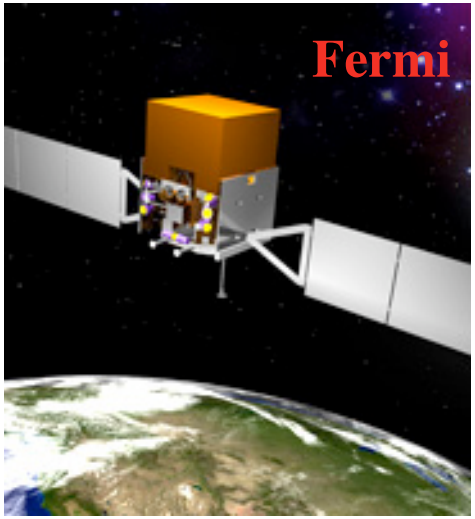
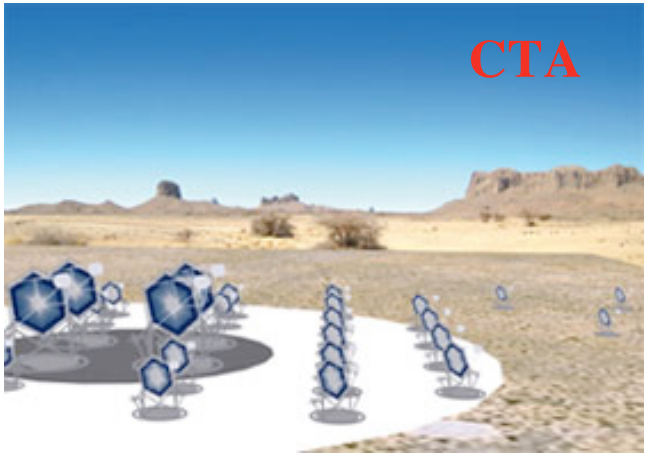
CTAで切り拓くガンマ線観測的宇宙論（超遠方宇宙）

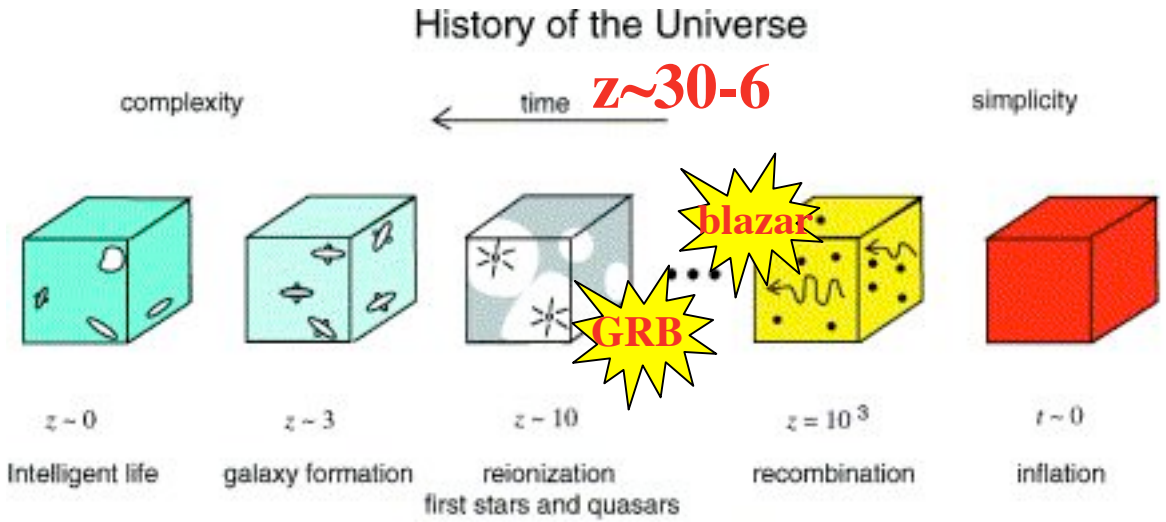
井上進（京大理）with



R. Salvaterra, T. R. Choudhury, A. Ferrara, B. Ciardi, R. Schneider
(MNRAS in press, arXiv:0906.2495)

Y. Inoue, M. Kobayashi, T. Totani, Y. Niinou
(in prep.)





gamma-ray absorption: probe of diffuse radiation fields

$\gamma + \gamma \rightarrow e^+ + e^-$

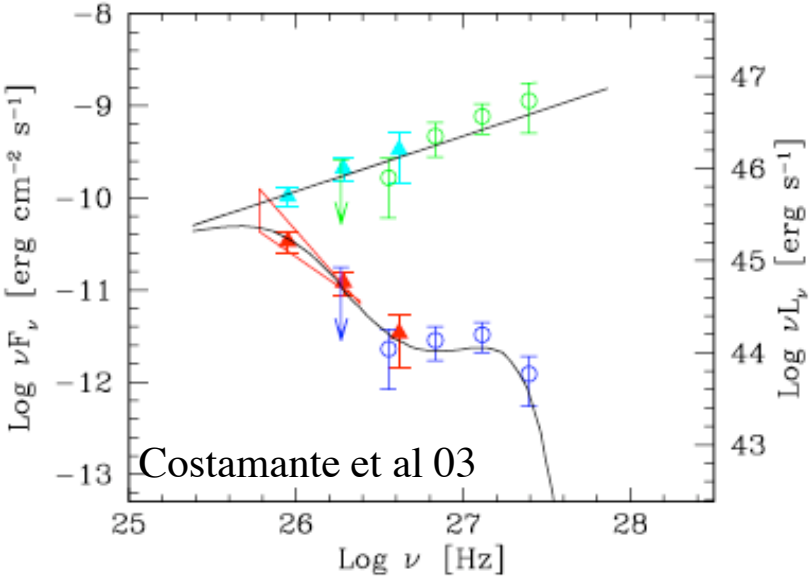
E ε

threshold condition: $E\,\varepsilon\,(1-\cos\theta) > 2\,m_e^2c^4$

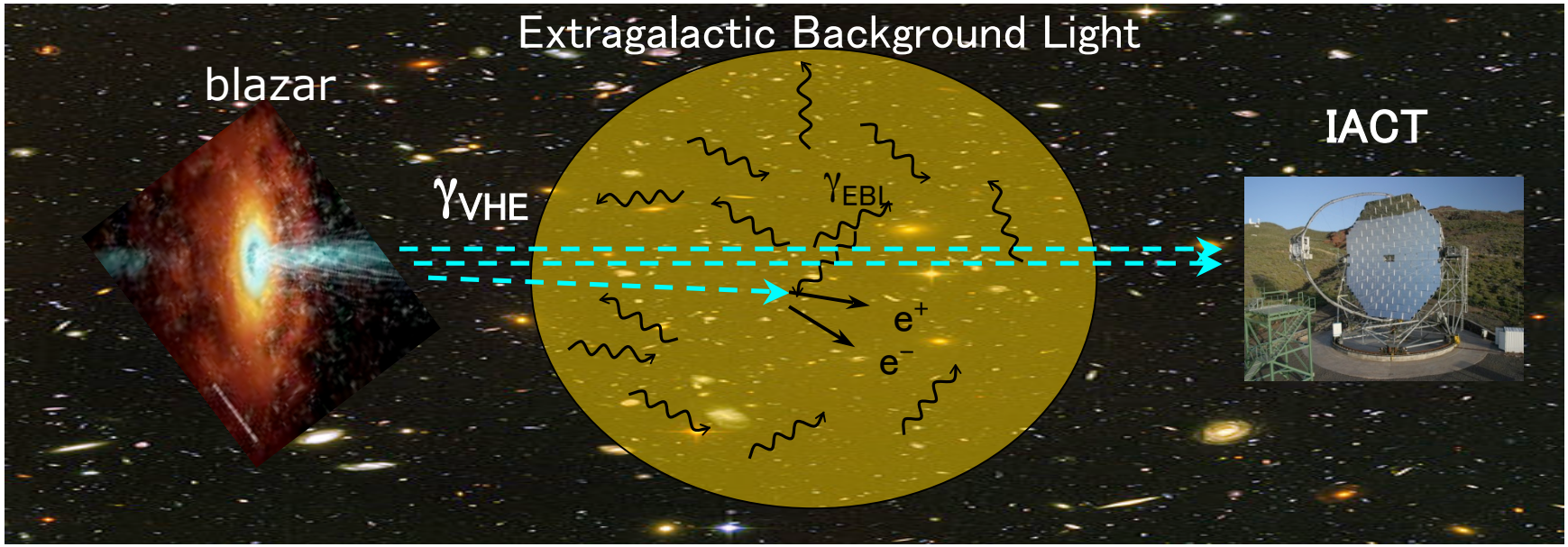
σ peak ,, $= 4\,m_e^2c^4$

e.g. TeV + 1eV (IR)

