

第二回銀河進化研究会 (2015/6/3-5 @名古屋大)

Can we predict dust extinction properties of star-forming galaxies from $H\alpha/UV$ ratio ?

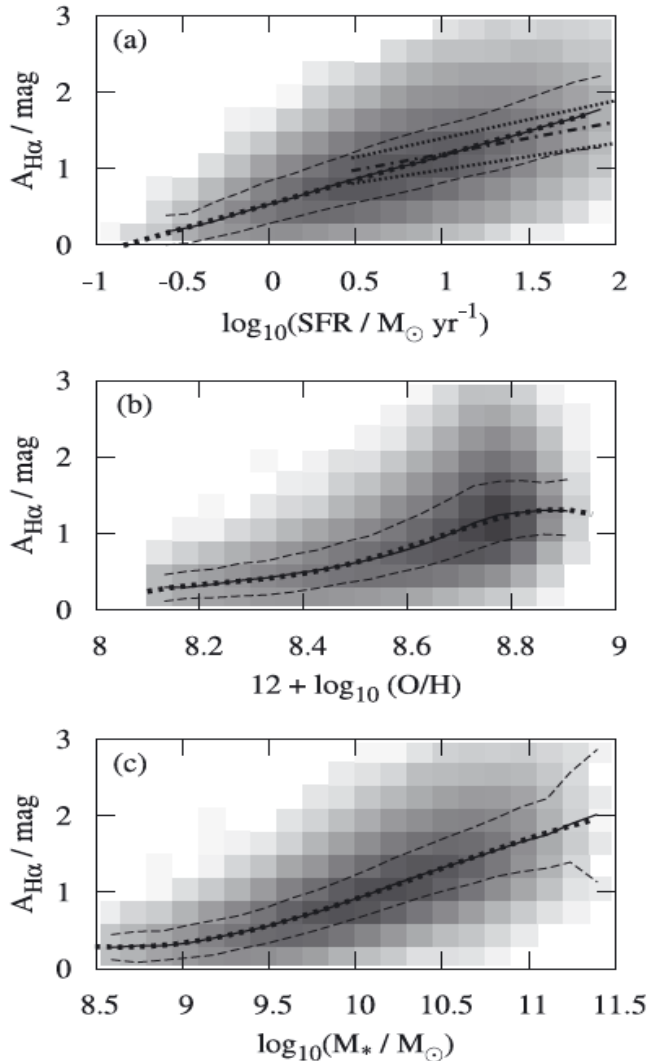
Koyama et al. (2015), MNRAS, submitted

小山佑世 (国立天文台ハワイ観測所)

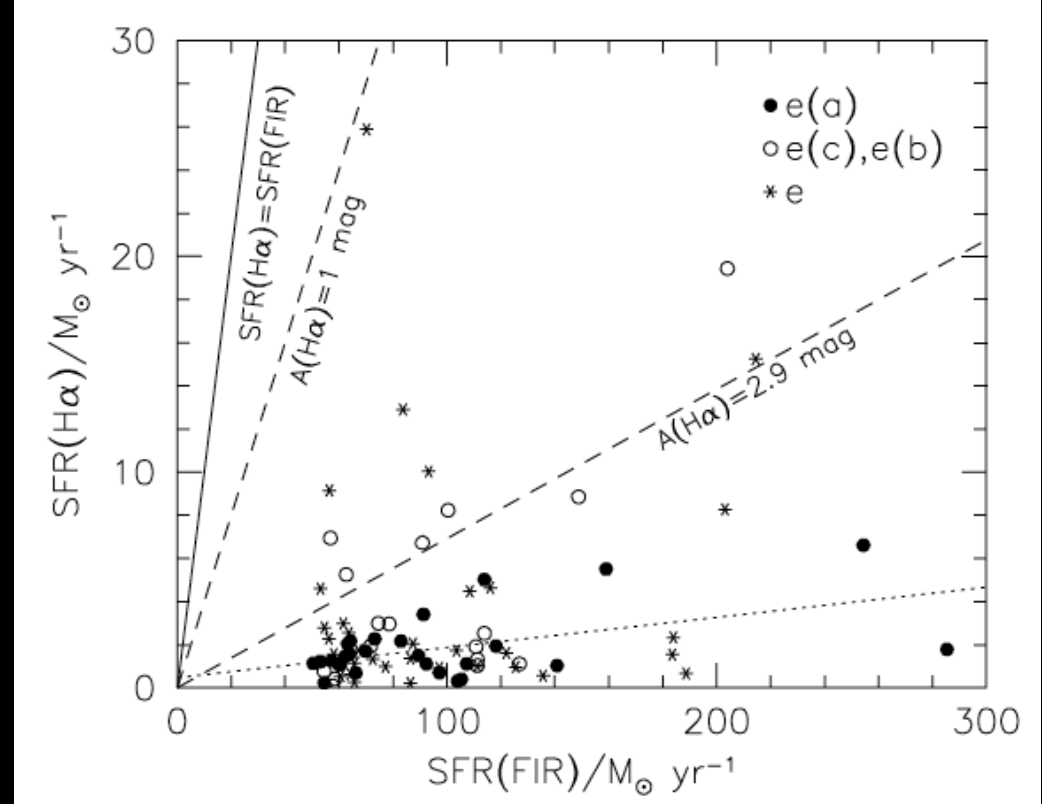
山村一誠, 江草芙実, 瀧田怜, 卷内慎一郎, 大井渚 (宇宙研)

児玉忠恭, 林将央, 田中壱 (国立天文台), 但木謙一 (MPE), 嶋川里澄 (総研大)

Dust extinction: always a big issue



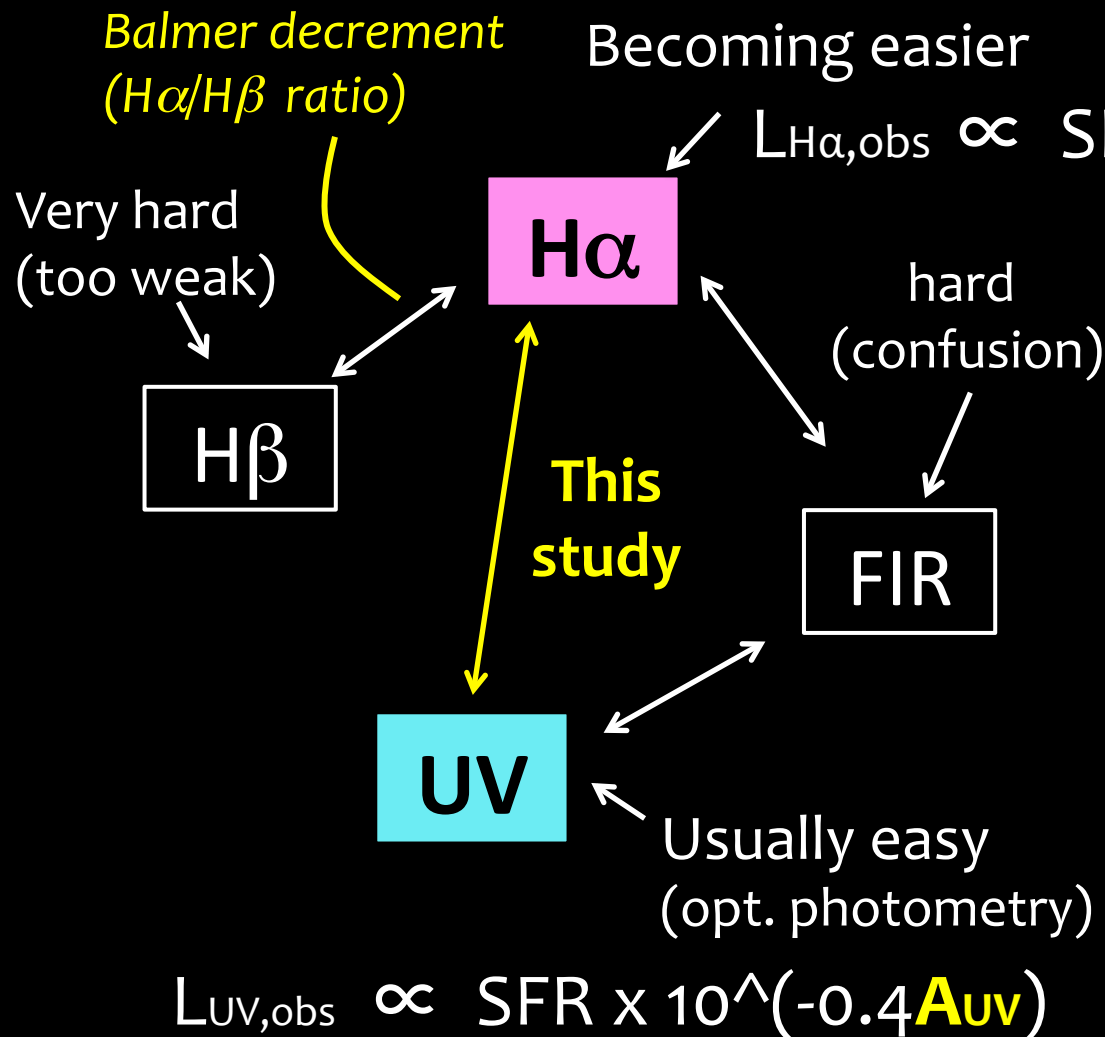
Garn & Best (2010)



Poggianti & Wu (2000)

SFRs from optical emission lines are a factor of ~ 10 - 70 ($\text{H}\alpha$) and ~ 20 - 140 ($[\text{OII}]$) lower than $\text{SFR}(\text{IR})$ in extreme cases (dusty starbursts).

This study



Problems so far

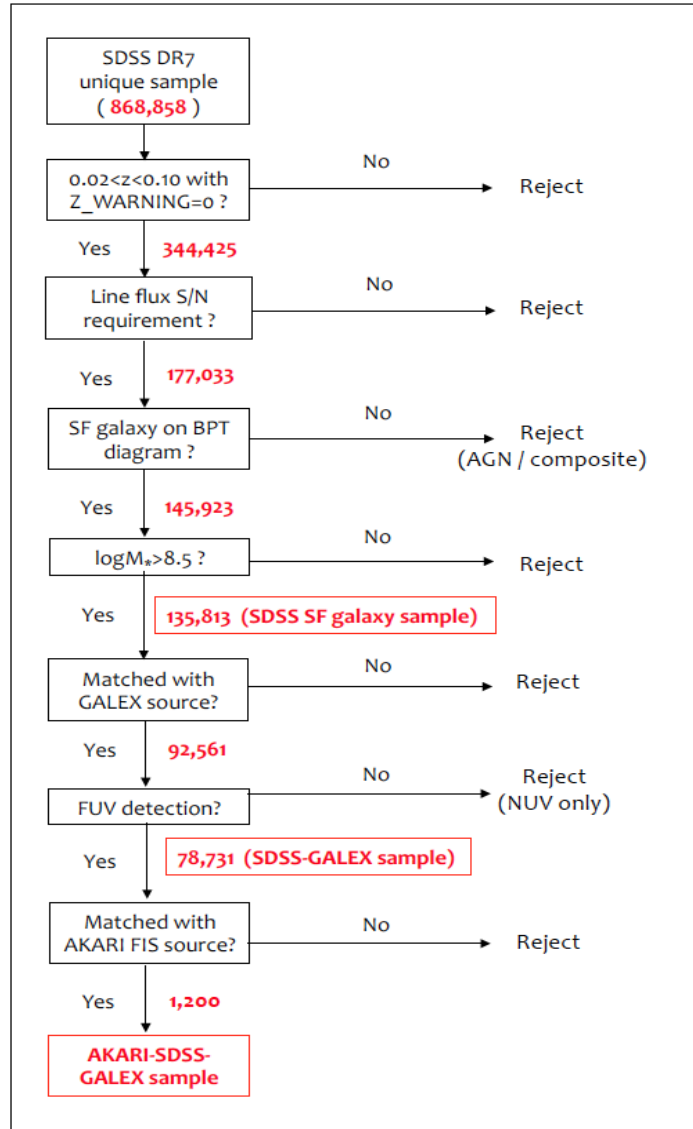
Detecting $H\alpha$ for high- z galaxies is becoming easier, but $H\beta$ is usually too faint even for 8-m class telescope, making it hard to estimate $H\alpha$ dust extinction.

