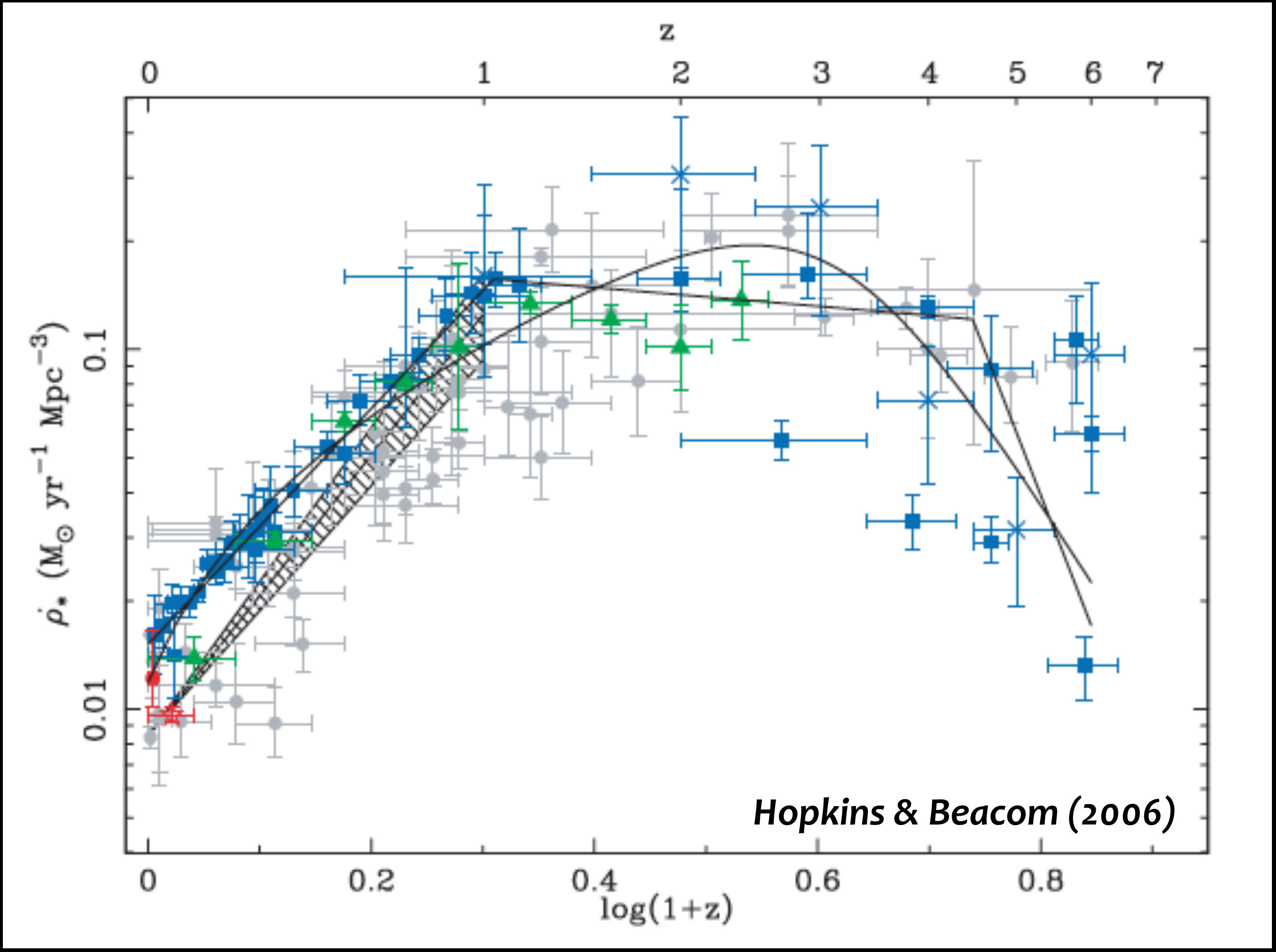
PFS-SSP galaxy survey WS (2015/11/13 @ IPMU)

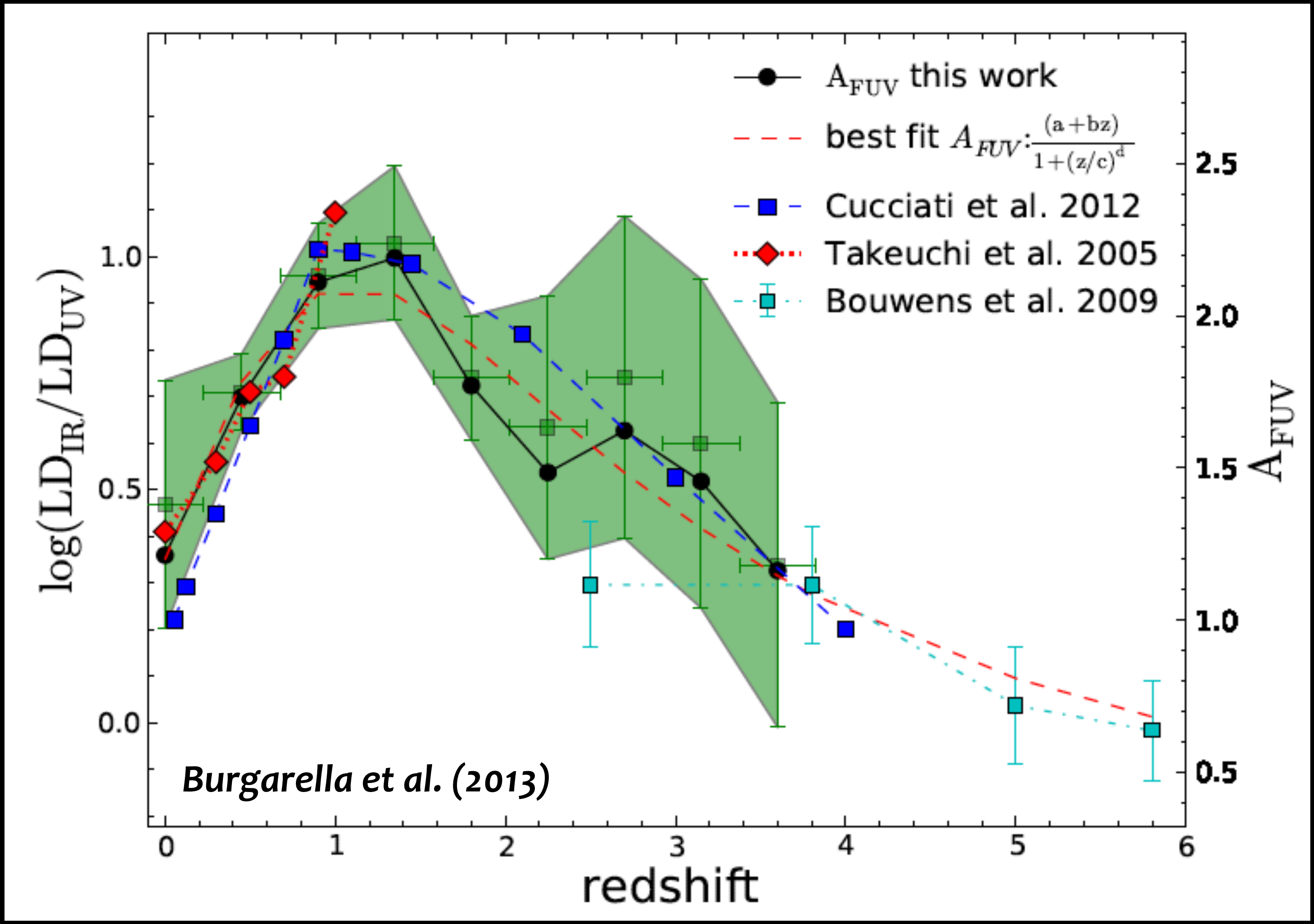
A systematic study of the geometry of stars and dust within distant SF galaxies with PFS

Yusei Koyama (Subaru Telescope)

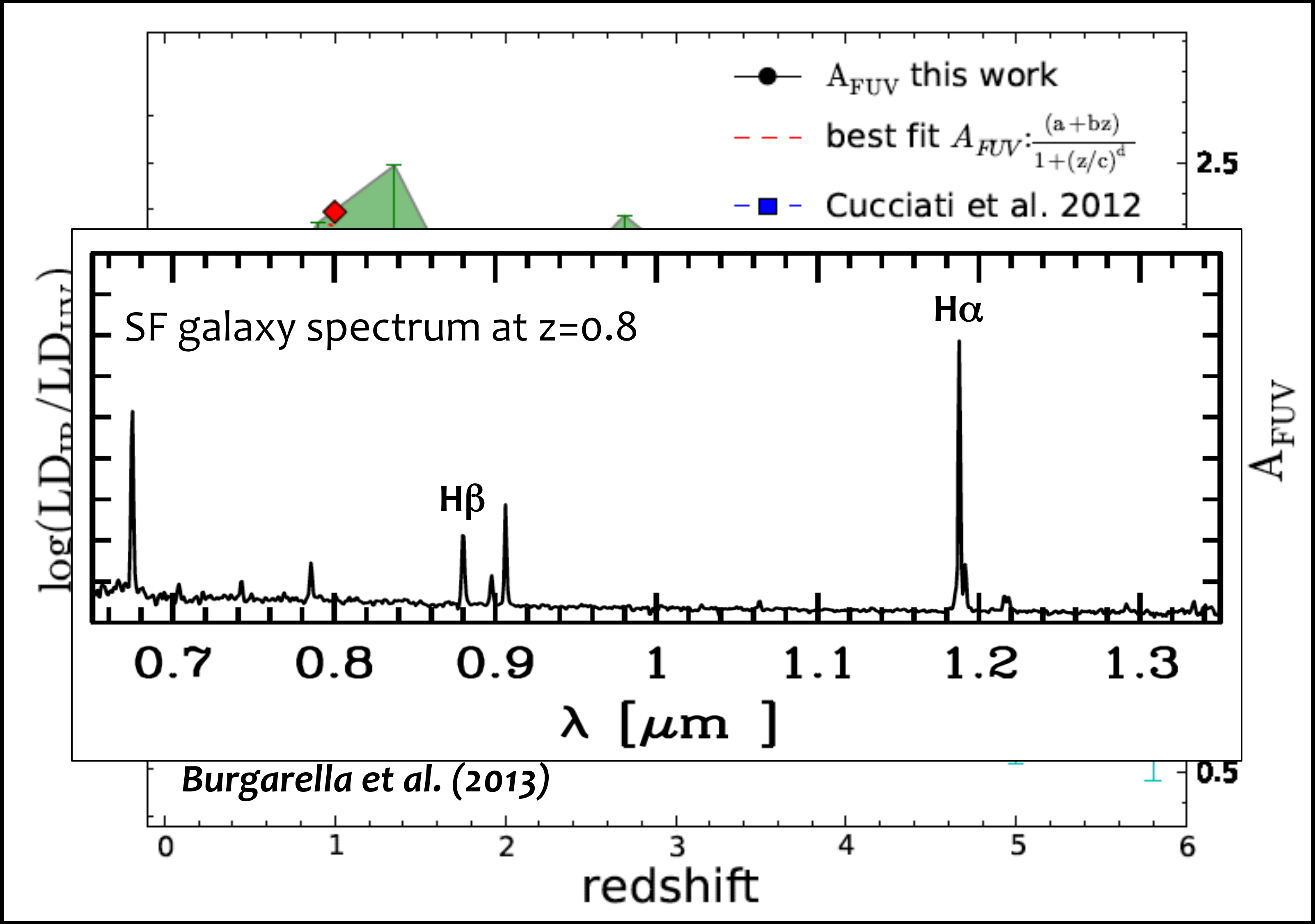
Cosmic SF activity peaks at z~1-3



Dust extinction peaks at z~1



Dust extinction peaks at z~1



Burgarella et al. (2013)

Outline

(1) Our understanding in the local universe with SDSS-GALEX-AKARI matched galaxy sample

(Koyama et al. 2015, MNRAS, 453, 879)

- Hα-UV-dust empirical correlation for z=0 SF galaxies
- $A_{V,gas}$ / $A_{V,star}$ as indicator of "dust geometry"

(2) How can we extend towards high-z with PFS?

