## 現実的なシミュレーション ライマン-αスペクトル

### マックス・グロンケ カリフォルニア大学サンタバーバラ校



### Lya observables contain *unique* information sta

...about the high-z Universe.

...to understand the behaviour of cold, neutral gas.

#### Lots of Lya data...





...to constrain galactic subgrid models!

The plan: correlate spectral properties with subgrid parameters!

SILCC:  ${\bf SI}{\bf mulating}$  the  ${\bf Life}{\bf C}{\bf ycle}$  of molecular  ${\bf C}{\rm louds}$ 



Stefanie Walch Philipp Girichidis Thorsten Naab Andrea Gatto Simon C. O. Glover Richard Wünsch Ralf S. Klessen Paul C. Clark Thomas Peters Dominik Derigs Christian Baczynski

Walch et al., MNRAS 454, 238 (2015) Girichidis et al., arXiv:1508.06646

KS SN rate, random driving

### The SILCC simulations

- 4pc fixed resolution
- radiative heating & cooling
- chemistry (CO & H2)
- ionizing RT
- several "subgrid" feedback mechanisms (SN, winds, ...)

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> Do not match observations! Lya photons escape through cleared channels! (similar problems with toy models of multiphase media) MG & Dijkstra (2016)

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- too much flux at line center
- too symmetric
- $\rightarrow$  diminishing constraining power of Lya.





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Simulated Lya spectra "look different"

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### Solutions?

1. IGM







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- 3. a new shape of cold gas





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 $t_{\rm esc}^{\rm h} \sim \frac{Bx_{\rm esc}(N_{\rm HI})}{N_{\rm HI}}$ 

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### increasing resolution?



### Other evidence for tiny "droplets"



+ many more...



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- smooth absorption & emission profiles over v
  ≥1000 km/s in BLR & CGM
- dense cold gas out to in galactic halos (large areal but low volume filling fraction; → e.g., Ting-Wen Lan's talk)



+ many more...



Prochaska et al. (2017)

## Other evidence for tiny "droplets"

8000

6000

ň1 4000

2000

0

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Arav

Dv ~ 6km/s

5007

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20

 $R_{\perp}$  (kpc)

Prochaska

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- 3. a new shape of cold gas
- 4. another form of feedback









#### Girichidis et al. (2018)





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MG, Girichidis, Naab, Walch (in prep.)

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- non-thermal feedback moves gas without heating it
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# Simulating realistic Lyman-a spectra

- Lya spectra can be used to probe our understanding of (cold) gas behaviour
- Modelling realistic spectra is crucial but problematic in high-resolution, multiphase systems
- Two proposes mechanisms to successfully model realistic Lya spectra:
  - 1. ubiquitous droplets
  - 2. cosmic ray feedback ...not exclusive!

#### Work in progress...

- Model small-scale gas dynamics
- □ Compare to the the "Lya triangle of truth"



 $\rightarrow$  The future is (Lya) bright!