Integral field spectroscopy of low-redshift extreme line emitters

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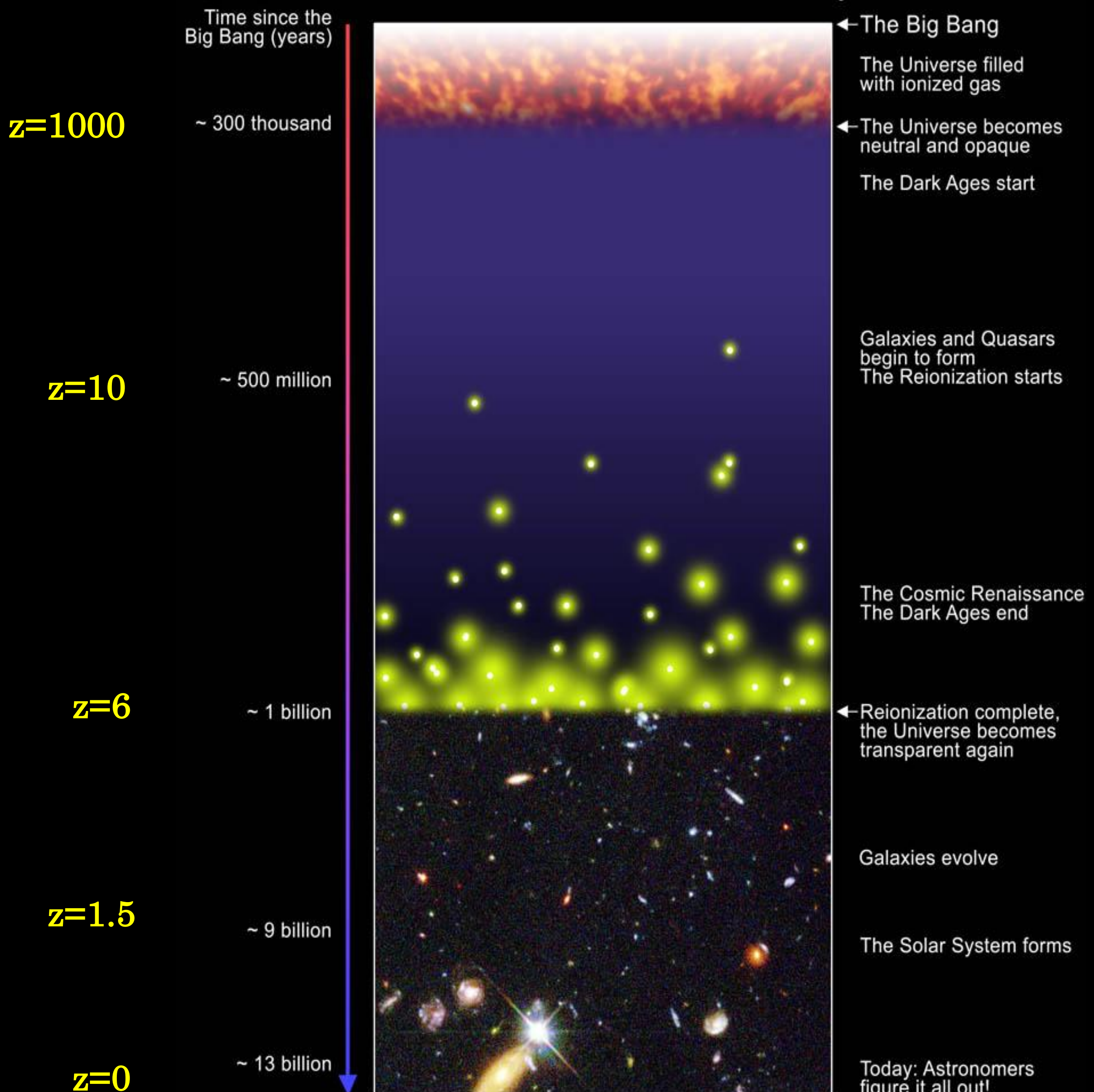
A Schematic Outline of the Cosmic History



S.G. Djorgovski et al. & Digital Media Center, Caltech

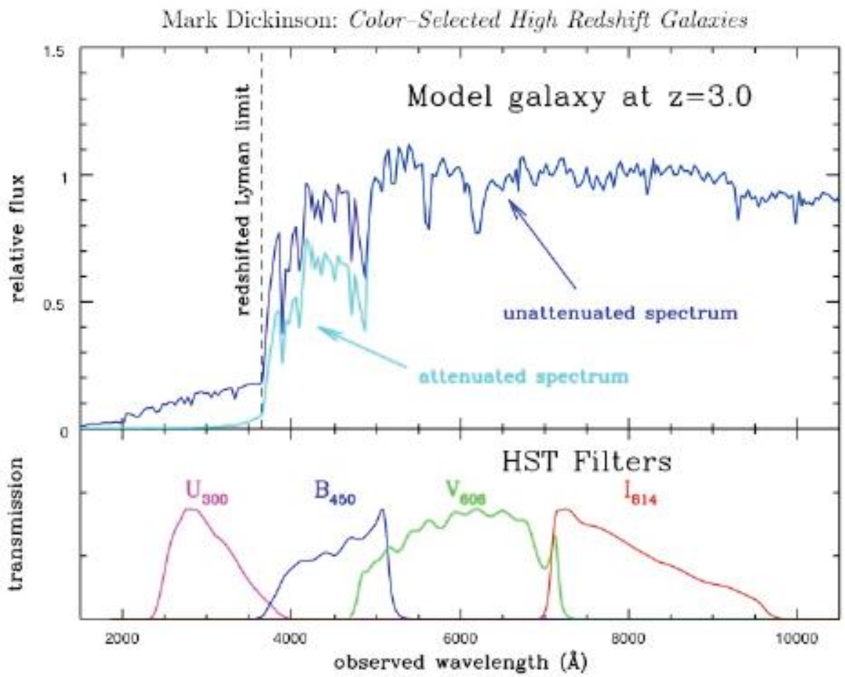
High-redshift galaxy population

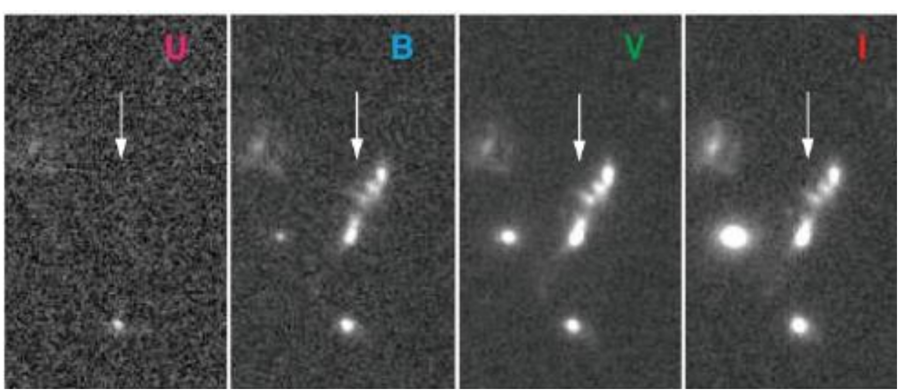
- represent major, early phase of galaxy formation (progenitors that later to form and evolve into present-day ellipticals)
- played an important role in the reionization of the universe
- share different properties with star-forming galaxies in local universe

Questions that needs to be answered include :

- mechanisms related in the formation and evolution of high-z galaxies (merging, cold gas accretion, etc.)
- whether these galaxies are responsible for the reionization