(3) From PFS to "ULTIMATE-Subaru"

Starting point …

Balmer decrement
($H\alpha/H\beta$ ratio)

Becoming easier

$L_{H\alpha,obs} \propto SFR \times 10^{(-0.4 \mathbf{A_{H\alpha}})}$

Very hard
(too weak)

Hα

Hβ

hard
(confusion)

FIR

This study

UV

Usually easy
(opt. photometry)

$L_{UV,obs} \propto SFR \times 10^{(-0.4 \mathbf{A_{UV}})}$

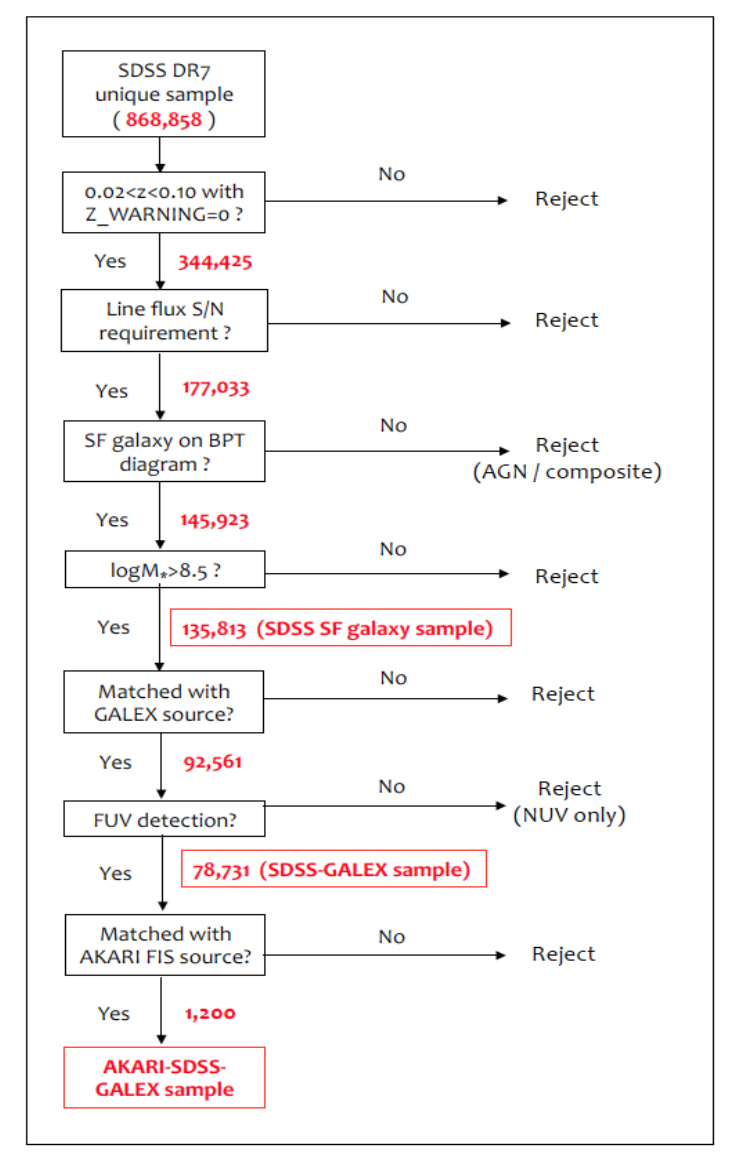
Problems so far

Detecting Hα for high-z galaxies is becoming easier, but Hβ is usually too faint even for 8-m class telescope, making it hard to estimate Hα dust extinction.

This work

Establish an empirical calibration for A(Hα) from Hα/UV ratio using nearby galaxies sample

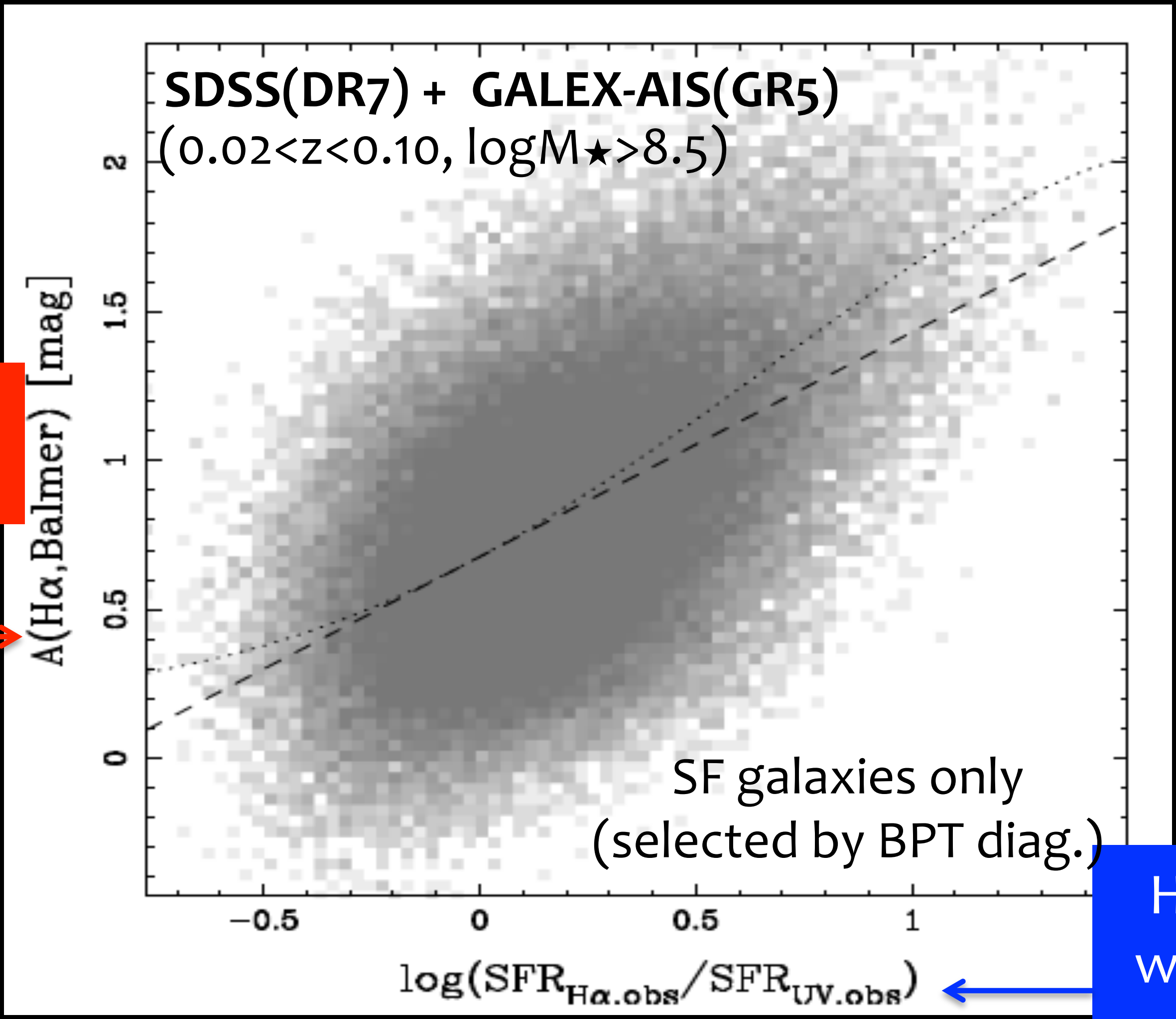
SDSS-GALEX-AKARI sample



- Starting from SDSS DR7, MPA/JHU catalogue, matched with GALEX All-sky catalogue (GR5).
- Redshift range of $0.02<z<0.10$.
- Requiring emission line detection of Hα, Hβ, [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(Hα) vs. "*observed*" Hα/UV ratio

Positive correlation (as expected), but with a substantial scatter.

