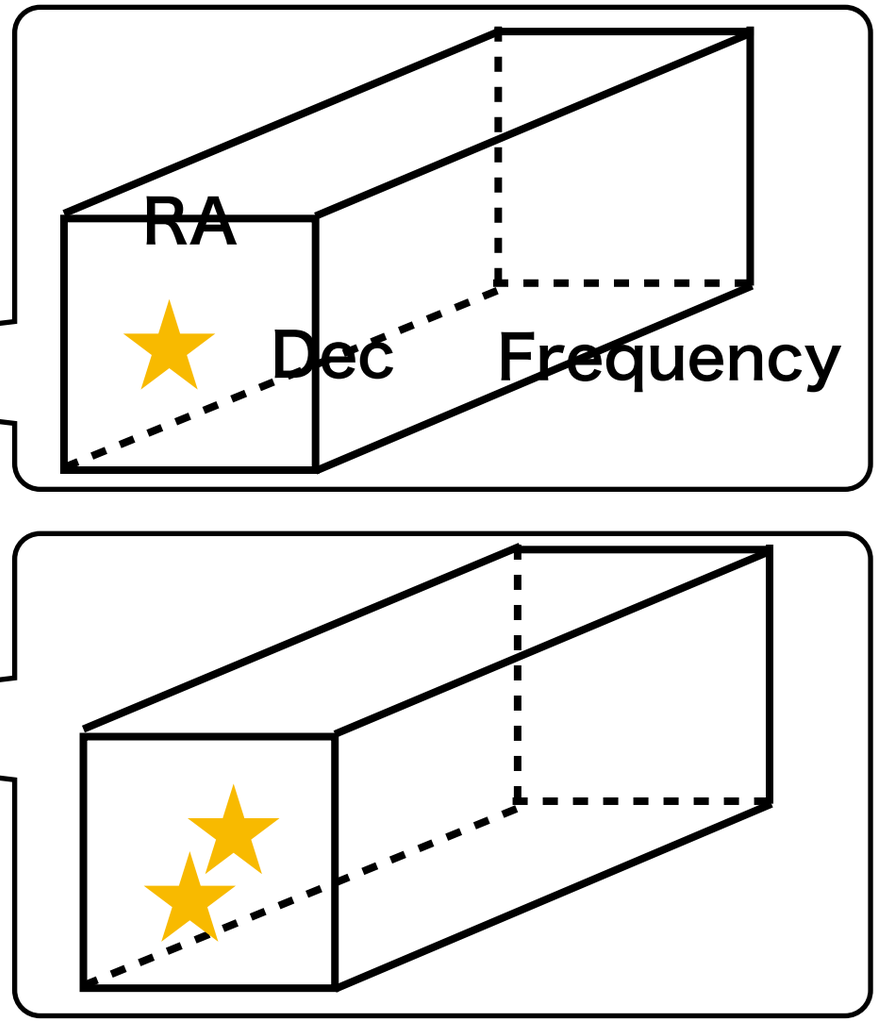


2.Data

- 領域：COSMOS (1.4×1.4deg^2)
- 元観測：SCUBA-2 (resolution~15”/1147SMGs/>4σ=4.8mJy)

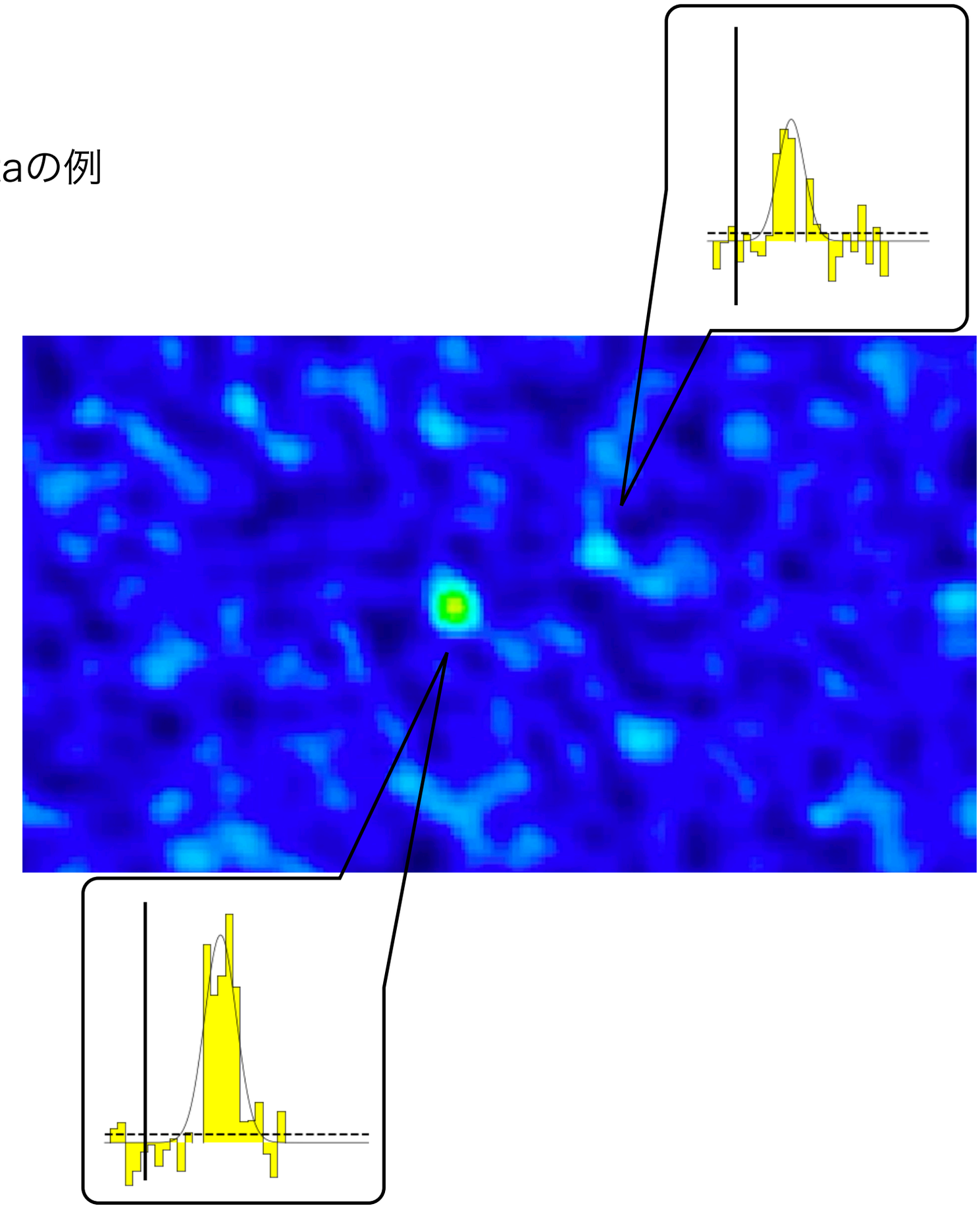
フォローアップ：ALMA band7 (resolution~1”/184field/>5σ=6.6mJy)





2.Data

cube dataの例

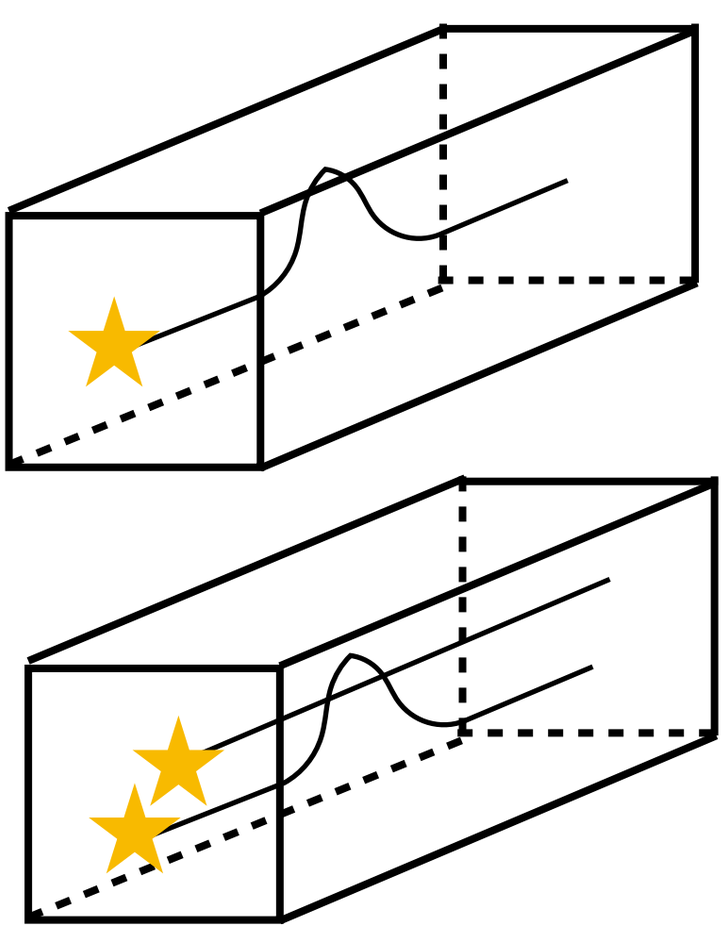


Presentation Table

3.Analysis

- 領域：COSMOS (1.4×1.4deg^2)
- 元観測：SCUBA-2 (resolution~15”/1147SMGs)

フォローアップ：ALMA band7 (resolution~1”/184field)