This work

Establish an empirical calibration for $A(H\alpha)$ from $H\alpha/UV$ ratio using nearby galaxies sample

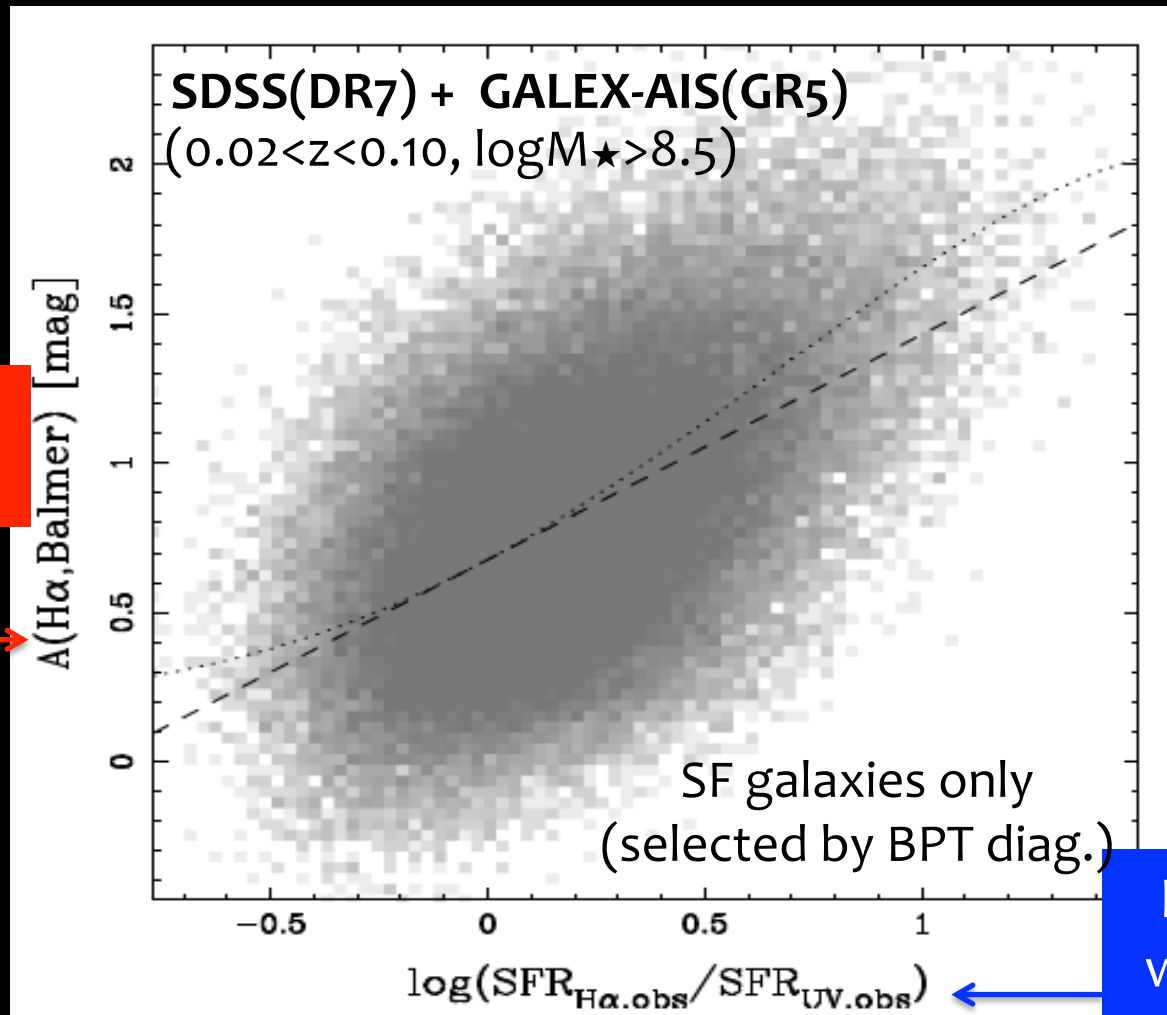
Sample selection

- Starting from SDSS DR7 spec. MPA/JHU catalogue, matched with GALEX All-sky catalogue (GR5).
- Redshift range of $0.02 < z < 0.10$.
- Requesting emission line detection for $H\alpha$, $H\beta$, $[NII]$, $[OIII]$. SF galaxies are selected using BPT diagram (removing AGNs & composites).
- Stellar mass with $\log(M_{\star}/M_{\odot}) > 8.5$.
- Our final “SDSS-GALEX” catalogue includes 78,731 FUV detected SF galaxies, among which 1,200 have AKARI 90um counterparts.



$A(\text{H}\alpha)$ vs. “observed” $\text{H}\alpha/\text{UV}$ ratio

A positive correlation (as expected), but there exists a substantial scatter.

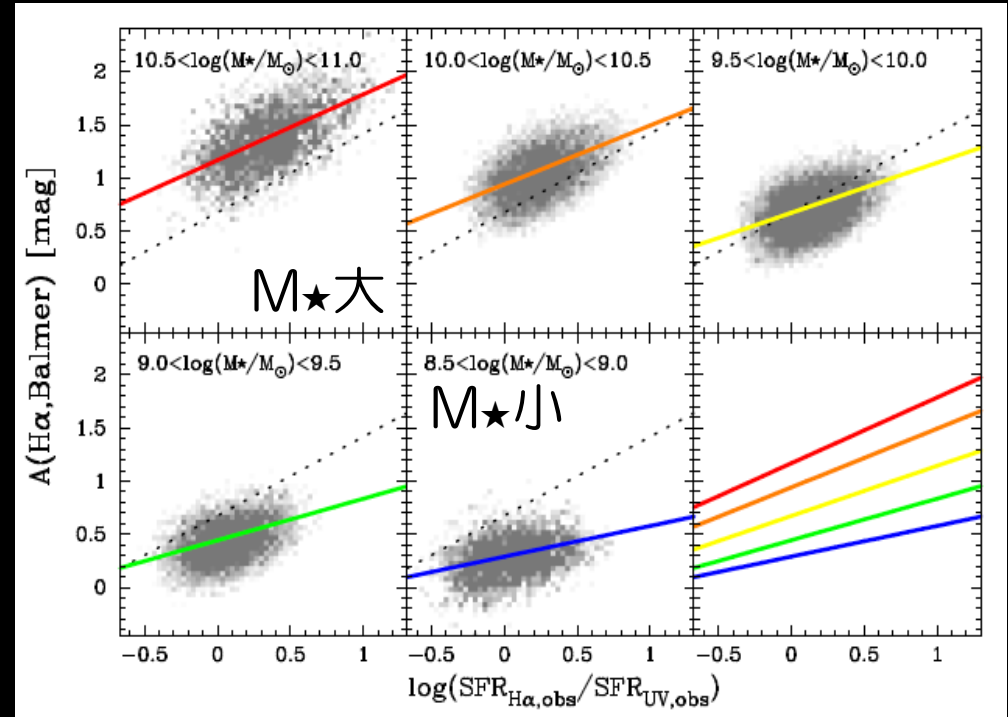
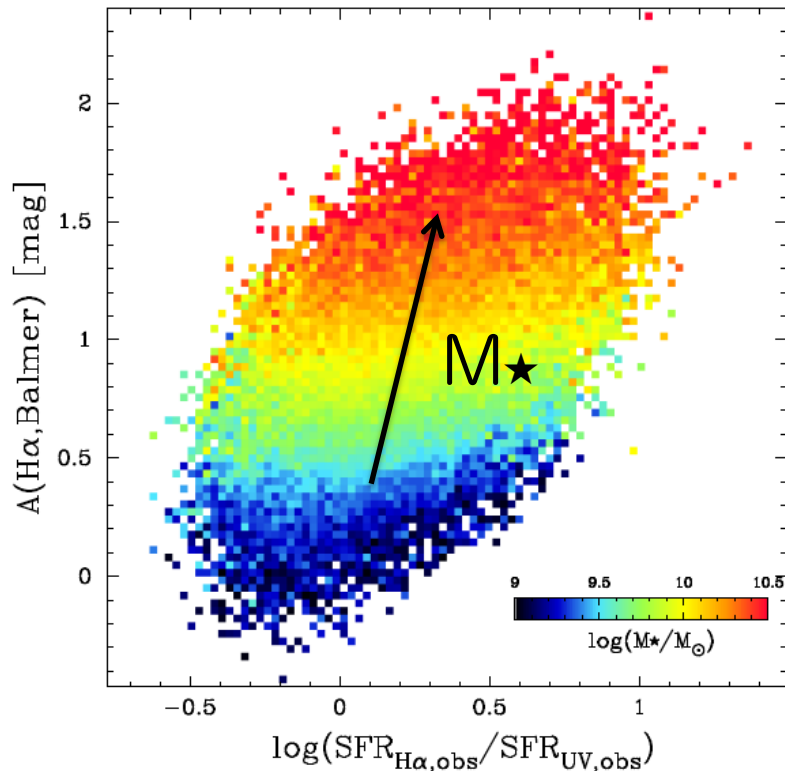


$A(\text{H}\alpha)$ from
 $\text{H}\alpha/\text{H}\beta$ ratio

$\text{H}\alpha/\text{UV}$ ratio
without dust
correction

Dependence on stellar mass

More massive galaxies tend to be dustier at fixed H α /UV ratio.



