Learning Galaxy Physics During the Cosmic Dawn With Roman Deep Fields

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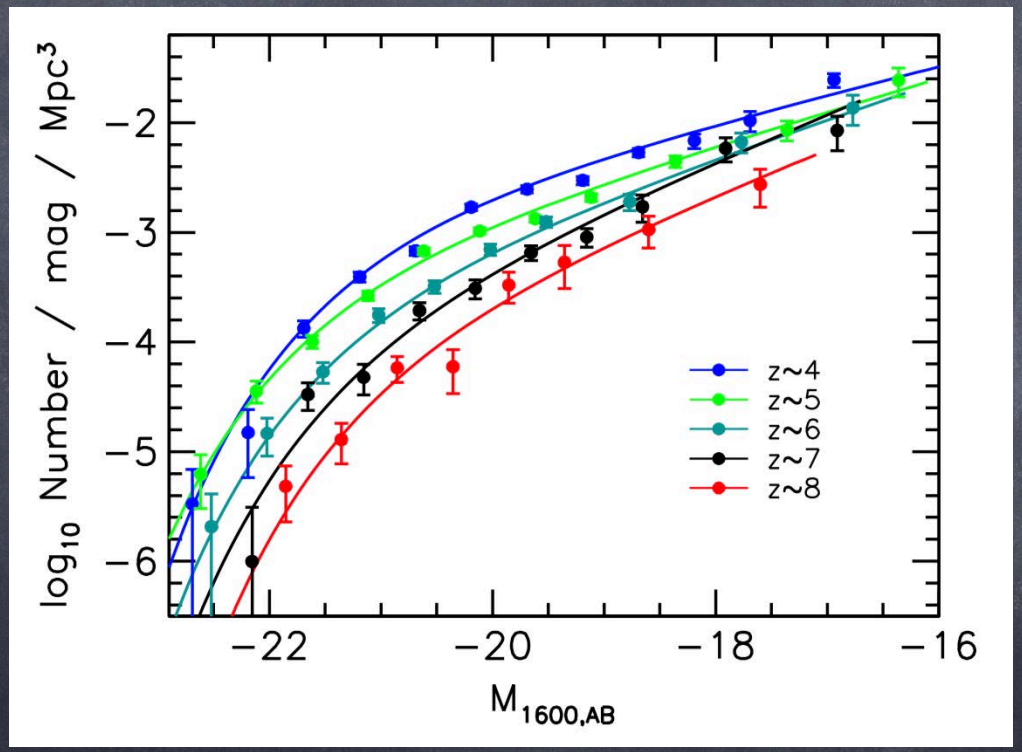
The Premise...

- All of our predictions for Roman surveys rely on extrapolations of known populations
- So we'd better understand the implications of these extrapolations!
- And be able to test the measurements

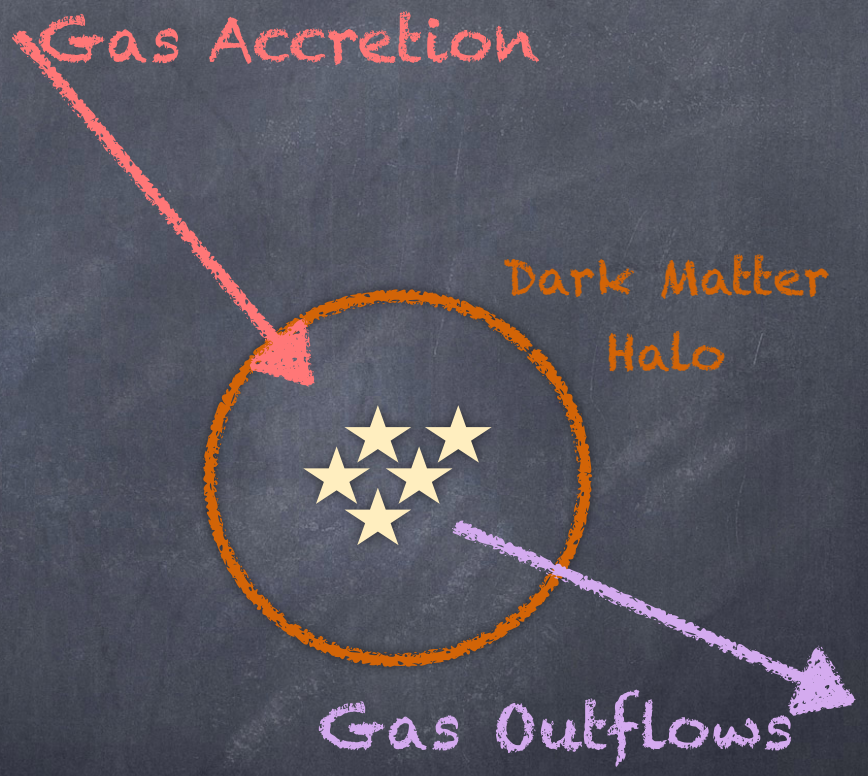
What do we know about galaxies during the Cosmic Dawn?



