

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

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1. Introduction

銀河の活動性に対するシナリオ

Starburst

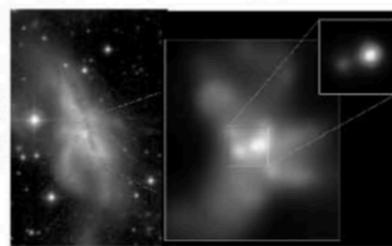
(Dry) Merger

(c) Interaction/"Merger"



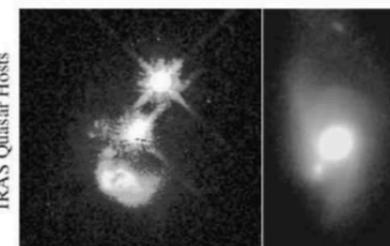
- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

(d) Coalescence/(U)LIRG



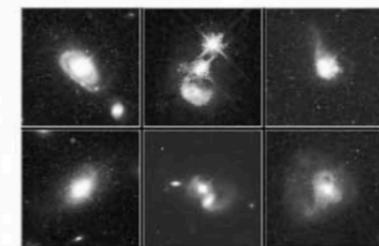
- galaxies coalesce: violent relaxation in core
- gas inflows to center: starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

(e) "Blowout"



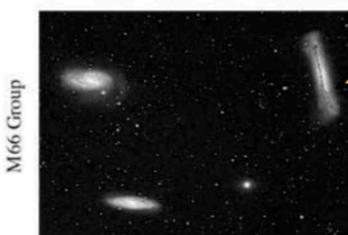
- BH grows rapidly: briefly dominates luminosity/feedback
- remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host

(f) Quasar



- dust removed: now a "traditional" QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(b) "Small Group"



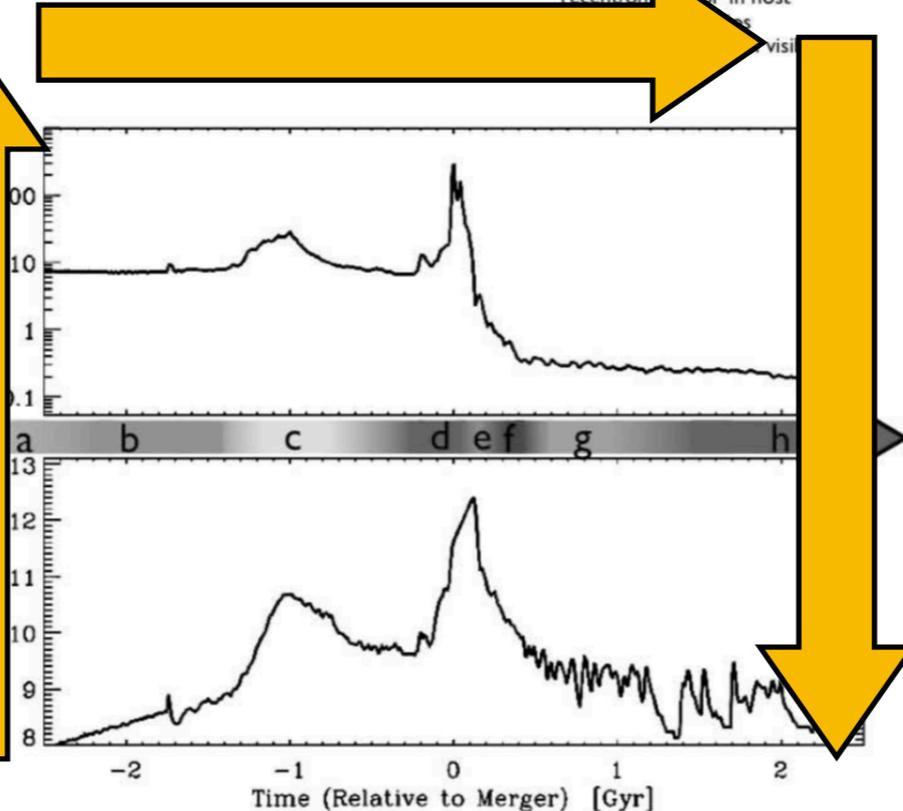
- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently

(a) Isolated Disk



- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- "Seyfert" fueling (AGN with $M_{\text{BH}} > 23$)
- cannot redden to the red sequence

Birth



(g) Decay/K+A



- QSO luminosity fades rapidly
- tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- "hot halo" from feedback
- sets up quasi-static cooling

(h) "Dead" Elliptical



- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to "large group" scales: mergers become inefficient
- growth by "dry" mergers

Quenching

"Dead"

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) $\sim 1000 M_{\text{solar}}$
- "dusty" starburst galaxy

Starburst

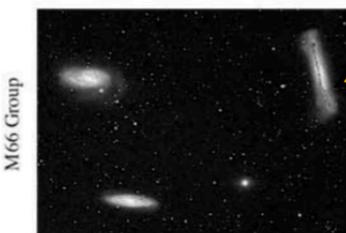
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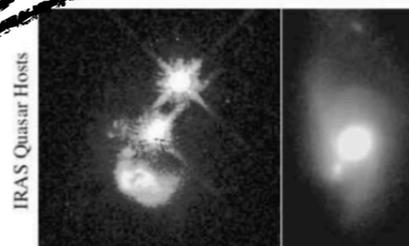
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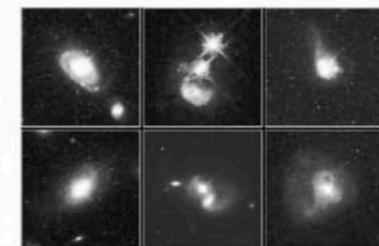
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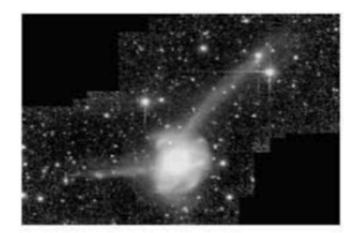
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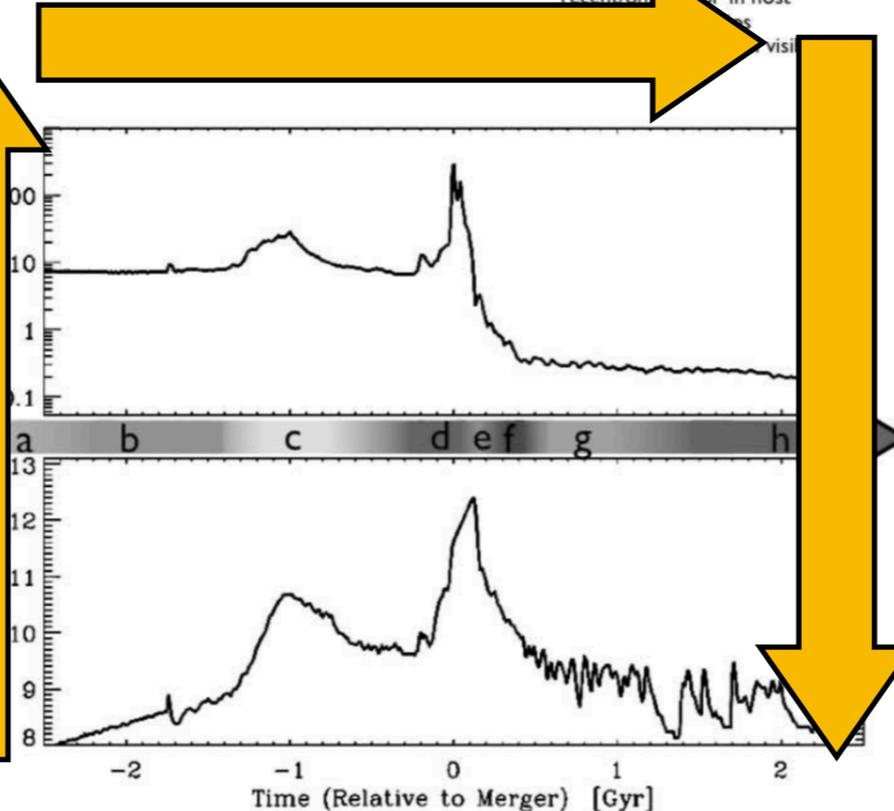
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- star formation terminated
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"Dead"



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。

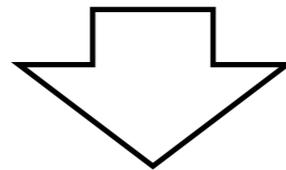
scale~6Mpc (total) Mass~ 10^{14-15} Msolar

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 ~ ?

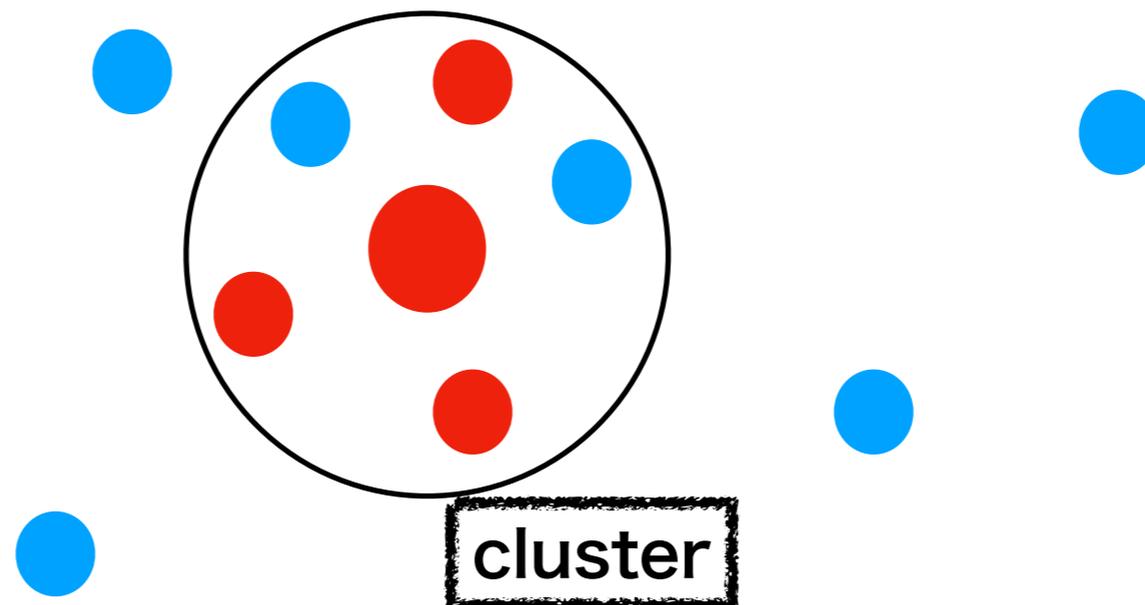
Proto-clusterを探す理由は？



今日見られるようなclusterの特徴を説明する！

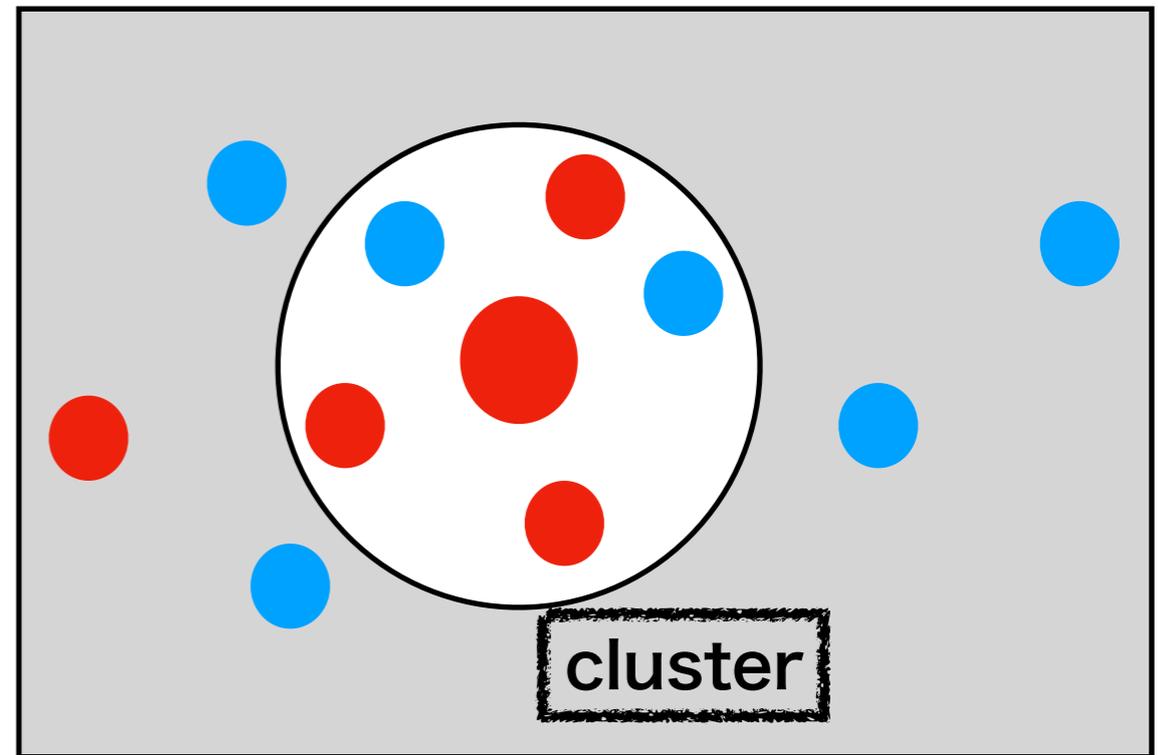
● : Elliptical galaxy

● : Spiral galaxy



1.Introduction

● : Elliptical galaxy ● : Spiral galaxy



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、
mergeが起きやすい

ので

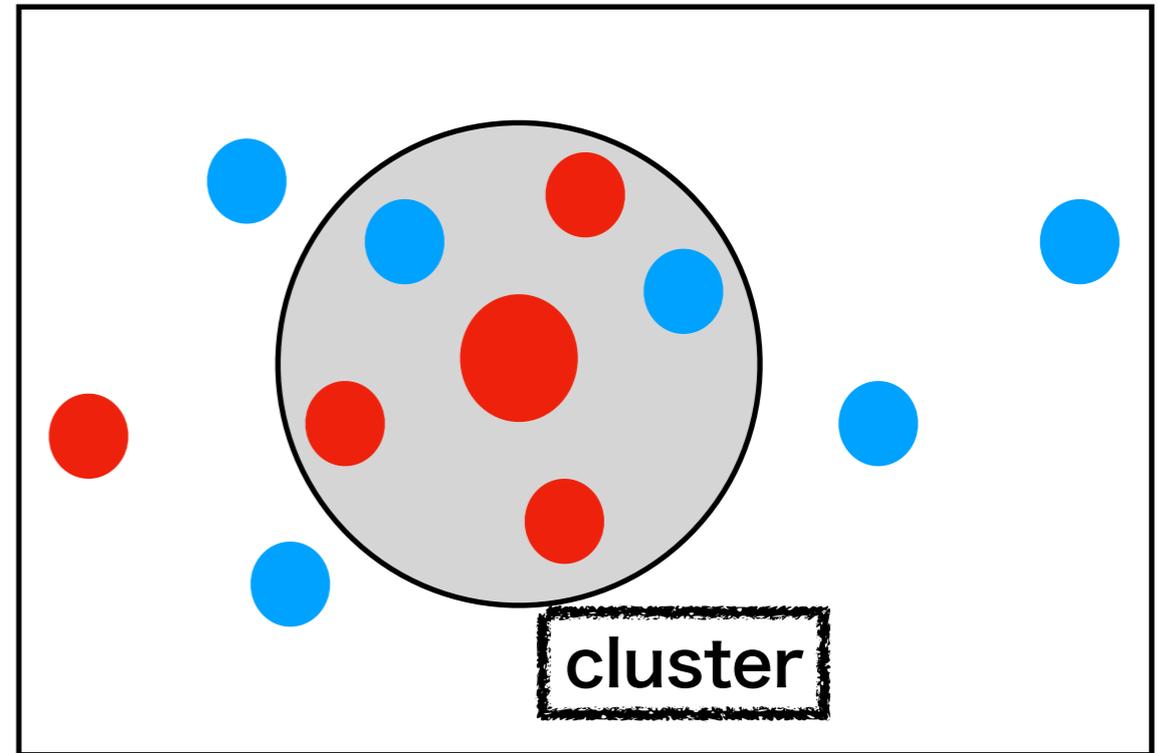
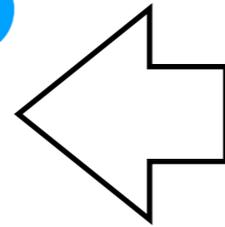
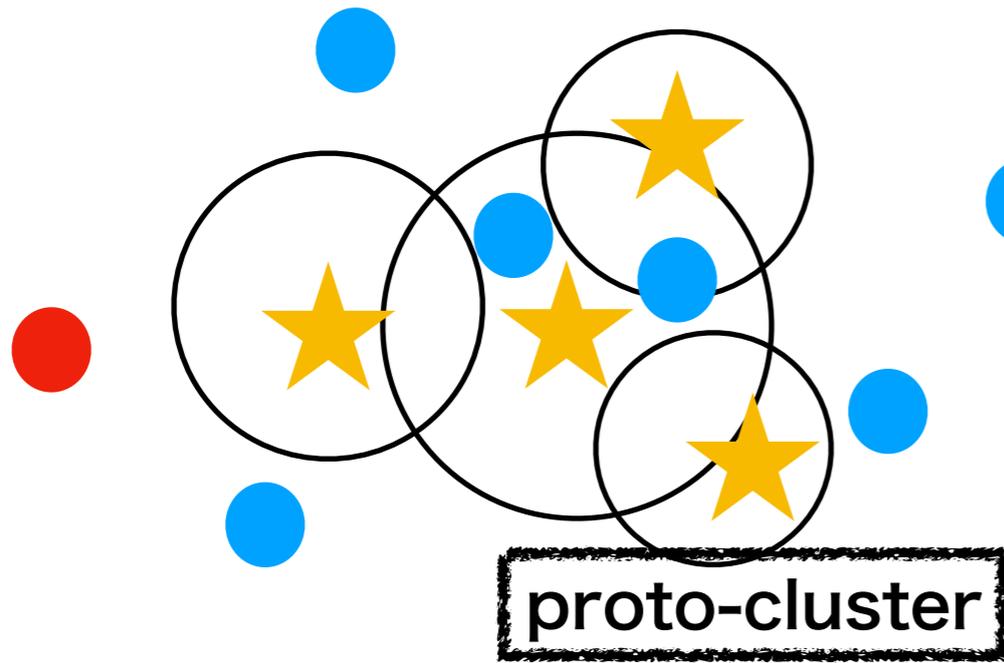
elliptical galaxyが多く存在