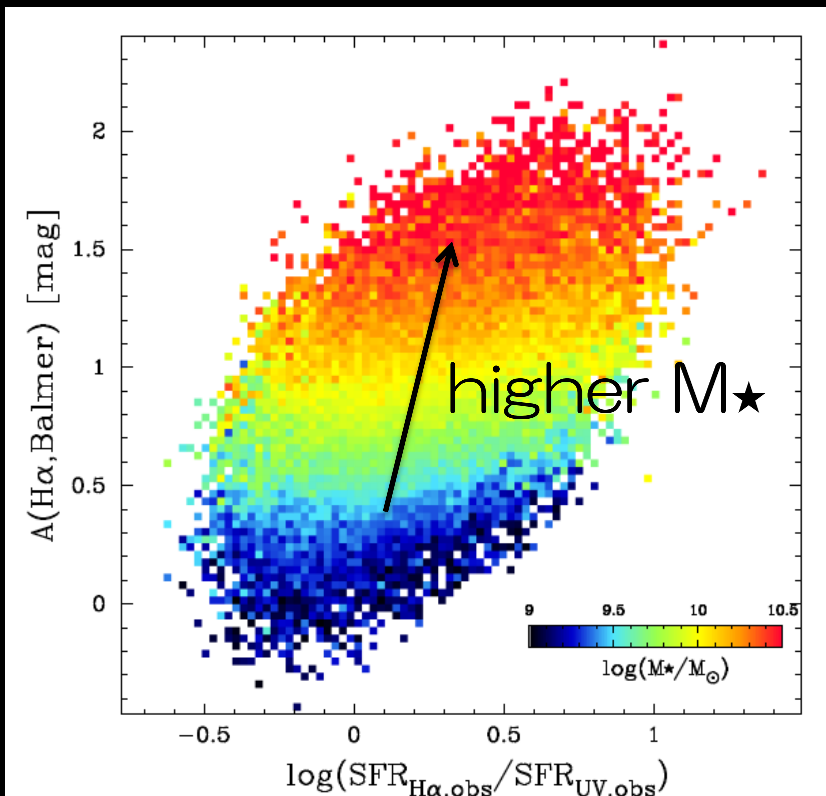


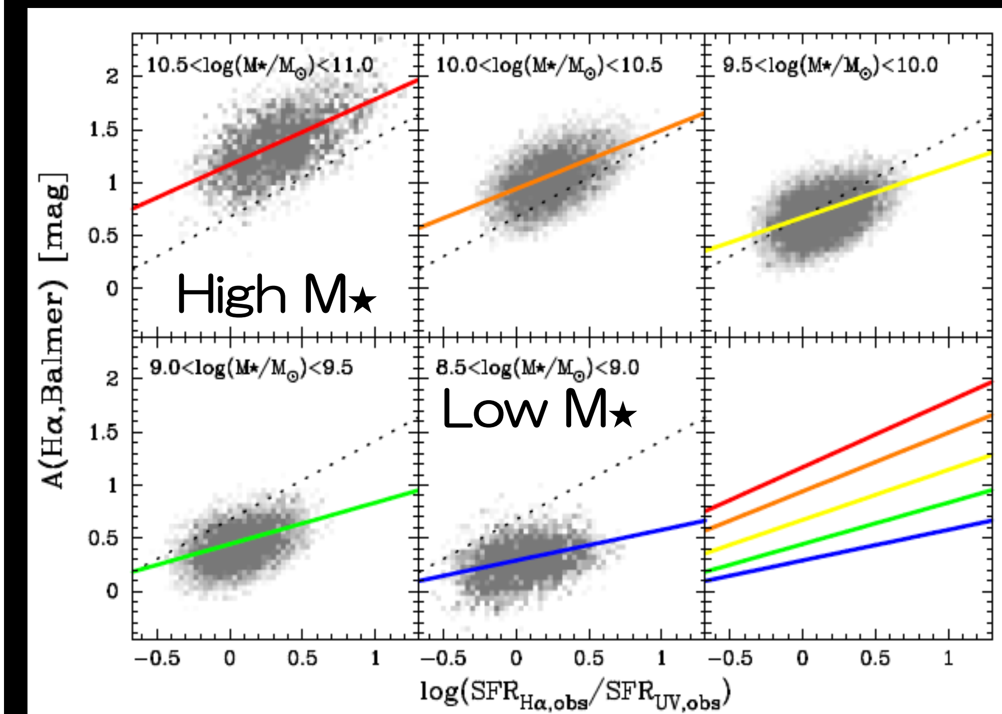
A(Hα) from Hα/Hβ ratio

Hα/UV ratio without dust correction

Stellar mass dependence

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





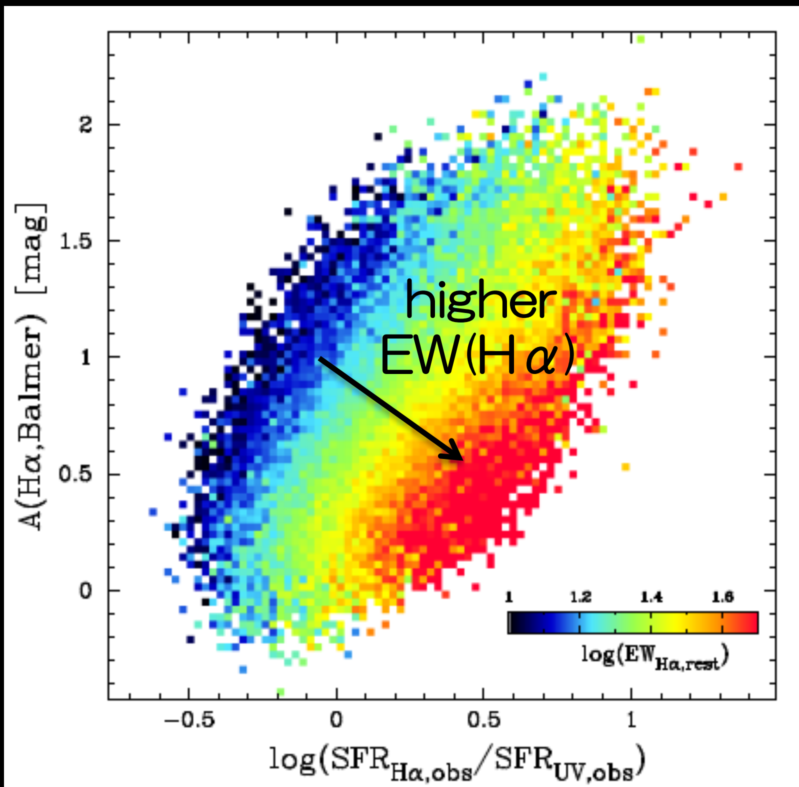
$$A_{\mathrm{H}\alpha} = a(\log M_\star) \times \log(\mathrm{H}\alpha/\mathrm{UV}) + b(\log M_\star),$$

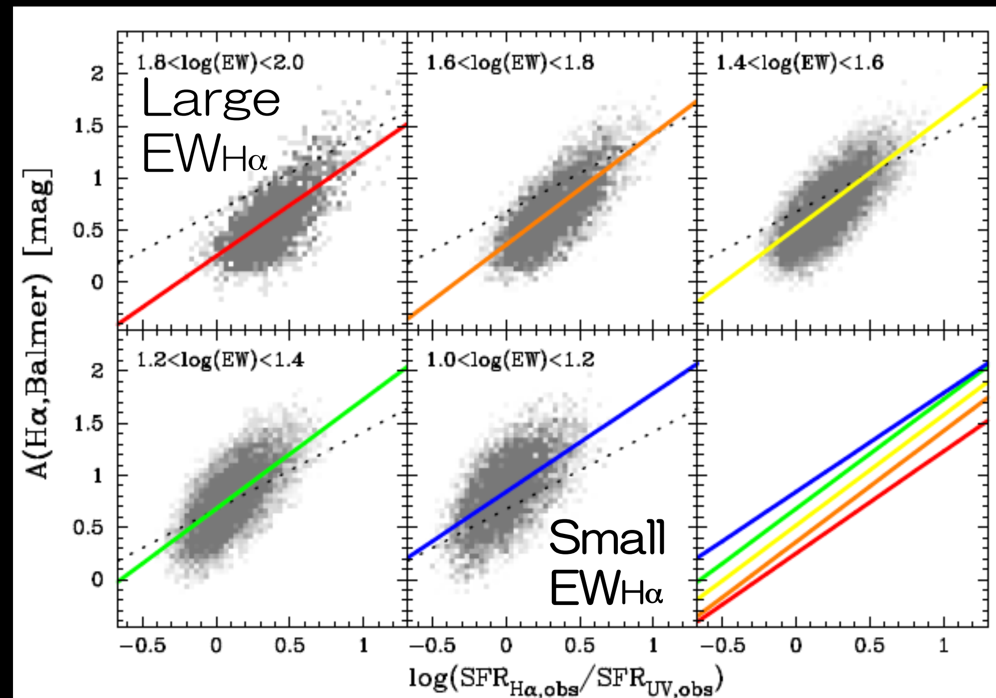
$$a(\log M_\star) = 0.210 \times \log M_\star - 1.597,$$
$$b(\log M_\star) = 0.493 \times \log M_\star - 4.121.$$

This equation provides an empirical calibration to predict dust extinction level from Hα/UV + M★.

Dependence on EW(Hα)

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





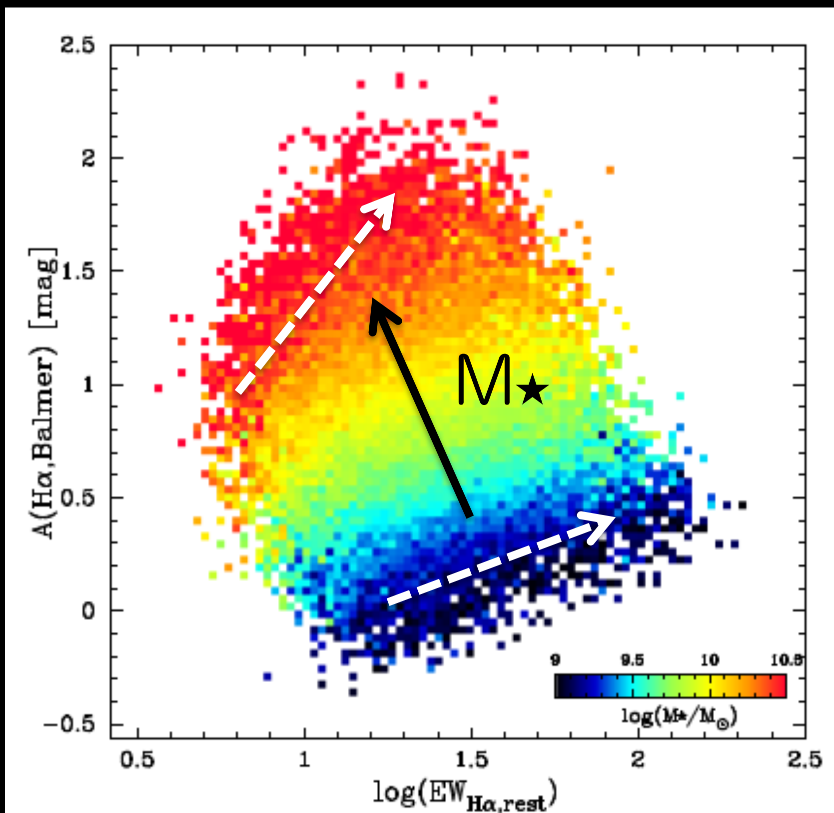
$$A_{\mathrm{H}\alpha} = a(\log \mathrm{EW}_{\mathrm{H}\alpha}) \times \log(\mathrm{H}\alpha/\mathrm{UV}) + b(\log \mathrm{EW}_{\mathrm{H}\alpha}),$$

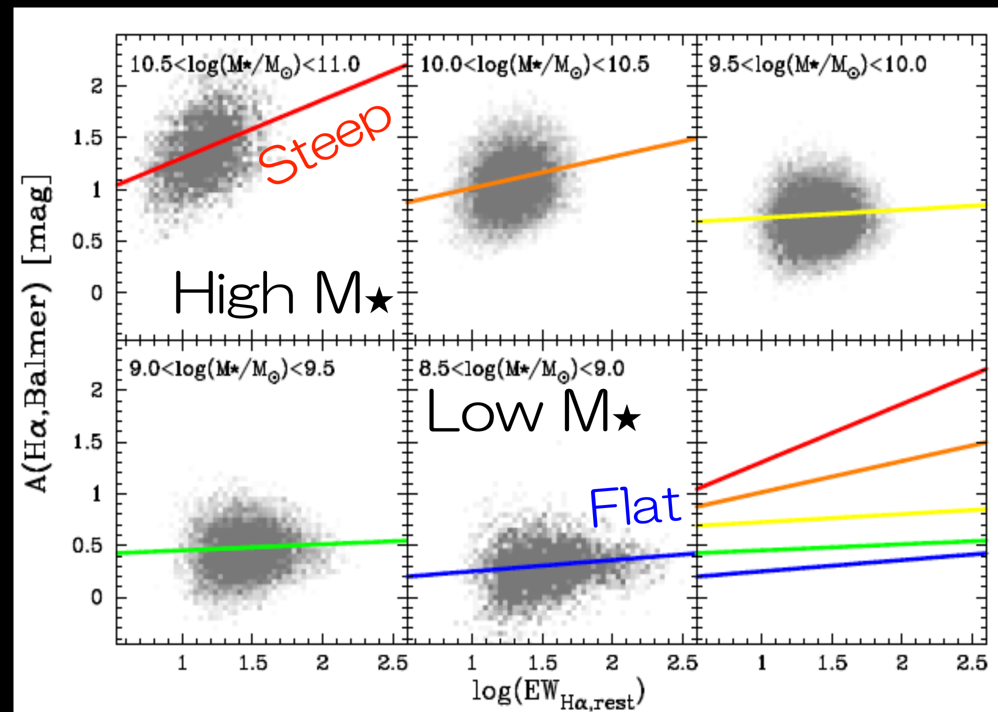
$$a(\log \mathrm{EW}_{\mathrm{H}\alpha}) = 0.101 \times \log \mathrm{EW}_{\mathrm{H}\alpha} + 0.872,$$
$$b(\log \mathrm{EW}_{\mathrm{H}\alpha}) = -0.776 \times \log \mathrm{EW}_{\mathrm{H}\alpha} + 1.688.$$

We can use EW(Hα) instead of M★, allowing us to predict A(Hα) only with Hα + UV measurements.

