Observability of first galaxies with a generic FIR/sub-mm telescope

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INTRODUCTION

Besides contributing to the reionization of the Universe, primordial stars enriched the pristine gas with the first heavy chemical elements (e.g. Bromm & Loeb 2003), including the formation of dust (e.g. Schneider+2006). In this context, the **first galaxies** might have been composed of **Pop II stellar systems**, surrounded by a mixed phase of **gas** and **dust** inside **atomic-cooling halos**.

Luminous sources at high redshifts, such as the first galaxies, constitute promising targets for **next-generation surveys** as they provide unique tools to test models of early structure formation. We explore the possibility of detecting first galaxies with a **generic far-infrared/sub-millimeter (FIR/sub-mm) telescope** by applying an analytical model of primordial dust emission.

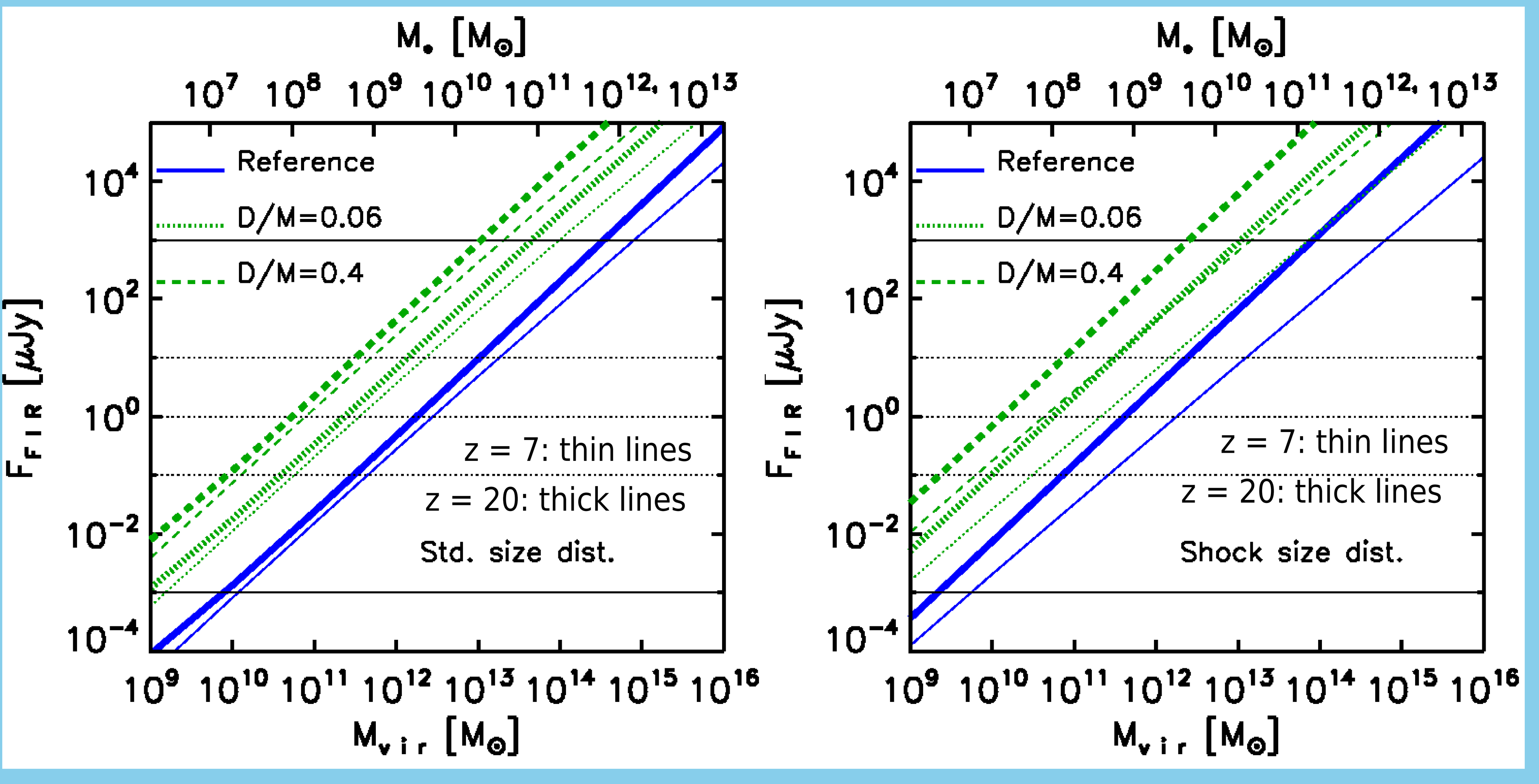
MODEL GALAXIES

