Small-scale Intensity Mapping:
Extended Halos as a Probe of Reionization Physics

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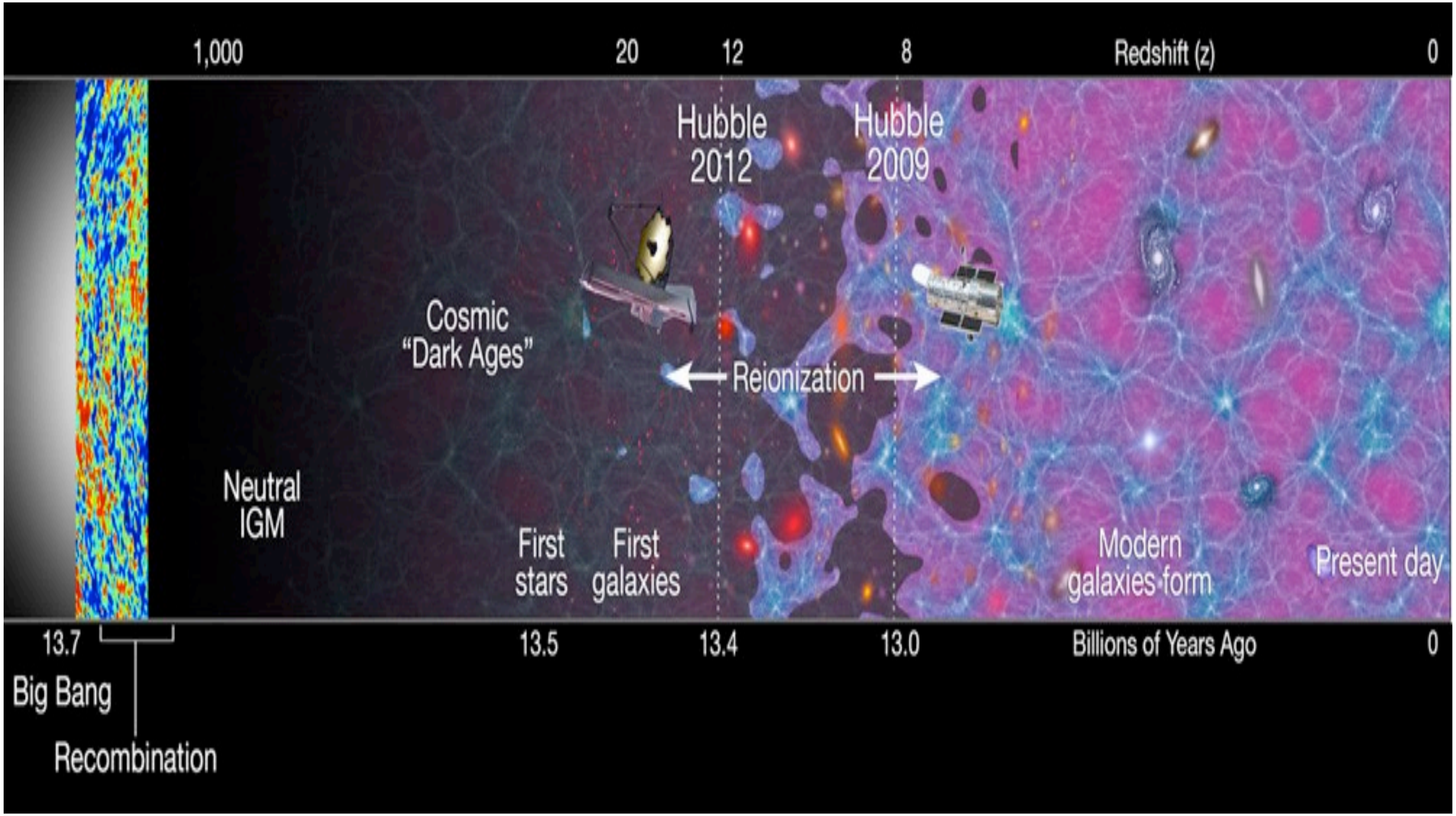
with Mark Dijkstra, Joseph Hennawi, Michele Trenti, Fred Davies, Jonathan Stern, Rieko Momose, Masami Ouchi and Hans-Walter Rix

UiO : Universitetet i Oslo



credit: m.caltech.edu/file/6861

Outline

Extended halos at $z \sim 0$

Extended halos at $z \sim 2 - 4$

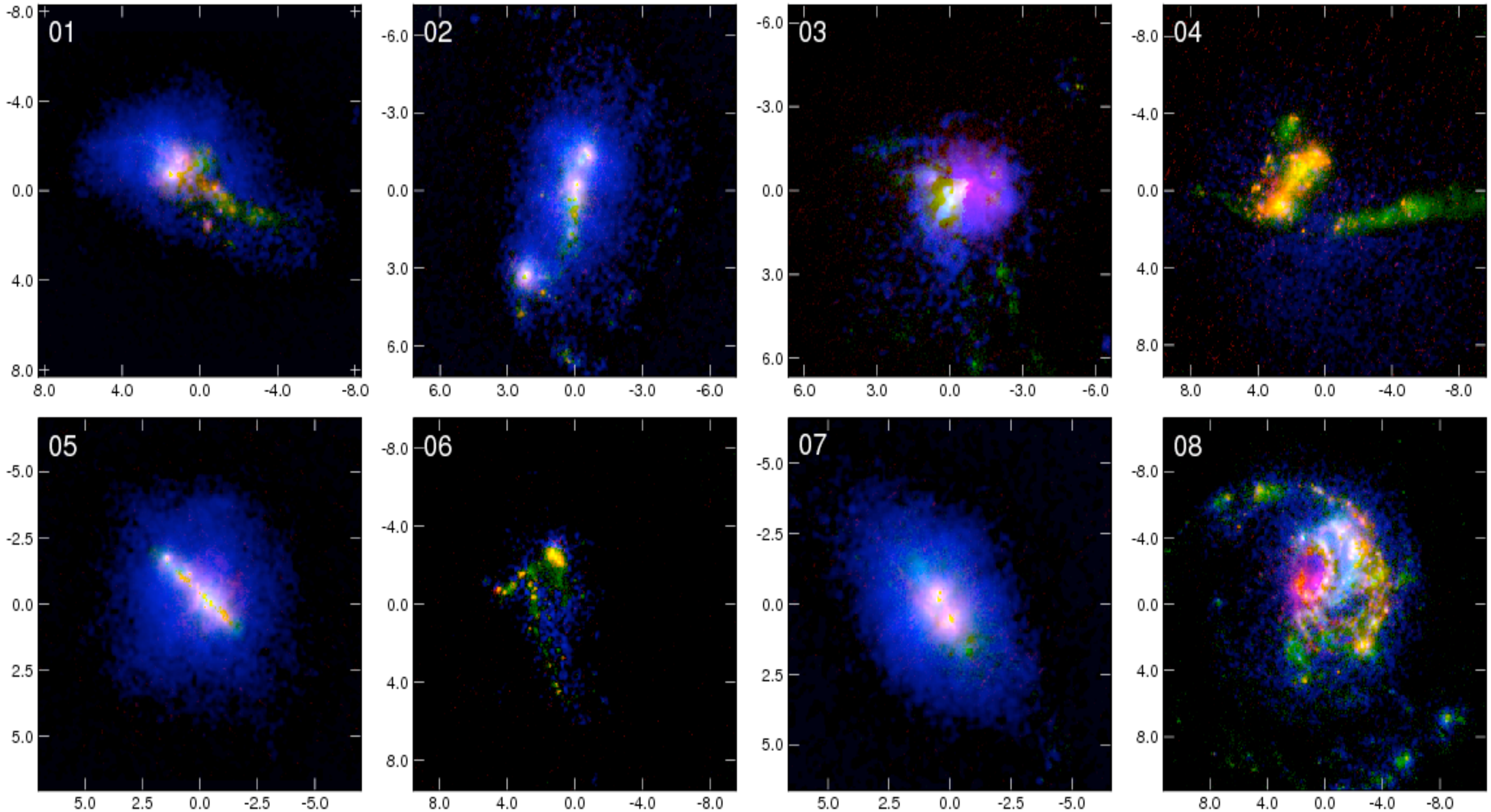
Production mechanisms

Halo star formation approach

Extended halos at $z \sim 5 - 7$ (EoR)