100 GeV + 10 eV (UV)



e.g. probe of local IRB through gamma absorption in TeV blazars

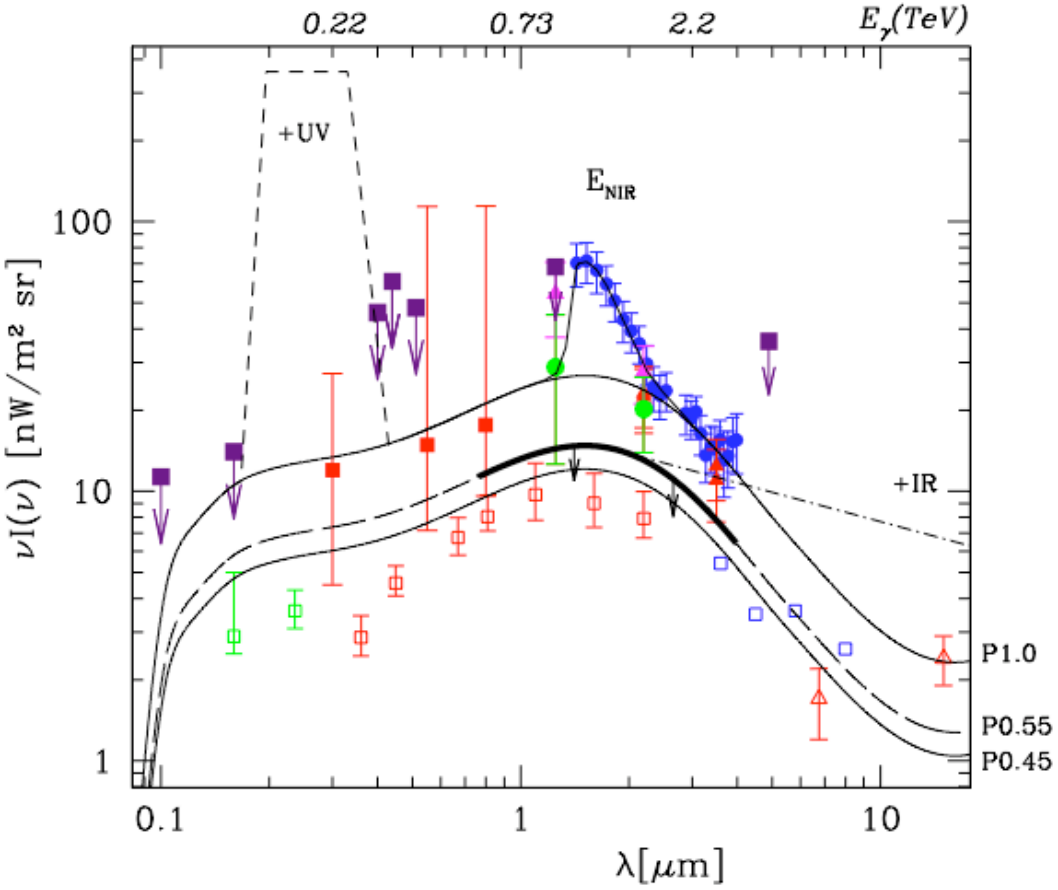


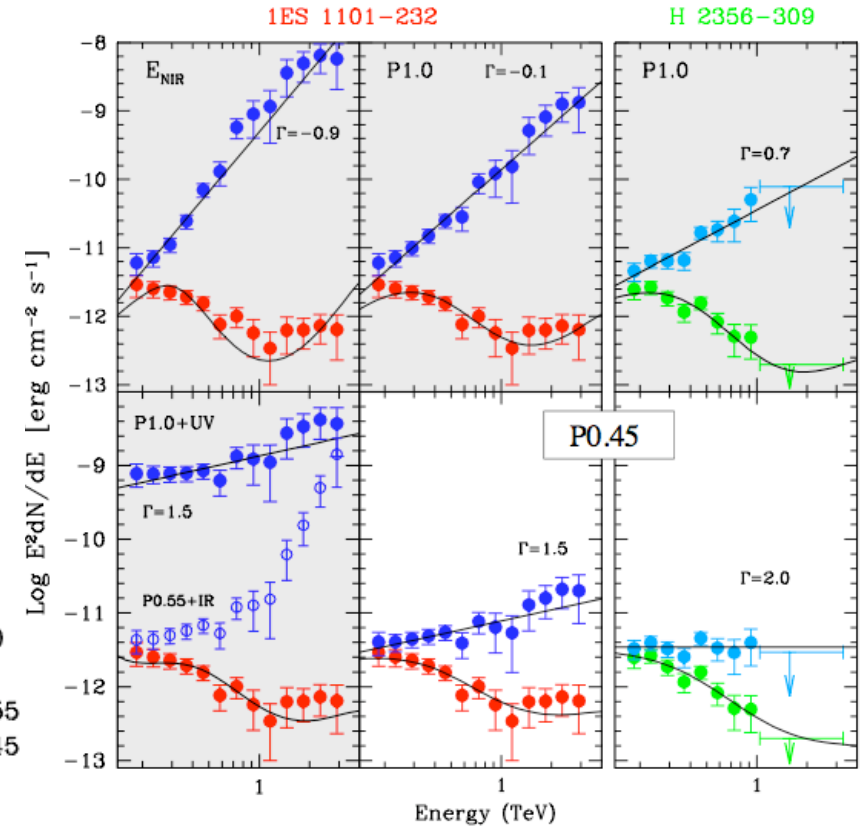
手嶋さんのスライドより

probing local IR background with gamma-ray absorption

HESS observations of TeV blazars @z=0.165, 0.186

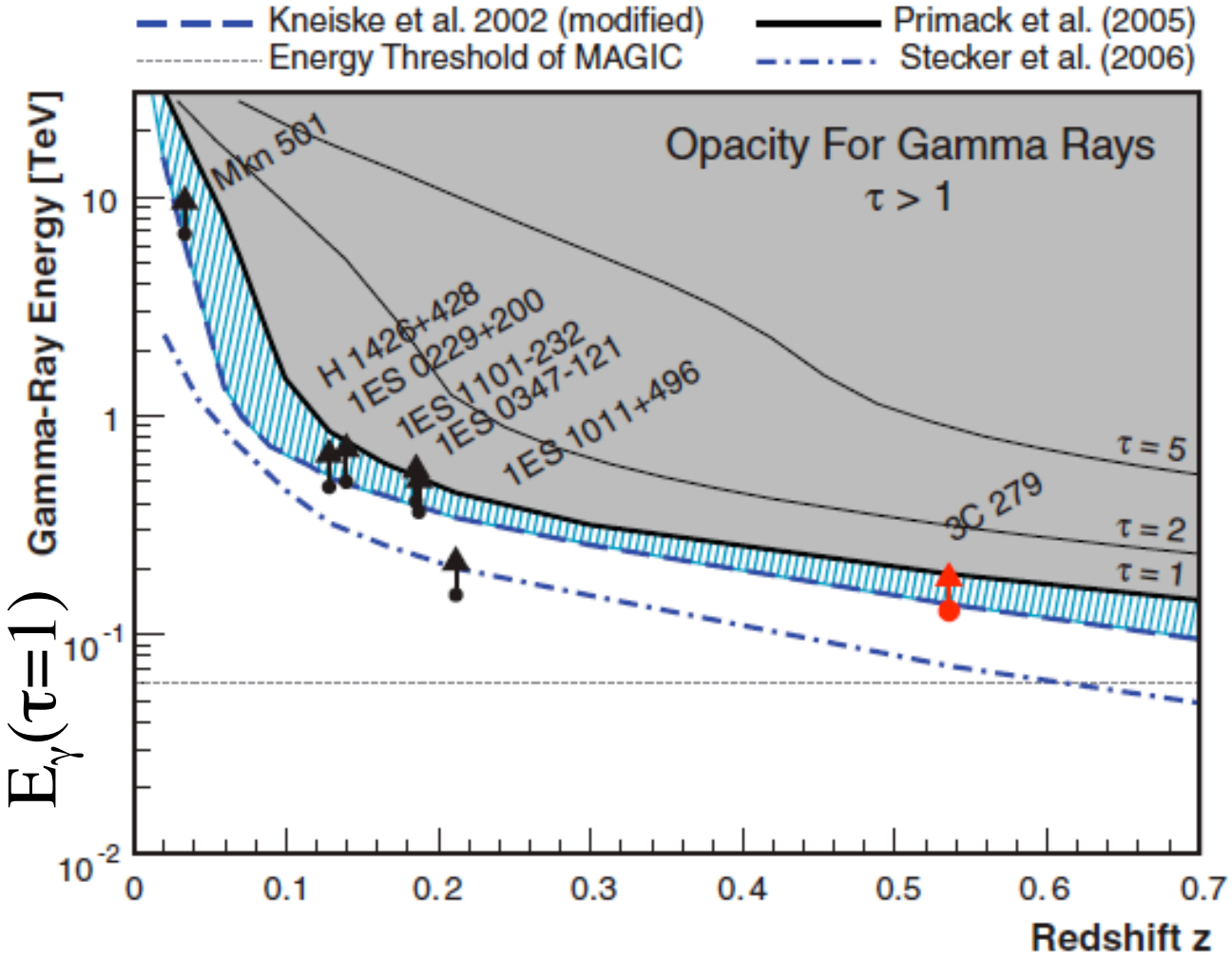
Aharonian+ 06 Nat.