1. Introduction

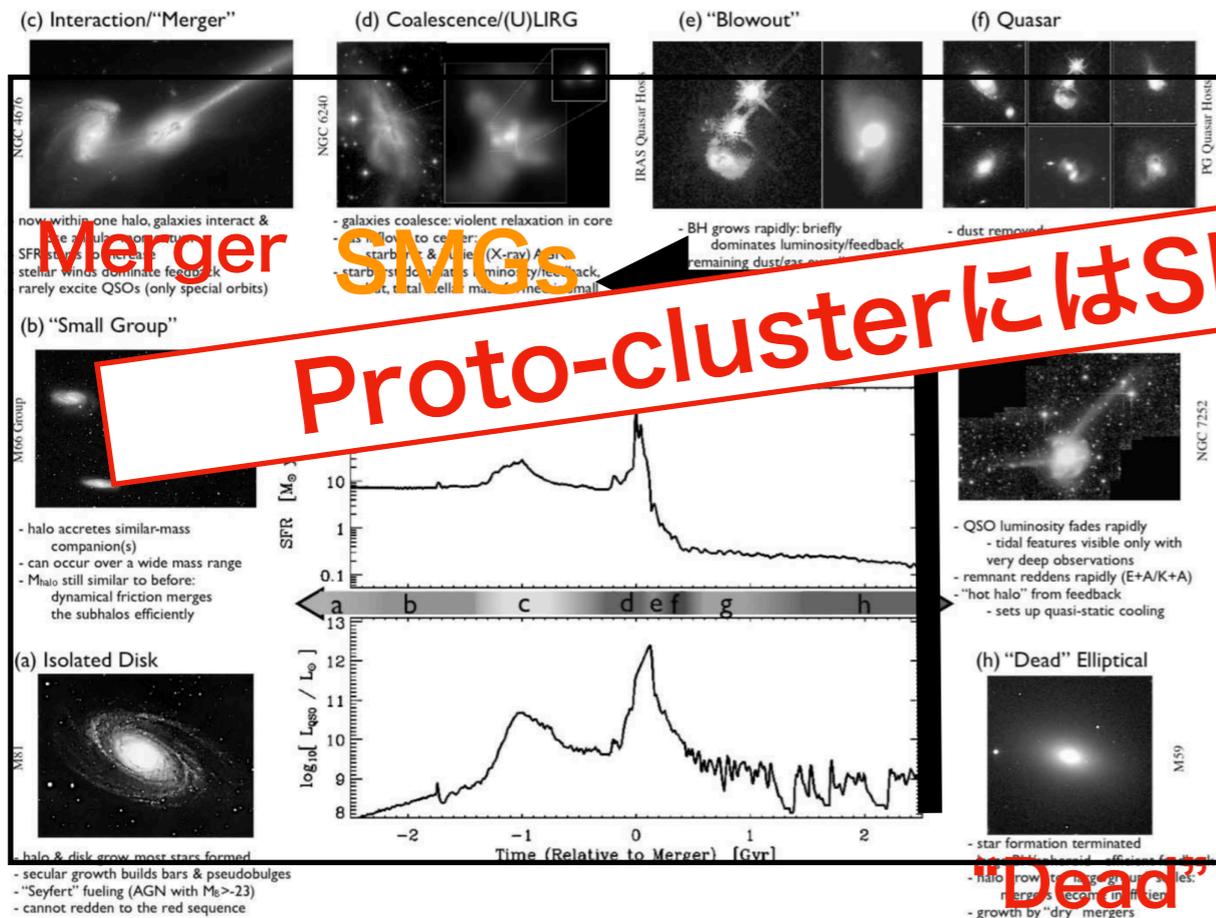
★ : SMGs

● : Elliptical galaxy

● : Spiral galaxy



階層的構造形成 + 銀河形成シナリオ = clusterの形成シナリオ



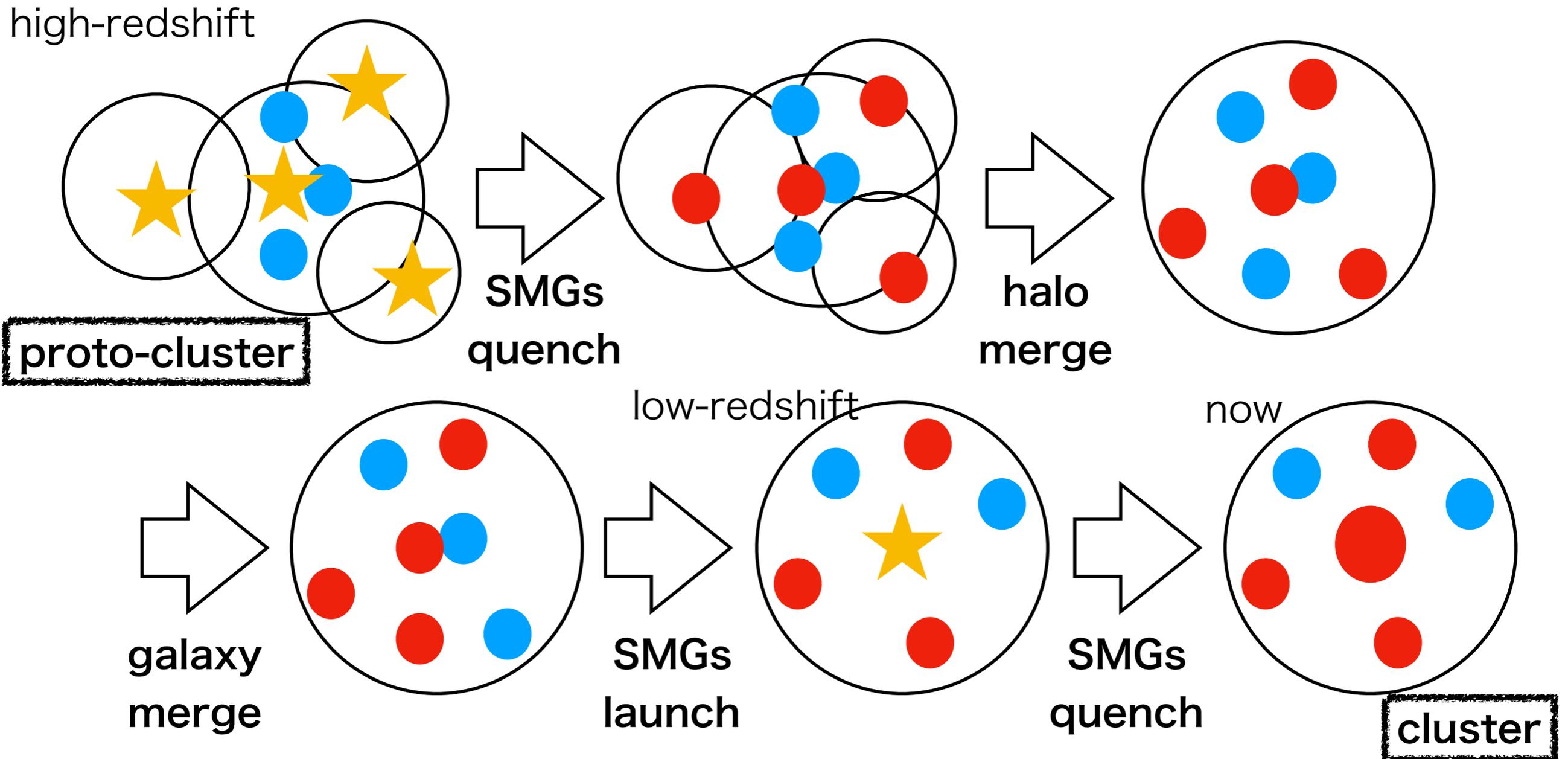
Proto-clusterにはSMGsが見られるはず!

銀河が密集しているので、merge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



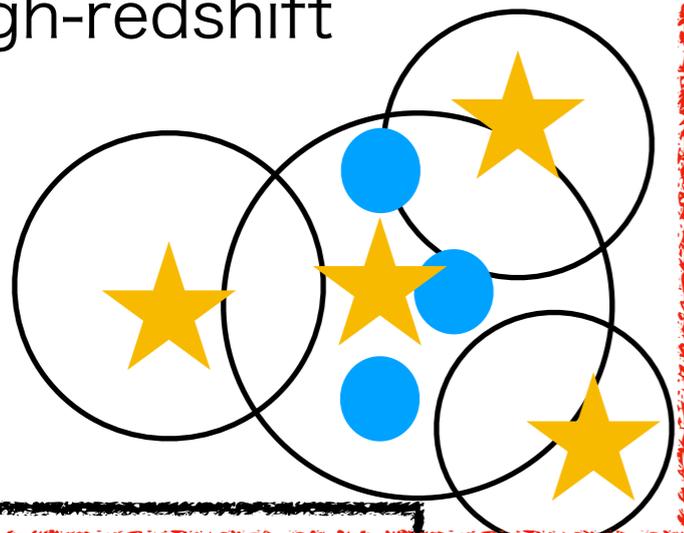
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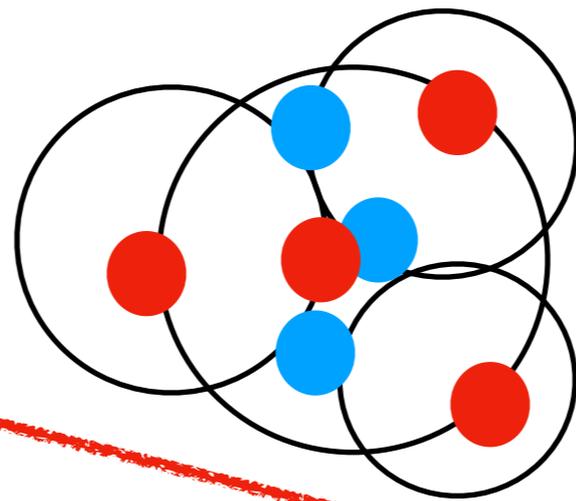
Low redshift SMGs → Ellipticals in cluster center