Identification using spectral features

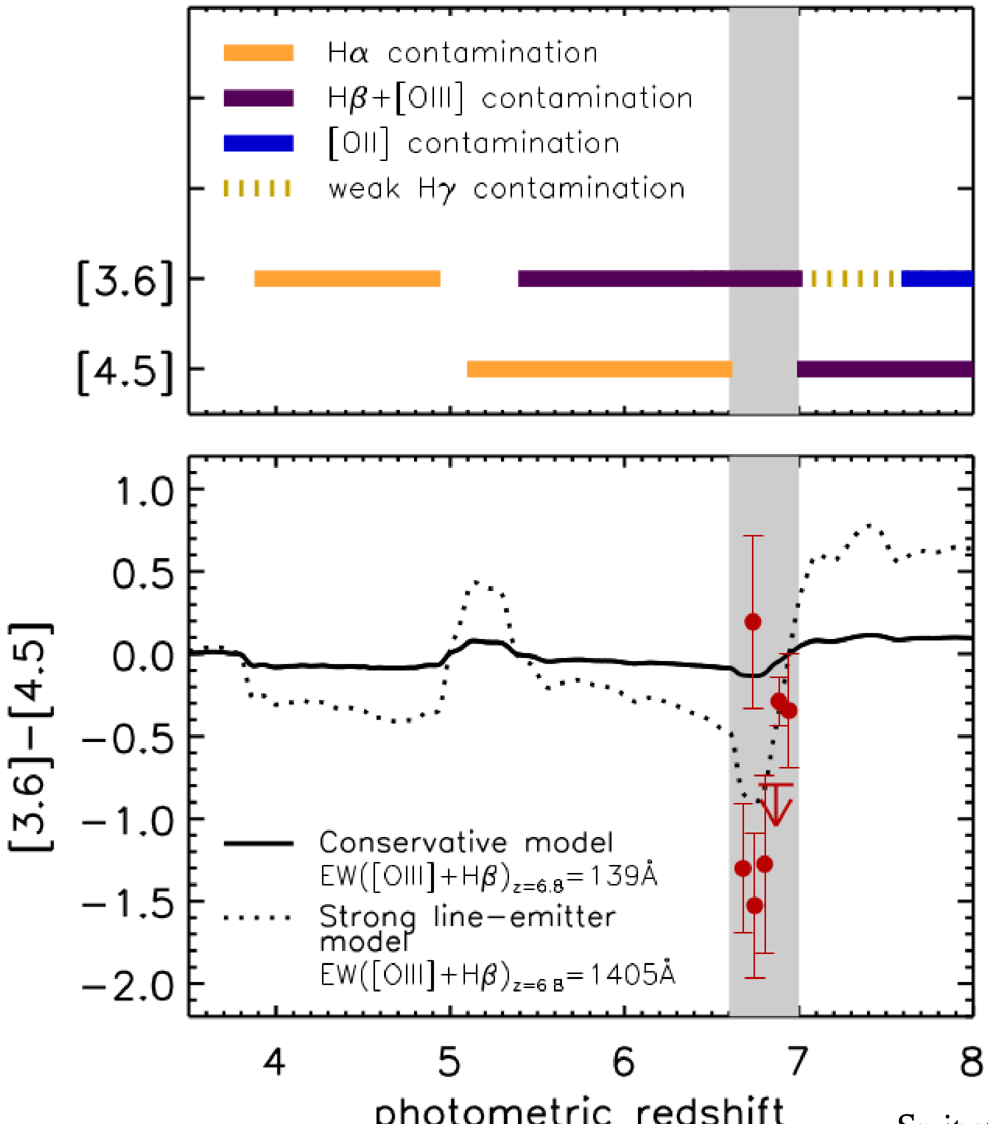




- One most frequent: continuum break (Lyman break, Balmer break, …)
- The other most frequent: emission lines (Ly**α**, [OII], H**β**, [OIII], H**α**, …)

- They may overlap or not. Faint continuum galaxies likely to be LAEs, others LBGs. Correlation between Ly**α** – Ly Continuum – H**α** is rather complicated

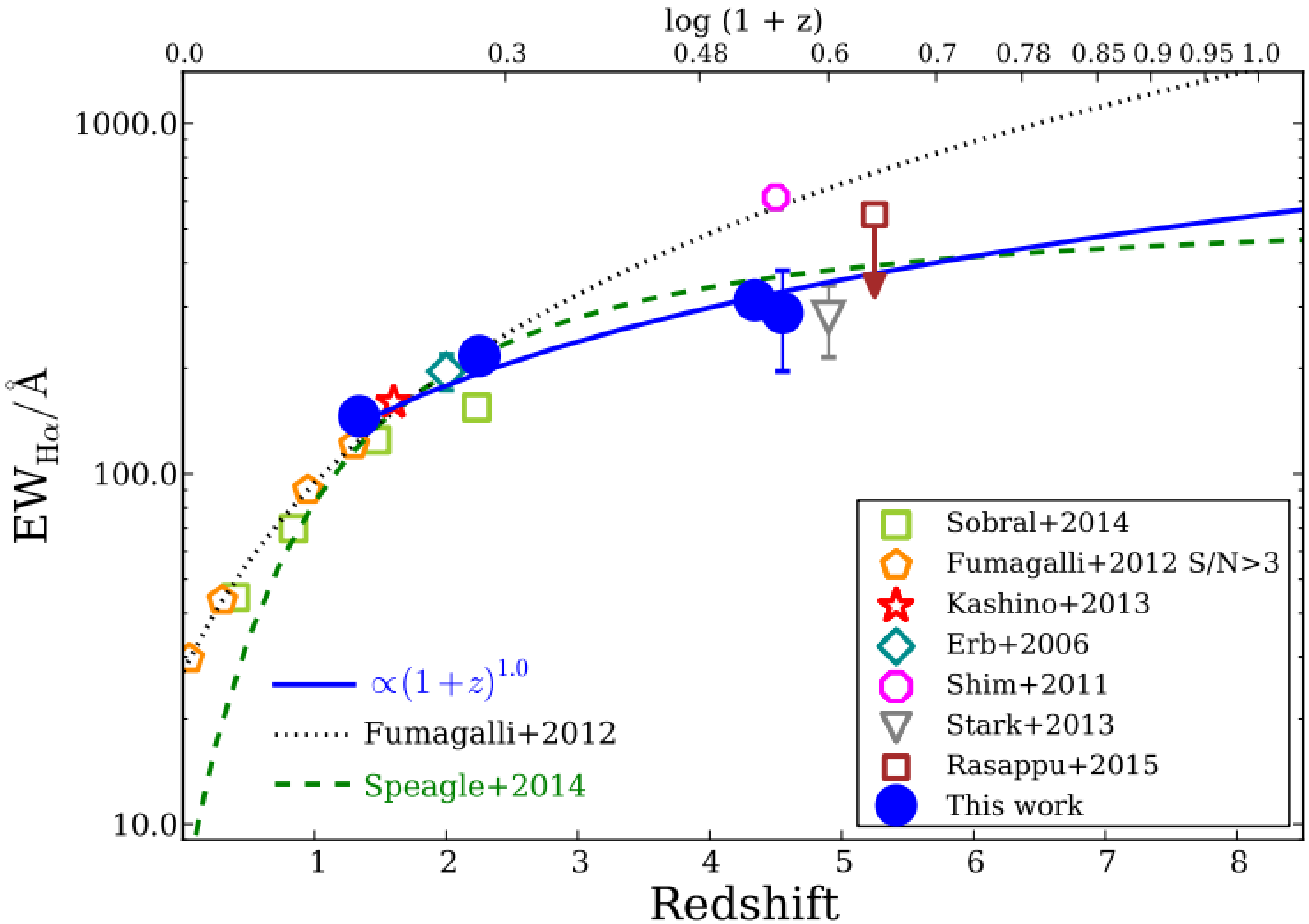
Strong 'Line Emitters' are ubiquitous



Smit et al. 2014

- SED fitting technique based on multi-band photometry provided fairly reliable way to measure the emission line fluxes at $z > 1$-5.
- Large EW reflects large specific SFR for early star-forming galaxies.

Increase of Hα EW at high redshift



Marmol-Queralto et al. 2016
3D-HST survey z = 1-5

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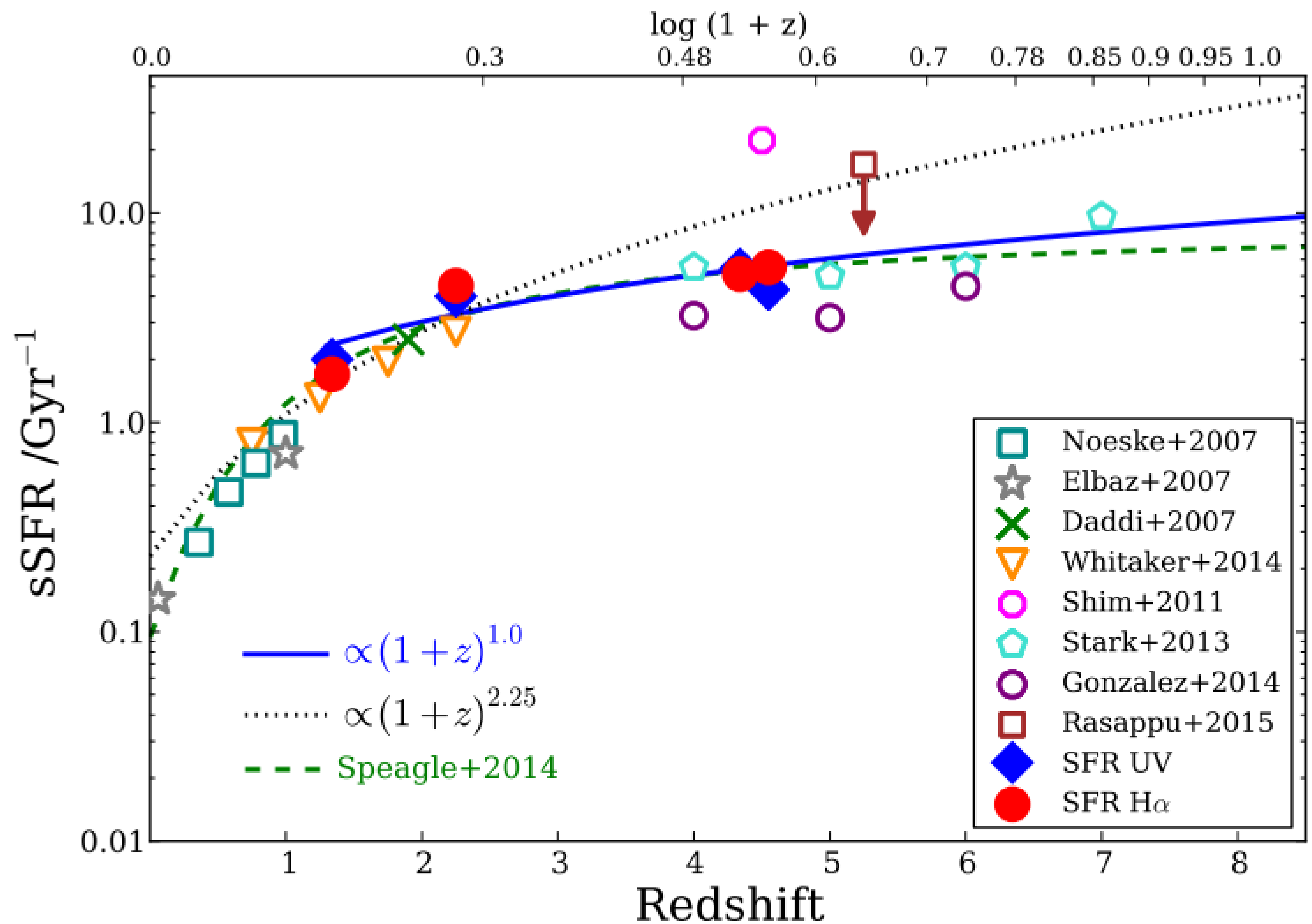