- strongly disfavors NIR peak no strong Pop III
- close to lower limits from galaxy counts

EBL constraints at z=0.536



Albert+ 08 Sci.

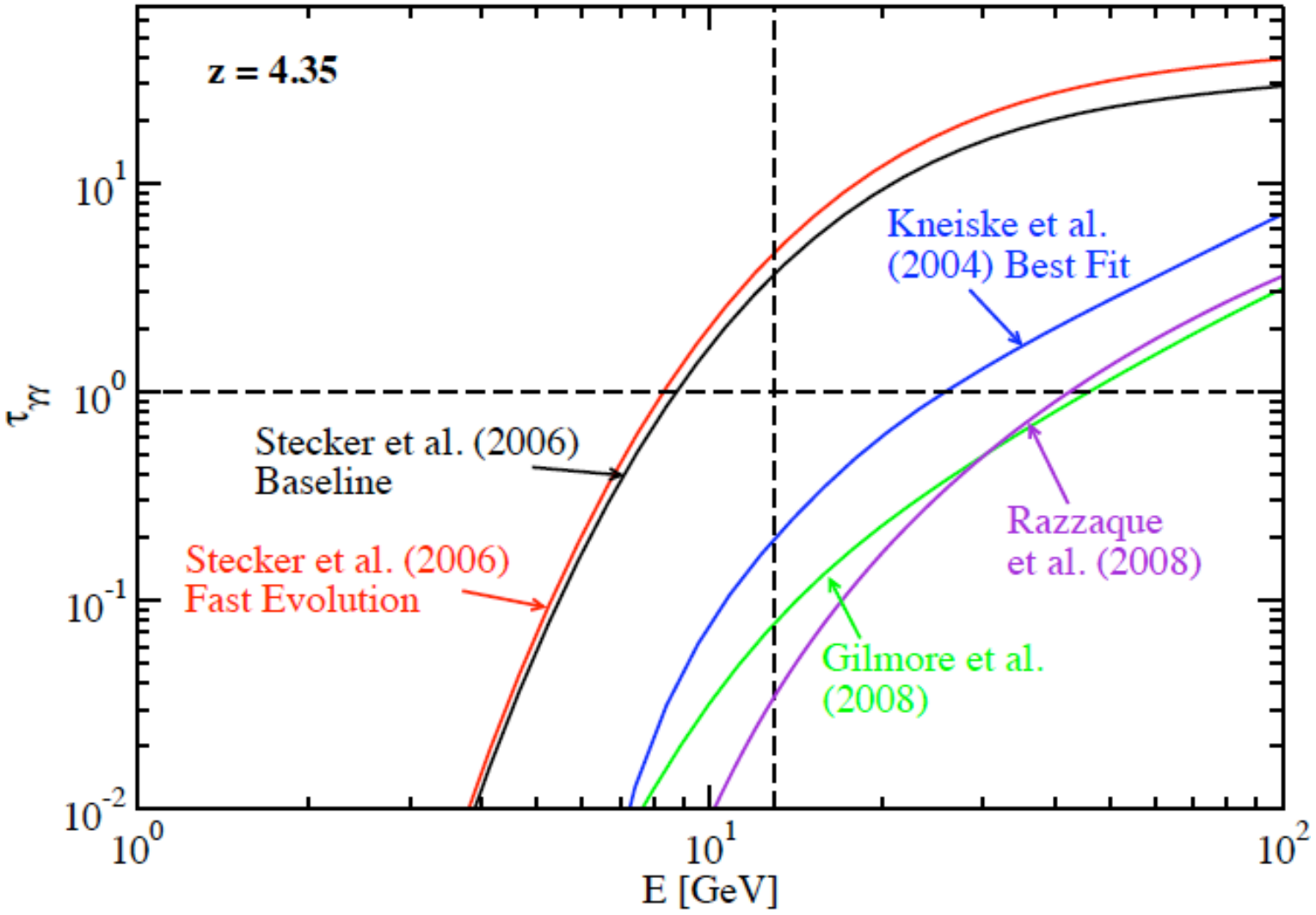
MAGIC observation
80-500 GeV
3C279 @z=0.536

close to lower limits from galaxy counts (little missing light)
if “normal” blazar spectra $\alpha>1.5$

EBL constraints at z=4.35

Abdo+ 09, Sci. 323, 1688

Fermi/LAT detection of GRB 080916C up to 13 GeV without cutoff



Reionization: The Basic Picture

slides from T. R. Choudhury

Start

$z \approx 1000$

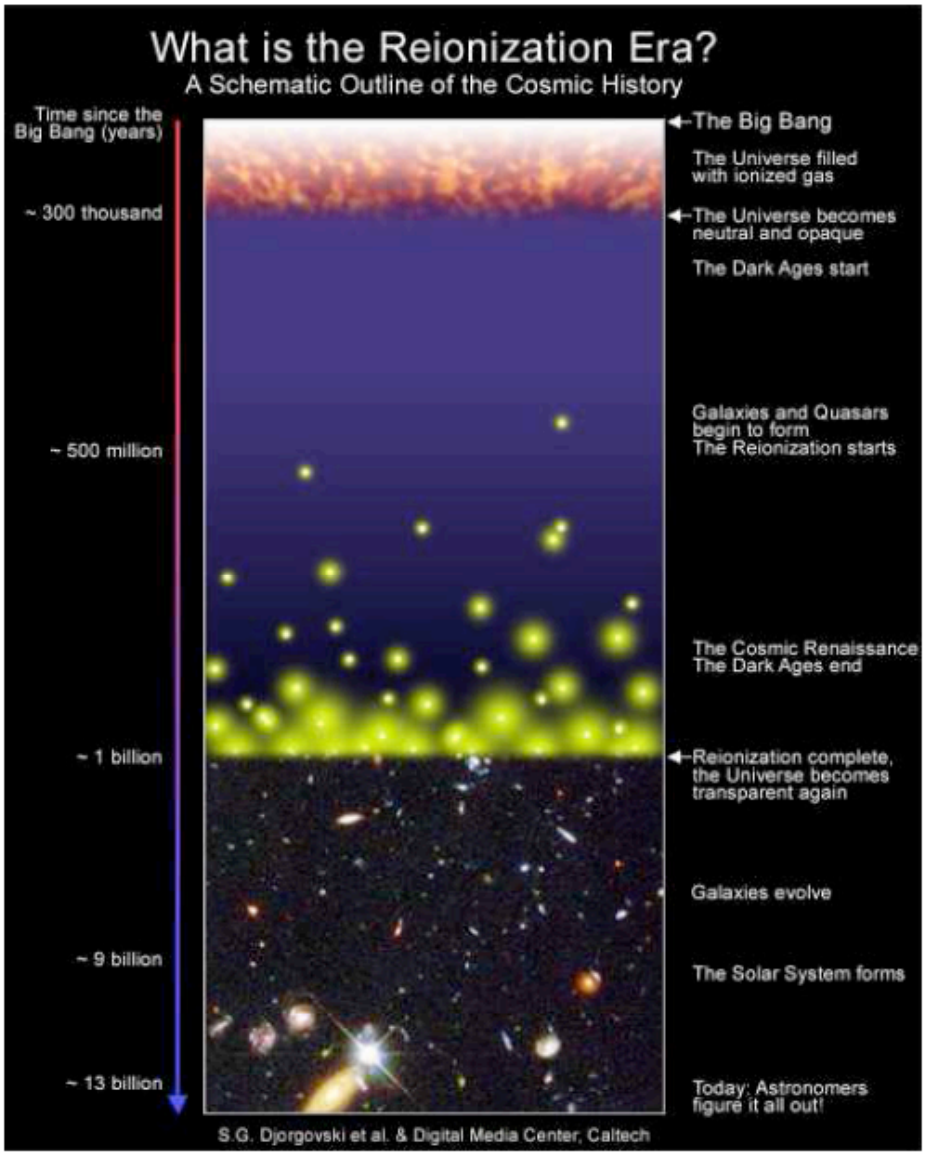
Big Bang

Last Scattering

Initial conditions (WMAP)

