

Cosmic Dawn II

Galaxy formation during the Epoch of Reionization

Ocvirk+2017

P. Ocvirk

Observatoire astronomique de Strasbourg
Universite de Strasbourg

Agence Nationale de la Recherche
ANR



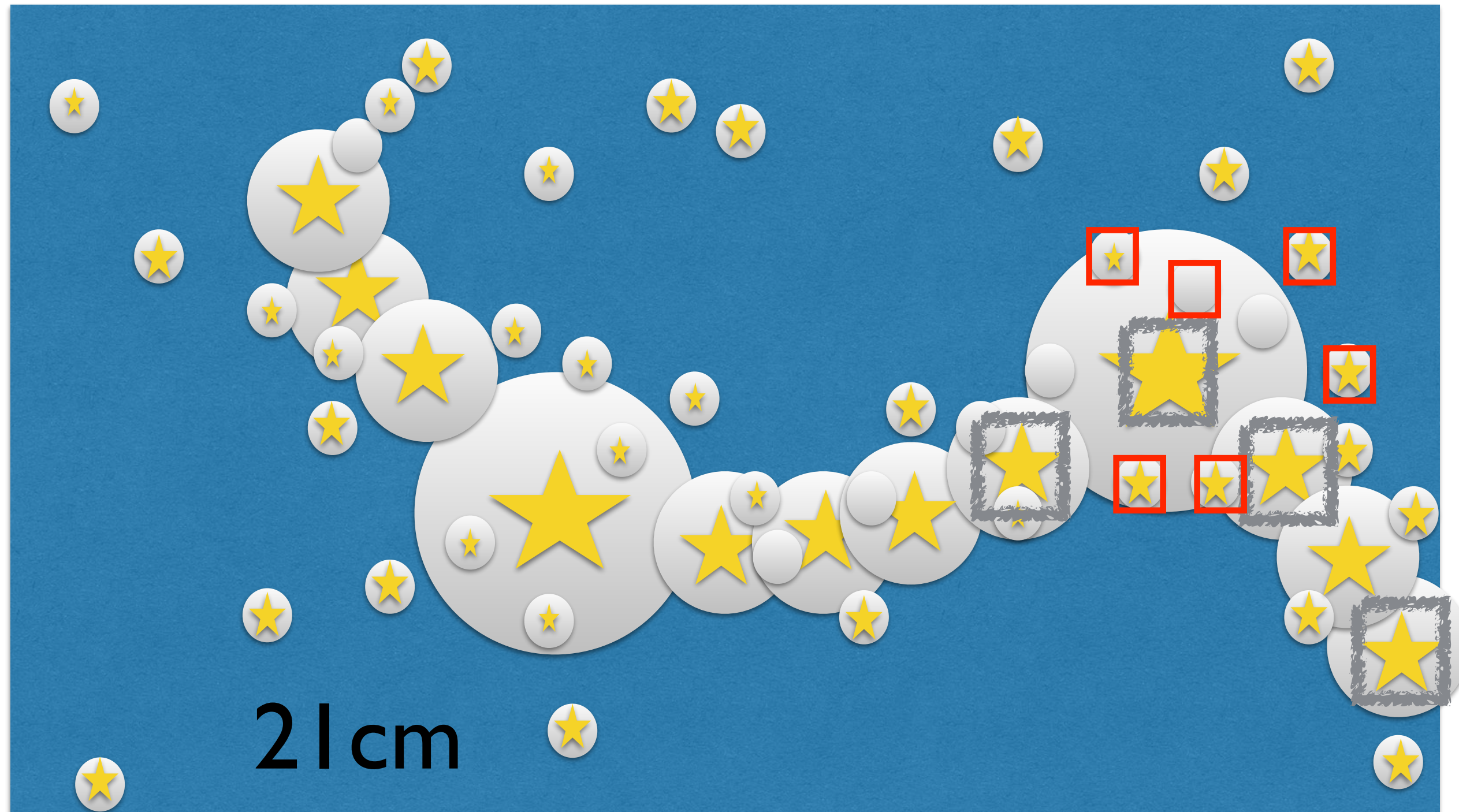
Observatoire astronomique
de Strasbourg



Collaborators

- **D. Aubert, N. Deparis, J. Sorce, J. Lewis** (Observatoire astronomique de Strasbourg) (RT + sci. exp.)
- **R. Teyssier**, T. Stranex, (University of Zurich) (code + sci. exp.)
- Y. Dubois (IAP) (SN feedback)
- **P. R. Shapiro**, J.-H. Choi (University of Texas, Austin) (sci. exp.)
- **I. Iliev**, D. Sullivan, (University of Sussex) (sci. exp.)
- **S. Gottloeber** (Leibniz Institute for Astrophysics, Potsdam) (ICs + sci. exp., **CLUES**)
- **G. Yepes**, A. Knebe (Universidad Autonoma de Madrid) (ICs + sci. exp., **CLUES**)
- **Y. Hoffmann** (Hebrew University of Jerusalem) (ICs, **CLUES**)
- F. Roy, Y. Rasera (Observatoire de Paris) (pfof)

The Epoch of Reionization: the next frontier



LSST
2019



SKA
2020+

JWST
2018



EoR open questions

- Ionising sources? Galaxies (high/low mass?) / BHs (stellar / supermassive)
- Ionising UV Escape fraction?
- **Radiative feedback on early galaxies? mass limit for star formation?**
- Signatures of large scale reionization for 21cm experiments?