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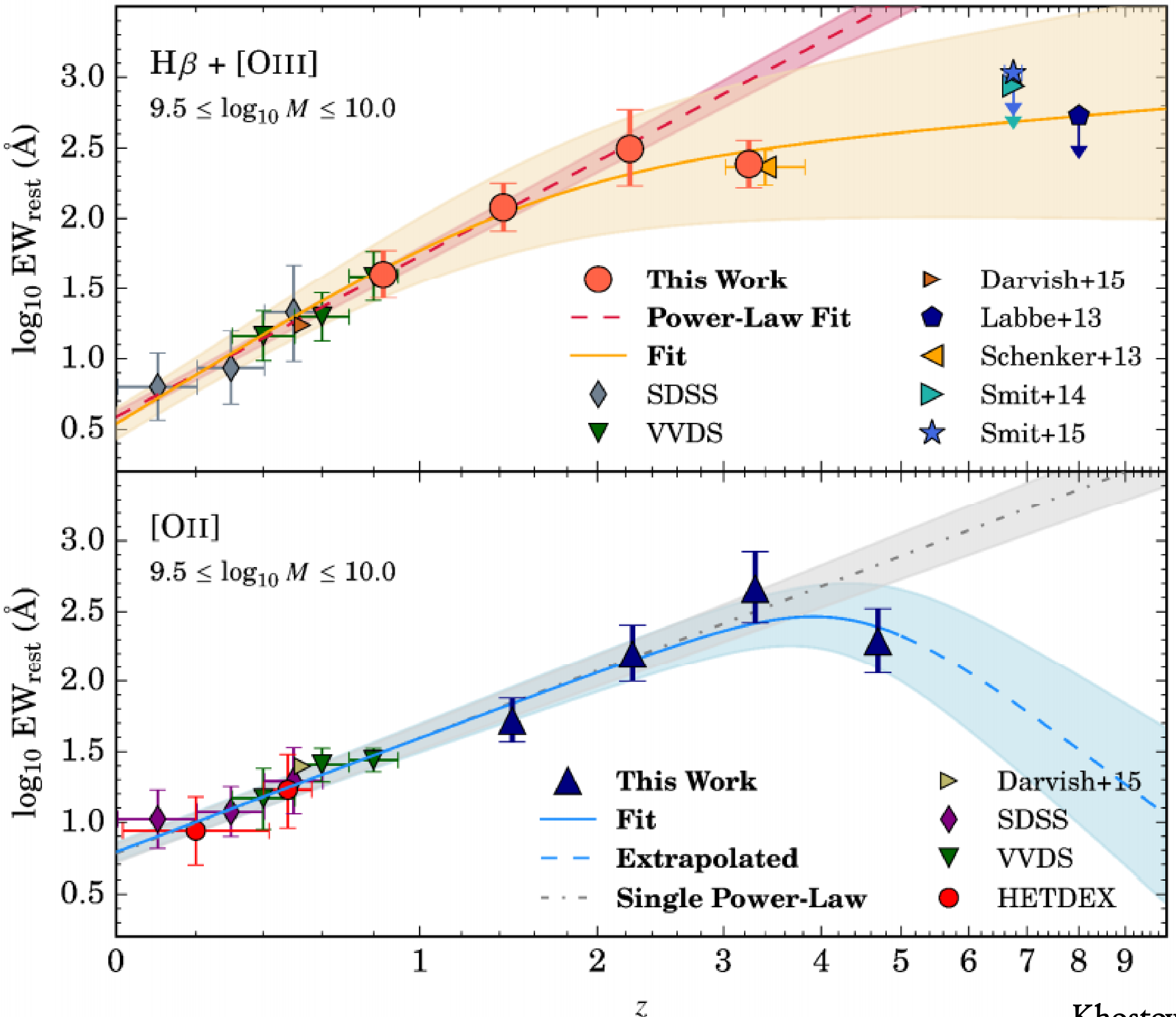
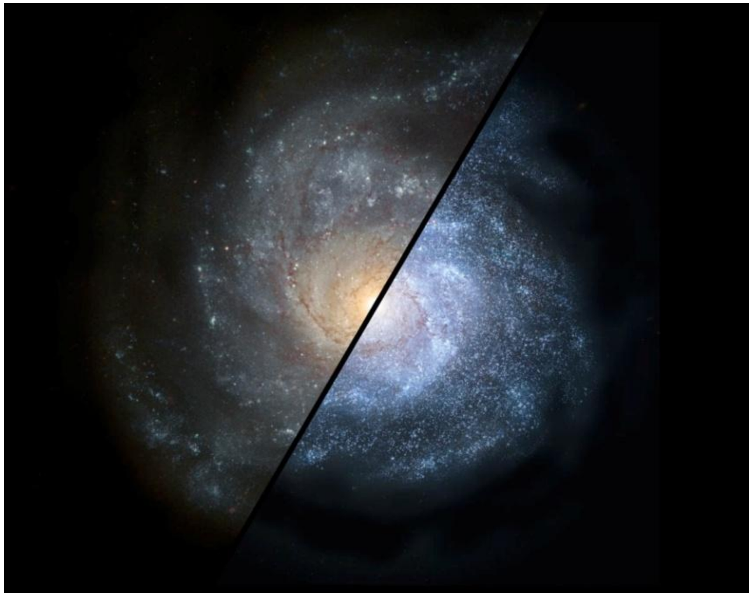
Other emission lines



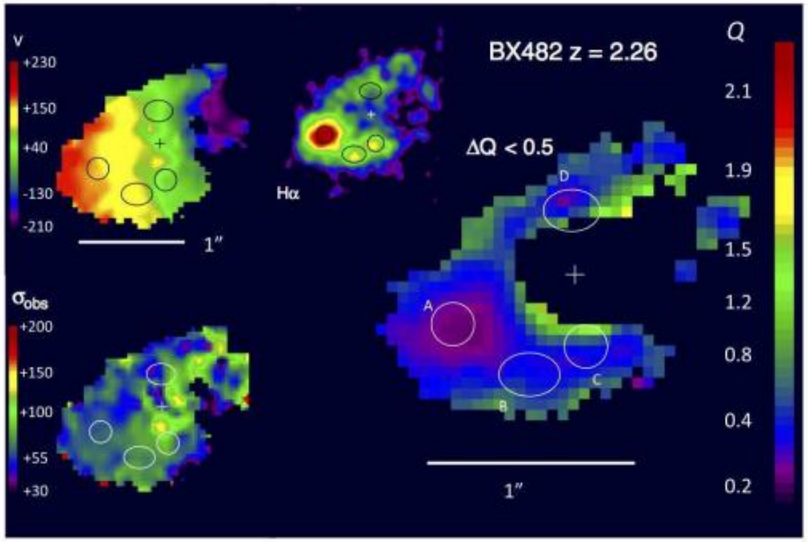
Khostovan et al. 2016

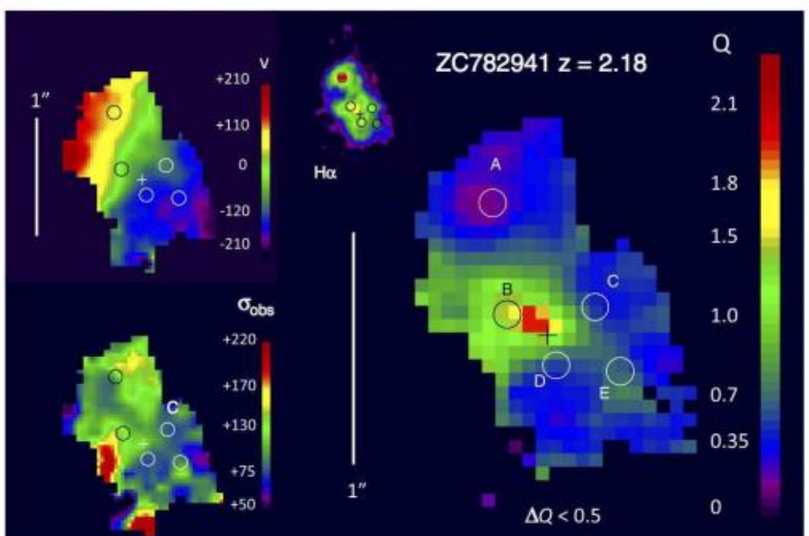
These are typical high-z galaxies, not special...



- Large equivalent width galaxies – in other words, "line emitters" are not a new population of galaxies. These are (previously selected) LBGs, LAEs, etc.
- How are these galaxies powered ? Through cosmological gas accretion, or via minor merger?

Integral field spectroscopy on z>1 SFGs





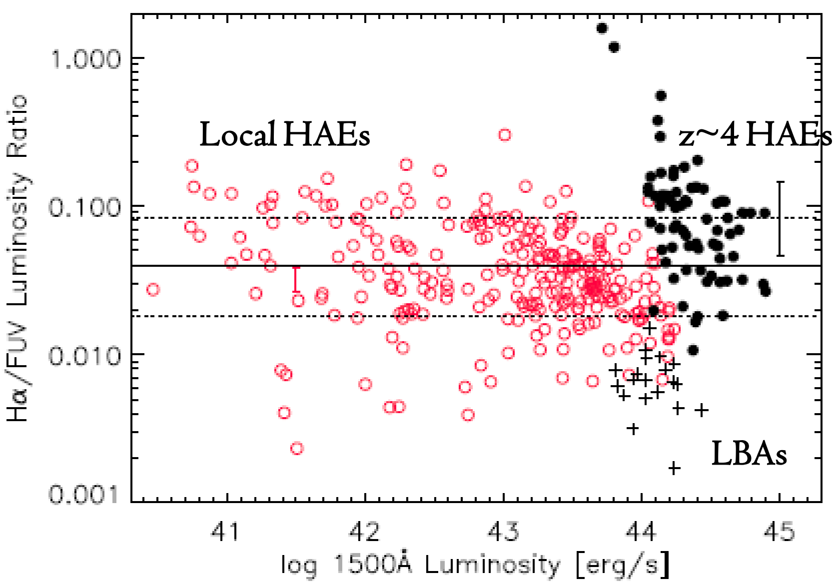
- Despite having irregular visual morphology, quite a lot (>30%?) galaxies are found to have rotating velocity fields with enhanced velocity dispersion.
- The result suggests high-z star formation is mainly occurring in clumpy, turbulent disk.
- Still there exists dispersion dominated galaxies especially with larger masses.