Conclusions

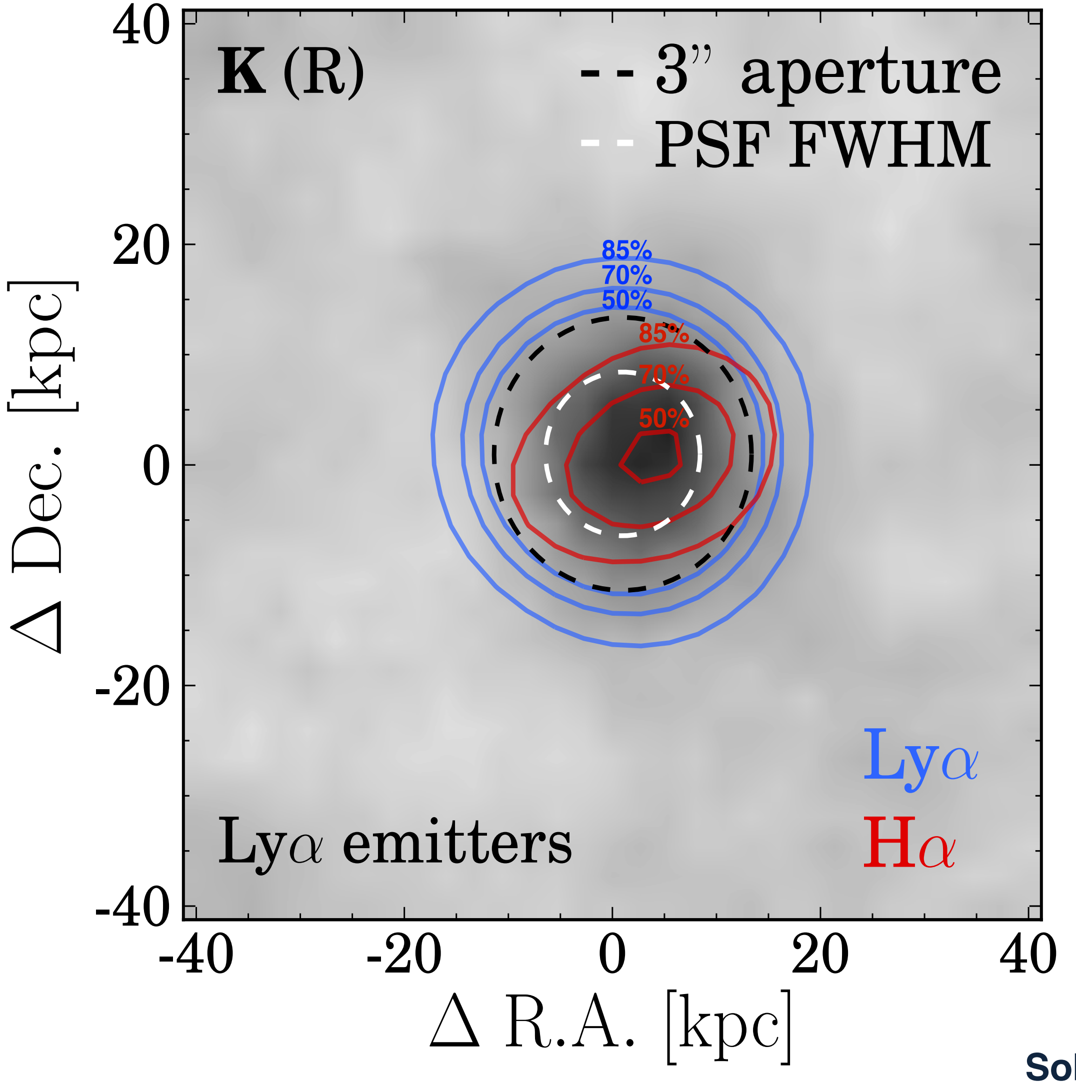
Extended halos at z ~ 0



UV Lya Ha

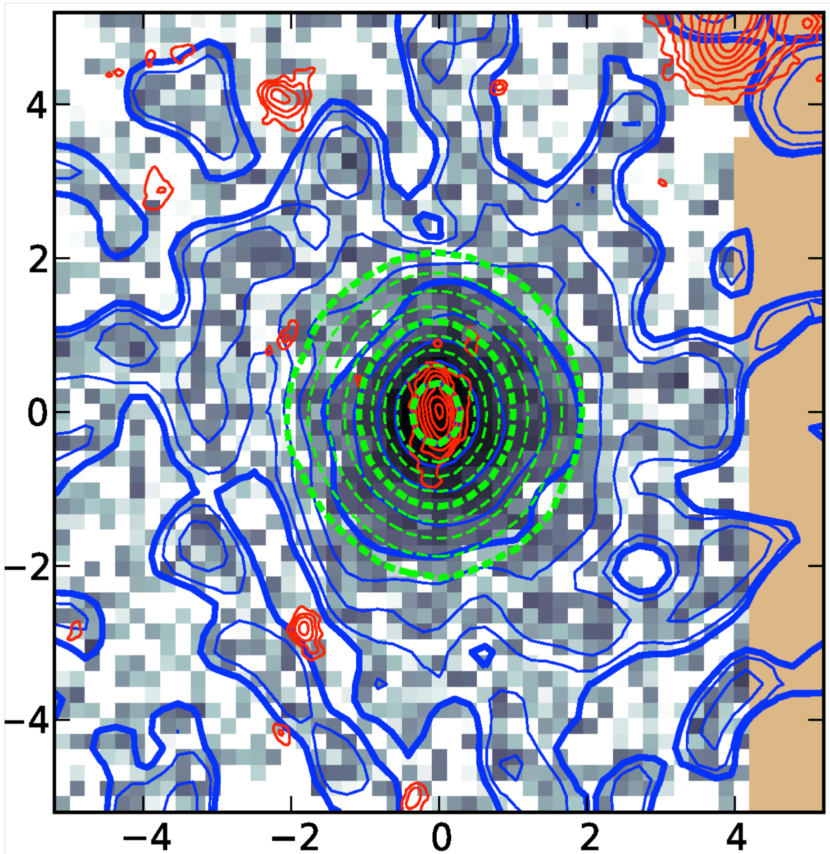
Hayes et al. 2013, and the LARS team

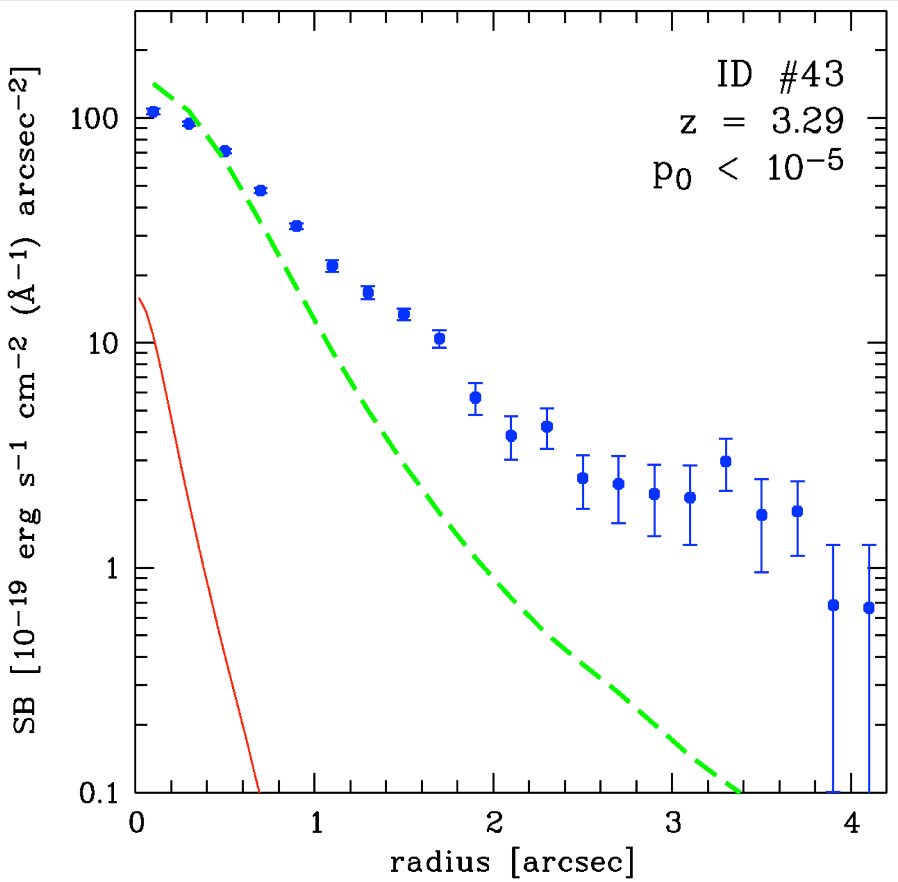
Extended halos at z ~ 2 - 4



Sobral et al. 2016

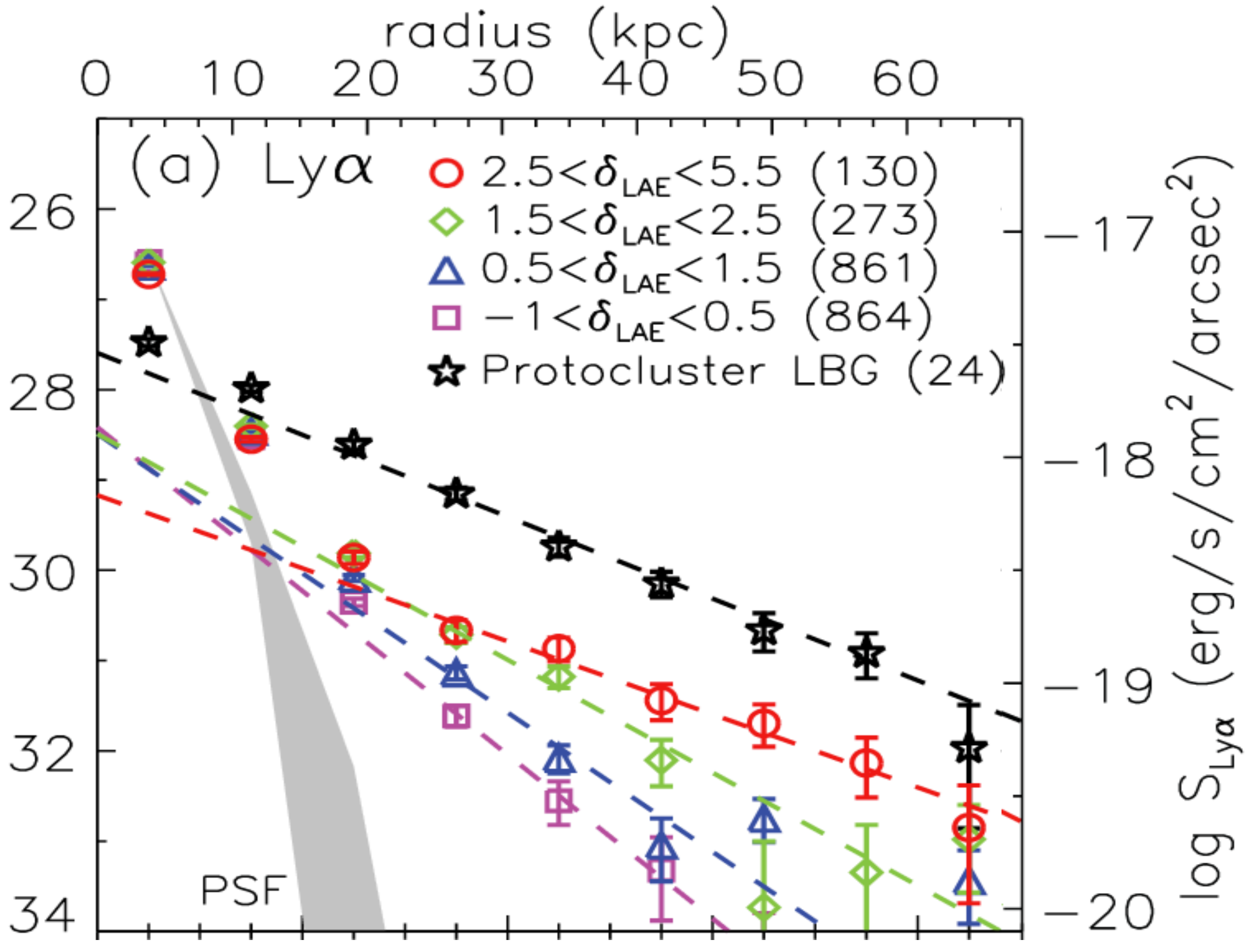
Extended halos at z ~ 2 - 4





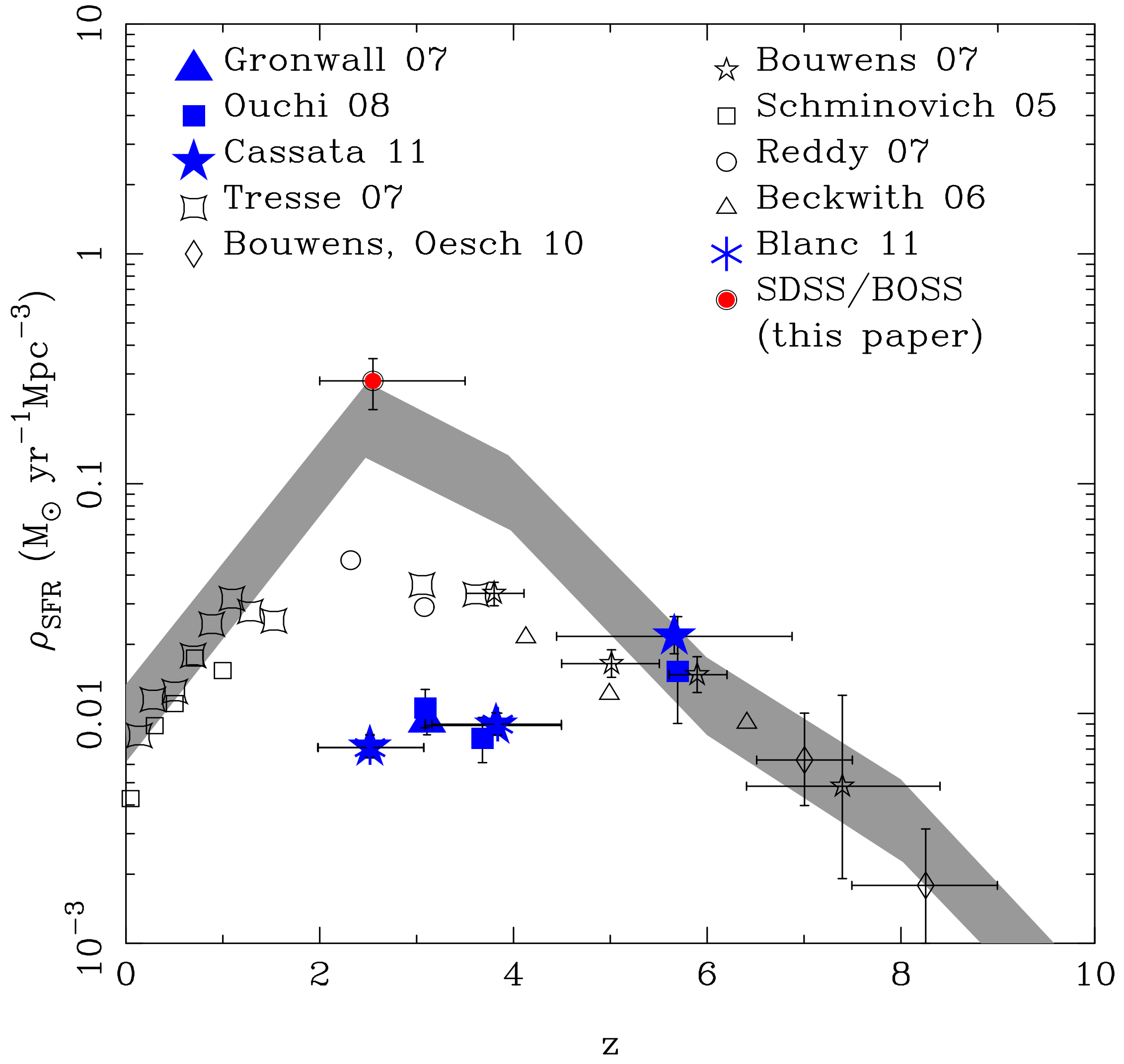
Wisotzki et al. 2016

Extended halos at z ~ 2 - 4



Matsuda et al. 2012 (see also Momose et al. 2014)

Lyα Intensity Mapping



Croft et al. 2016

Production mechanisms

Who plays a role and where ?