$z > 30$

Dark Ages



$z \approx 15 - 30$

First Sources

$z \approx 6 - 15$

Reionization

Galaxies

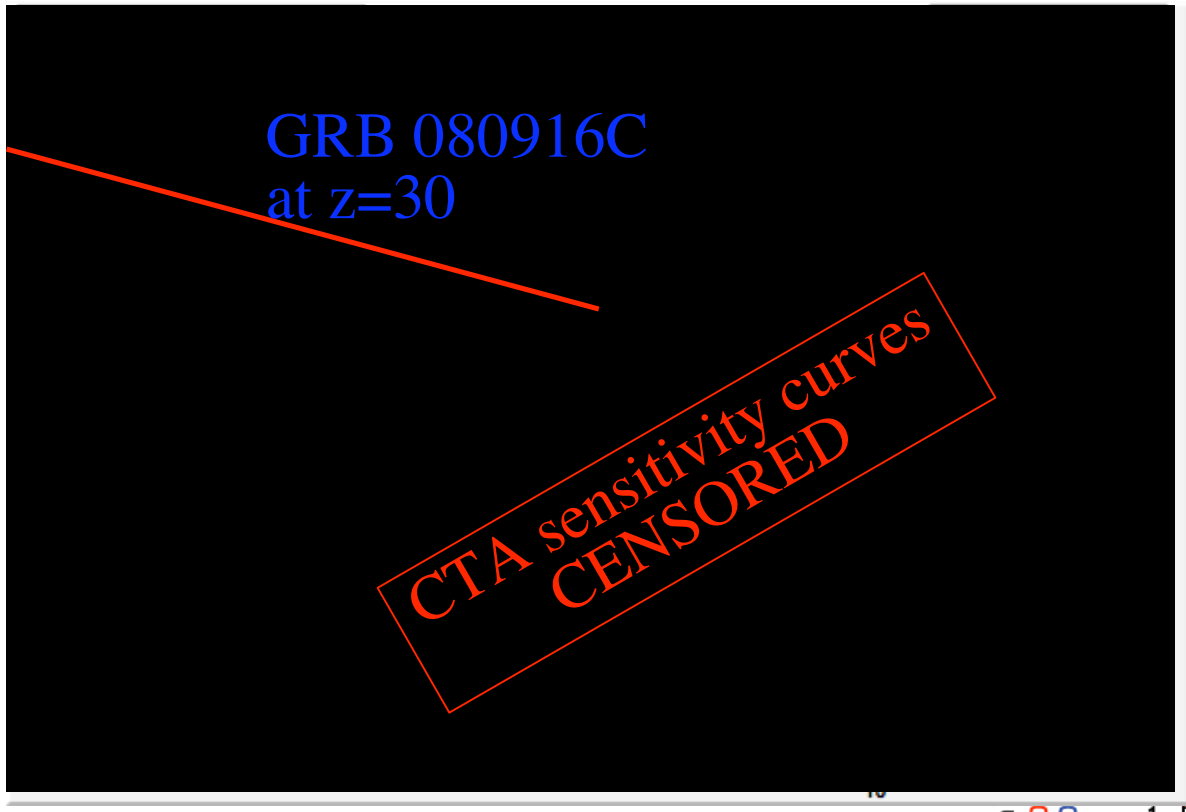
Nonlinear Structures (HST)

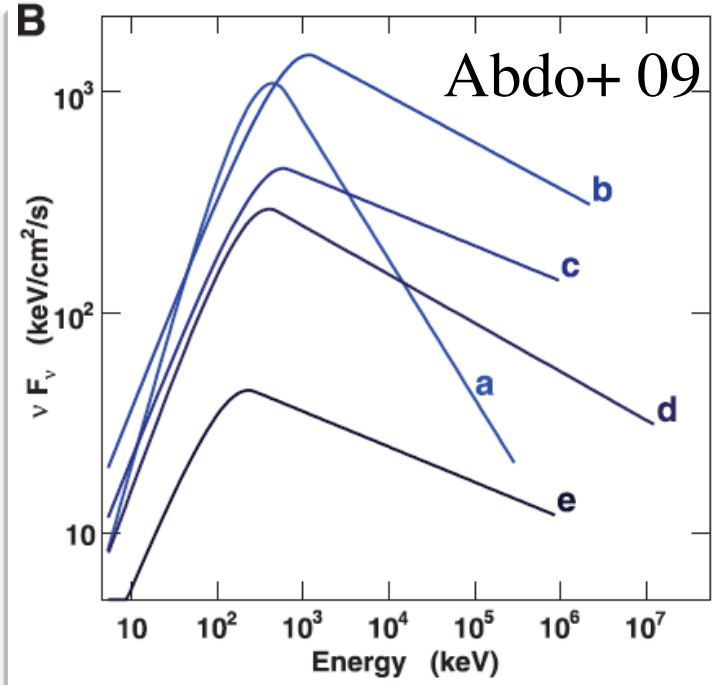
$z \sim 3$

$z \sim 0$

Now

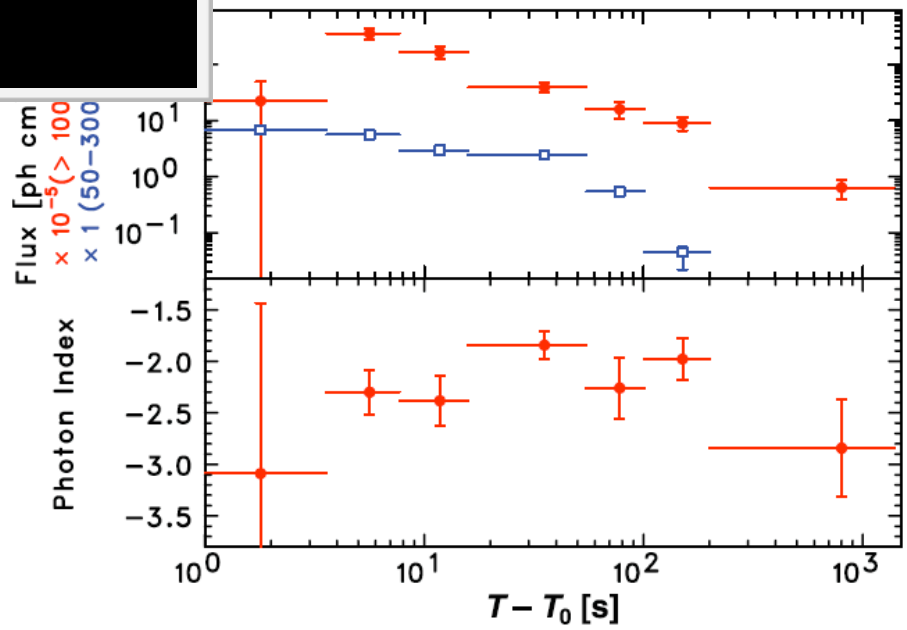
detectability of high-z GRBs by CTA





GRB 080916C Fermi (z=4.3)
TeV extrapolation, delayed
~ 10^{-9} erg/cm^2/s at T~1000s

neglecting EBL absorption,
detectable out to z=30!!!



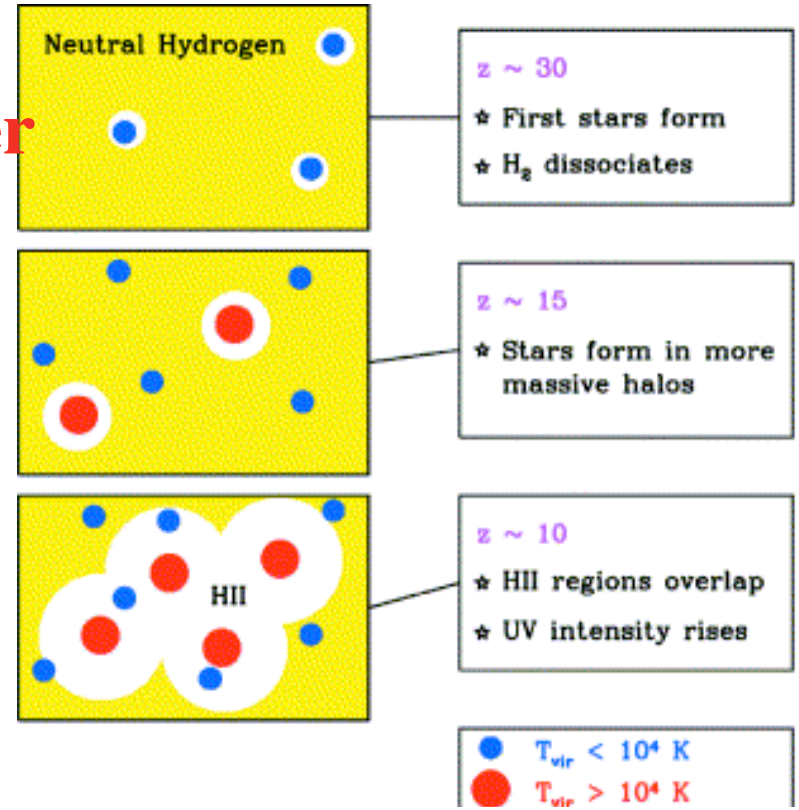
cosmic reionization epoch

z>6 current observational frontier

When? early? late? two-epoch?

