How recent limits on the extragalactic background light constrain the star formation history

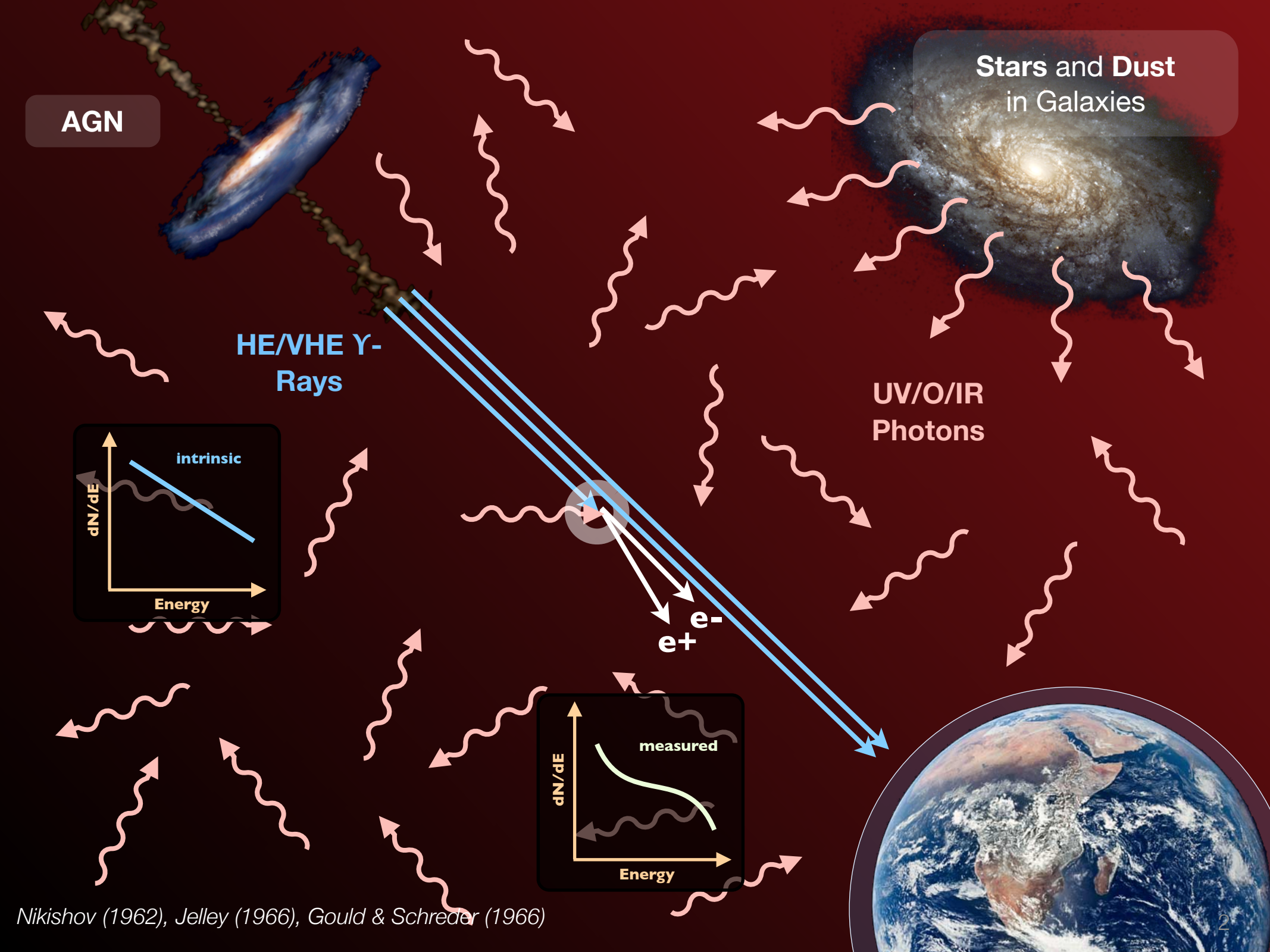
Martin Raue* **& Manuel Meyer**

5th International Symposium on
High-Energy Gamma-Ray Astronomy
July 9-13, 2012
Heidelberg, Germany

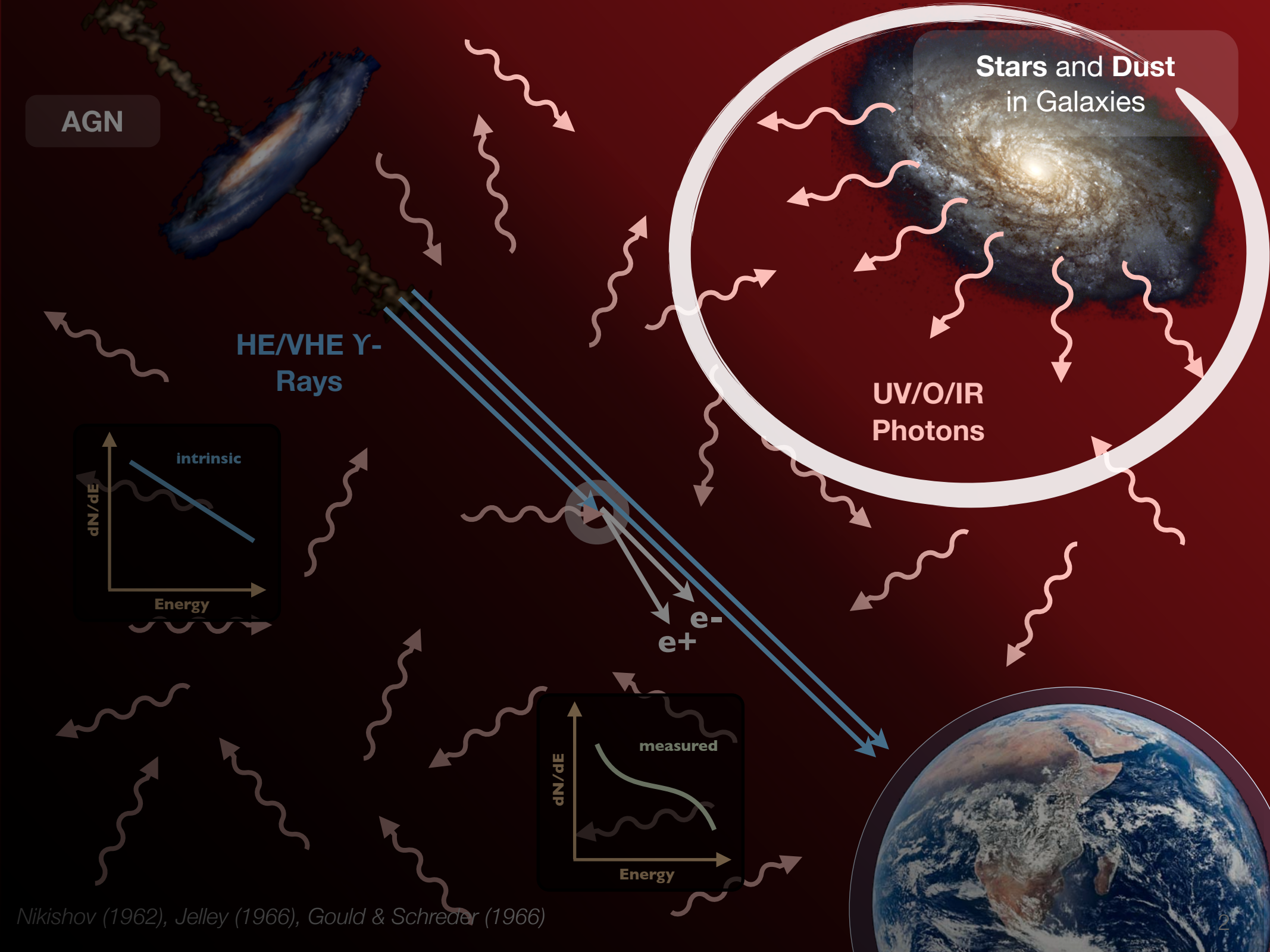
Universität Hamburg

LANDESEXZELLENZINITIATIVE HAMBURG

*martin.raue@desy.de



Nikishov (1962), Jelley (1966), Gould & Schreder (1966)



Nikishov (1962), Jelley (1966), Gould & Schreder (1966)

How to connect stellar formation with the EBL?

$$P_\nu(z) = \nu I_\nu(z) = \nu \frac{c}{4\pi} \int_z^{z_m} \mathcal{E}_{\nu'}(z') \left| \frac{dt'}{dz'} \right| dz'$$

EBL

$$\mathcal{E}_\nu(z) = \int_z^{z_m} L_\nu(t(z) - t(z')) \dot{\rho}_*(z') \left| \frac{dt'}{dz'} \right| dz'$$