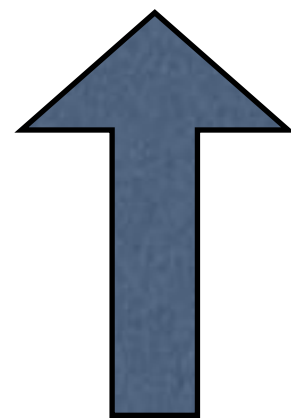
Addressing these questions numerically is extremely challenging:

- **COUPLED** hydro-radiative galaxy formation code, $c=1$ if possible
 - High mass resolution (to resolve all sources down to $10^8 M_{\odot}$ haloes)
 - Large volume (galaxy clusters) $\Rightarrow L \sim \times 10s \text{ Mpc}$
- \Rightarrow big simulation

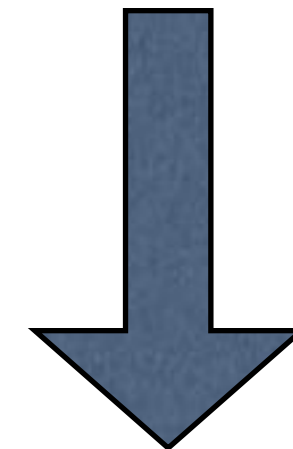
Fully coupled Radiation-hydro with RAMSES-CUDATON

- **RAMSES** (Teyssier 2002): **CPU**
 - gravity (PM) + hydrodynamics
 - star formation + SN thermal + kinetic feedback