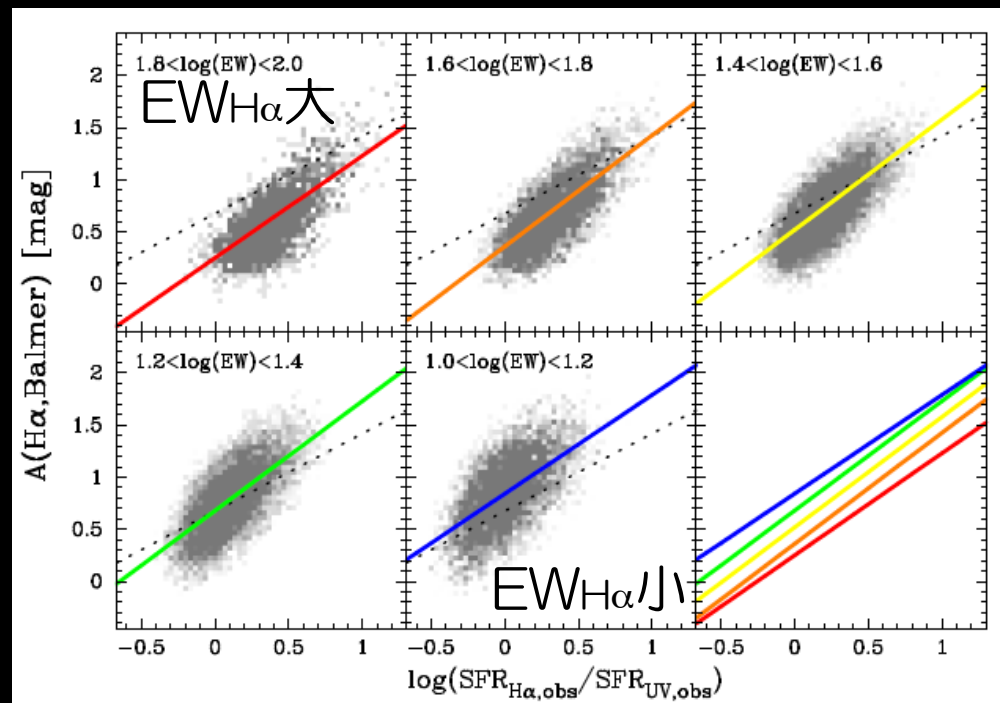
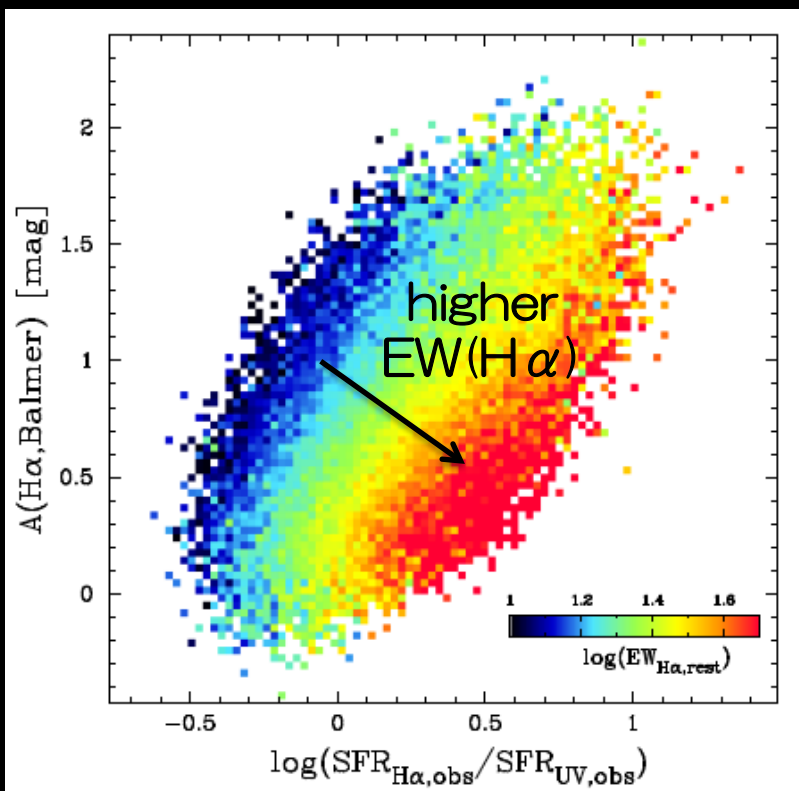
H α /UVの情報に M_* の情報を加えることで、より現実的な $A(\text{H}\alpha)$ の見積りが可能になる。

$$A_{\text{H}\alpha} = a(\log M_*) \times \log(\text{H}\alpha/\text{UV}) + b(\log M_*),$$

$$a(\log M_*) = 0.210 \times \log M_* - 1.597,$$
$$b(\log M_*) = 0.493 \times \log M_* - 4.121.$$

Dependence on EW(H α)

At fixed H α /UV ratio, high-EW galaxies tend to be *less* dusty.



M $\star$ の代わりにEW(H α)を用いても
A(H α)を見積ることができる。これ
ならM $\star$ の見積りがなくても使える。

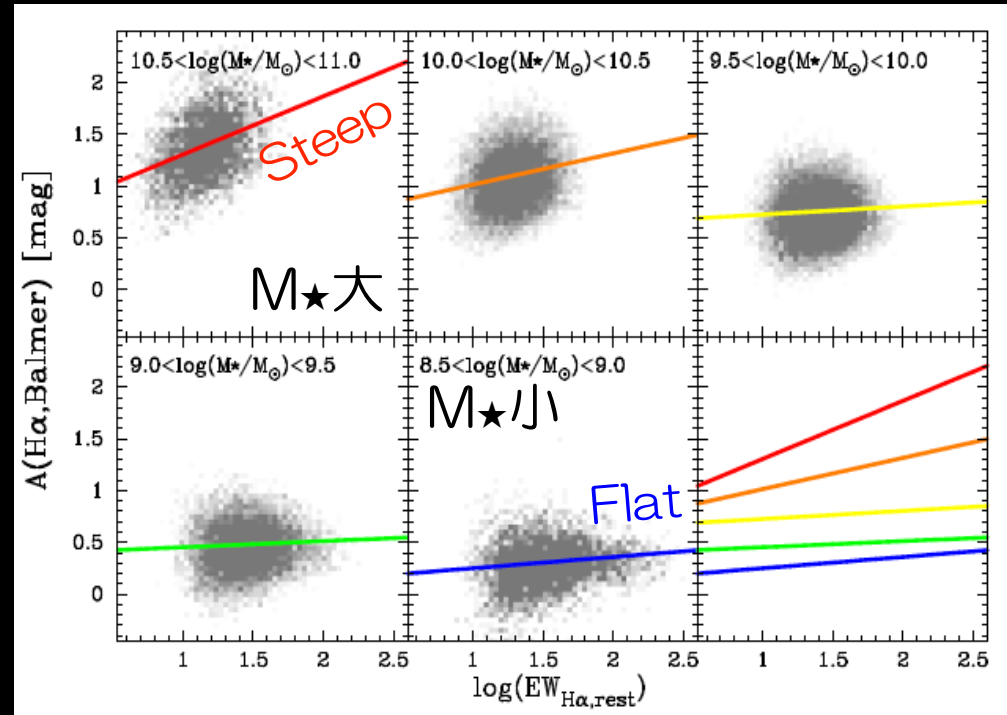
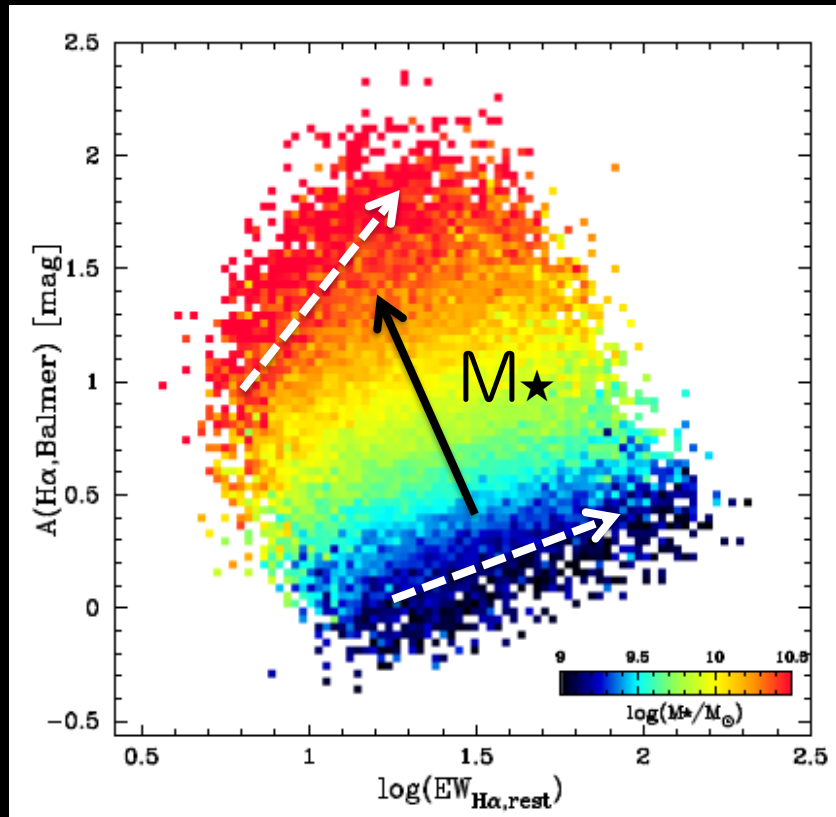
$$A_{H\alpha} = a(\log EW_{H\alpha}) \times \log(H\alpha/UV) + b(\log EW_{H\alpha}),$$

$$a(\log EW_{H\alpha}) = 0.101 \times \log EW_{H\alpha} + 0.872,$$

$$b(\log EW_{H\alpha}) = -0.776 \times \log EW_{H\alpha} + 1.688.$$

Predicting $A(\text{H}\alpha)$ without UV info

$A(\text{H}\alpha)$ vs $\text{EW}(\text{H}\alpha)$ relation is strongly dependent on stellar mass.



重い銀河の場合、 $\text{EW}(\text{H}\alpha)$ が大きいほどダスティーになるが、軽い銀河の場合は EW によらずダスト減光は小さい。

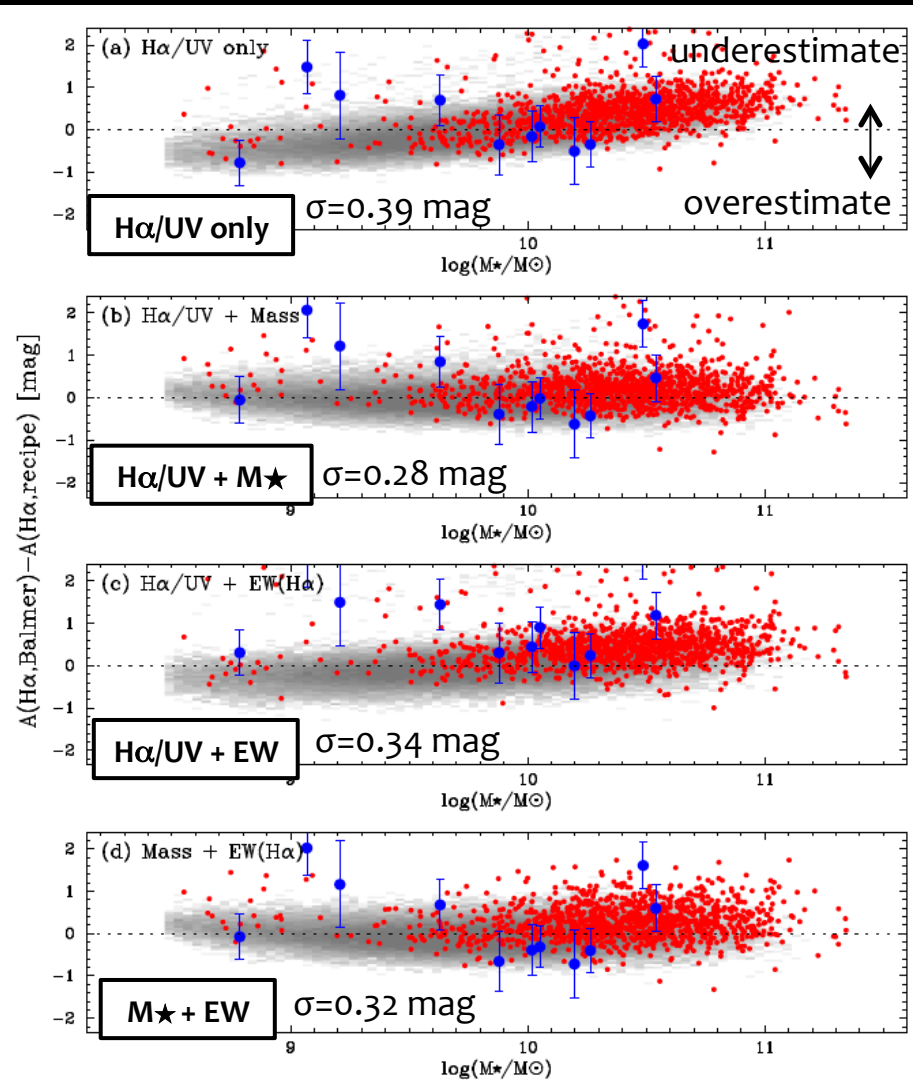
$$A_{\text{H}\alpha} = a(\log M_{\star}) \times \log(\text{EW}_{\text{H}\alpha}) + b(\log M_{\star}),$$

$$a(\log M_{\star}) = 0.096 \times \log M_{\star} - 0.717,$$

$$b(\log M_{\star}) = 0.538 \times \log M_{\star} - 4.745.$$

Which is the best way to approximate $A(H\alpha)$?