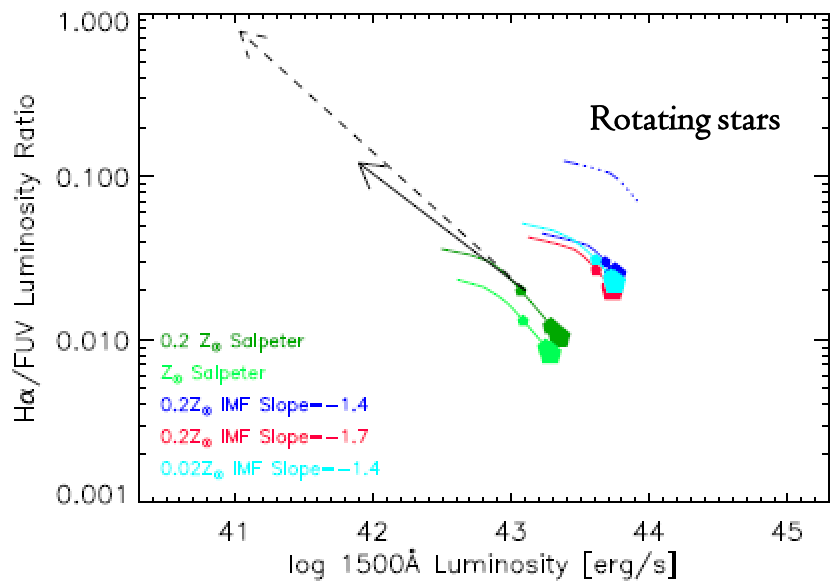
Genzel et al. 2011

Looking for local analogs of high-z SFGs

Local galaxies with strong Hα emission (local HAEs)

- <0.1% among the SDSS DR8 galaxies, on average high sSFR
- The observed Hα/UV ratio is not easily explainable (alternative IMF, low metallicity, dust, stellar rotation, …)

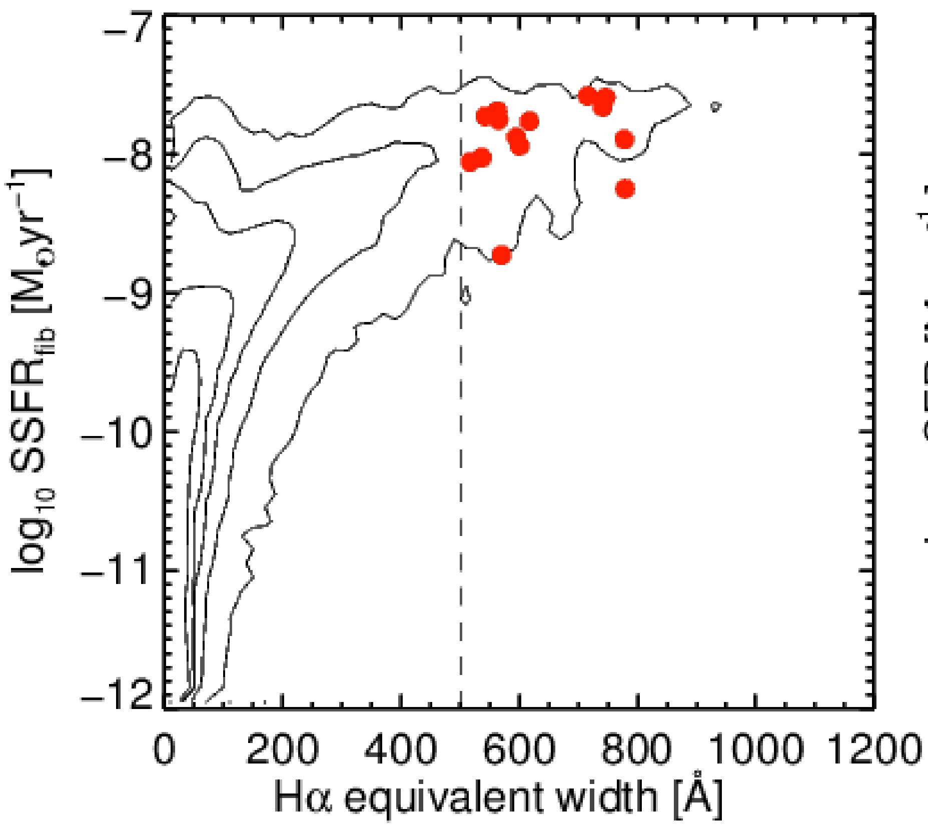


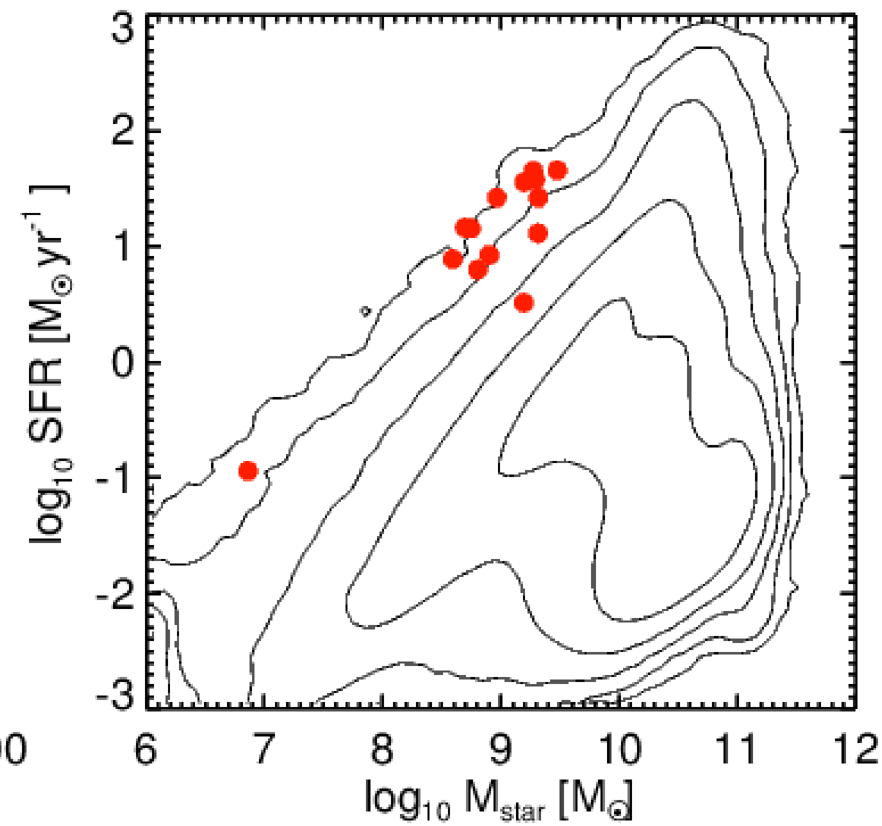


(Starburst99)

Target selection

- Rest-frame H**α** EW larger than 500 Å
- R_{50} > 3arcsec





Observation

- Palomar/SWIFT (Image-slicer based integral field spectrograph from Oxford covering 6500-10000Å, R~3300-4400)
- AO was not working during the observation, therefore the data is seeing-limited (~0.7-8")

89 x 44 spaxels

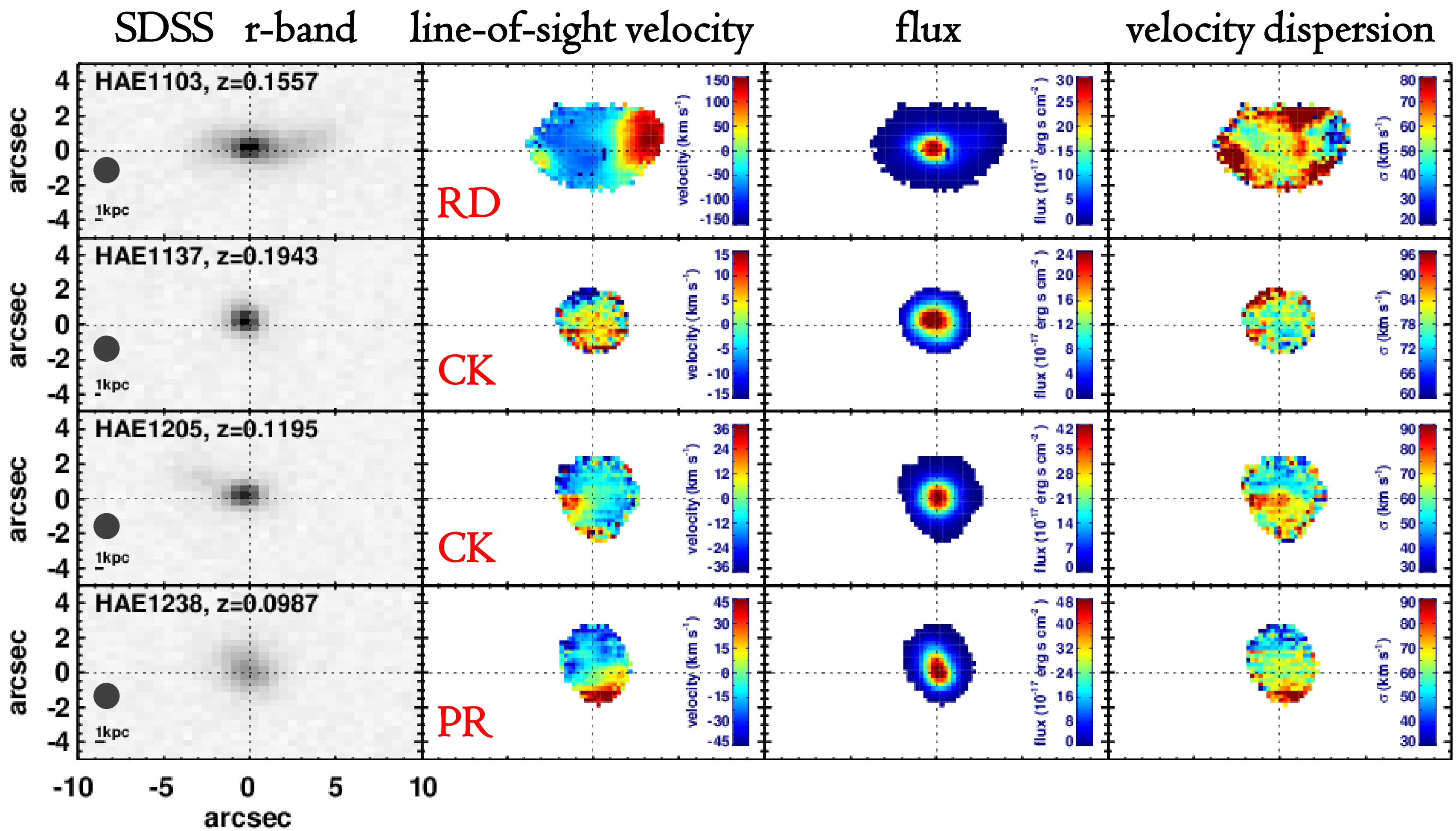
Used 0.235"/pixel,
FOV~10" x20"