A(Hα) vs. EW(Hα) relation

A(Hα) vs EW(Hα) relation is strongly dependent on stellar mass.





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

$$a(\log M_\star) = 0.096 \times \log M_\star - 0.717,$$
$$b(\log M_\star) = 0.538 \times \log M_\star - 4.745.$$

Another empirical calibration of A(Hα) using M★ and EW(Hα). In this case we do not need rest-UV information.

A(Hα) vs. EW(Hα) relation

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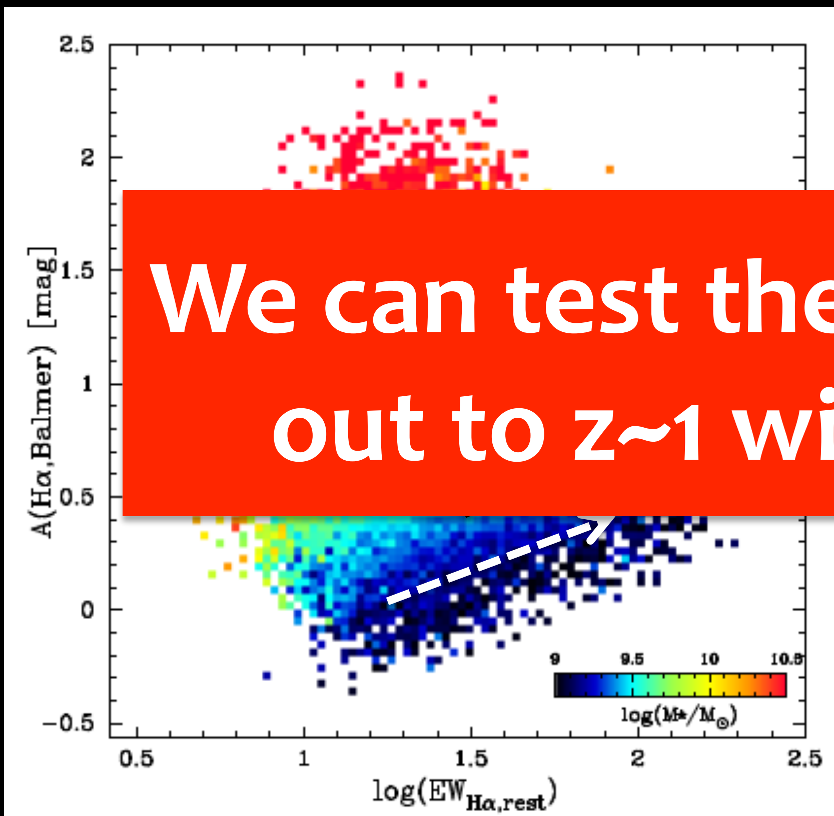

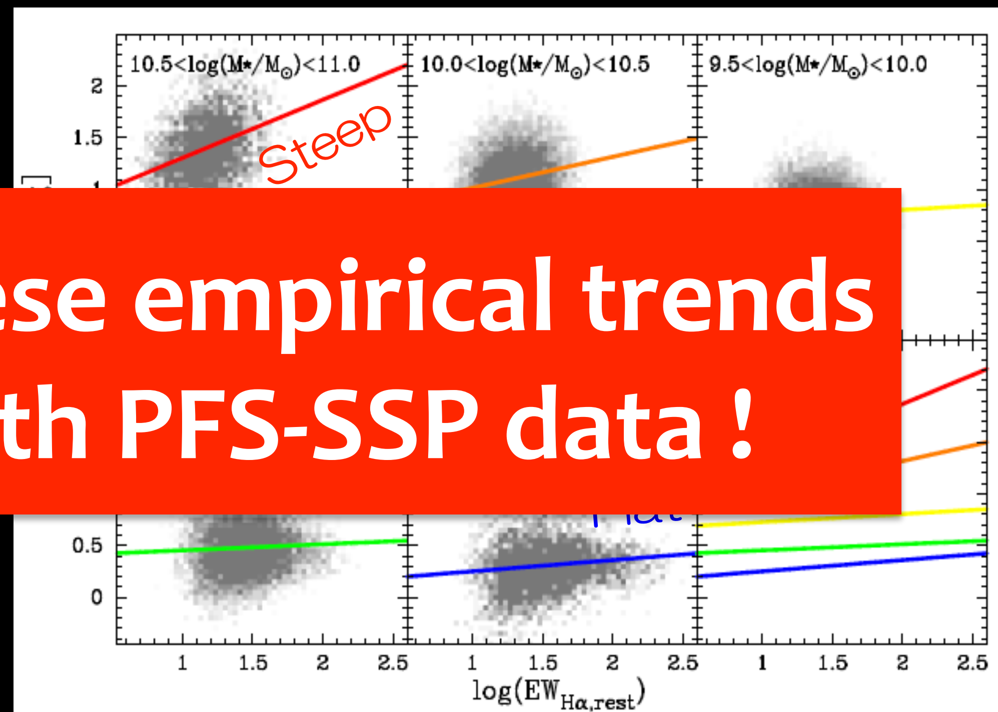

We can test these empirical trends out to z~1 with PFS-SSP data !

Another empirical calibration of A(Hα) using M★ and EW(Hα). In this case we do not need rest-UV information.

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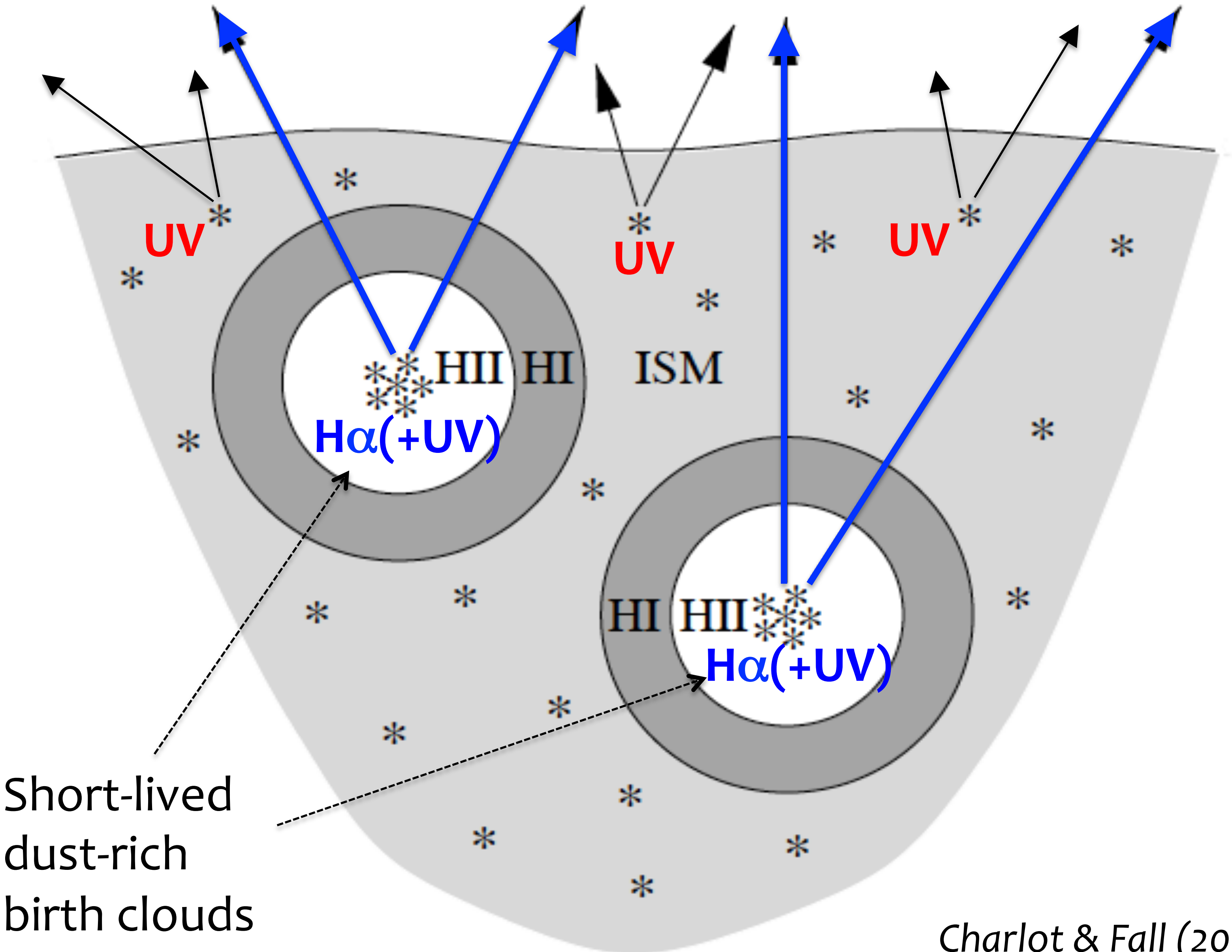
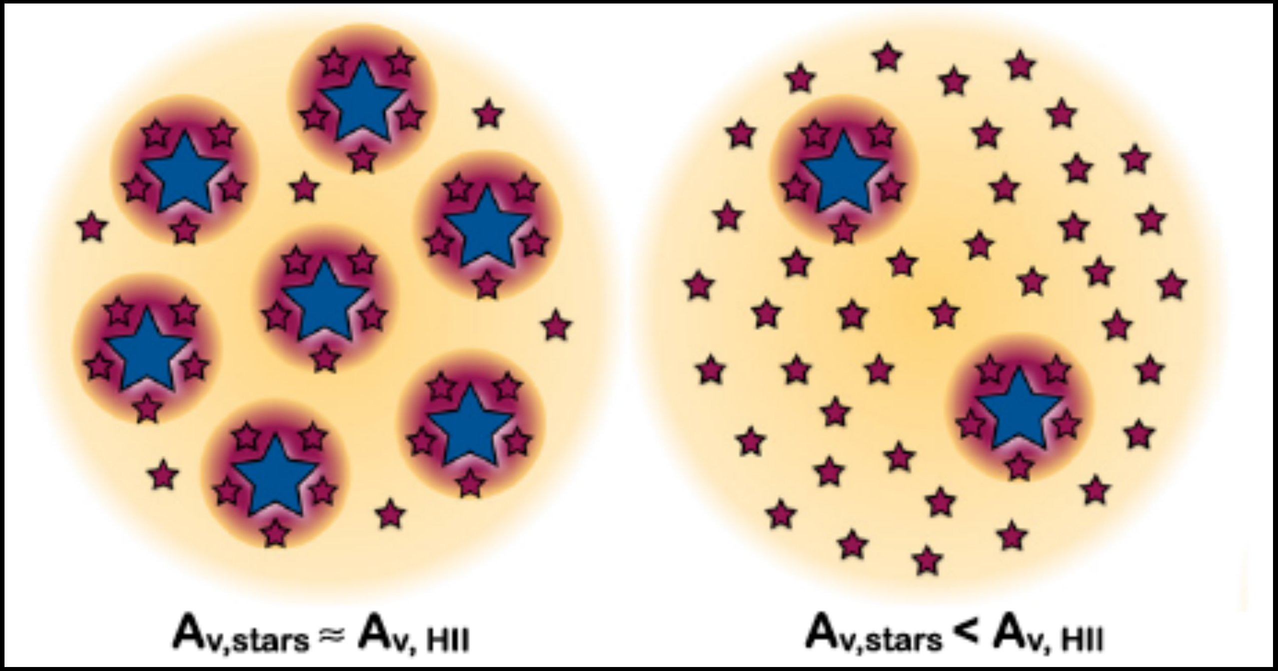
Physical interpretation?