Can we apply our recipe to high-z galaxies?



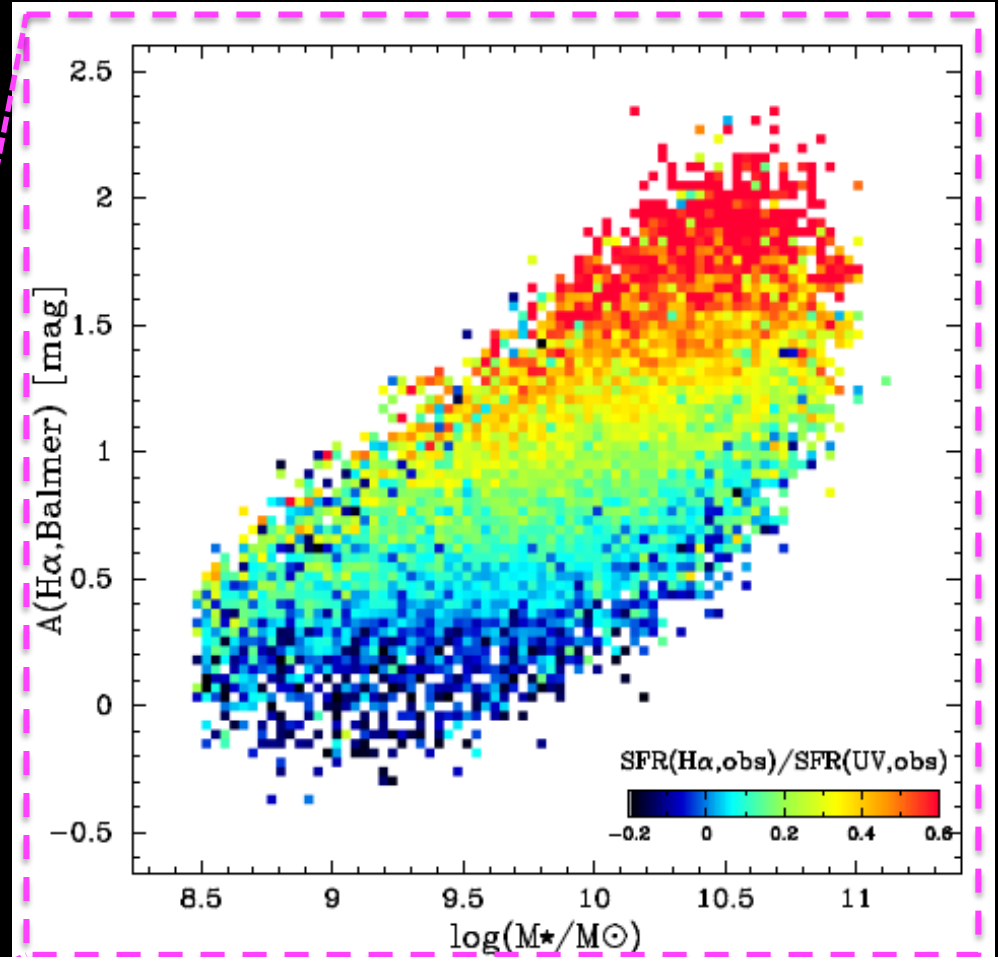
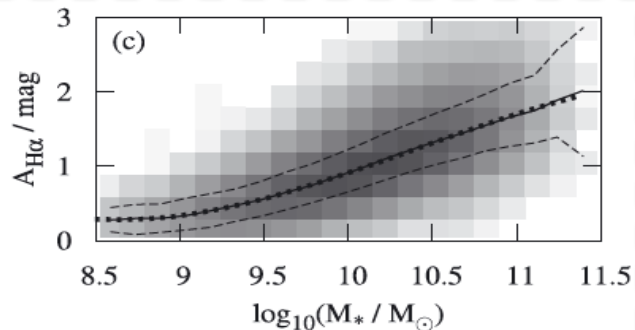
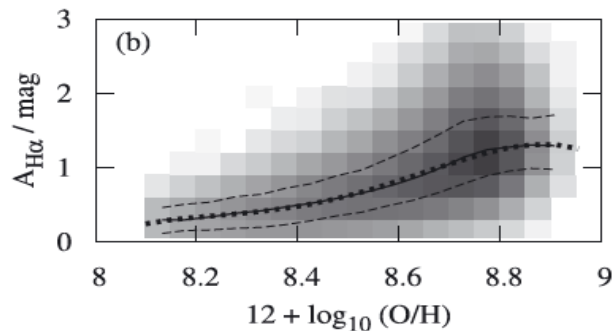
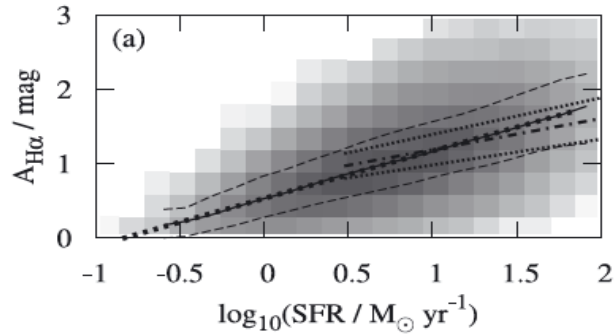
- We can successfully reduce the scatter by adding $M_{\star}$ or $EW(H\alpha)$ info (by $\sim 15\text{-}30\%$), with the $H\alpha/UV +$ stellar mass approach being the best.
- High-z galaxy sample is by far too small to test if our methods can work.

● **AKARI FIR source**

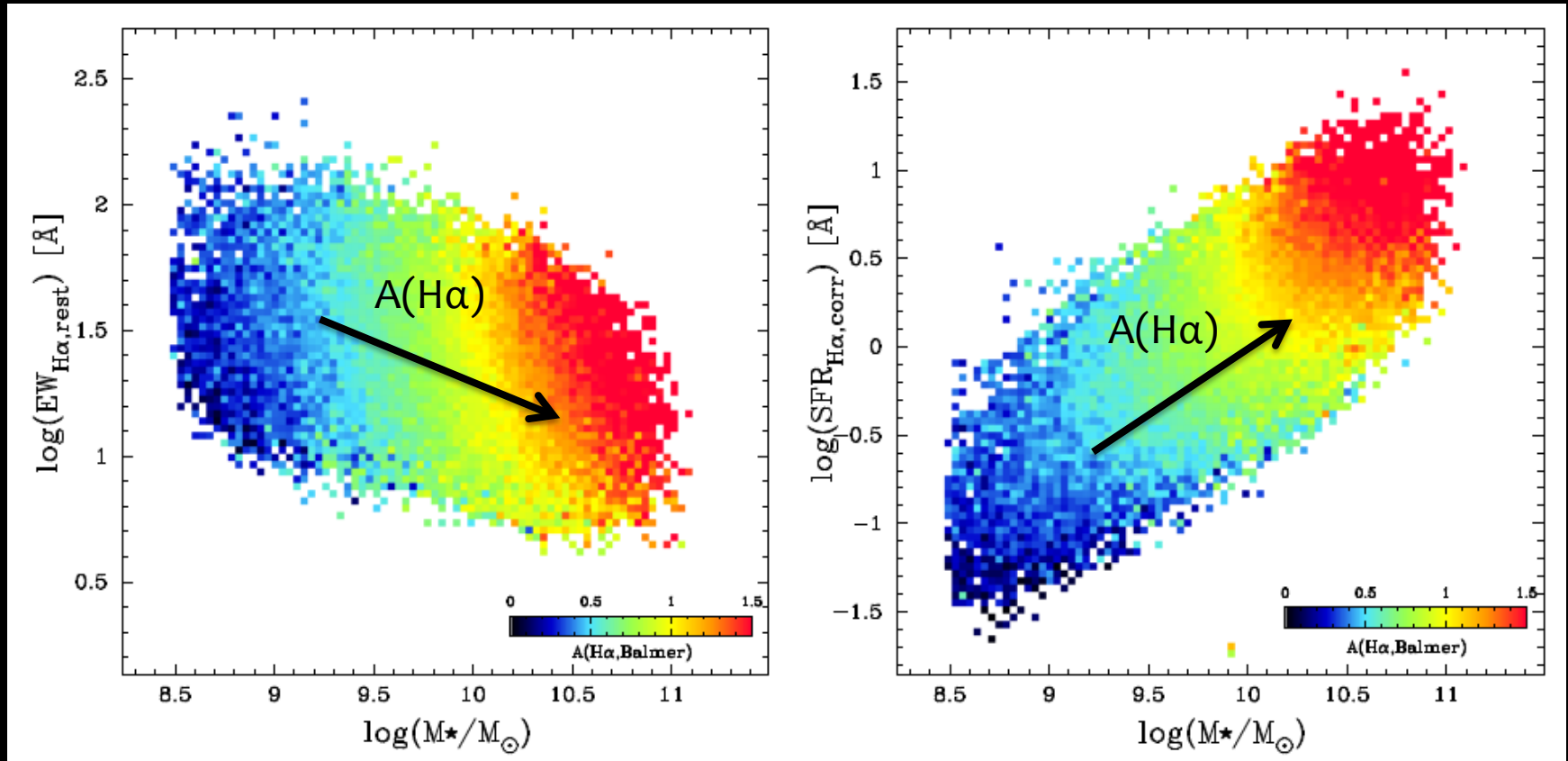
● **high-z galaxies**

(Keck/MOSFIRE spectroscopy by Shimakawa+15)

Can we really predict dust extinction from stellar mass alone?