Data reduction

- Spectral cube was produced for each target after the: basic pre-processing, primary/slave frame merging (using swiftred), cosmic ray rejection (using la_cosmic), wavelength calibration (swiftred), and flux calibration (standard).

- Gaussian emission line fitting was performed in every single spaxel to extract the intensity, the line center, and the line width (FWHM) of significant emission lines including OI(6300Å), Hα, [NII](6548, 6583Å), and [SII](6716, 6731Å).

Kinematic maps (Hα)



Kinematic maps (Hα)

Kinematic morphology classification (e.g., Flores et al. 2006)

- **Rotating disk (rotation-dominated galaxies)**

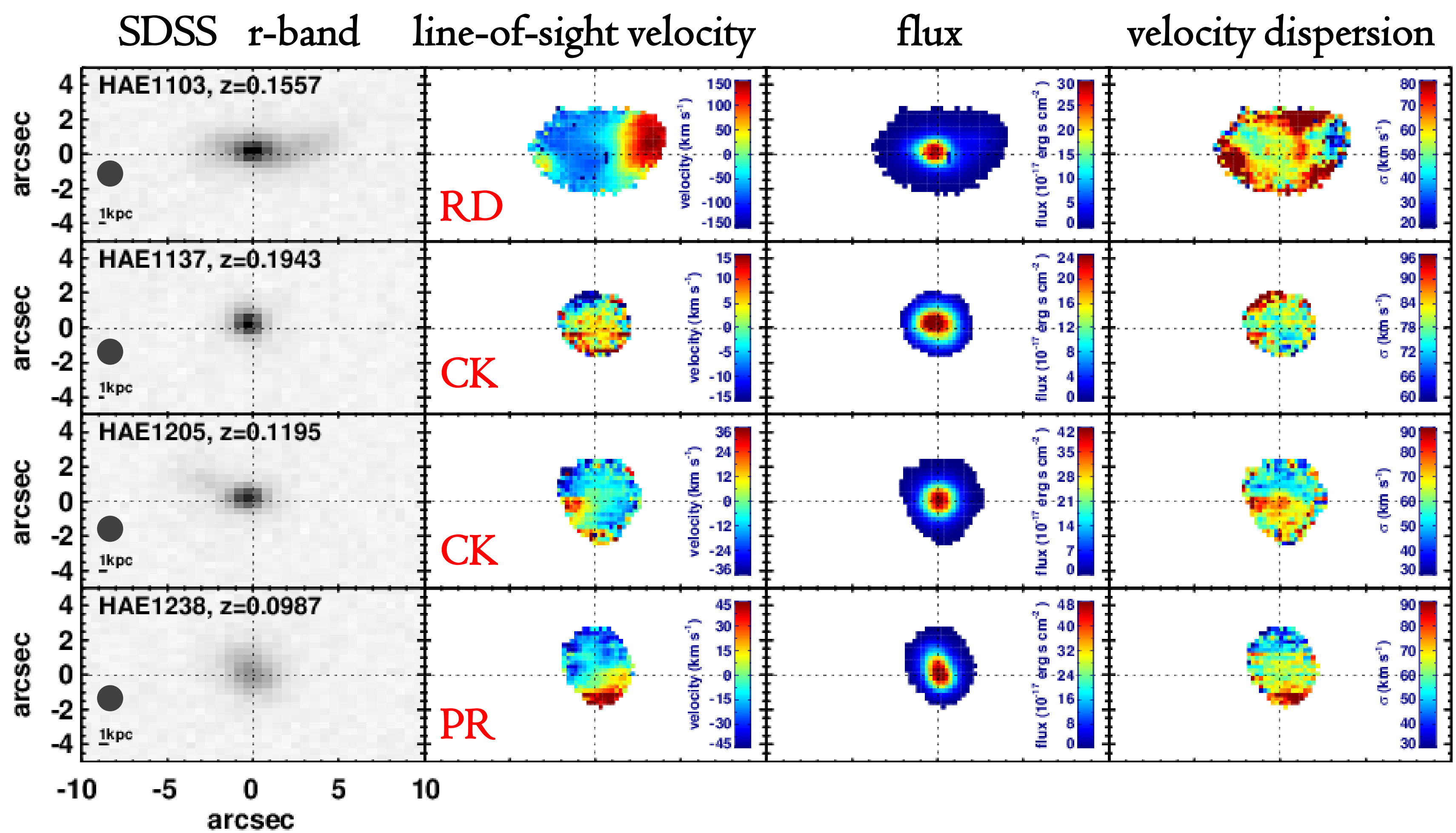
  The velocity field is consistent with rotation; the velocity dispersion peak corresponds to the rotation center; the rotation axis aligns with the minor axis in r-band image.

- **Perturbed rotators**

  The velocity field is consistent with rotation; the rotation axis aligns with the minor axis in r-band image; there is no distinct peak in the velocity dispersion, or the peak of the velocity dispersion is offset from the center.

- **Complex kinematics**

Kinematic maps (Hα)



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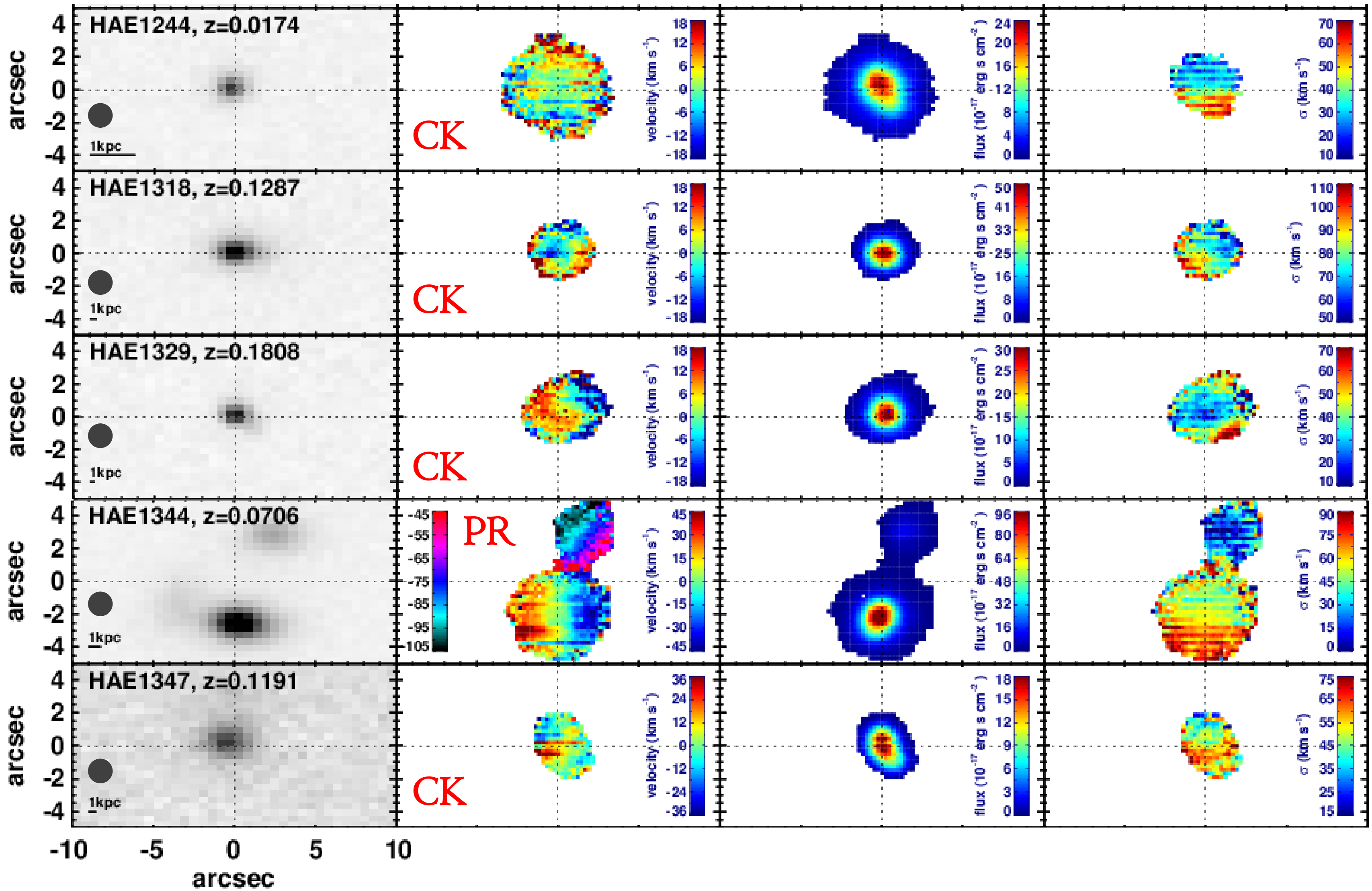