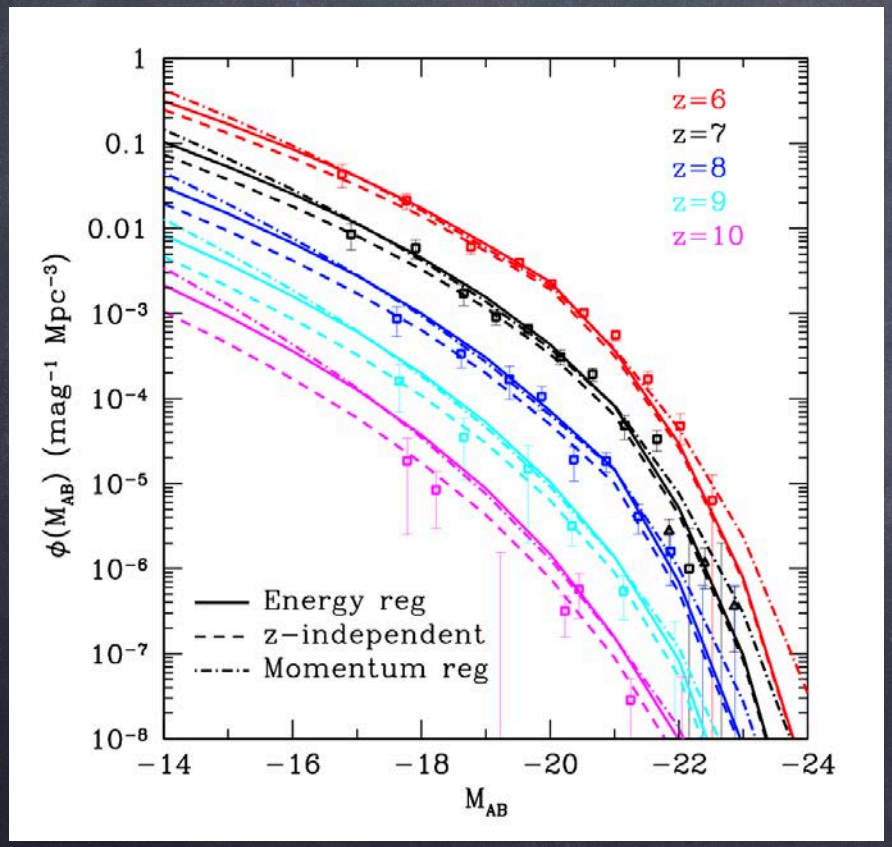
Bouwens et al. (2015)

So how do galaxies form?

- "Minimalist model" inputs
  - Gas accretion
  - Star formation
  - Gas outflows
- "One parameter": feedback efficiency



"Minimalist" model of galaxy formation

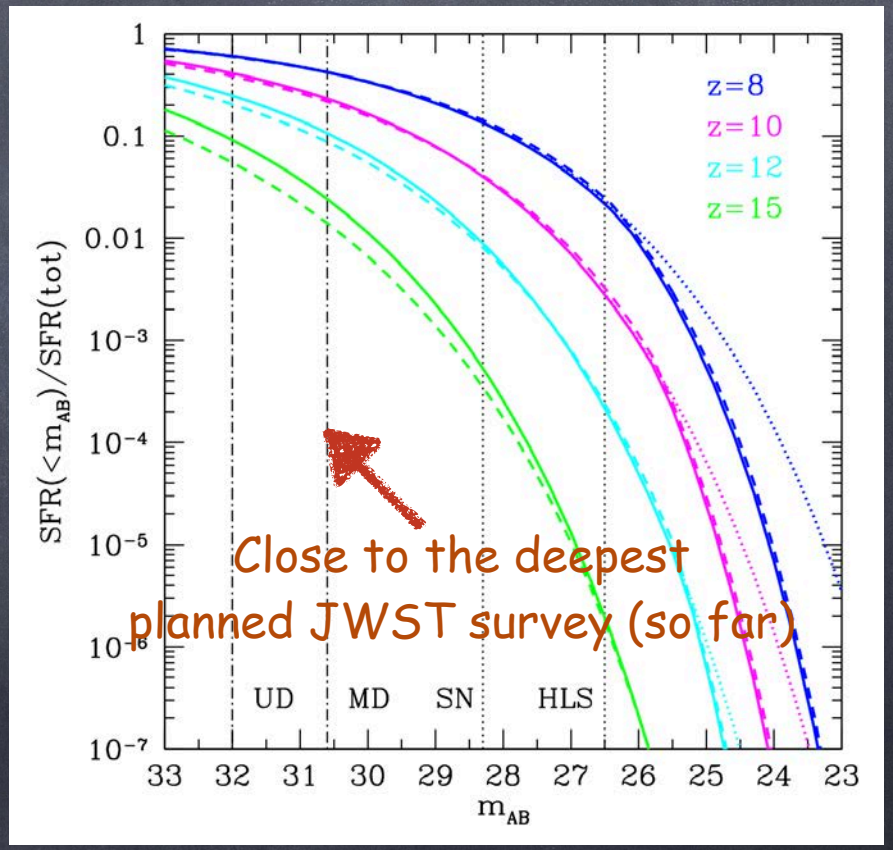


Furlanetto et al. (2017)

- Provides satisfactory fits to luminosity functions!
- At least if we take a "reasonable" feedback model

Faint Galaxies

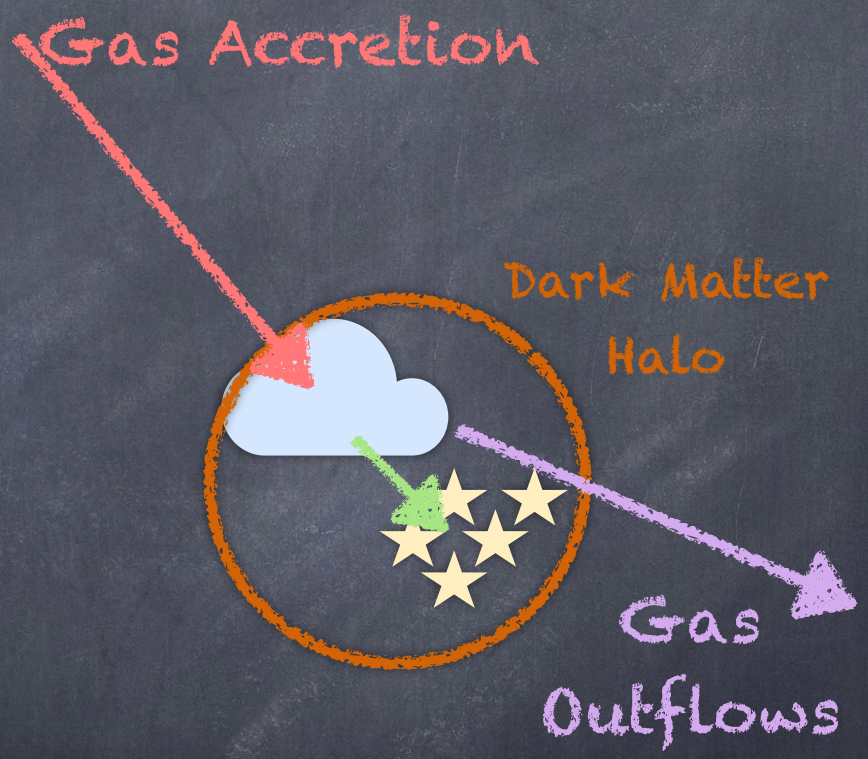
- Only a fraction of the star formation will be directly observable!
- How do we learn about the small, early galaxies?