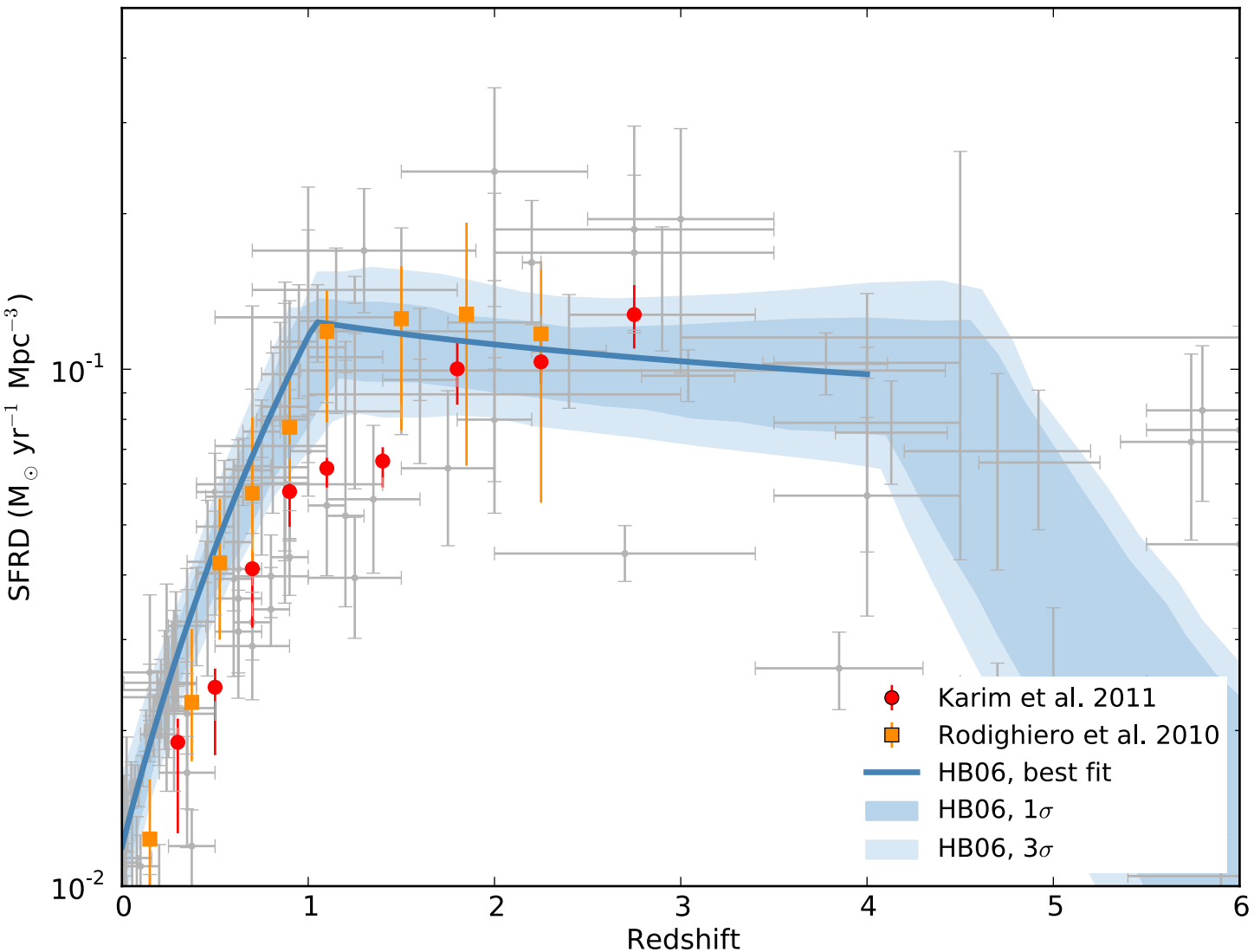
Emissivity

Stellar population spectra (SPS)

Star formation rate density (SFRD)

e.g. Dwek et al. 1998, Kneiske, Mannheim, Hartmann 2002

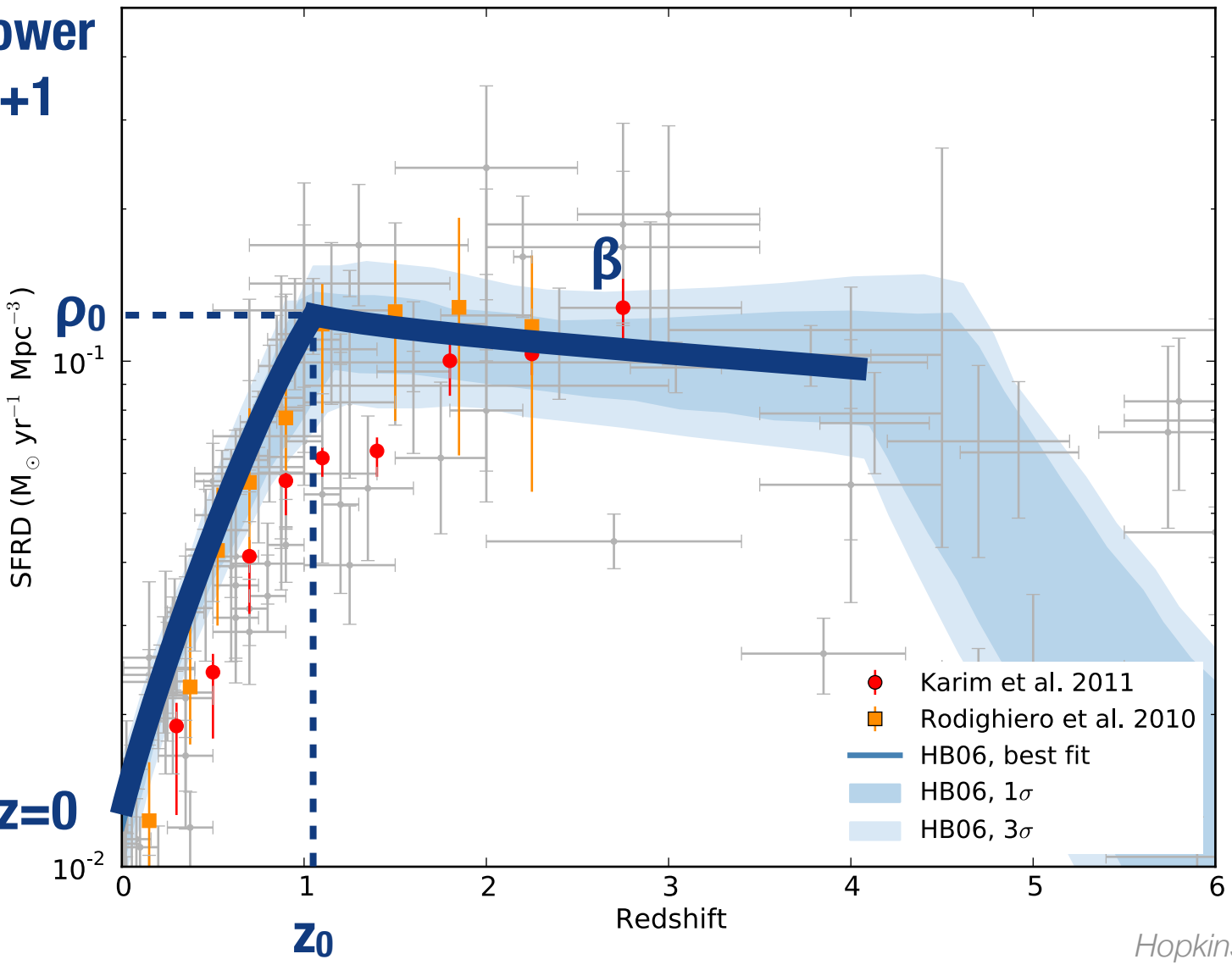
Star formation rate density (SFRD)



Hopkins & Beacom 2006

Star formation rate density (SFRD)

Broken power law in z+1



Fixed at z=0

Free parameters: z_0, ρ_0, β

Hopkins & Beacom 2006

Stellar emission from SPS

Parameters

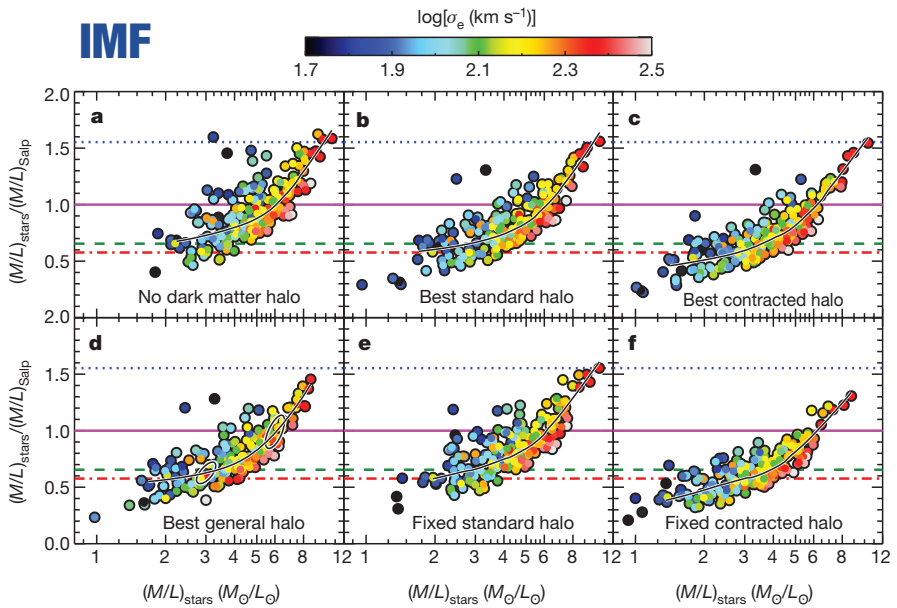
- Initial mass function (IMF)
  Chabrier, Salpeter
- Metallicity (Z)
  $2 \times Z_\odot$ - $5 \times 10^{-3} \times Z_\odot$
- Dust absorption & reemission
  Using IR SED from Chary & Elbaz 2001
- Code
  Bruzual & Charlot 2003, Starburst 99

Fiducial model

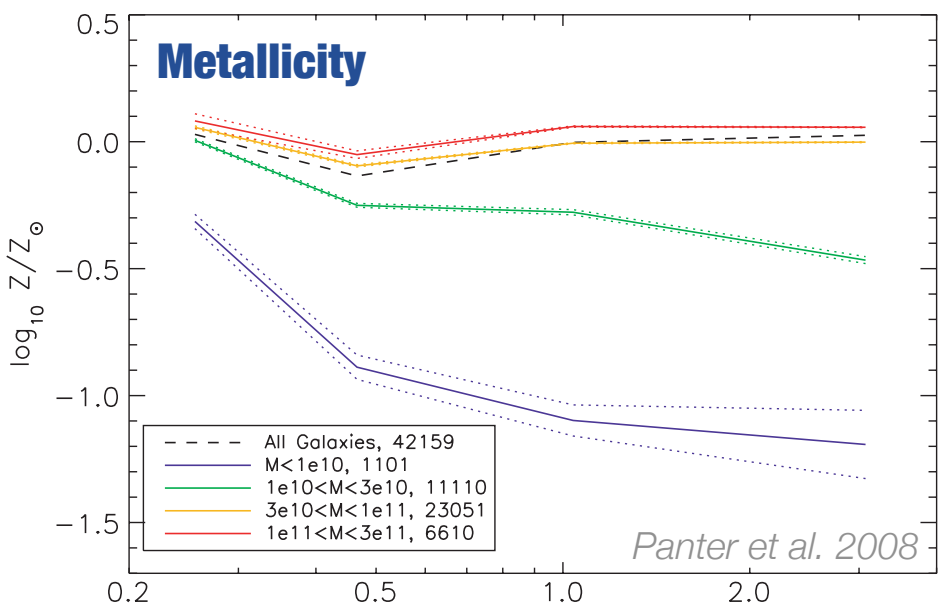
- Chabrier IMF
- $Z_\odot$
- Minimal dust abs./em. model matched to EBL UL limit