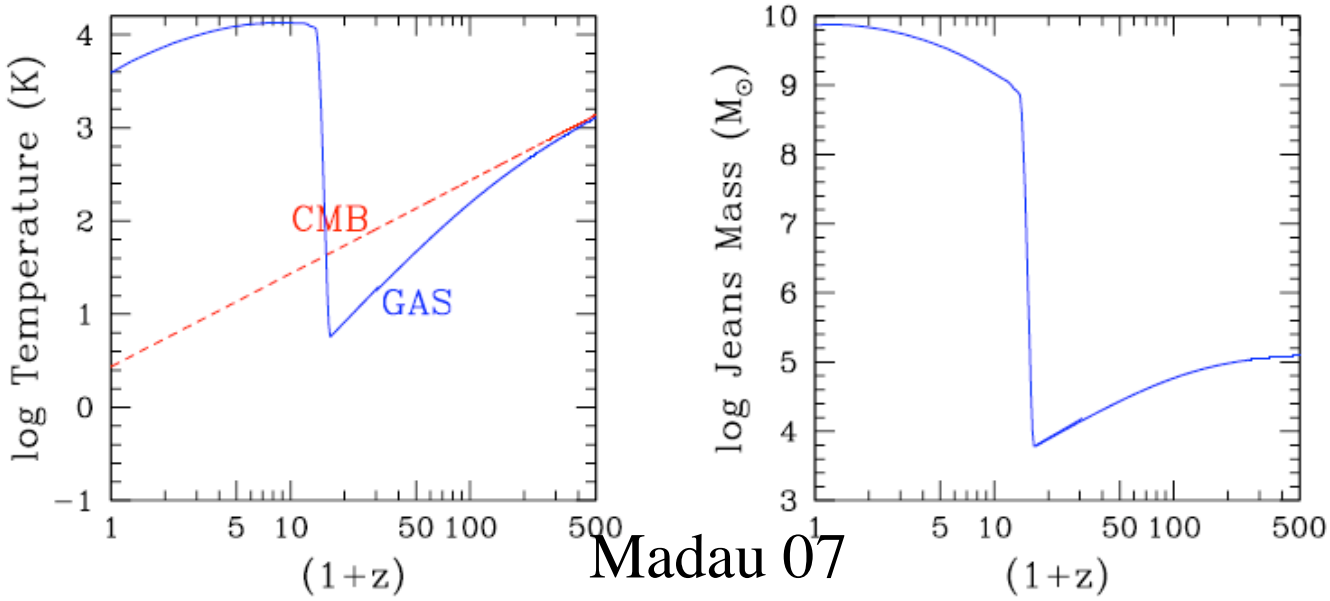
How? topology?

What? Pop III? Pop II?
mini-QSOs?
dark matter decay?



So what?

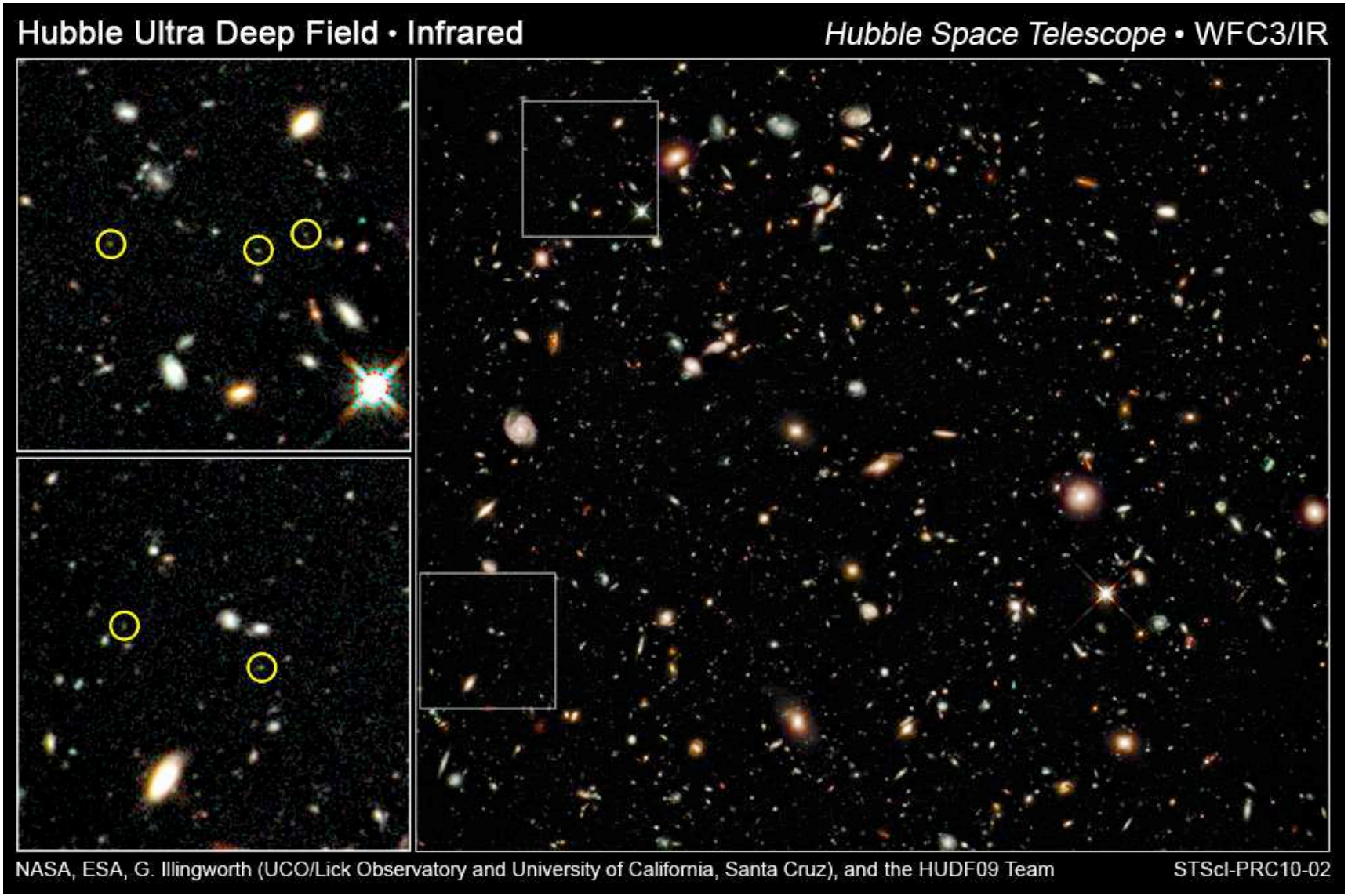
suppression of dwarf galaxy formation



Hubble Ultra Deep Field 2009 (HUDF09) with newly installed WFC3/IR

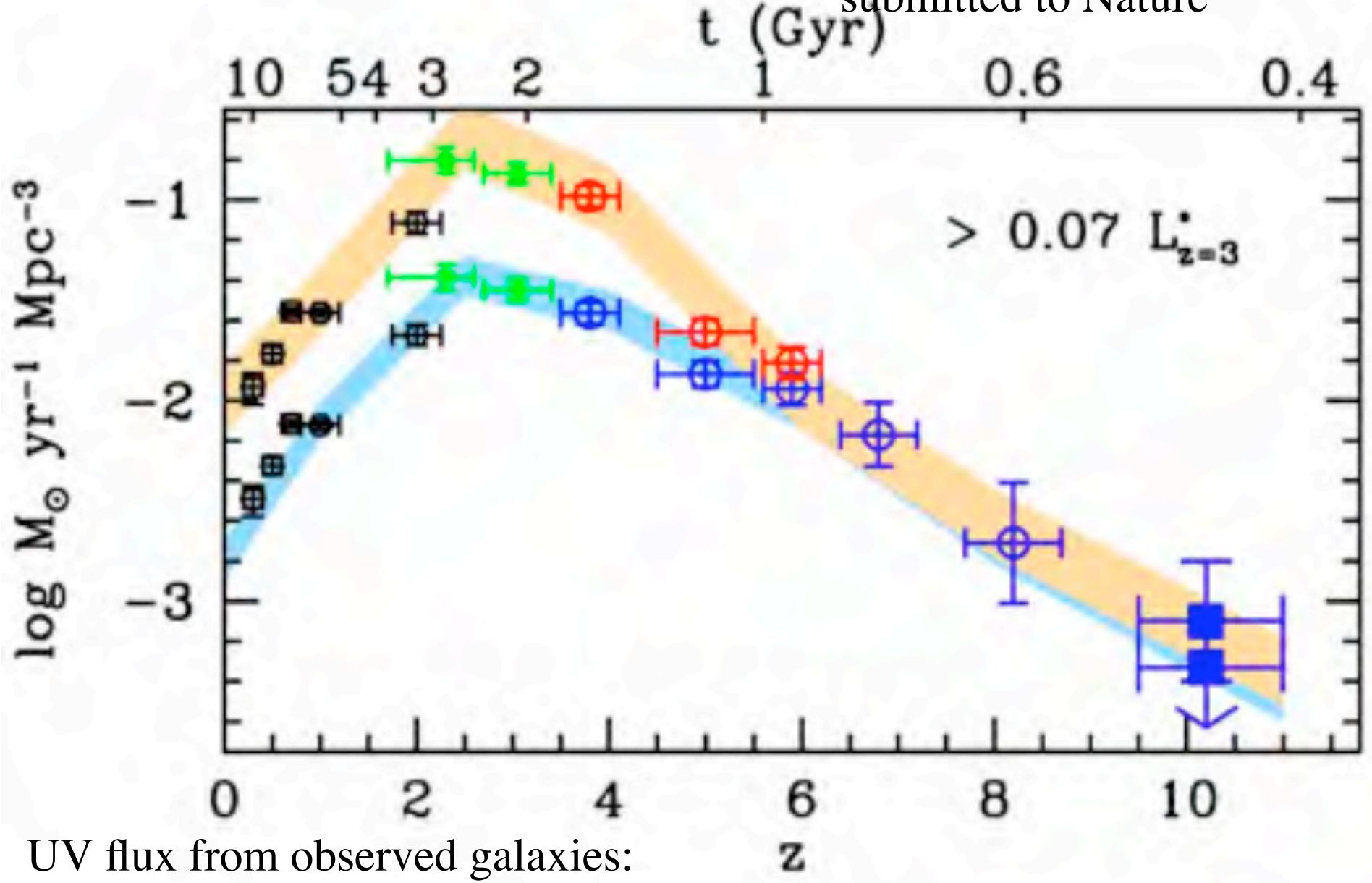
News Release Number: STScI-2010-02 *January 5, 2010 10:30 AM (EST)*