$T, x_{\text{HI}}, \Lambda$

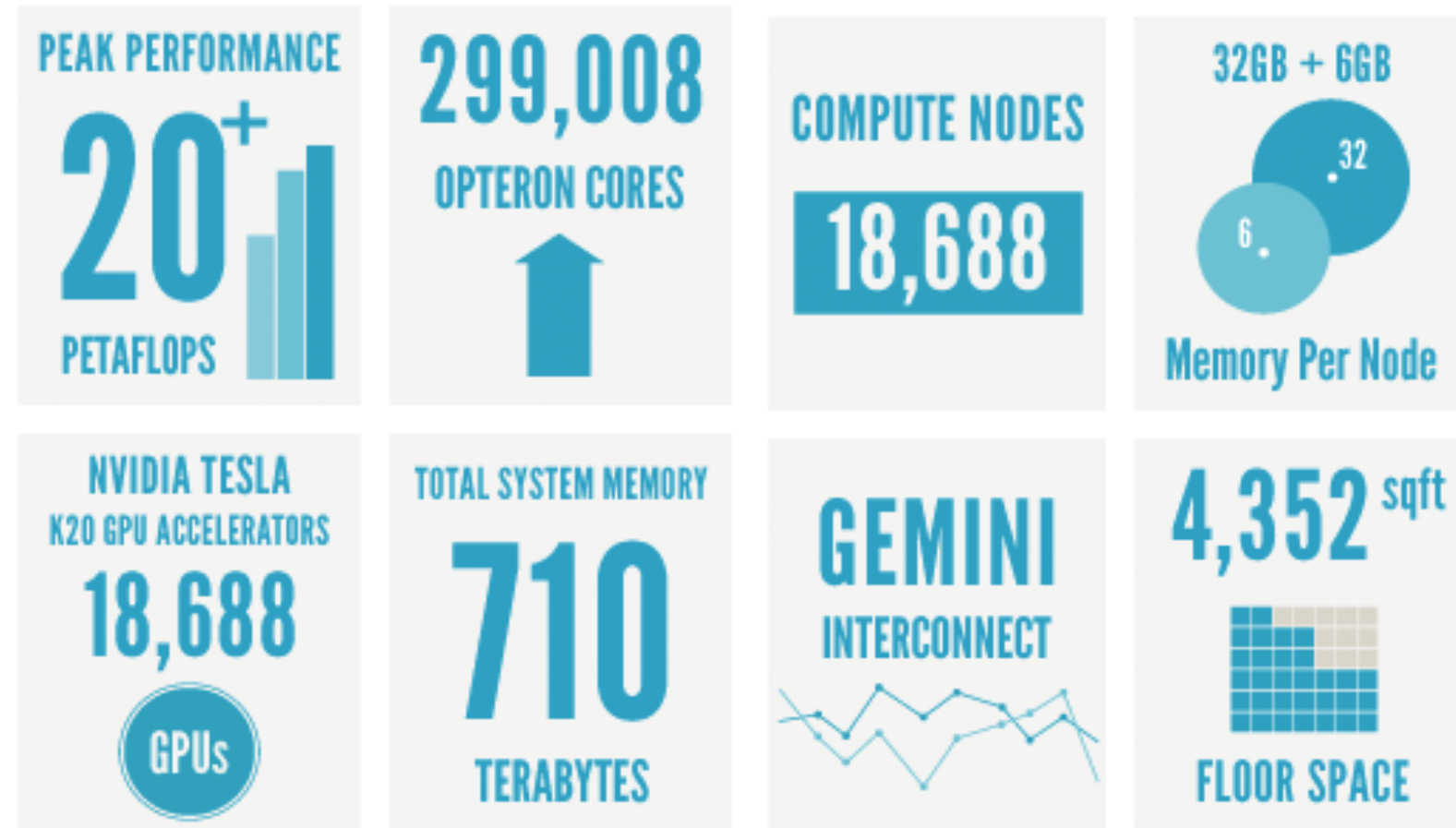


T, ρ, stars

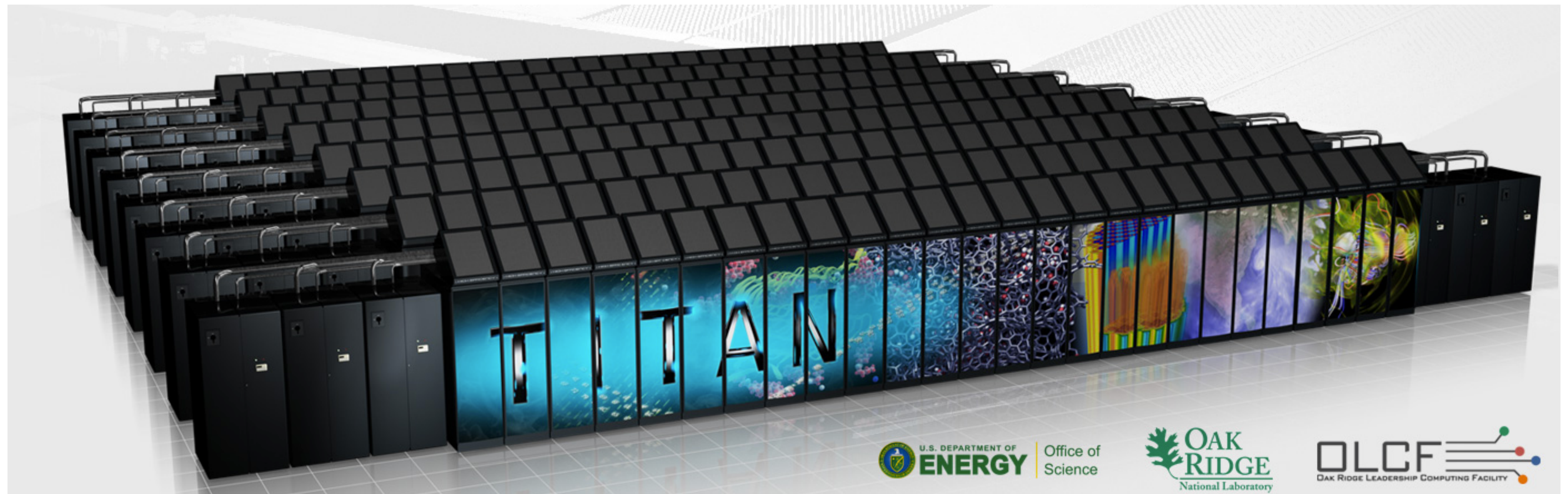


- **ATON** (Aubert 2008): UV Radiative Transfer,