Nebular (stellar) radiation: **UV** + **Lya** + **Ha**

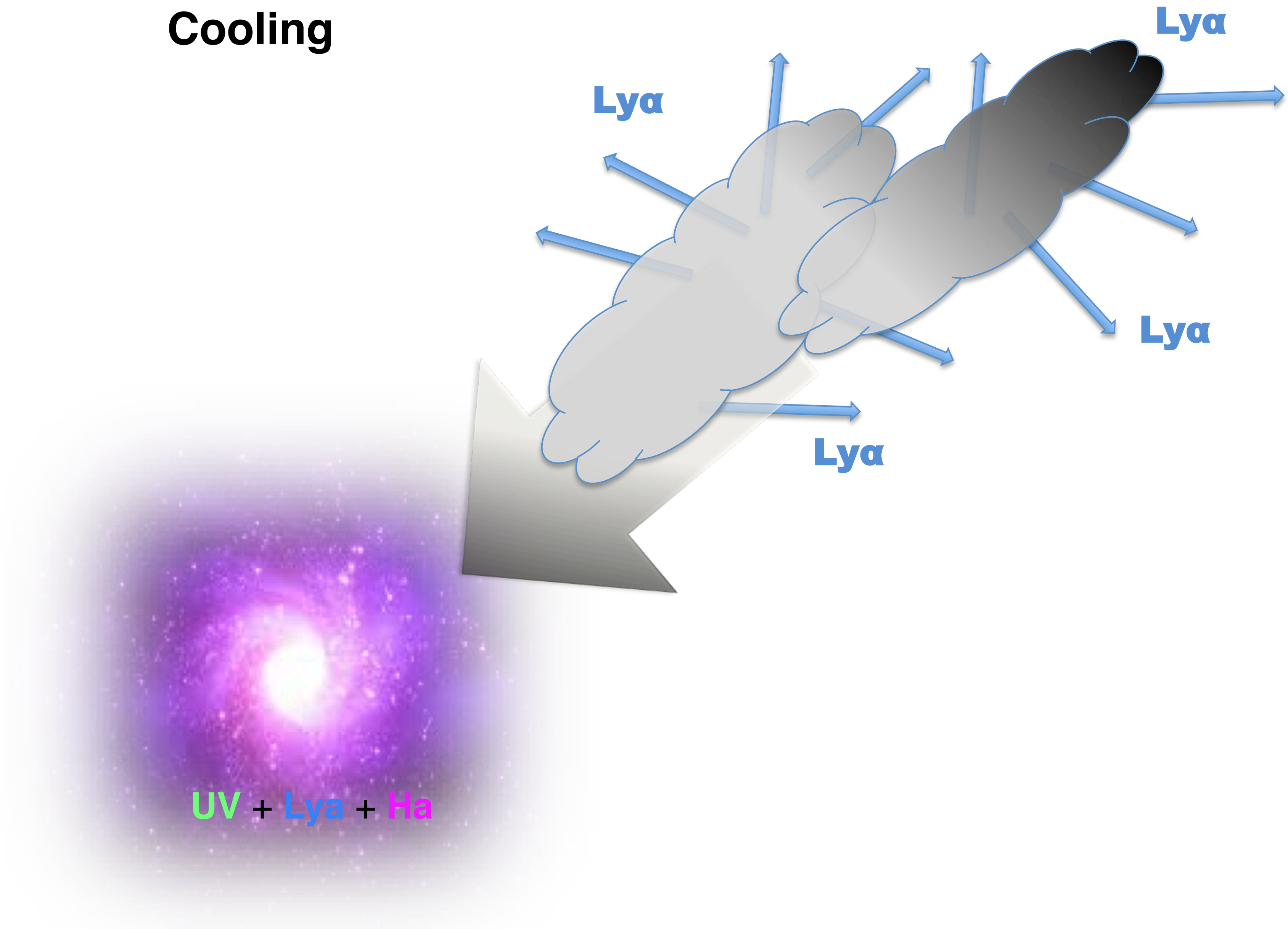
Cooling: **Lya**

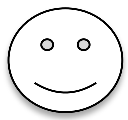
Scattering: **Lya**

Flourescence: **Lya** + **Ha**

Production mechanisms

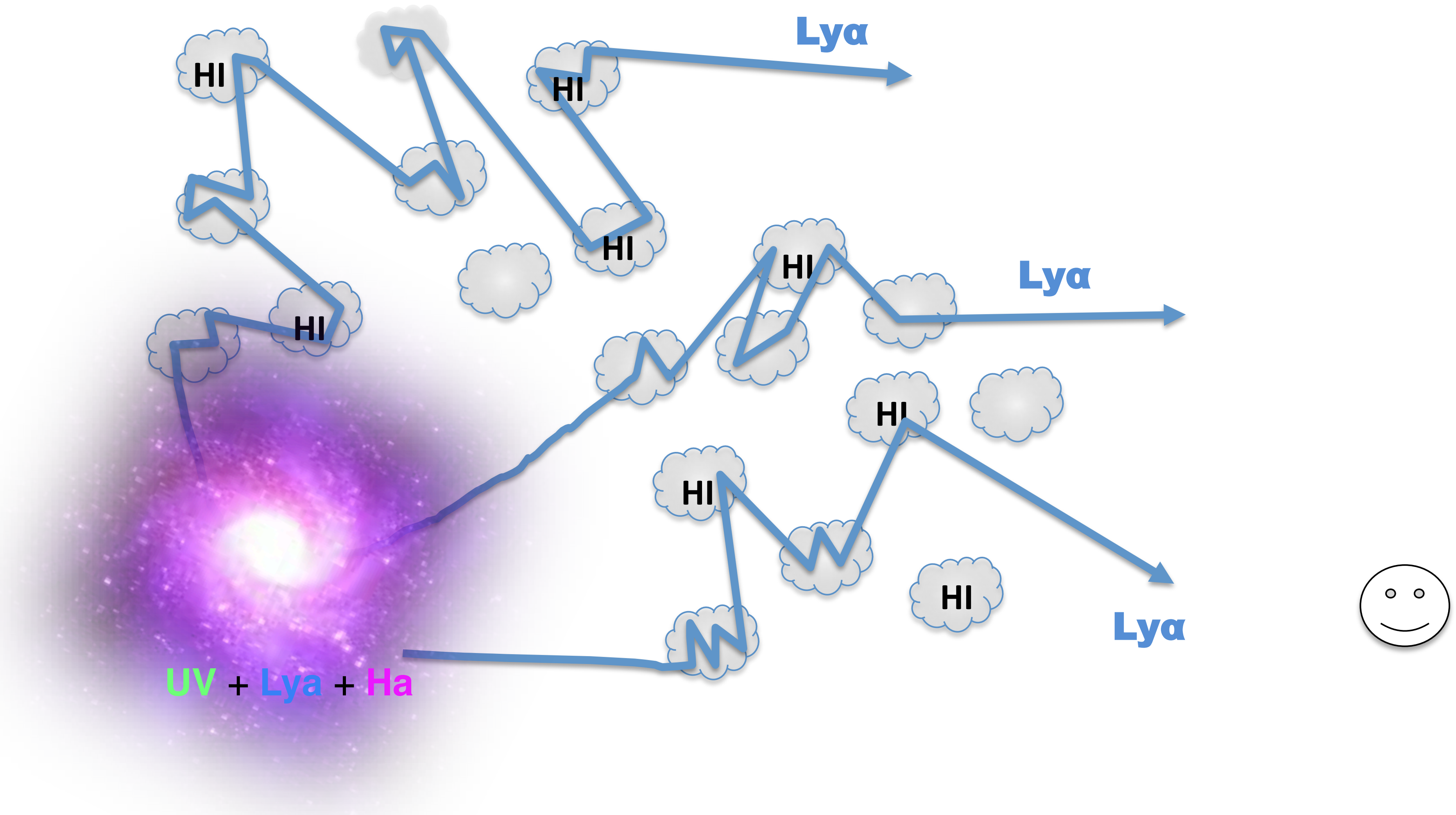
Cooling





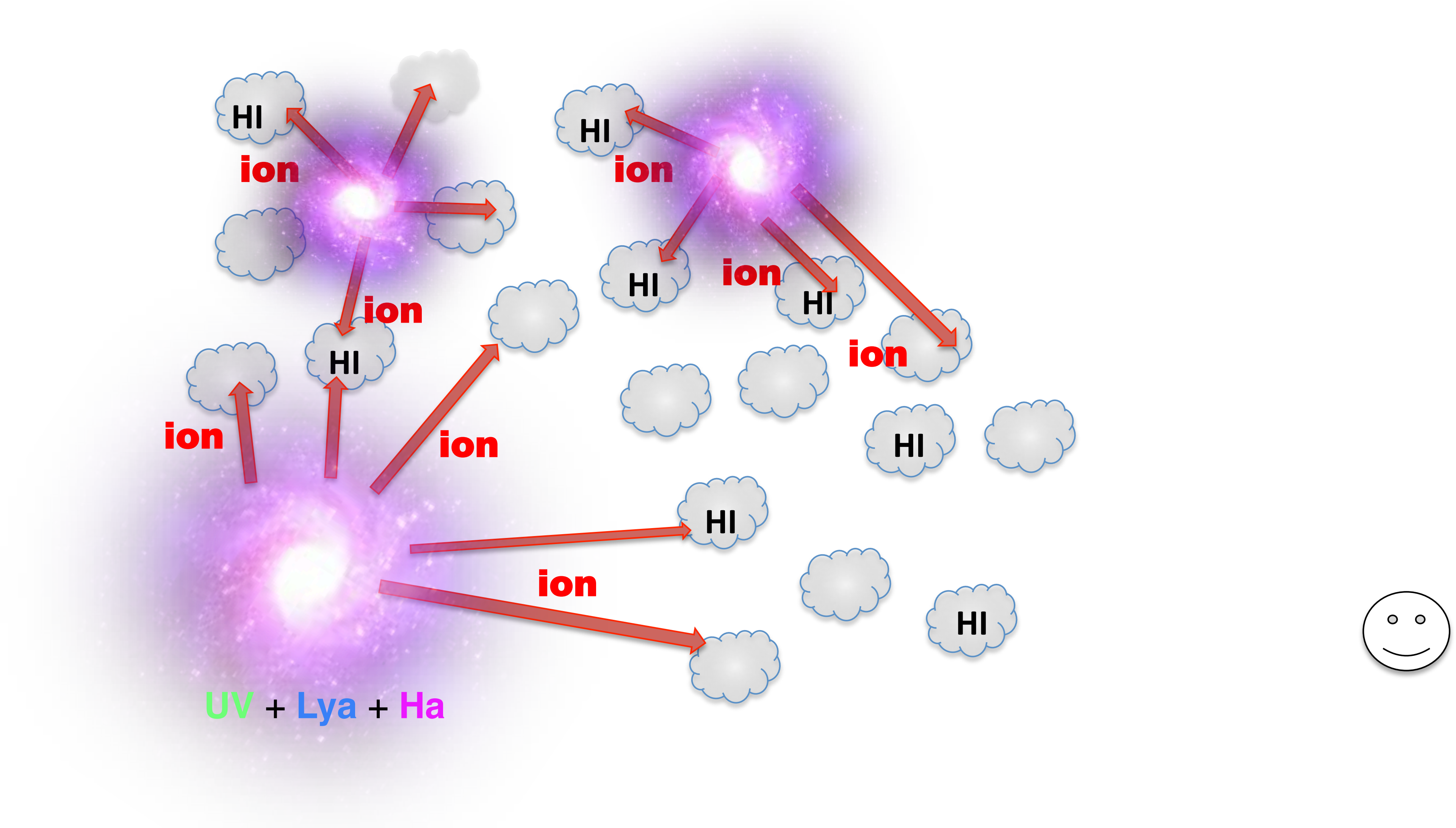
Production mechanisms

Scattering



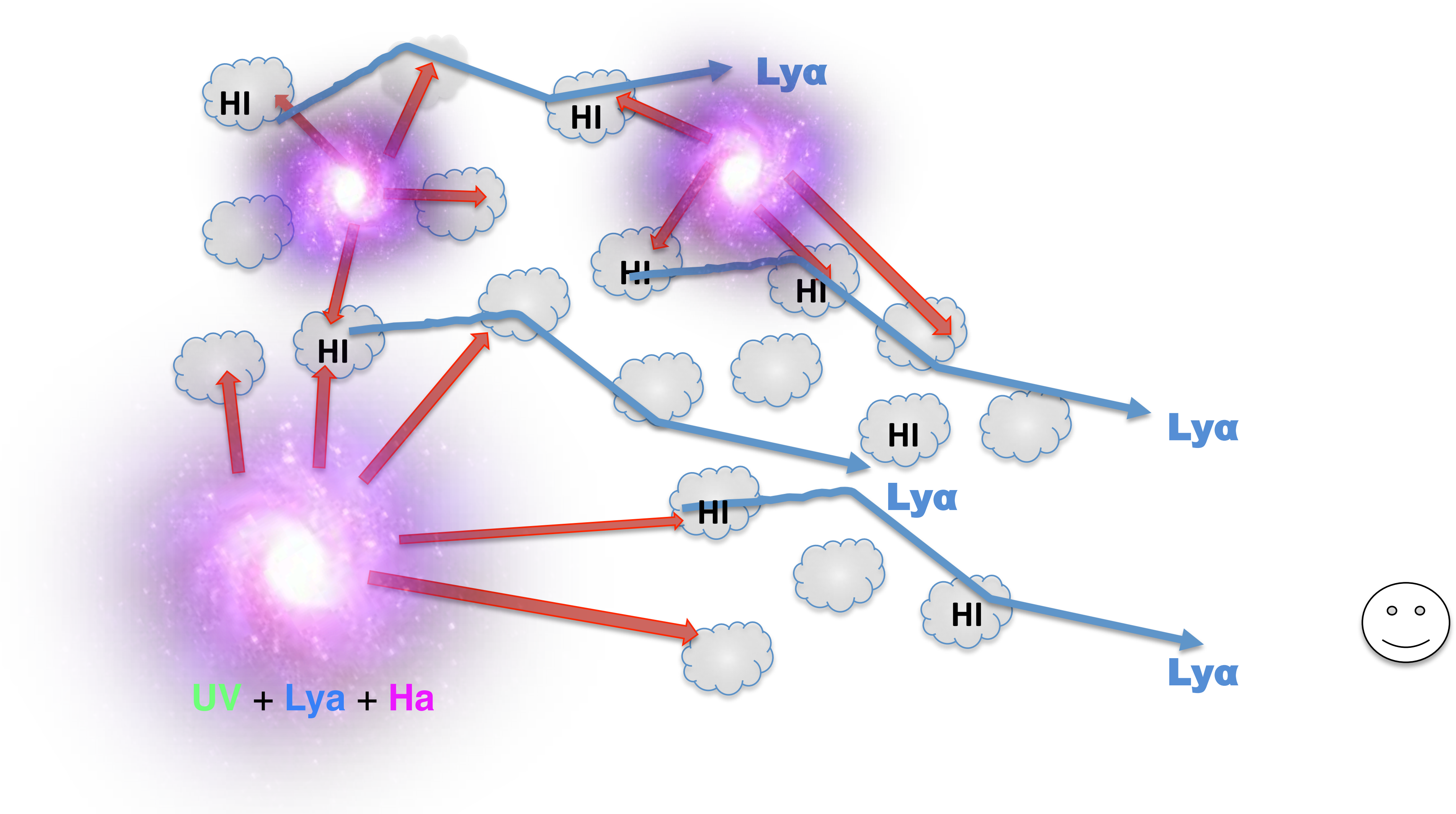
Production mechanisms

Fluorescence



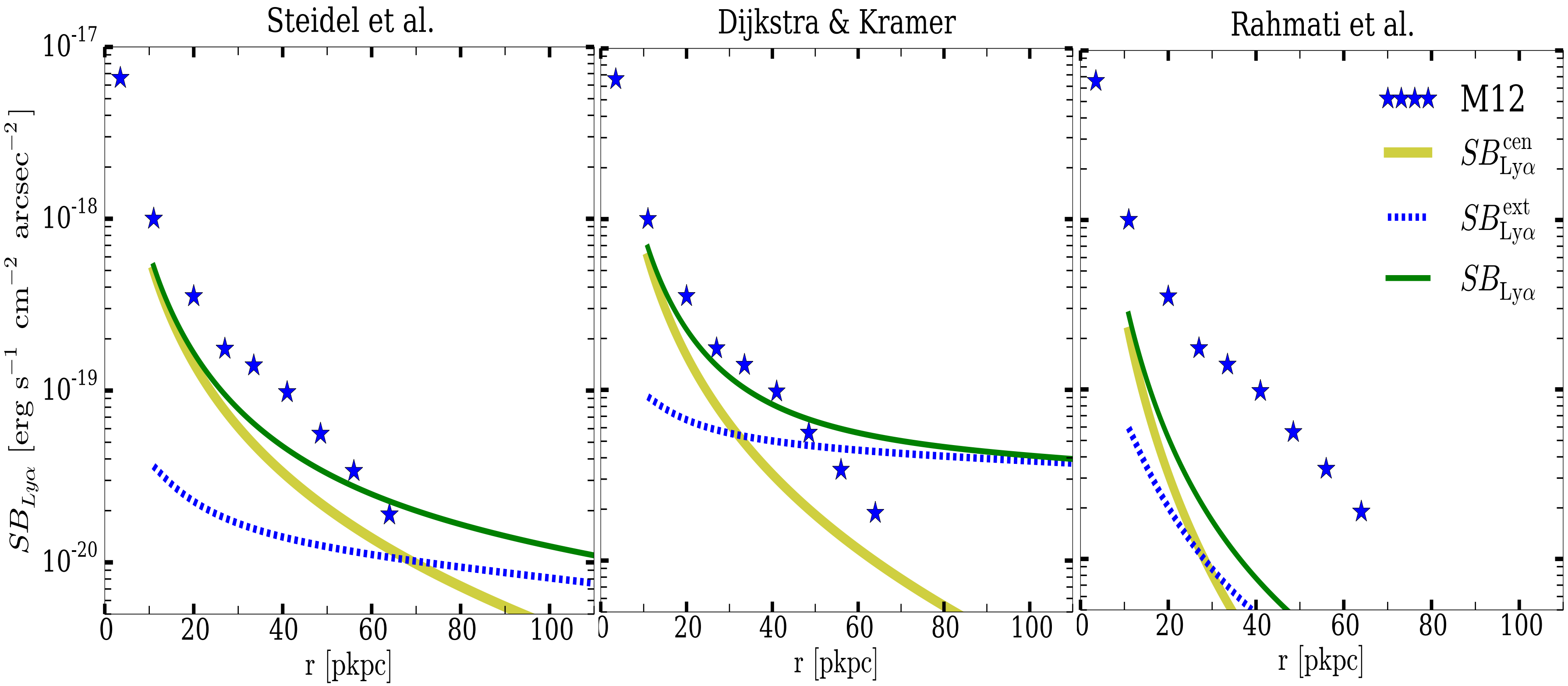
Production mechanisms

Fluorescence