Hubble Reaches the "Undiscovered Country" of Primeval Galaxies



cosmic star formation rate

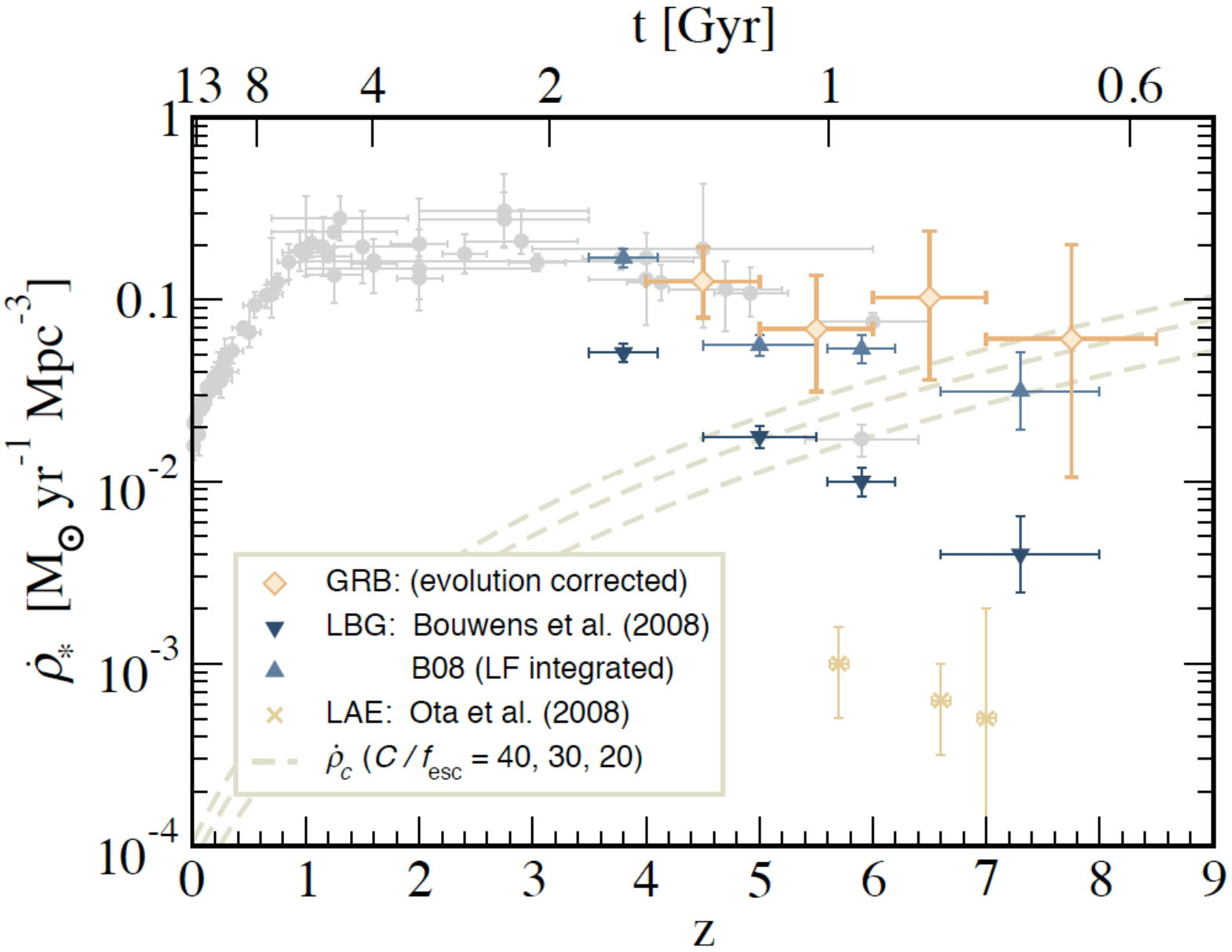
Bouwens+ arXiv:0912.4263
submitted to Nature



UV flux from observed galaxies:
only ~13% of reionization requirement (with f_{esc}=0.5, C=3, Salpeter IMF)

cosmic star formation rate

estimated from GRB rate Kistler+ 09

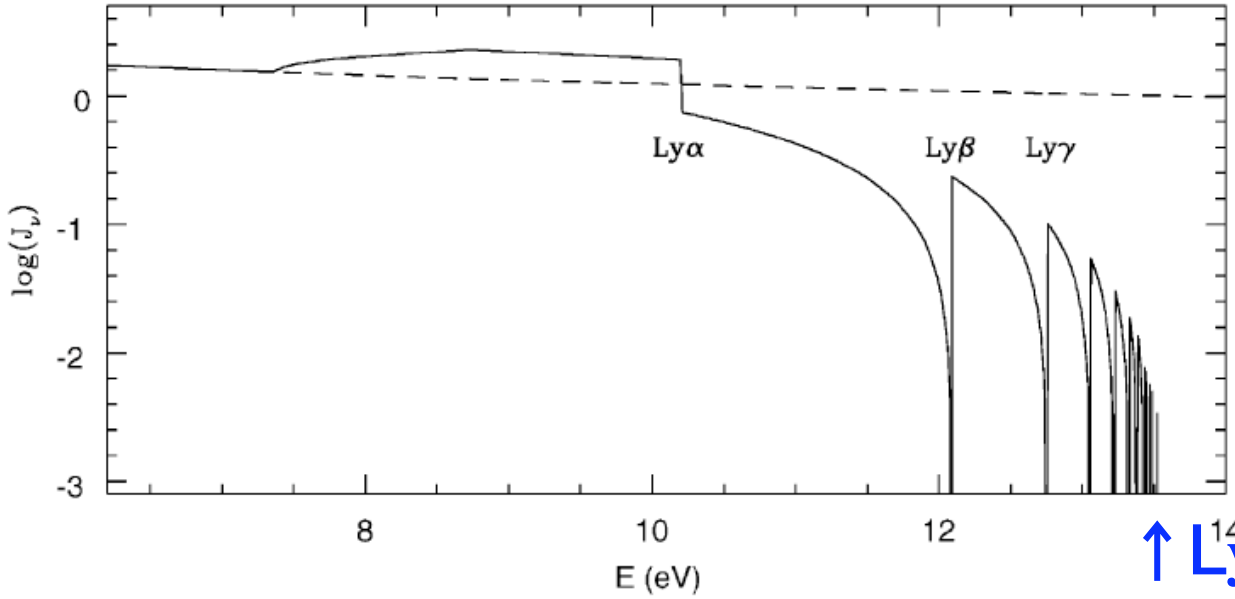


UV intergalactic radiation field (IRF) at high-z

crucial in cosmic reionization/first star formation era

- IRF above Lyman edge ε>13.6 eV
  reionizes the IGM (feedback on galaxy formation)
- IRF below Lyman edge
  dissociates H_2 molecules (feedback on star formation) ε=11.2-13.6 eV
  Lyα pumping (affects HI 21cm emission) ε=10.2 eV

but direct detection impossible!