} conservative

- SFRD: β=0.3



Cappellari et al. 2012



Panter et al. 2008

Stellar emission from SPS

Parameters

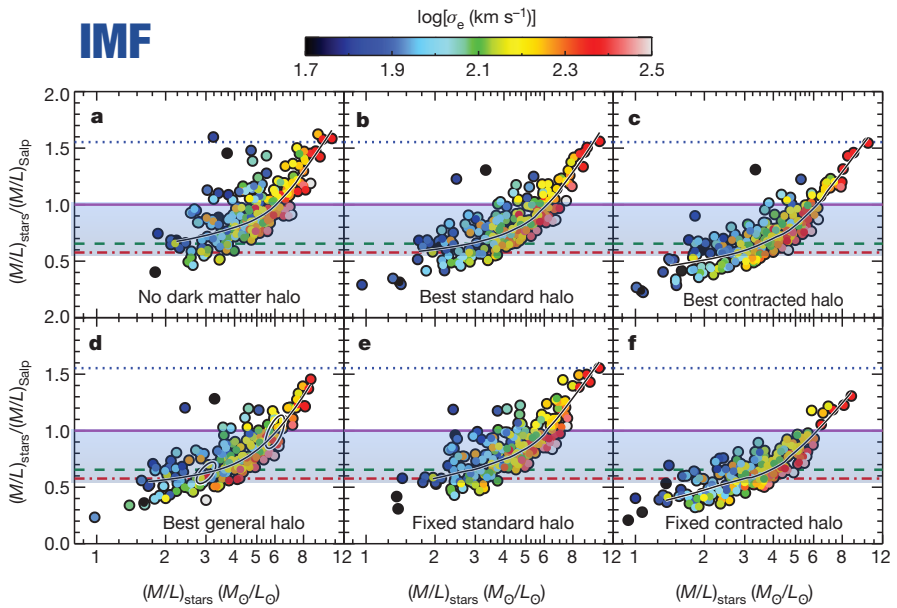
- Initial mass function (IMF)
  Chabrier, Salpeter
- Metallicity (Z)
  $2 \times Z_\odot$ - $5 \times 10^{-3} \times Z_\odot$
- Dust absorption & reemission
  Using IR SED from Chary & Elbaz 2001
- Code
  Bruzual & Charlot 2003, Starburst 99

Fiducial model

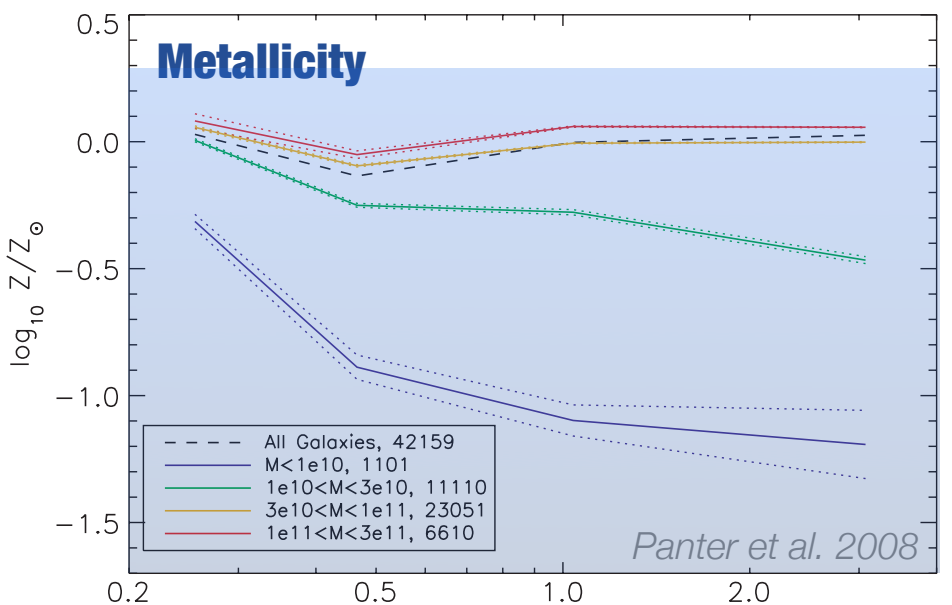
- Chabrier IMF
- $Z_\odot$
- Minimal dust abs./em. model matched to EBL UL limit