 - Hydrogen ionization
 - Photo-heating + cooling

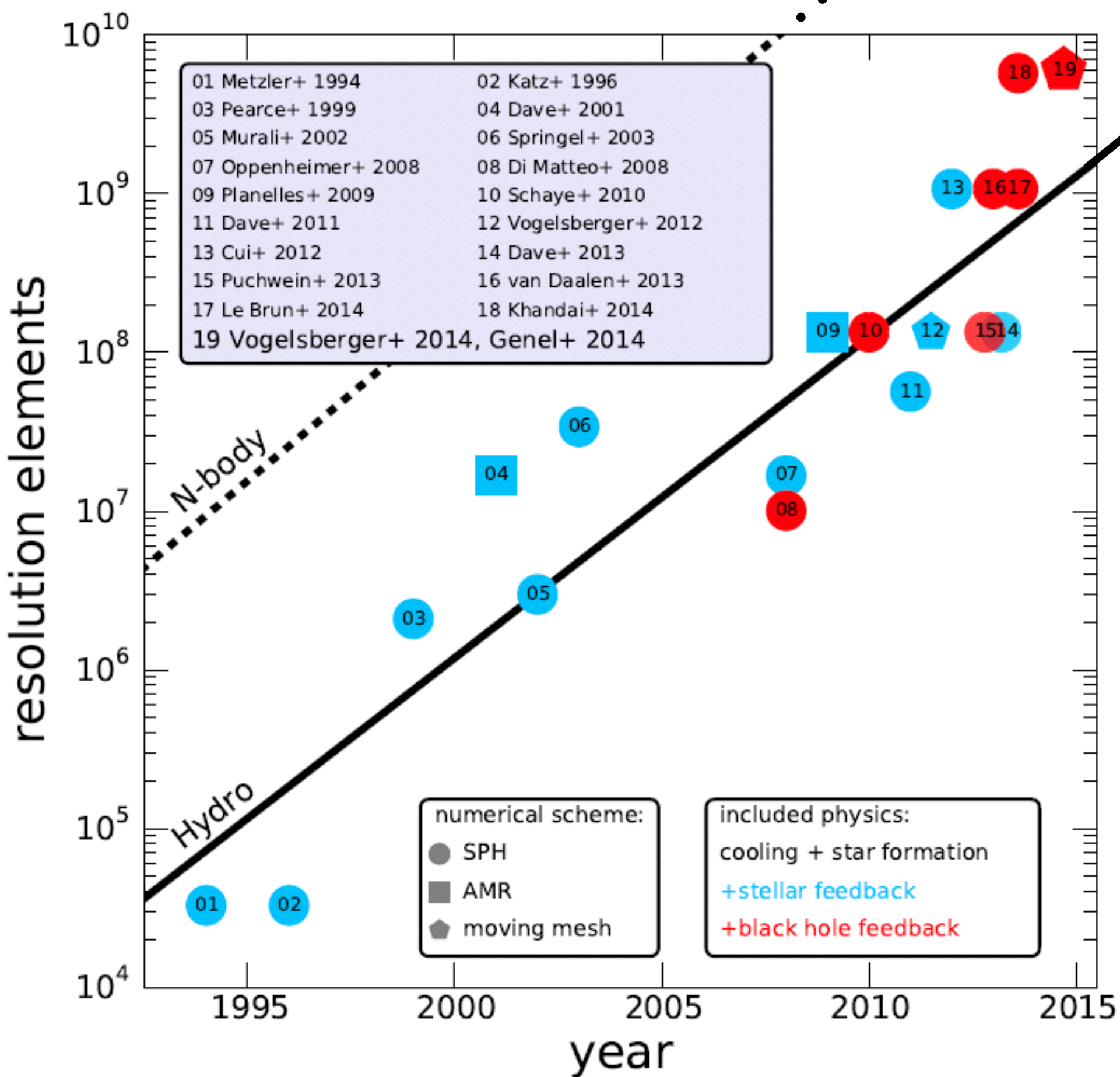
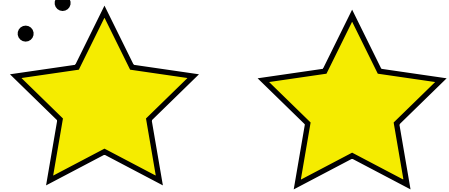
TITAN at Oak Ridge National Laboratory