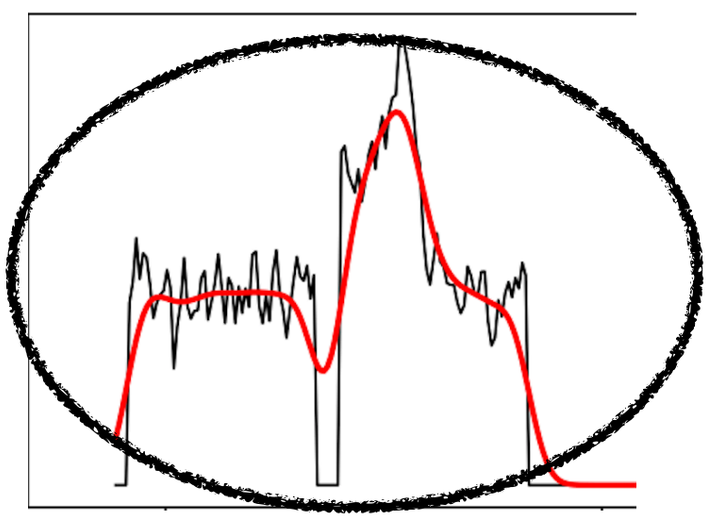


×184

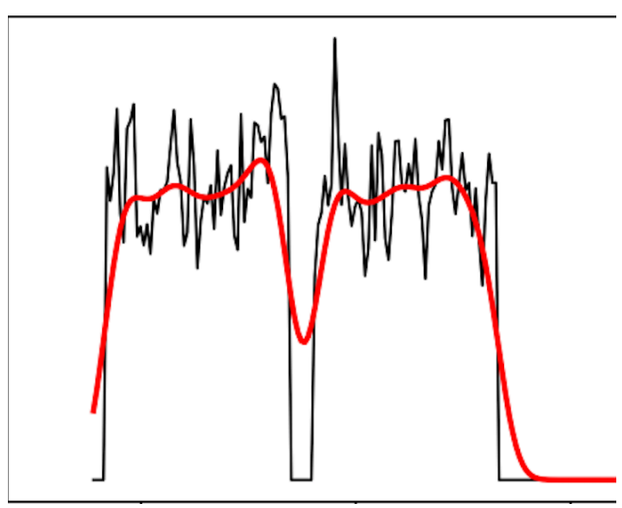
background noiseから
5σ以上のpixelの有無

無 → 特に何もしない

有 → そのpixelで
周波数方向に切り出し



S/N>10のlineを抽出



Presentation Table

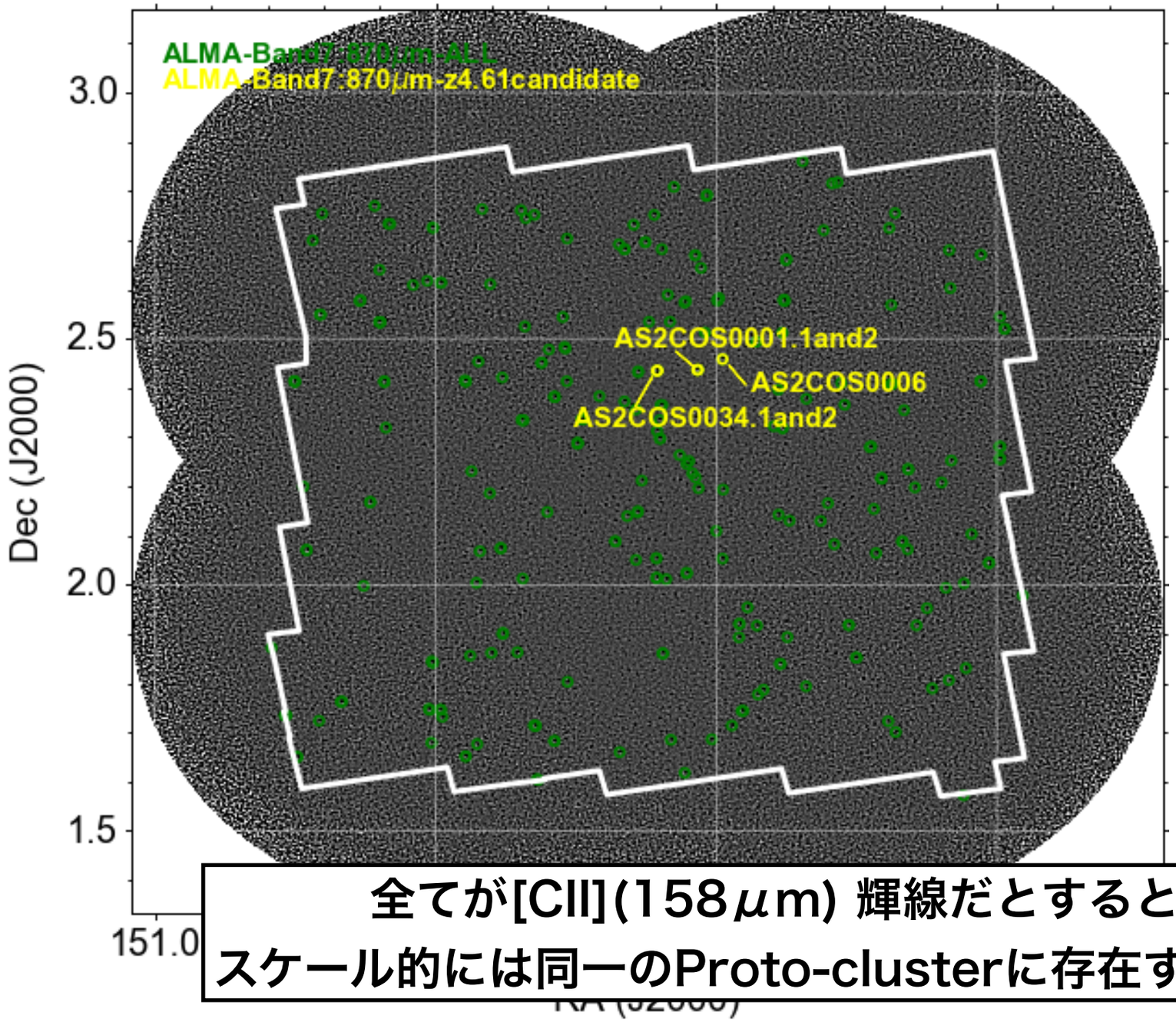
4.Result

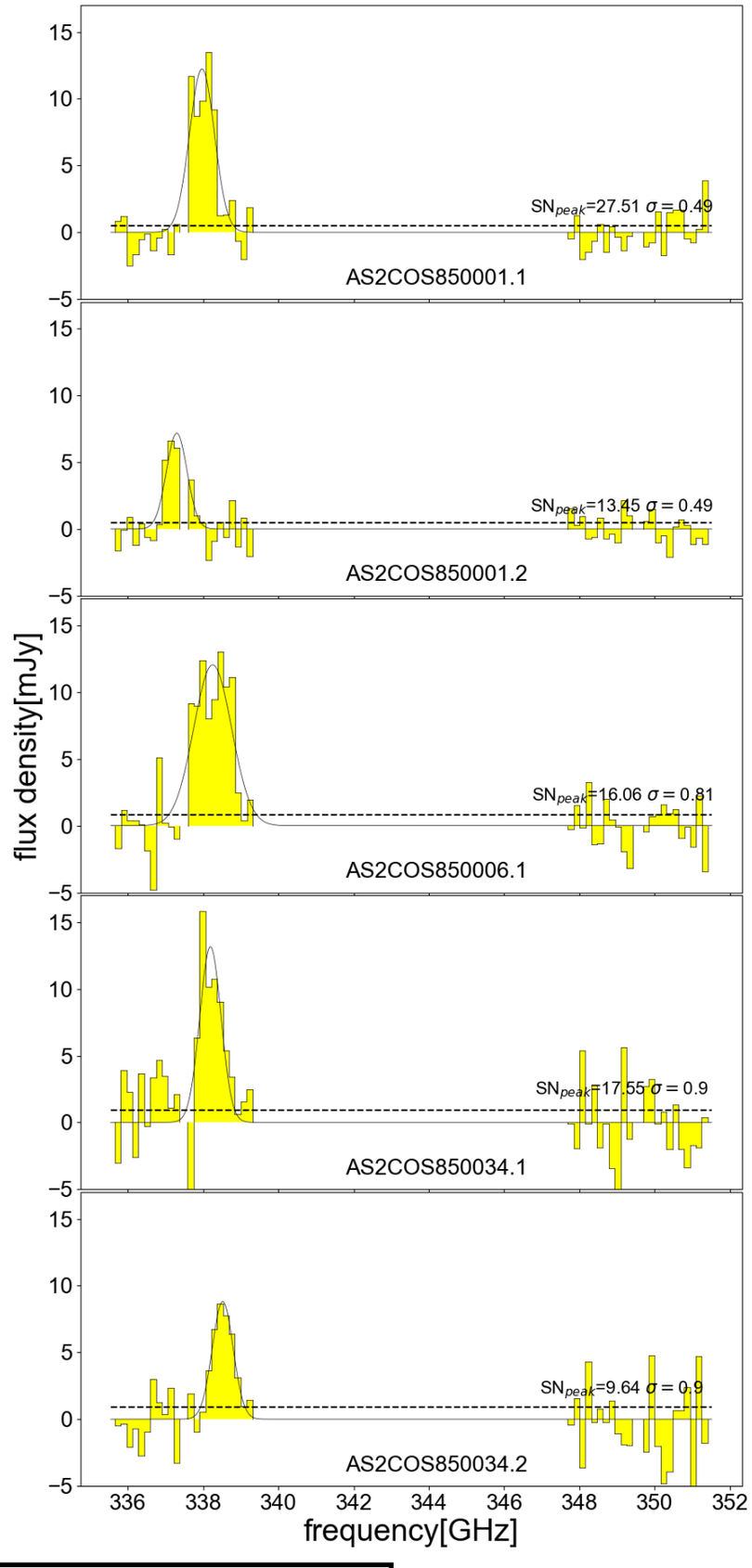
5天体で

ほぼ同じ周波数

かなり近い距離(~7'=~10Mpc@z=4.62)

の輝線を検出





全てが[CII](158μm) 輝線だとするとz~4.62,

スケール的には同一のProto-clusterに存在する可能性は高い

4.Result

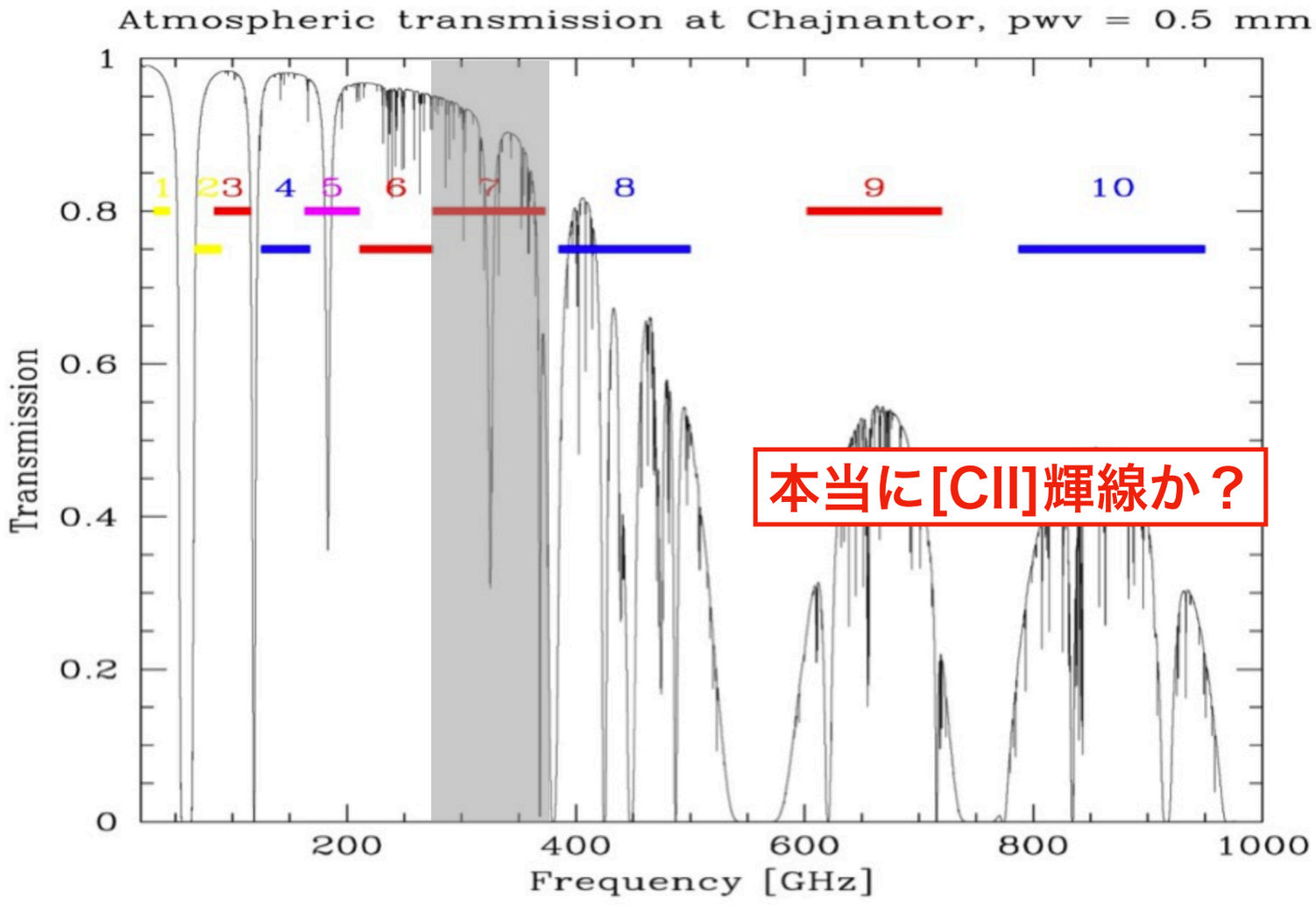
うち5天体で

ほぼ同じ周波数

かなり近い距離(~7'=~10Mpc@z=4.62)