high-redshift

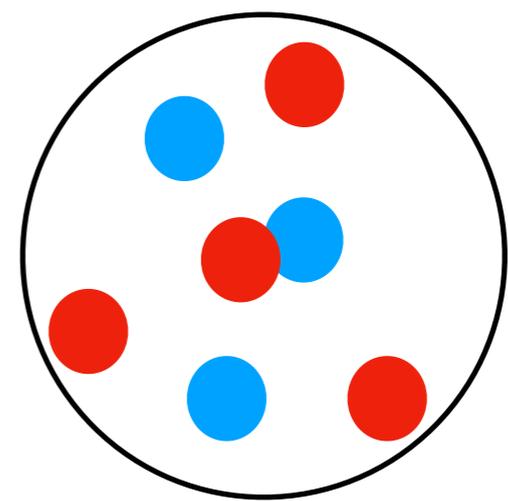


proto-cluster

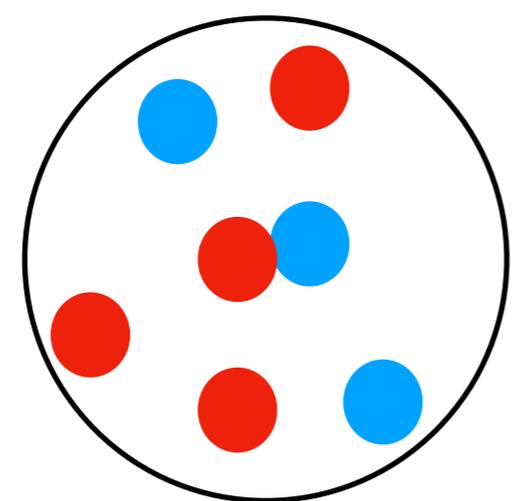
SMGs
quench



halo
merge

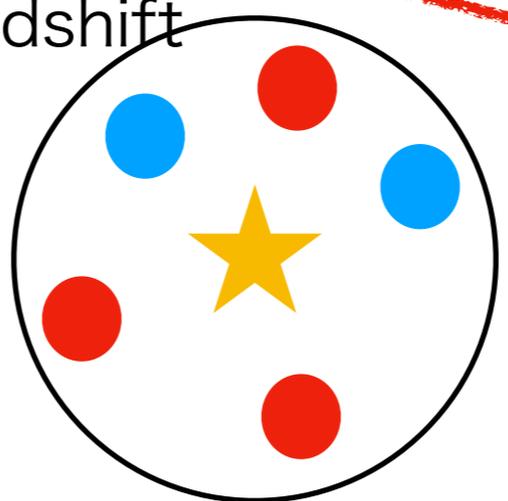


galaxy
merge



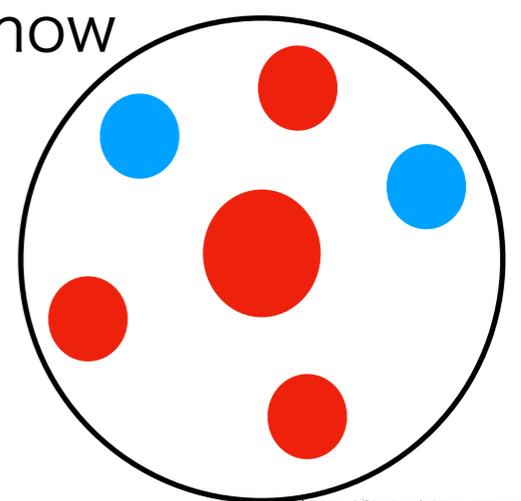
SMGs
launch

low-redshift



SMGs
quench

now

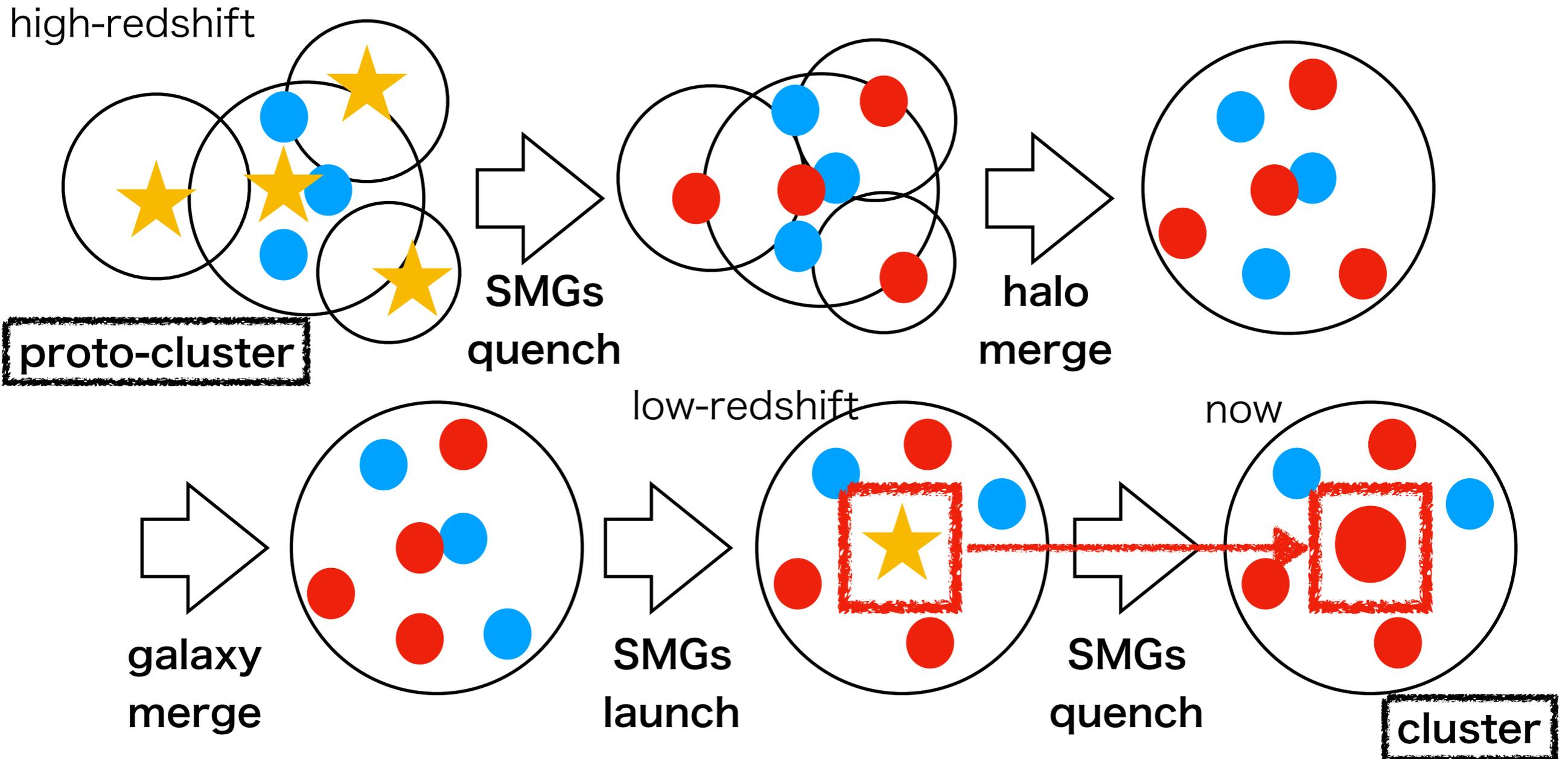


cluster

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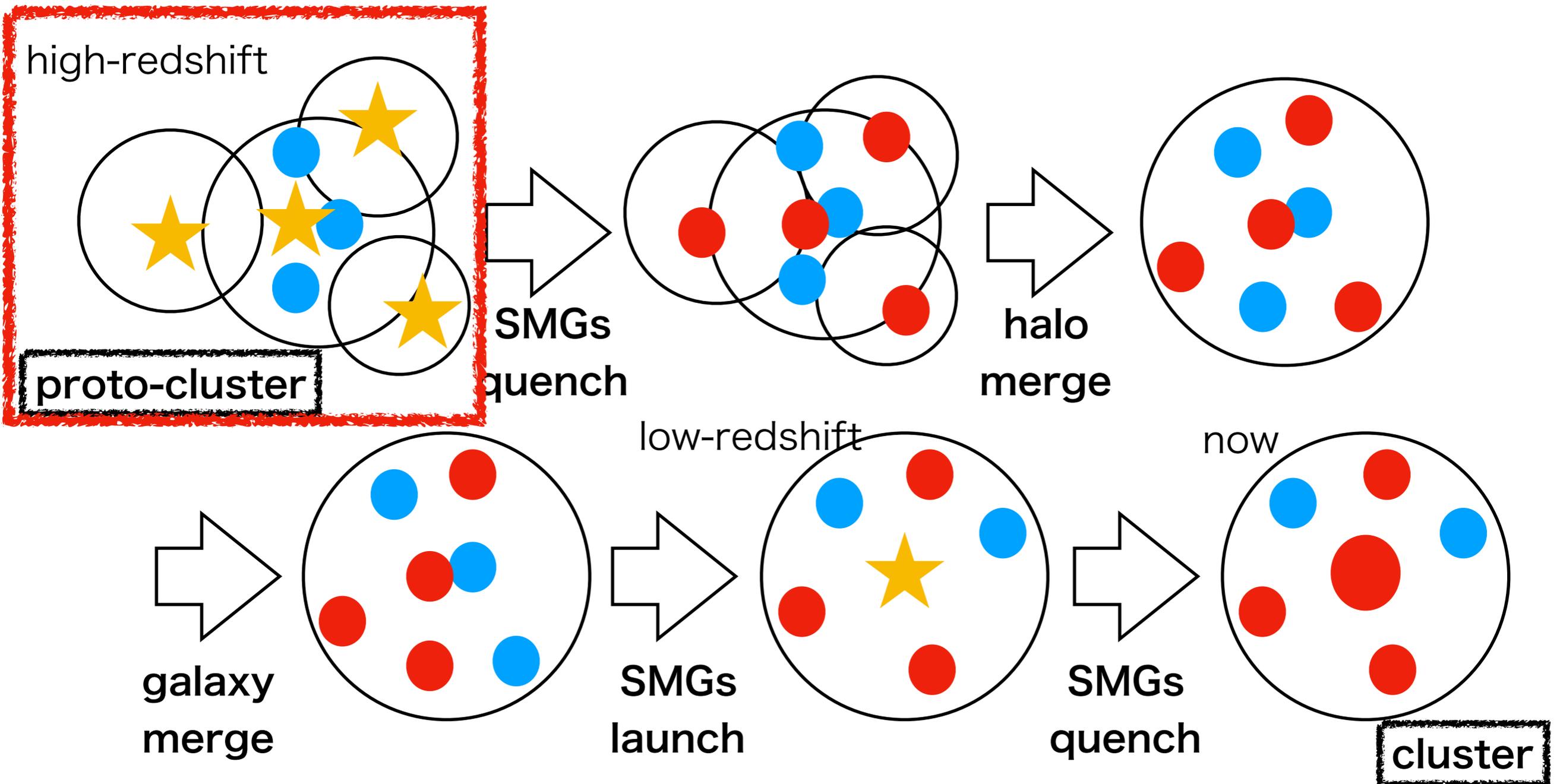
High redshift SMGs → Cluster
Low redshift SMGs → Ellipticals in cluster center



1. Introduction

In previous research (clustering)

High redshift SMGs → Cluster
Low redshift SMGs → Ellipticals in cluster center



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 $N_{\text{spec}} \geq 10$									
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	$\sim 5.5-11.0$	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
CIJ0227-0421	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								K00,04a,04b,P00,02, V07,K13,Z18
LAE/LBG \rightarrow SMG									
HAE/SMG									
Protocluster with $N_{\text{spec}} < 10$									
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							
PCIJ1001+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
DIUD01	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
BoöetesJ1430+3522	2.3	0	2.7 ± 1.1	LAE	$\pi \times 5^2$	0.0037	...	1.51×10^{15}	B17

**SMGのoverdensityから
Proto-clusterを発見!**

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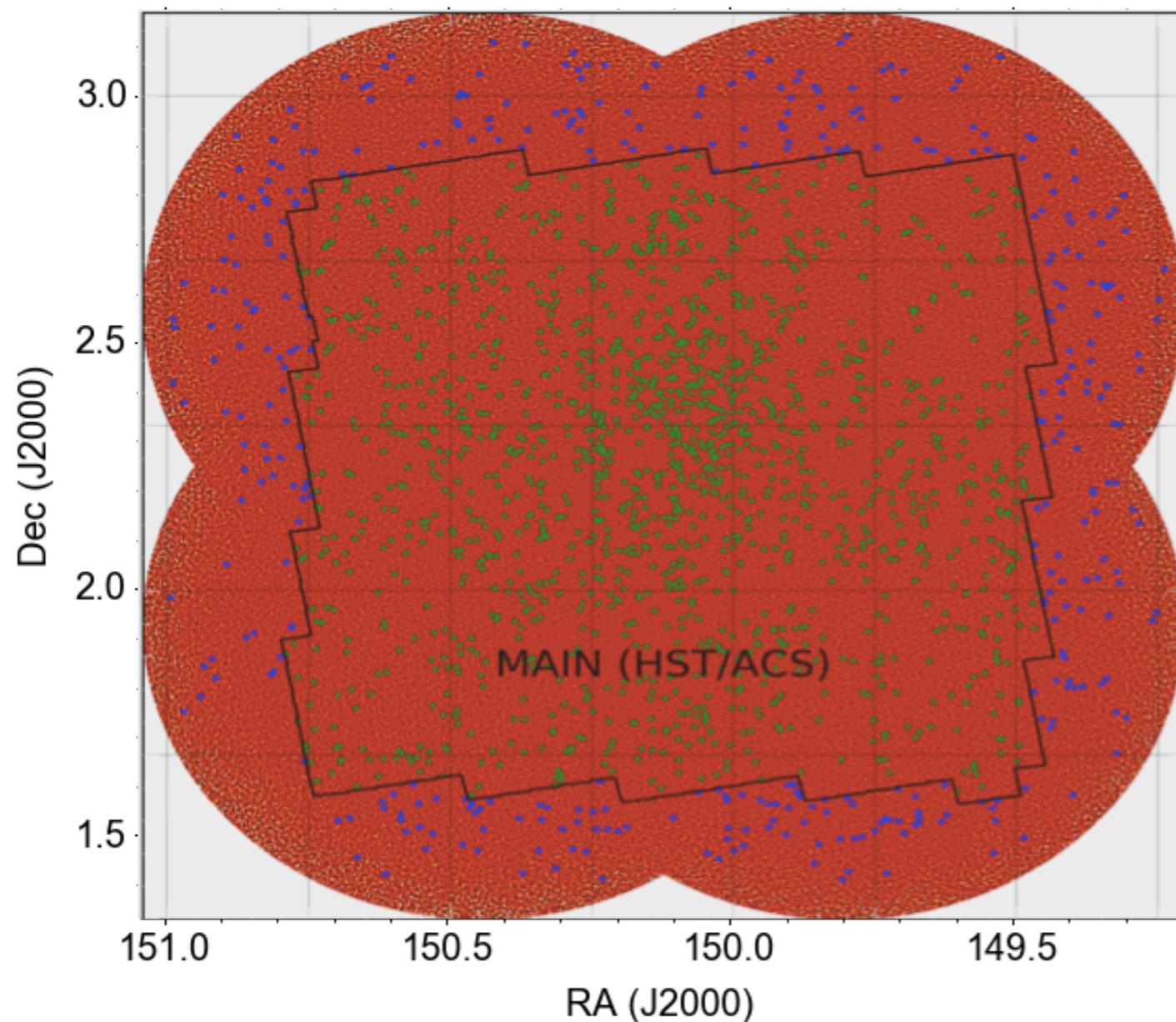
7.Future Work/Proposals

2.Data

- 領域 : COSMOS ($1.4 \times 1.4 \text{deg}^2$)
- 元観測 : SCUBA-2 (resolution $\sim 15''$ / 1147 SMGs / $> 4\sigma = 4.8 \text{mJy}$)

豊富な測光データ

- SUBARU HSC U-deep
- UVISTA UD & Deep etc..

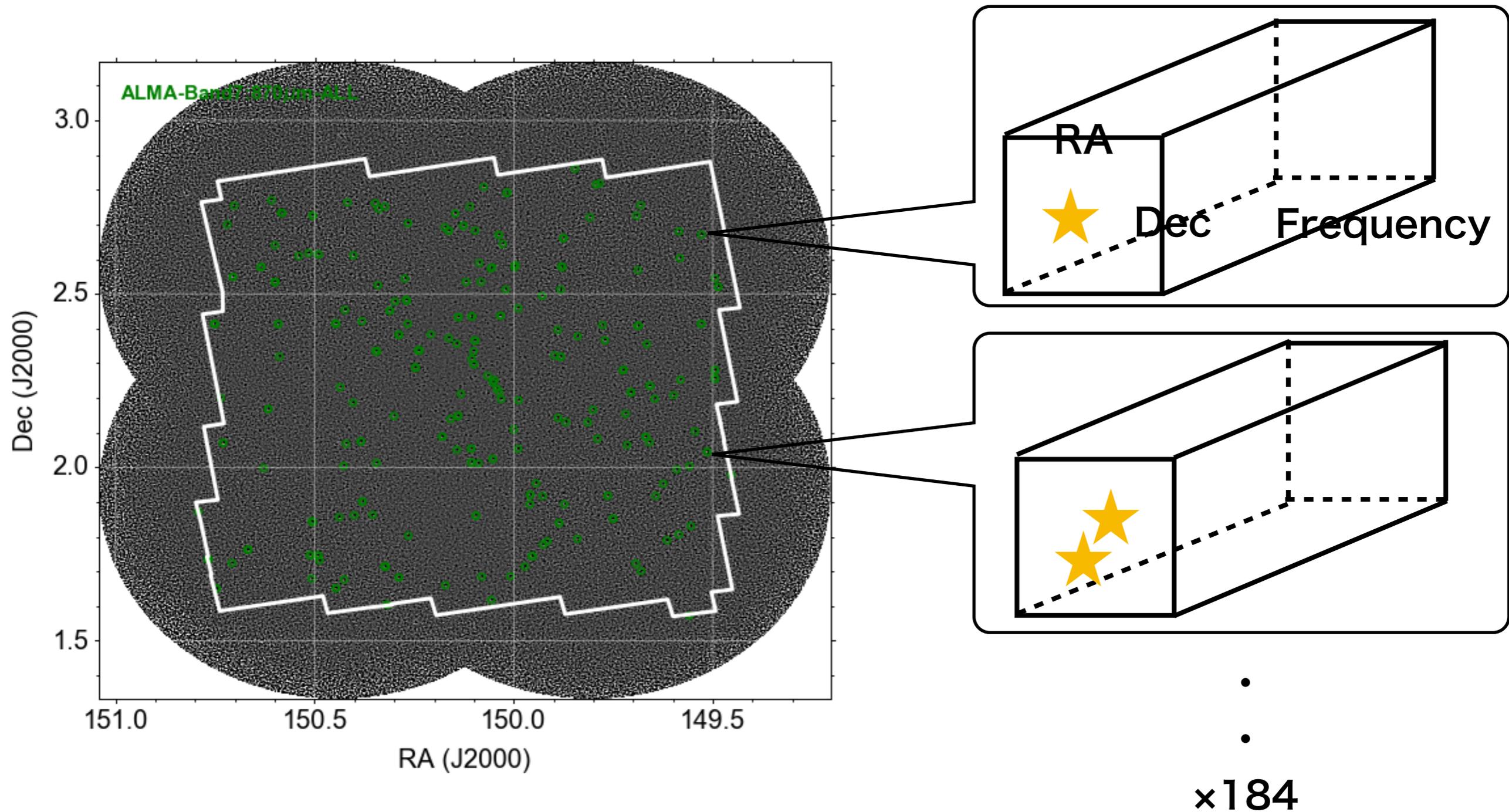


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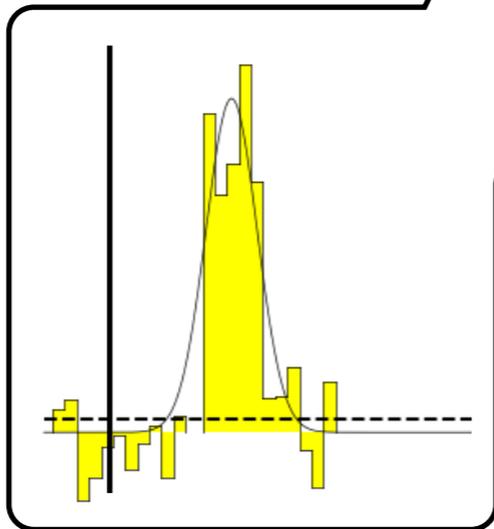
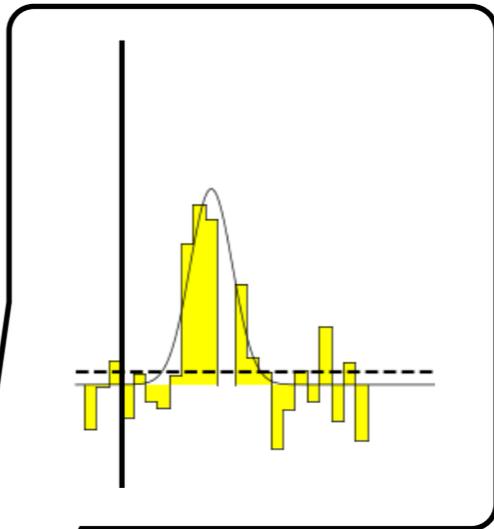
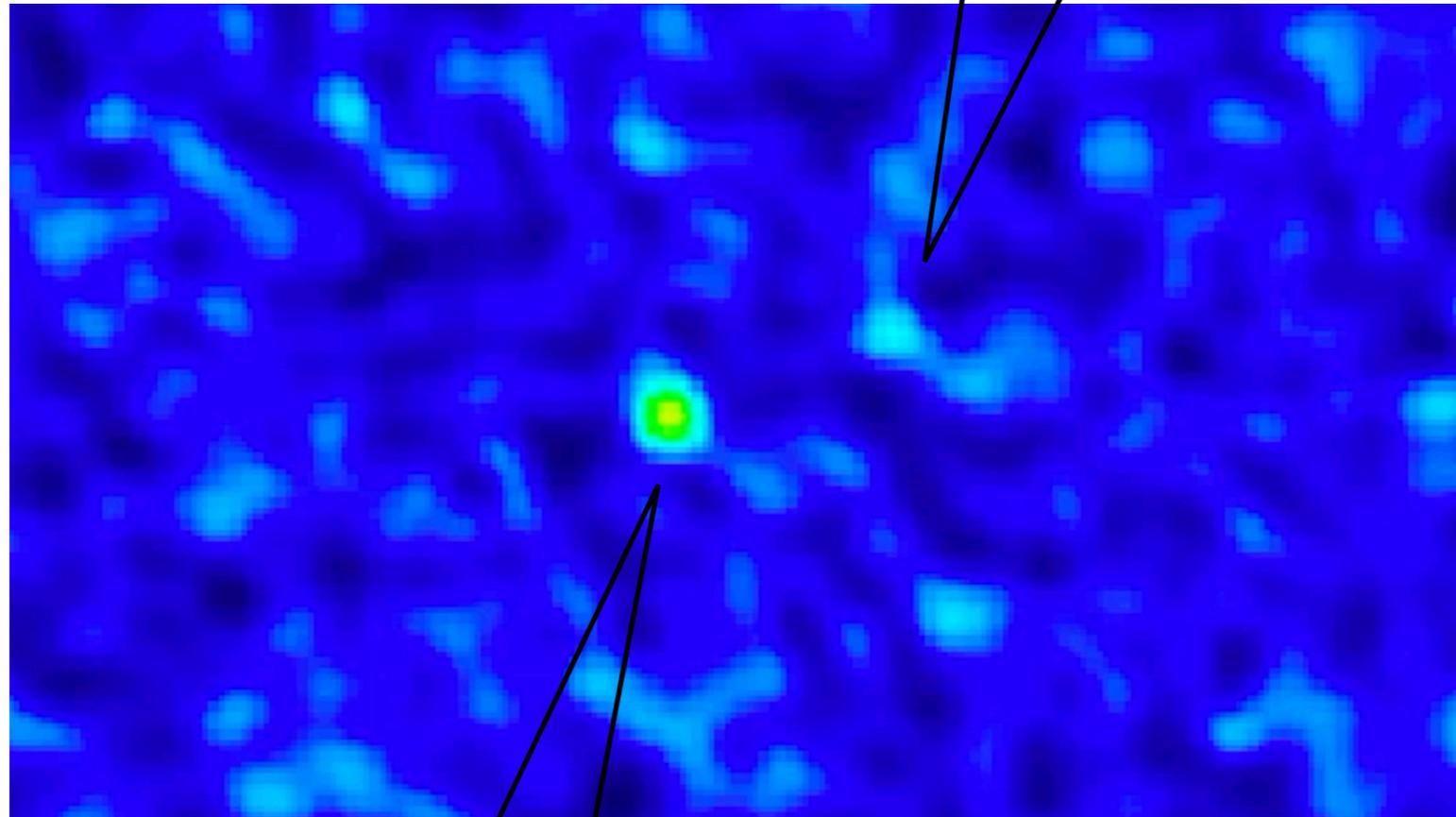


フォローアップ : ALMA band7 (resolution $\sim 1''$ /184field/ $>5\sigma = 6.6 \text{mJy}$)