↑ Ly edge

gamma-ray absorption
= direct census of diffuse UV below Ly edge (indep. of f_{esc}, C)

model of cosmic reionization

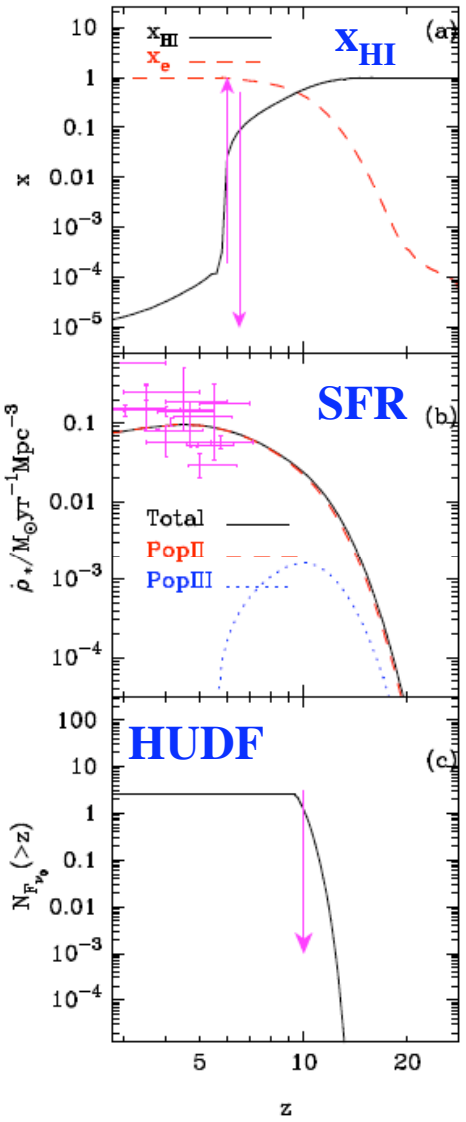
SI+ arXiv:0906.2495

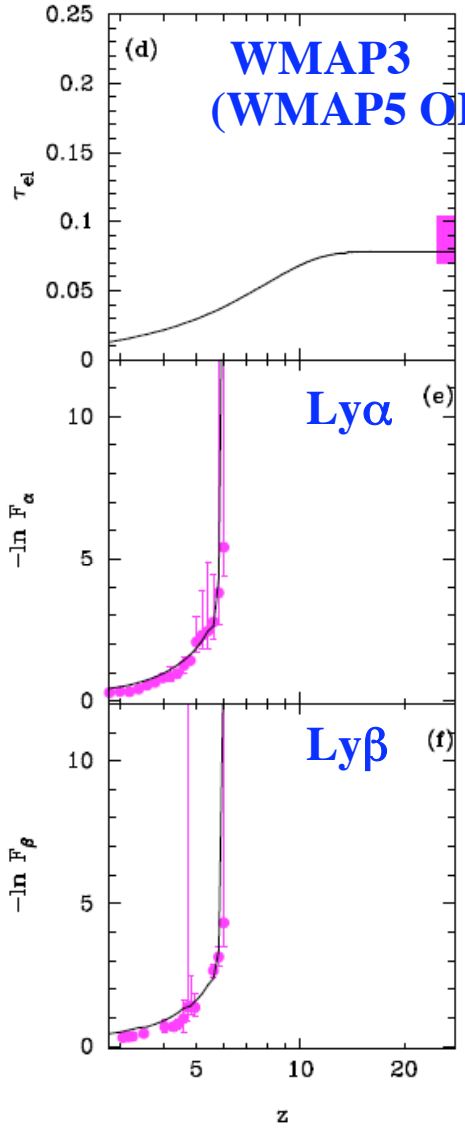
Choudhury & Ferrara 05, 06, Choudhury 09

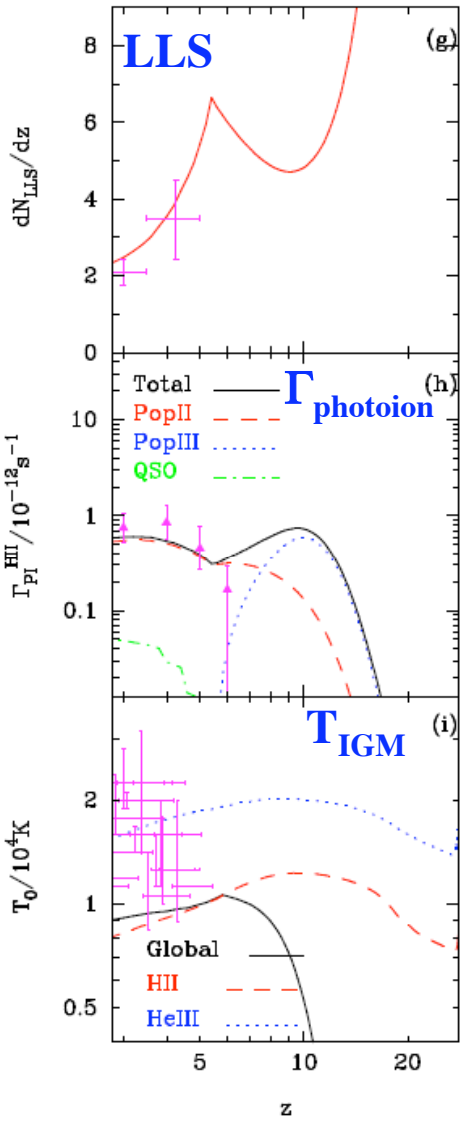
parameters ε_{*II}, ε_{*III}, η_{esc}, λ_{0IGM}

semi-analytical model with Pop III+II stars+QSOs, radiative+chemical feedback

consistent with large set of high-z observations: WMAP, x_{HI}, HUDF NIR counts, etc.