A **model galaxy** consists of a **dark matter halo** hosting a **central cluster of Pop II stars**, surrounded by a mixed phase of **gas** and **dust**. Our **reference model** assumes a dust-to-metal mass ratio **D/M = 5×10^{-3}**, a gas metallicity of **Z_g=5×10^{-3} $Z_\odot$** and a star formation efficiency of **η=0.01**, which are typical values for first galaxies. The spectral energy distribution corresponding to stars was obtained from YGGDRASIL model grids (Zackrisson+2011).

We considered different **silicon-based dust models** (Cherchneff & Dwek 2010). For the sake of clarity, we only present results corresponding to the so-called UM-ND-20 model. For the **grain-size distribution**, we adopted the **'standard' and 'shock'** prescriptions used in Ji+2014. Dust temperature (T_d) was determined assuming thermal equilibrium and dust emissivity was estimated by applying the Kirchhoff's law for the estimated T_d profile.

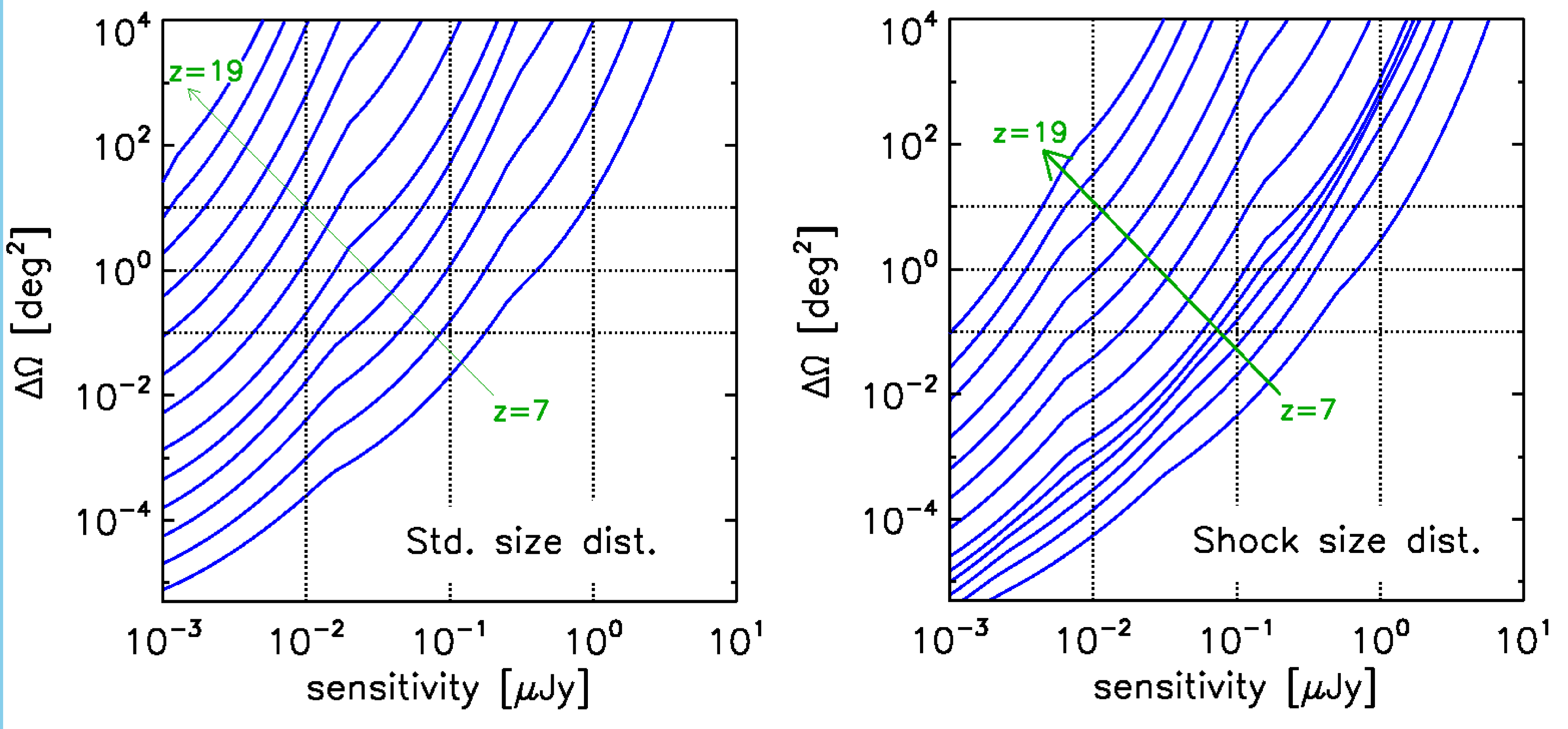
F_{FIR} – M_{vir} relation as a function of D/M