} conservative

- SFRD: β=0.3

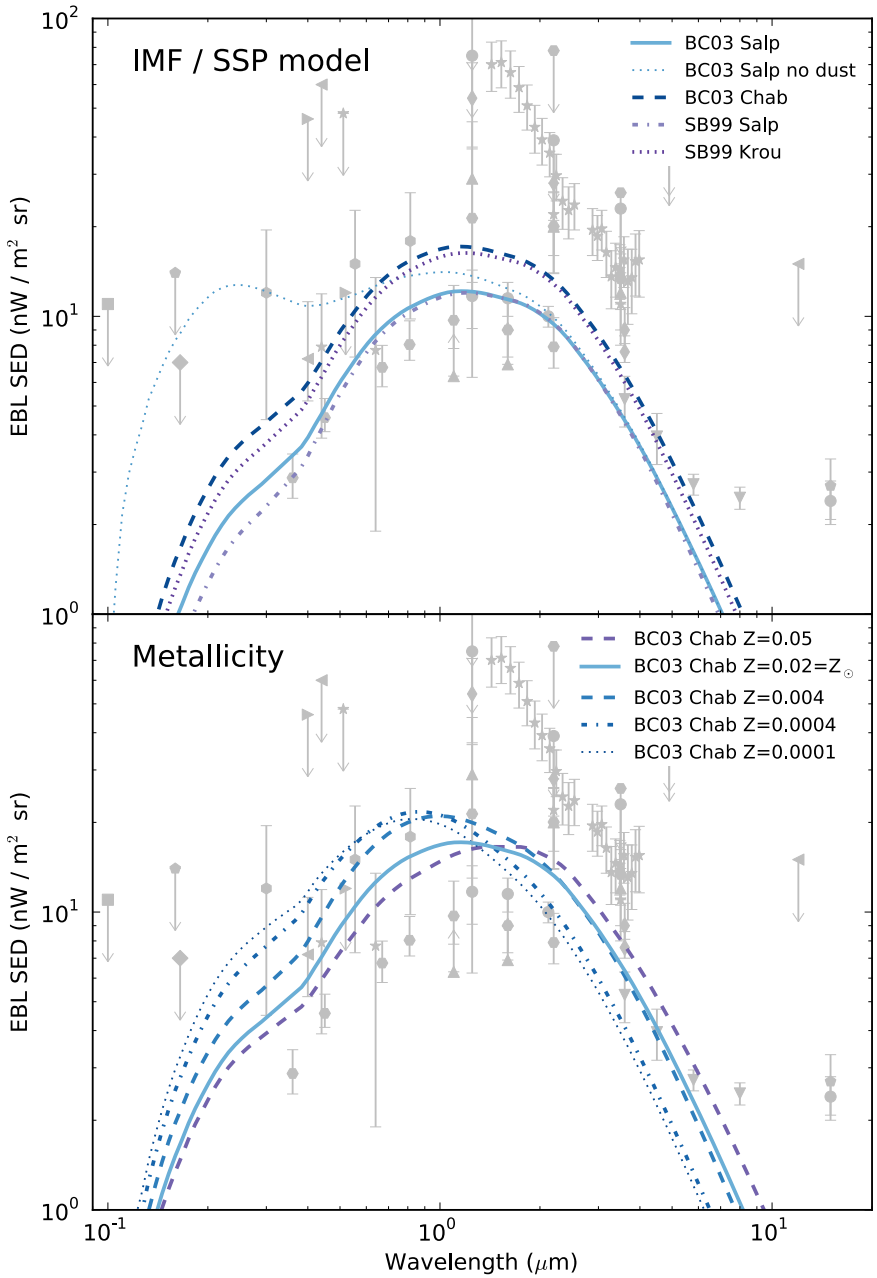


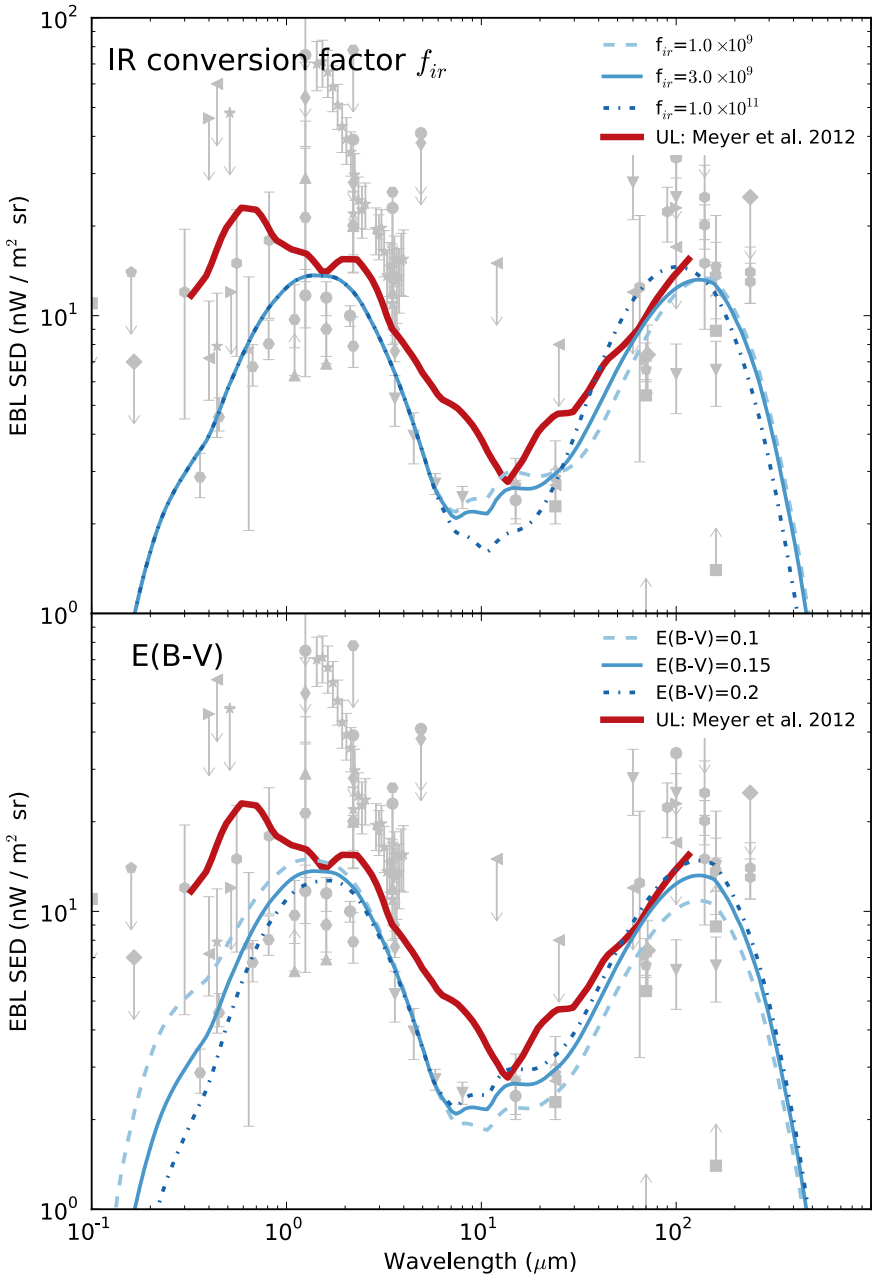
Cappellari et al. 2012



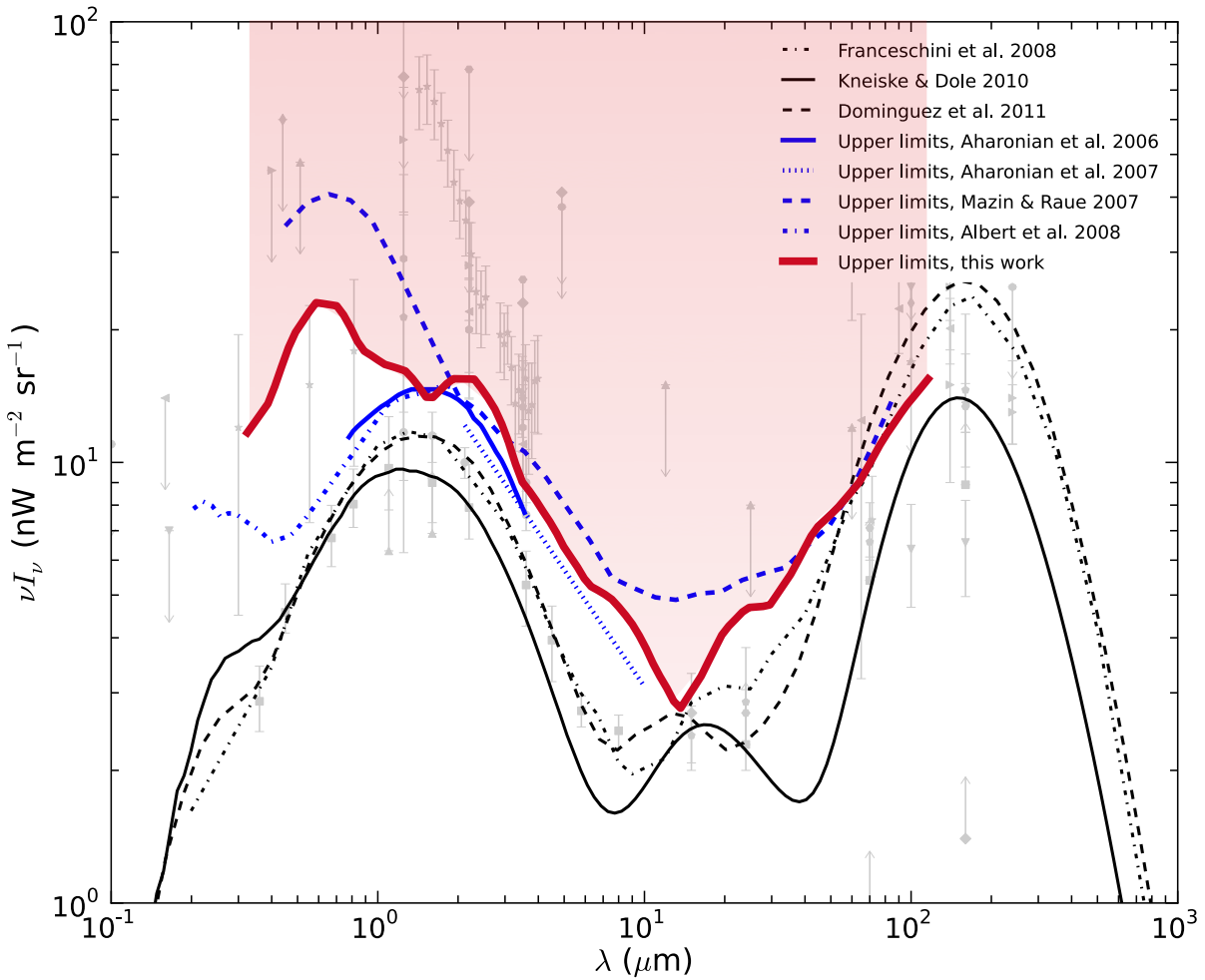
Panter et al. 2008

Resulting EBL: examples





Compare to EBL limits at z=0



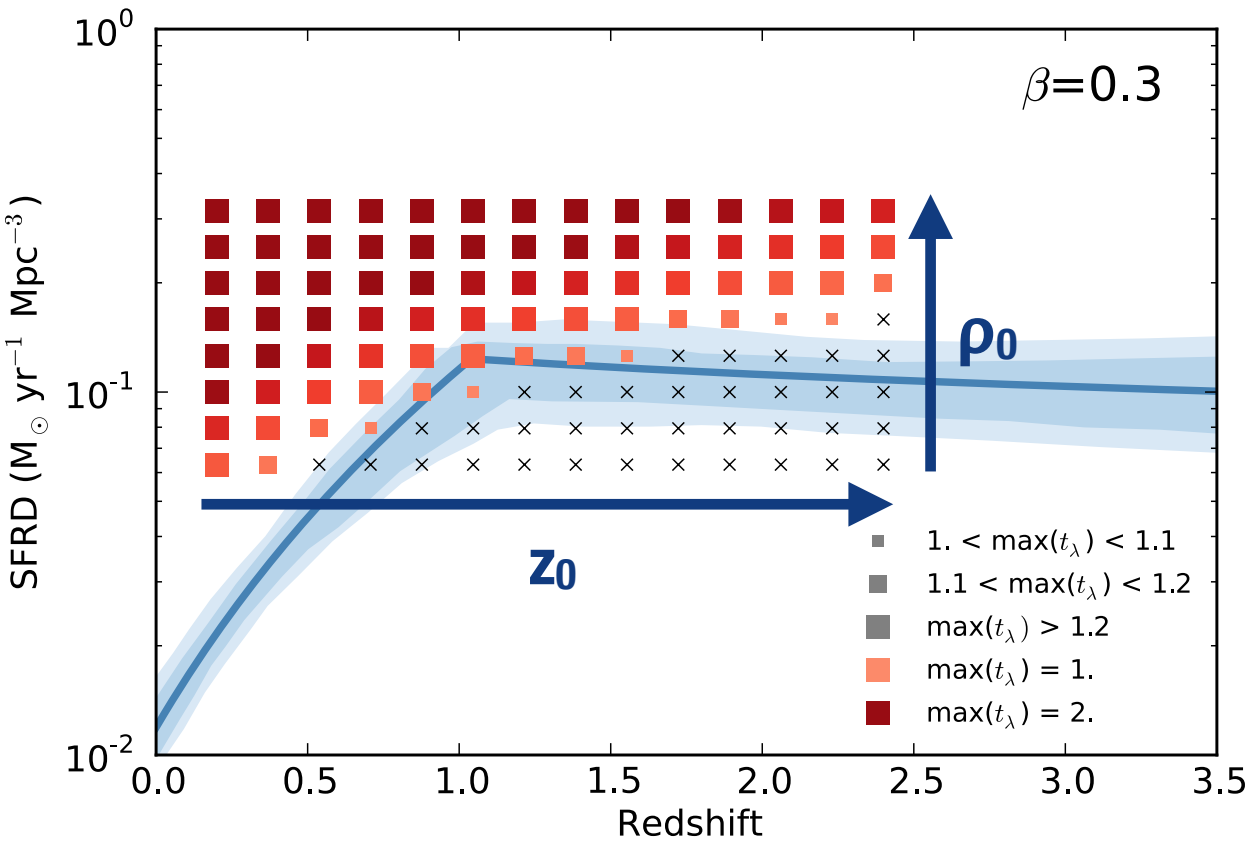
EBL limits used here

- Meyer, Raue, Mazin, Horns 2012, A&A 542
- Fermi-LAT + VHE
- Wide wavelength range
- Poster: P7-01

See also ...