Charlot & Fall (2000)

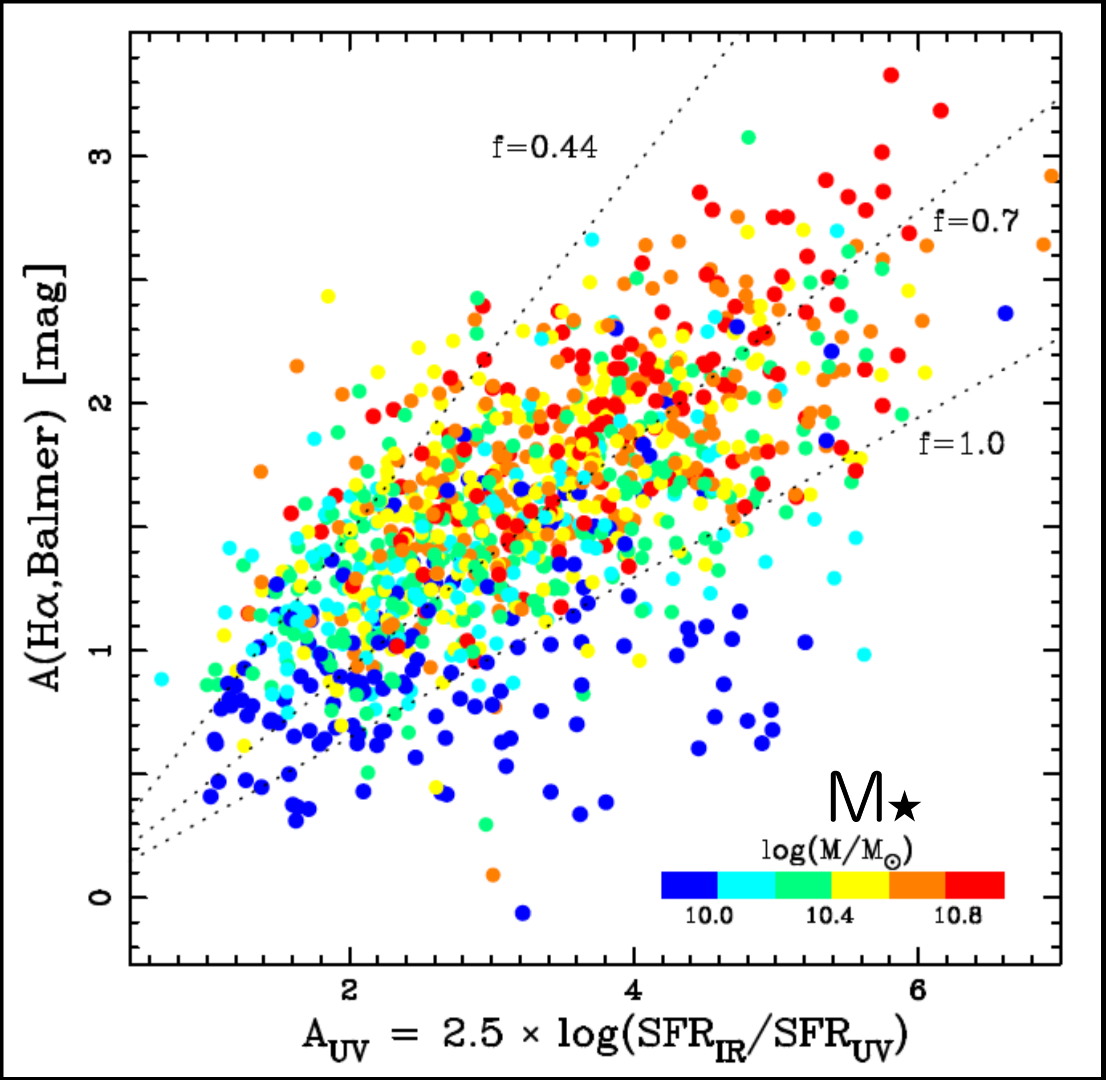
- Hα/Hβ ratio (Balmer decrement) :
  - dust extinction for nebular regions ($A_{V,\,HII}$).
- IR/UV ratio (IRX) :
  - dust extinction for averaged stellar light ($A_{V,\,star}$)
- By comparing $A_{V,HII}$ and $A_{V,star}$, we can understand star/dust geometry (without spatially resolving the data).



Price et al. (2014)

Av, gas vs. Av, star for z~0 galaxies

Extinction for nebular region

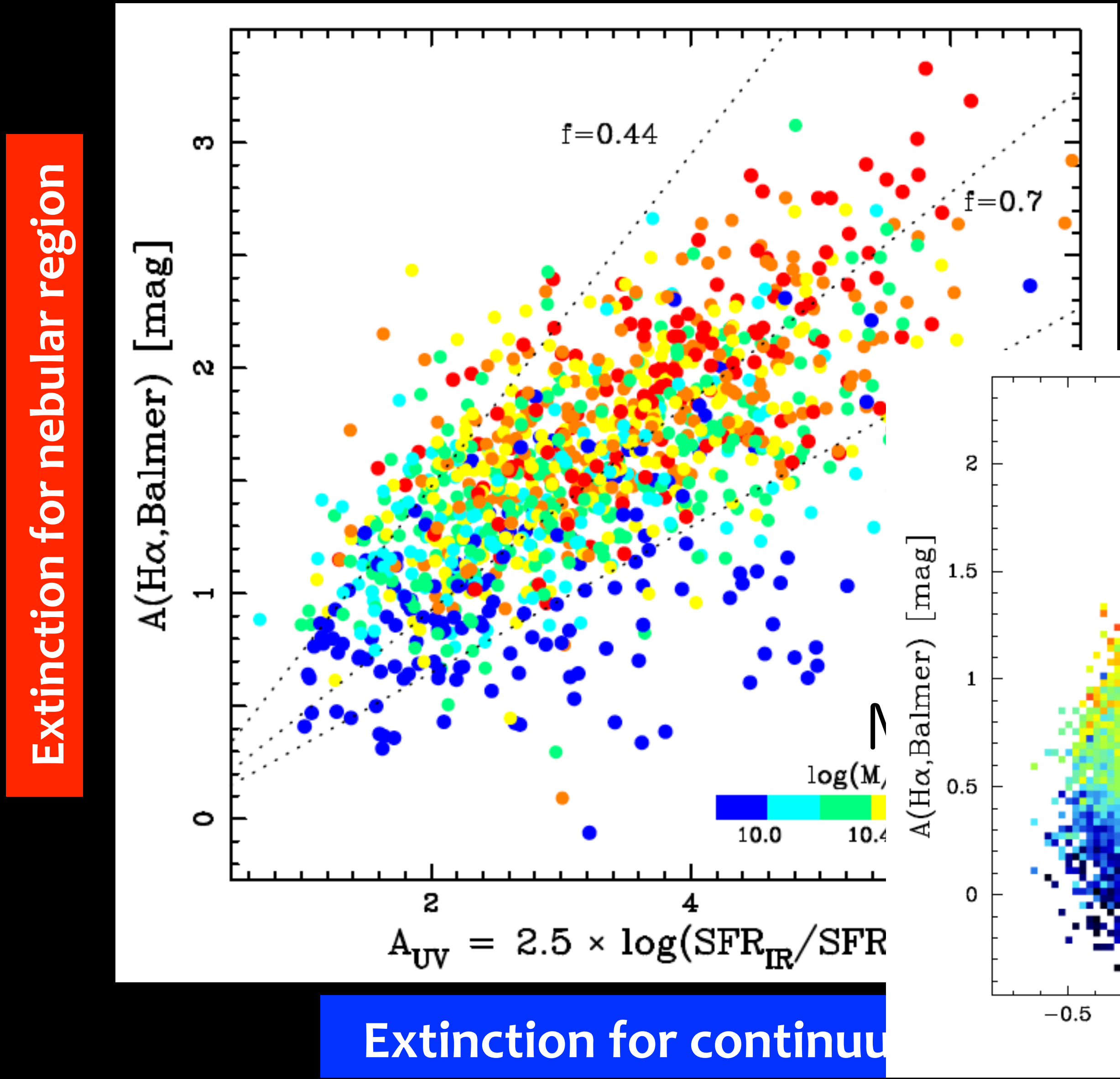


Extinction for continuum

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

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

Av, gas vs. Av, star for z~0 galaxies



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

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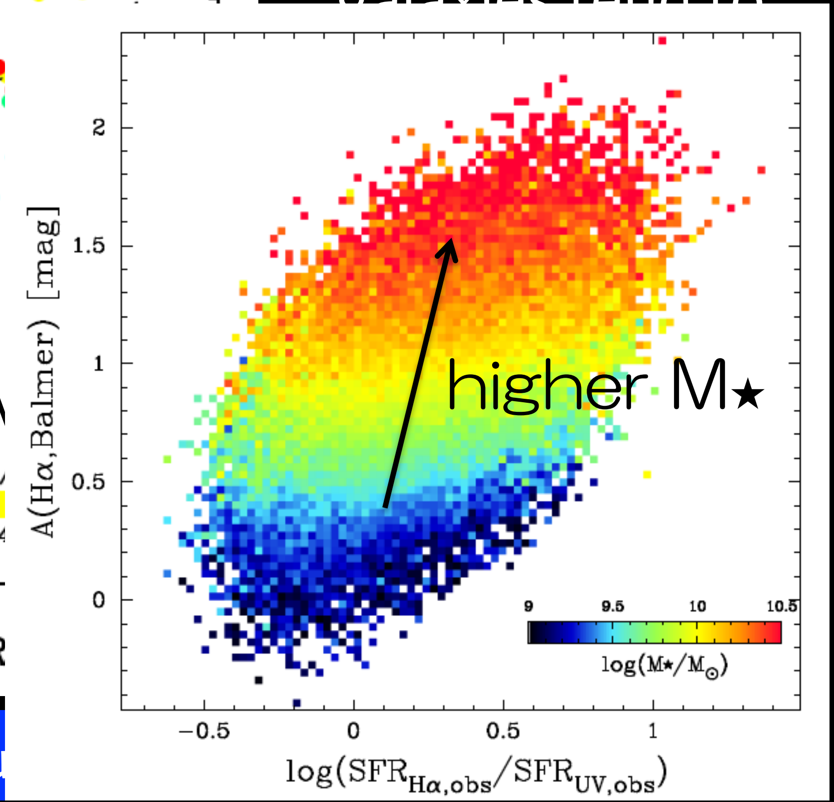
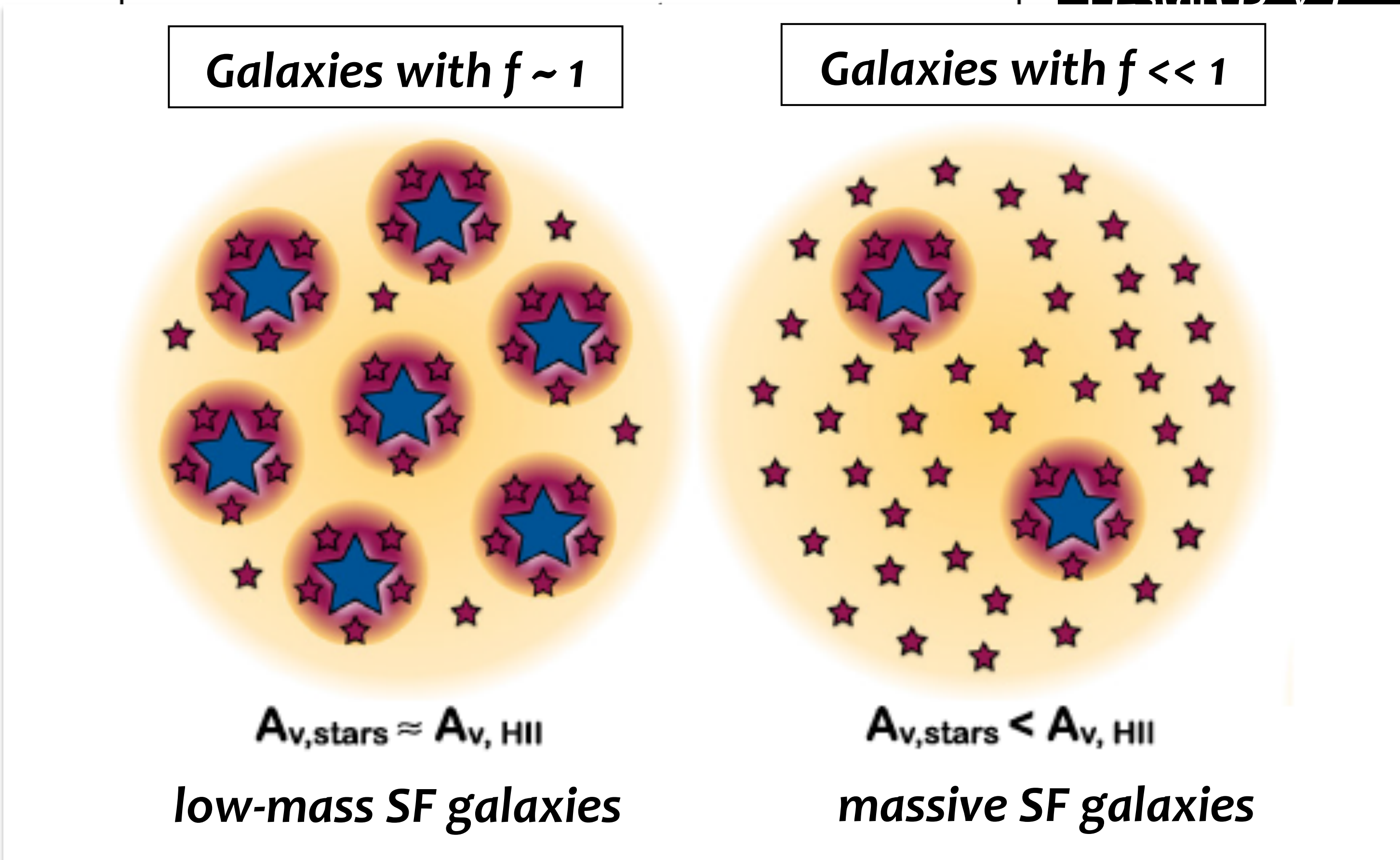