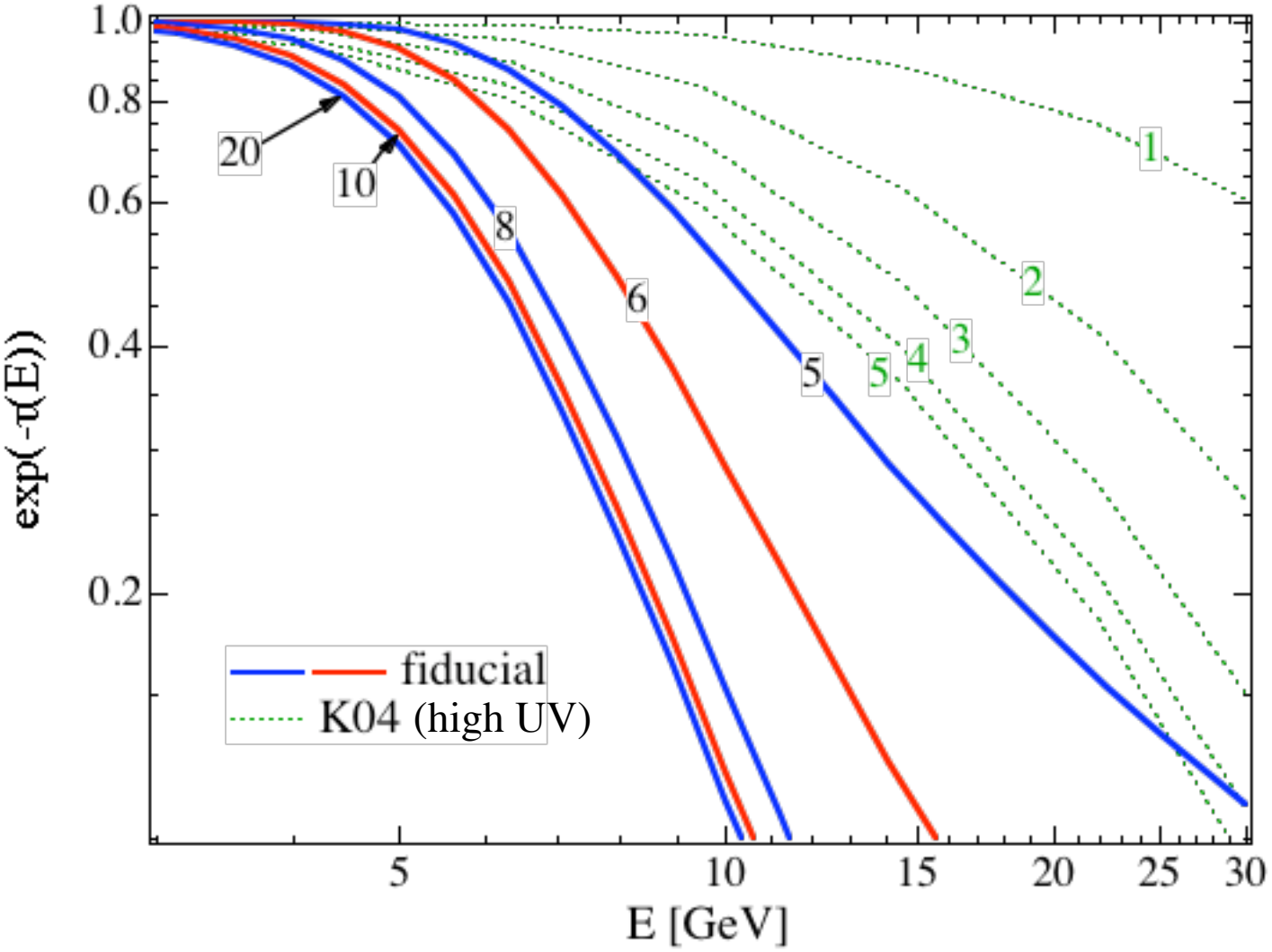




reionization
begins z~15
90% z~8
100% z~6

γγ absorption attenuation factor

SI+ arXiv:0906.2495



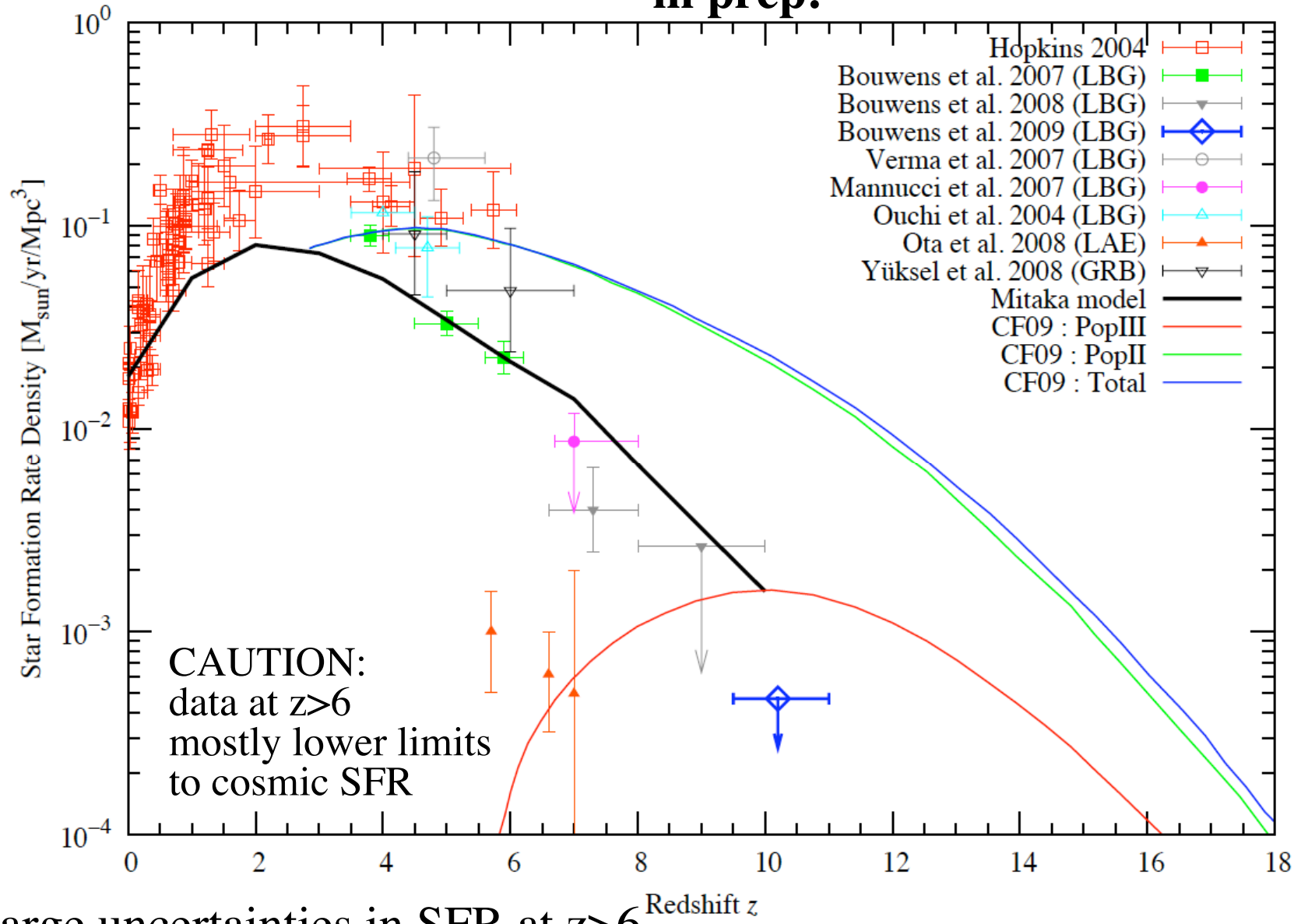
low z model
Kneiske+ 04
(high stellar UV)

Fermi
CTA, AGIS
5@5

appreciable differences in attenuation between z~5-8 at several GeV
→ unique, important info on evolution of UV IRF below Ly edge
= direct census of cosmic star formation rate (indep. of f_{esc}, C)

cosmic star formation rate

Y. Inoue, M. Kobayashi, Totani, SI+ in prep.

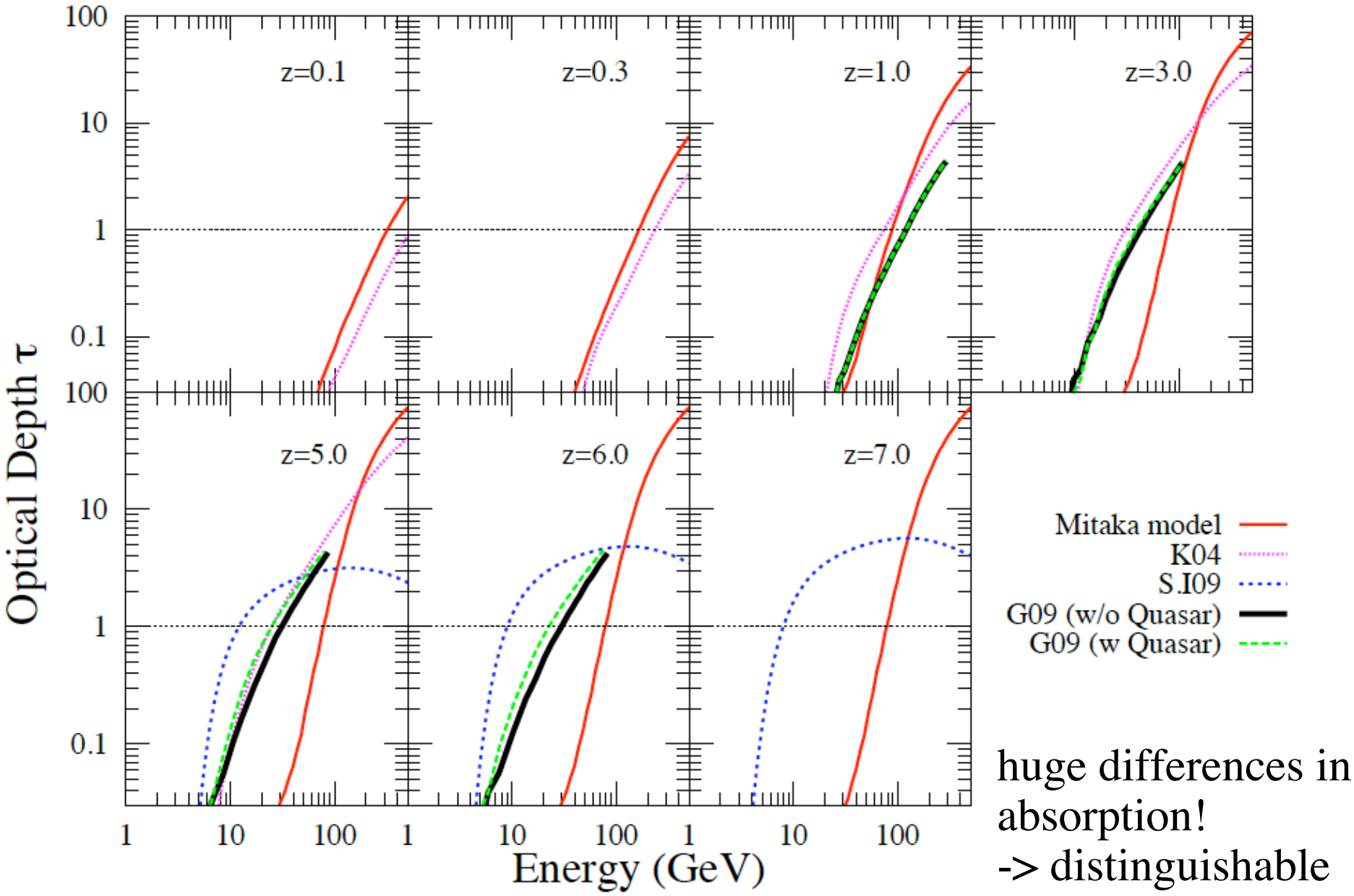


large uncertainties in SFR at z>6

models with low Pop II but high Pop III also possible?

γγ optical depth: comparison

Y. Inoue+, in prep.



huge differences in absorption!
-> distinguishable through CTA obs.

まとめ

CTAでGRBはz~30（初代星形成期）でも見える

ガンマ線吸収からhigh-zのdiffuse UVを探る
＝宇宙星形成率の（最も？）robustな測定方法

現実的モデルは10-100GeV領域で大きな違い

CTAは観測的宇宙論に本質的な寄与ができる！