Production mechanisms

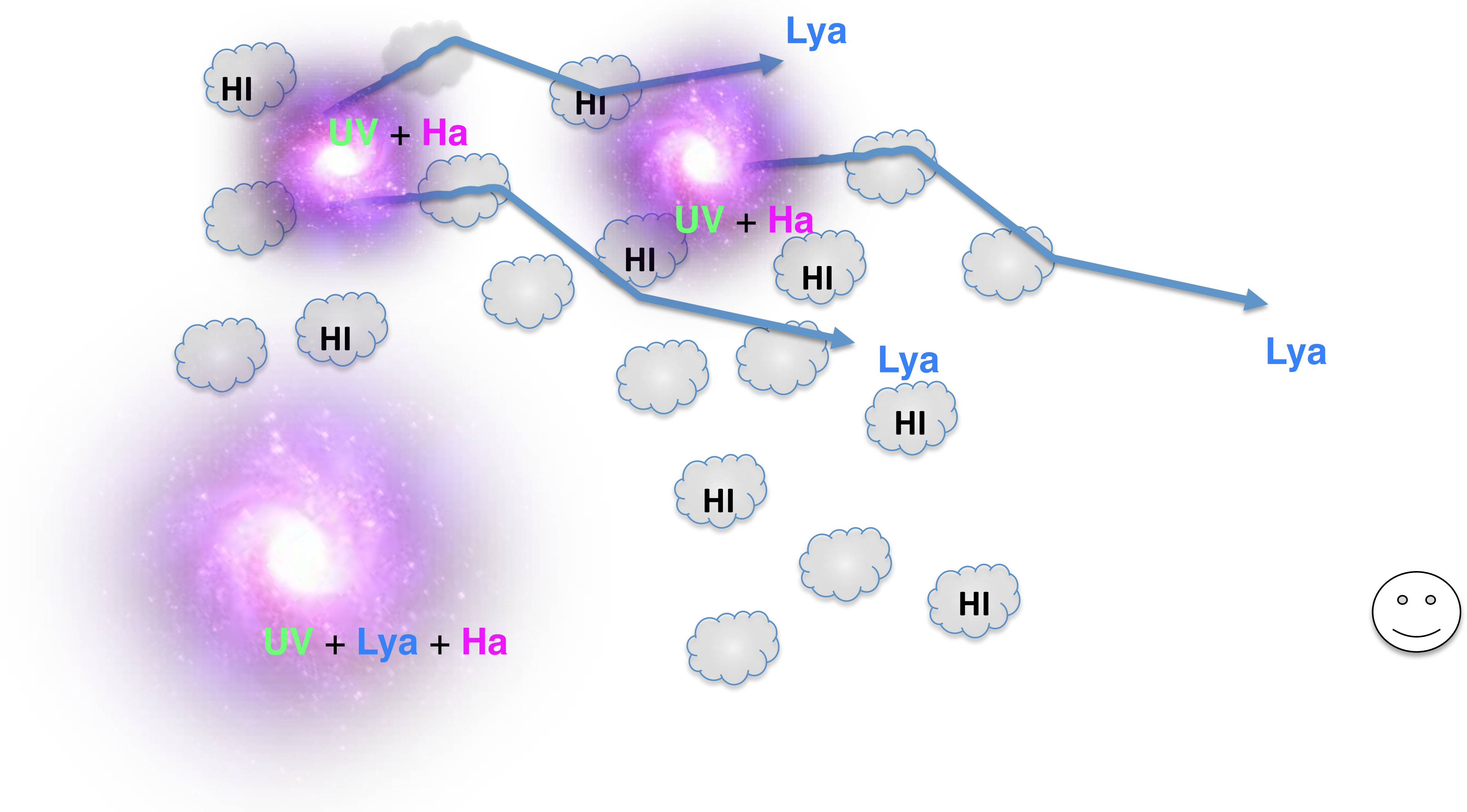
Fluorescence



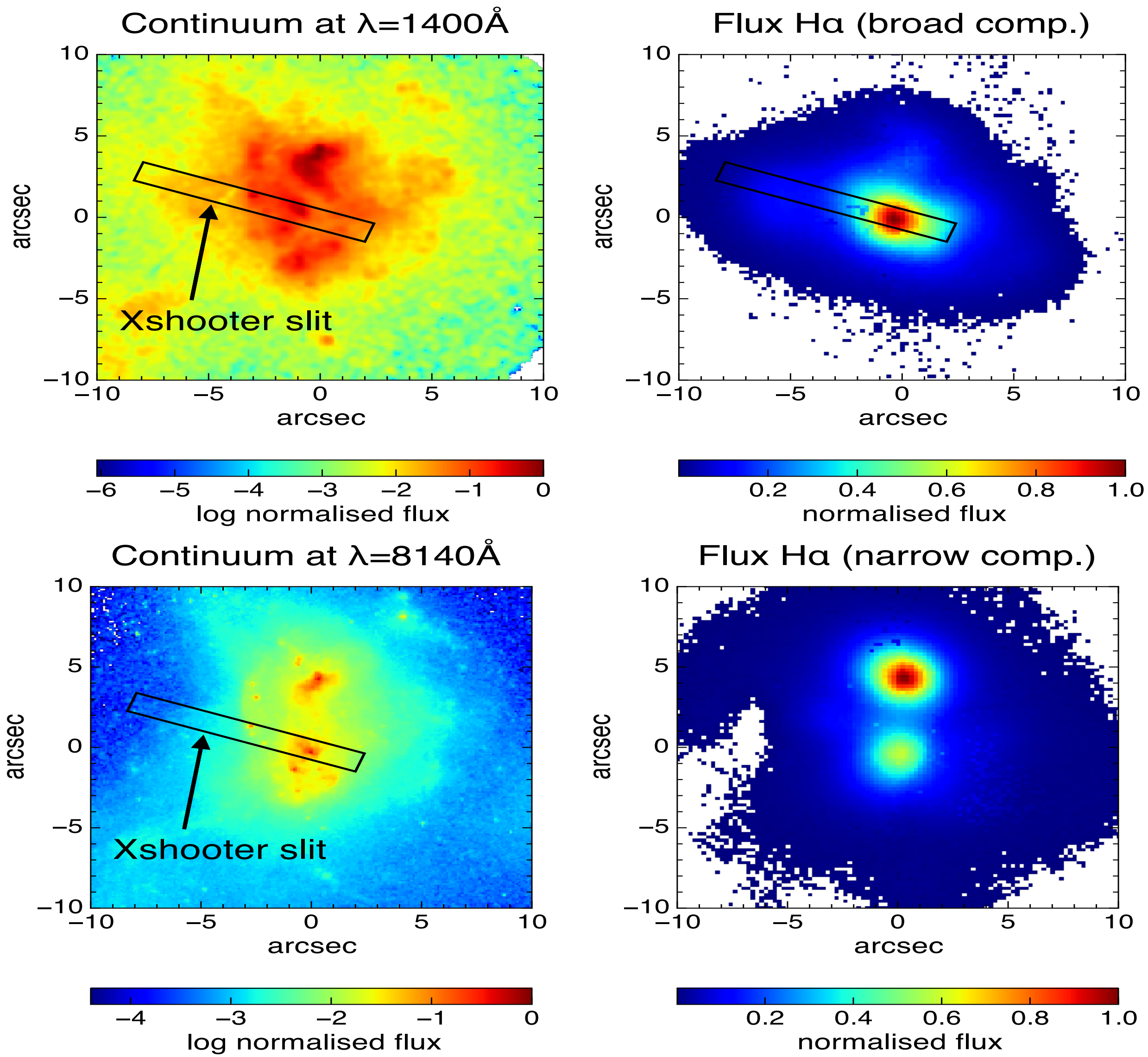
LMR & Dijkstra 2016

Production mechanisms

Halo star formation: nebular ‘in-situ’ radiation

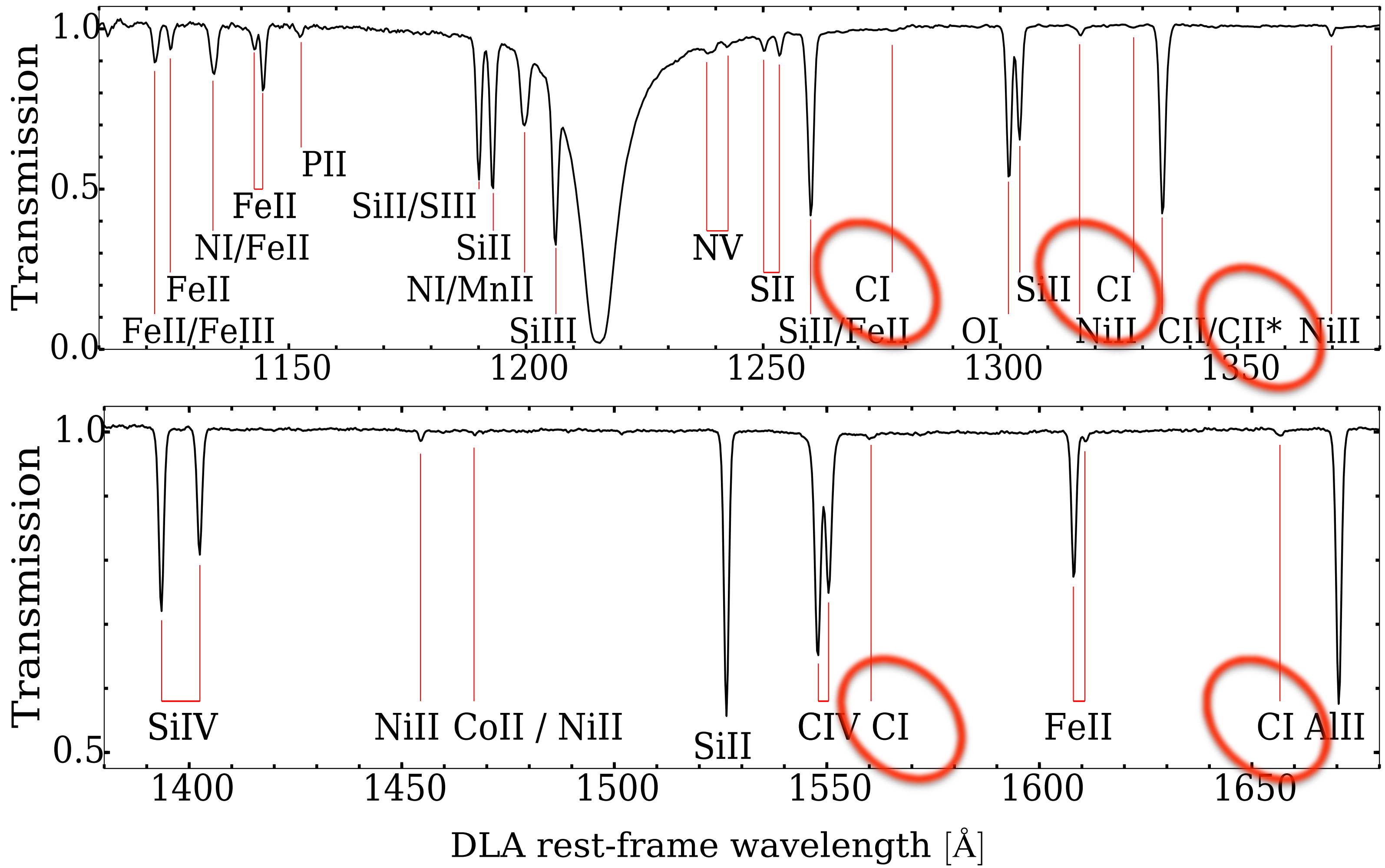


Halo star formation approach



Maiolino et al. 2017 (Nature)

Halo star formation approach



LMR, Miralda-Escudé et al. 2016

Halo star formation approach

Star formation activity in the outer Galaxy

“… we successfully **identified 711 new candidate star-forming regions in 240 