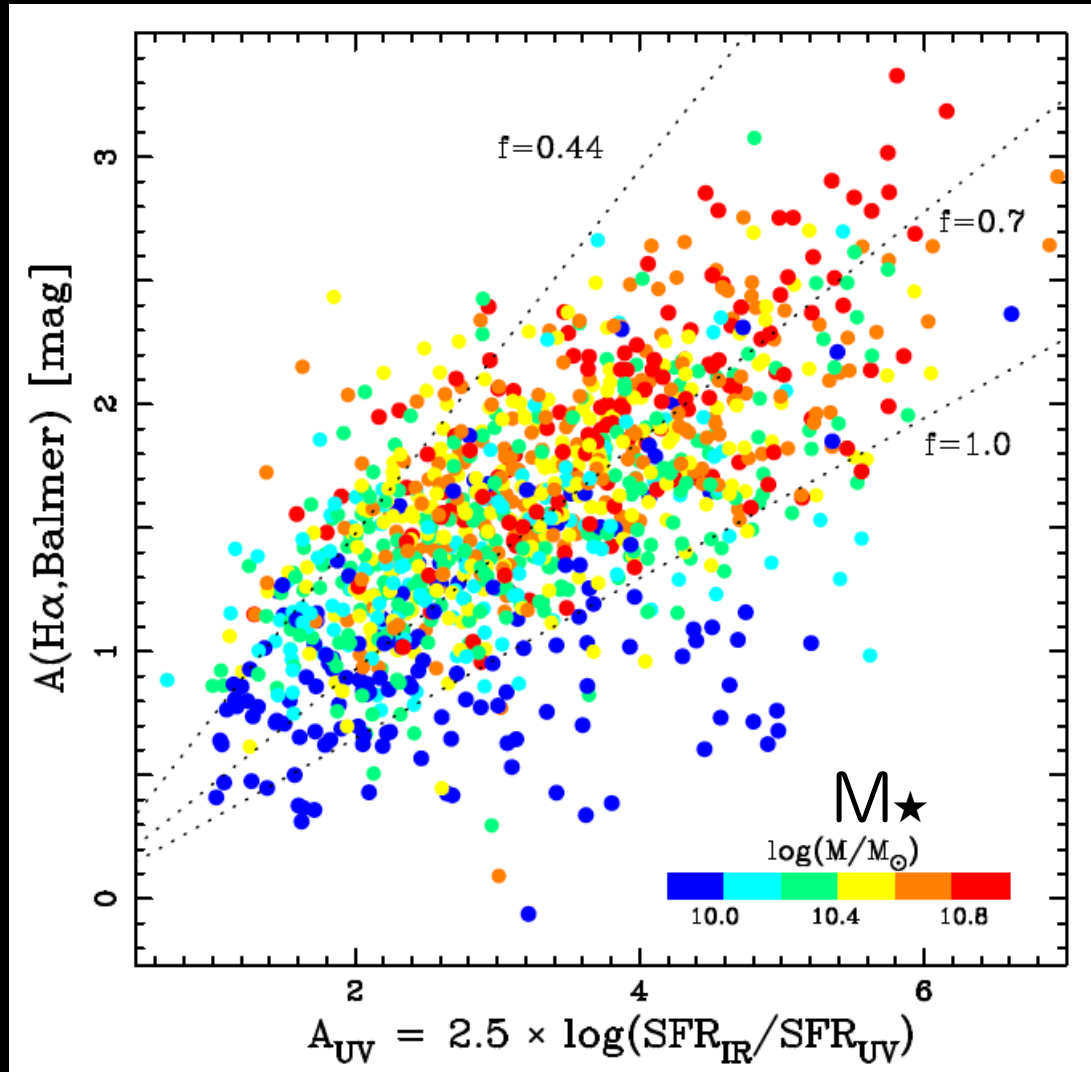
$A(\text{H}\alpha)$ on the $\text{SFR-M}_\star$ / $\text{EW-M}_\star$ diagram



There is a clear trend that more massive galaxies tend to be dustier, but at the same time, it might be too simplistic to determine dust extinction from stellar mass alone...

Extra extinction towards nebular regions

Extinction for nebular region



$$E_{\text{star}}(\text{B-V}) = f \times E_{\text{gas}}(\text{B-V})$$

More massive galaxies tend to have higher extinction towards nebular region (i.e. smaller “ f ” value).

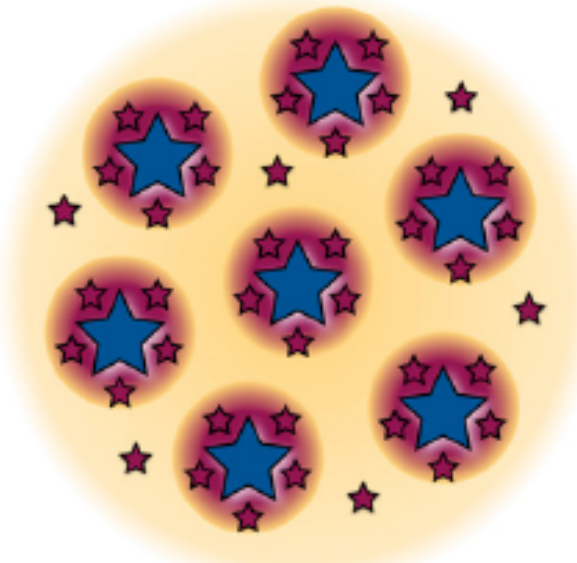
Extinction for continuum

Extra extinction towards nebular regions

Extinction for nebular region



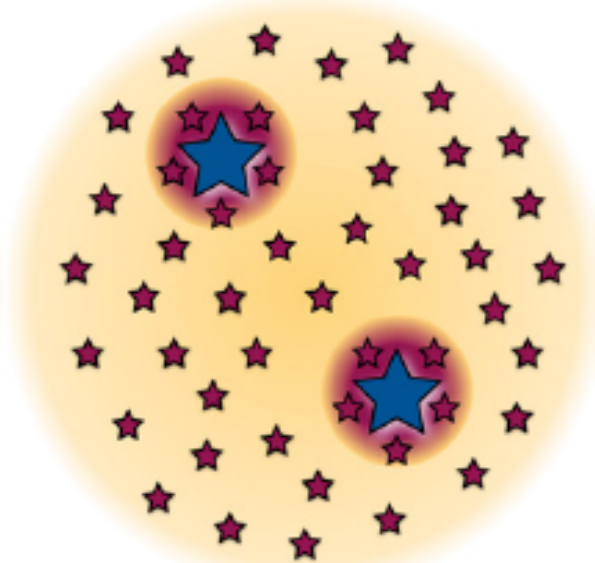
$f \sim 1$ の状況



$$A_{v, \text{stars}} \approx A_{v, \text{HII}}$$

低質量銀河に対応？

$f < 1$ の状況



$$A_{v, \text{stars}} < A_{v, \text{HII}}$$

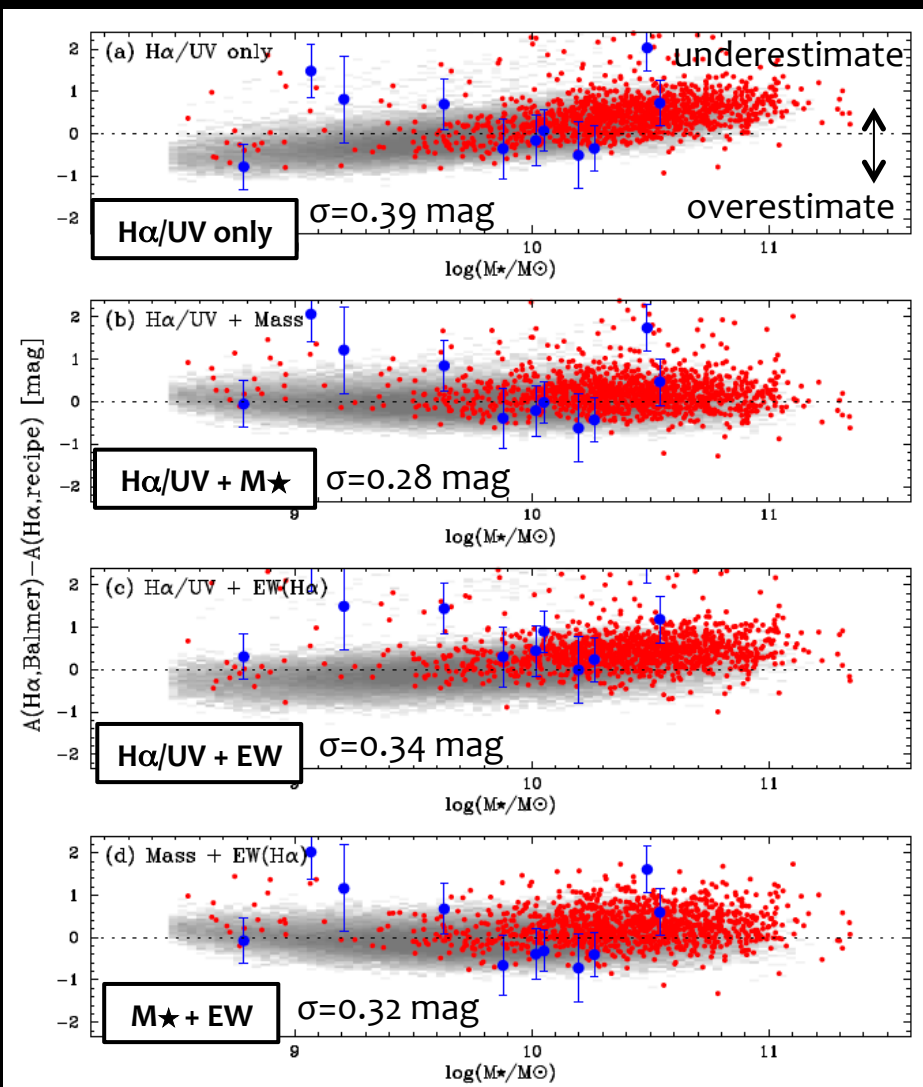
大質量銀河に対応？

(Illustrated by Price et al. 2014)

Extinction for continuum

Future prospects

(1) $H\alpha$ /UV レシピを遠方銀河で検証したい



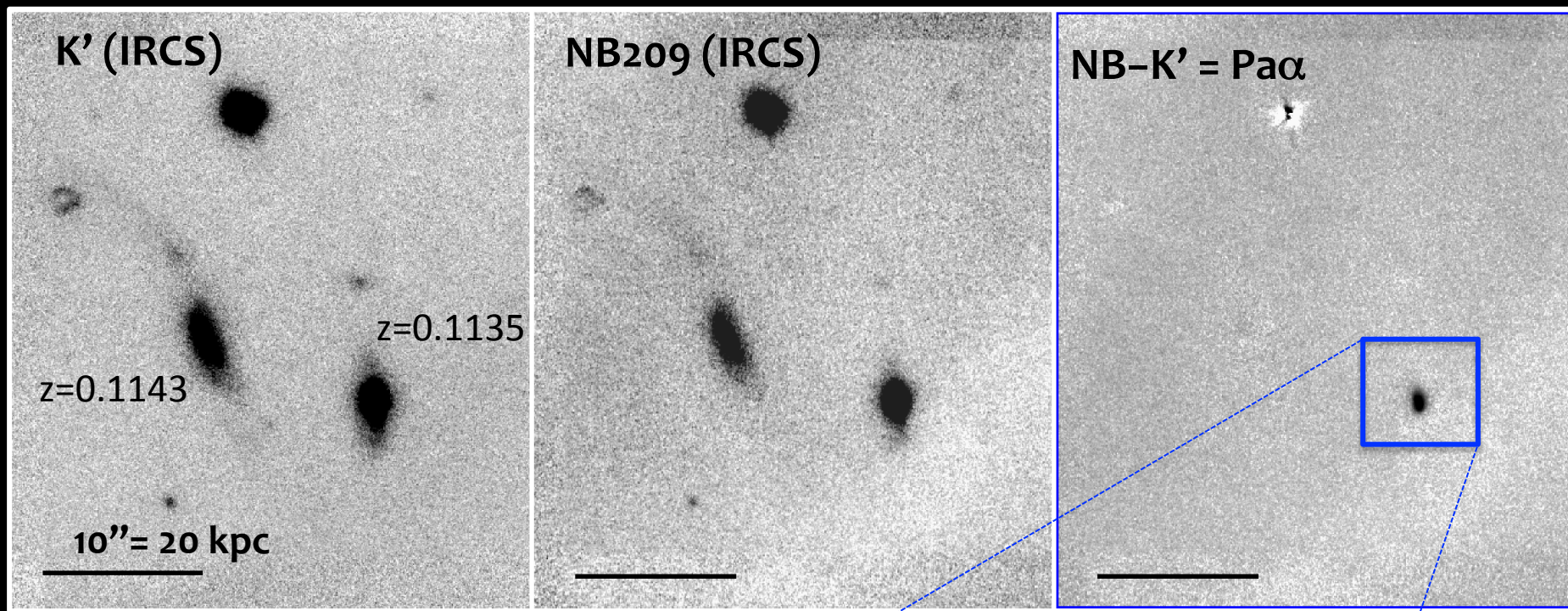
必要な情報は $H\alpha$, $H\beta$, UV。
PFS + u-band photometry
を利用して $z \sim 1$ の大サンプル
で検証可能(なはず)。