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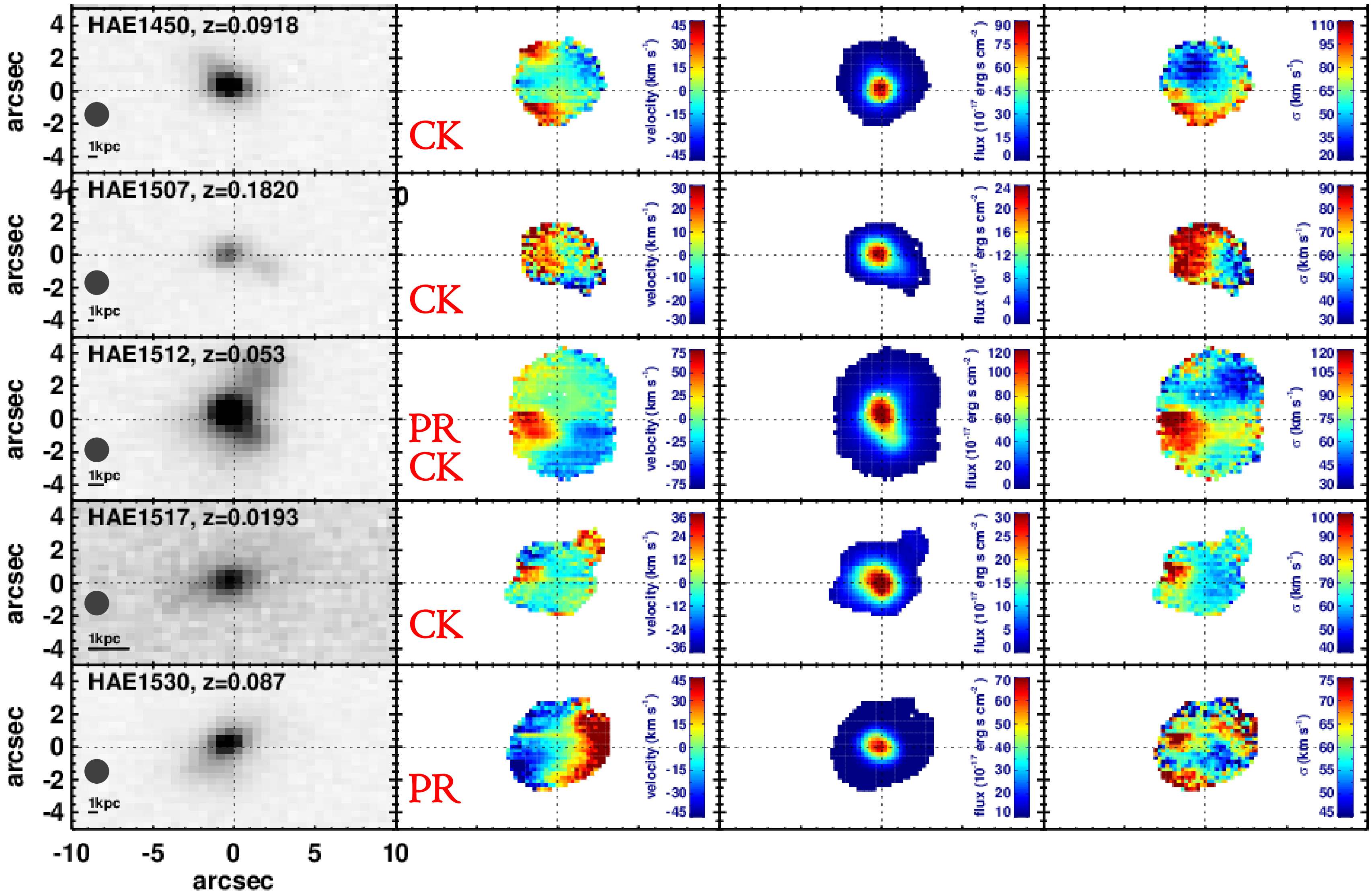
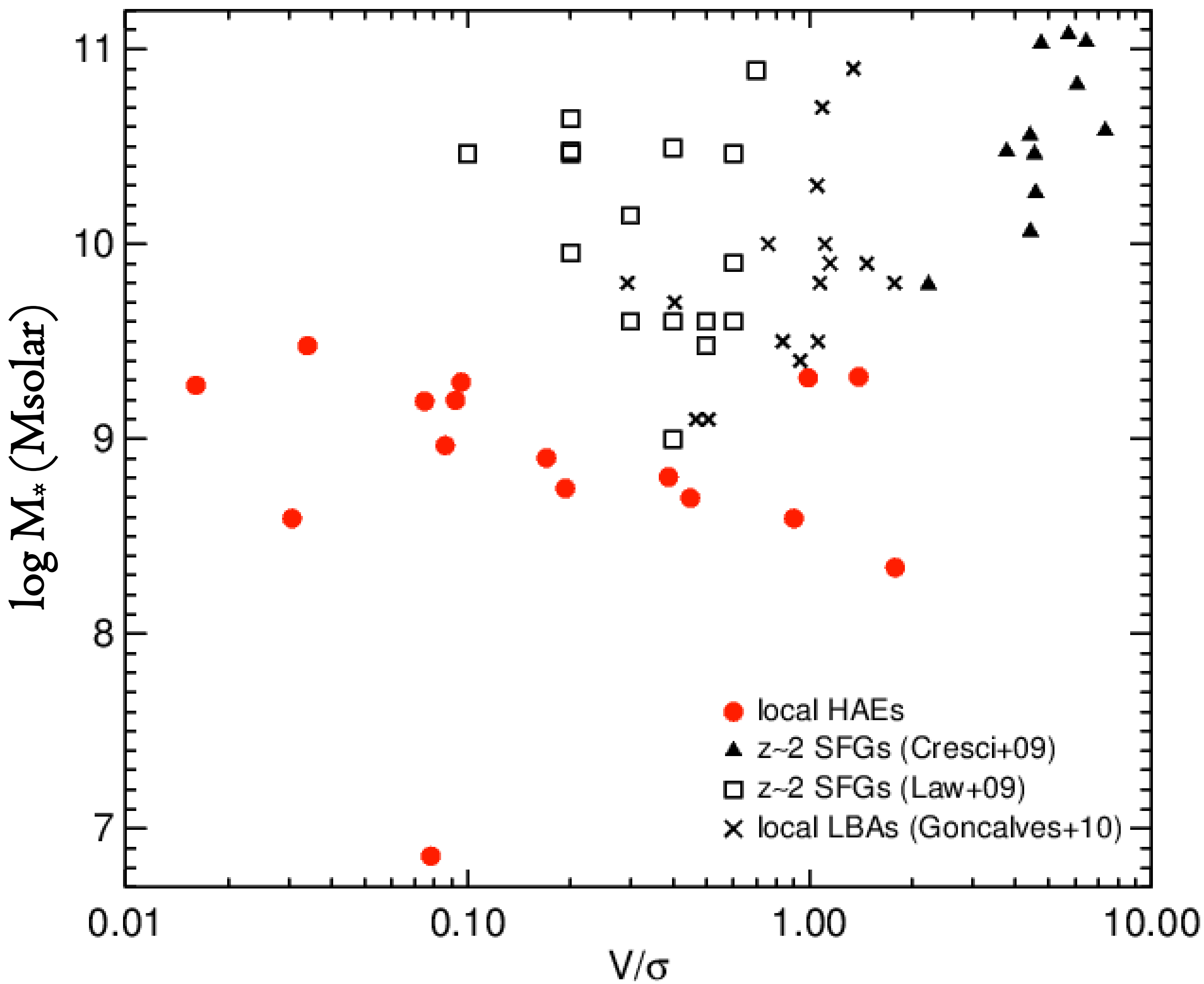


