Constraining the star formation rate with the extragalactic background light

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What is the extragalactic background light?

- Radiation emitted by stars and cosmic dust throughout the whole lifetime of the Universe at ultraviolet, optical and infrared wavelengths
- Spectra has two maxima
- Hard experimental problem

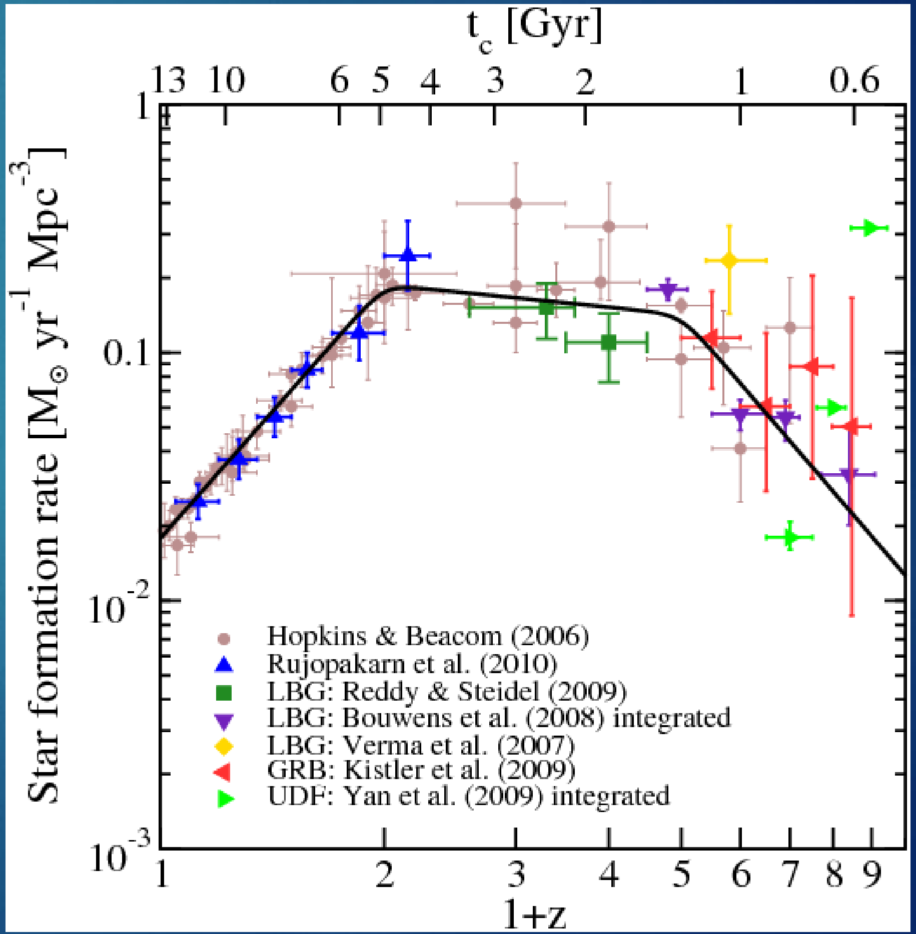
I. Contribution of stars

$$G_s(\lambda, z_g) = \int_{m_{\min}}^{m_{\max}} dm \int_0^{\eta_{\mathrm{end}}(m)} d\eta' B_s(\lambda, m, \eta', z_g)\xi(m)\psi(t(z_g) - \eta')$$

$\psi(t)$ - Star formation rate

$\xi(m)$ - Initial mass function

$$\xi(m) = \begin{cases} \frac{C_{\mathrm{imf}}}{m} e^{-\frac{(\log(m)-\log(m_0))^2}{2D}} & \text{if } m \leqslant 1, \\ k m^{-a_{\mathrm{imf}}} & \text{if } m > 1. \end{cases}$$



II. Contribution of dust

Star formation in giant molecular clouds

Characteristics:

- Lifetime
- Size
- Density
- Star formation efficiency
- Optical density
- Optical density slope

$$\tau(\lambda) = \tau_{\lambda_0}\left(\frac{\lambda}{\lambda_0}\right)^{-n}$$

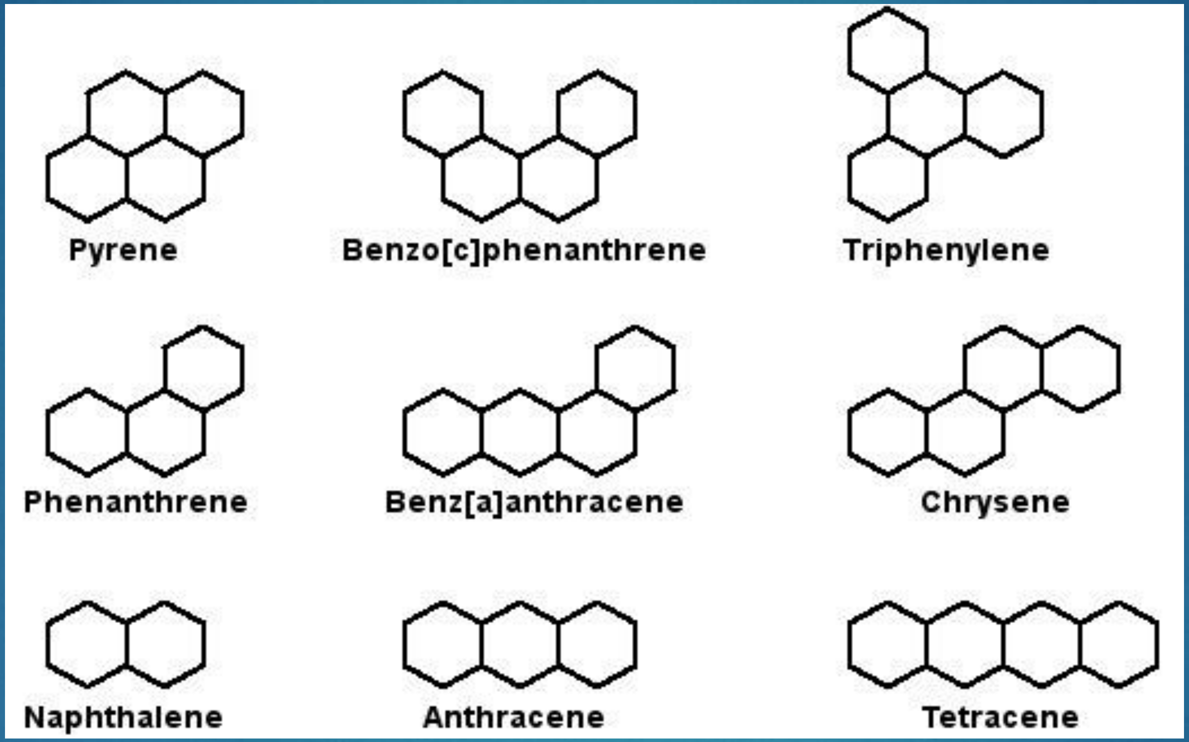
Energy balance equation

$$\pi a^2 \int_0^\infty Q^a_{\rm abs}(\lambda) B_c(\lambda,\eta,r) d\lambda = 4\pi a^2 \int_0^\infty Q^a_{\rm abs}(\lambda) B_{\rm Pl}(\lambda, T_d(a,r,\eta))$$