● AKARI FIR source

● high-z galaxies

(Keck/MOSFIRE spectroscopy by Shimakawa+15)

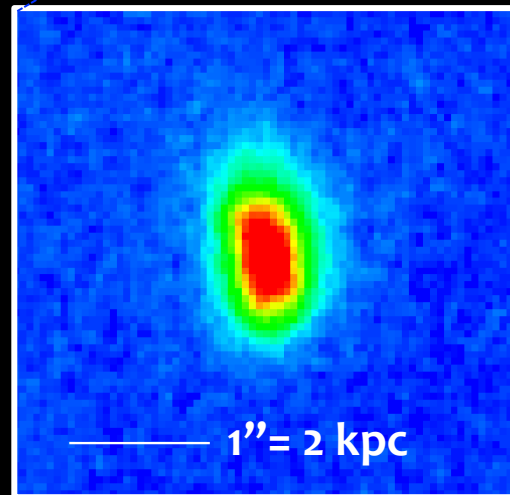
(2) 星形成&ダスト減光を空間分解したい



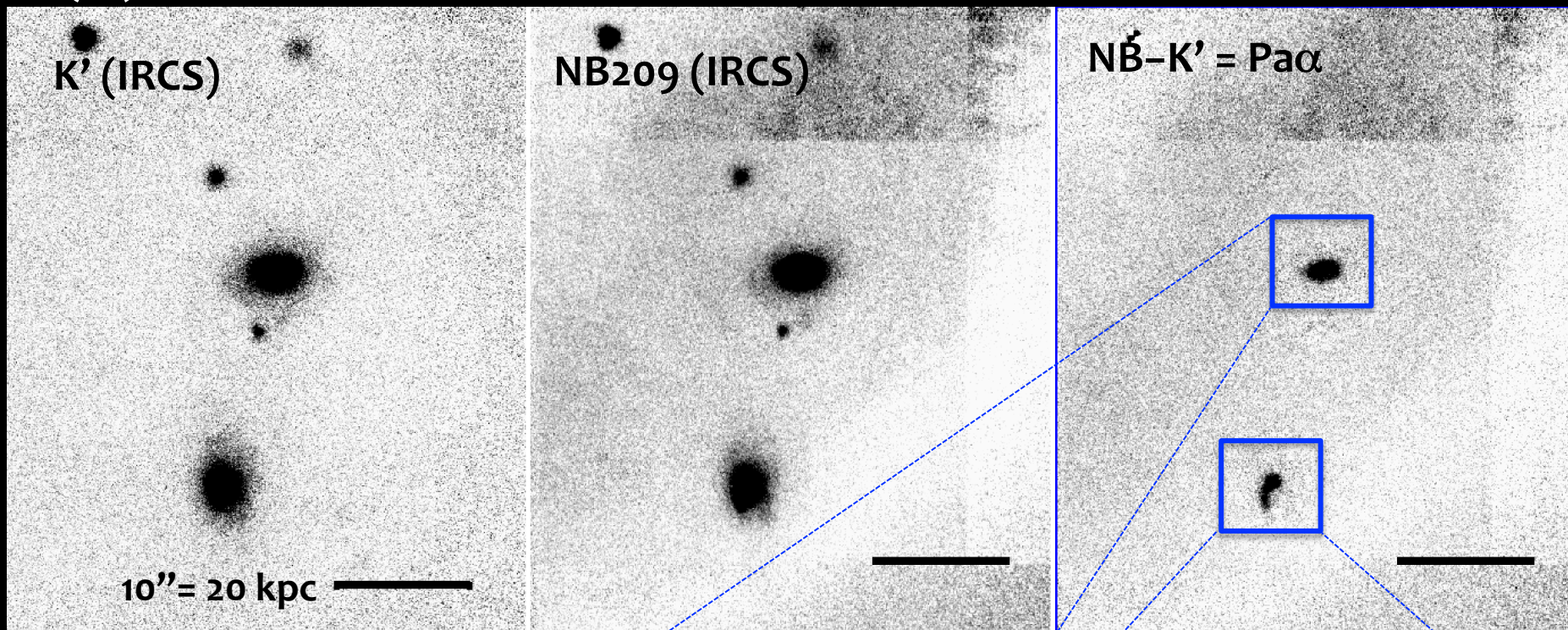
AKARI-FIS-1209390+432635 ($z=0.11$)

PARADISES-Subaru :

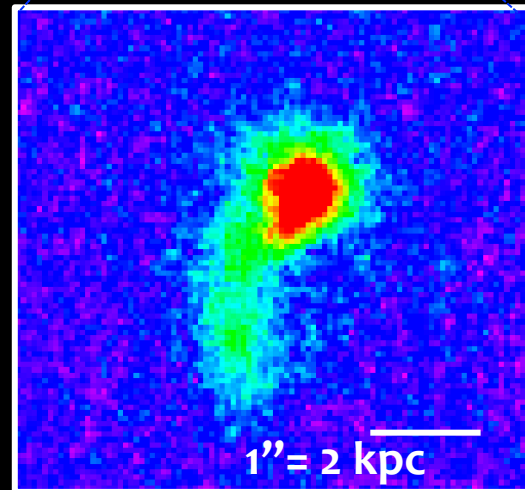
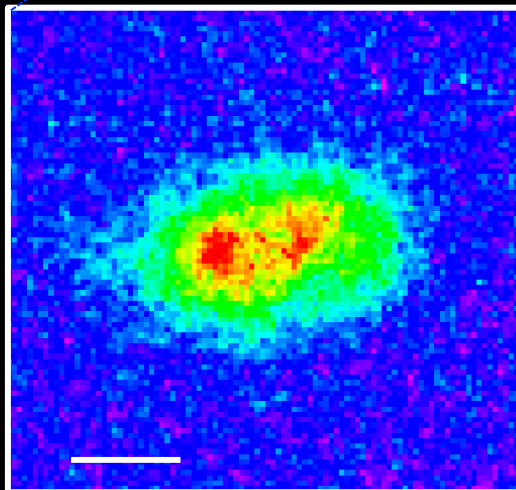
Pa-Alpha Resolved Activity and
Dynamics of Infrared Selected
Extreme Starbursts with
Subaru



(2) 星形成&ダスト減光を空間分解したい

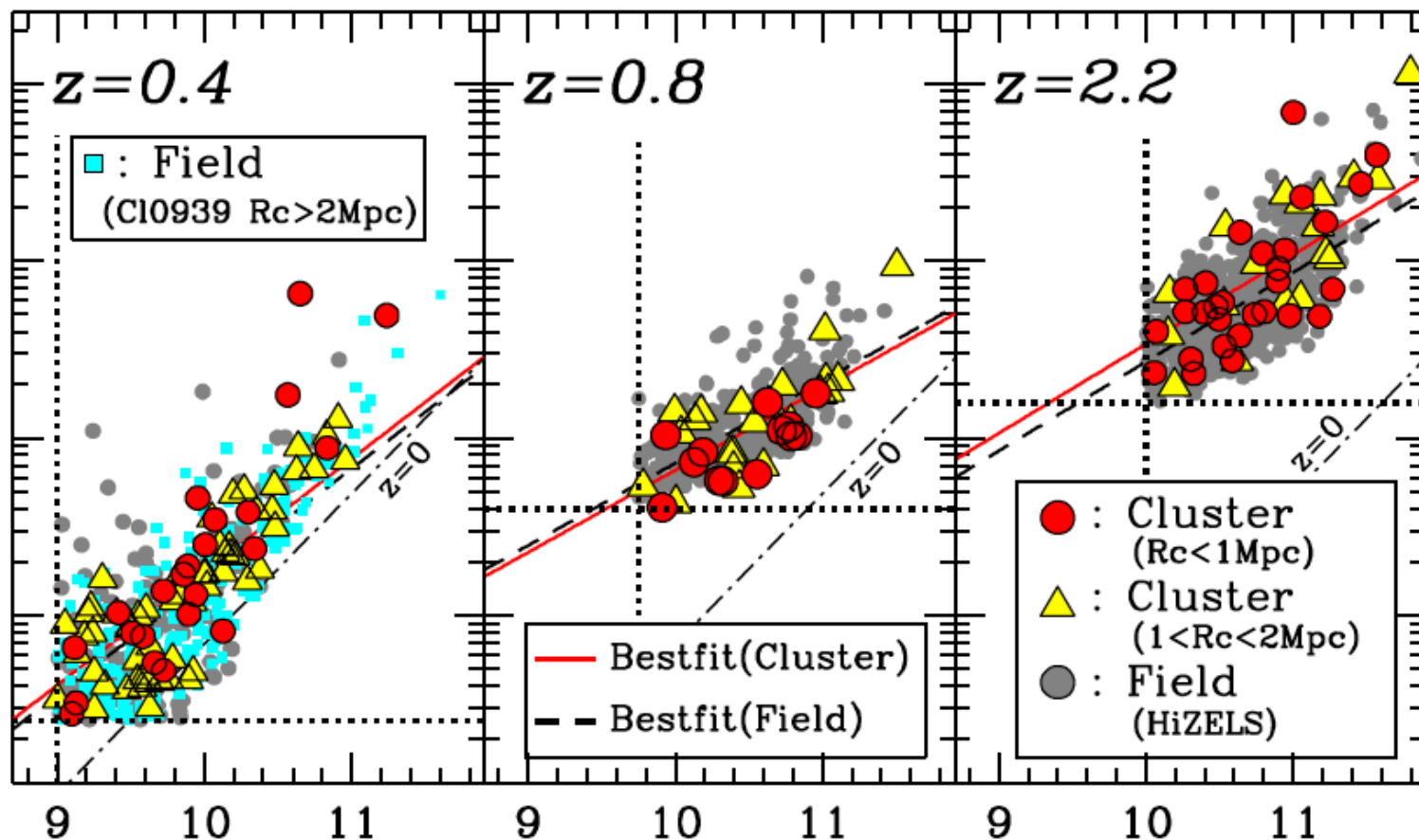


AKARI-FIS-1318102+041922
($z=0.11$)