2.Data

cube dataの例



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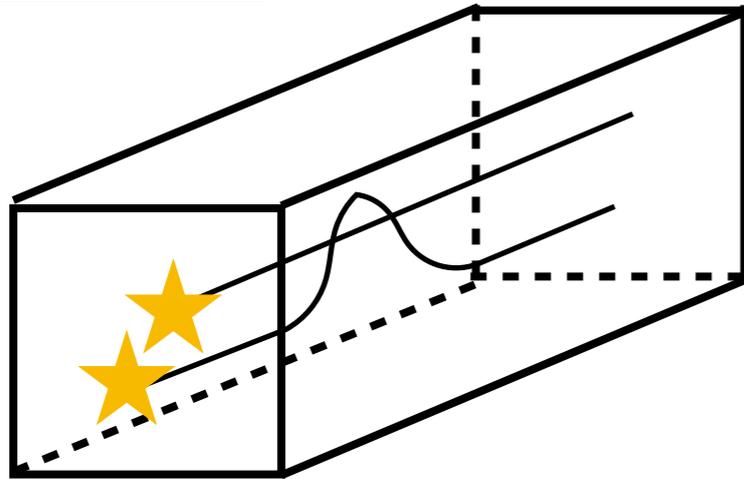
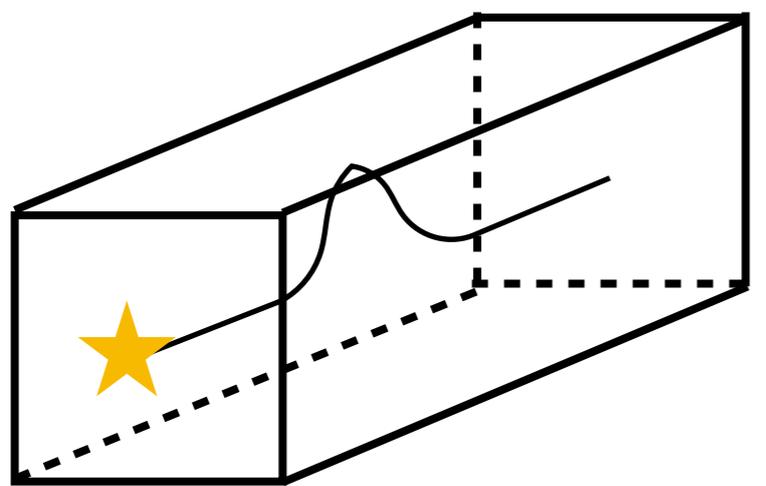
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フォローアップ : ALMA band7 (resolution $\sim 1''$ / 184 field)



•
•
x184

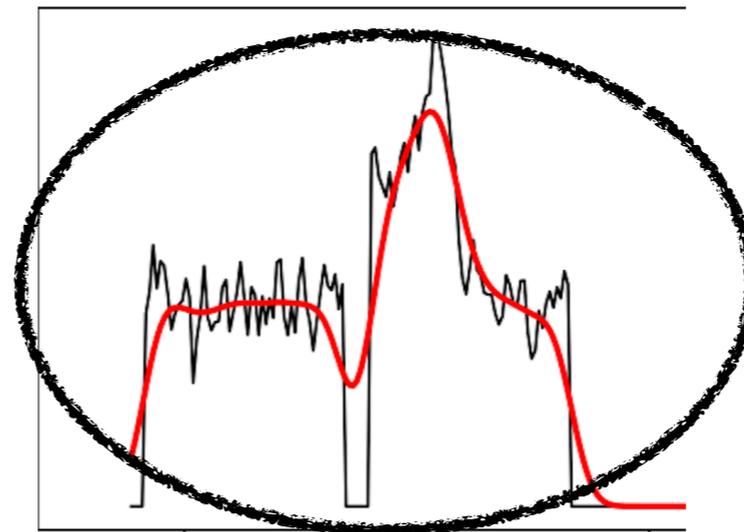
background noiseから
 5σ 以上のpixelの有無

無

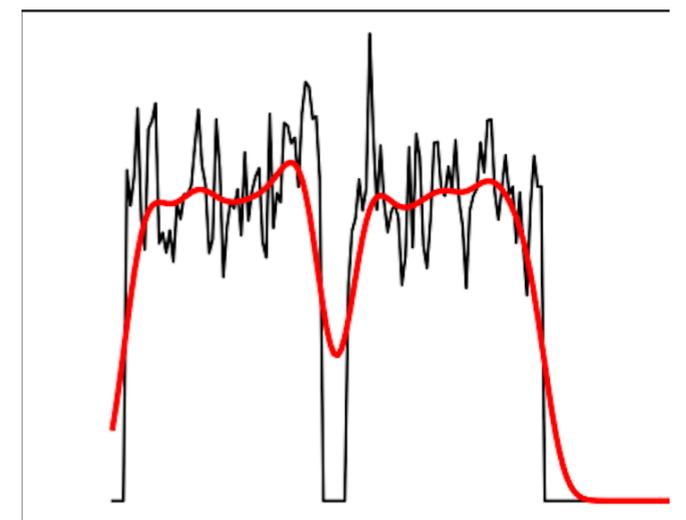
特に何もしない

有

そのpixelで
周波数方向に切り出し



S/N > 10のlineを抽出



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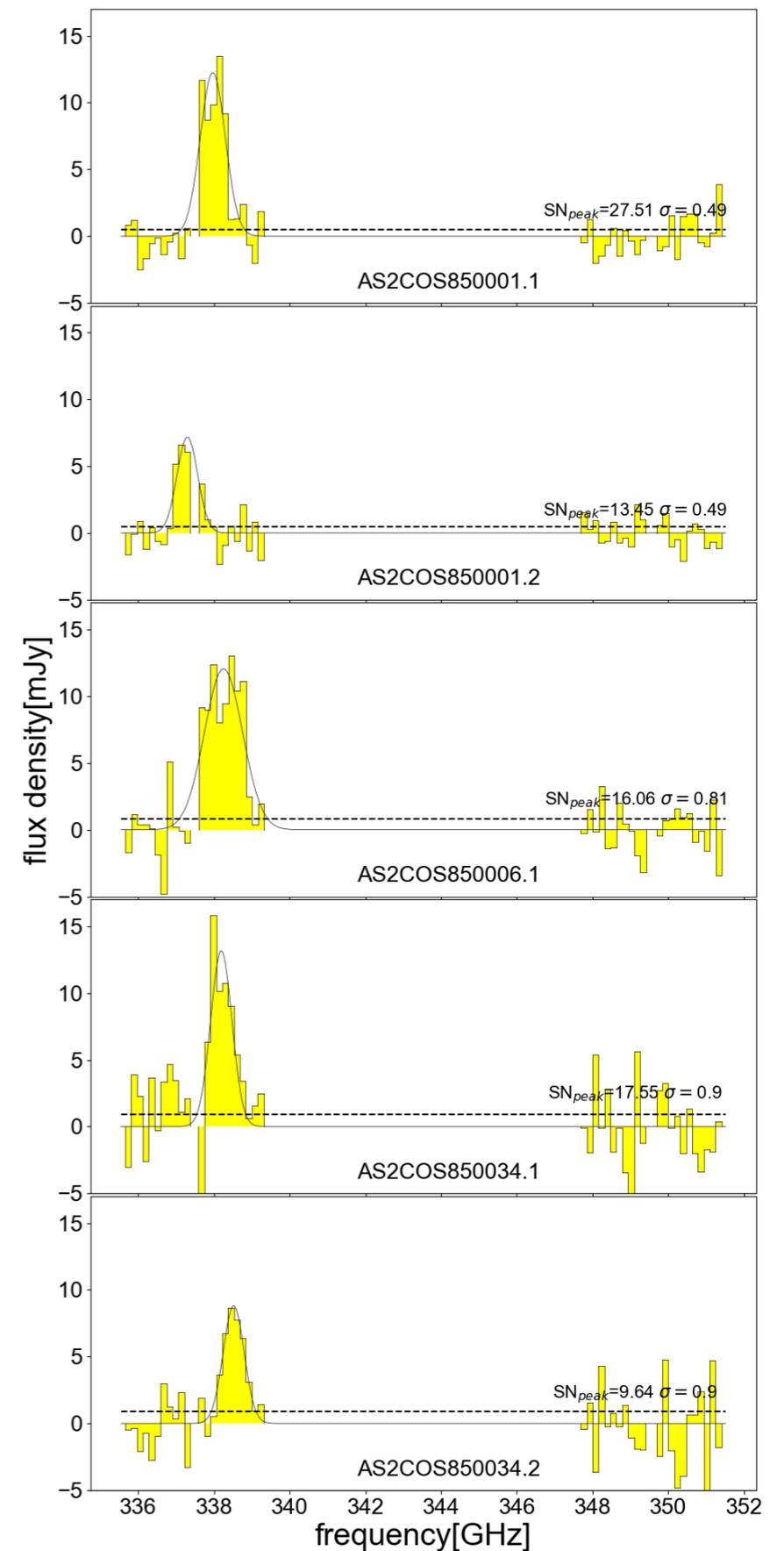
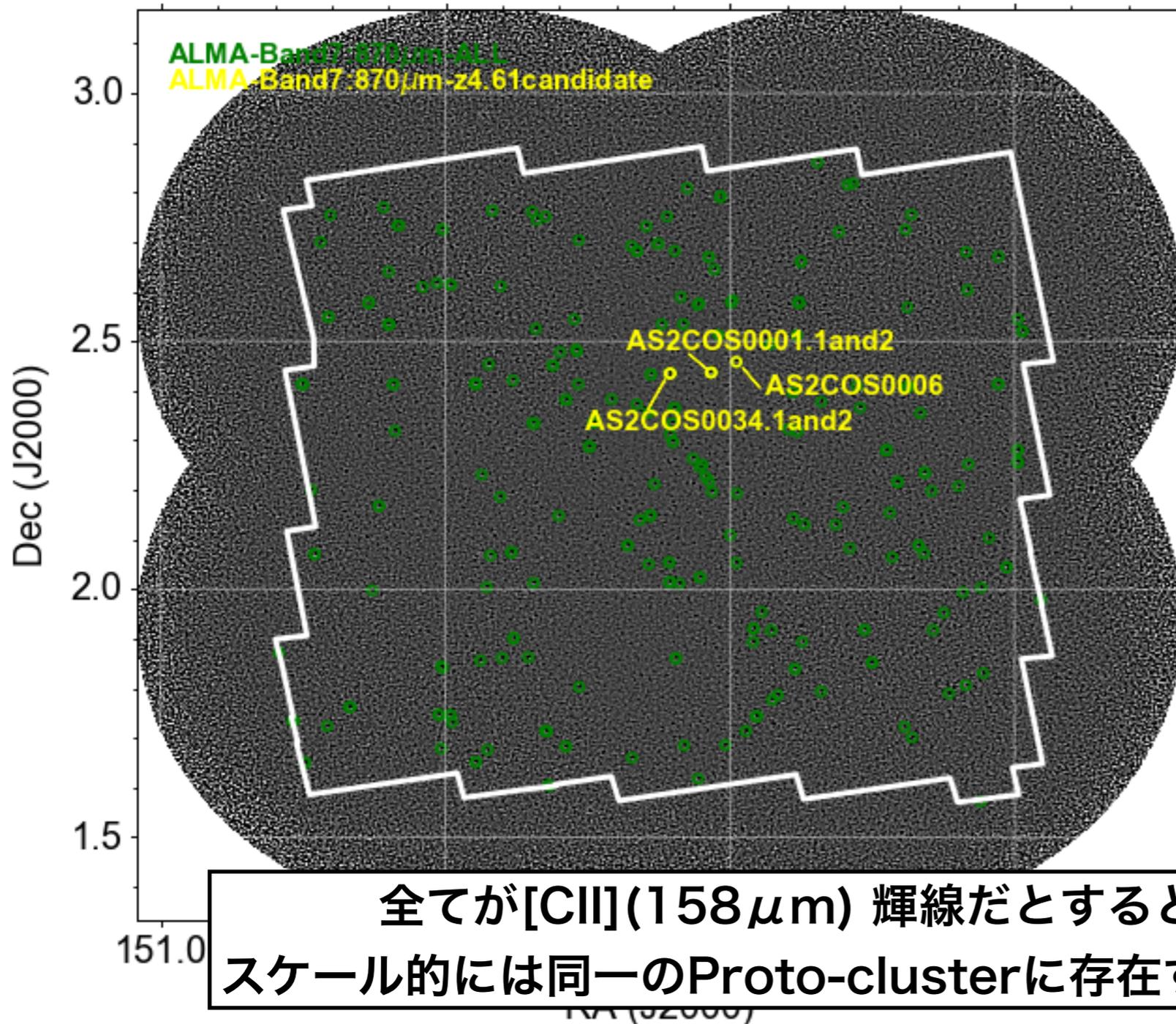
4.Result

5天体で

ほぼ同じ周波数

かなり近い距離($\sim 7'$ = $\sim 10\text{Mpc}@z=4.62$)

の輝線を検出



全てが[CII](158 μm)輝線だとすると $z\sim 4.62$,
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

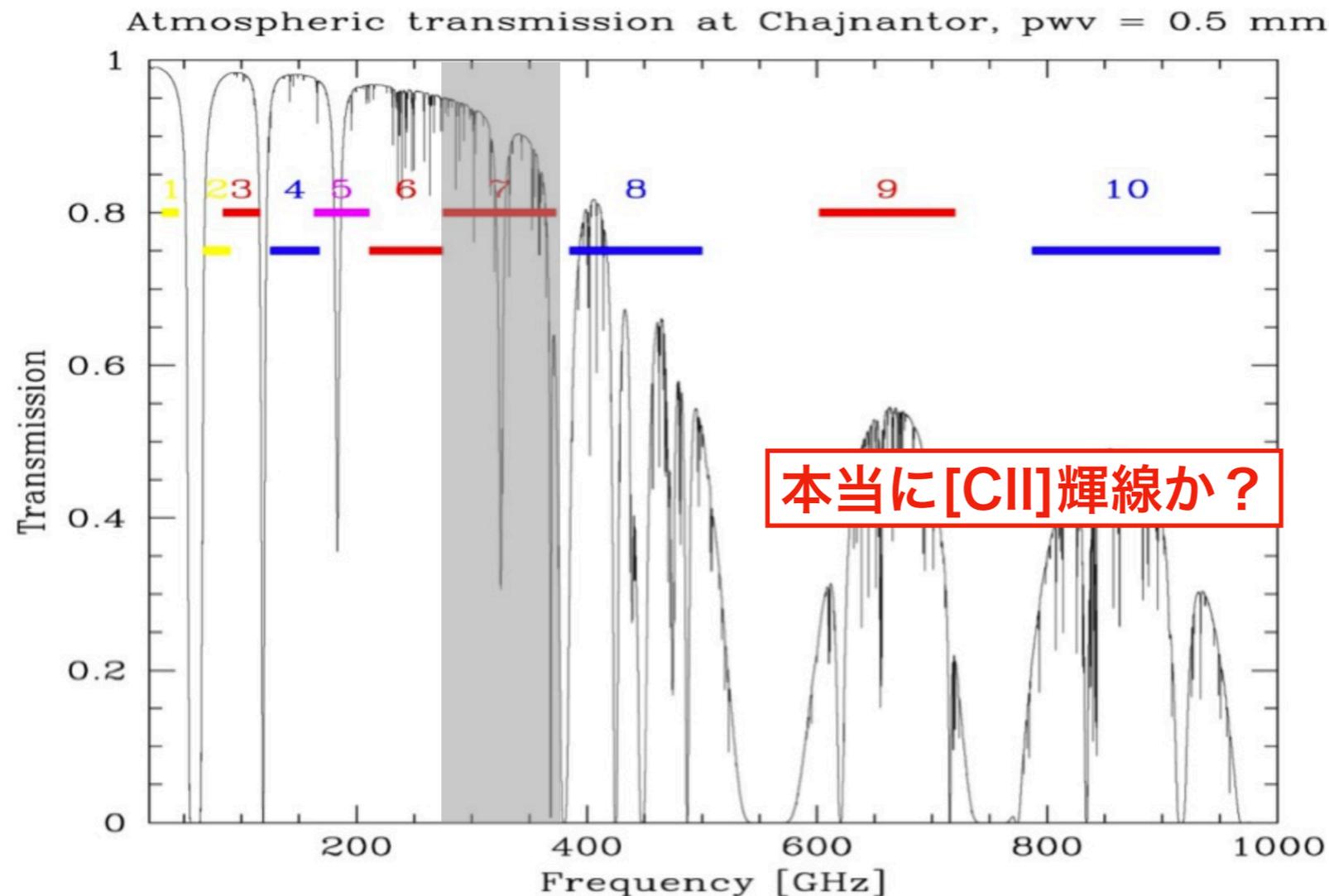
うち5天体で

ほぼ同じ周波数

かなり近い距離($\sim 7' = \sim 10\text{Mpc}@z=4.62$)

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) $@z\sim 0.02$
- CO(4-3) $@z\sim 0.35$
- CO(12-11) $@z\sim 3.0$
- more high-J CO $@z>2.0$
- [C I](610 μm) $@z\sim 0.46$
- [C I](370 μm) $@z\sim 1.4$
- [O I](146 μm) $@z\sim 5.0$
- [O III](88 μm) $@z\sim 9.0$
- [O I](63 μm) $@z\sim 13$
- [O III](52 μm) $@z\sim 16$