- **18,688 GPUs (world's largest GPU accelerated supercomputer)**
- top 1 in 2013
- now top 2 (top 1 = Tianhe)



Setup: CoDall specs



(taken from illustris website)

- 16384 GPUs, 65536 CPUs
- 64 h⁻¹ Mpc side, 4096³ grid
- Mhalo_{min} ~ 1 x 10⁸ M_⊙
- Δx ~ 15 h⁻¹ kpc comoving (< 5 kpc physical)
- z_{end}=5.6
- ~ 6 days runtime, 2 PB data
- Planck 2013 cosmology
- New ICs: M_{Virgo} = 2.e14 Msun

110
24.149

6 Mpc deep slice

gas density

photon density

temperature

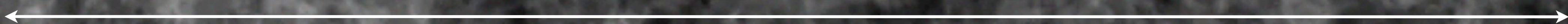
> 10 million haloes

200 million star
particles

Credit:

N. Deparis

26 h^{-1} cMpc (full box is 64 h^{-1} cMpc)

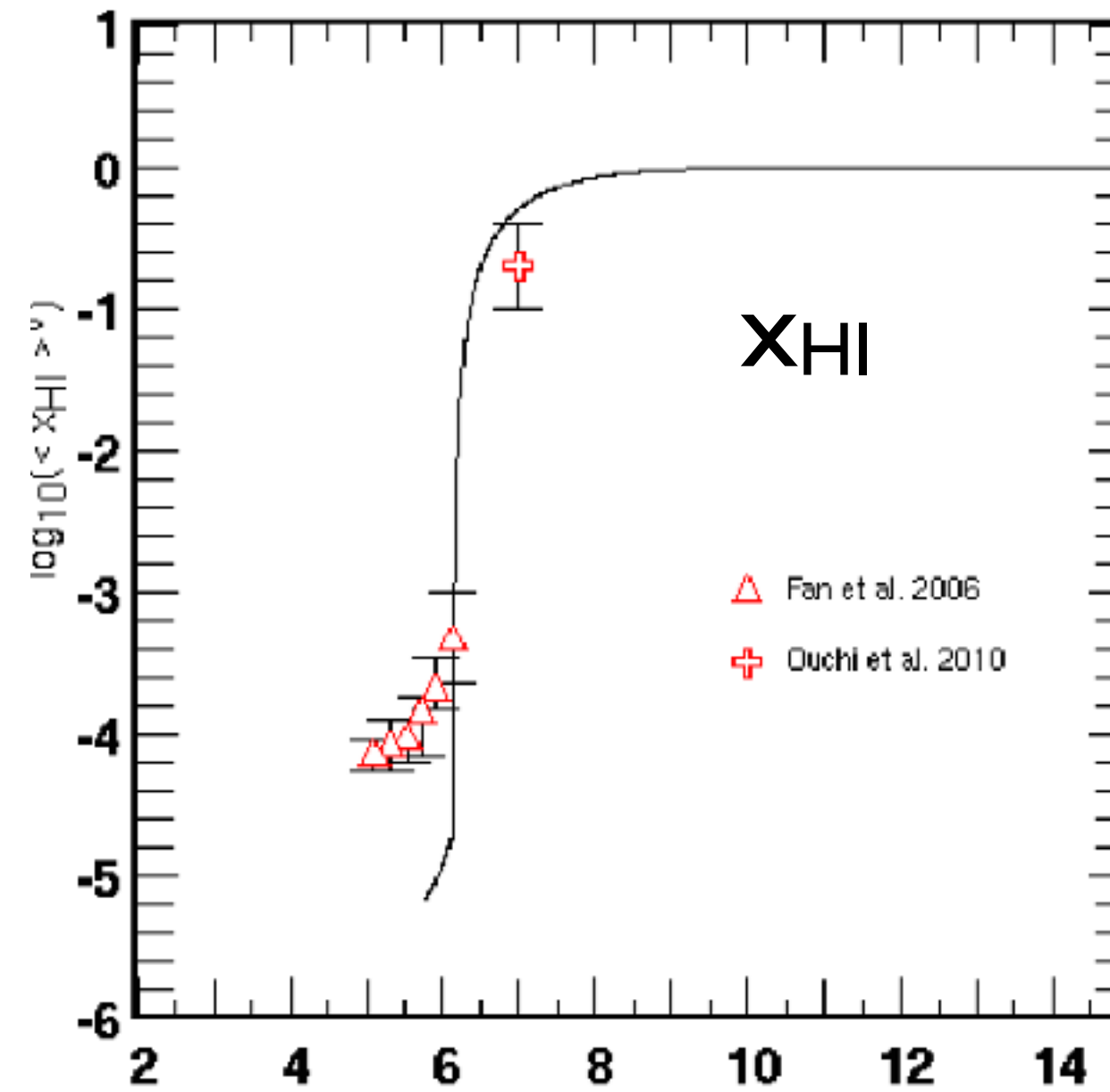


Cosmic Dawn II global properties

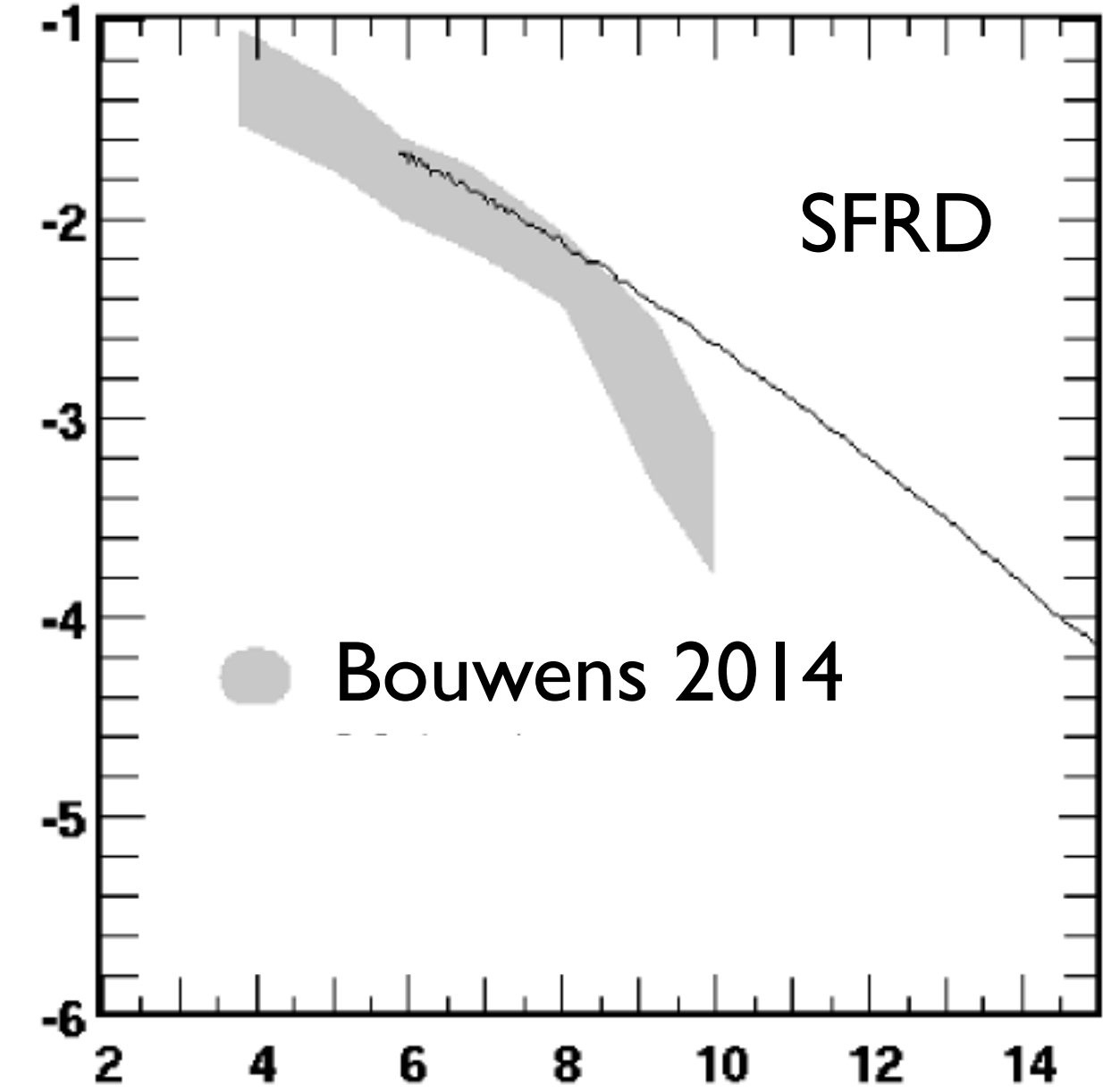
- Good general agreement, however:
- x_{HI} too low, J_{21} too high
- \Rightarrow too many photons, or not enough recombinations?
- \Rightarrow gas clumping missing at small scales?