(3) 環境効果と絡めた仕事につなげたい

The MS location is always independent of environment since $z \sim 2$



From $L(\text{H}\alpha)$ +
 $M_\star$ -dependent
dust correction

From rest-frame
R-band photometry
+ M/L correction

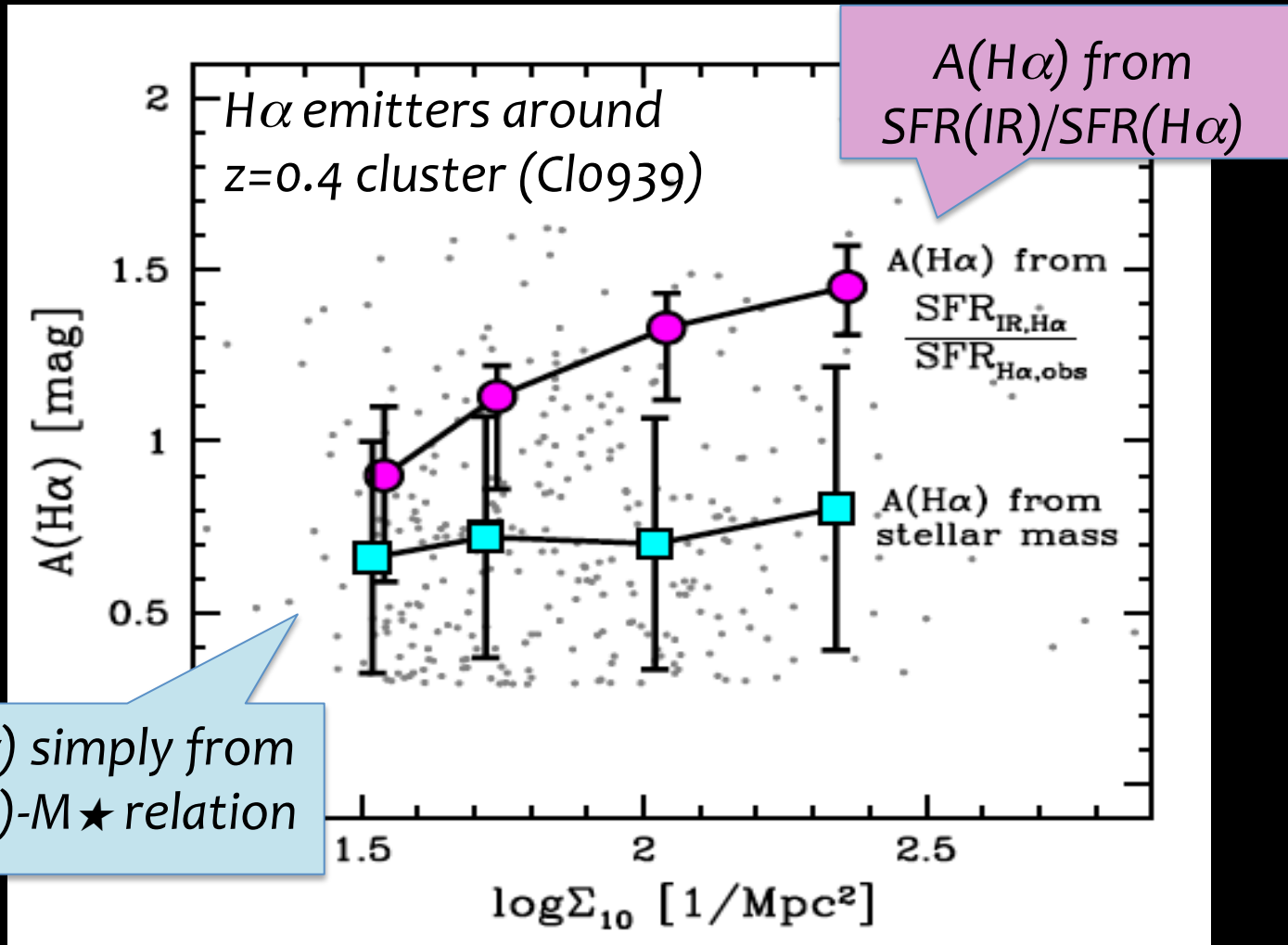
$\log(M^*/M_\odot)$

H α emitters with $\text{EW}_r > 30\text{\AA}$

(Koyama et al. 2013b, MNRAS, 434, 423)

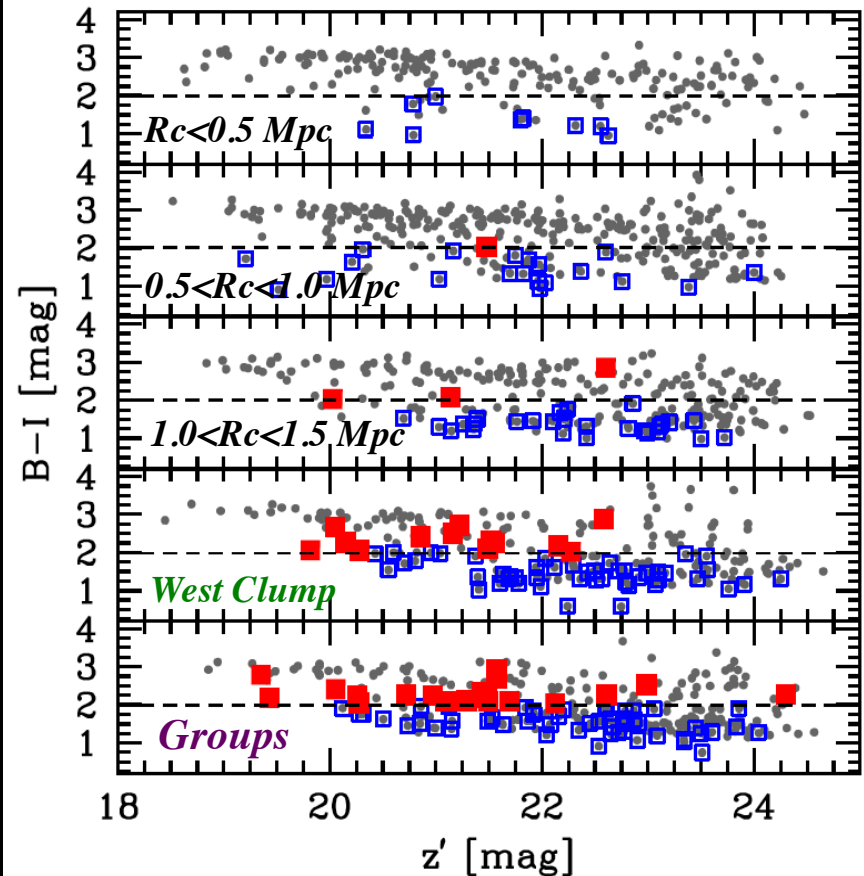
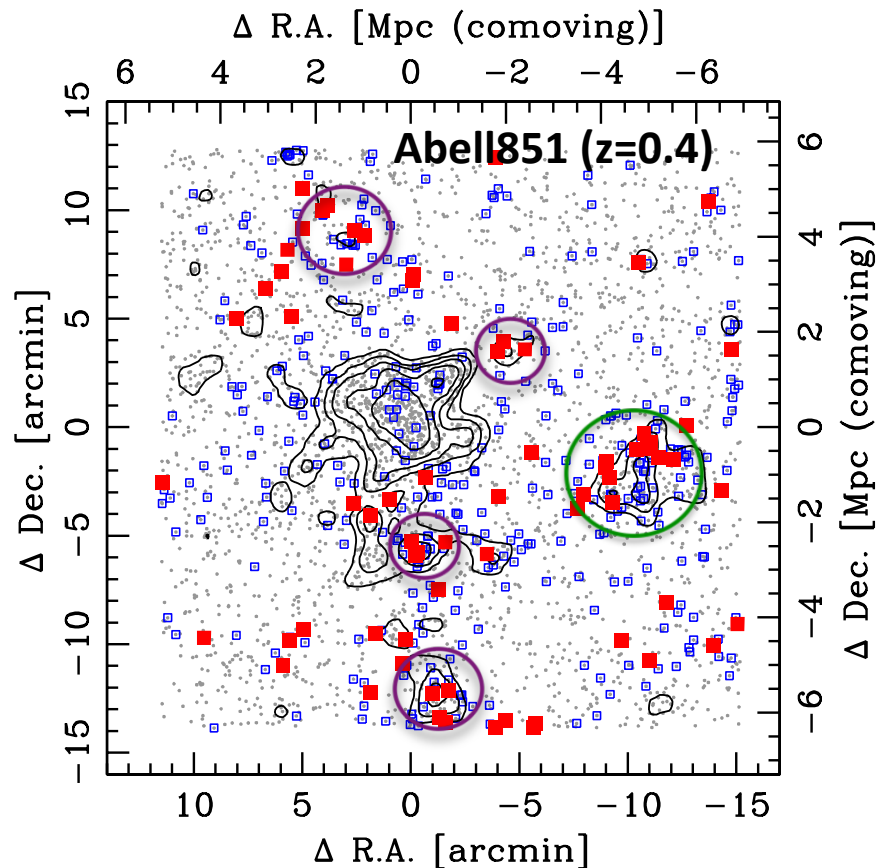
(3) 環境効果と絡めた仕事につなげたい

Higher dust extinction level for galaxies in high-density environment ?



Red SF galaxies in group environment

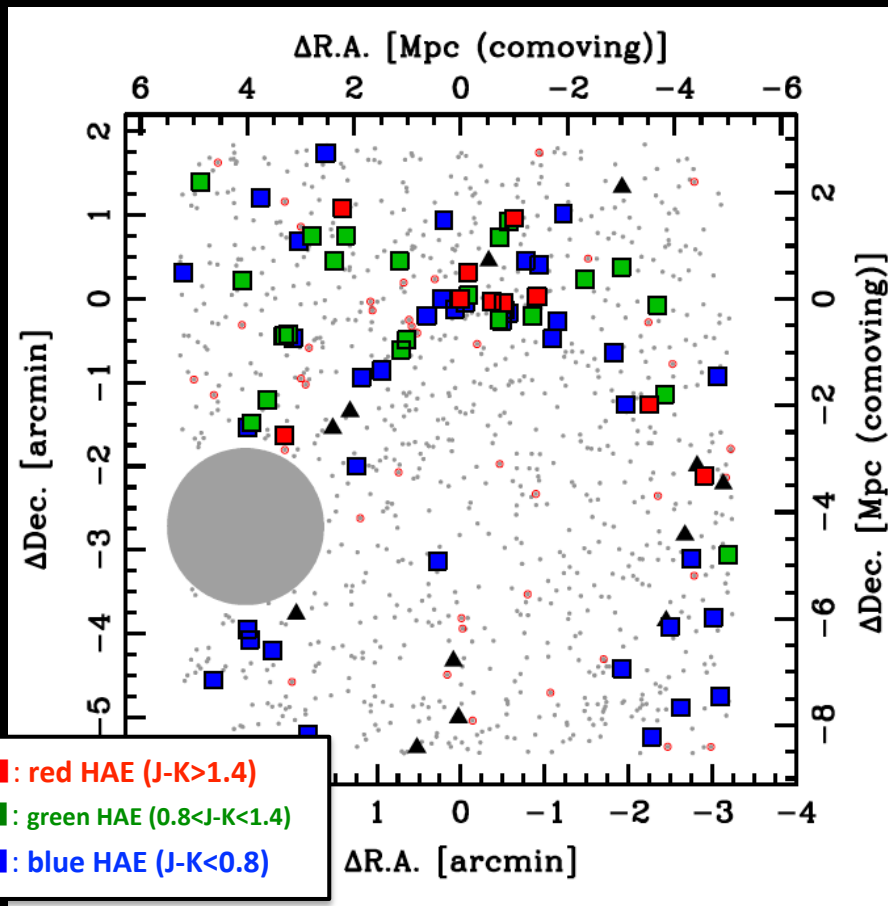
Red H α emitters strongly clustered in group-scale environments