Interpretation of kinematic maps

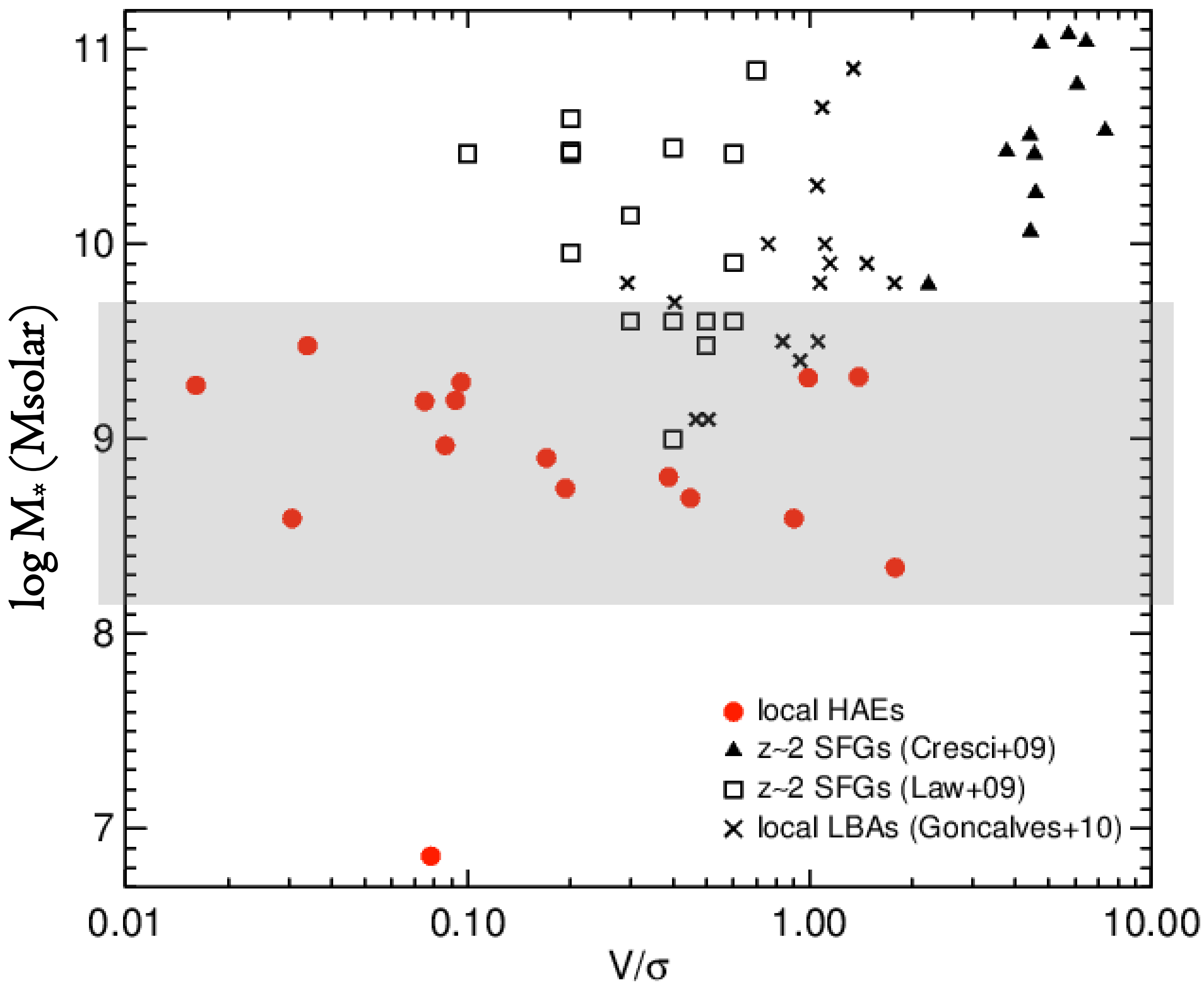
- Among 14 observed, 5 (less than 30%) are rotators, while others are dispersion-dominated.
- Rotators are 'perturbed', not showing line-of-sight dispersion peaks.
- Flux-weighted mean velocity dispersion ($\sigma_m = \frac{\sum \sigma_{pix} I_{pix}}{\sum I_{pix}}$) of the HAEs ranges 40-100 km/s, with a mean value around ~70km/s. This is much higher than those observed in typical local galaxies; yet is consistent with those observed in local LBAs (Goncalves et al. 2010), ULIRGs (Arribas et al. 2008), and z~2-3 star-forming galaxies (Law et al. 2009; Jones et al. 2010).
- Vrot for galaxies were derived through the kinemetry (Krajnovic et al. 2006) tool doing the surface photometry on the LOSVD.

HAEs and other star-forming galaxies



HAEs cover low-mass end of the high SFR population

HAEs and other star-forming galaxies



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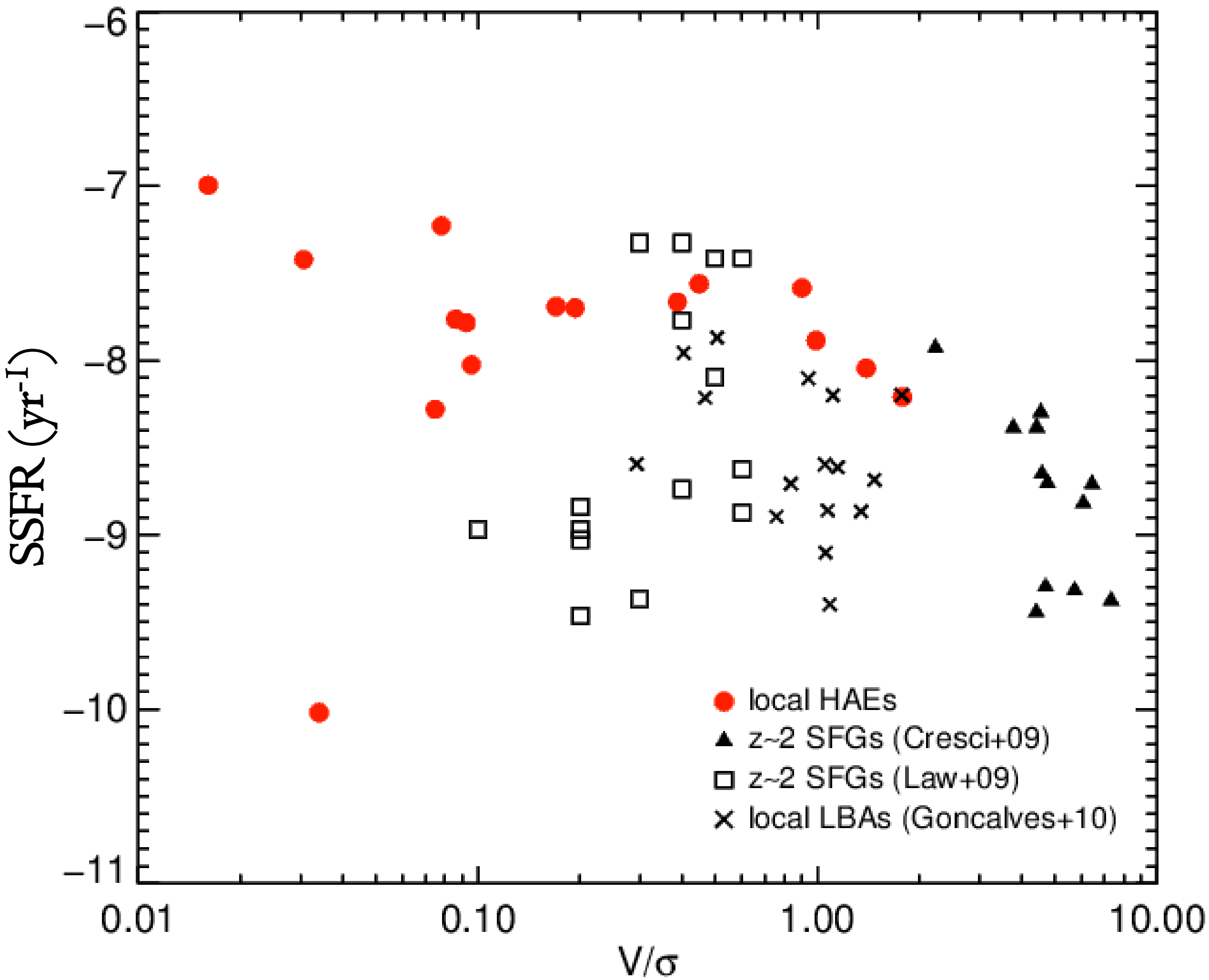
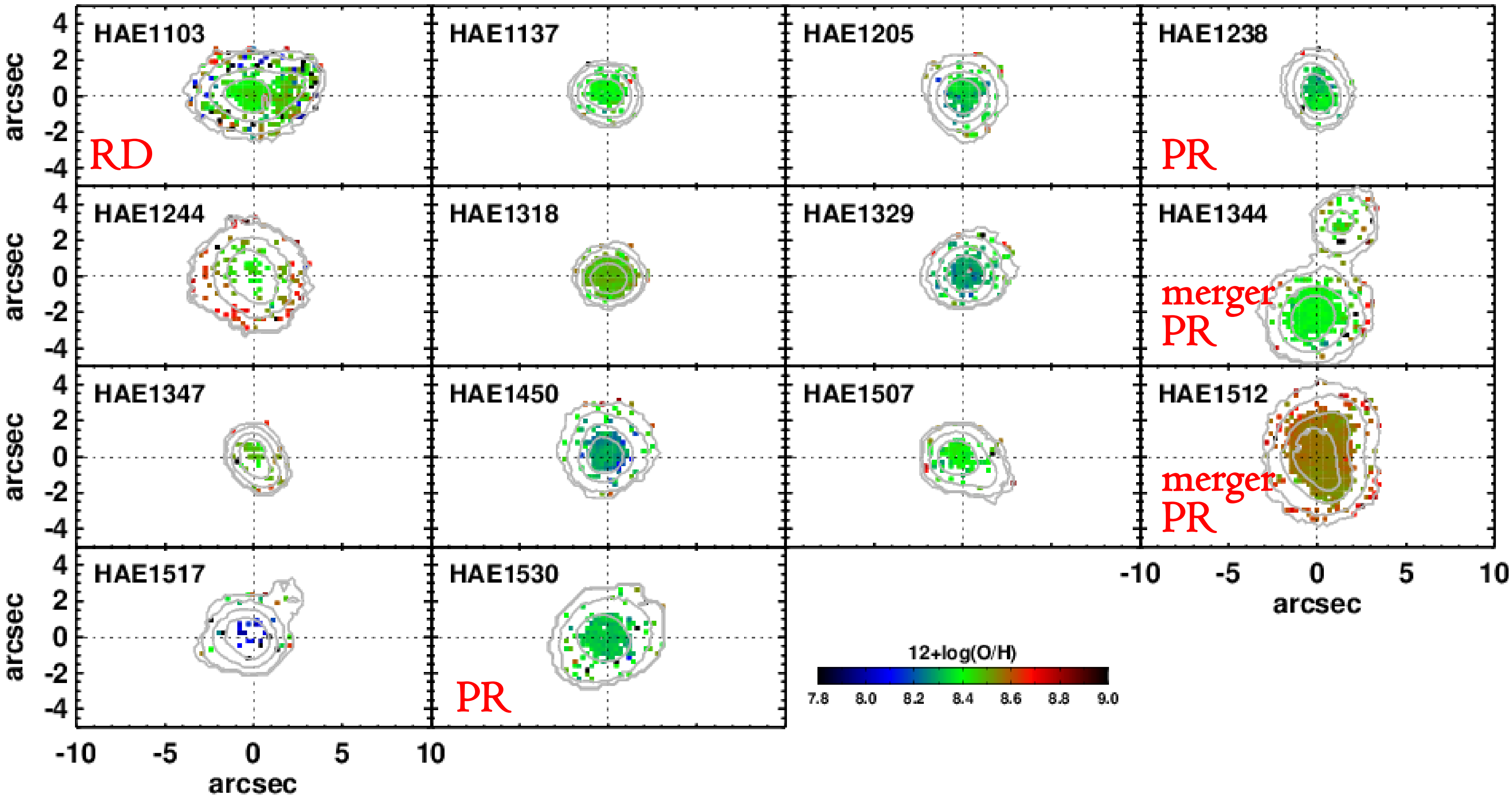