の輝線を検出

ただし他の輝線が紛れている可能性は十分ある



- CO(3-2)@z~0.02
- CO(4-3)@z~0.35

  ⟆
- CO(12-11)@z~3.0
- more high-J CO @z>2.0
- [CI](610μm) @z~0.46
- [CI](370μm) @z~1.4
- [OI](146μm) @z~5.0
- [OIII](88μm) @z~9.0
- [OI](63μm) @z~13
- [OIII](52μm) @z~16

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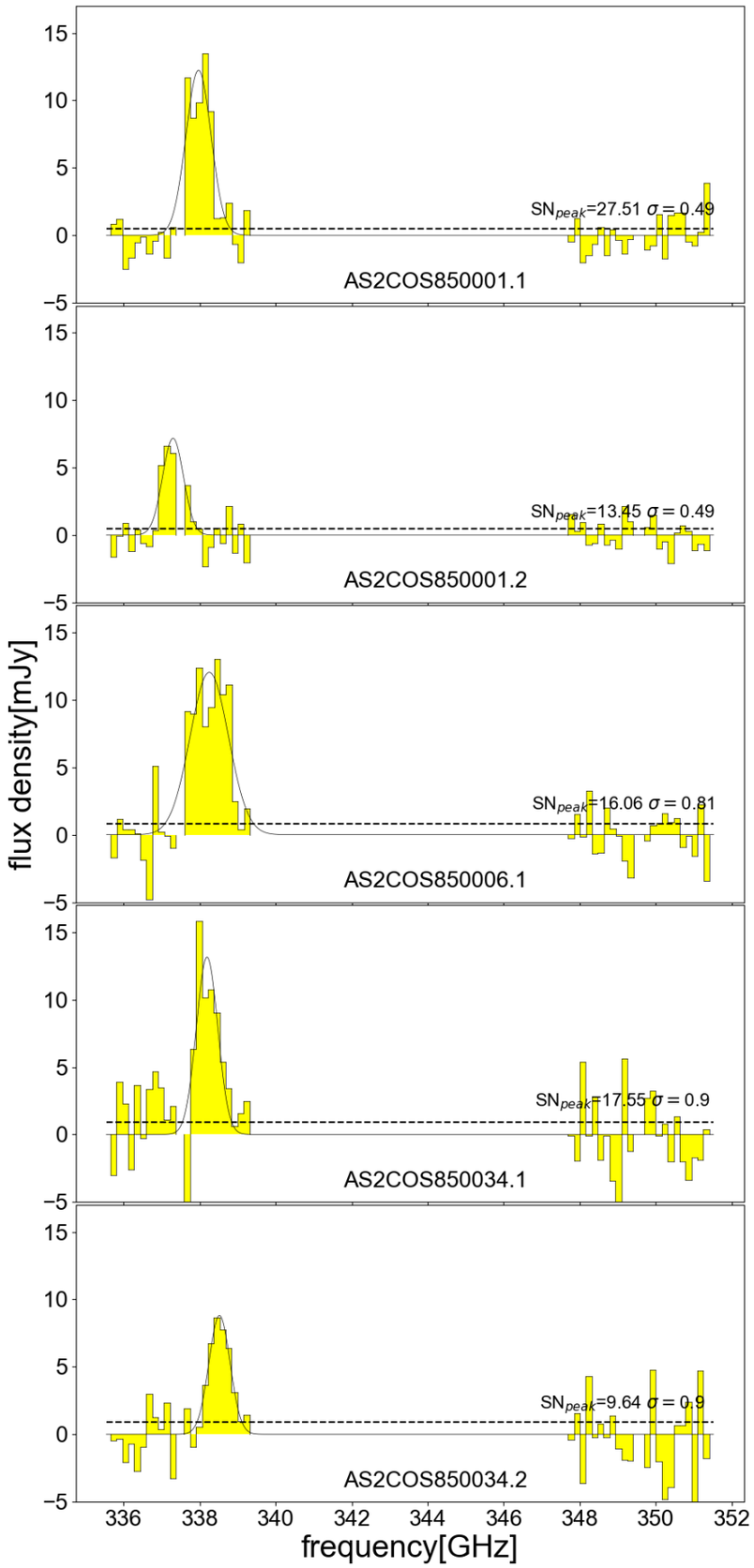

本当に[CII]輝線か？

[CII]輝線候補の特徴

- 連続波が検出
  (in ALMA)
- opticalにcontarpart
  なし
- かなり明るめ
- @158μm
  IR peak(~100μm)
  よりも長波長側か？

band7に入ってくる
他の輝線

- CO(3-2)@z~0.02
- CO(4-3)@z~0.35
  ⟆
- CO(12-11)@z~3.0
- more high-J CO
  @z>2.0
- [CI](610μm)
  @z~0.46
- [CI](370μm)
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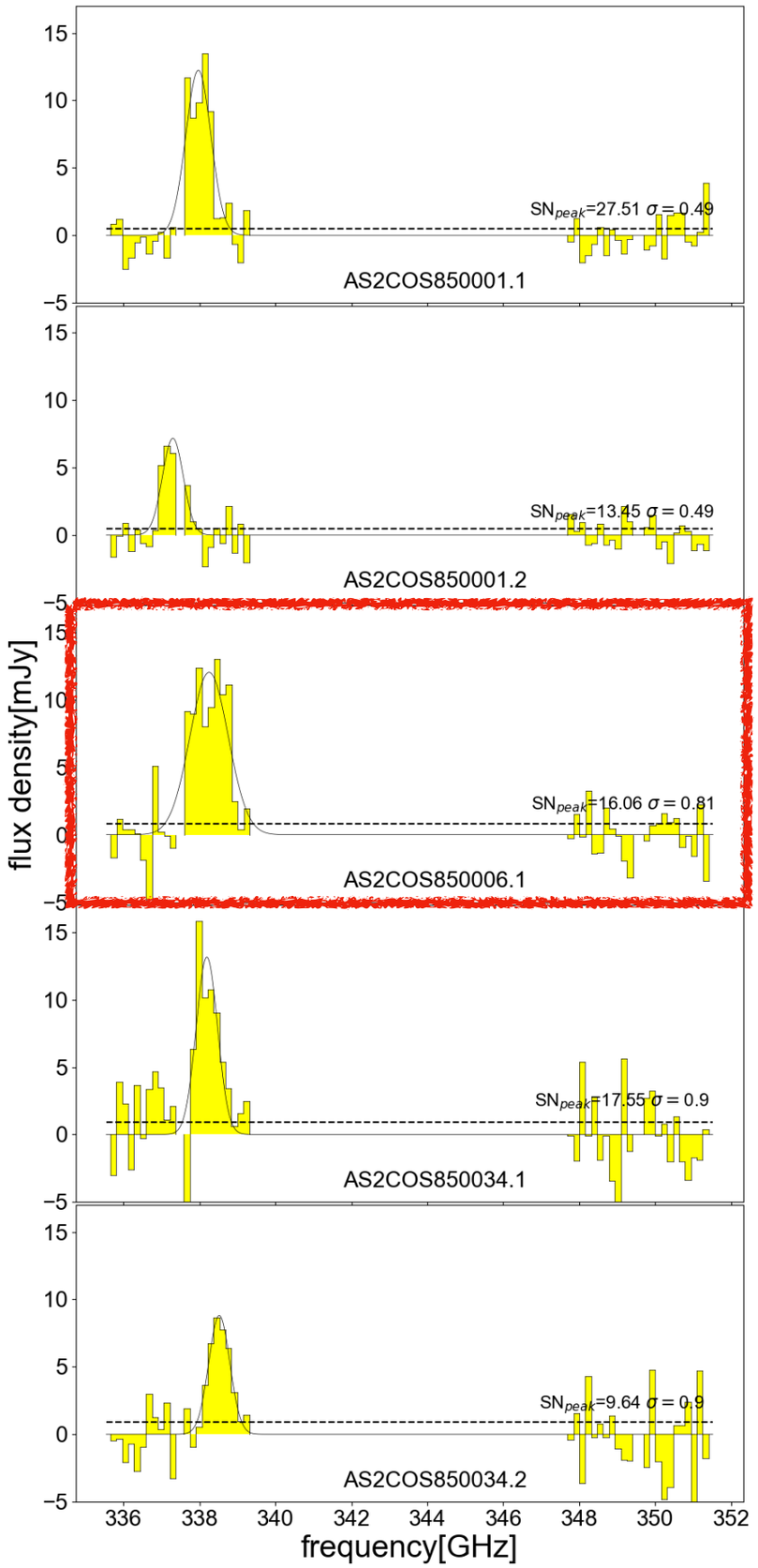
- [OIII](52μm)
  @z~16

5.Discussion-6.1



CO(4-3) line detected with NOEMA

assuming this line is [CII]

[CII] emission line !