- By comparing plausible **sensitivities** of a generic instrument with the **average observed fluxes (F_{FIR})** of model galaxies at a reference **FIR wavelength band (Δλ = 250 – 750 μm)**, we determined the lowest **virial mass (M_{vir})** that a galaxy should have to be detected at a given z.
- For a given dust model, **higher FIR fluxes** are obtained for galaxies located at **higher z**. This is a consequence of the **strong negative K-correction** affecting primeval dust-emitting sources at z ~ 7.
- At a given mass, FIR fluxes increase almost proportionally to the increase of D/M , with higher fluxes obtained for the shock size distribution.



Observability of FIR sources in the ΔΩ-sensitivity plane for the reference model

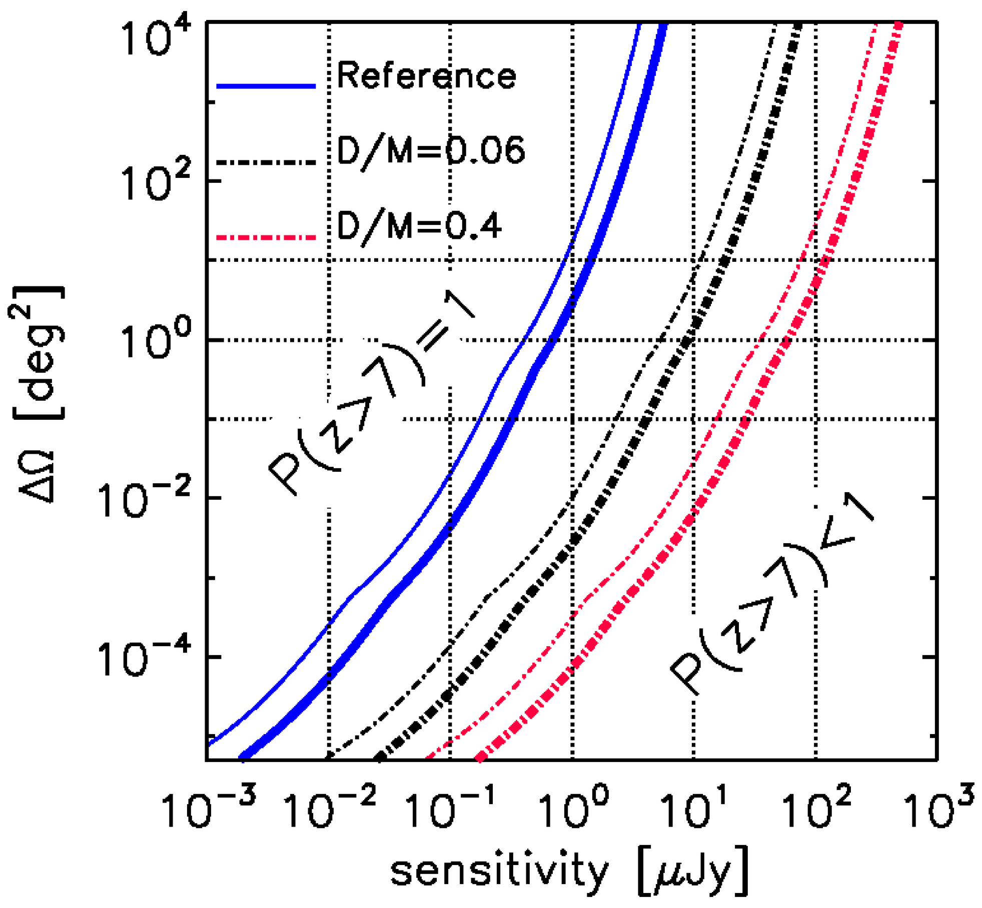
By combining our dust model for individual sources with the **Sheth-Tormen mass function** (Sheth+2001), we estimated the **projected number of detected sources** that are located at redshift higher than z, within a given solid angle ΔΩ (for a detail description of this methodology, see De Rossi & Bromm 2019).



ΔΩ-sensitivity curves above (below) which the probability of detecting one individual source at a redshift higher than z is P = 1 (< 1). Results are shown for z = 7 – 19, with successive curves corresponding to variations of Δz=1 (i.e. z = 7, 8, 9…, etc).

For the standard size distribution, lower sensitivities (S) and larger surveys areas are required for detecting sources at all analysed z, with such constraints being stronger towards higher z. For a **ΔΩ ≲ 10 deg^2** and a **standard (shock) size distribution**, **S ≲ 1, 0.1 and 0.01 μJy** are required to detect at least **one source at z > 7, 10 and 14 (z > 7, 13 and 18)**.