molecular clouds up to Rg ~ 20 kpc,** which enable statistical studies of star-formation activities up to the extreme outer Galaxy for the first time. “

Natsuko Izumi (NAOJ) 8 Mar ‘17

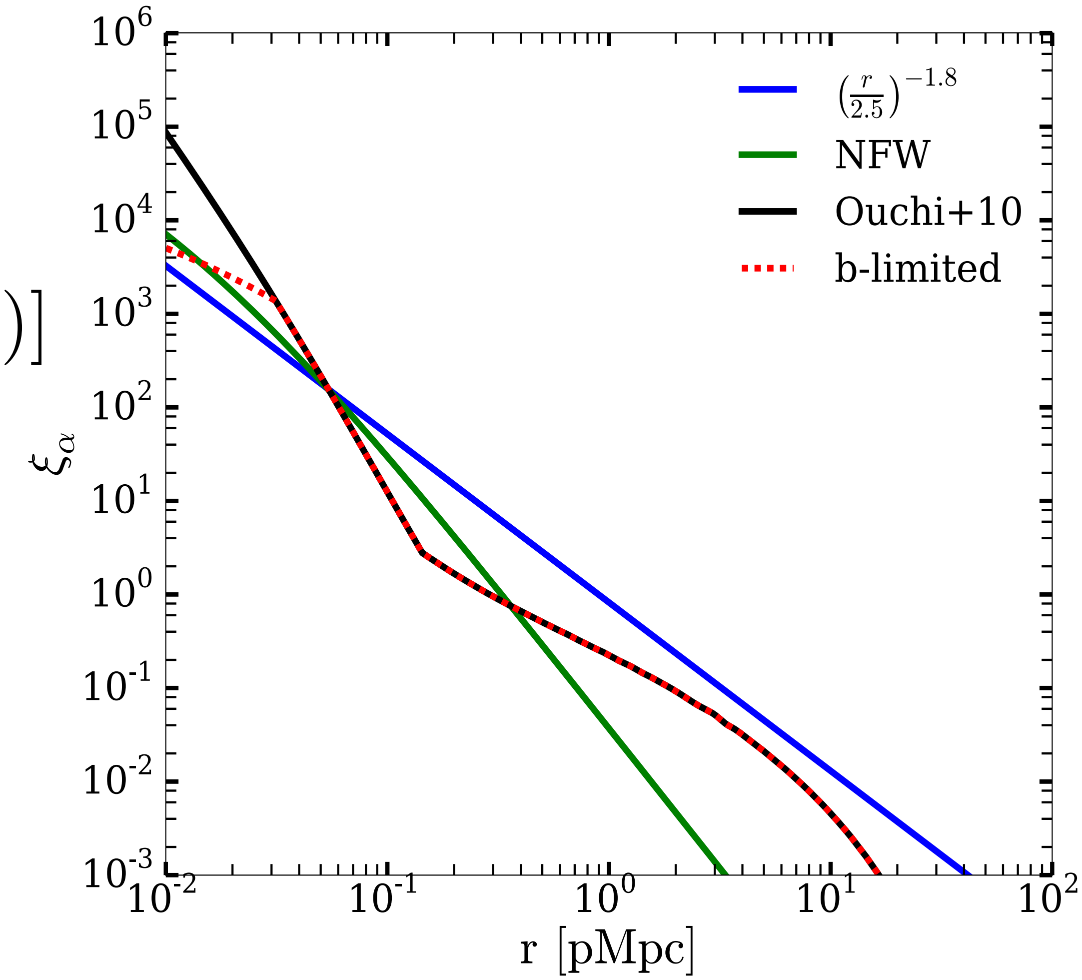
Astronomy Tea Talks at Caltech

Mondays, Cahill 312
Tea: 4.00pm
Talk: 4.05pm

Halo star formation approach

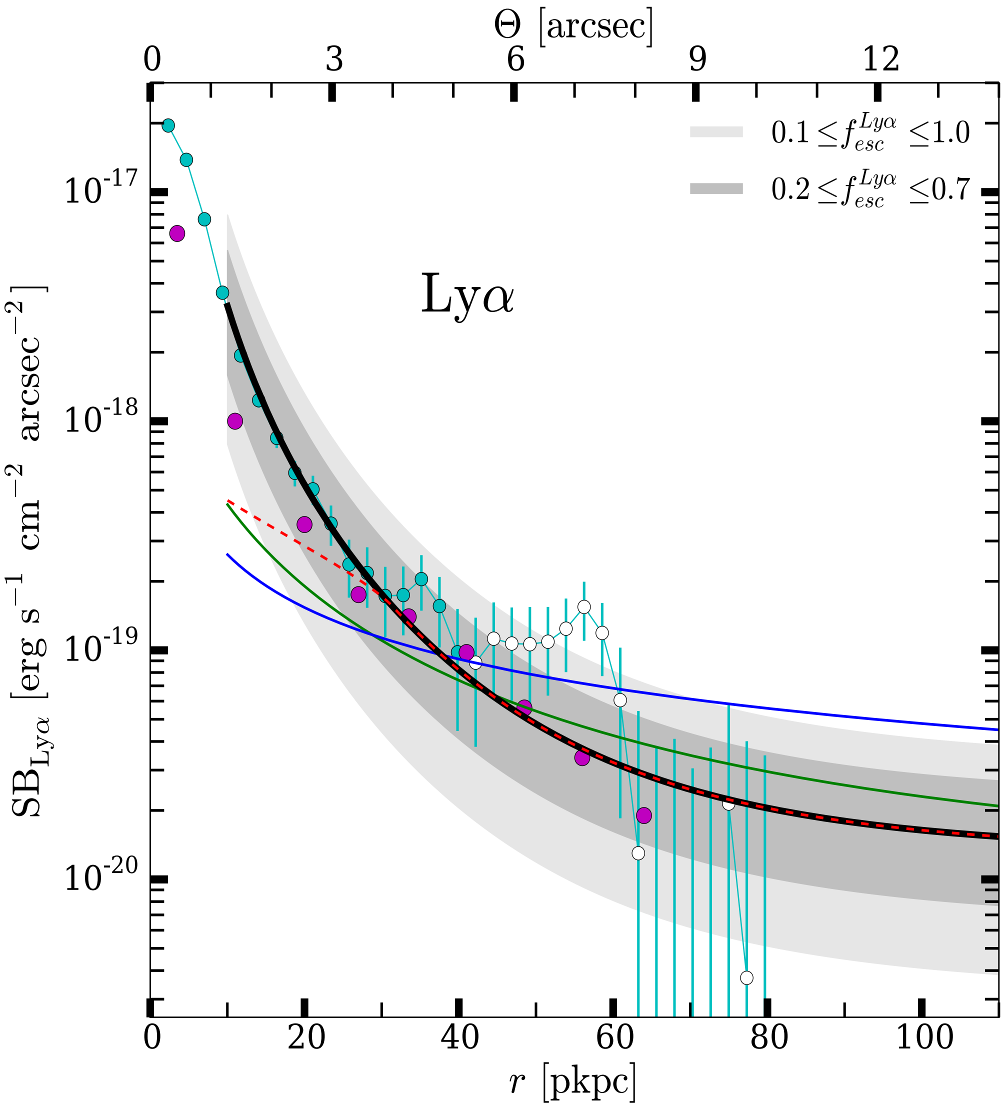
$$\bar{\epsilon}_{\mathrm{Ly}\alpha} \propto \rho_{\mathrm{SFR}}$$

$$\epsilon_{\mathrm{Ly}\alpha} = \bar{\epsilon}_{\mathrm{Ly}\alpha}[1 + \xi_\alpha(r)]$$