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

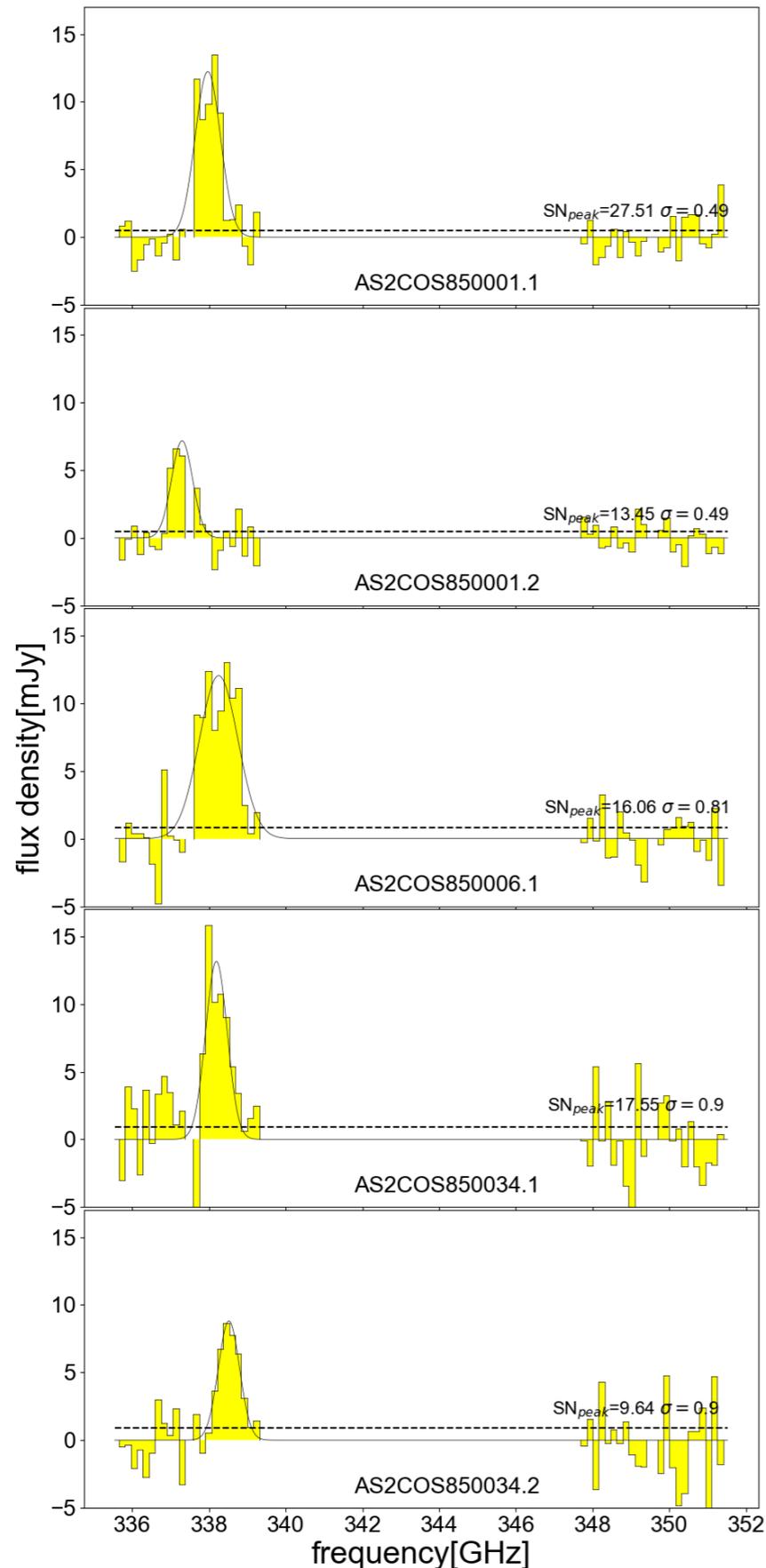
Discussion-34.1/34.2

6.Conclusion

7.Future Work/Proposals

5. Discussion

本当に[CII]輝線か？



[CII]輝線候補の特徴

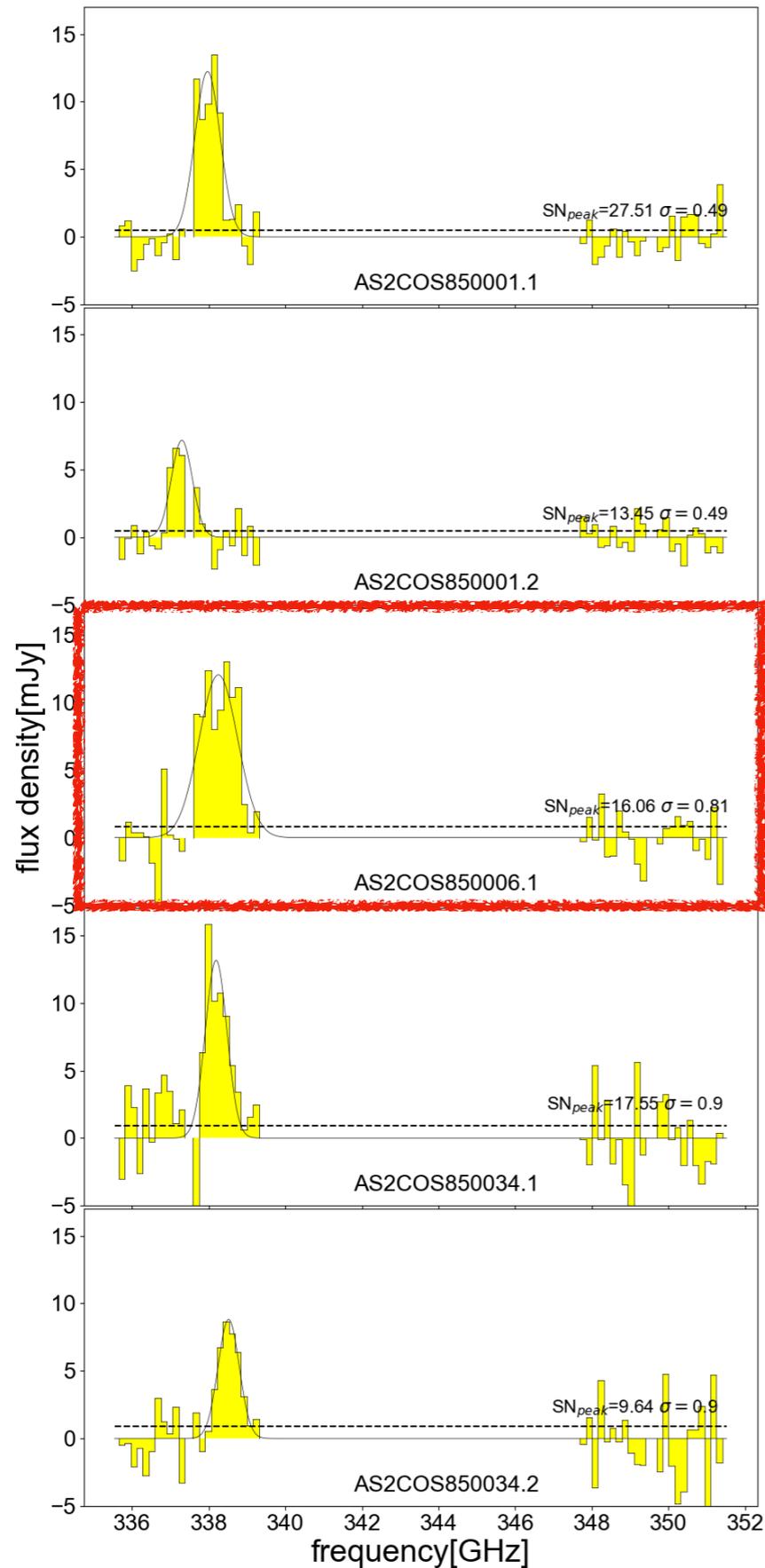
- 連続波が検出 (in ALMA)
- opticalに counterpart なし
- かなり明るめ
- @158 μm
- IR peak (~100 μm) よりも長波長側か？

band7に入ってくる 他の輝線

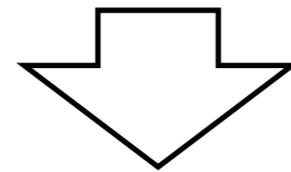
- CO(3-2)@z~0.02
- CO(4-3)@z~0.35
- CO(12-11)@z~3.0
- more high-J CO @z>2.0
- [C I](610 μm) @z~0.46
- [C I](370 μm) @z~1.4
- [O I](146 μm) @z~5.0
- [O III](88 μm) @z~9.0
- [O I](63 μm) @z~13
- [O III](52 μm) @z~16

5.Discussion-6.1

本当に[CII]輝線か？



CO(4-3) line detected with NOEMA
assuming this line is [CII]



[CII] emission line !

[CII]輝線候補の特徴

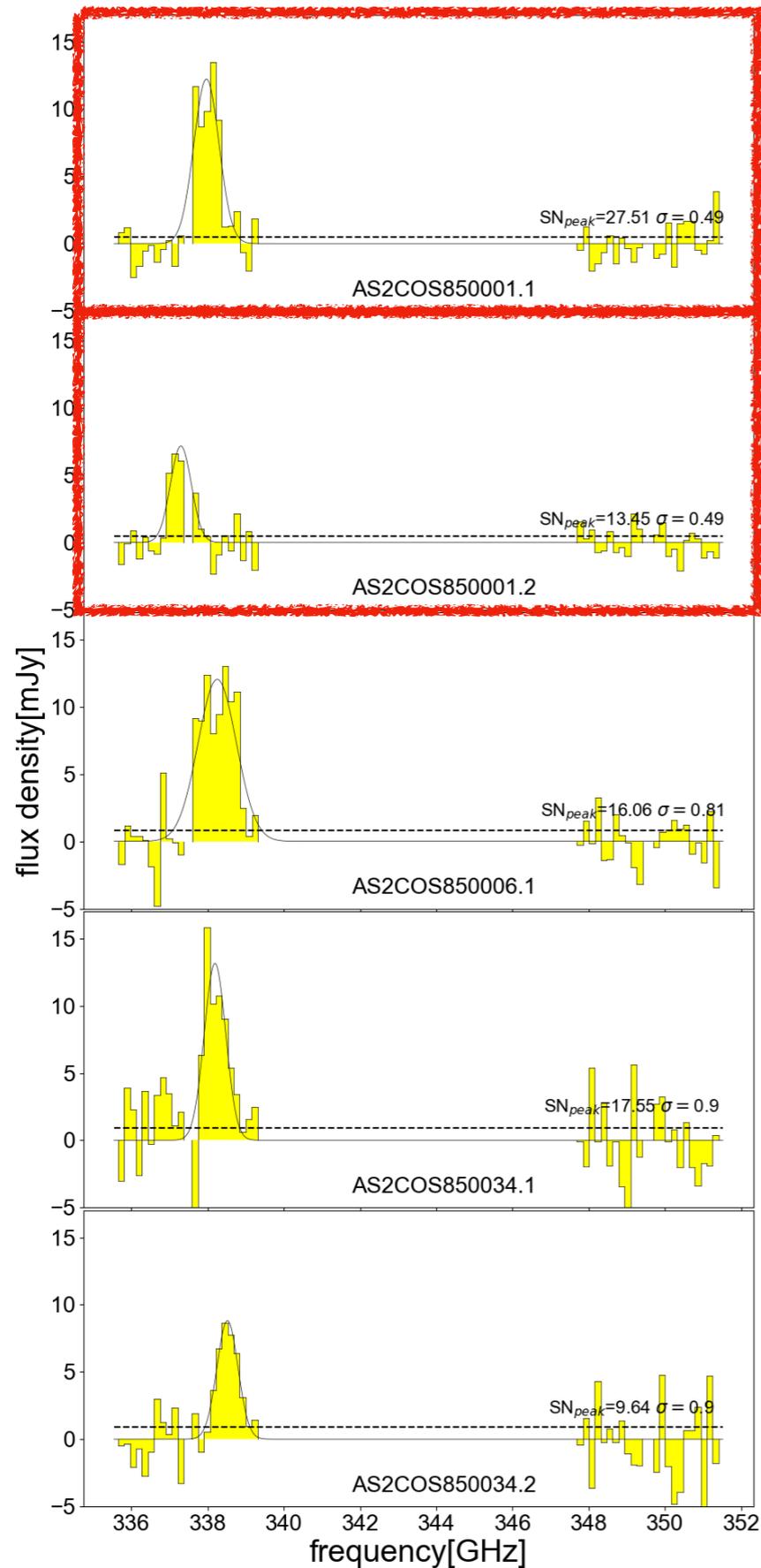
- 連続波が検出 (in ALMA)
- opticalにcounterpartなし
- かなり明るい
- IR peakよりも長波長か？

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
- [Cl](610 μm) @z~0.46
- [Cl](370 μm) @z~1.4
- [OI](146 μm) @z~5.0
- [OIII](88 μm) @z~9.0
- [OI](63 μm) @z~13
- [OIII](52 μm) @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
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- [Cl](370 μm) @z~1.4
- [OI](146 μm) @z~5.0
- [OII](88 μm) @z~9.0
- [OI](63 μm) @z~13
- [OIII](52 μm) @z~16

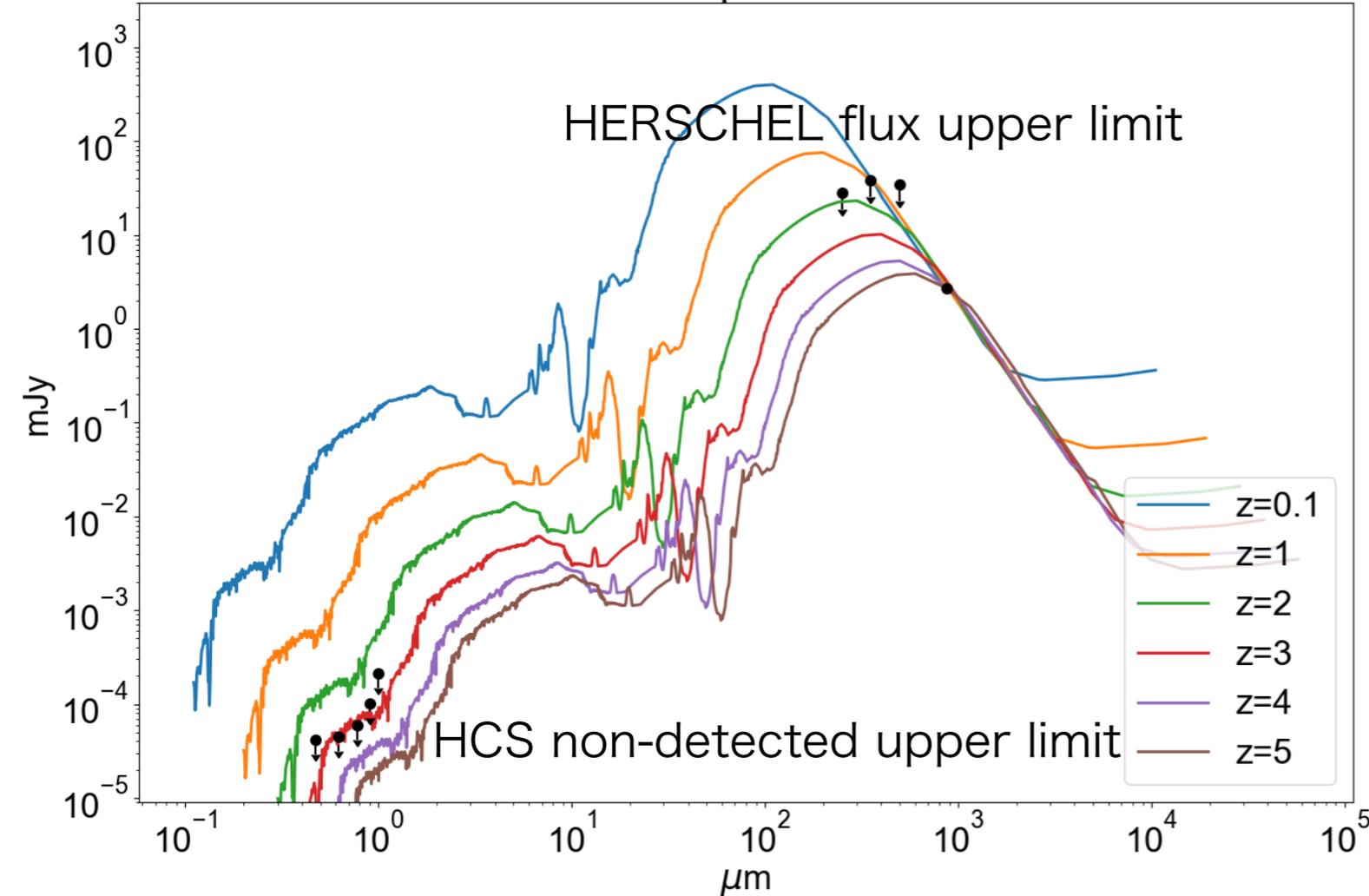
5. Discussion-1.1/1.2

本当に[CII]輝線か？

Arp220

HERSCHEL flux upper limit

HCS non-detected upper limit



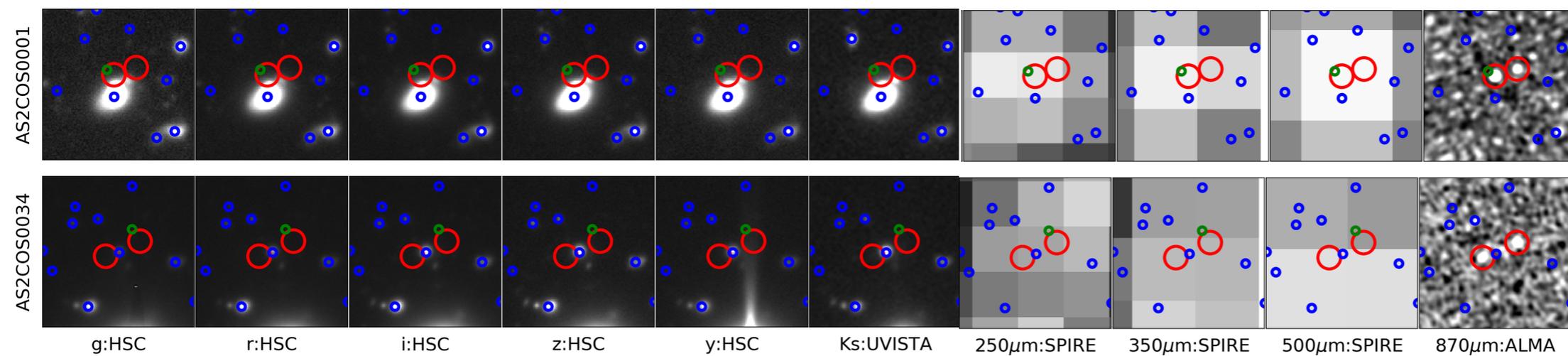
[CII]輝線候補の特徴

他の輝線の候補

- 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

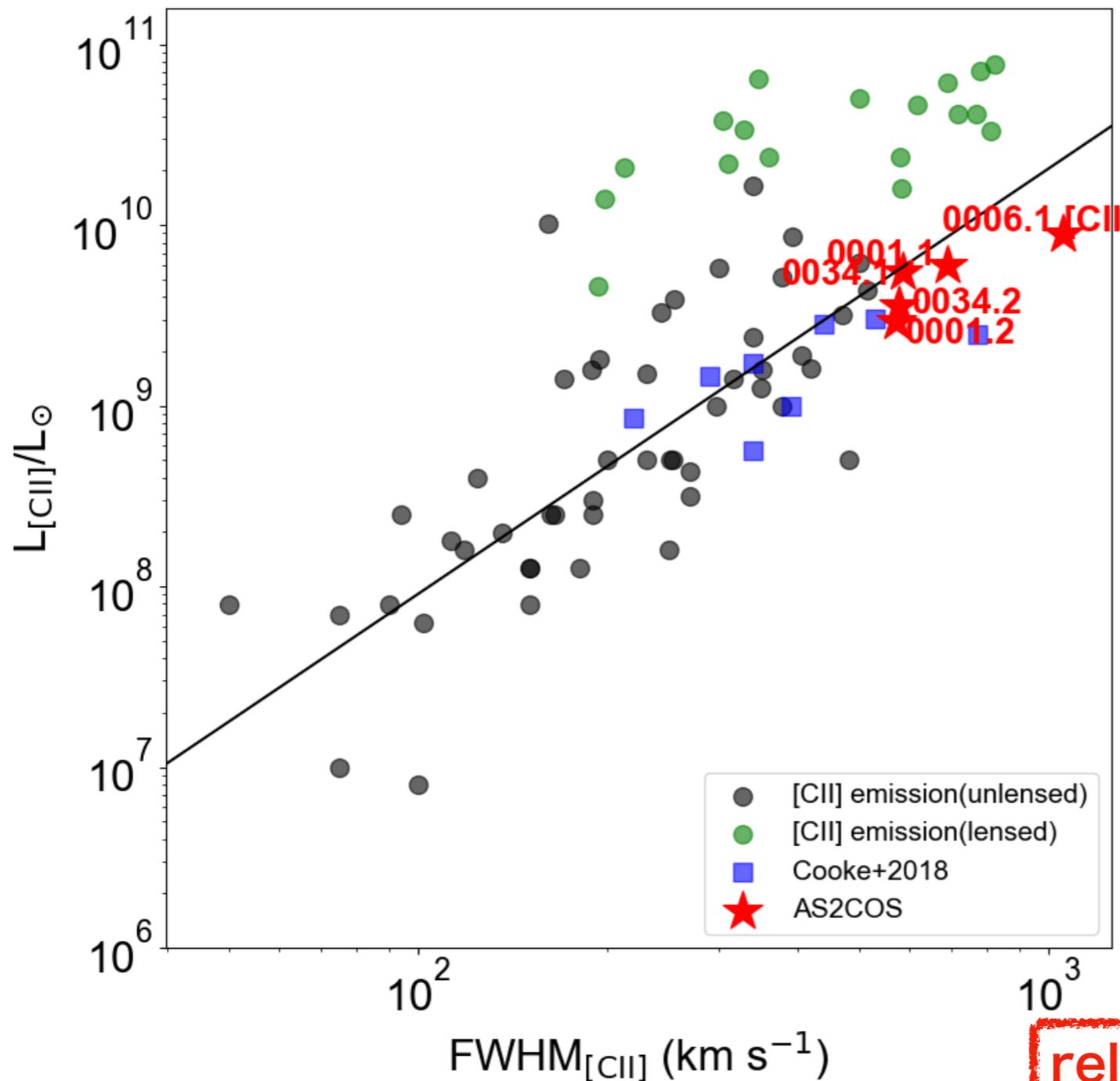
- ~~CO(3-2)@z=0.02~~
- ~~CO(4-3)@z=0.35~~
- ~~CO(12-11)@z=3.0~~
- more high-J CO @z>3.0
- ~~[CI](610 μm) @z=0.46~~
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- [OIII](88 μm) @z~9.0
- [OI](63 μm) @z~13
- [OIII](52 μm) @z~16