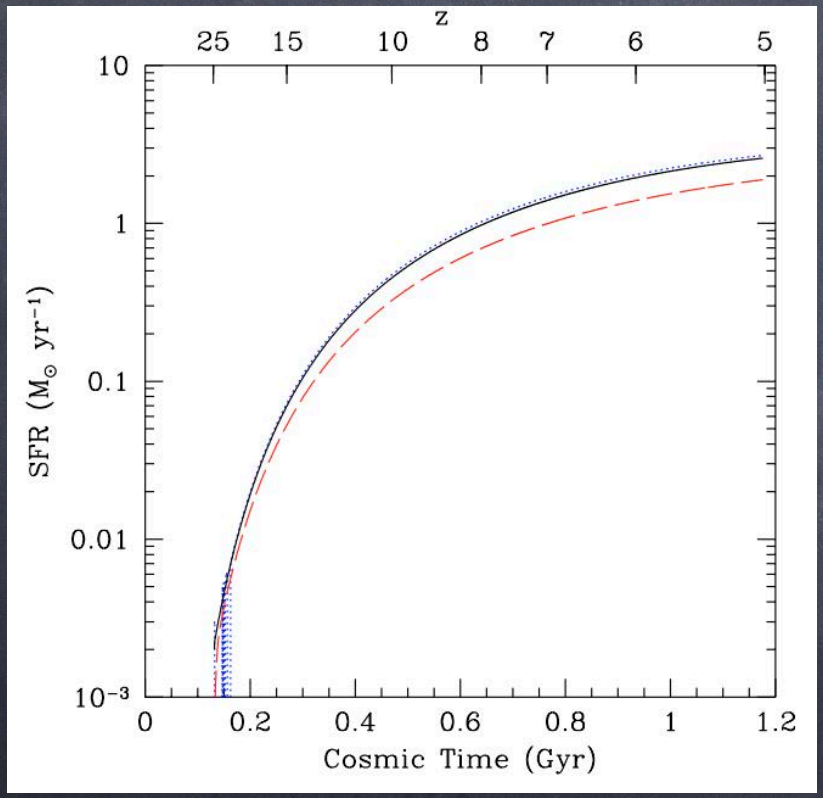
Furlanetto et al. (2017)

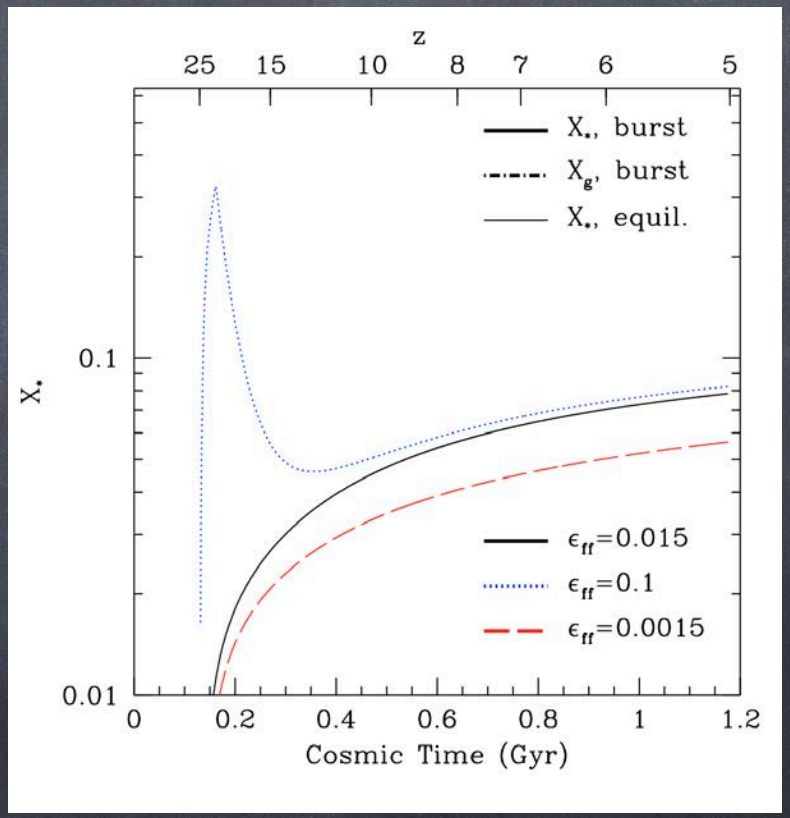
Upgrade #1: An ISM

- "Bathtub/Regulator model" (Bouche et al. 2010, Dave et al. 2012, Lilly et al. 2013, Dekel et al. 2013)
  - Gas accretion
  - Interstellar medium
  - Star formation
  - Gas outflows
- Two parameters
  - Mass-loading factor $\eta(M,z)$
  - Star formation efficiency ε_{ff}