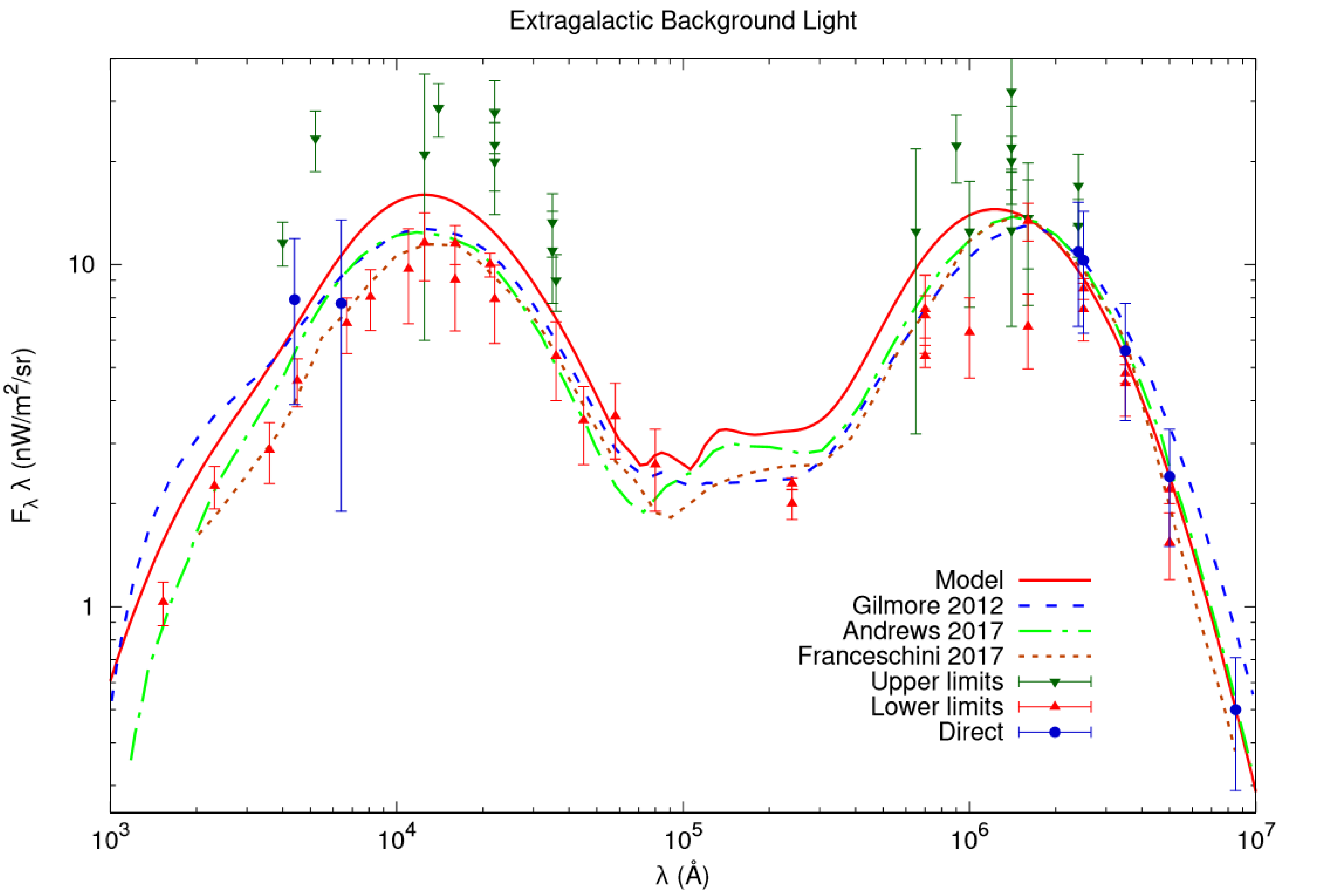
Dust spectra of the cloud

$$B_d(\lambda,\eta) = \int_\rho^{R_{\rm out}} dr\ 4\pi r^2 \times \int_{a_{\rm min}}^{a_{\rm max}} da\ \left(\frac{a}{R_{\rm out}}\right)^2 C_d a^{-n_{\rm dust}} Q^a_{\rm abs}(\lambda) B_{\rm Pl}(\lambda, T_d(a,r,\eta))$$

III. Contribution of polycyclic aromatic hydrocarbons



$$B_{PAH}(\lambda,\eta)=\int_{\rho}^{R_{\rm out}} dr\;4\pi r^2\times n_{PAH}\int_{\lambda_c}^{\infty} d\lambda'\;B_c(\lambda',\eta,r)\times\sum_i\left(\sigma_i\frac{\gamma_i c^3/\lambda^4}{\pi^2(\frac{c^2}{\lambda^2}-\frac{c^2}{\lambda_0^2})^2+(\frac{\gamma_i c}{2\lambda})^2}\right)$$



Extragalactic Background Light
F_λ λ (nW/m²/sr)
λ (Å)
10
1
10^3
10^4
10^5
10^6
10^7
Model
Gilmore 2012
Andrews 2017
Franceschini 2017
Upper limits
Lower limits
Direct

Data

LOWER LIMITS

From galaxy counting:

- Hubble ultra deep field
- Subaru
- Spitzer
- Herschel
- BLAST

DIRECT

Zodiacal light is neglectful

- Pioneer 10/11
- COBE/FIRAS

UPPER LIMITS

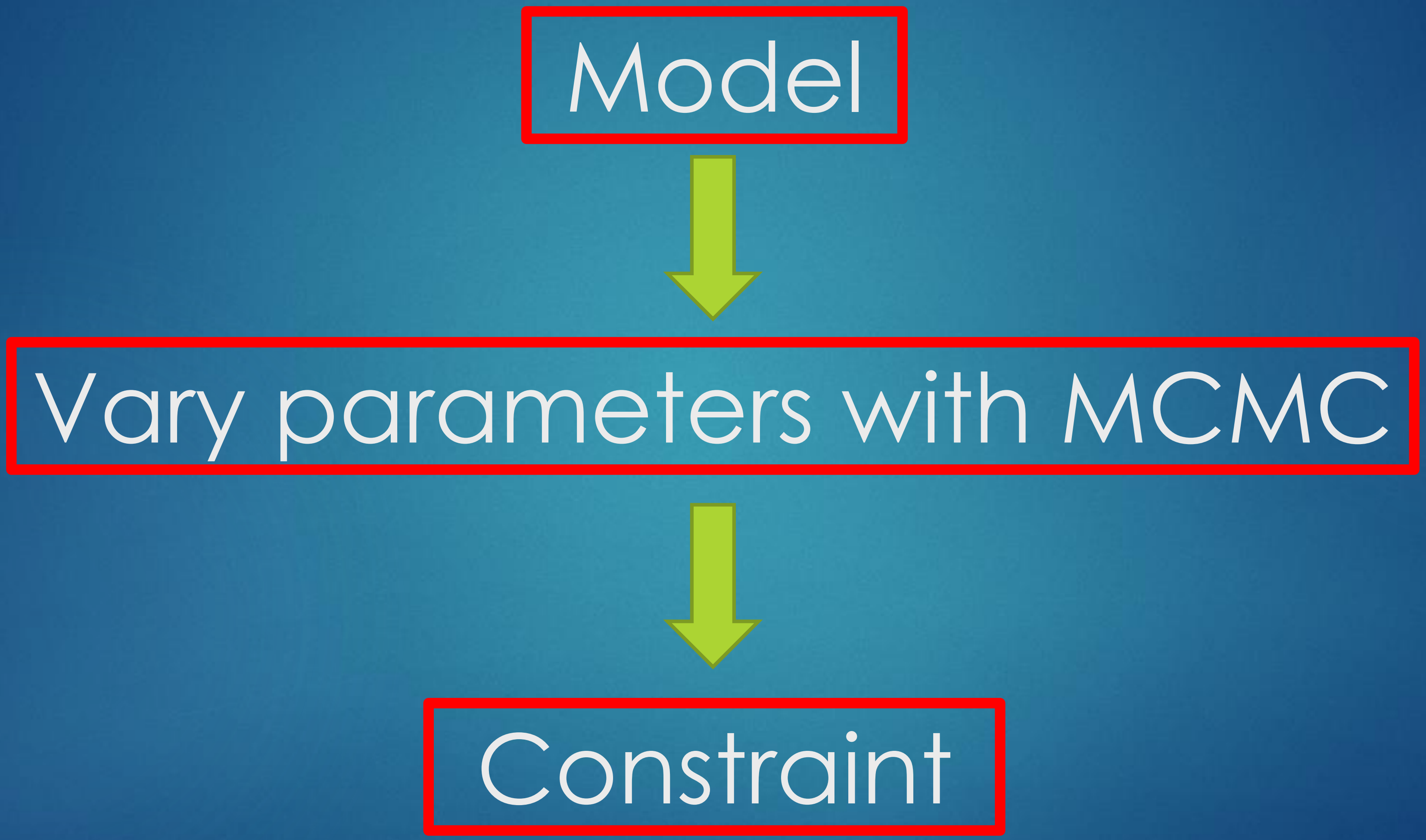
Direct measurements with subtraction