blue : optical detected green : HERSCHEL detected

5. Discussion-1.1/1.2

本当に[CII]輝線か？



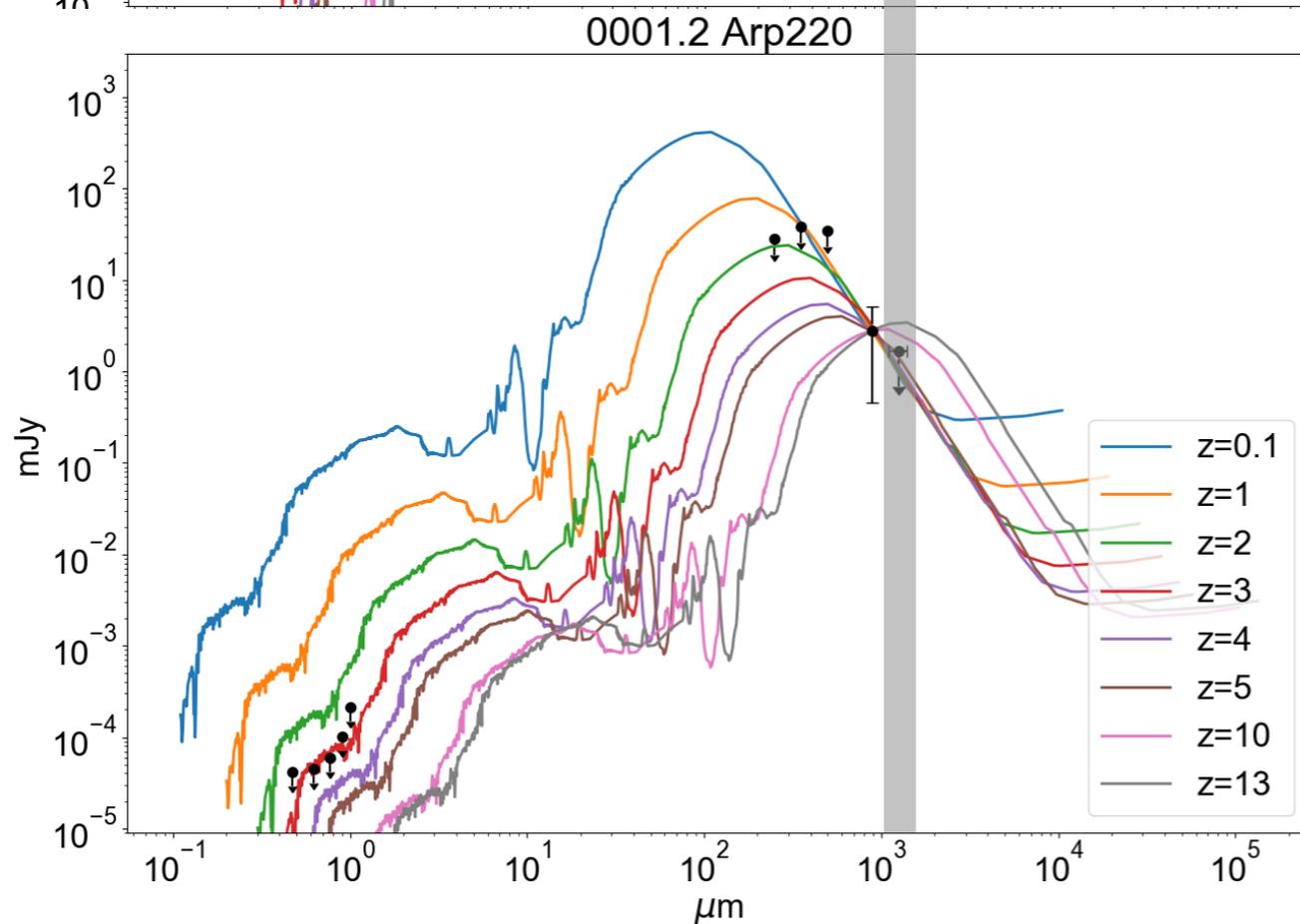
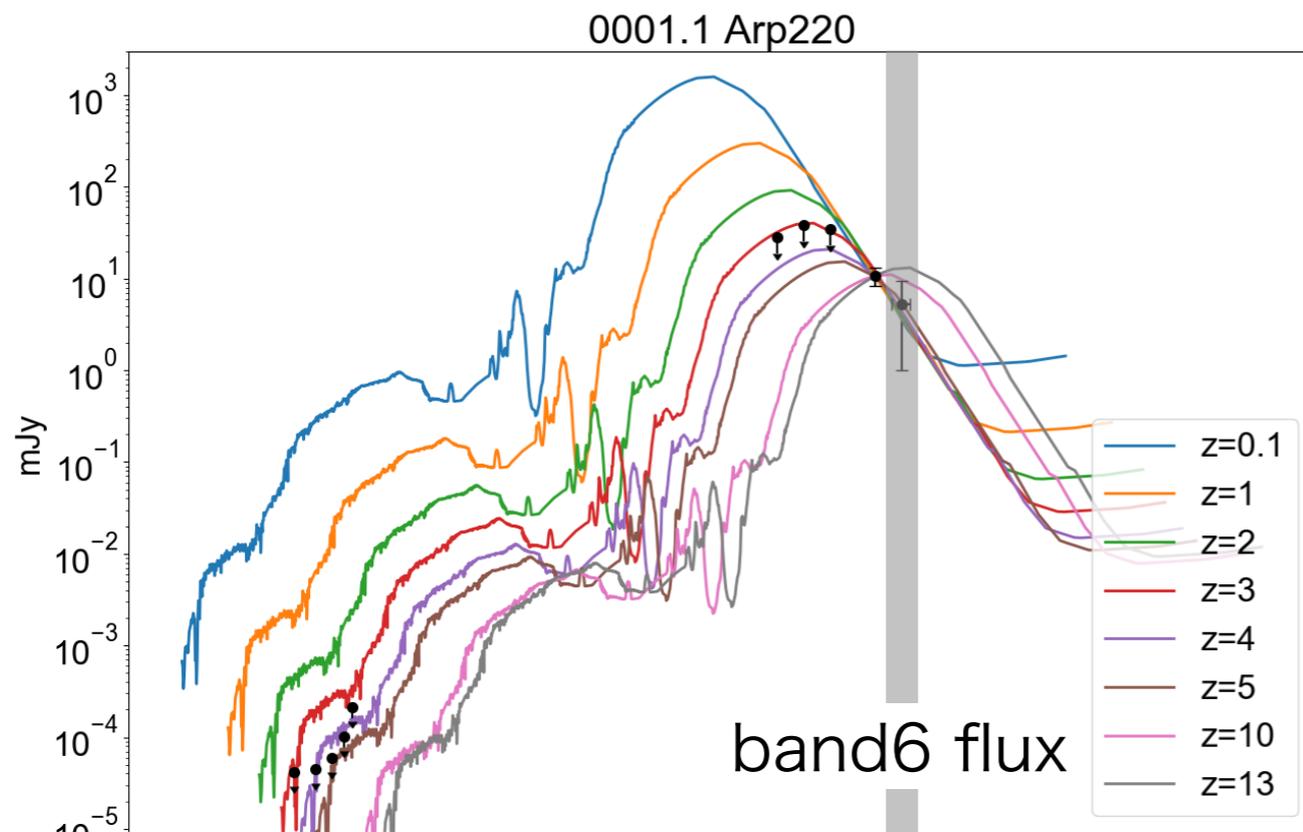
- [CII]輝線候補の特徴
- 連続波が検出 (in ALMA)
 - opticalにcounterpartなし
 - **かなり明るい**
 - IR peakよりも長波長か？

- 他の輝線の候補
- ~~CO(3-2)@z=0.02~~
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 - ~~CO(12-11)@z=3.0~~
 - ~~more high-J CO @z>3.0~~
 - ~~[CI](610 μm) @z=0.46~~
 - ~~[CI](370 μm) @z=1.4~~
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 - [OIII](88 μm) @z~9.0
 - [OI](63 μm) @z~13
 - [OIII](52 μm) @z~16

relatively bright line

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)
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- かなり明るい
- IR peakよりも長波長か？

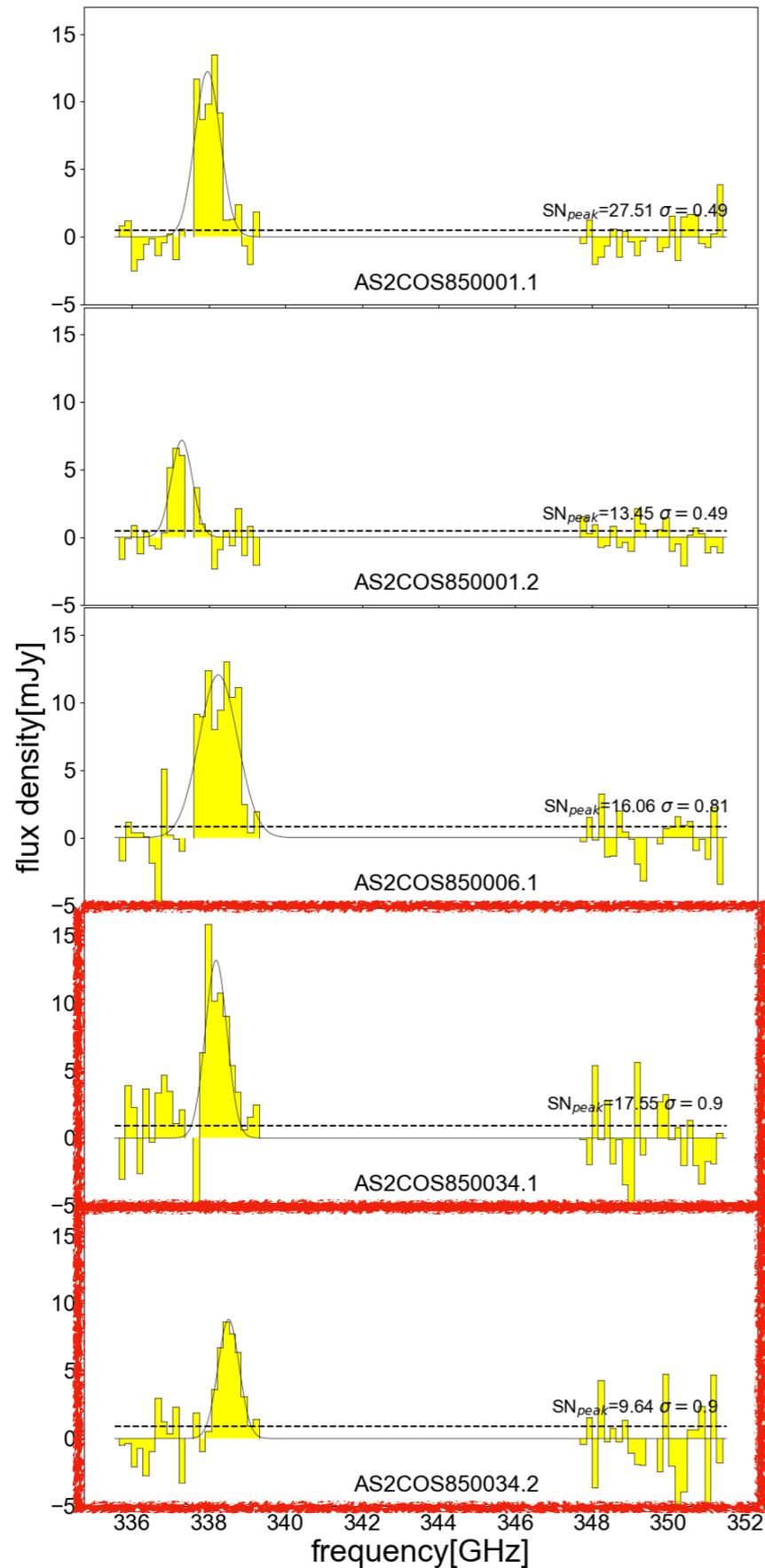
他の輝線の候補

- ~~CO(3-2)@z=0.02~~
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z<9

5. Discussion-34.1/34.2

本当に[CII]輝線か？



[CII]輝線候補の特徴

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- IR peakよりも長波長か？

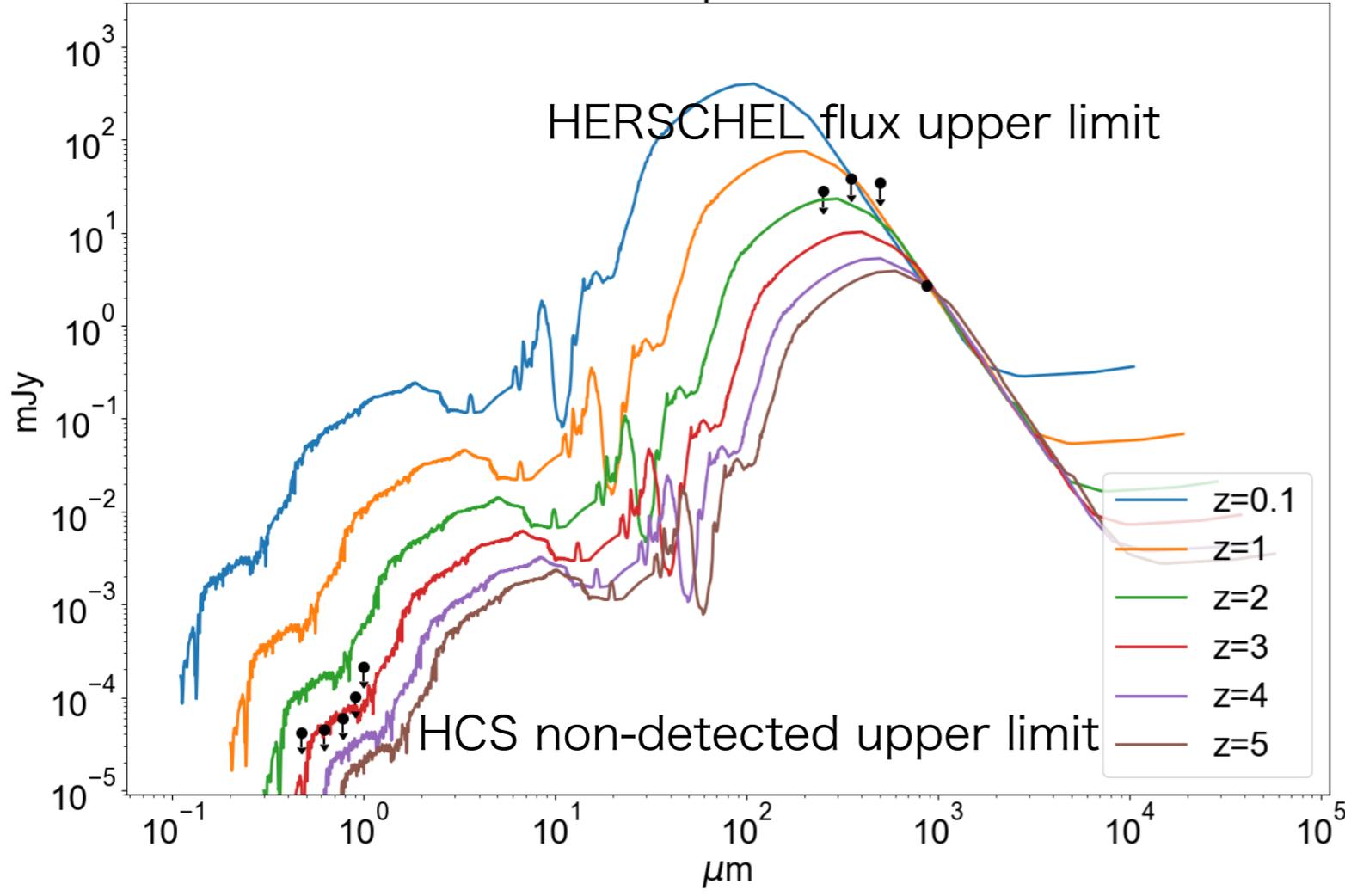
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5. Discussion-34.1/34.2