A_V, gas vs. A_V, star for z~0 galaxies



(Illustrated by Price et al. 2014)

Extinction for nebular region

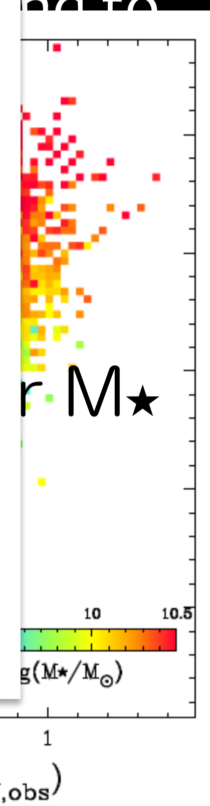
Estar(B-V)

(B-V)

ssive

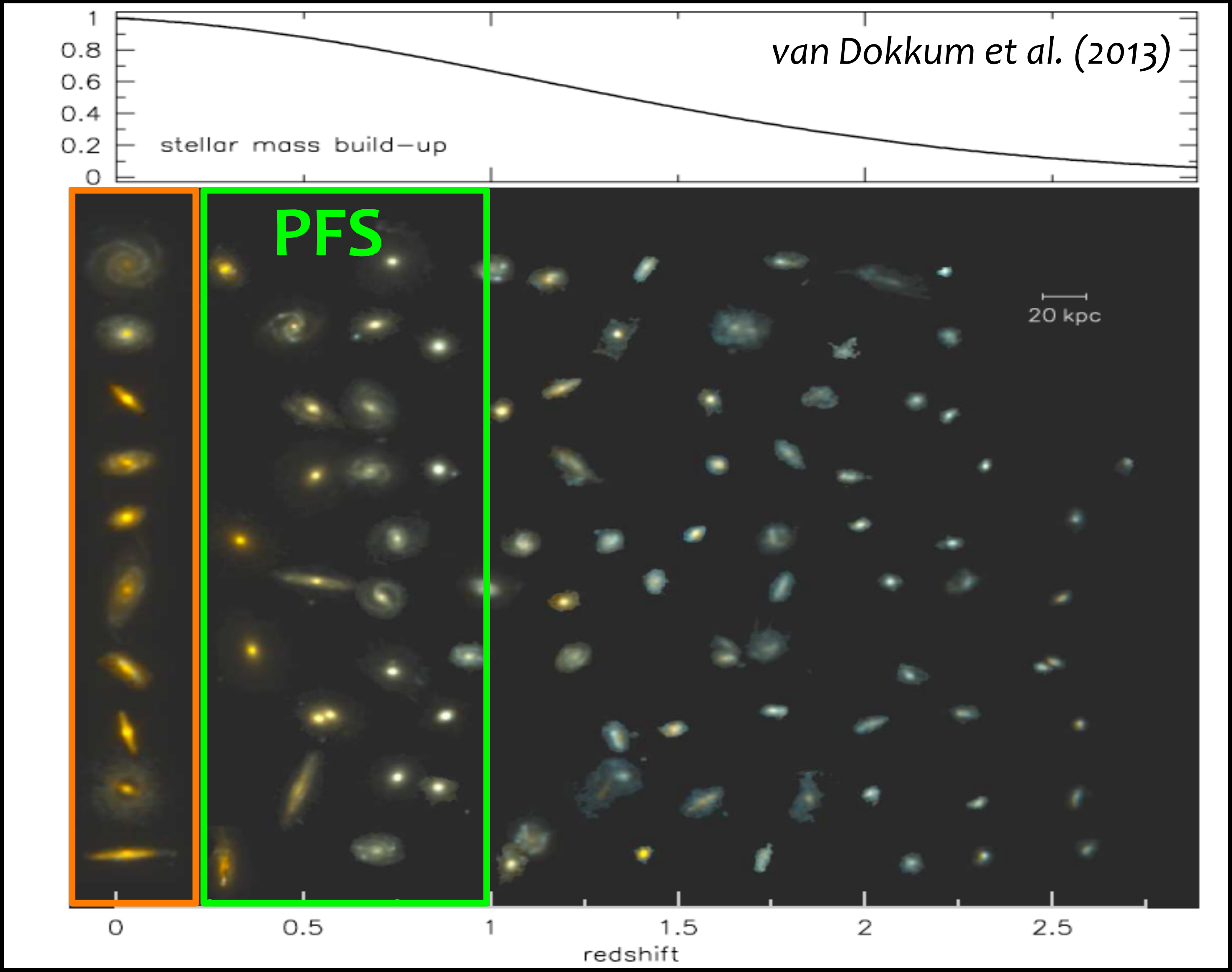
nd to

r $M_\star$



Extinction for continuu

What about high-z galaxies ?