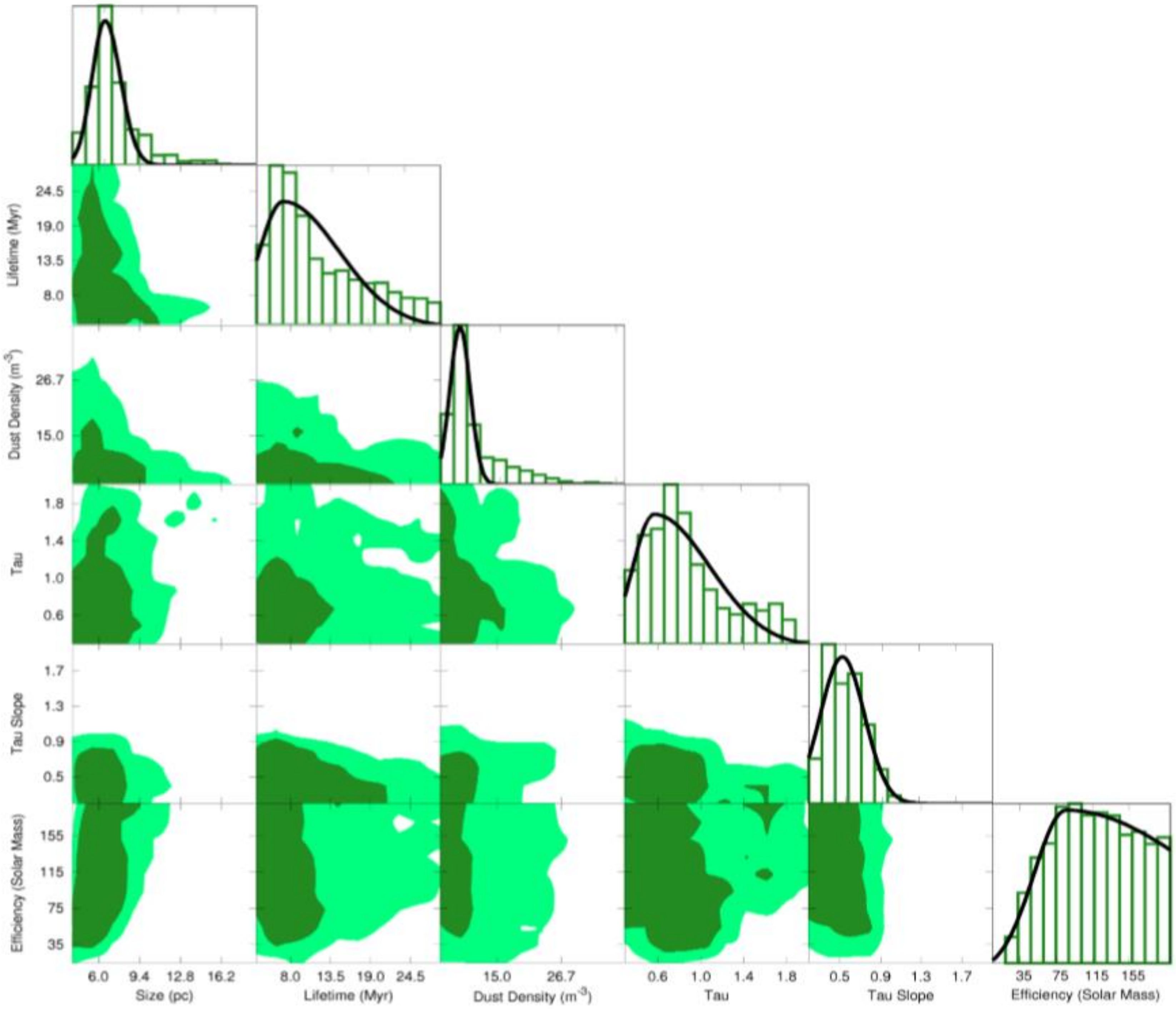
- COBE/DIBRE
- COBE/FIRAS
- Akari
- ESO VLT/FORSE

Parameters of the model

- Global parameters
- Parameters of giant molecular clouds
- Parameters of dust particles
- Parameters of initial mass function