本当に[CII]輝線か？

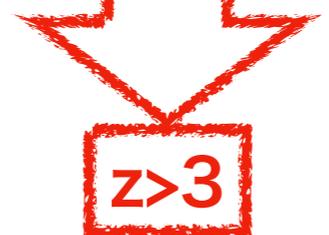
Arp220



[CII]輝線候補の特徴

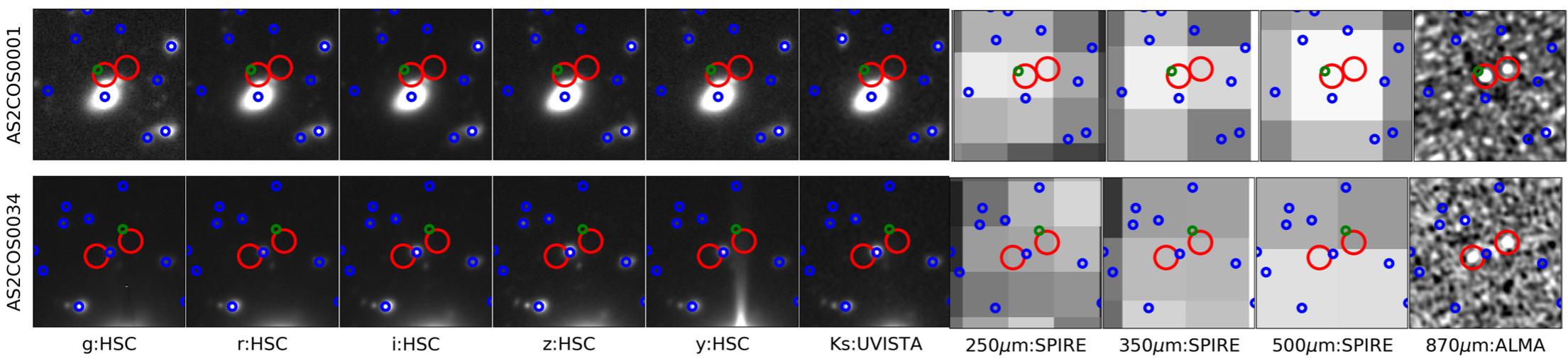
- 連続波が検出 (in ALMA)
- opticalにcounterpartなし

- かなり明るい
- IR peakよりも長波長か？



他の輝線の候補

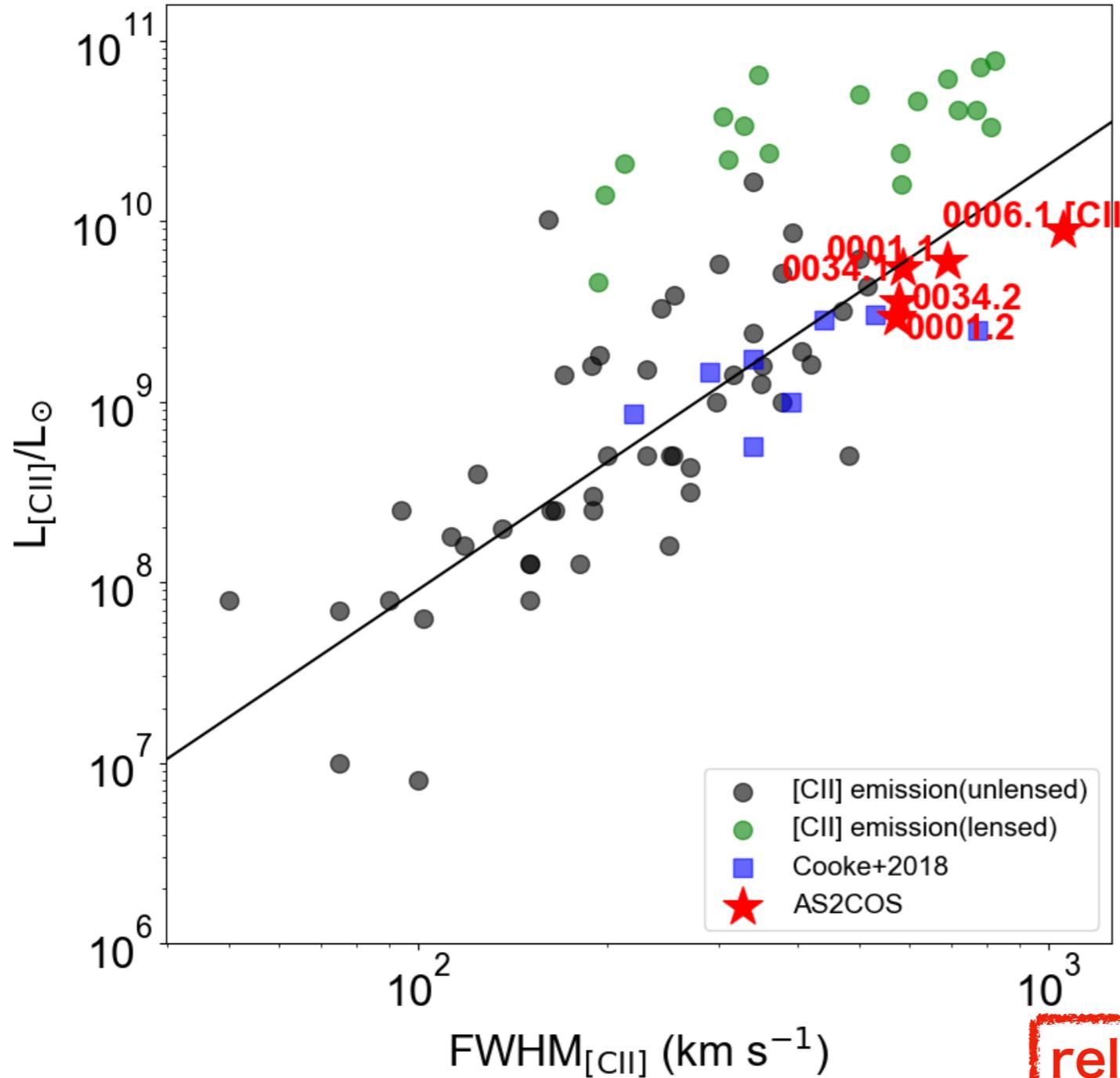
- ~~CO(3-2)@z=0.02~~
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blue : optical detected green : HERSCHEL detected

5. Discussion-34.1/34.2

本当に[CII]輝線か？



- [CII]輝線候補の特徴
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 - opticalにcounterpartなし
 - **かなり明るい**
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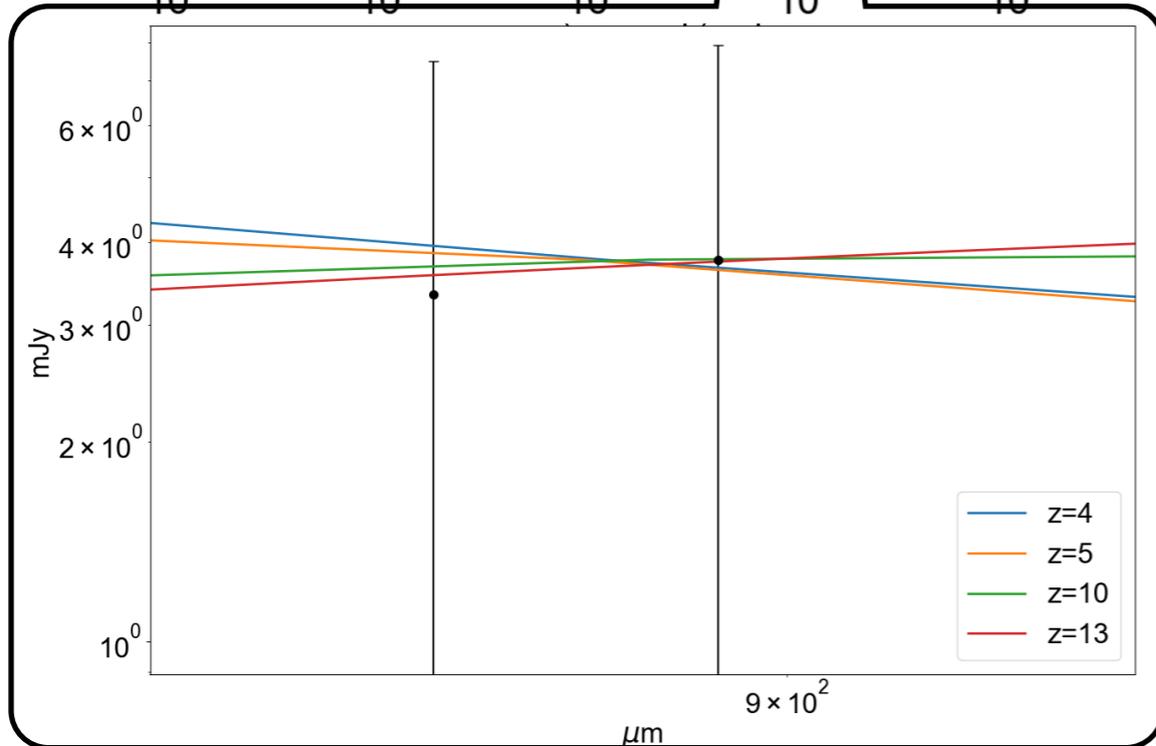
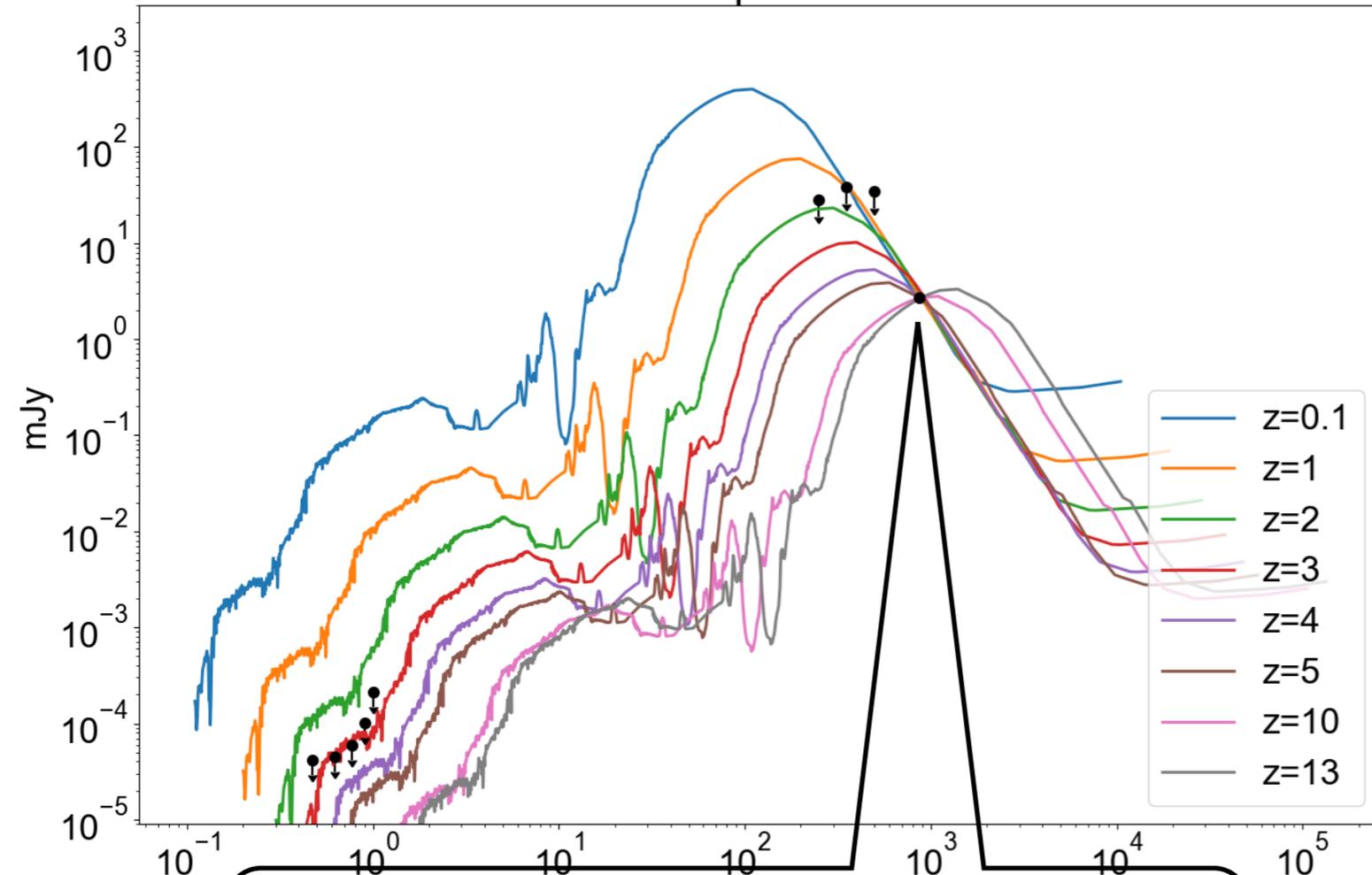
- 他の輝線の候補
- ~~CO(3-2)@z=0.02~~
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relatively bright line

5. Discussion-34.1/34.2

本当に[CII]輝線か？

Arp220



[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？

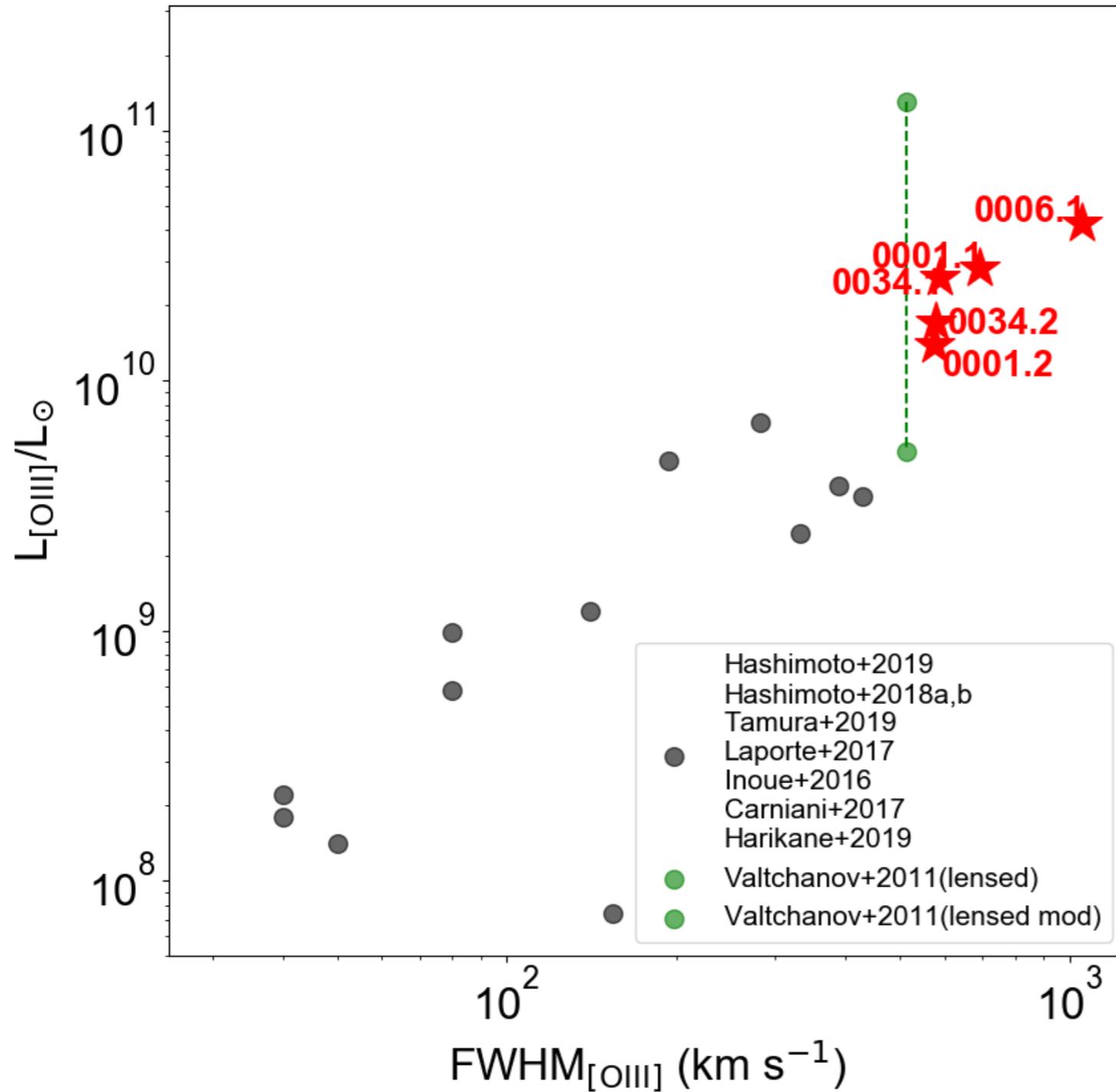
他の輝線の候補

- ~~CO(3-2)@z=0.02~~
- ~~CO(4-3)@z=0.35~~
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z<9 ?

?

5. Discussion-34.1/34.2



本当に[CII]輝線か？

[CII]輝線候補の特徴	他の輝線の候補
<ul style="list-style-type: none"> 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？ 	<ul style="list-style-type: none"> 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](610 μm) @z=0.46 [CI](370 μm) @z=1.4 [OI](146 μm) @z=5.0 [OIII](88 μm) @z=0.0 [OI](63 μm) @z=1.3 [OII](52 μm) @z=1.6

z<9 ?