本当に[CII]輝線か？

[CII]輝線候補の特徴

- 連続波が検出 (in ALMA)
- opticalにcounterpartなし
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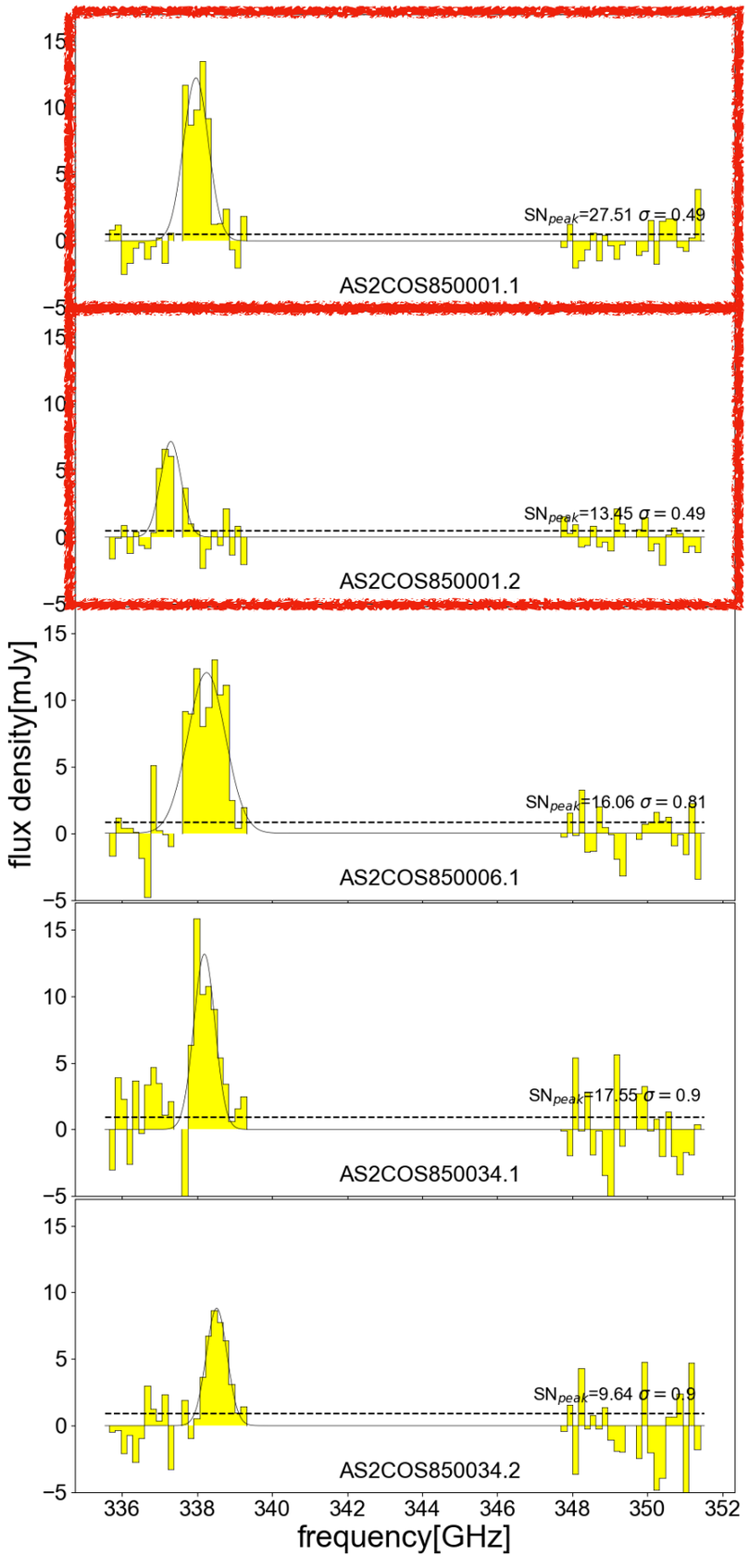
5.Discussion-1.1/1.2



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- opticalにcounterpartなし
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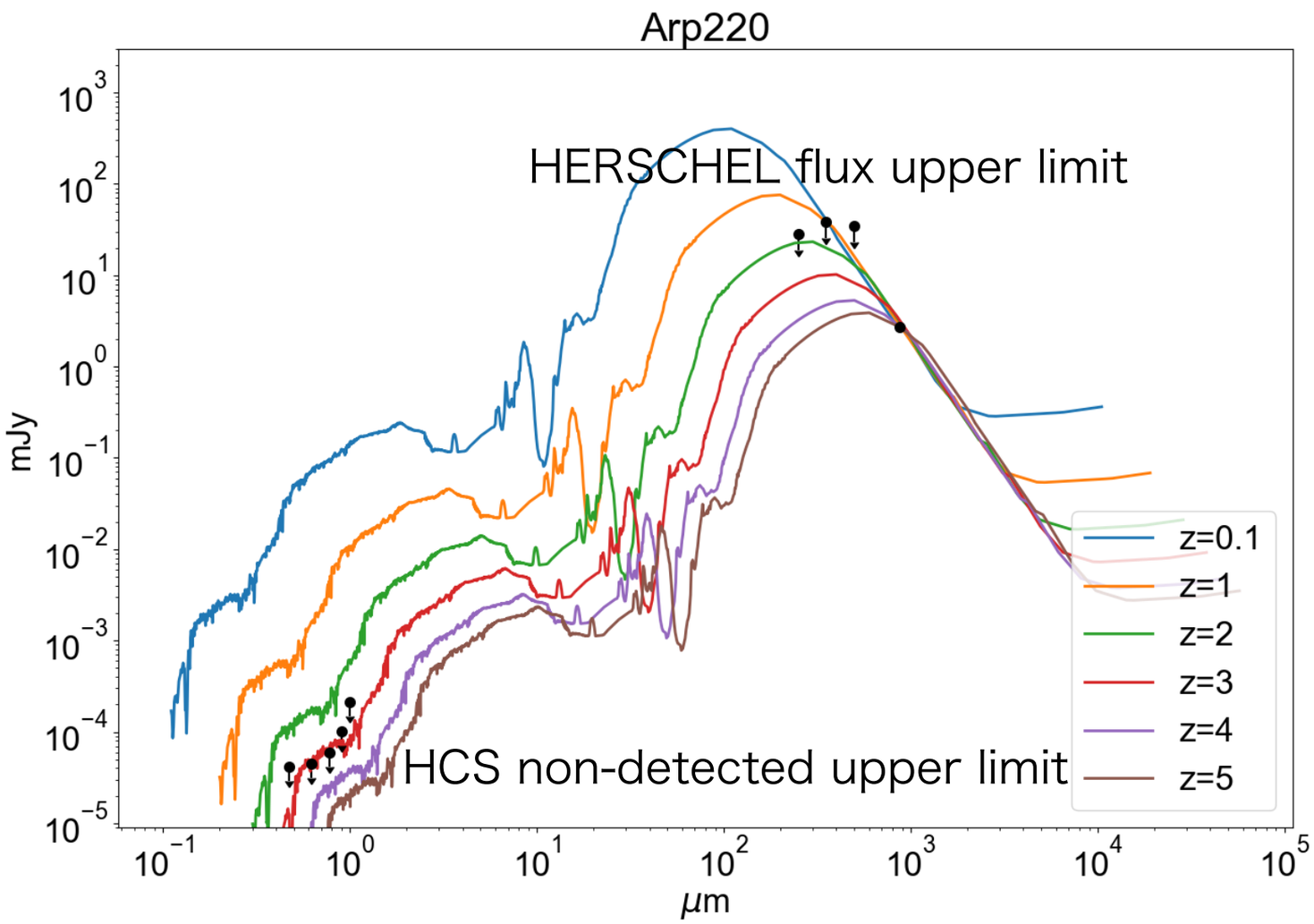

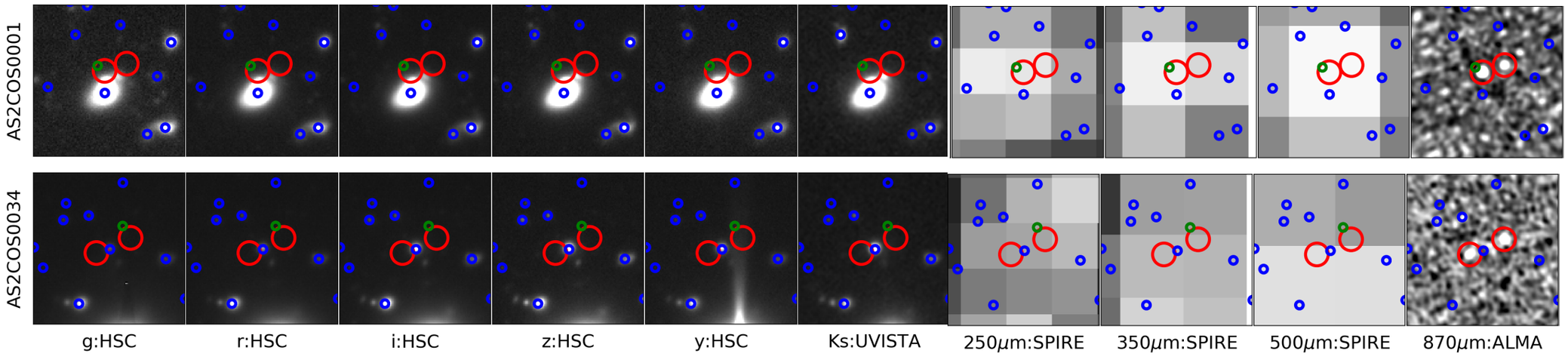

blue : optical detected　green : HERSCHEL detected

本当に[CII]輝線か？

[CII]輝線候補の特徴

- 連続波が検出 (in ALMA)
- opticalにcounterpartなし
- かなり明るい
- IR peakよりも長波長か？

z>3

他の輝線の候補

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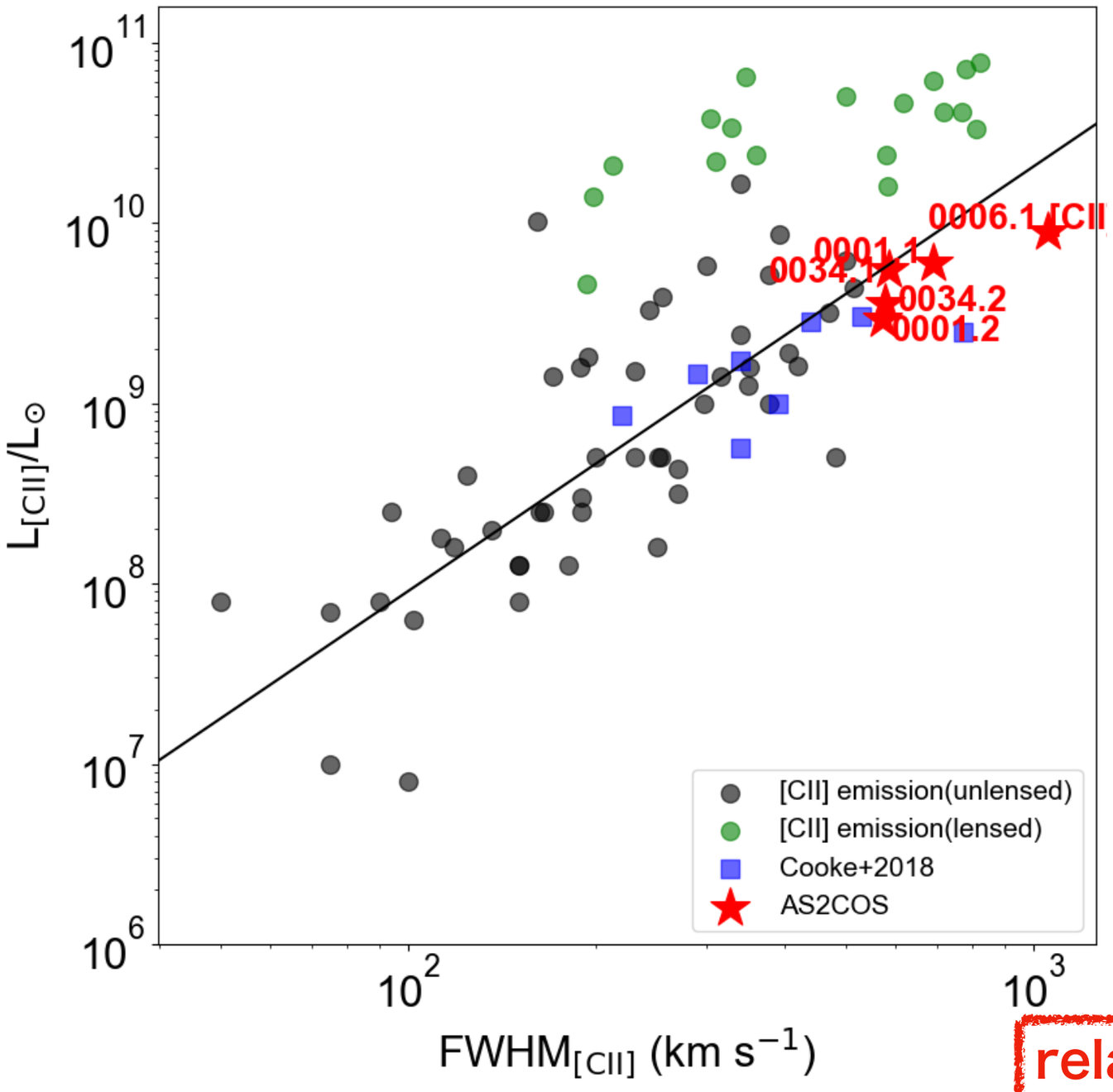
- [OIII](52μm) @z~16