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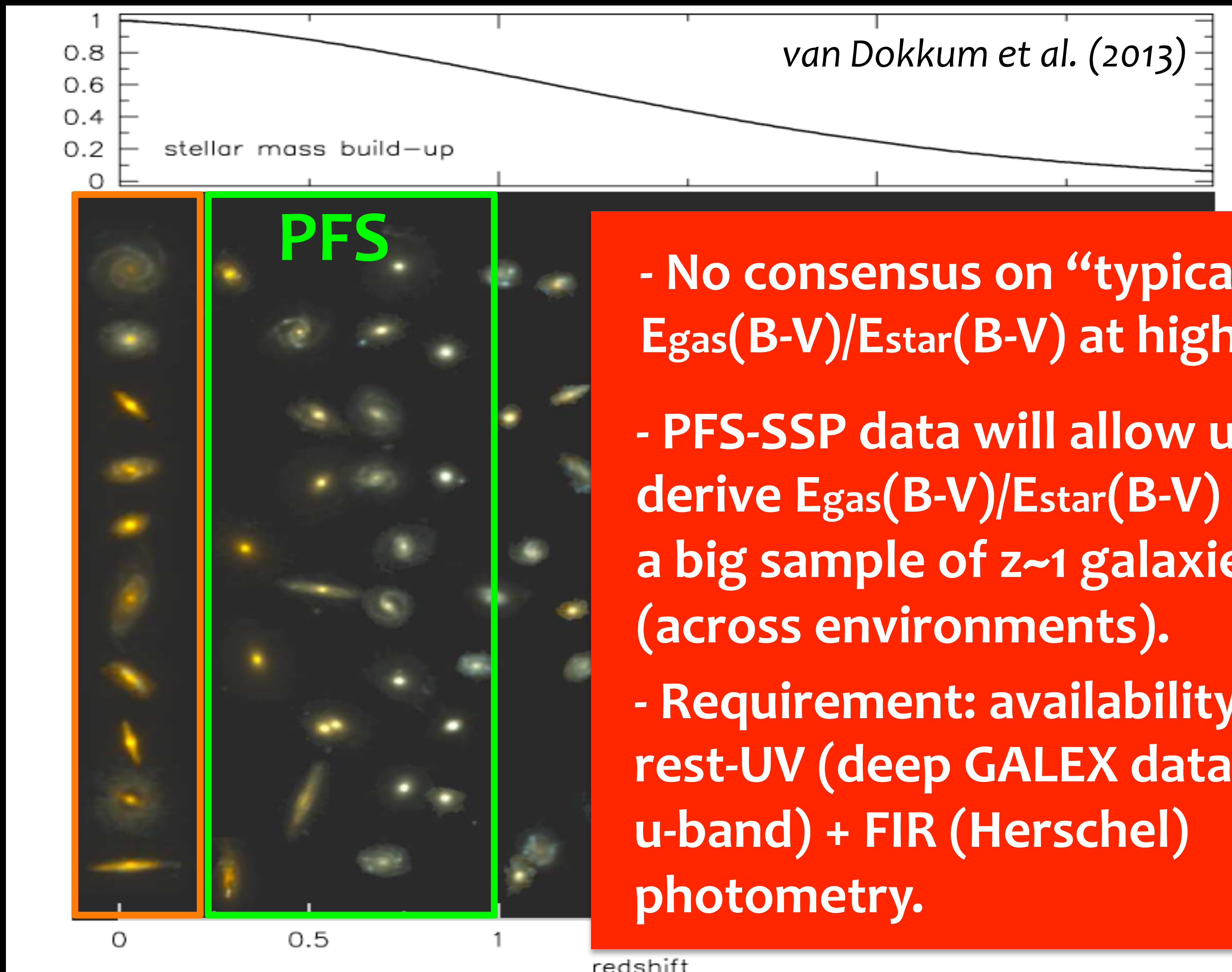
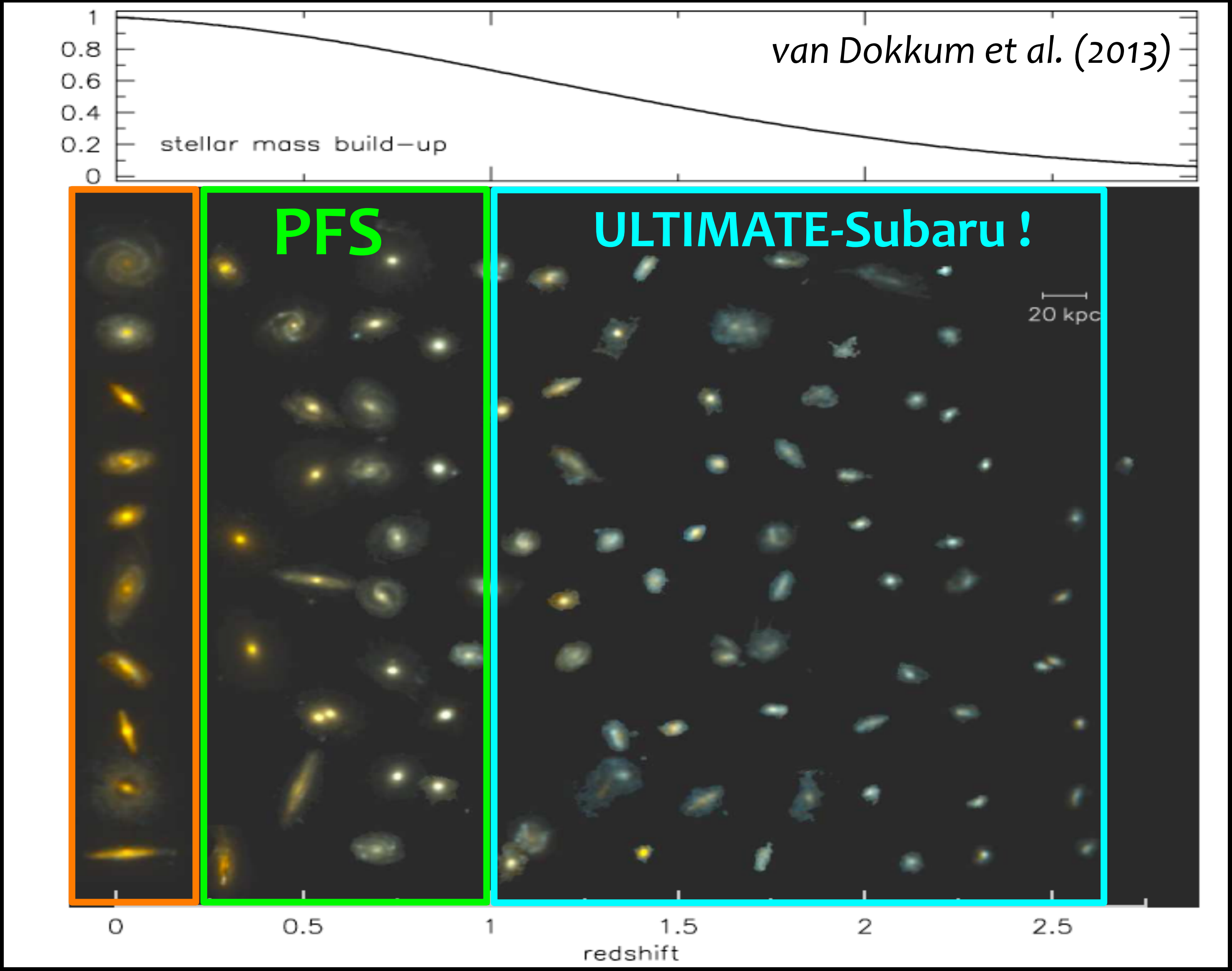
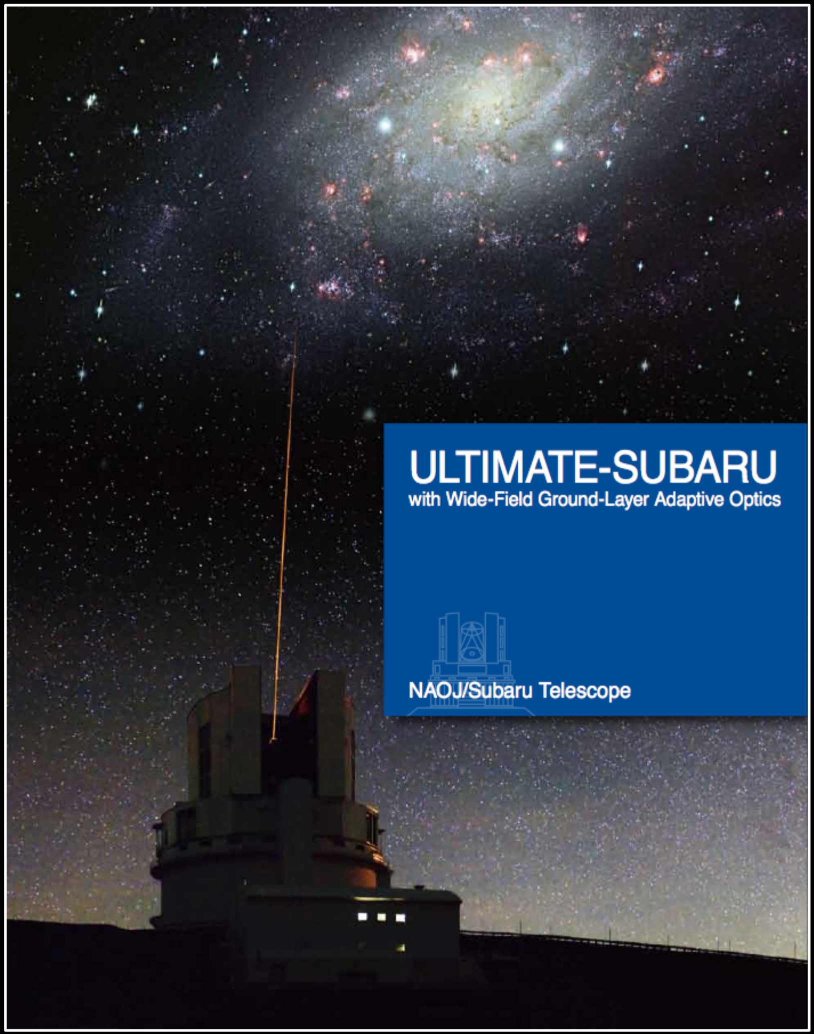


- No consensus on "typical" $E_{gas}(B-V)/E_{star}(B-V)$ at high-z.
- PFS-SSP data will allow us to derive $E_{gas}(B-V)/E_{star}(B-V)$ for a big sample of z~1 galaxies (across environments).
- Requirement: availability of rest-UV (deep GALEX data or u-band) + FIR (Herschel) photometry.

What about high-z galaxies ?



ULTIMATE-Subaru



- Adaptive Secondary Mirror
- 4 LGS + 3 NGS
- Seeing Improvement (J~0.3”, K~0.2”)
- >10-arcmin Field-of-View at Cassegrain
- http://www.naoj.org/Projects/newdev/ngao/
- New Wide-field Near-IR Instrument(s)

(Mainly for “bright” nights: HSC & PFS are for “Dark” nights)

- Incremental Development of instrument(s) and GLAO
  - Expected start science observations around beginning of 2020s

ULTRA-WIDE-FIELD LASER TOMOGRAPHIC IMAGER and MOS with AO for TRANSCENDENT EXPLORATION by SUBARU TELESCOPE.

ULTIMATE-Subaru Instruments

(1) Wide-field imager(16’x12’)

- Focus on NB/MB imaging (to complement space missions)
- Collaboration with Canada (HIA)

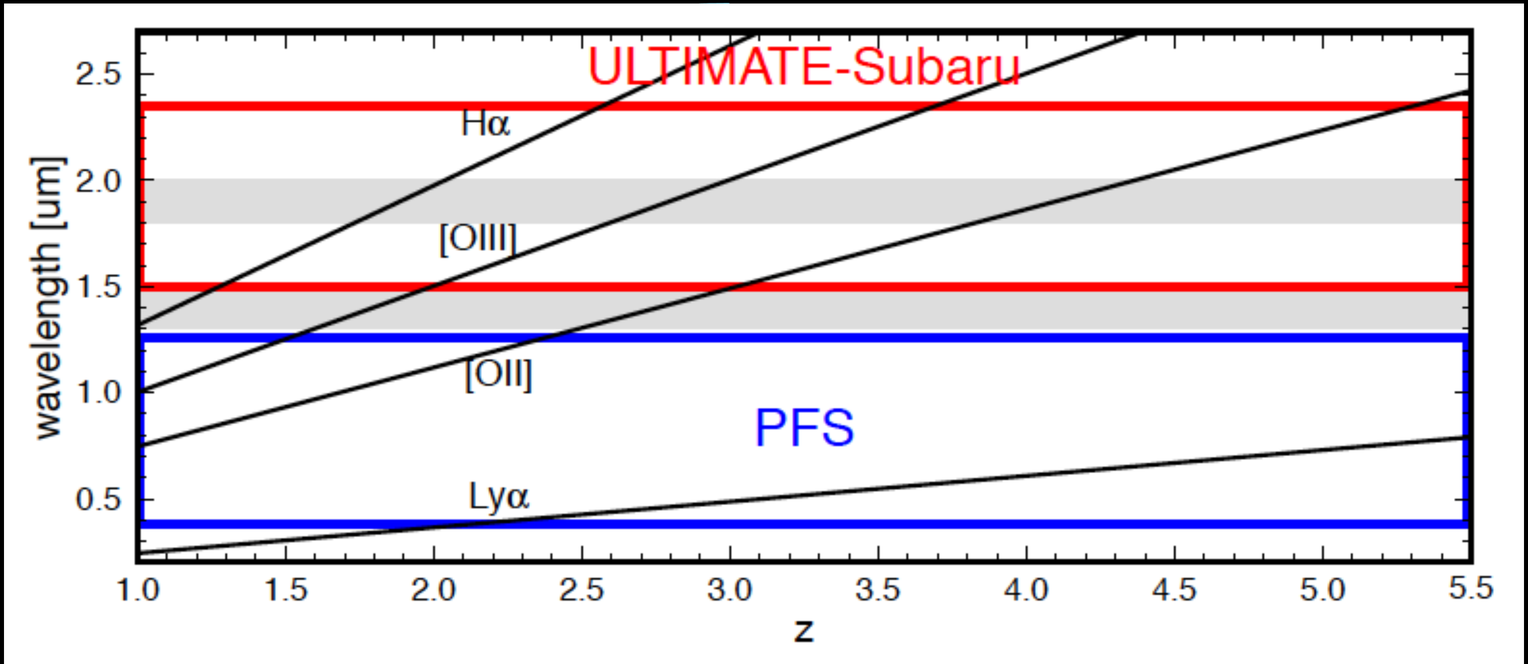
(2) Multi-object IFU spectroscopy

- 3D spectroscopy (J+H) for ~20-60 galaxies at once.
- Collaboration with Australia (AAO)

(3) Multi-object spectrograph

- MOSFIRE-like instrument with GLAO ?
- Can be a natural extension from PFS?