Presentation Table

1.Introduction

Galaxy Evolution

Sub-Millimetre Galaxies (SMGs)

Proto-Clusters

2.Data

3.Analysis

4.Result

5.Discussion

Discussion-6.1

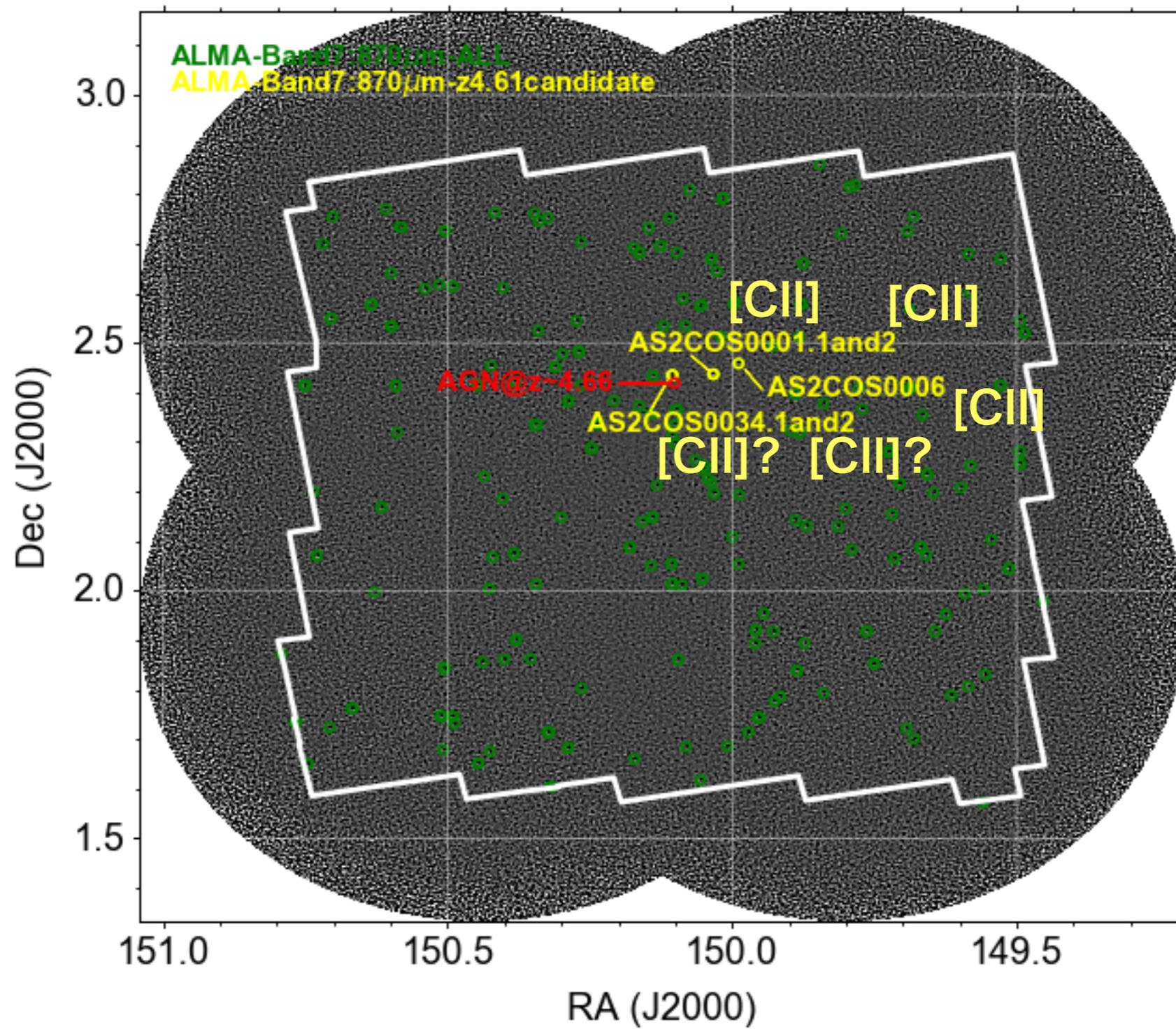
Discussion-1.1/1.2

Discussion-34.1/34.2

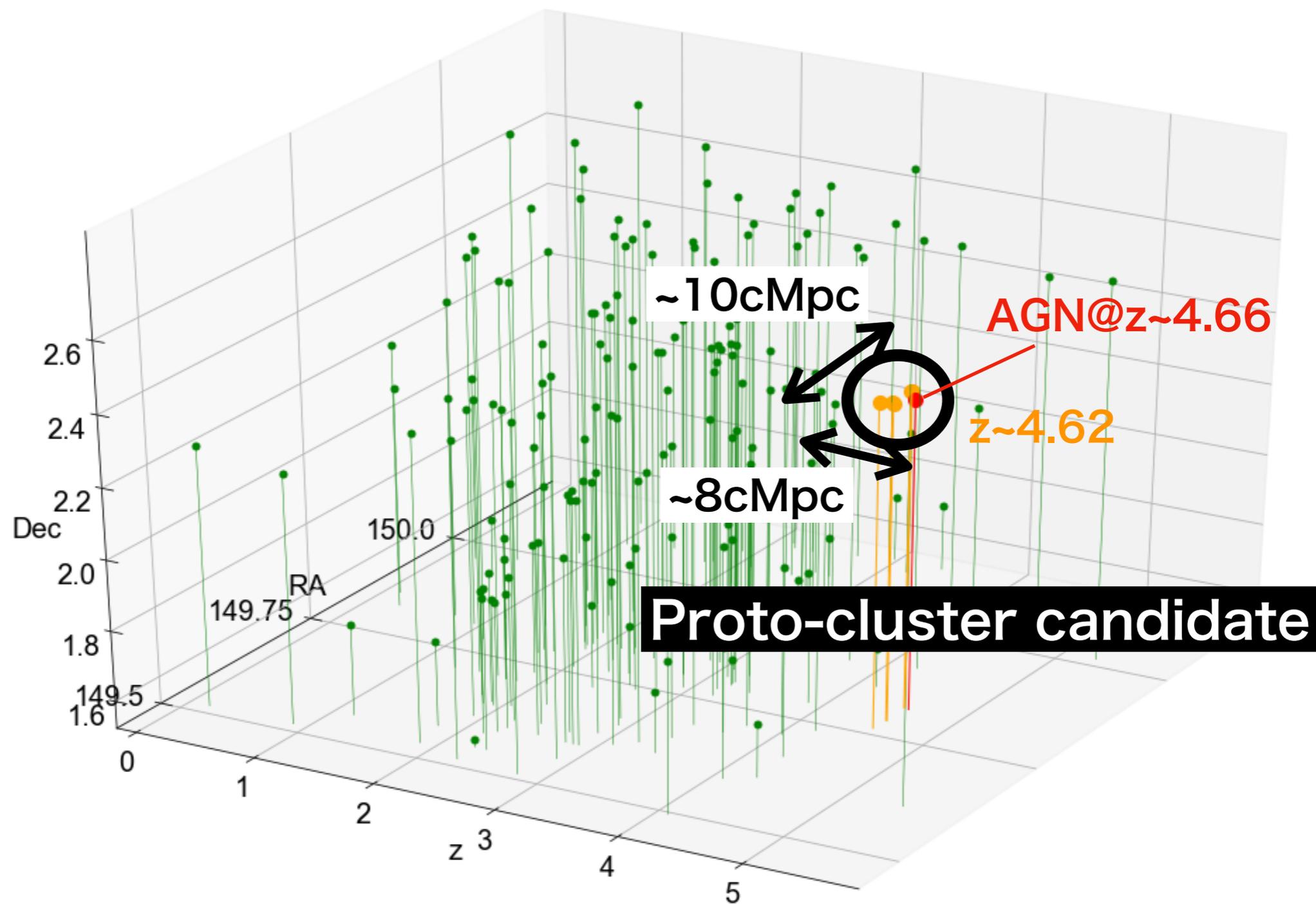
6.Conclusion

7.Future Work/Proposals

6. Conclusion

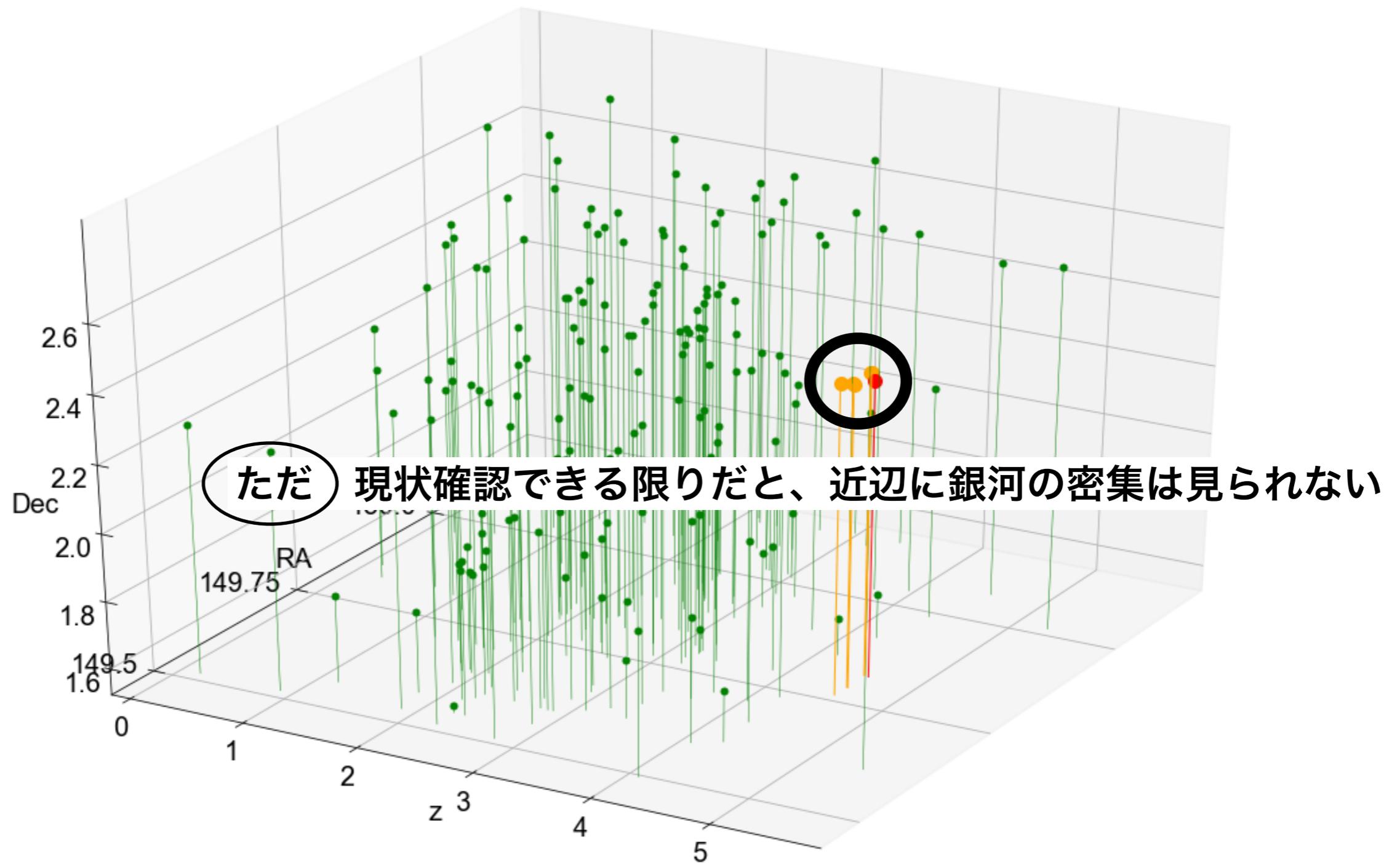


6. Conclusion



Proto-clusterの候補とみなして良さそう

6. Conclusion



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

Presentation Table

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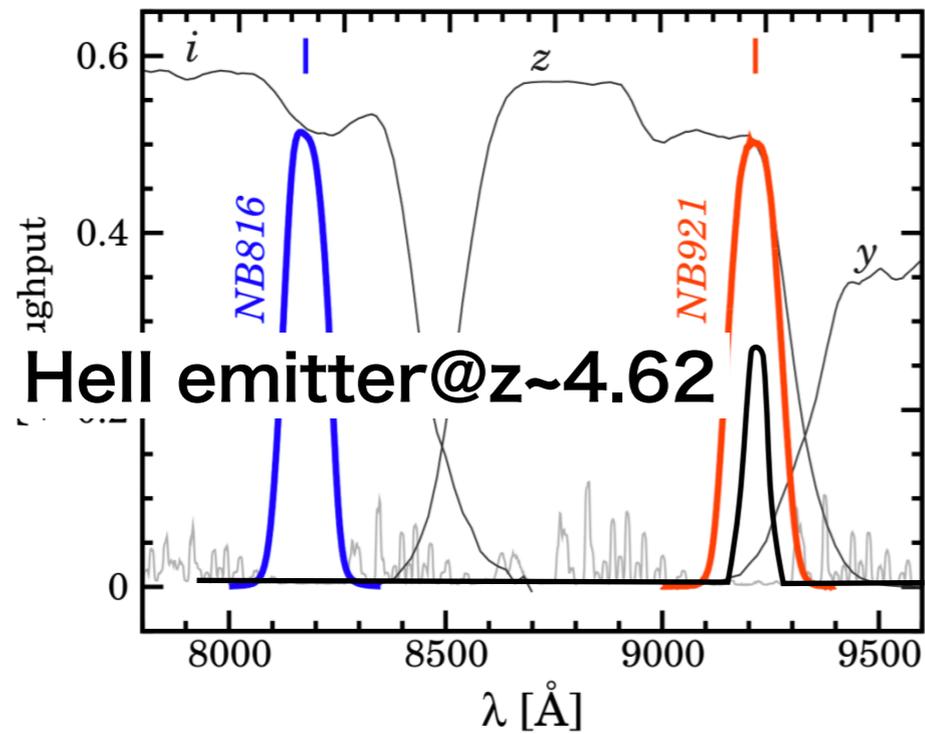
Discussion-1.1/1.2

Discussion-34.1/34.2

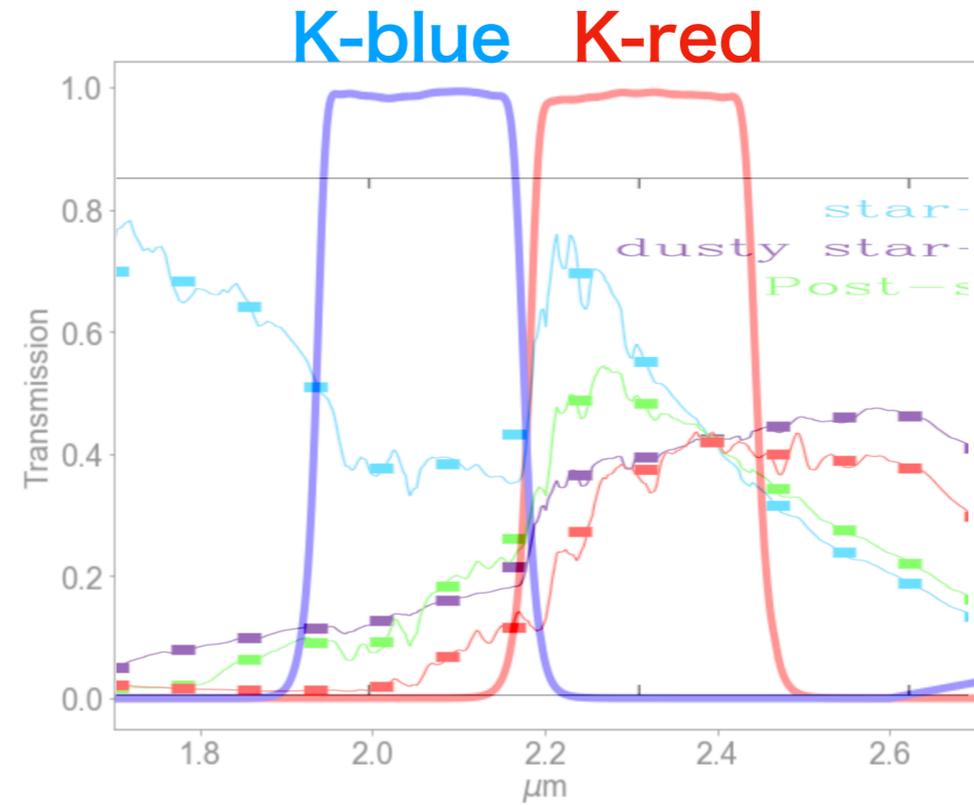
6.Conclusion

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6.Future work/Proposal



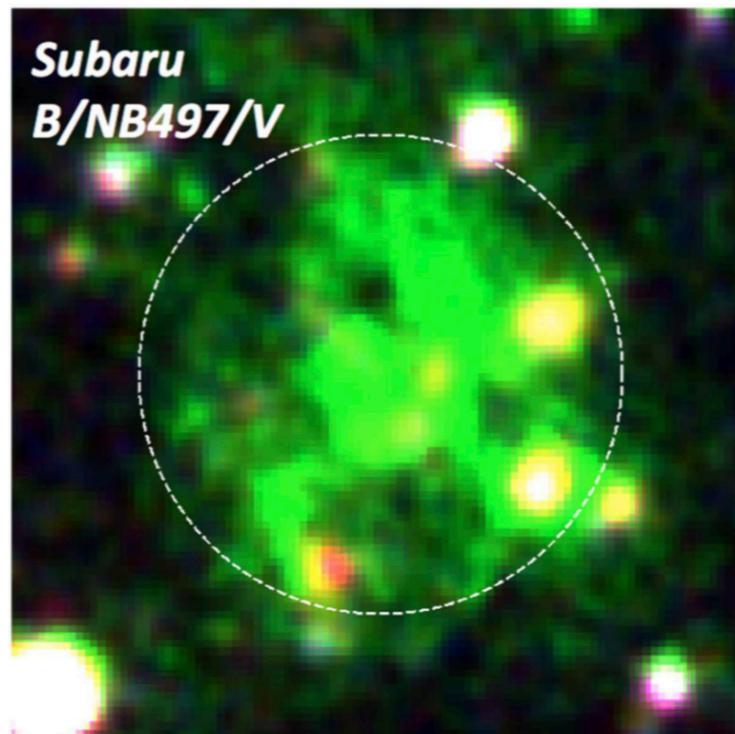
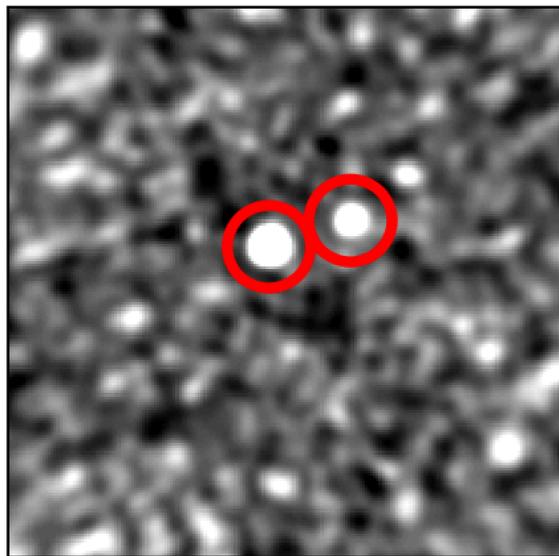
from Shibuya+2018



emitter/BBG @ $z \sim 4.62$

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 $Ly\alpha$ 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