5.Discussion-1.1/1.2



本当に[CII]輝線か？

[CII]輝線候補の特徴

- 連続波が検出 (in ALMA)
- opticalにcounterpartなし
- かなり明るい
- IR peakよりも長波長か？

他の輝線の候補

- ~~CO(3-2)@z~0.02~~
- ~~CO(4-3)@z~0.35~~

⟆

- ~~CO(12-11)@z~3.0~~
- ~~more high-J CO @z>3.0~~
- ~~[CI](610μm) @z~0.46~~
- ~~[CI](370μm) @z~1.4~~
- ~~[OI](146μm) @z~5.0~~
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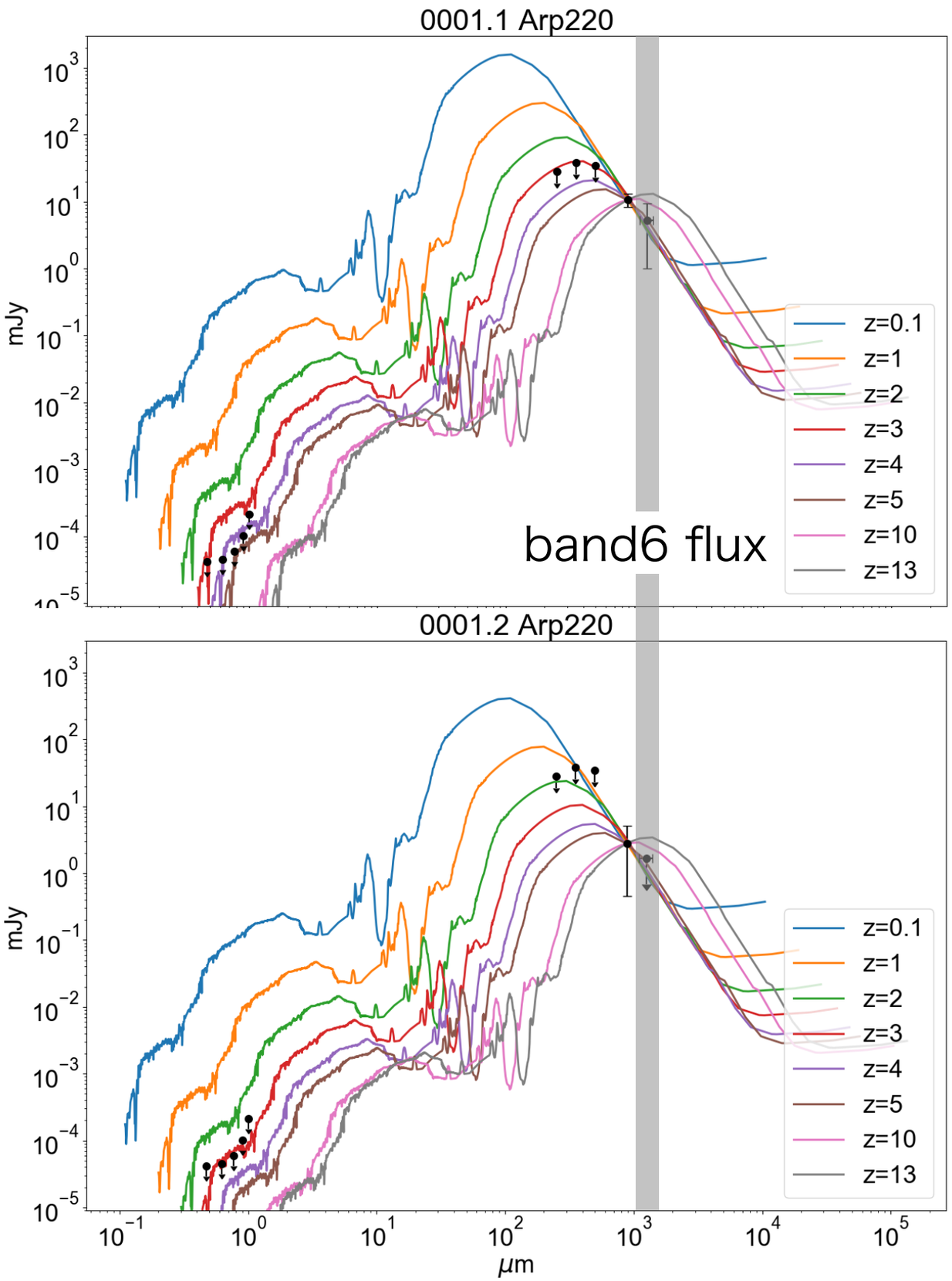
- [OI](63μm) @z~13
- [OIII](52μm) @z~16

relatively bright line

5.Discussion-1.1/1.2



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z<9

他の輝線の候補

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⟆

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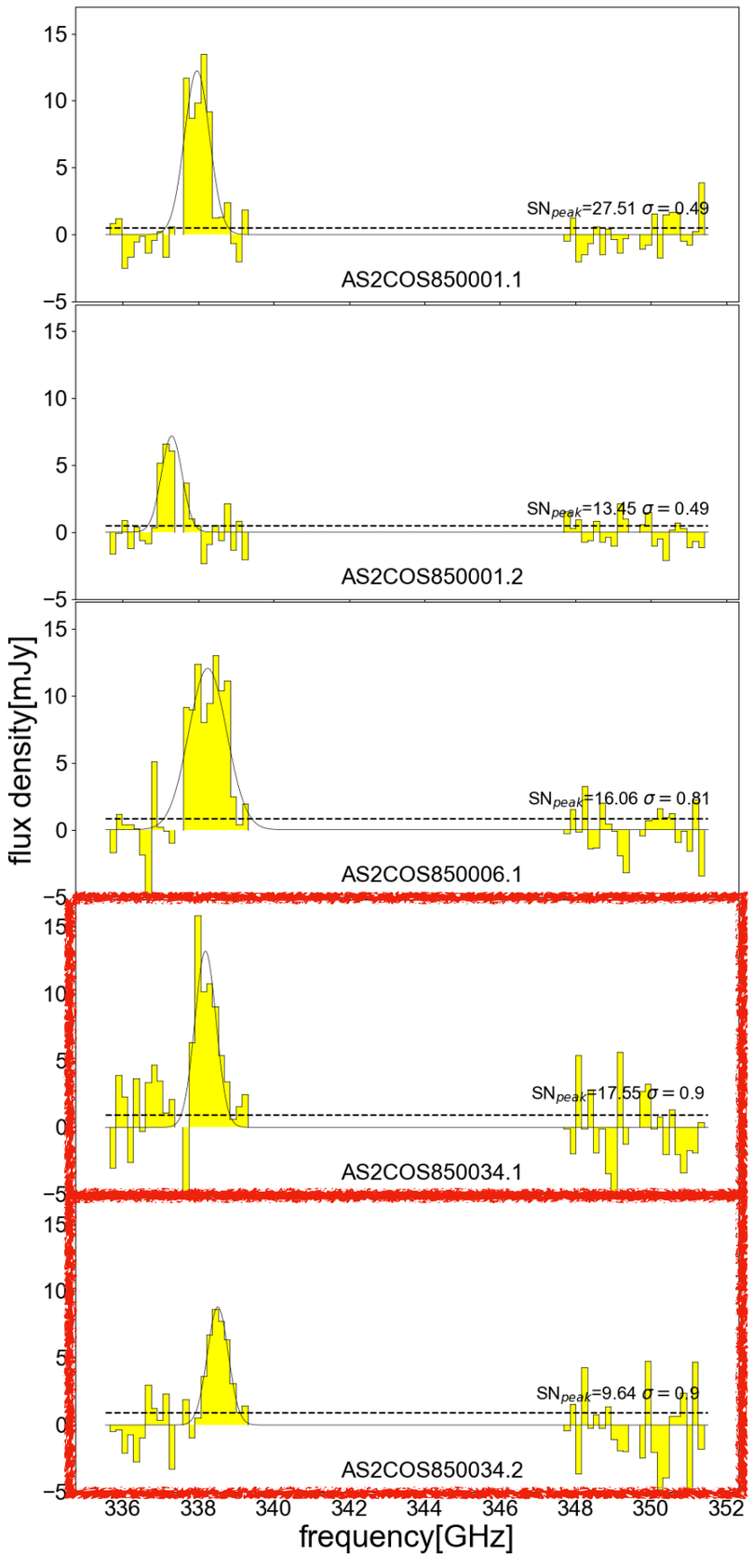
5.Discussion-34.1/34.2