CoDa II —

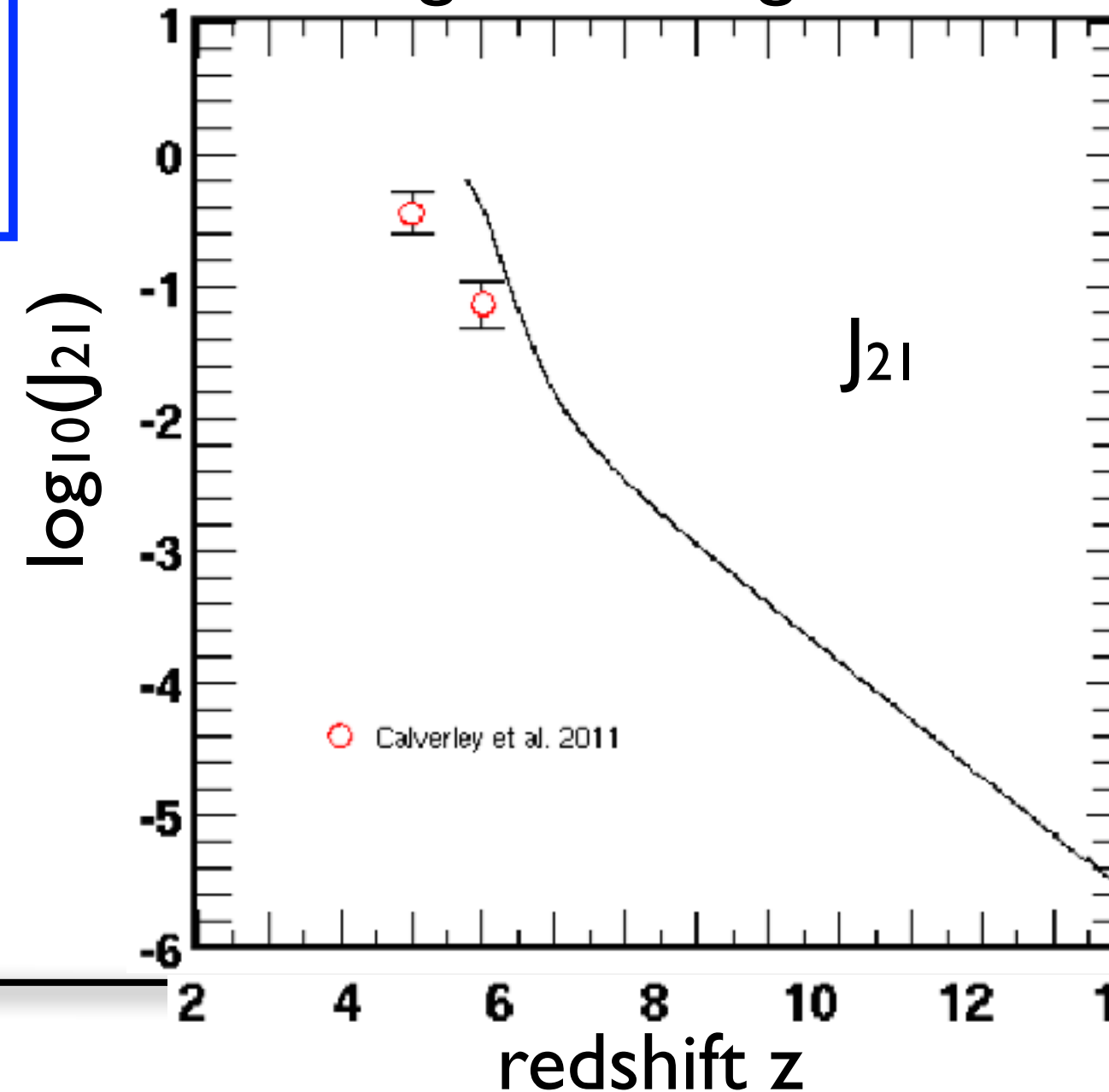
x_{HI} neutral fraction



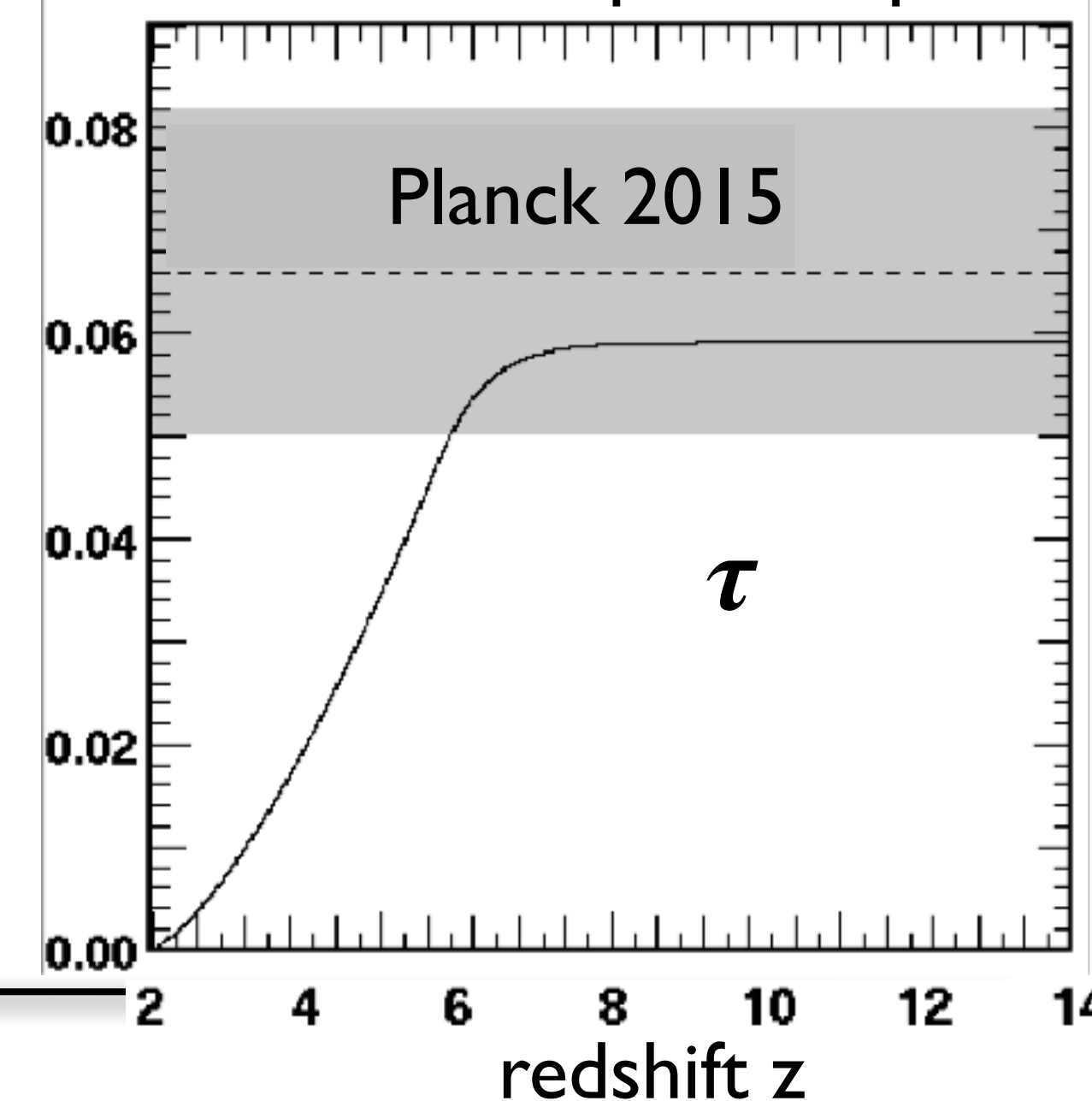
cosmic SFRD



ionising UV background flux

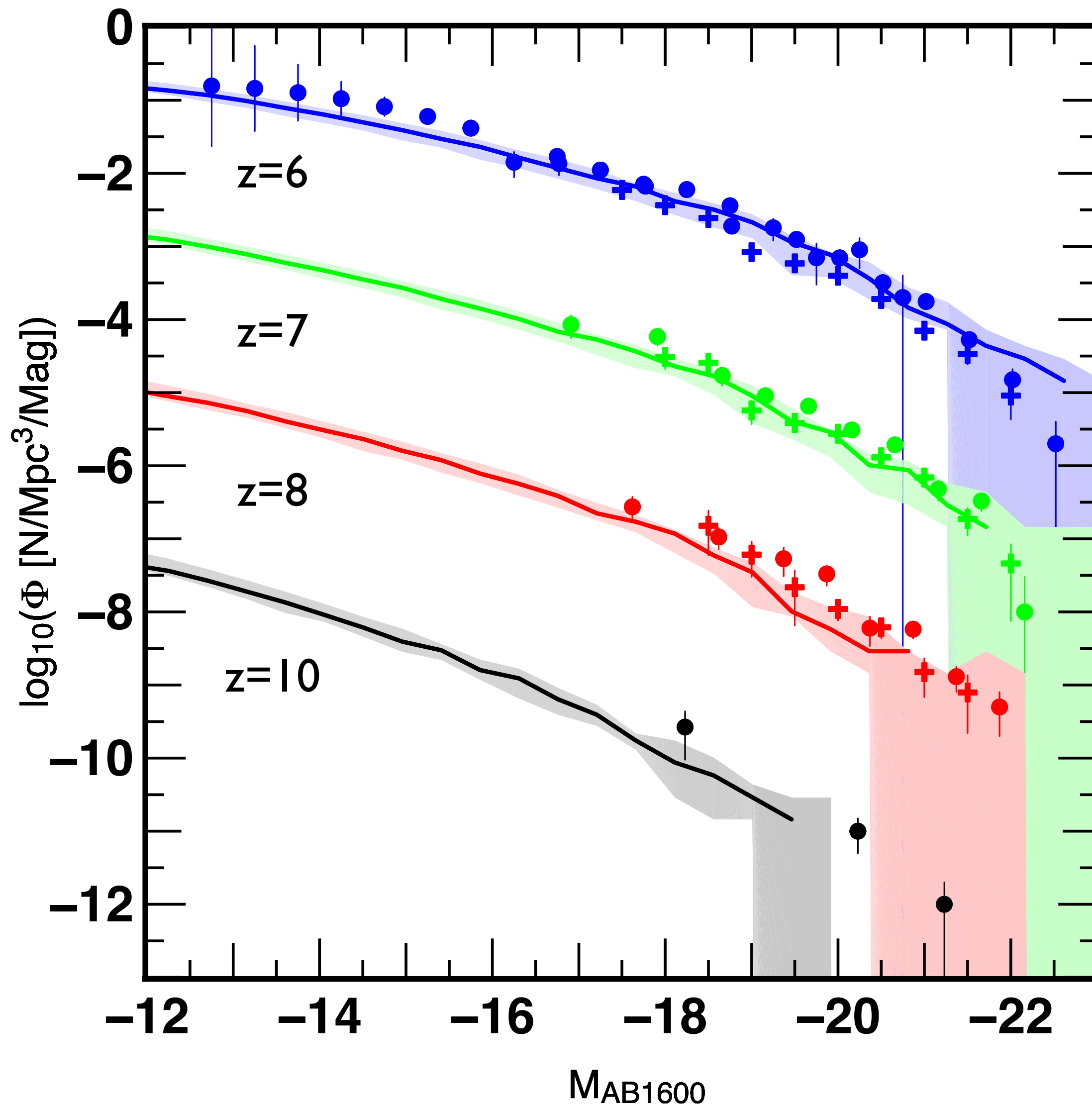


Thomson optical depth



CoDa11 Luminosity Function

CoDa UV Luminosity Function



- Much better overall agreement than CoDa1
- slope!
- down to much fainter mags
- increasing offset with z ?