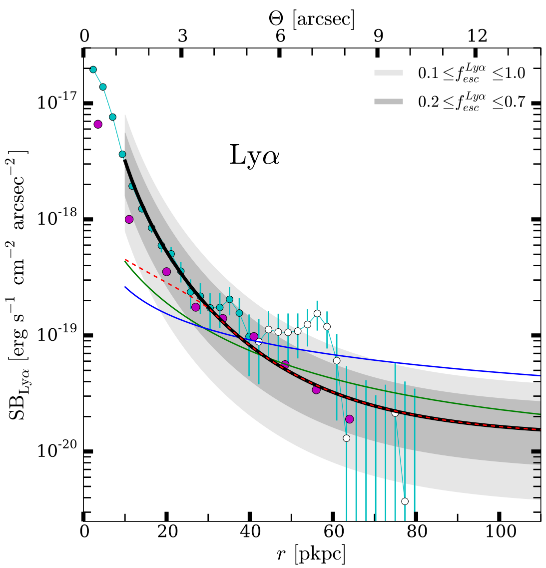
LMR et al. 2017a

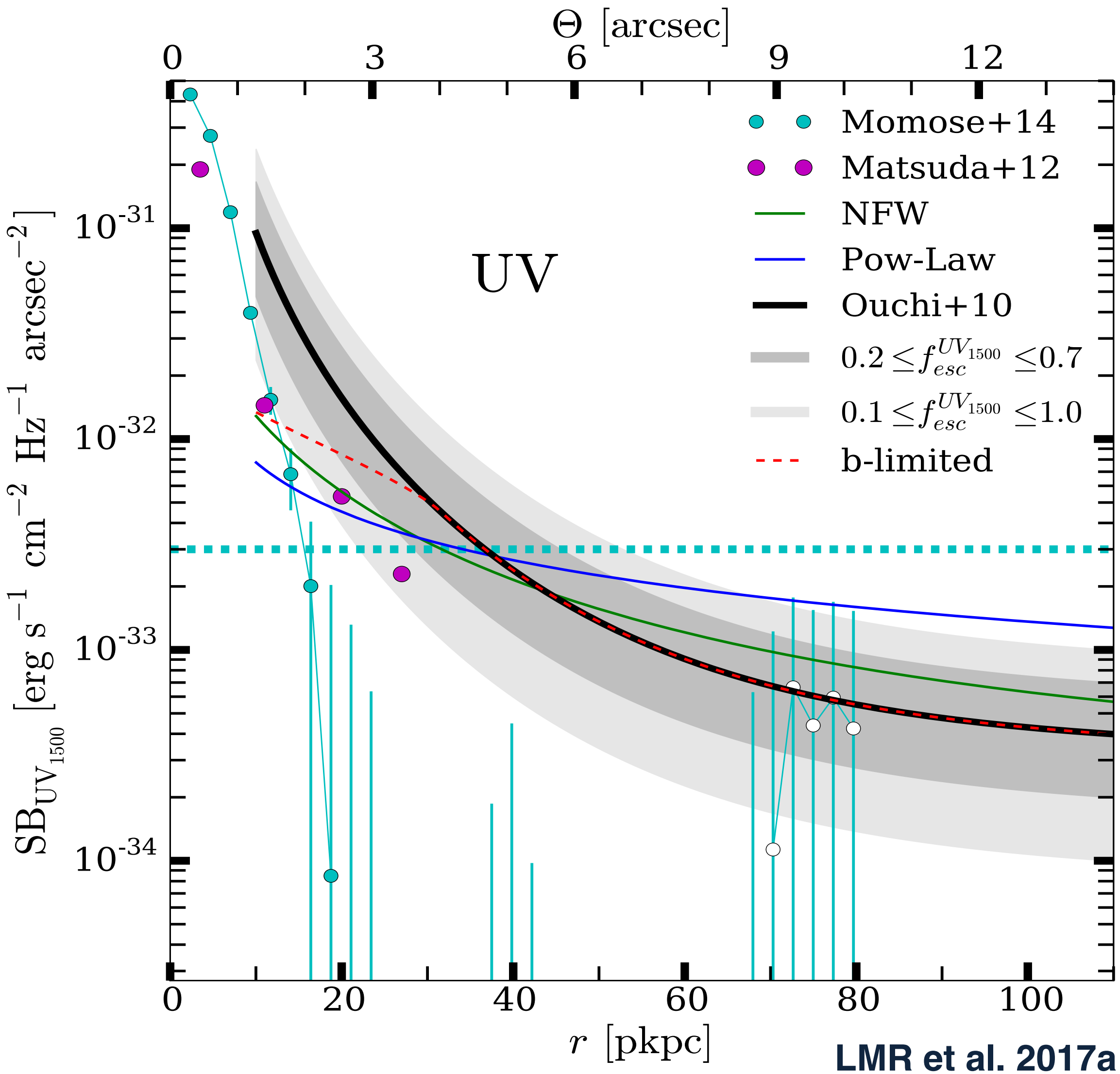
Halo star formation approach



LMR et al. 2017a

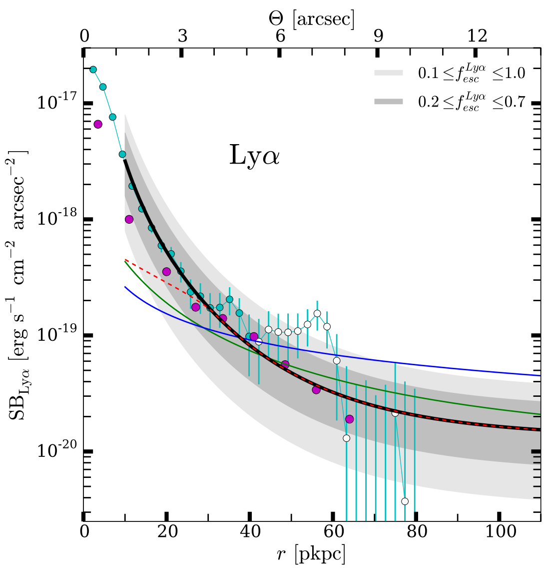
Halo star formation approach

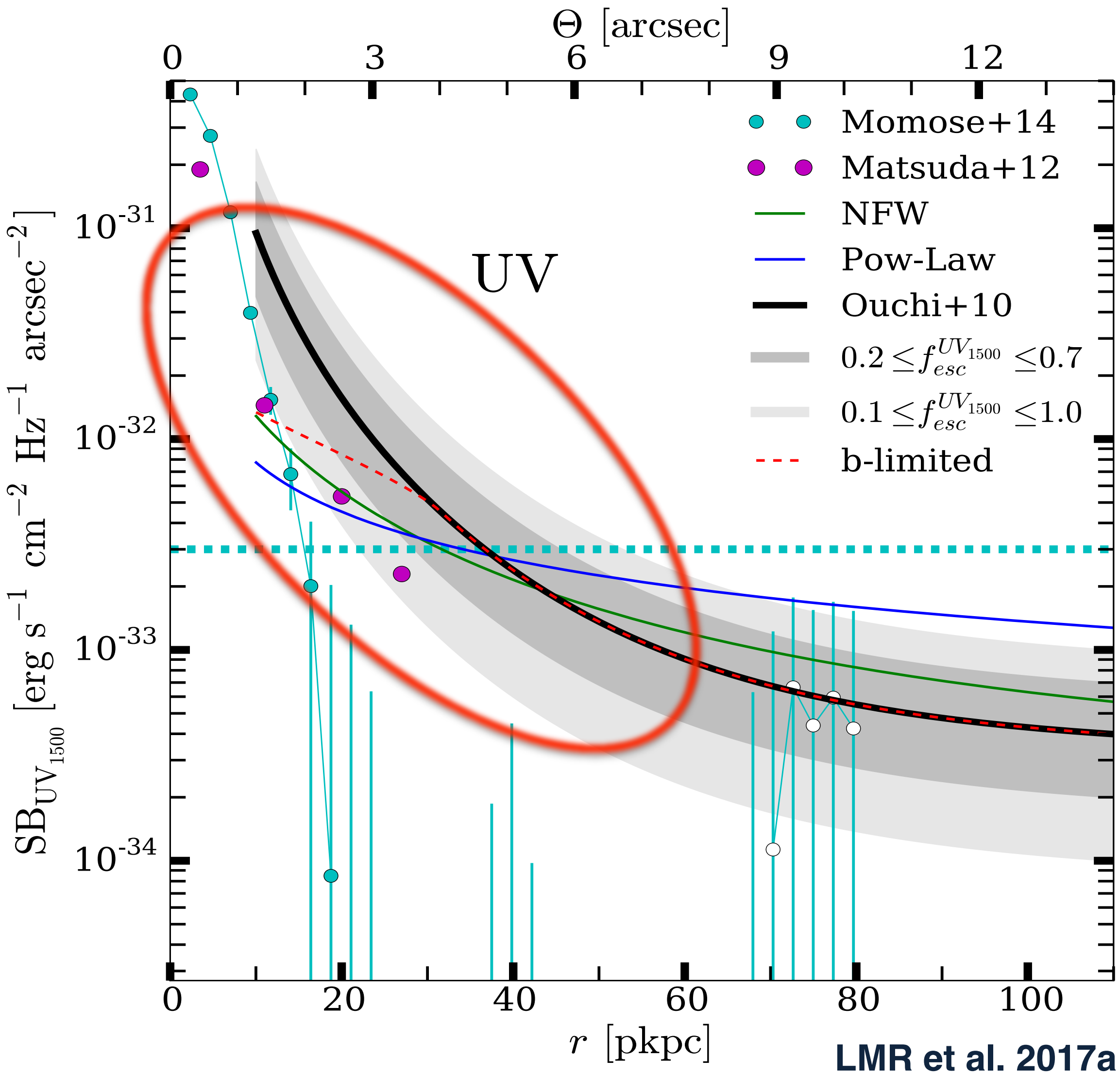




LMR et al. 2017a

Halo star formation approach





LMR et al. 2017a

Halo star formation approach

$$L_{\mathrm{Ly}\alpha}\,[\mathrm{erg\,s^{-1}}] = 1.3\times10^{42}\,\mathrm{SFR}\,[\mathrm{M_\odot\,yr^{-1}}]$$
$$L_{\mathrm{UV}}\,[\mathrm{erg\,s^{-1}\,Hz^{-1}}] = 8\times10^{27}\,\mathrm{SFR}\,[\mathrm{M_\odot\,yr^{-1}}]$$

Halo star formation approach

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Case-B recombination → departures at low metallicities