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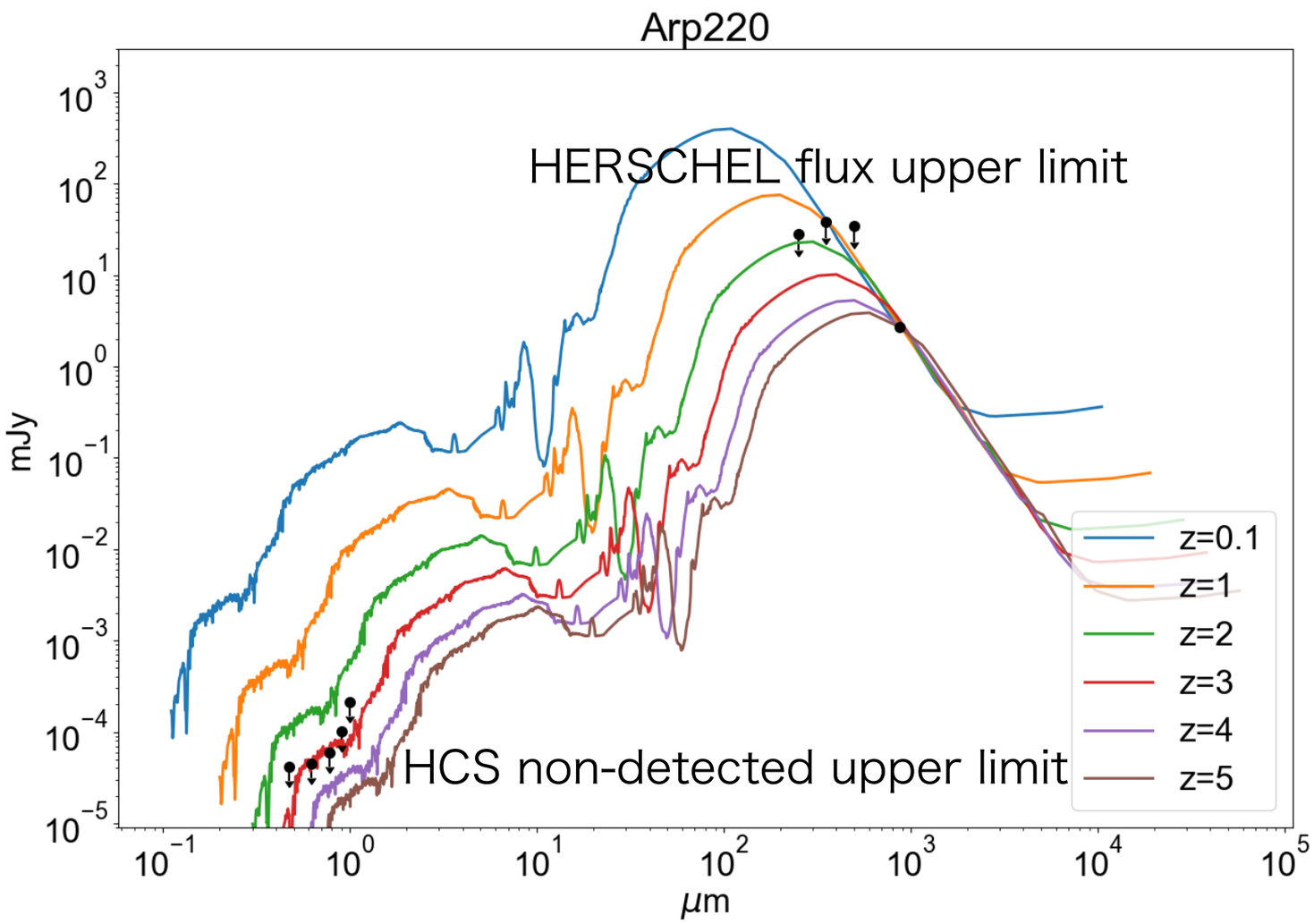
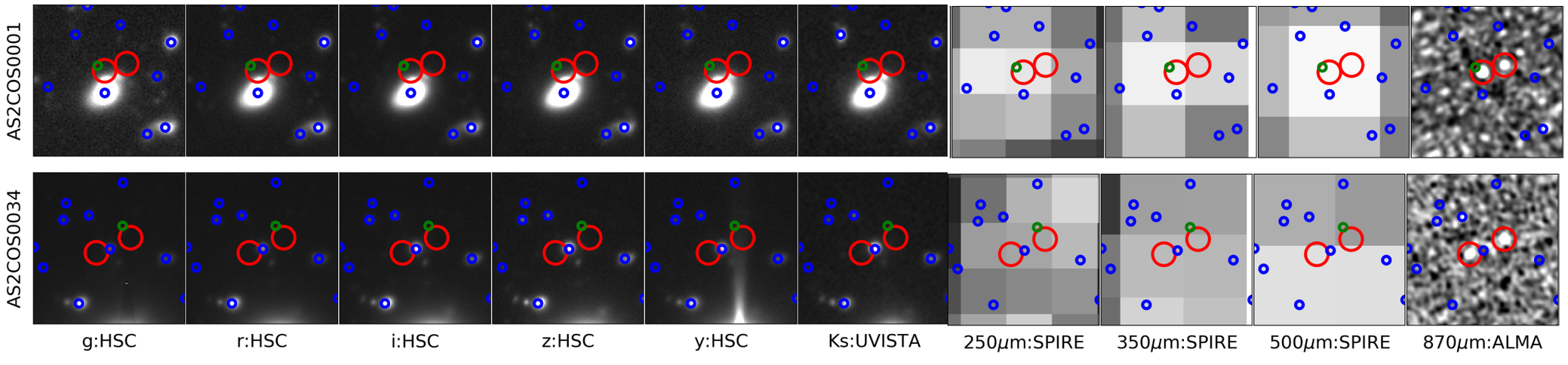
5.Discussion-34.1/34.2





blue : optical detected　green : HERSCHEL detected

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- IR peakよりも長波長か？

z>3

他の輝線の候補

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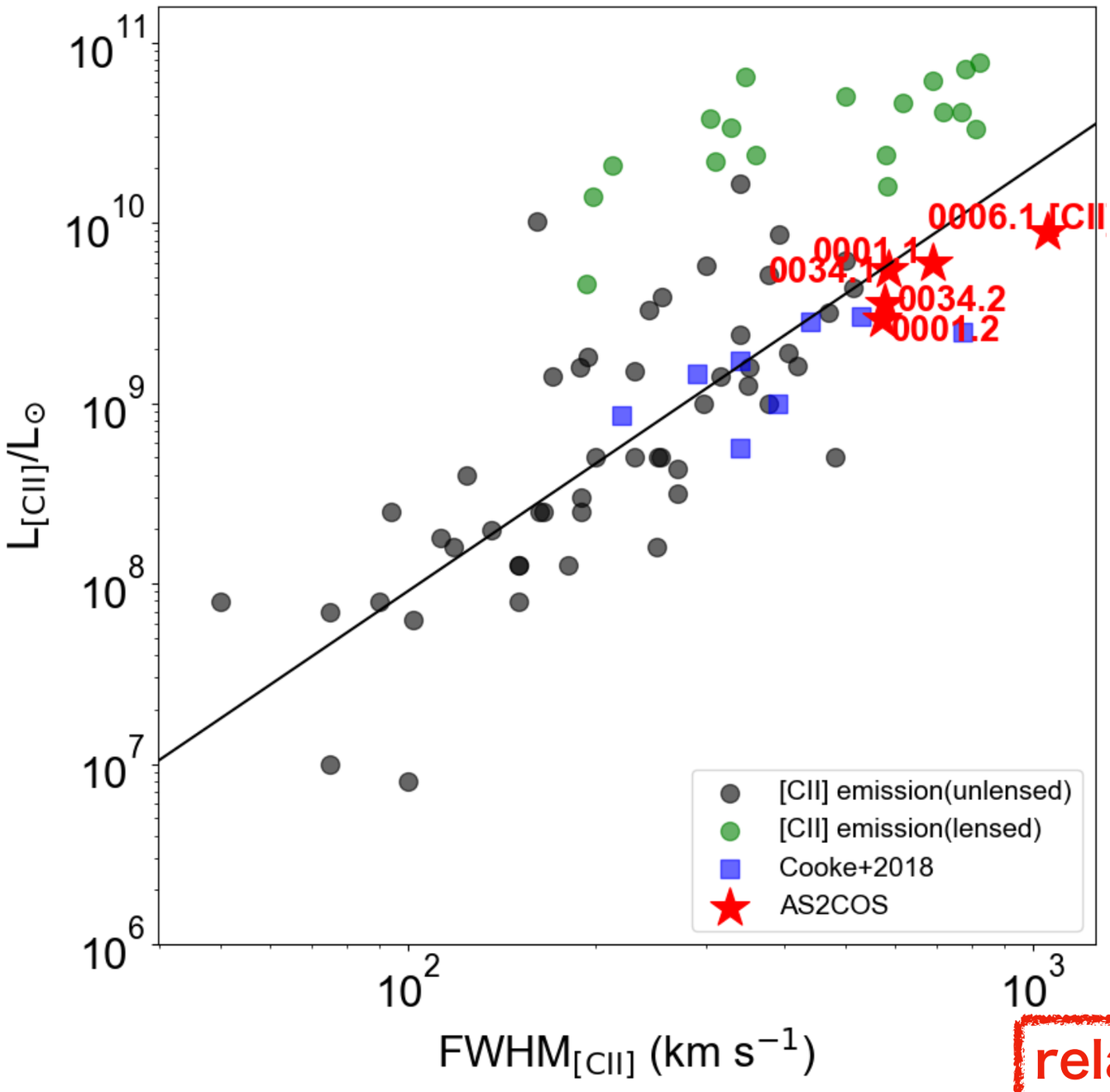
5.Discussion-34.1/34.2



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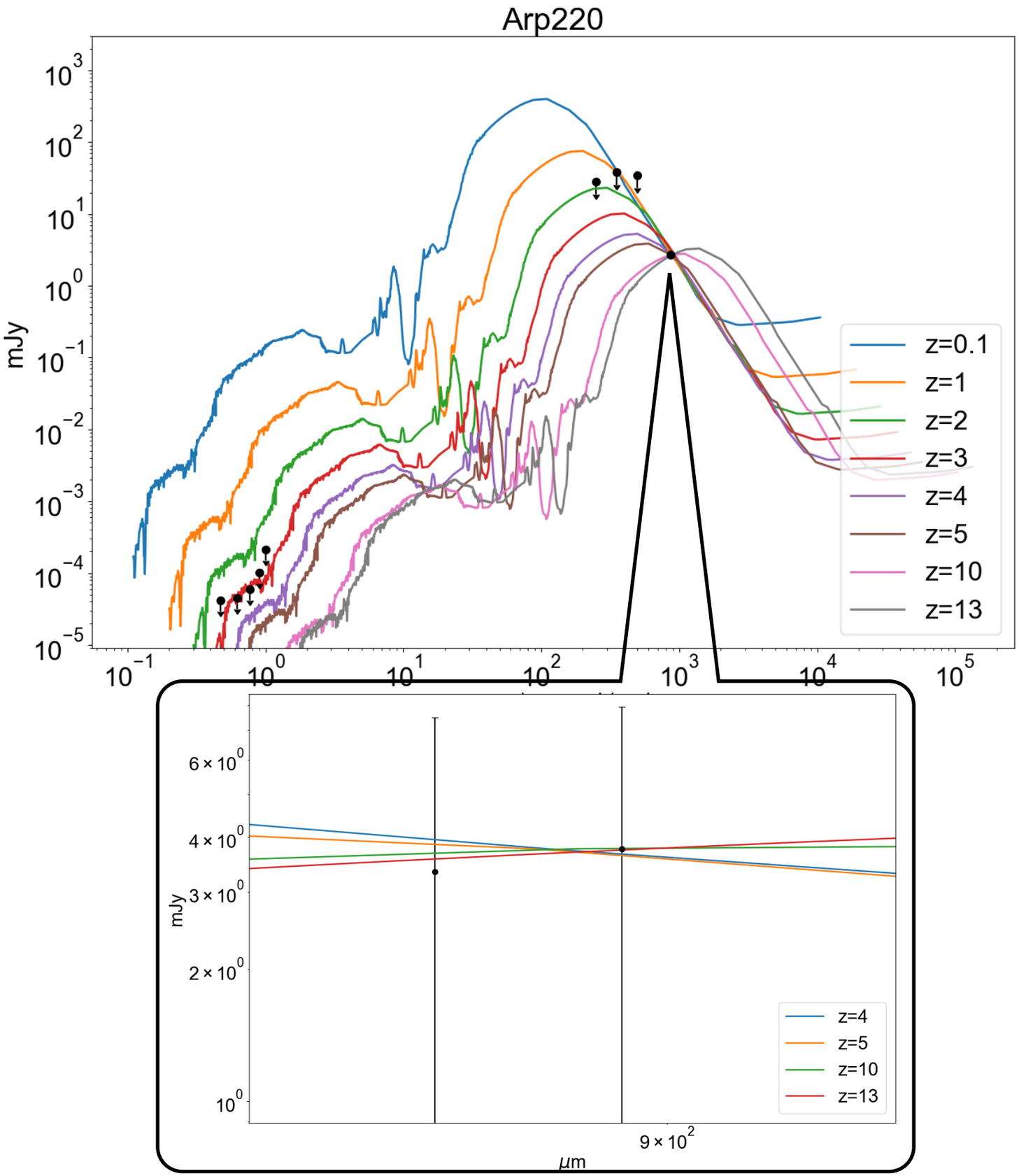