- No Fe/H evolution
- No evolving dust content

●●● Bouwens 2016
— — — CoDa II

SUMMARY

- **Cosmic Dawn simulations** are the largest GPU-driven Radiation-Hydrodynamics galaxy formation simulation ever made.
- Describes galaxy formation \Leftrightarrow reionization self-consistently.
- CoDa II reproduces current observational constraints at $z > 6$: x_{HI} , J_{21} , SFR, τ , UV LF down to $M_{1600} = -13$.
- SF suppression less strong than CoDa I due to omitting temperature criterion for SF.
- $10^9 - 10^{10.5} M_{\odot}$ haloes dominate the ionising photon budget during the EoR.

- Future work:
- CoDa: environmental impact on SF suppression, reionization histories of galaxies and local group analogs (Jenny Sorce), Lyman alpha absorbers, ...
- CoDa III: improve physics: chemical enrichment + dust, AGNs?

Rise and Shine: galaxies in the epoch of reionization

June 18-22 2018
Strasbourg, France

CoDa I-AMR, simulated with EMMA. Credit: N. Deparis

Home

Program

Venue

Participants

Abstract
submission

Register

Contact



Rise and shine: galaxies in the epoch of reionization

"The co-evolution of galaxies and the intergalactic medium during the first billion years of the Universe"

Palais Universitaire de Strasbourg, France, June 18-22, 2018

Registration opening soon

Follow on twitter
#R&S2018



○ **Strasbourg, 18-22nd of June 2018**

○ First stars, first galaxies

○ Hydrogen reionisation

○ 21 cm experiments

○ Foregrounds mitigation

○ Galaxies and quasars at $z > 6$

○ Molecular gas at high z

○ Star formation at high z and

2 postdoc positions in Strasbourg

The screenshot shows the website of the Observatoire astronomique de Strasbourg. The header includes the URL 'unistra.fr', the observatory's logo, and logos for CNRS INSU and the University of Strasbourg. A navigation menu contains links for 'Actualités', 'Observatoire', 'Recherche', 'Service d'observation', 'Formation', 'Tout public', 'Annuaire', 'Nous joindre', and 'FR'. The main content area features a 'Séminaires et réunions' section with an event on October 6, 2017, and a 'Strasbourg Observatory Postdoctoral Fellowship' announcement dated September 21, 2017. The announcement describes the observatory's research focus and location. A search bar and a 'Rechercher' button are visible on the right side of the page.

unistra.fr

Observatoire astronomique de Strasbourg

cnrs INSU Observer & comprendre

UNIVERSITÉ DE STRASBOURG

Actualités Observatoire Recherche Service d'observation Formation Tout public Annuaire Nous joindre FR

Séminaires et réunions

Le 6 octobre 2017
De 10h30 à 12h00

[Séminaires hebdomadaires]

Giulia Migliori CEA

Du 13 novembre 2017 au 15 novembre 2017
Strasbourg, France

[Réunions scientifiques] [Alsacian Workshop on X-ray](#)

Accueil > Actualités : Strasbourg Observatory Postdoctoral Fellowship

Strasbourg Observatory Postdoctoral Fellowship

SEPT. 21 2017 The astronomical observatory of Strasbourg (Observatoire astronomique de Strasbourg, ObAS) is opening a post-doctoral (fellowship) position on any scientific topic covered by the laboratory: stellar and star cluster populations, high energy astrophysics including processes associated with compact objects and black holes, galactic archeology including exploitation of Gaia, galaxy evolution and cosmology, and data sharing.

ObAS is located on the premises of Strasbourg University - one of the major universities in France - in historical buildings surrounded by a botanic garden, within walking distance from the city center. A total of about 80 people work at the observatory, including 25

Rechercher Valider

Actualités

SEPT. 21 2017 [Strasbourg Observatory Postdoctoral Fellowship](#)

The astronomical observatory of Strasbourg (Observatoire astronomique de Strasbourg, ObAS) is...

- o starting date: 1 in ~autumn 2018, 1 in early 2018 (~March)
- o Duration: 1+1, 2+1
- o Talk to Dominique Aubert or myself

SUMMARY

- **Cosmic Dawn simulations** are the largest GPU-driven Radiation-Hydrodynamics galaxy formation simulation ever made.
- Describes galaxy formation \Leftrightarrow reionization self-consistently.
- CoDa II reproduces current observational constraints at $z > 6$: x_{HI} , J_{21} , SFR, τ , UV LF down to $M_{1600} = -13$.
- SF suppression less strong than CoDa I due to omitting temperature criterion for SF.
- $10^9 - 10^{10.5} M_{\odot}$ haloes dominate the ionising photon budget during the EoR.

- Future work:
- CoDa: environmental impact on SF suppression, reionization histories of galaxies and local group analogs (Jenny Sorce), Lyman alpha absorbers, ...
- CoDa III: improve physics: chemical enrichment + dust, AGNs?