Bursty Star Formation in the Cosmic Dawn

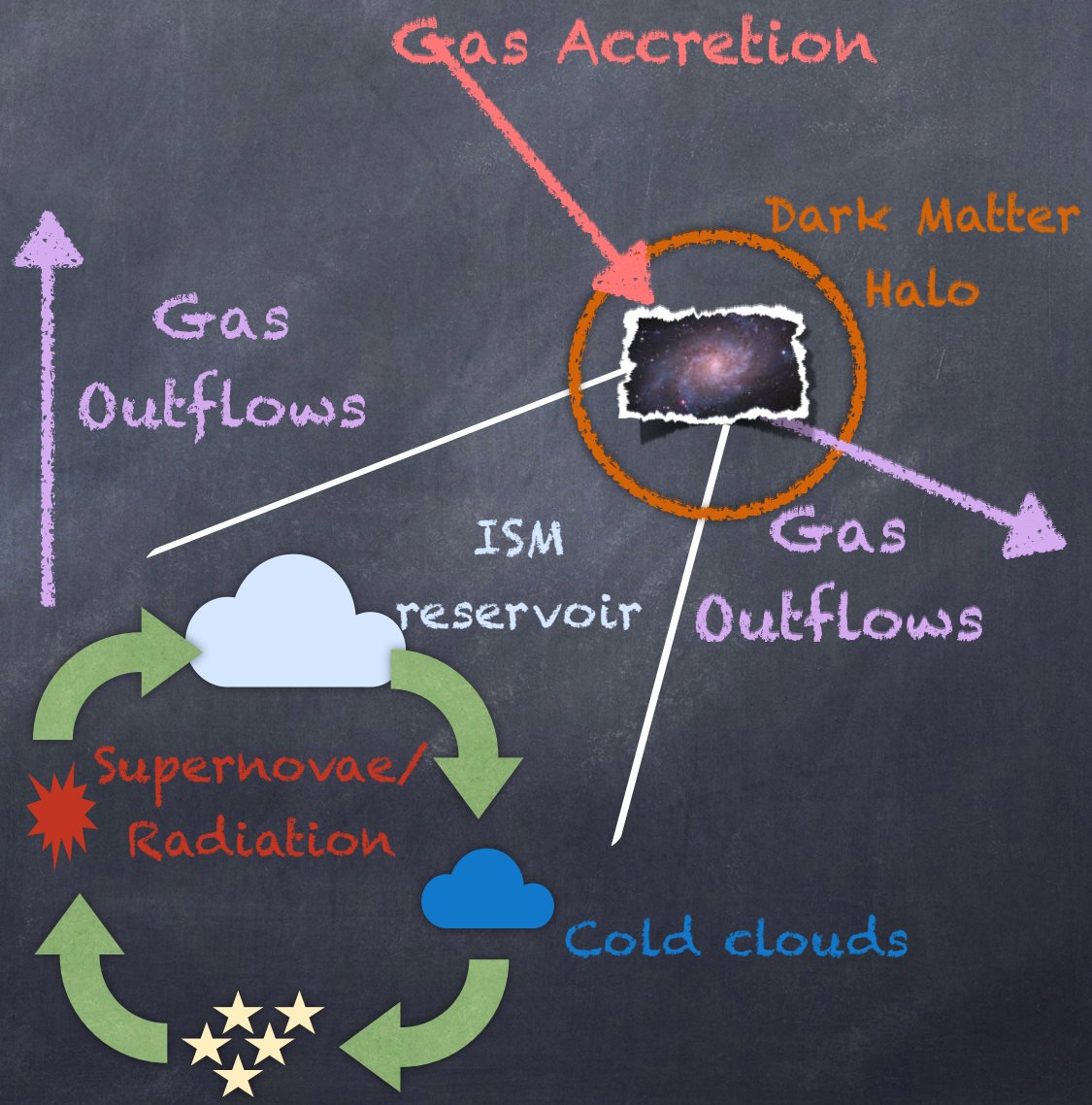




Furlanetto (2020)

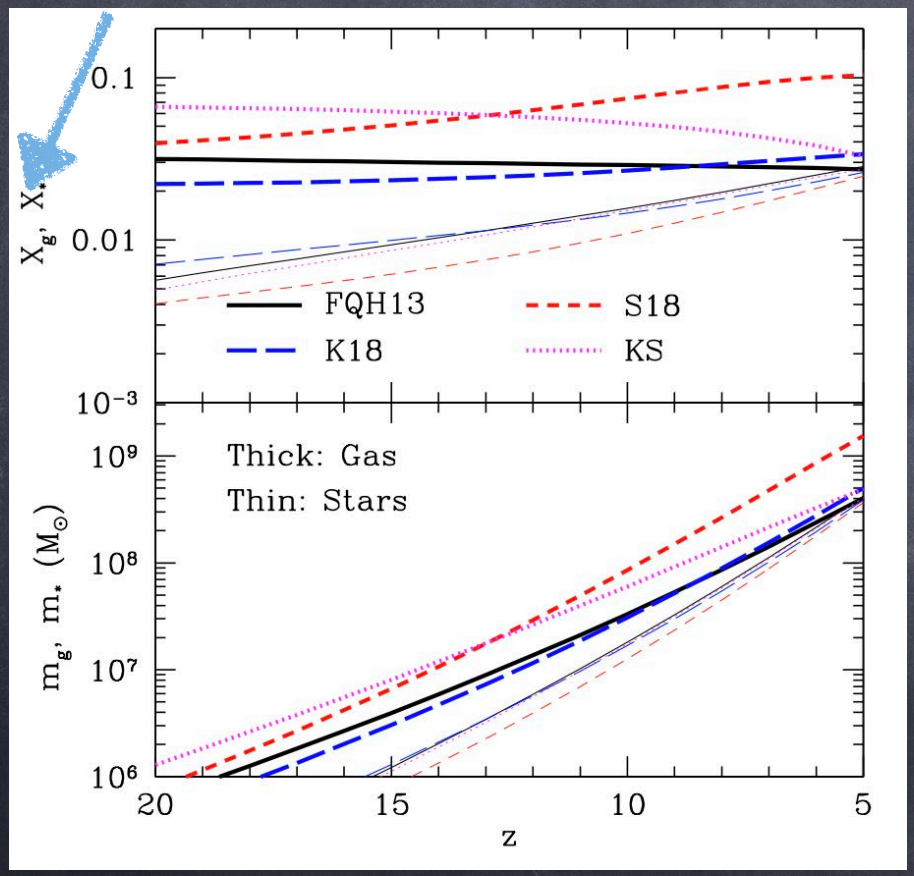
Upgrade #2: Star Formation Models!