V/**σ** anti-correlates with SSFR? (c.f., Bellocchi et al. 2013 – V/**σ** vs. IR luminosity)

Metallicity distribution

Gas-phase metallicity from N2 parameter ([NII]6584/Hα; Pettini & Patel 2004)



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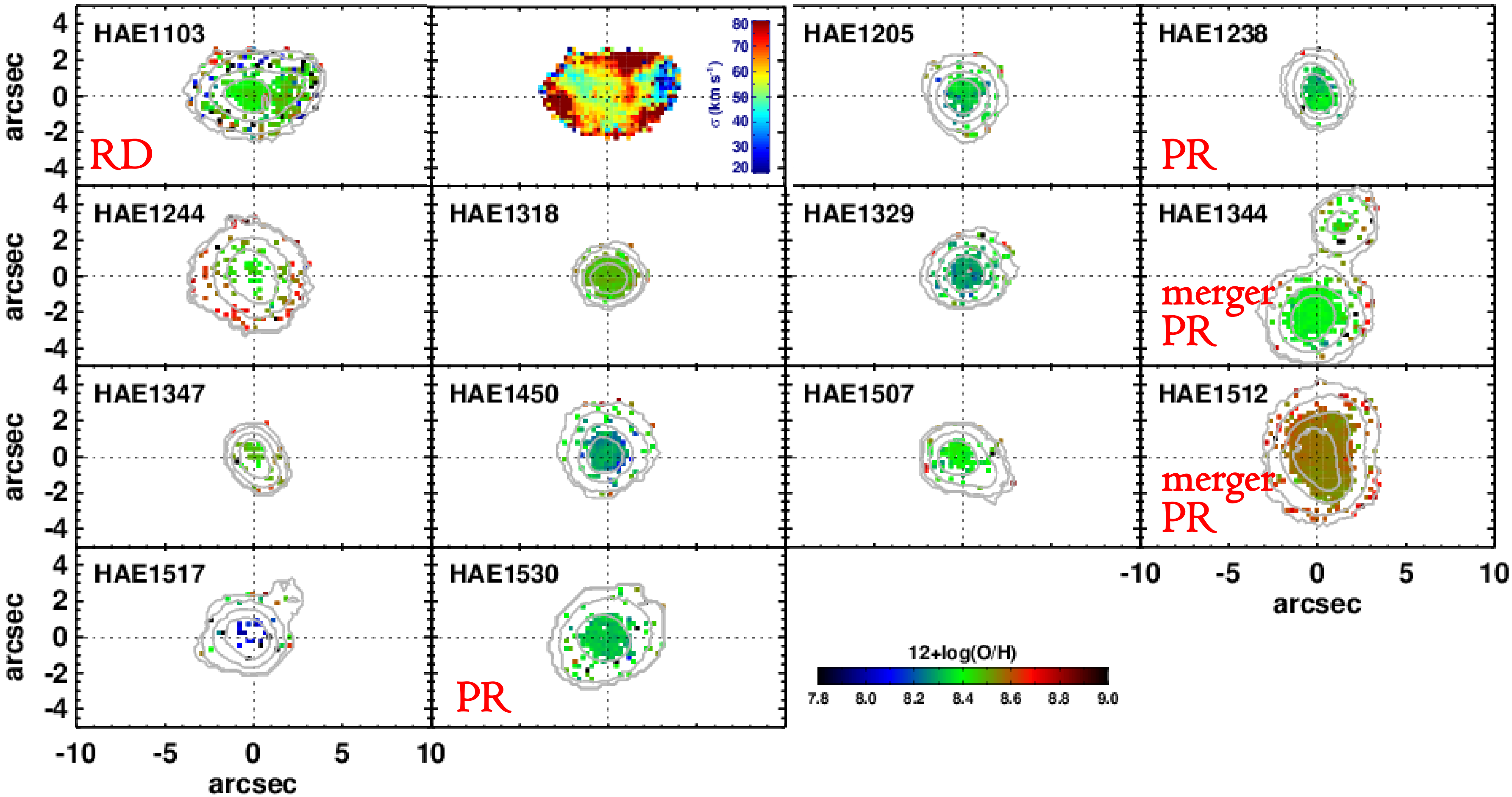
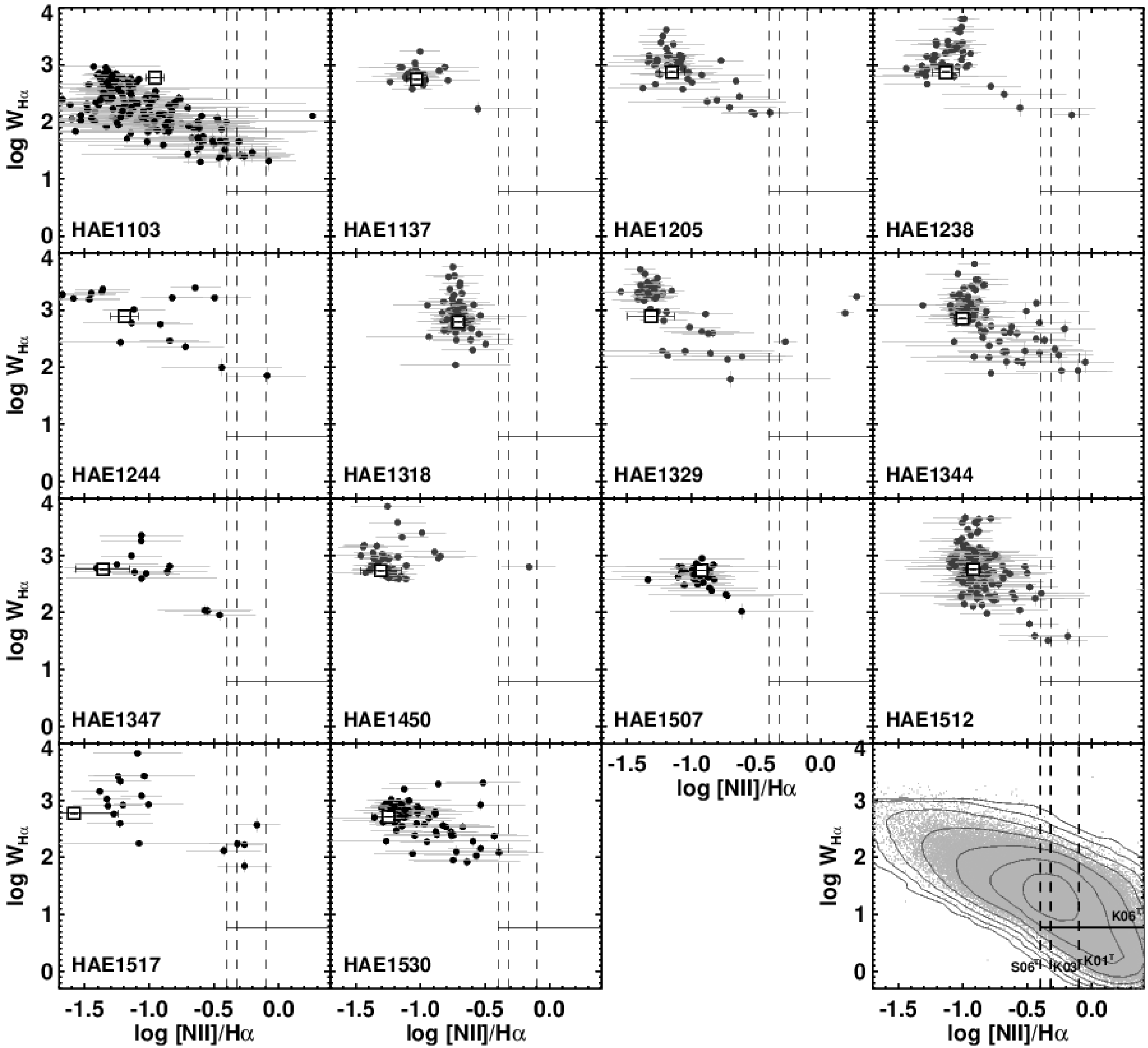


Origin of excitation : HII region vs. low-metallicy AGN?



Summary

- Local HAEs (selected using large Hα EW) are not dominated by stable rotating disks. Observation showed more 'dispersion-dominated galaxies' among these, which could be compact and clumpy clusters are embedded. Additionally, minor merger seems to be more efficient gas fueling mechanism in these galaxies compared to the filamentary accretion.

- By adding the lowest stellar mass range, local HAEs may suggest the overall anti-correlation between V/σ and the SSFR.

- It is possible that local HAEs are dynamically hot thus could have high gas fraction. Could this be measured independently through molecular observation?