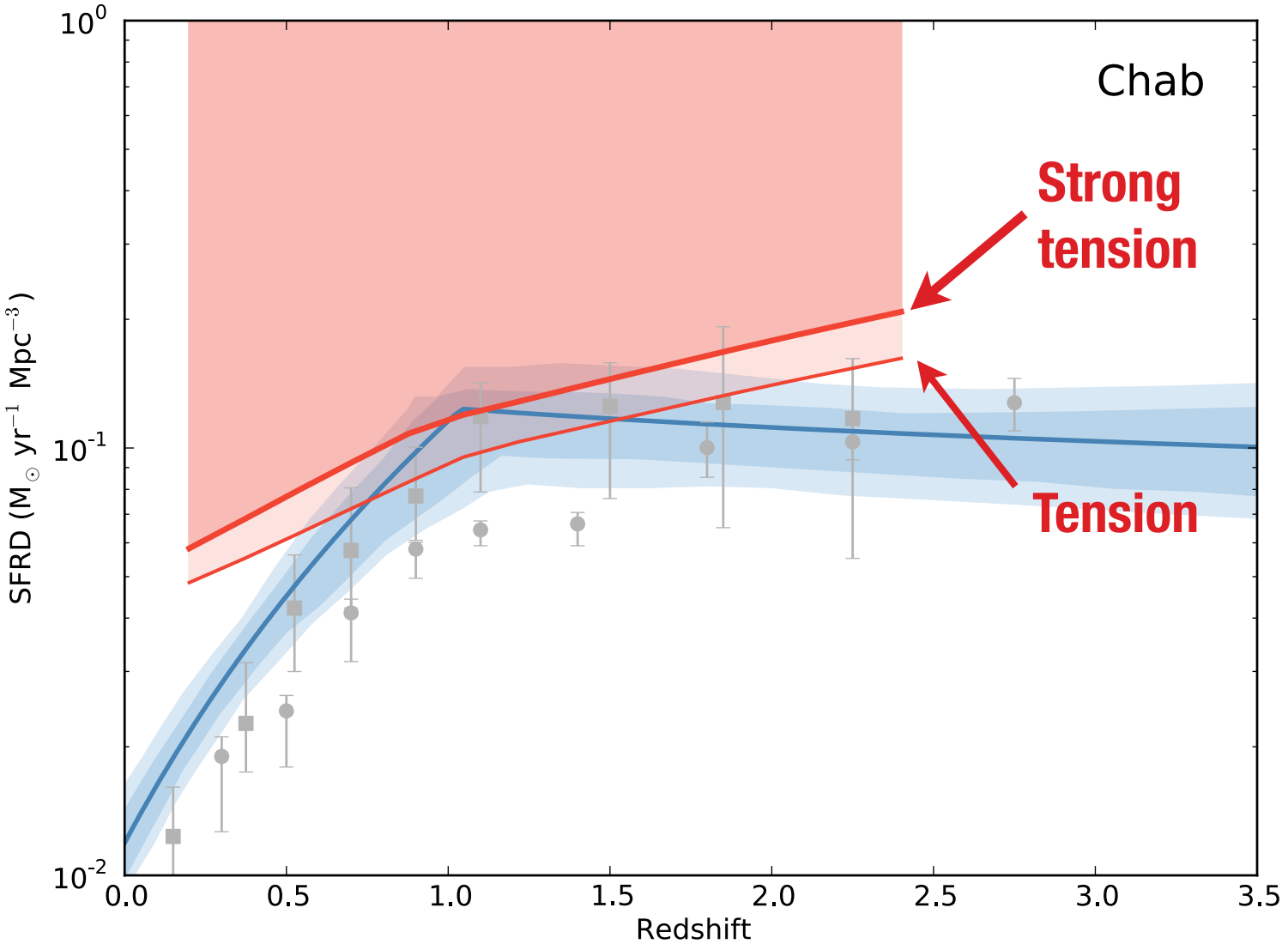
- Presentations by J. Biteau and M. Ajello in the next session

Method

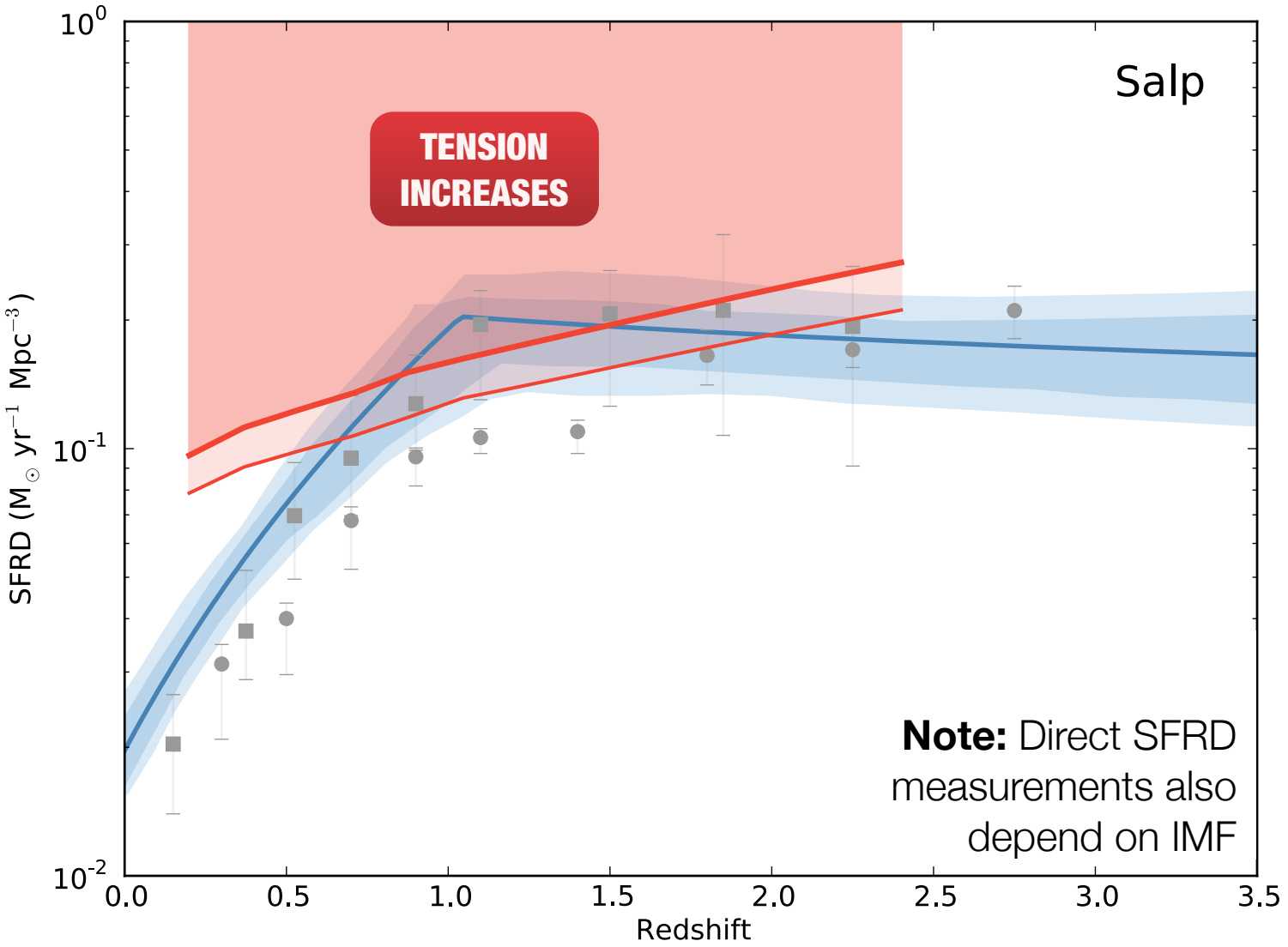


- Calculate EBL SED for grid in ρ_0 and z_0
- Divide each EBL SED by the EBL UL:
  - t = SED / UL
  - t > 1: tension
  - t > 1.2: strong tension
- Calculate SFRD limit from t=1 (1.2) SFRDs

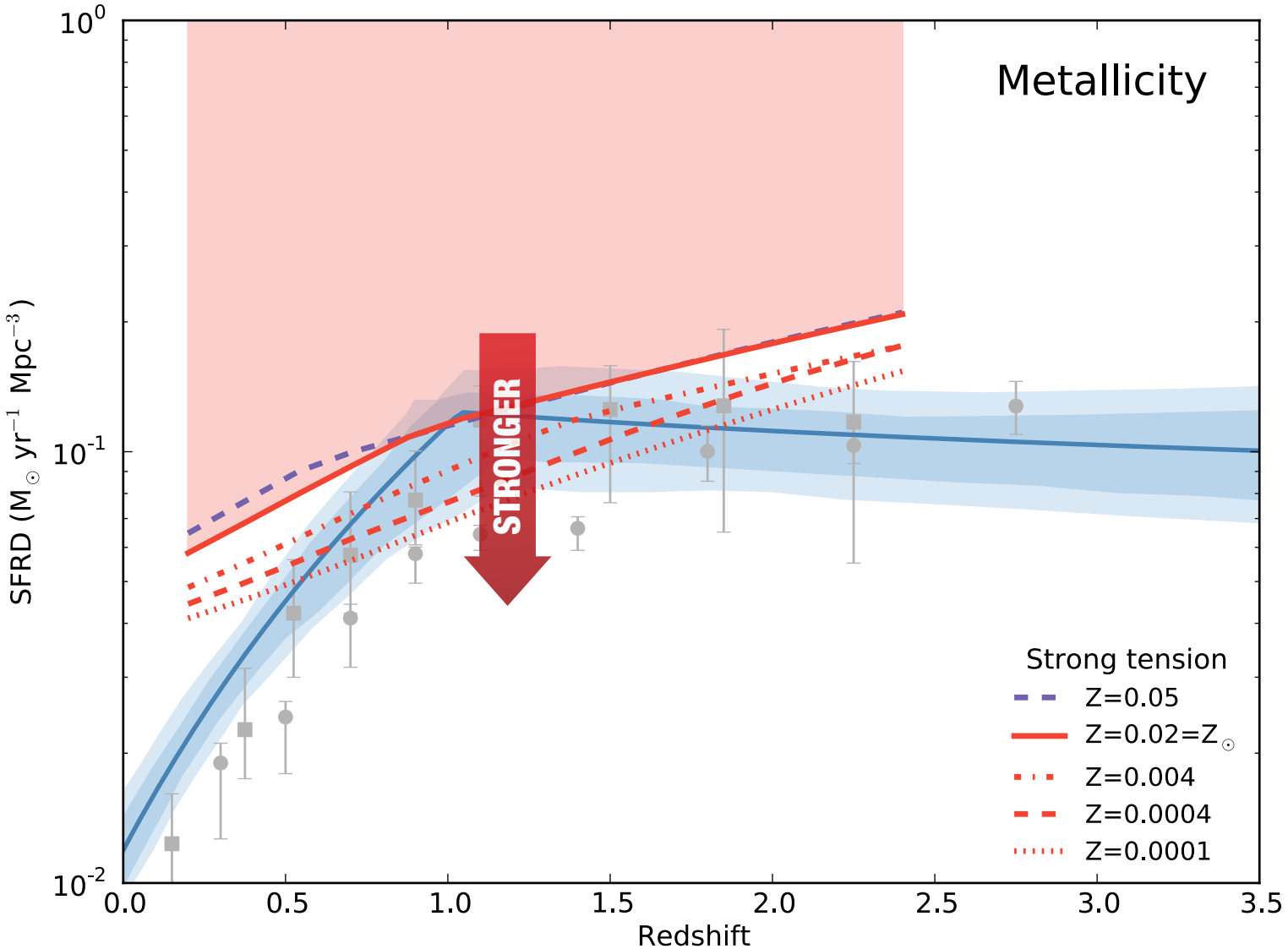
Results: fiducial model (Chabrier IMF, $Z_\odot$, β=.3)