- Add star formation laws:
  - Fragmentation
  - Star formation
  - Feedback
  - Turbulent support
- Cycling between ISM phases poorly understood!



Bursty Star Formation in the Cosmic Dawn

Fractions relative to cosmic mean

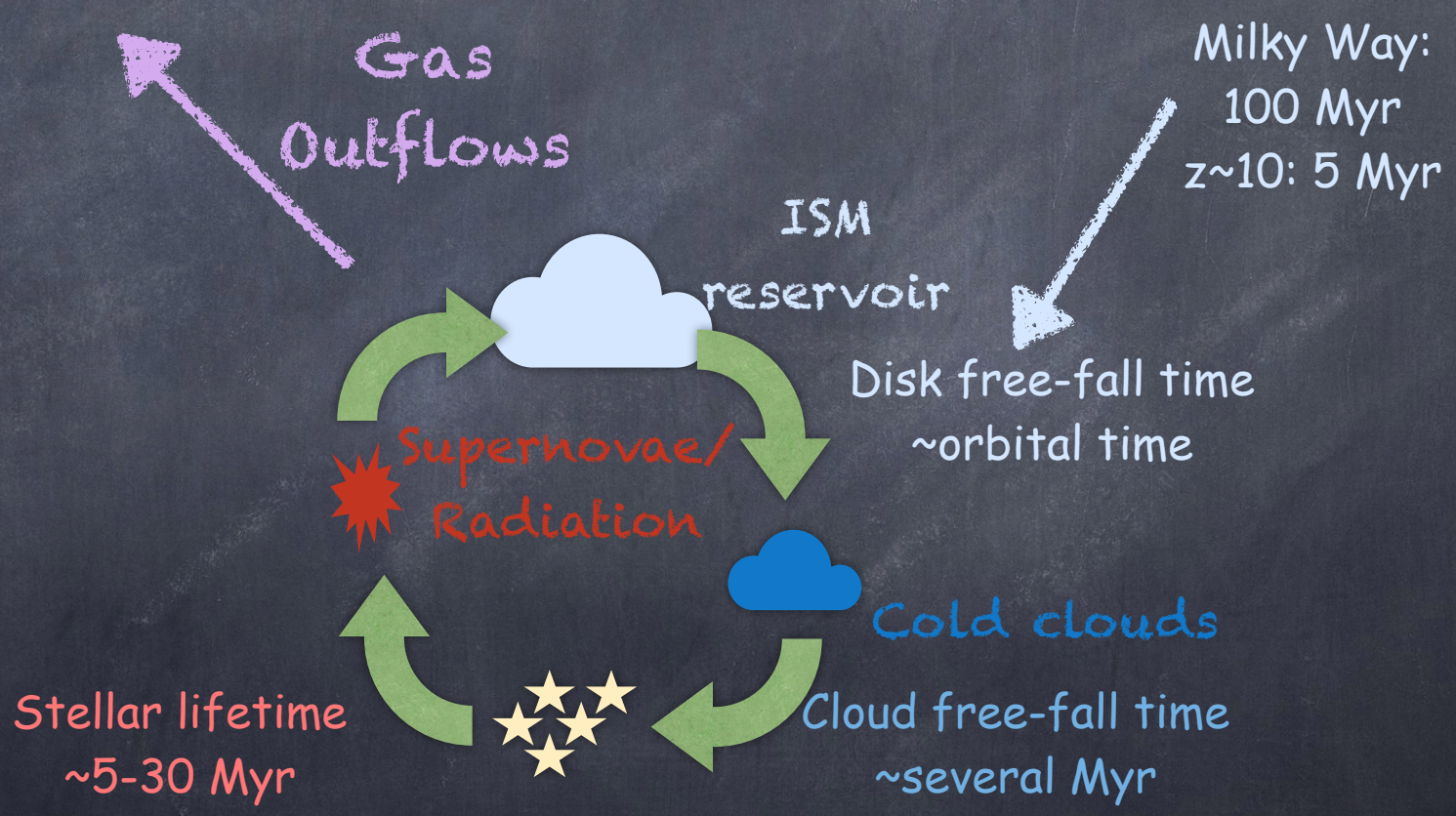


Furlanetto (2020)