■: red H α emitter ($B-I > 2$)
□: blue H α emitter ($B-I < 2$)

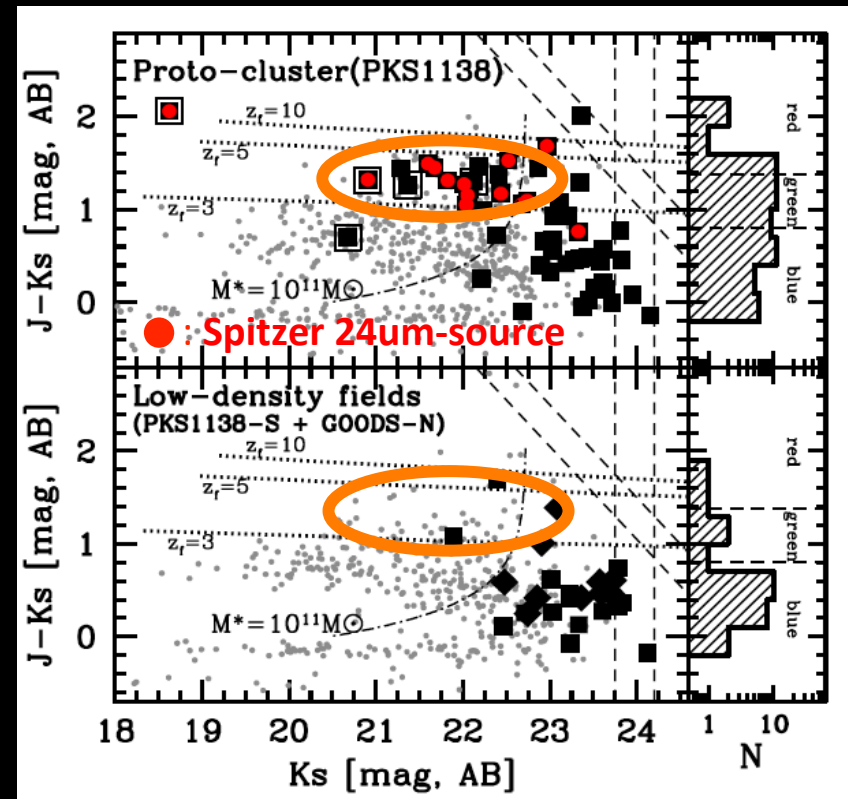
(Koyama et al. 2011)

Red SF galaxies in $z>2$ proto-cluster



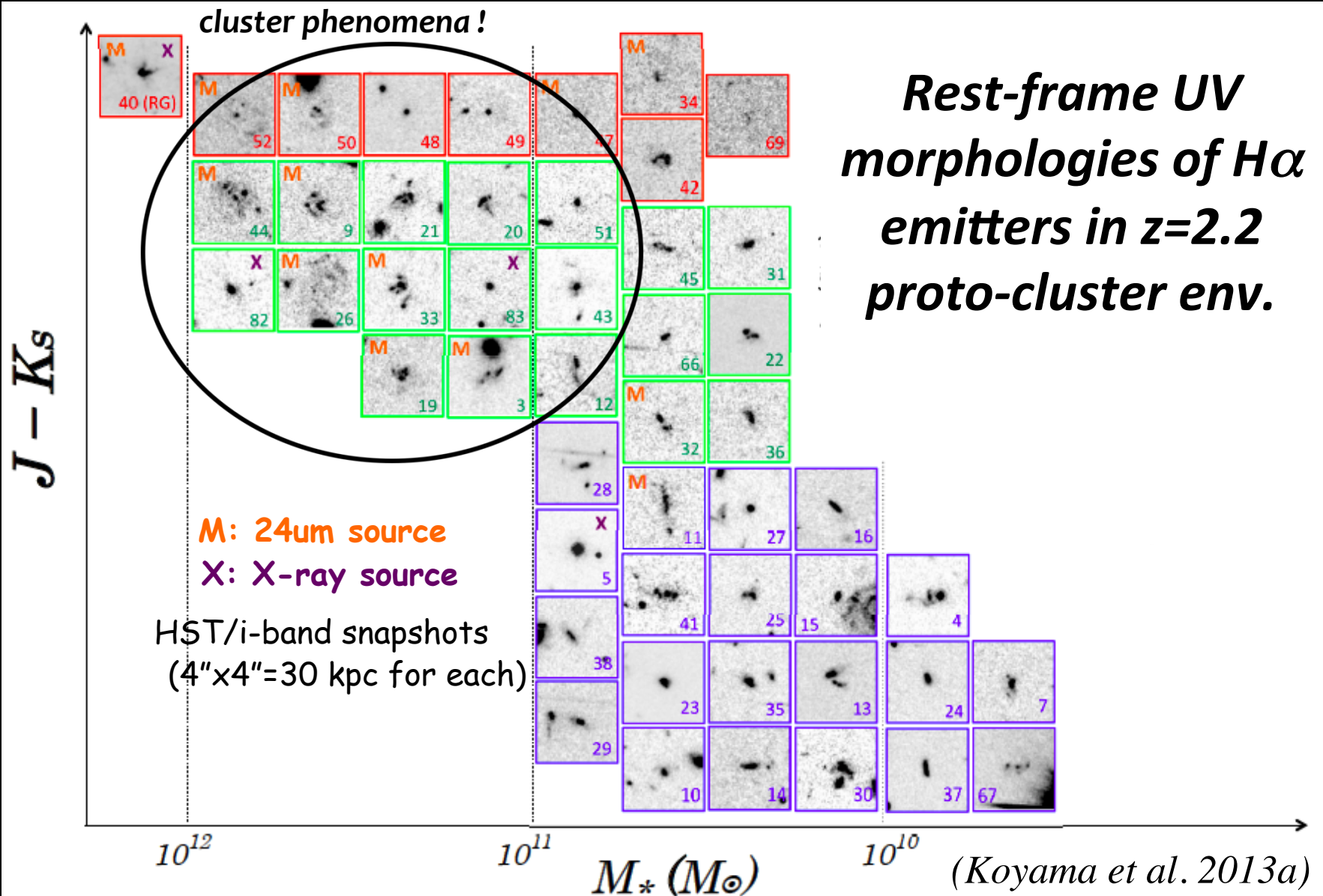
Red emitters are massive ($M_{\star} > 10^{11} M_{\odot}$), and clearly dominate dense environment at $z \sim 2$.

Our MOIRCS+NB(H α) survey revealed **red H α emitters** dominate the core of $z=2.16$ proto-cluster (PKS1138-262).

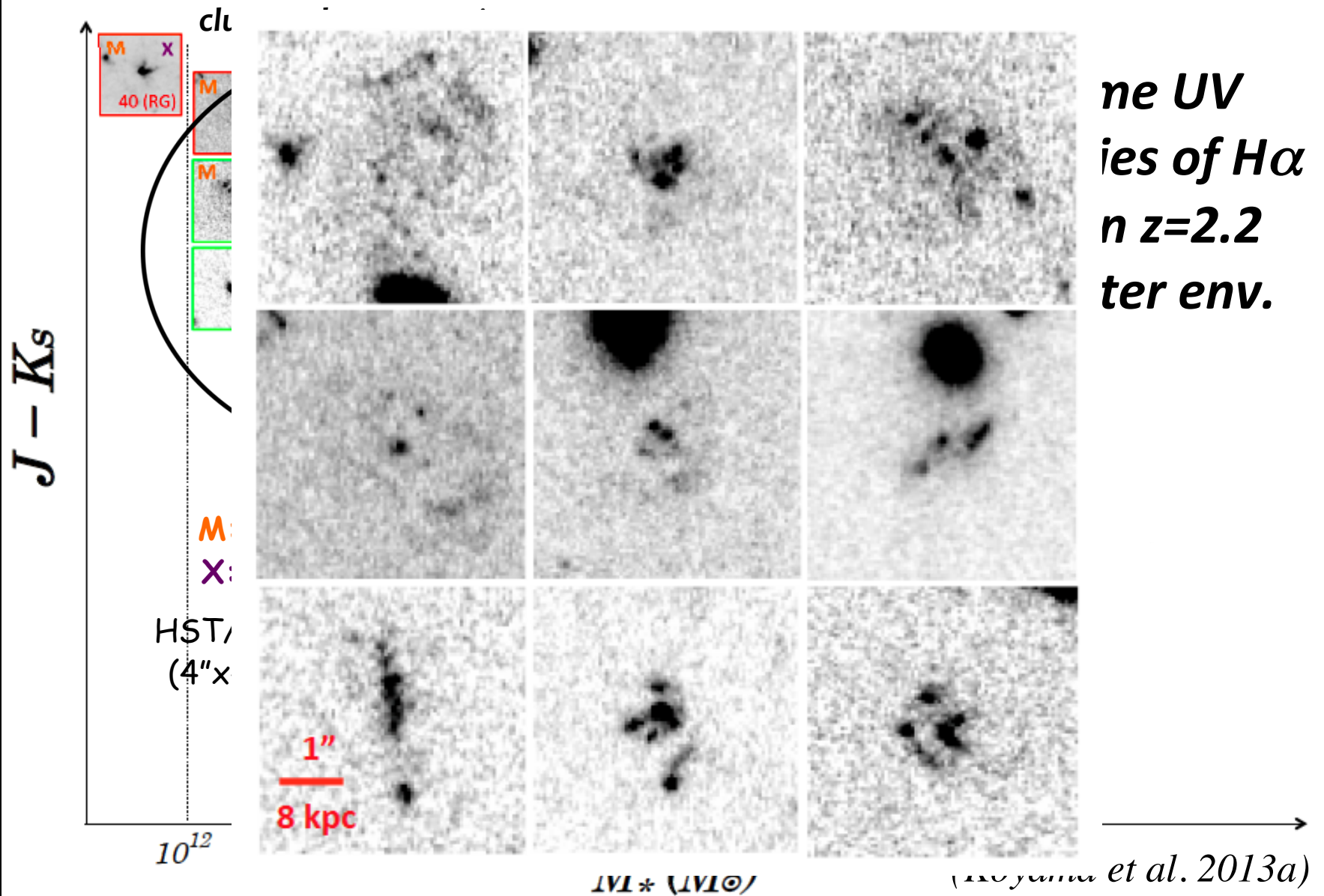


(Koyama et al. 2013a)

Clumpy galaxies in $z > 2$ proto-clusters



Clumpy galaxies in $z > 2$ proto-clusters



Summary

Q: Can we predict dust extinction properties of star-forming galaxies from $H\alpha$ /UV ratio ?

A: Yes – but we provide more realistic dust extinction estimates by adding $M_\star$ and/or $EW(H\alpha)$ information.