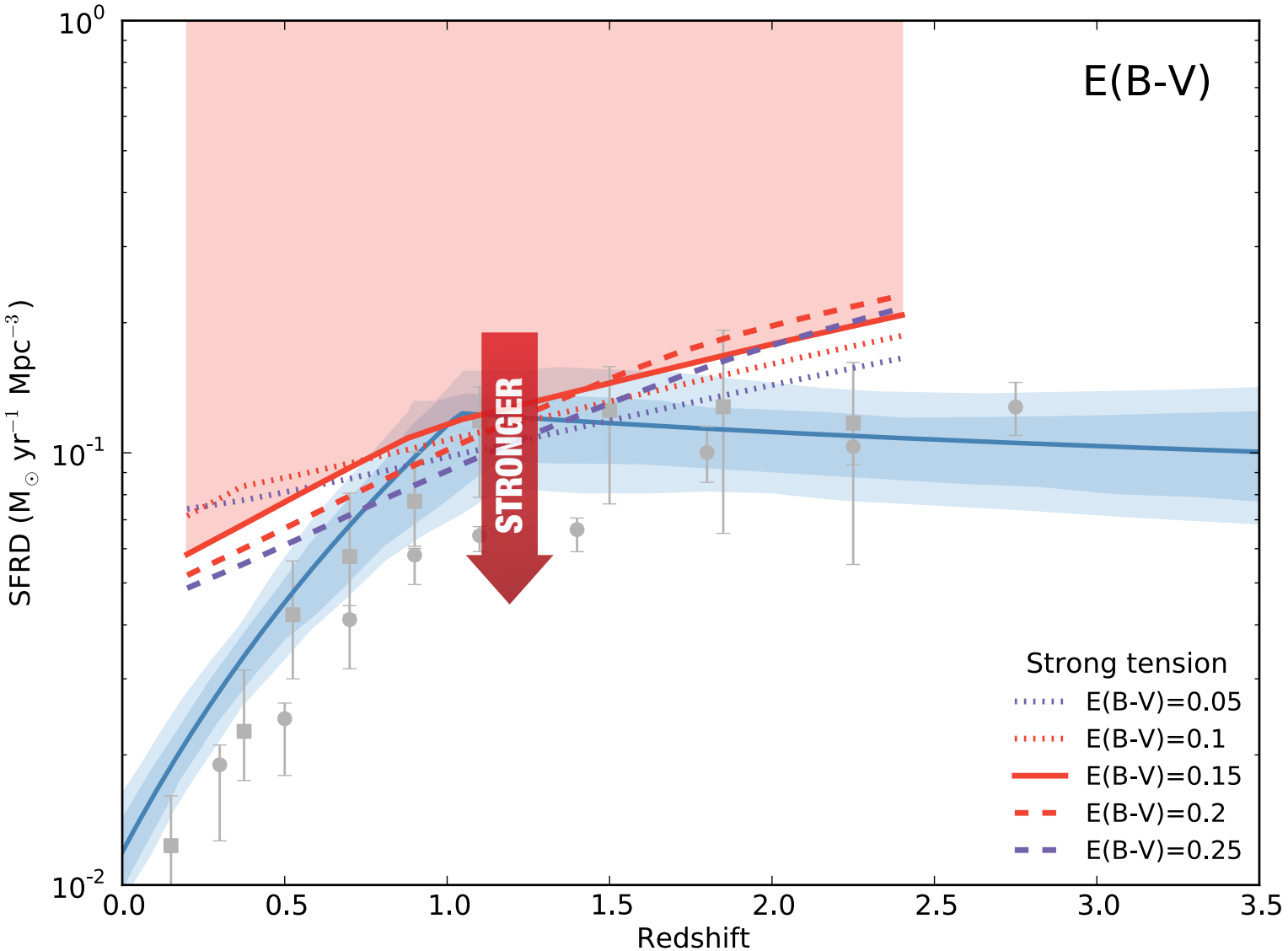
Results: Salpeter IMF



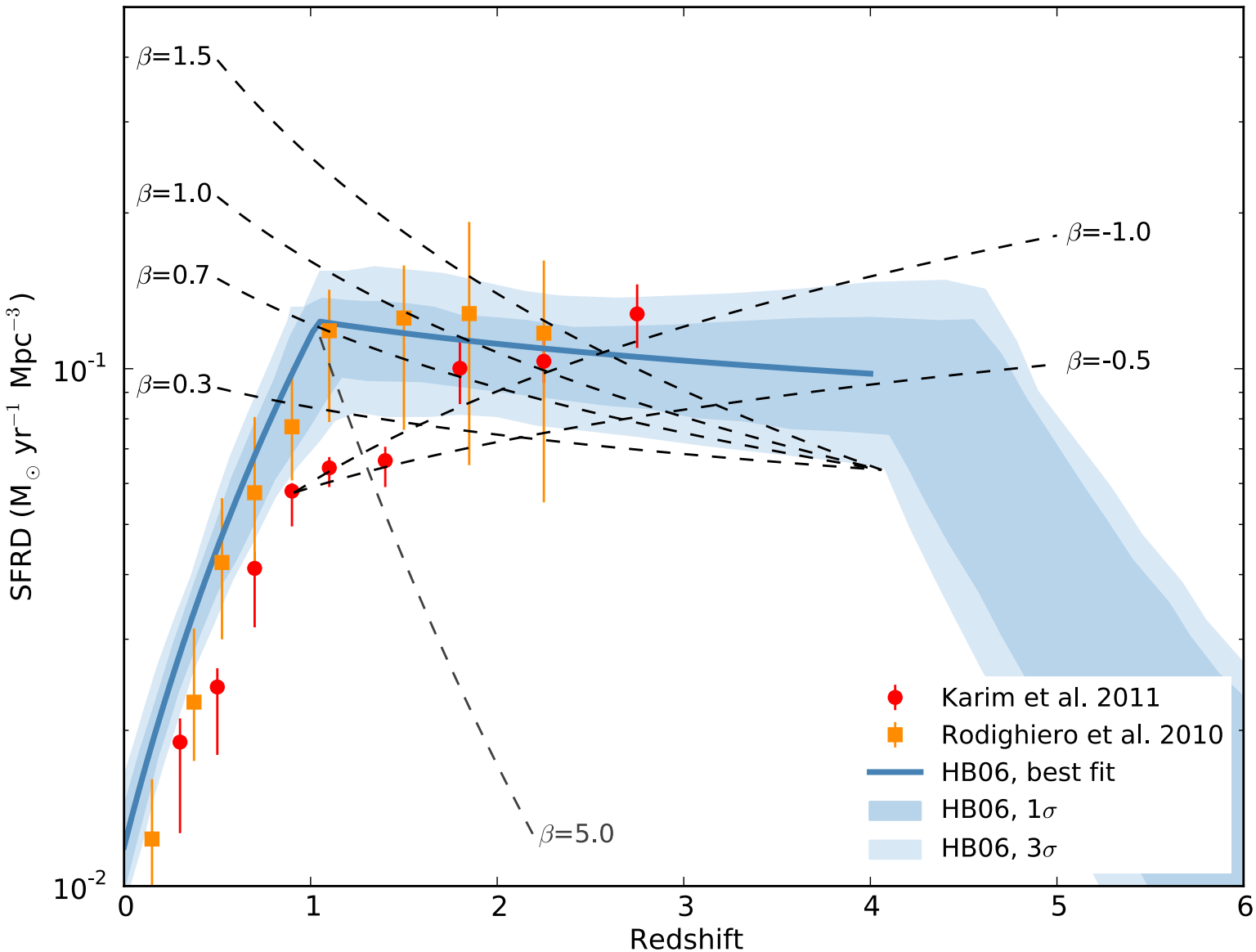
Results: metallicity



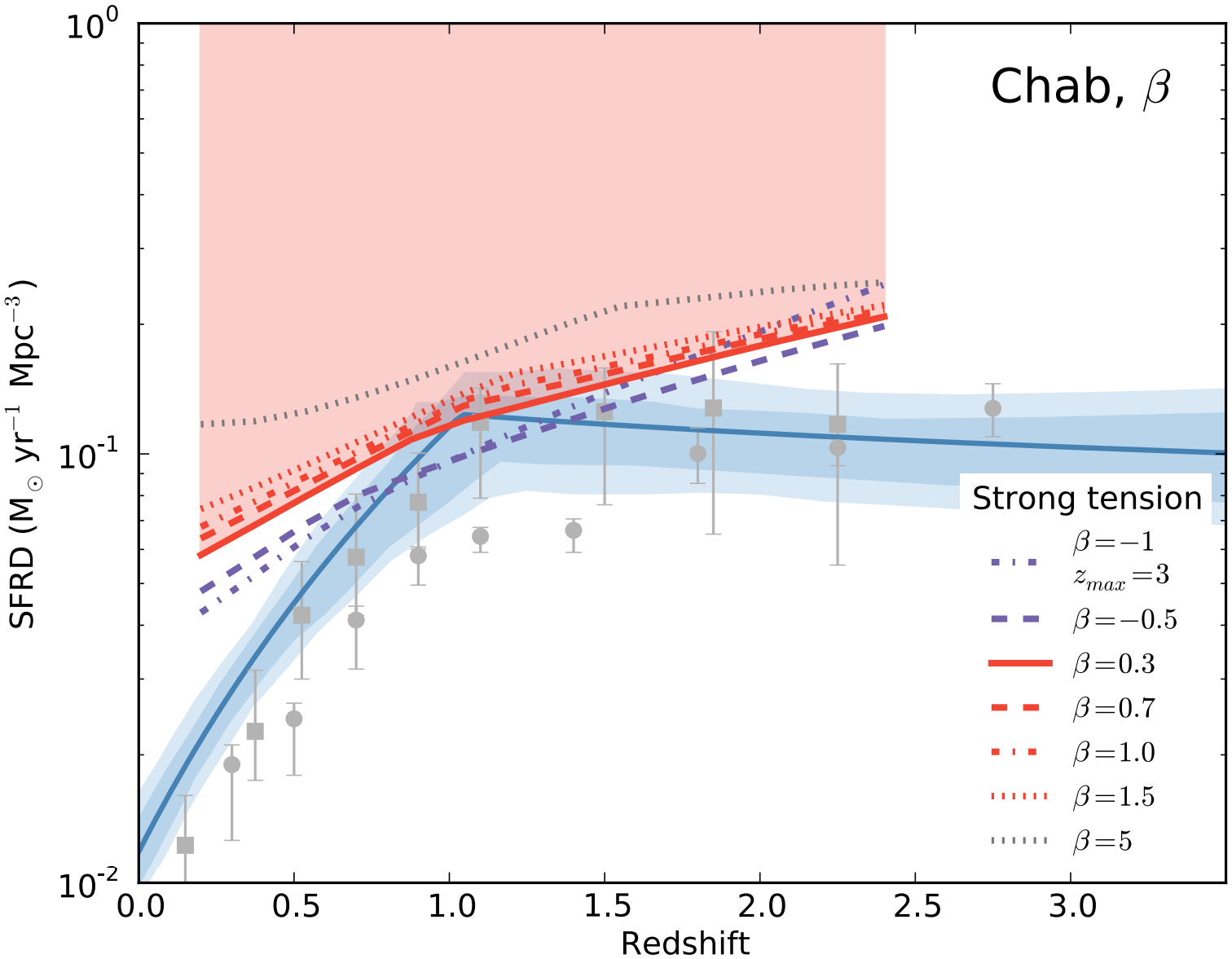
Results: IR attenuation - E(B-V)



SFRD: β


β=1.5
β=1.0
β=0.7
β=0.3
β=-1.0
β=-0.5
β=5.0
SFRD (M$_\odot$ yr^{-1} Mpc^{-3})
10^{-1}
10^{-2}
0
1
2
3
4
5
6
Redshift
Karim et al. 2011
Rodighiero et al. 2010
HB06, best fit
HB06, 1σ
HB06, 3σ

Results: β


Chab, β
Strong tension
$\beta=-1$
$z_{max}=3$
$\beta=-0.5$
$\beta=0.3$
$\beta=0.7$
$\beta=1.0$
$\beta=1.5$
$\beta=5$
SFRD ($M_\odot$ yr^{-1} Mpc^{-3})