$N_e \sim 100$ cm^{-2}

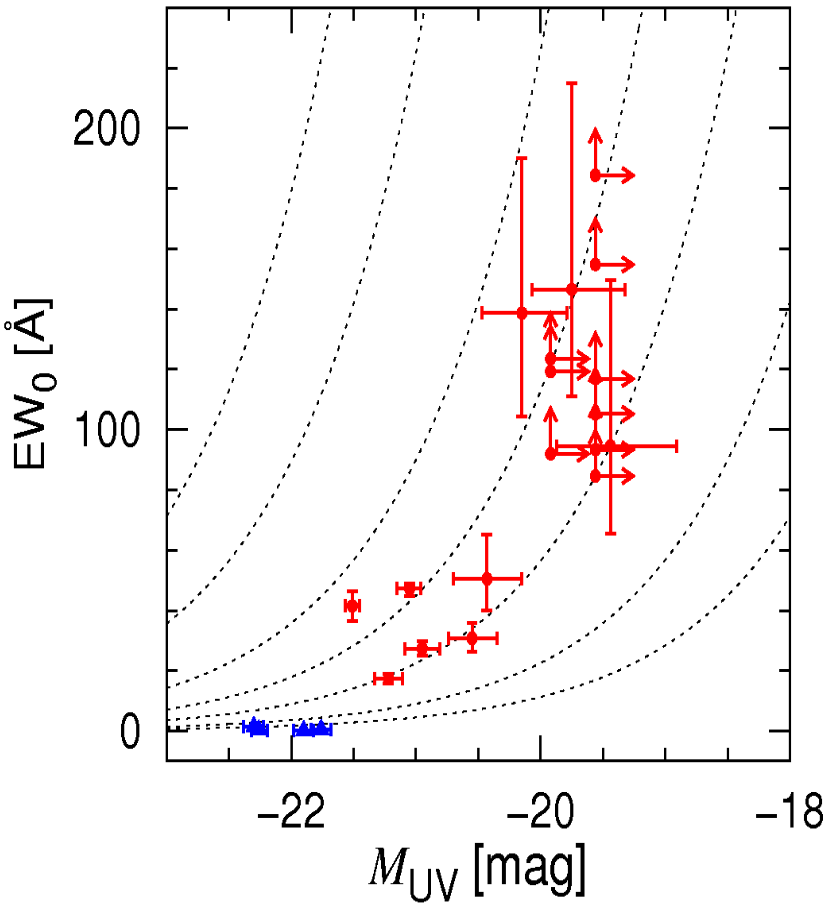
$T_e \sim 10^4$ K

1 – 100 Msun stellar masses

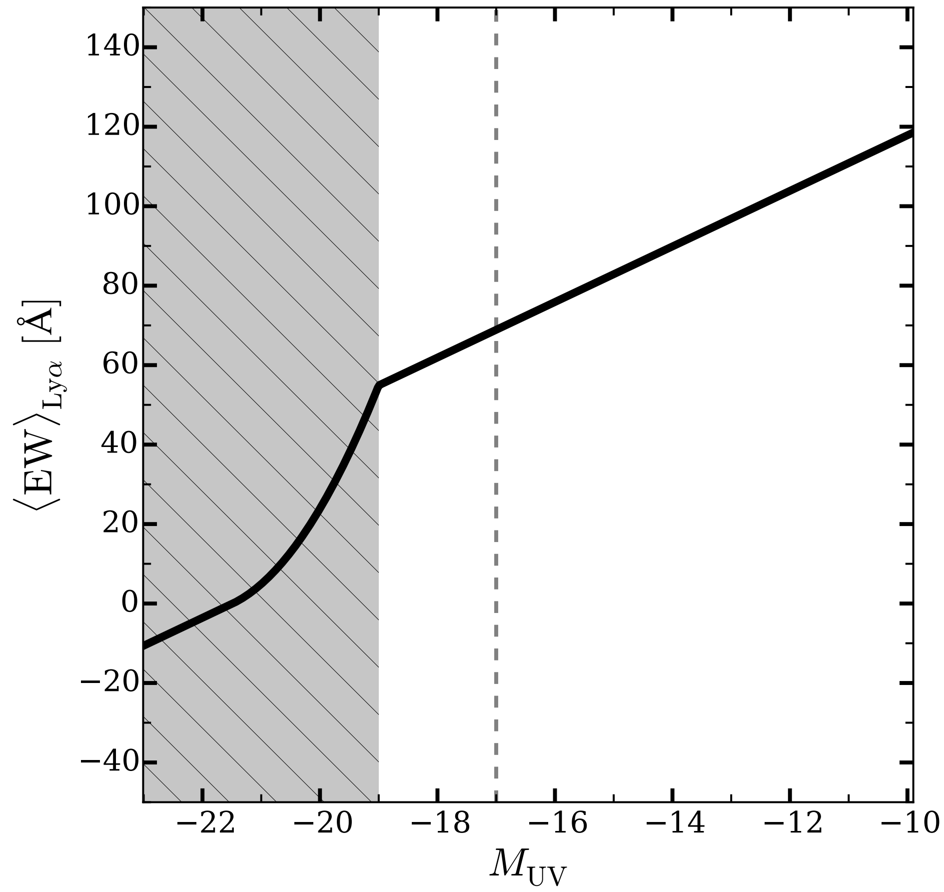
Salpeter IMF

$\langle EW_{Ly\alpha} \rangle \sim 80$ A

Halo star formation approach

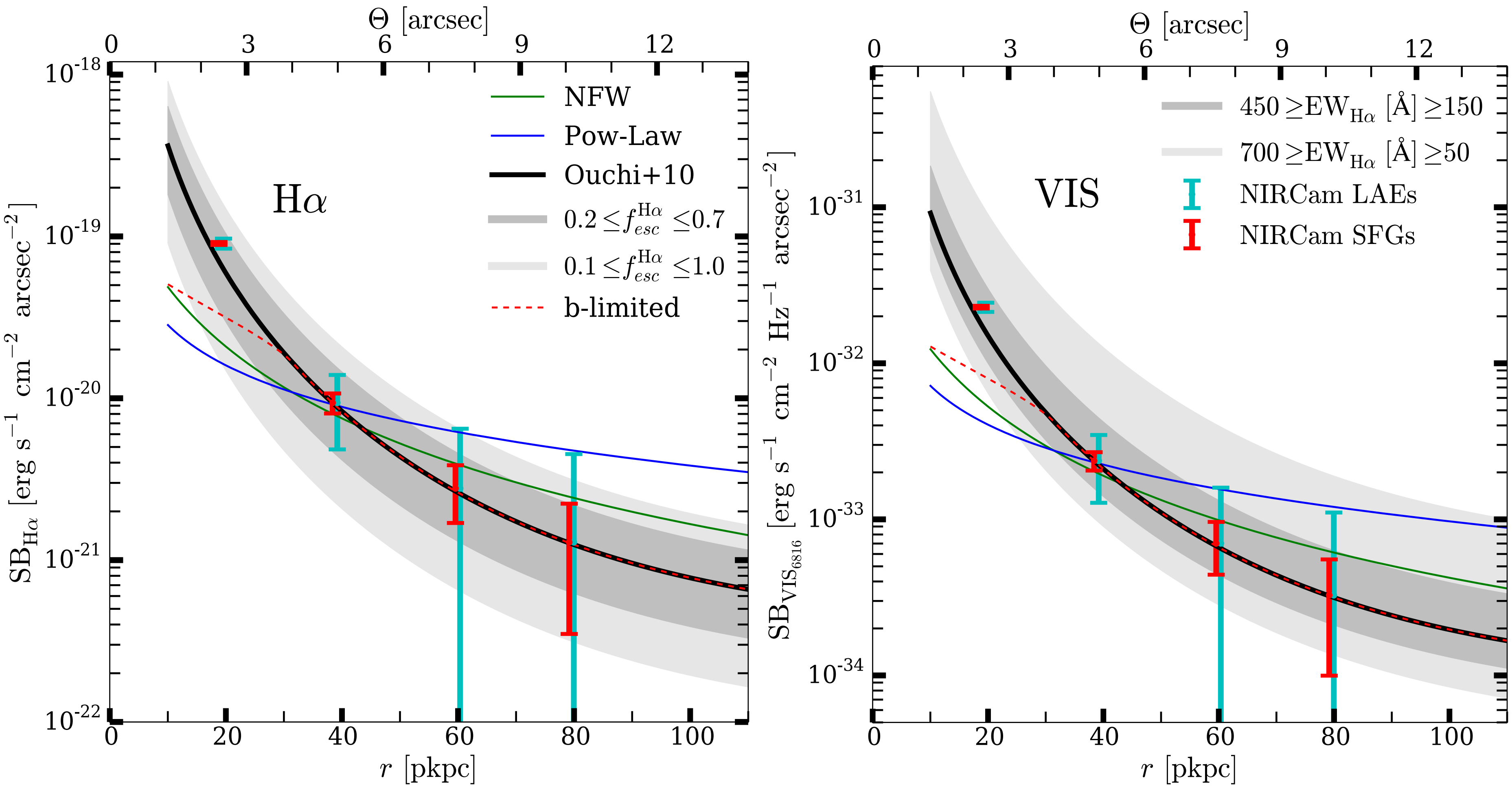


Ota et al. 2017 (z~7)



LMR et al. 2017a (see also Dijkstra & Wyithe 2012)

Halo star formation approach



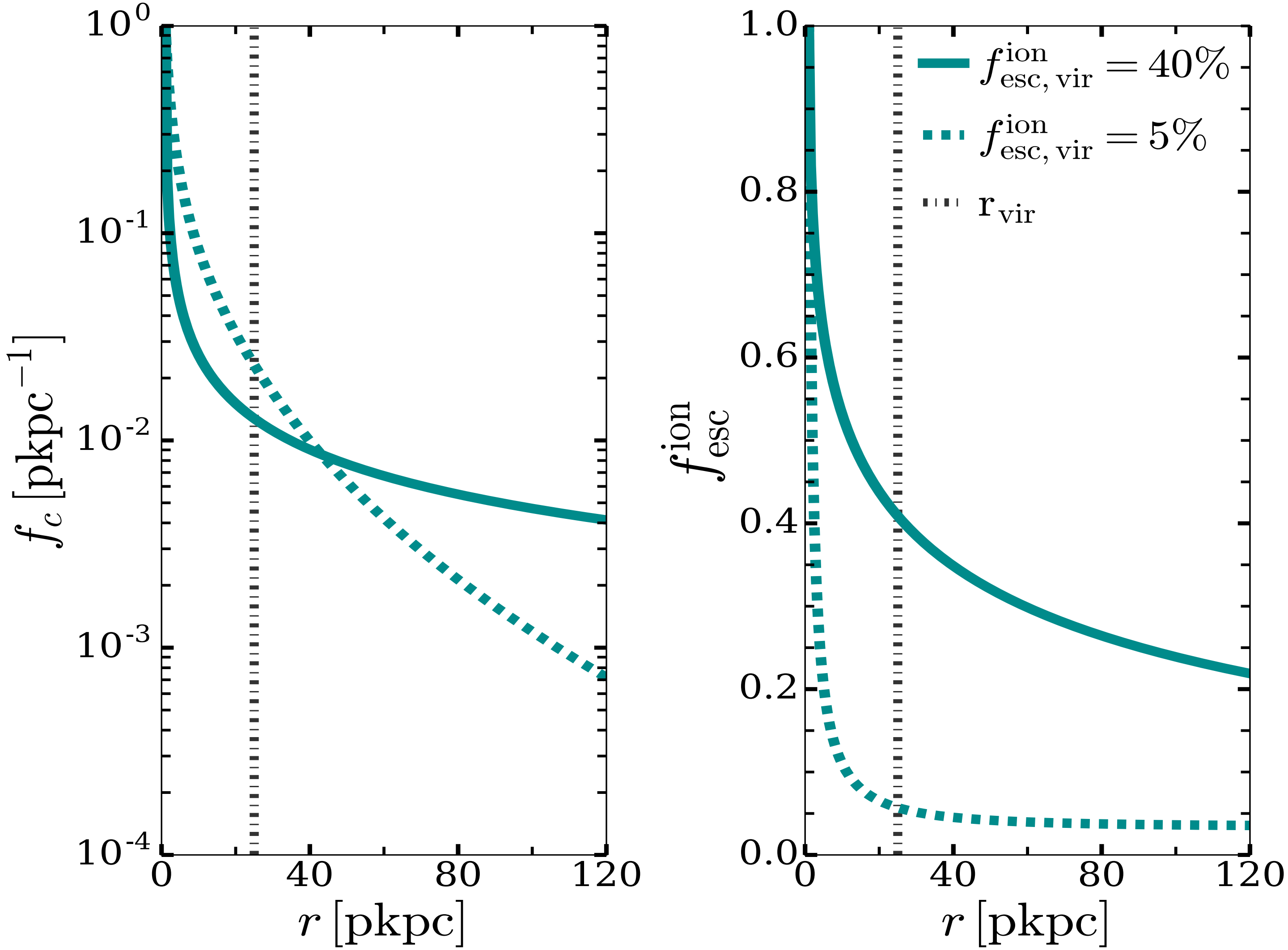
LMR et al. 2017a

Halo star formation approach

Breaking degeneracies:

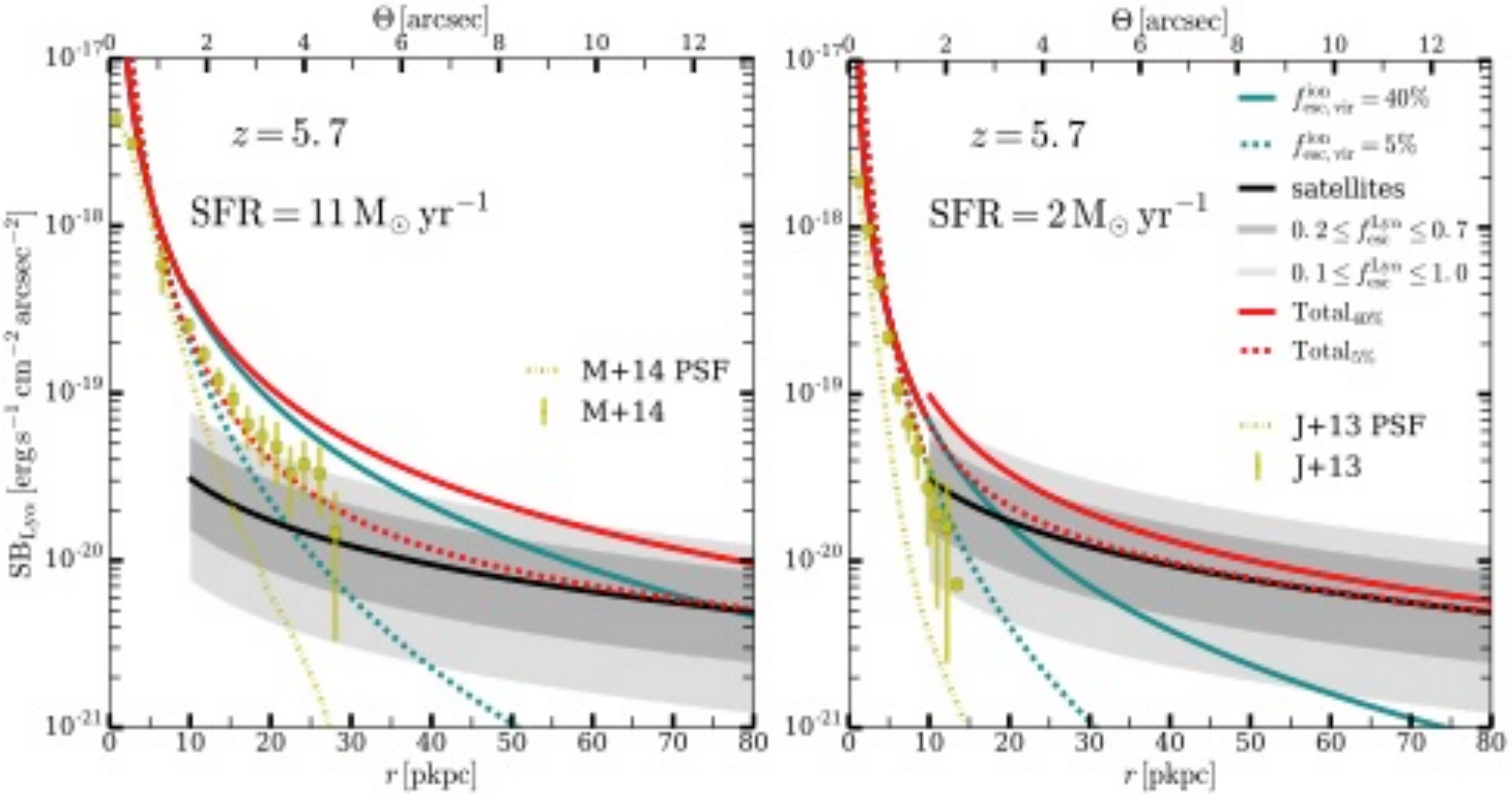
- Strong Lyα, no UV, no Hα → scattering or cooling
- Lyα vs Hα profile → importance of scattering
- UV vs Hα profile → ‘in-situ’ vs fluorescence

Extended halos at z ~ 5 - 7



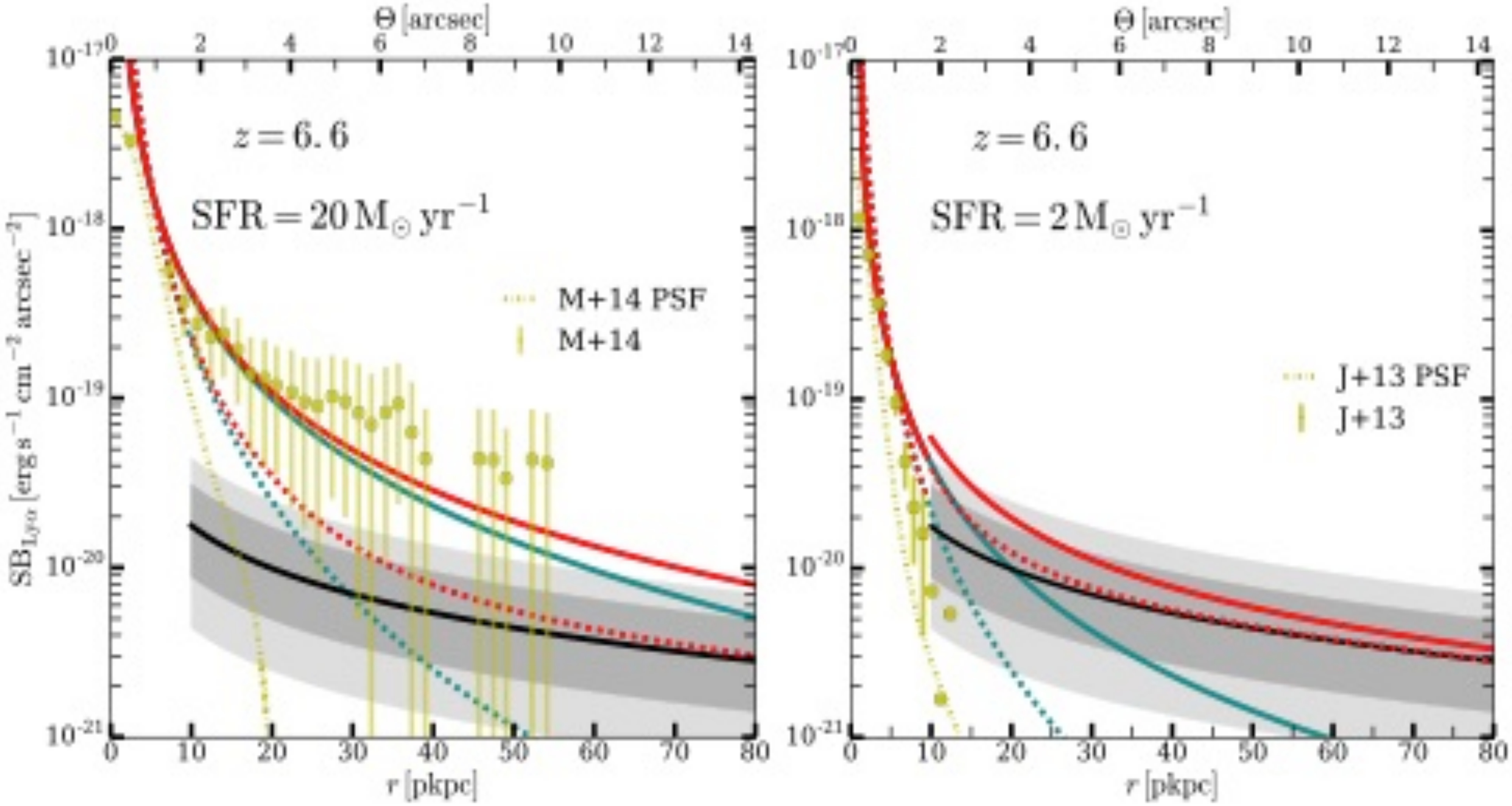
LMR et al. 2017b

Extended halos at z ~ 5 - 7



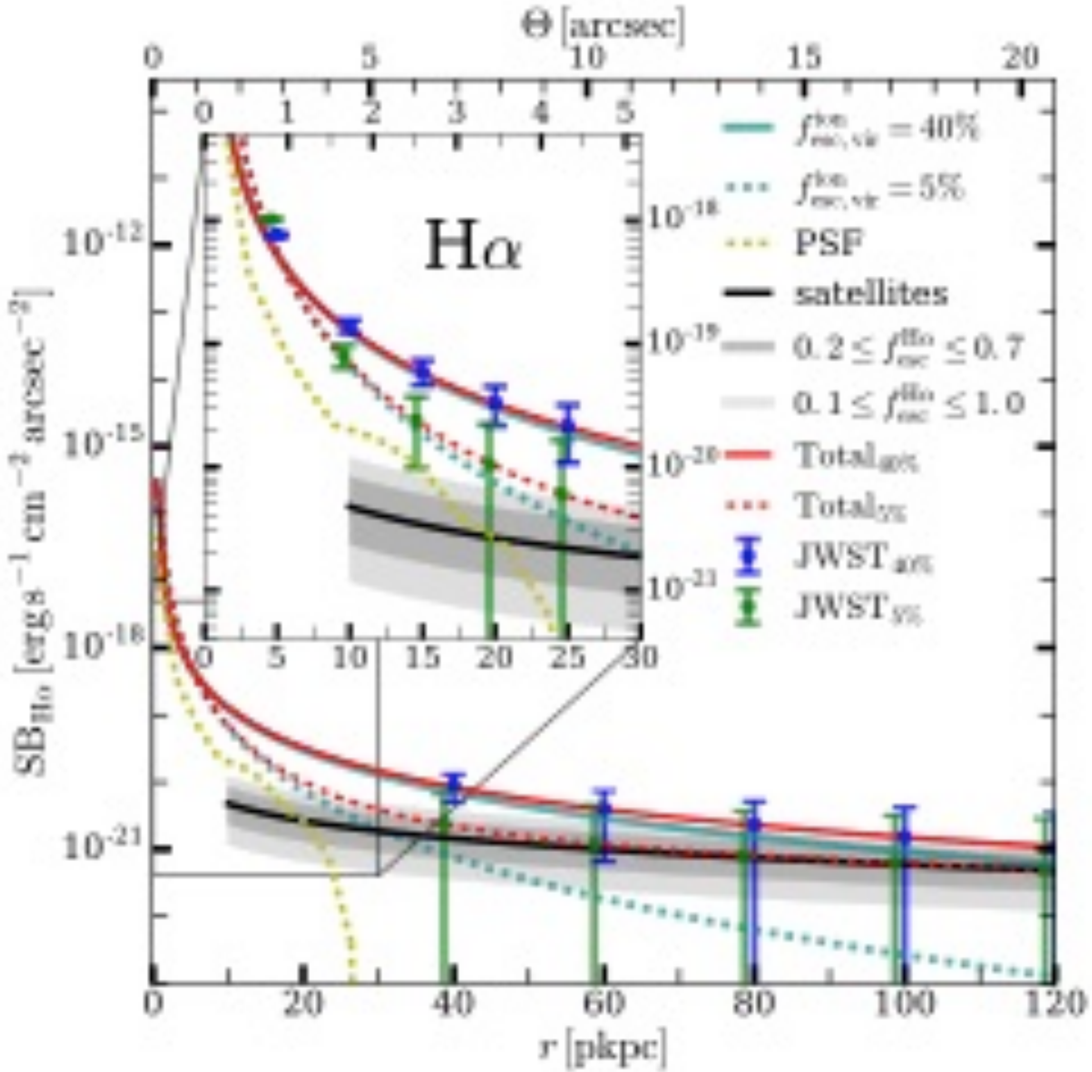
LMR et al. 2017b

Extended halos at z ~ 5 - 7



LMR et al. 2017b

Extended halos at z ~ 5 - 7



LMR et al. 2017b

Conclusions

Halo star formation may play a major role to extended halos & cosmic photon budget

Evolution of the $EW_{Ly\alpha}$ with M_{UV} required by observations

Observations of Hα and continuum emission key to probe the origin of LAHs

Observations of fluorescent halos may be used to infer the ionizing escape fraction during EoR