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z<9 ？

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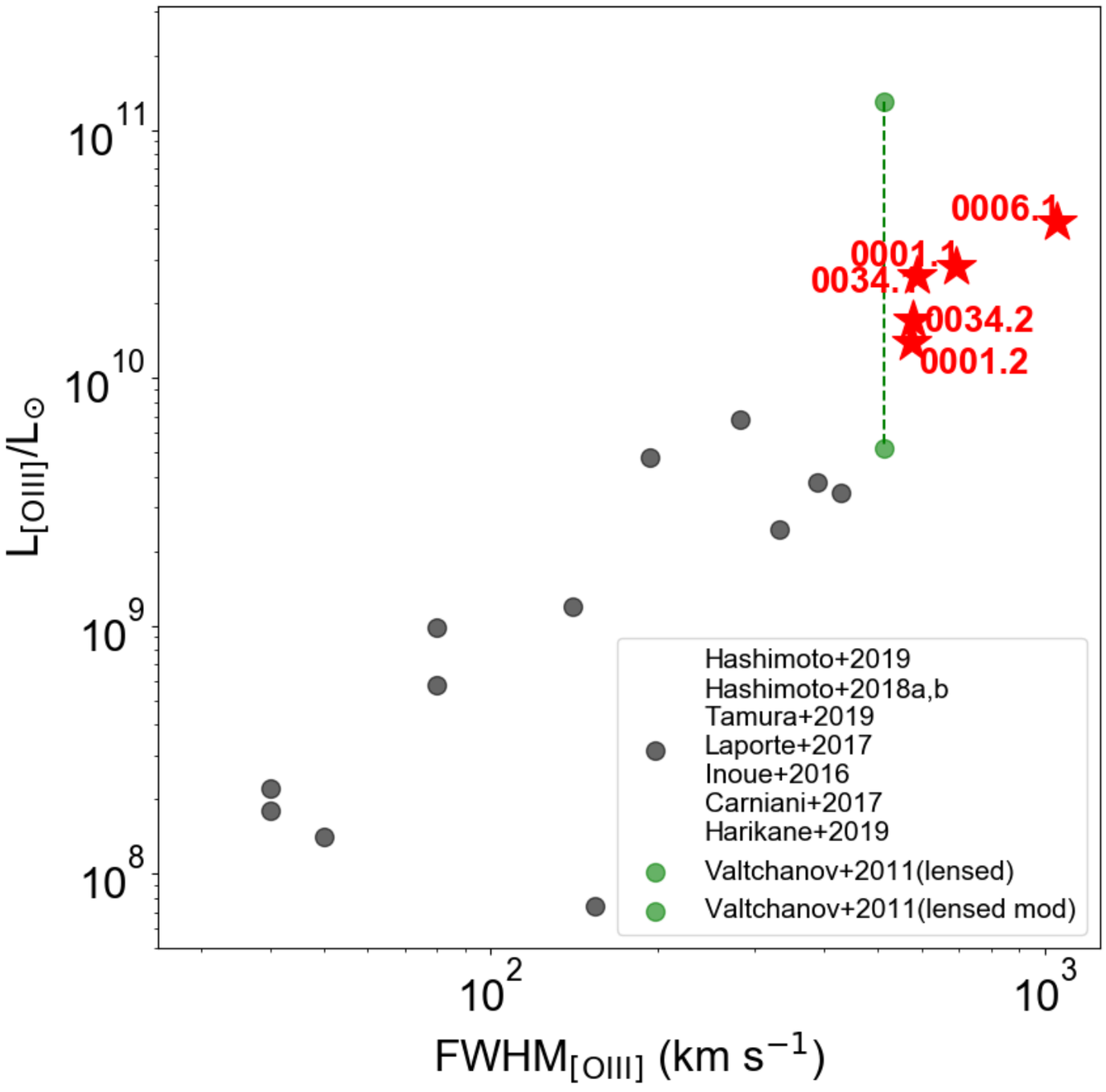
？

5.Discussion-34.1/34.2



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？

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- Galaxy Evolution
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- Proto-Clusters