- Detailed SF laws have little effect on stellar mass
- Stronger effect on ISM

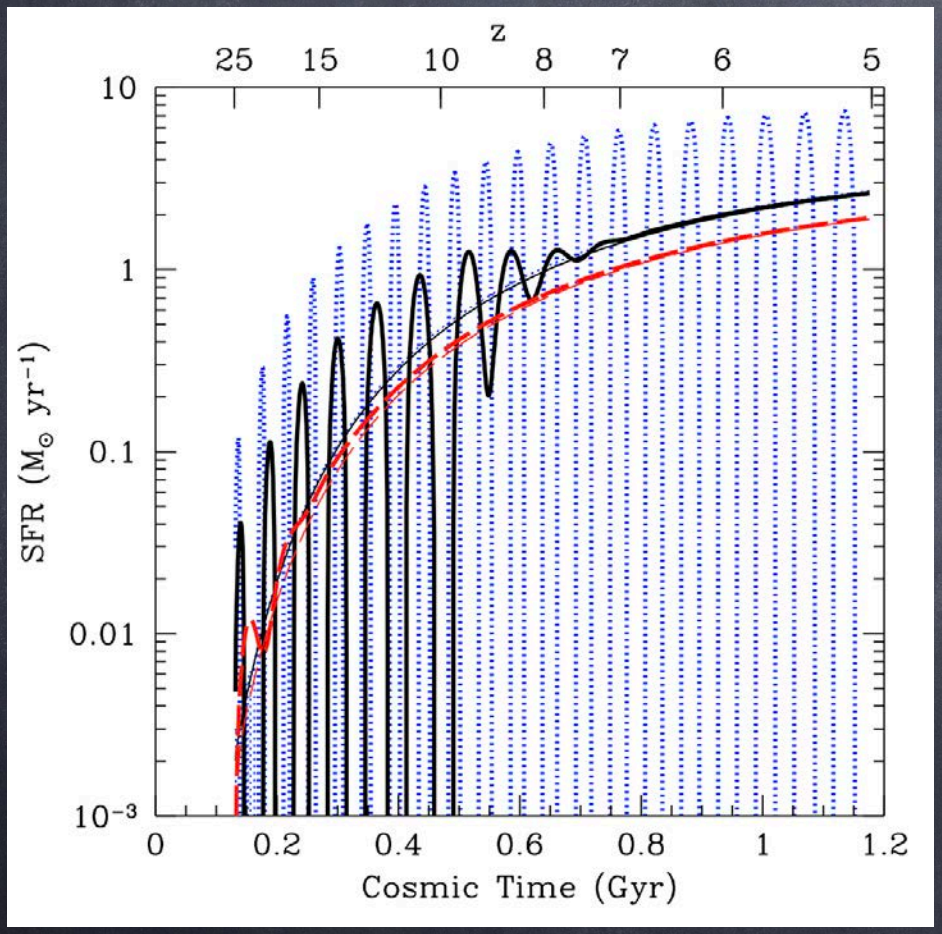
see SF laws by Faucher-Giguere/Hopkins/FIRE group; Krumholz group; Semenov &Kravtsov

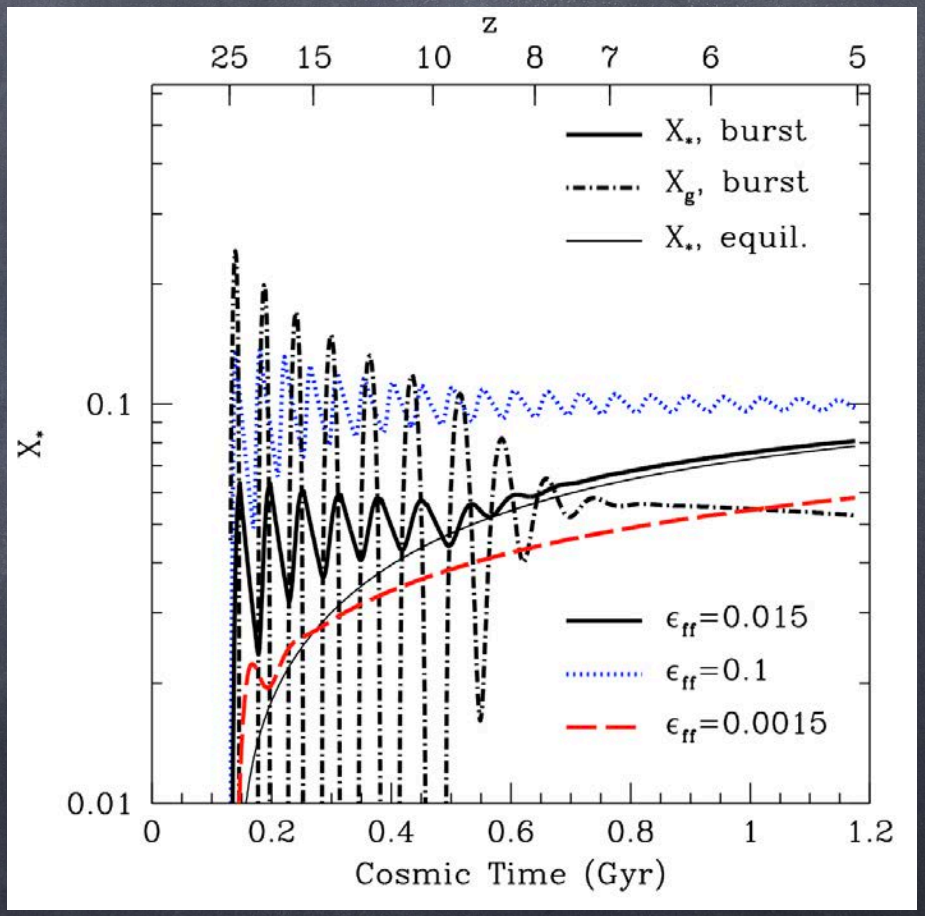
What if our assumptions break down?