Redshift
10^0
10^{-1}
10^{-2}
0.0
0.5
1.0
1.5
2.0
2.5
3.0

Summary & conclusions

VHE observations of distant sources delivers strongest EBL limits in the IR

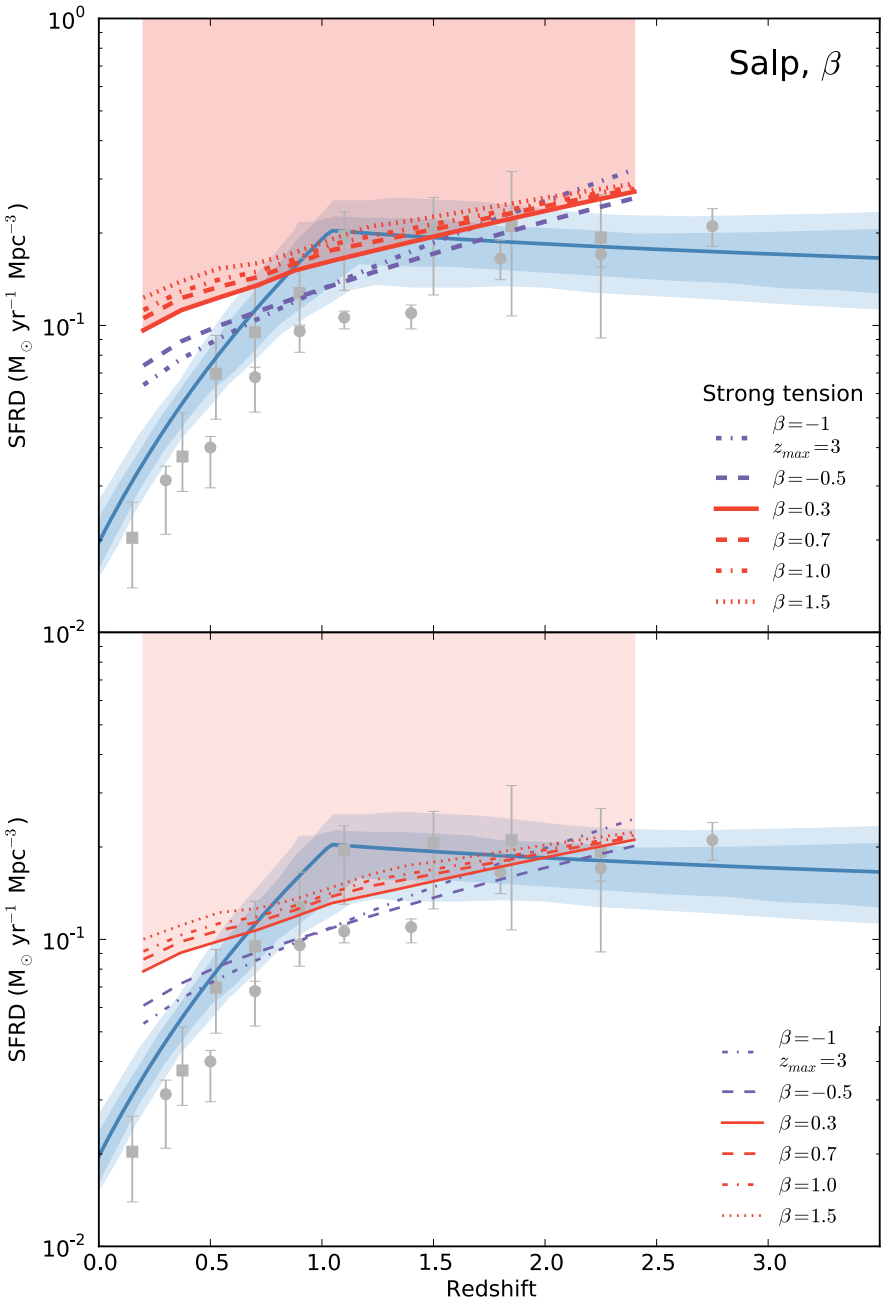
EBL limits constrain the SFRD

- Wide range of parameters investigated
- Most conservative model in tension with SFRD from direct measurements
- Tension increase for other choices of model parameters

Why conservative?

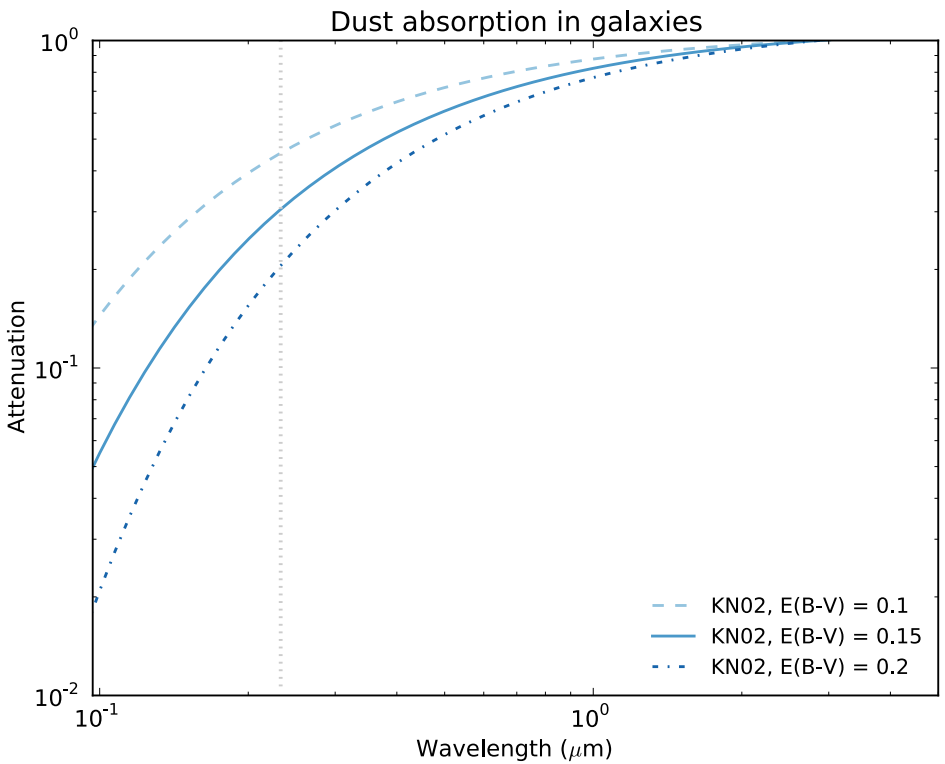
- Other contributions to EBL (AGN~10%, z>4, ...)
- Metallicity lower at z~1-3
- Narrow EBL shapes for EBL limit