2.Data

3.Analysis

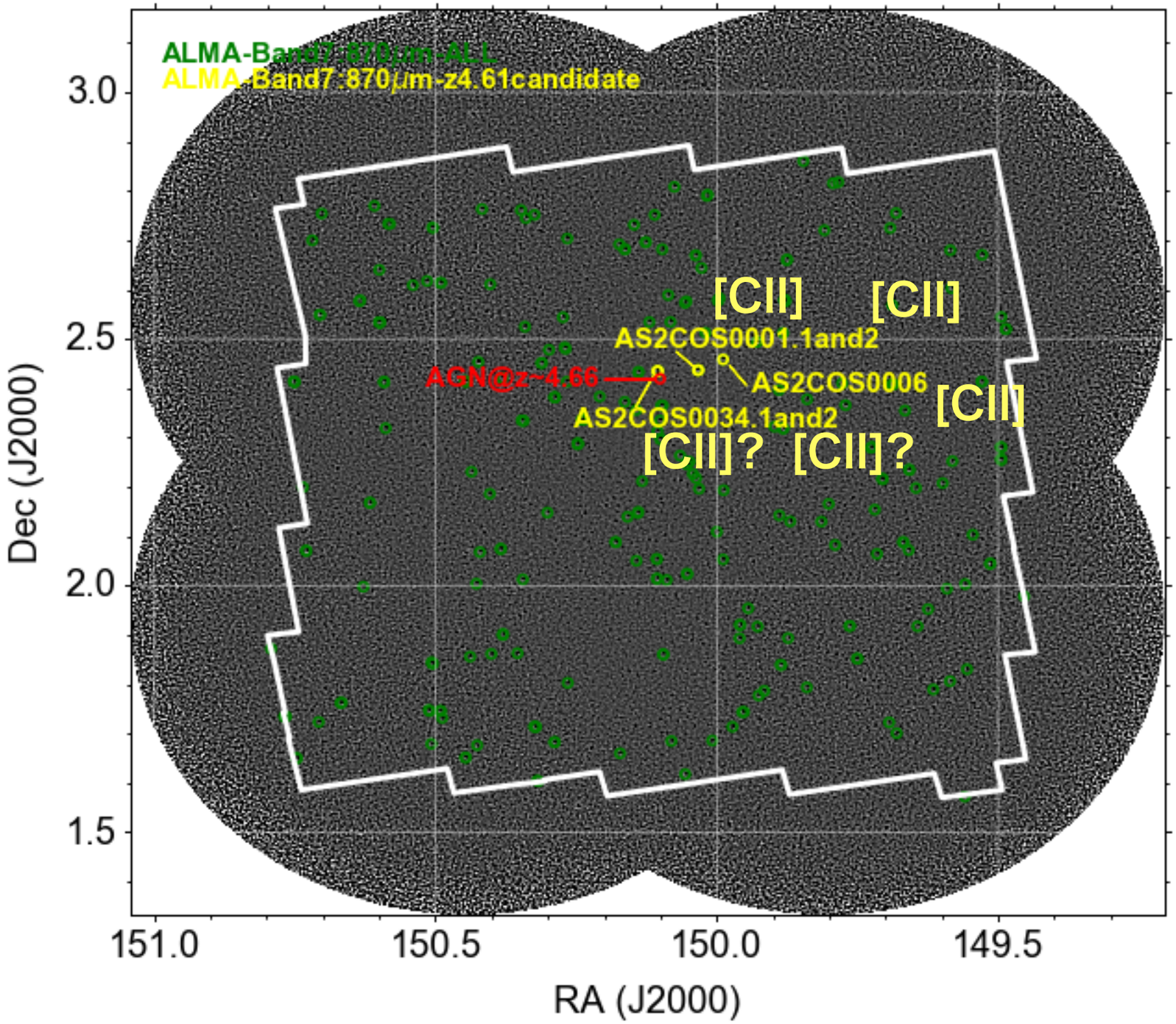
4.Result

5.Discussion
- Discussion-6.1
- Discussion-1.1/1.2
- Discussion-34.1/34.2

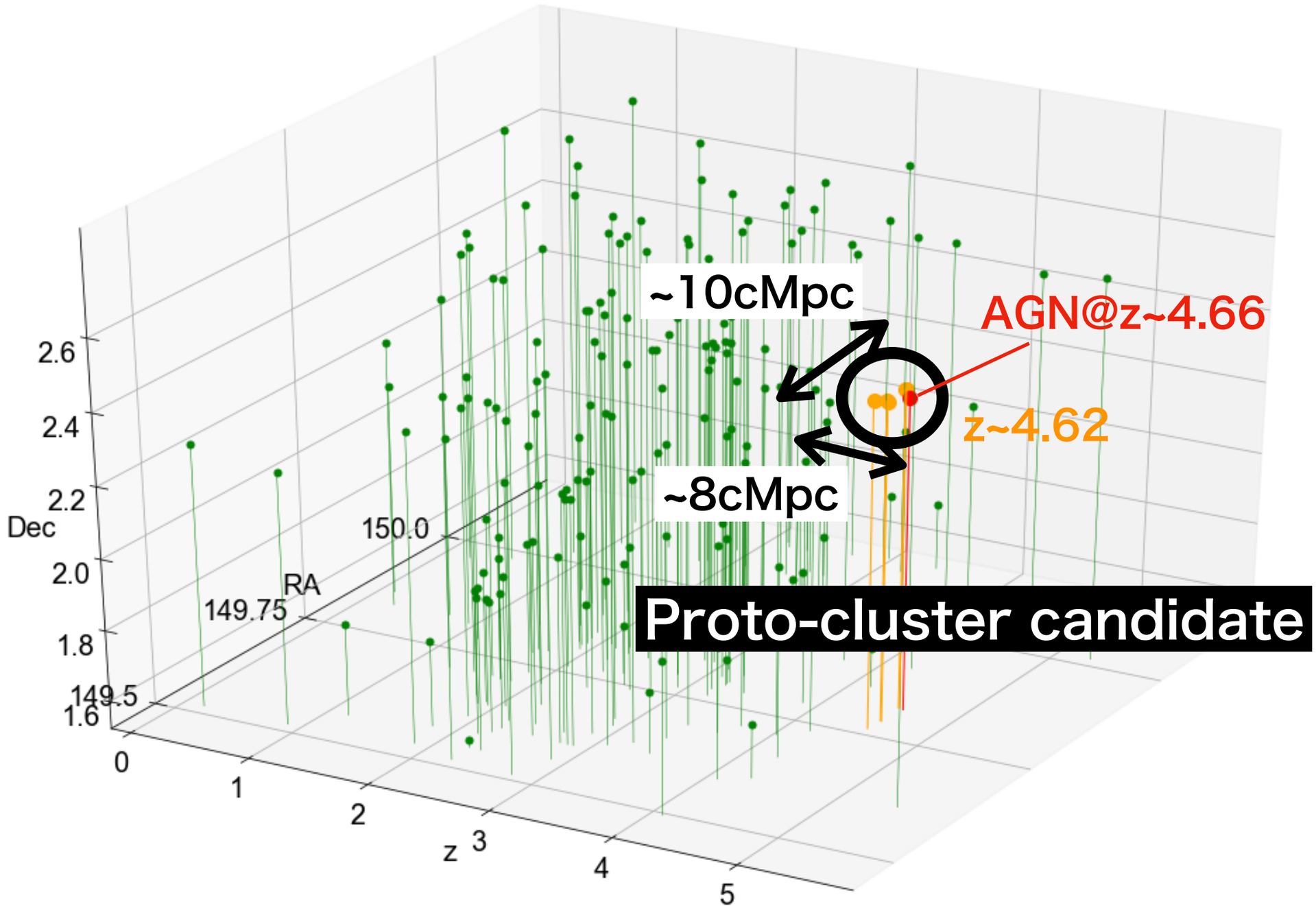
6.Conclusion

7.Future Work/Proposals

6.Conclusion

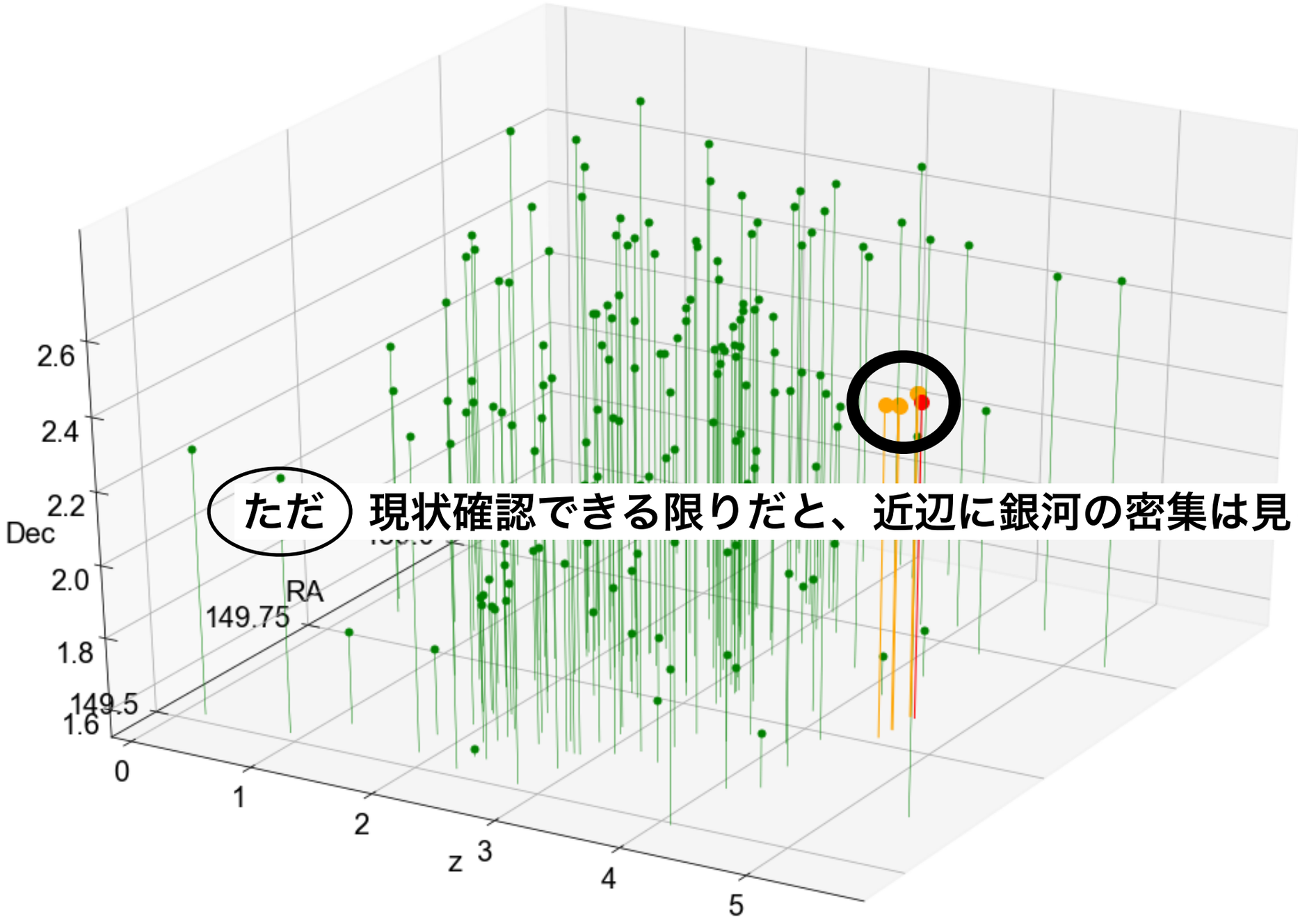


6.Conclusion



Proto-clusterの候補とみなして良さそう

6.Conclusion



ただ 現状確認できる限りだと、近辺に銀河の密集は見られない

LBGsやLAEsをproveとしたProto-clusterと何か異なった特徴があるかも?

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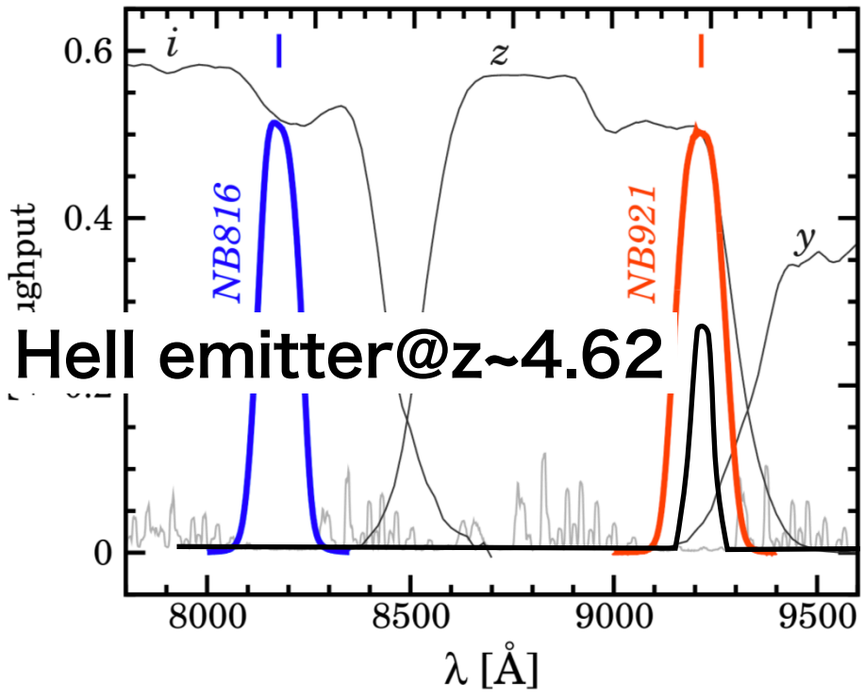
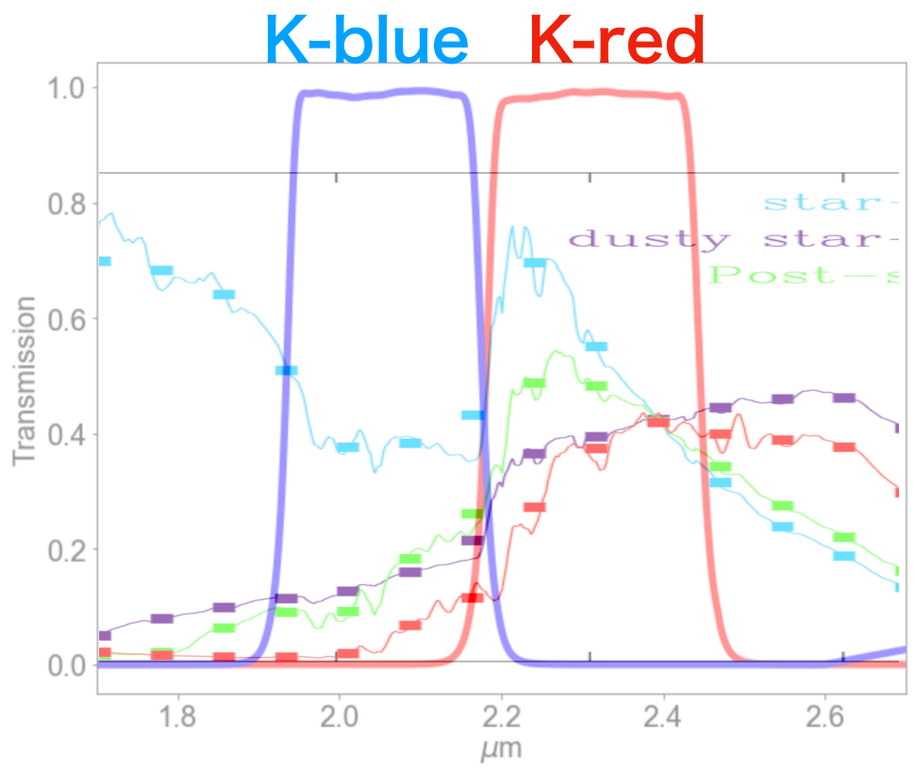
6.Future work/Proposal



Hell emitter@z~4.62

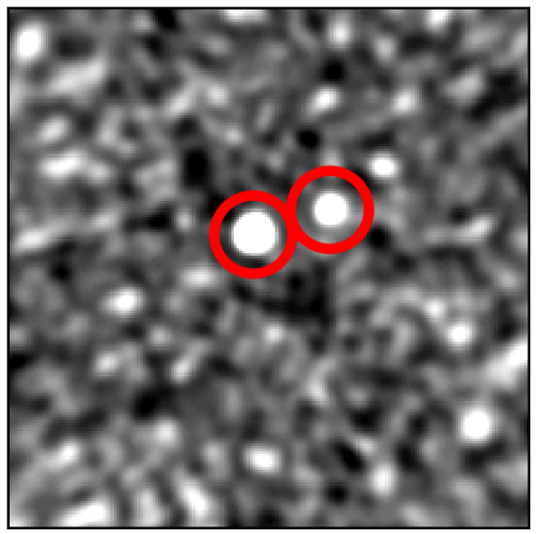
from Shibuya+2018

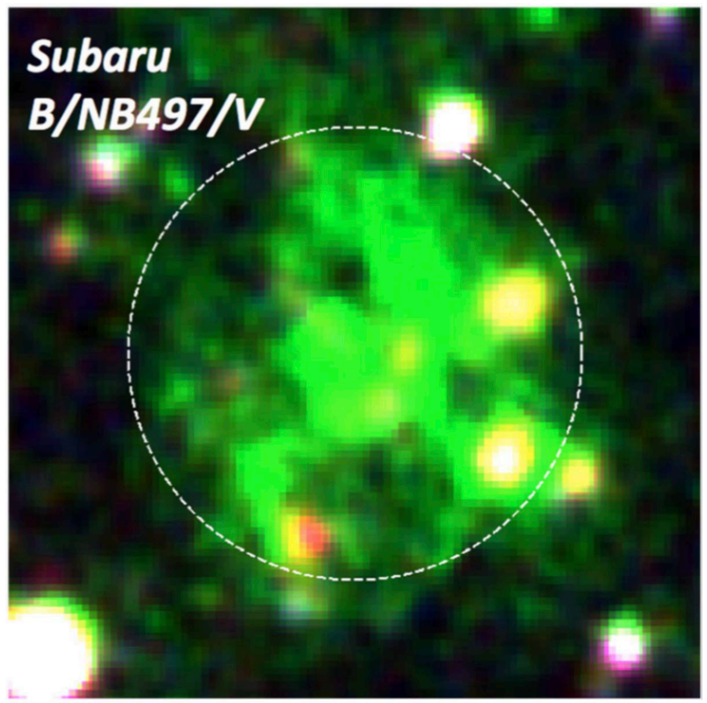


emitter/BBG@z~4.62

HCS-NB921 Hell emitter

FLAMINGOS2-Kblue dropout BBG





Umehata+2017

SUBARU FOCAS IFU(service)

IGM/ICM等
広がった構造からのLyαを狙う
+
SMGs multipleの領域で
IGM/ICMはどうなっているか？

ご静聴、ありがとうございました