Faucher-Giguere (2018), Orr & Hopkins (2019)

Bursty Star Formation in the Cosmic Dawn





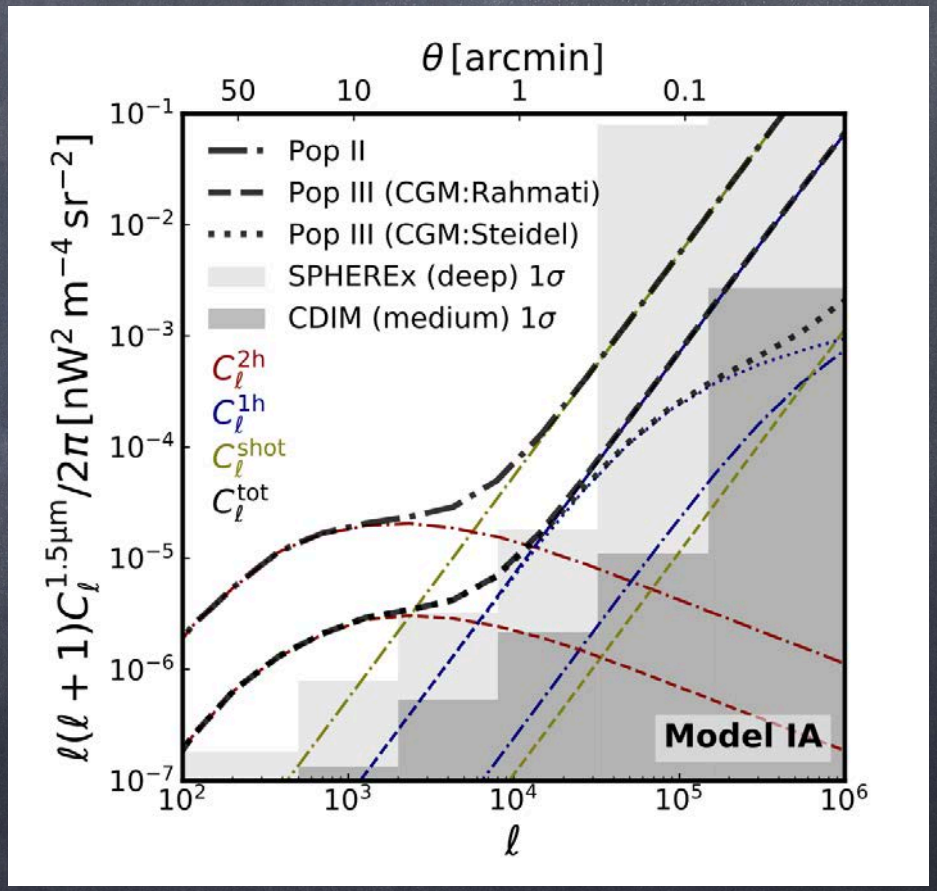
Furlanetto & Mirocha (2021)

How do we study these faint galaxies?

- Compare the bright galaxies to a probe sensitive to ALL galaxies!
- Intensity mapping is a "direct" method
- Reionization probes offer other advantages

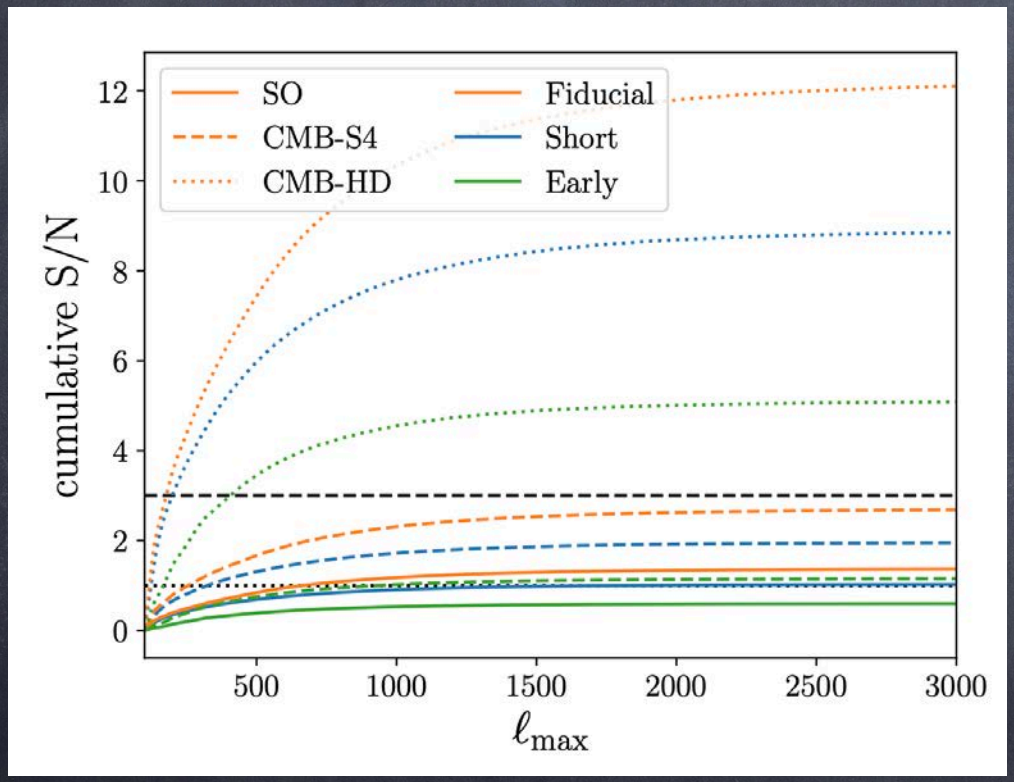
Intensity Mapping in the NIR

- NIR intensity mapping depends mostly on stellar continua + Lyα
- Should be detectable with planned surveys
- (Though component separation challenging - cross-correlation helps!)