ULTIMATE-Subaru Instruments



(3) Multi-object spectrograph

- MOSFIRE-like instrument with GLAO ?
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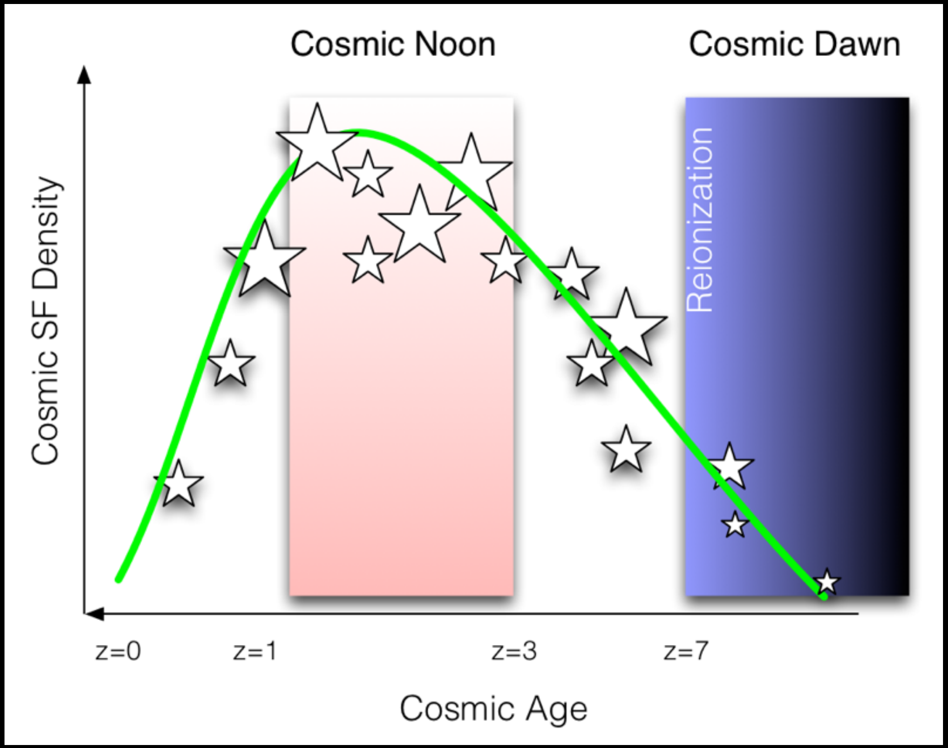
Science goals with ULTIMATE-Subaru

- *Complete Census of Galaxy Evolution*
  - ‘Cosmic Noon’ (1<z<3)
  - Galaxy Anatomy
- *Exploring Very High-z Universe*
  - ‘Cosmic Dawn’ (z>7)



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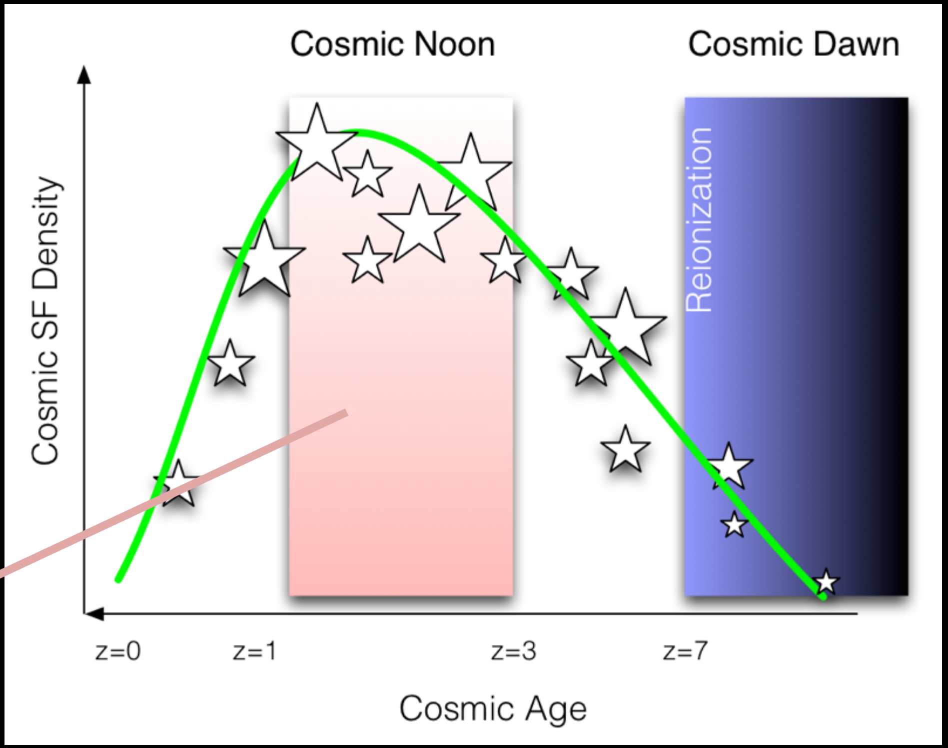

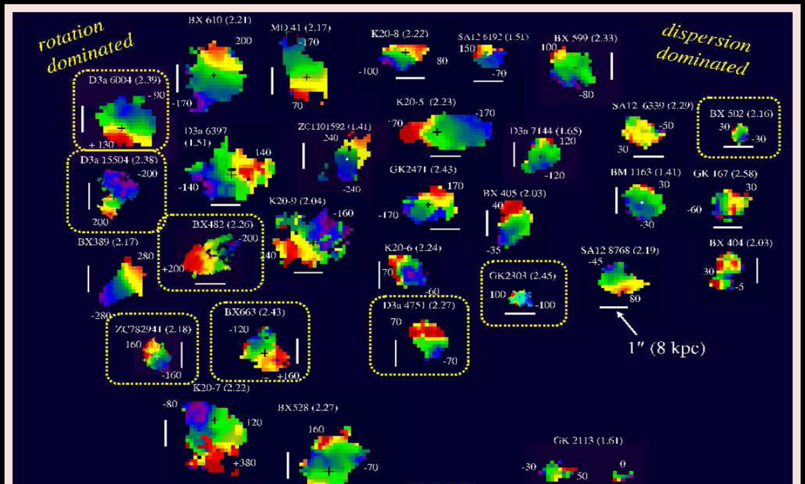

SINS survey (Foster-Schreiber 2011)

Science goals Subaru

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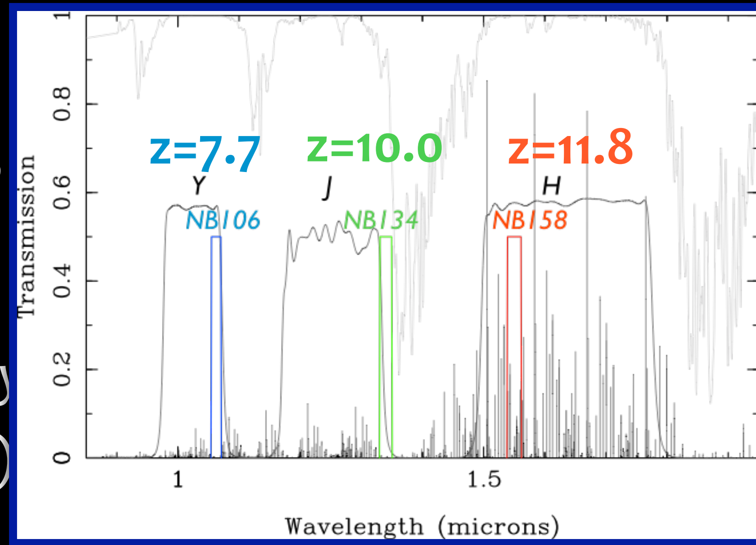

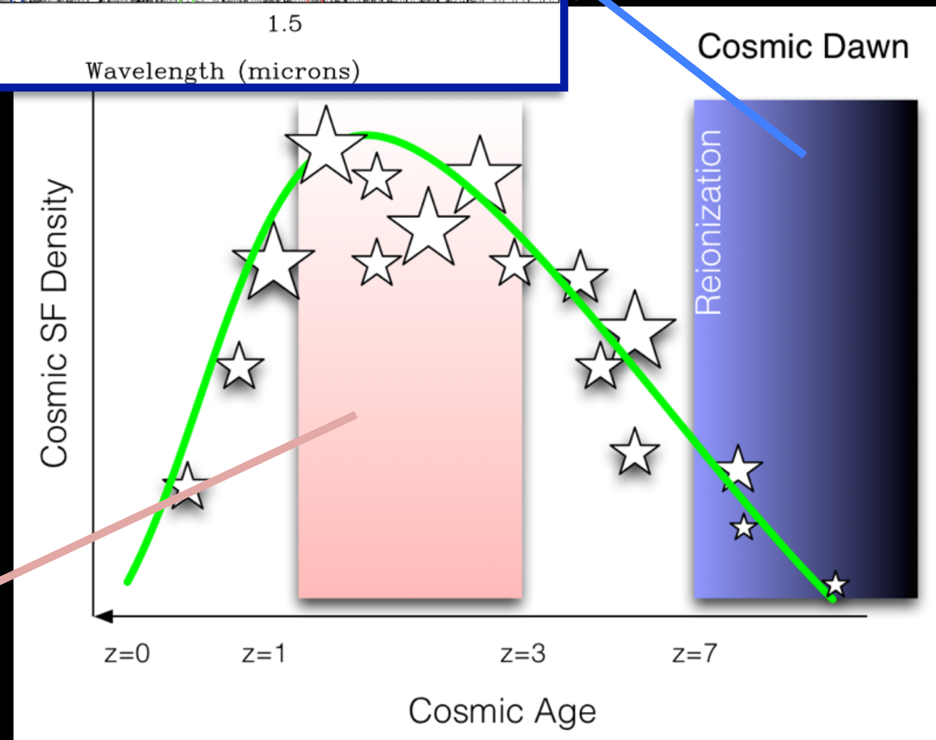

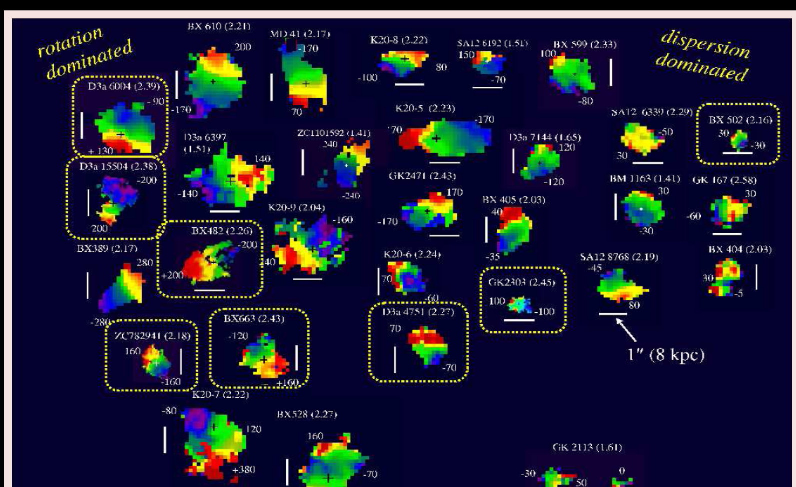

SINS survey (Foster-Schreiber 2011)


https://www.businessprodesigns.com/pillars-website-3/
We are here !
HSC
PFS
ULTIMATE
2013
2019?
202x

Summary

- Our experiment using SDSS-GALEX-AKARI sample showed that Hα/UV ratio increases with increasing dust extinction, but the $A_{H\alpha}$ vs Hα/UV relation is strongly dependent on stellar mass and EW(Hα).
- By comparing A_{UV} vs $A_{H\alpha}$, we find that the level of "extra" extinction towards nebular regions is higher for more massive galaxies, suggesting stellar mass dependence of "dust geometry" of galaxies at z=0.
- Subaru/PFS is ideally suited for testing our interpretation at high redshifts (z~1): we need Hα, Hβ, rest-FUV (u-band), and FIR photometry (Herschel).
- ULTIMATE-Subaru can potentially extend PFS survey towards higher redshifts in 2020s.