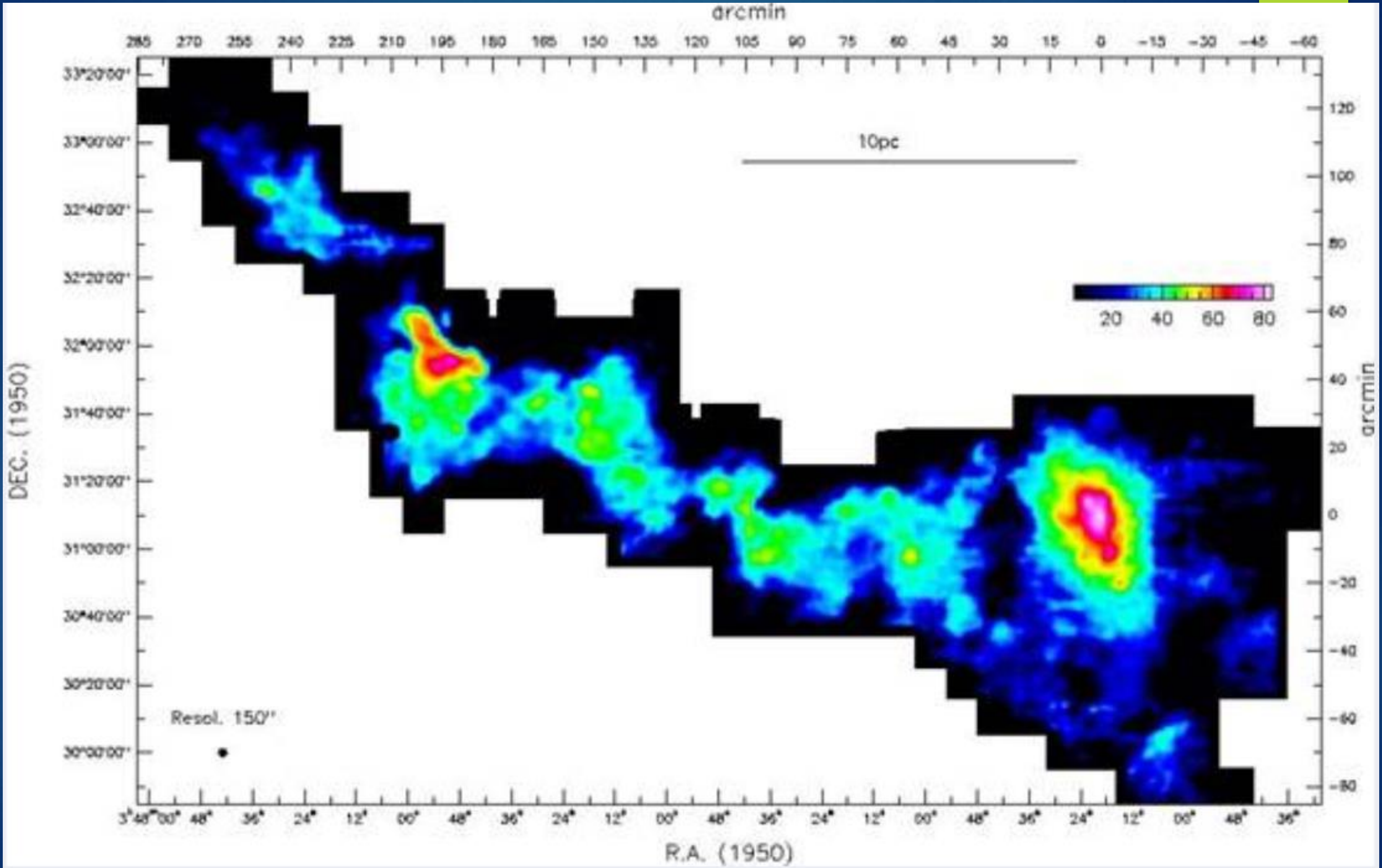
Exploring the parameter space



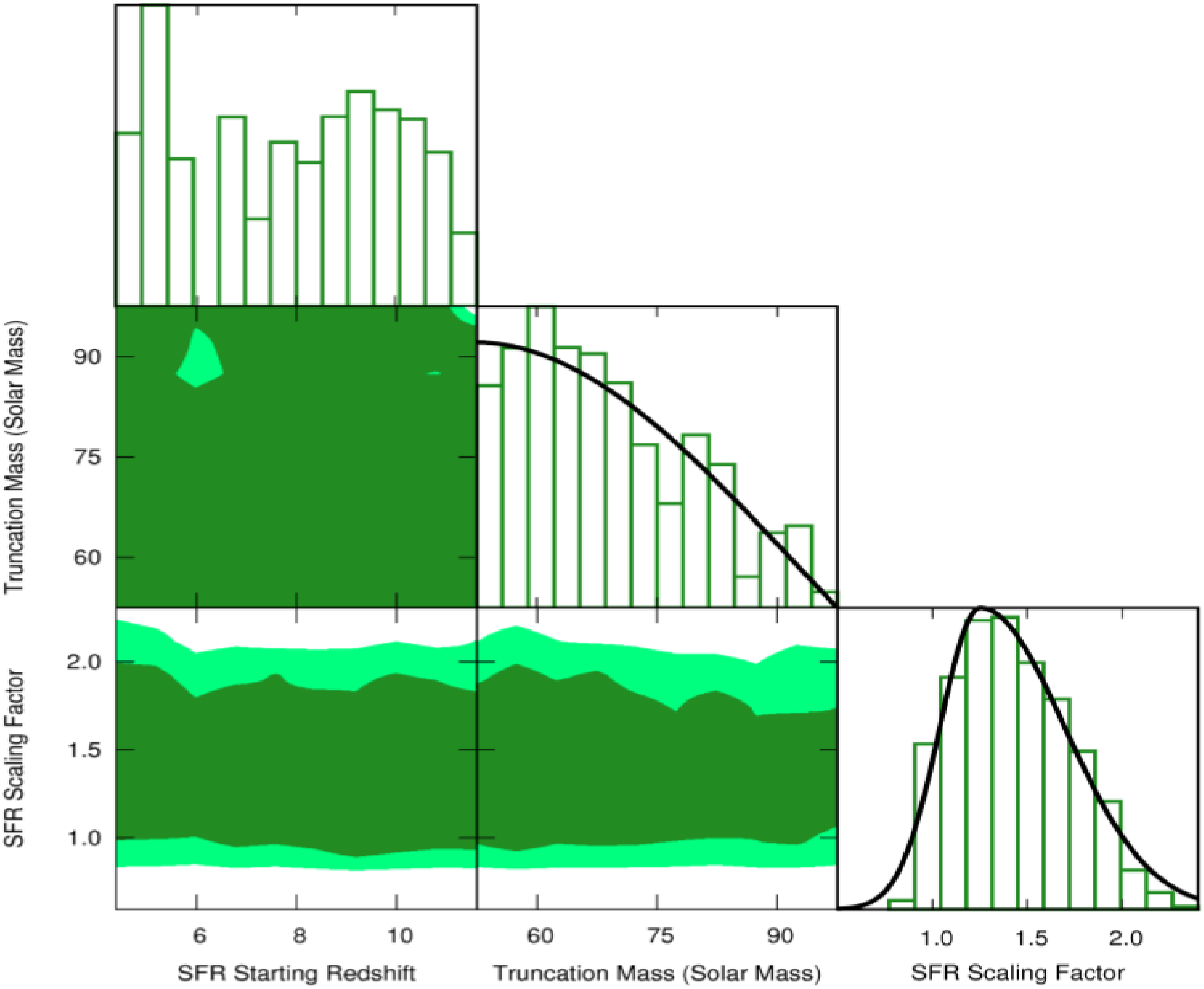

Lifetime (Myr)
24.5
19.0
13.5
8.0
Dust Density (m^{-3})
26.7
15.0
Tau
1.8
1.4
1.0
0.6
Tau Slope
1.7
1.3
0.9
0.5
Efficiency (Solar Mass)
155
115
75
35
6.0 9.4 12.8 16.2
Size (pc)
8.0 13.5 19.0 24.5
Lifetime (Myr)
15.0 26.7
Dust Density (m^{-3})
0.6 1.0 1.4 1.8
Tau
0.5 0.9 1.3 1.7
Tau Slope
35 75 115 155
Efficiency (Solar Mass)

Comparison with observations

	GMC in Milky Way	Model
Size (pc)	2.5 - 100	6.1 +1.4 -1.2
Lifetime (Myr)	~10	6.0 +8.5-3.6
Dust density (m^{-3})	~10	6.9 +-2.0
Optical depth at 5500 Å	~0.7	0.47 +-0.24
Optical depth slope	~1	0.59 +0.57-0.21
Cloud efficiency	~2 %	3.5 %



arcmin
10pc
20 40 60 80
DEC. (1950)
arcmin
Resol. 150"
R.A. (1950)



90
75
60
Truncation Mass (Solar Mass)
2.0
1.5
1.0
SFR Scaling Factor
6
8
10
SFR Starting Redshift
60
75
90
Truncation Mass (Solar Mass)
1.0
1.5
2.0
SFR Scaling Factor

Conclusion and results

- New flexible EBL model was built
- Estimates of astrophysical parameters of the EBL were obtained
- Normalization factor of the SFR is constrained in the range $1.01 < C < 1.69$ at 68% C.L.
- Slope of the distribution of the massive stars is constrained in the range $2.05 < a_{imf} < 2.44$

  [$2.0 < a_{imf} < 2.6$]

Thank you