Sun et al. (2021)

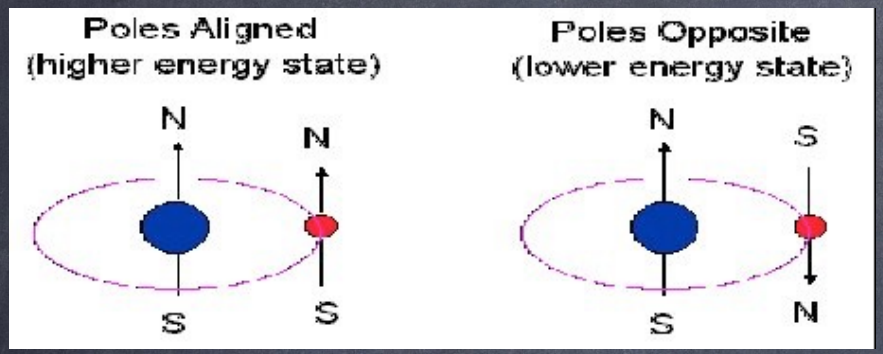
Cross-Correlation With the CMB: kSZ^2-Galaxy



La Plante et al. (2021, in prep)

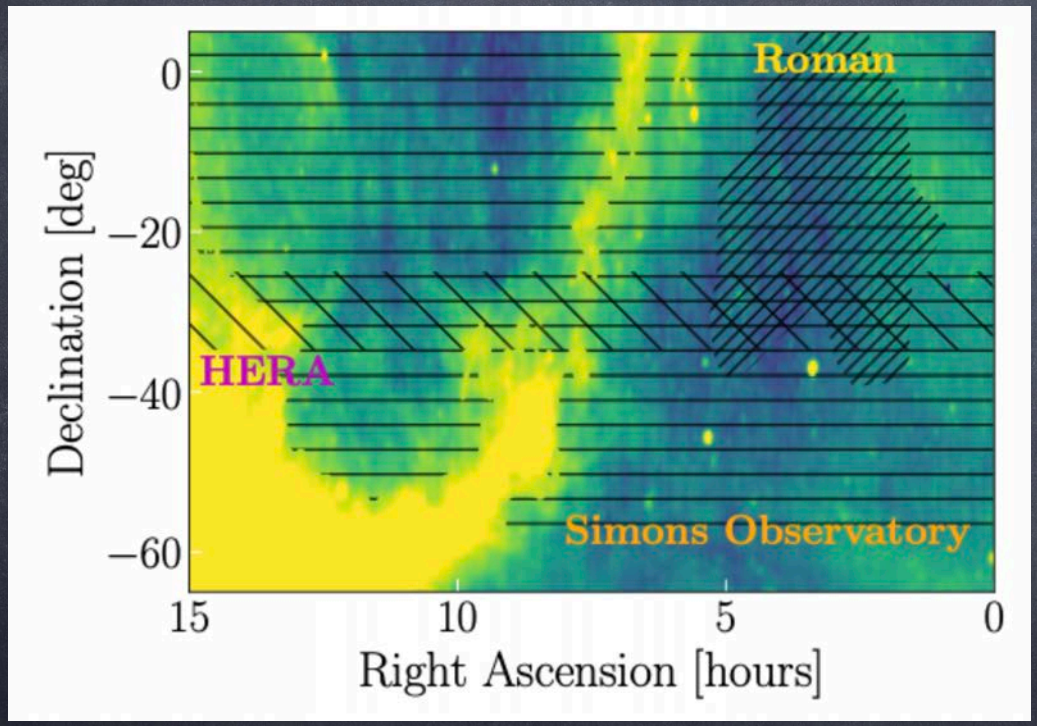
- Shown is HLS (with photo-z) + futuristic CMB surveys
- Can be detected (in principle) and used to characterize history/ morphology of reionization!
- Limited by HLS area (better to have fewer galaxies over wider area)

The 21-cm Line



- First interferometric galaxy constraints came this summer from HERA Collaboration et al. (2021a, 2021b)!

Cross-Correlation With 21-cm: HERA

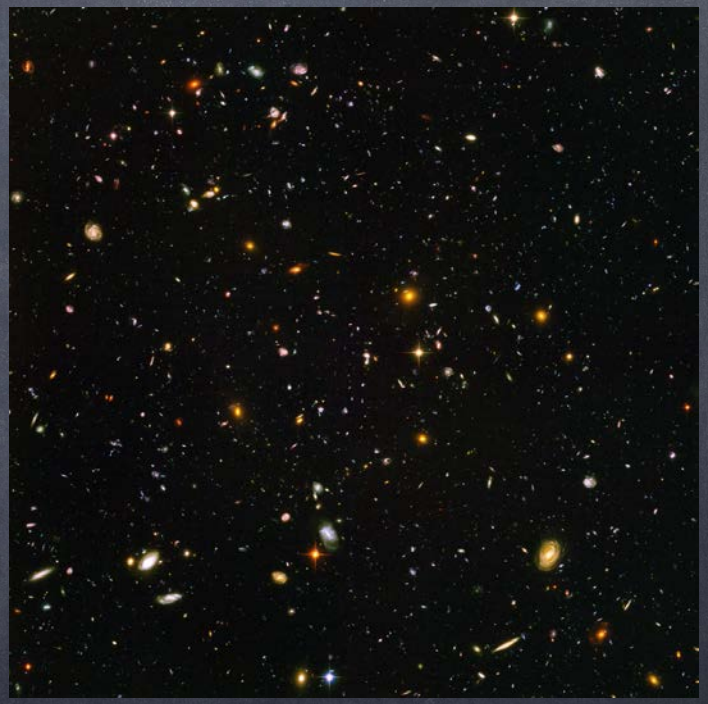


La Plante et al. (2022, in prep)

- Overlap with HERA stripe + HLS is nominally ~500 sq. deg.
- PRELIMINARY calculations show detection at modest S/N!
- But cross-correlation requires spectroscopic redshifts (or major advances in 21-cm)
  - Can we get spec-z at z>7.5?

Looking forward...

- Roman will pin down the galaxy LF, but extrapolating to the dominant faint population is a fraught exercise!
- Best constraints will come from cross-correlations, which must be planned ahead of time!
  - kSZ^2-galaxy and 21cm-galaxy both promising, but different requirements!



HST UDF

See also https://cosmicdawn.astro.ucla.edu for more reasons to study this era!