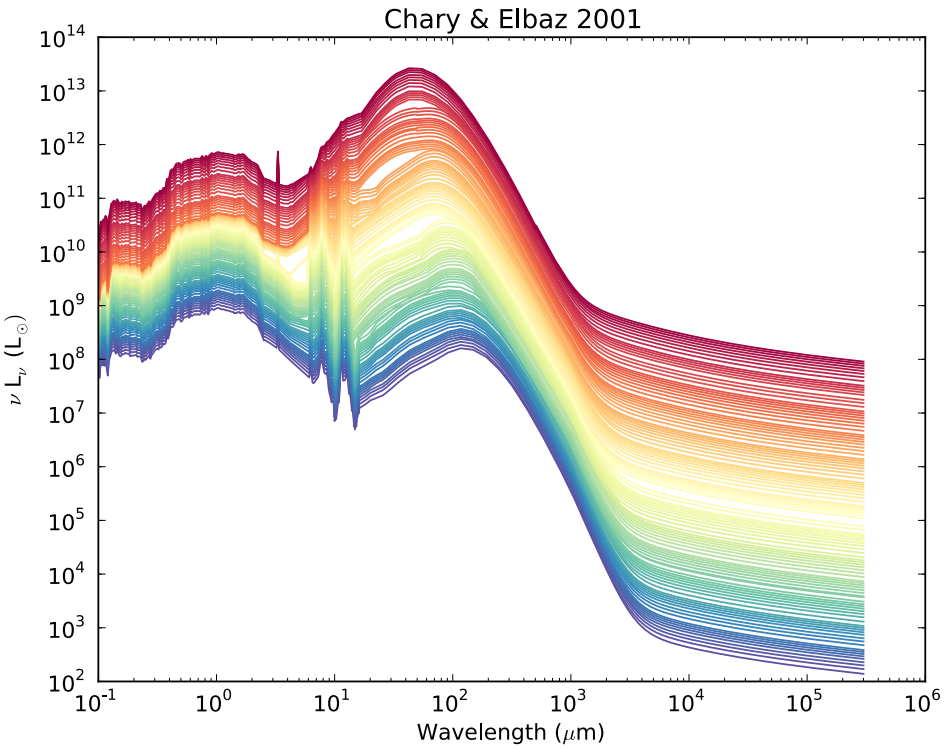
Raue & Meyer 2012, `arXiv:1203.0310`



Backup slides

Dust absorption/emission





Absorption

- Extinction curve

  $A(\lambda) = 0.68 \cdot E(B-V) \cdot R \cdot (\lambda^{-1} - 0.35)$

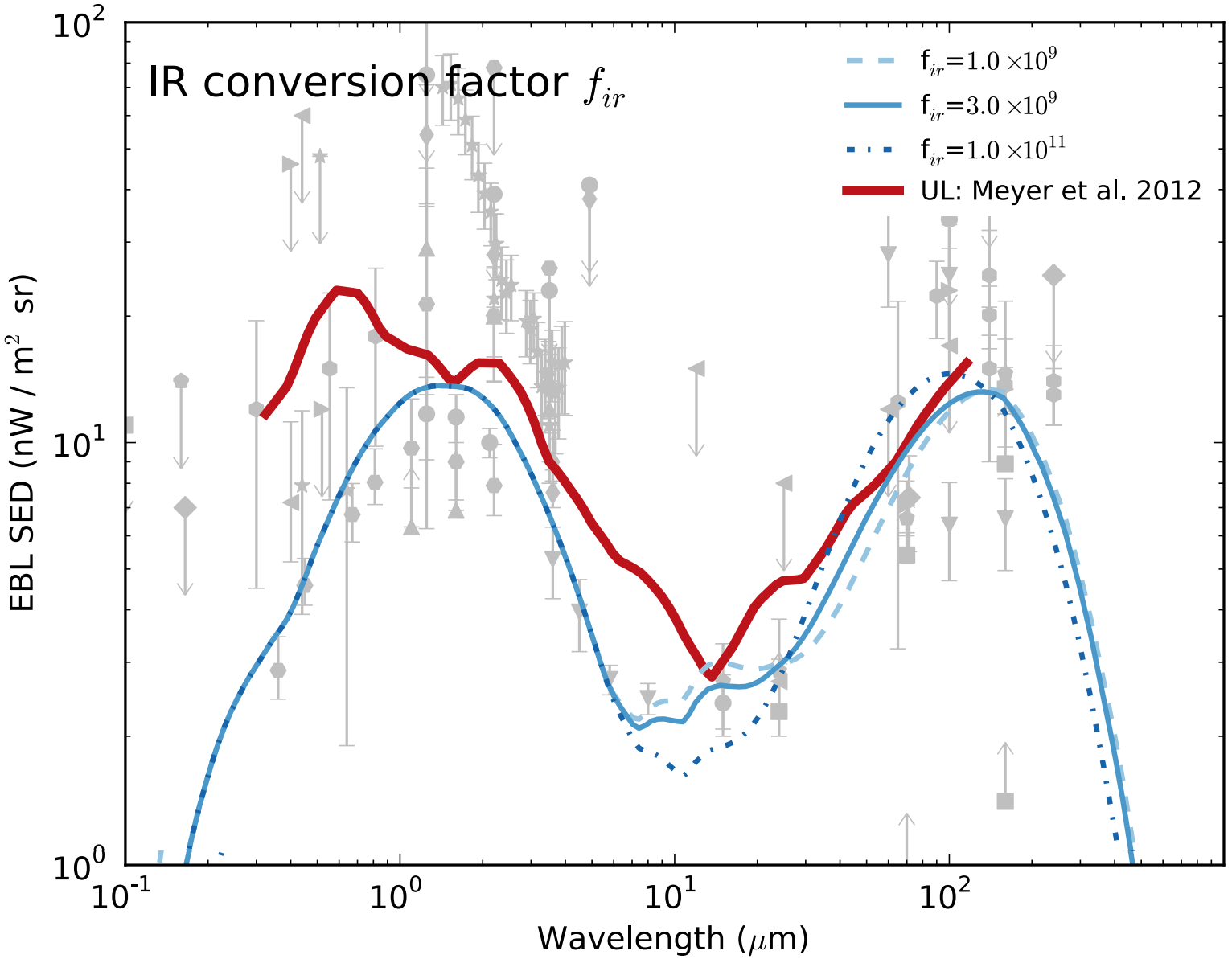
- Full absorption of ionizing emission

  50% into Ly-alpha -> scattered -> dust emission

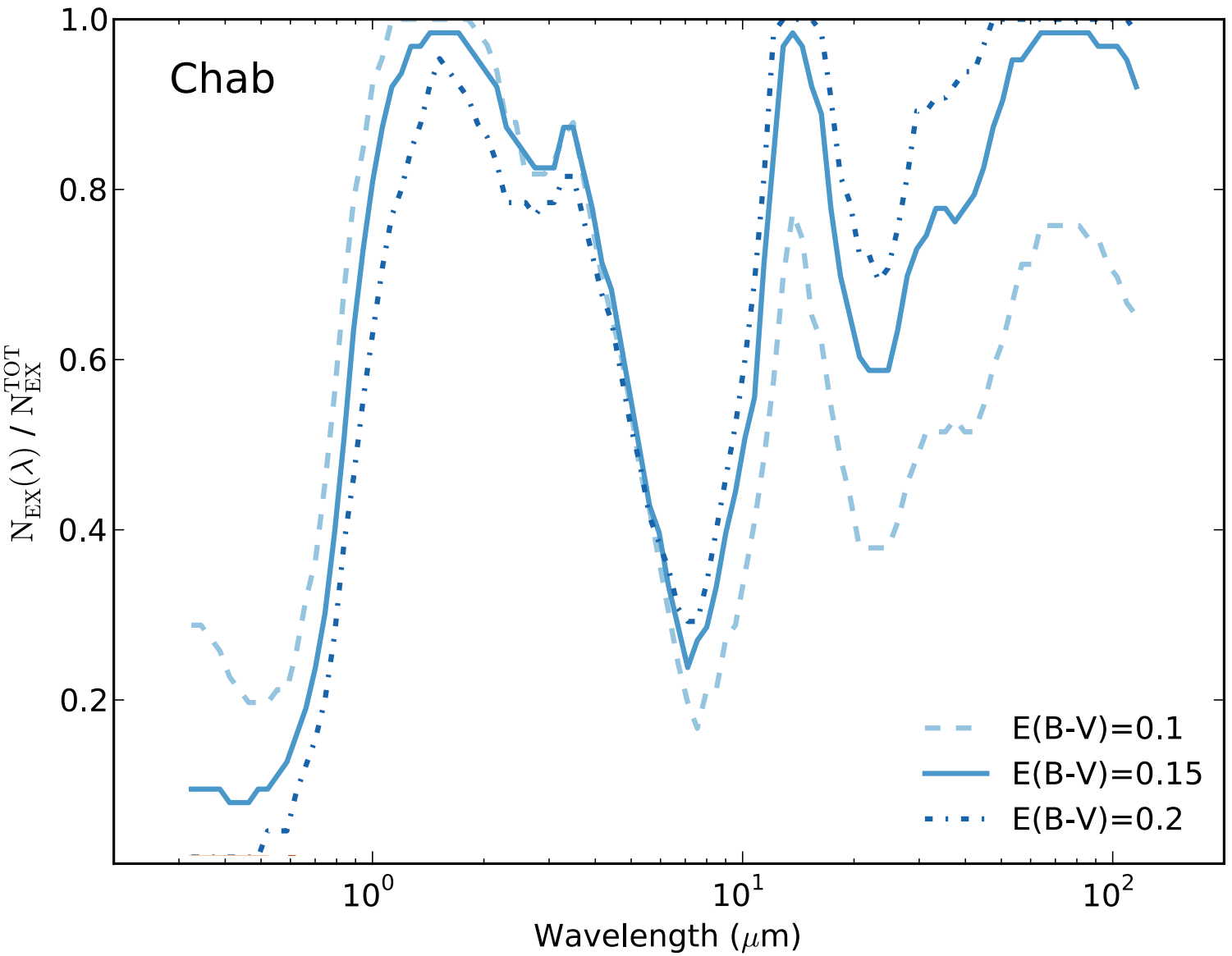
Dust emission

- Match absorbed luminosity with IR galaxy emission templates from Chary & Elbaz 2001
- Parameter: fIR

Dust emission



SFRD limits: wavelength dependence



SFRD IMF normalization