Observability of FIR sources as a function of the dust-to-metal mass ratio



ΔΩ-sensitivity curves above (below) which the probability of detecting one individual source at z>7 is P(z>7)=1 (<1). Results are shown for different dust-to-metal ratios (D/M), considering the standard (thin lines) and shock (thick lines) size distributions.

At a given ΔΩ, the minimum **sensitivity** required to assure at least one individual detection **increases** almost **proportionally to D/M** .

For a sensitivity **S ≈ 1 μJy** (which could be a plausible value for a next-generation FIR telescope) and D/M = 5 × 10^{-3} , 0.06 and 0.4, surveys areas ΔΩ ≳ 1 – 10 deg^2, ≳ 10^{-3} – 10^{-2} deg^2 and ≳ 10^{-4} –10^{-3} deg^2 would be required to assure the detection of at least one individual source at z > 7.

SUMMARY AND CONCLUSIONS

*We explore the possibility of **detecting first galaxies** with a **generic far-infrared/sub-millimeter telescope** by applying an analytical model of **primordial dust emission**. Galaxies at z>7 experience a **strong negative K-correction** in such a way that systems of similar masses are brighter at higher z. At a given mass and z, our model predicts that luminosity fluxes increase proportionally to the **dust-to-metal ratios (D/M)** of primeval sources. We evaluate the observability of model sources at different z > 7 as a function of the observed survey area (ΔΩ) and sensitivity (S) of a generic instrument. Assuming **ΔΩ ~ 10 deg^2** and a plausible **S ~ 1 μJy** for a near future survey, we could assure the detection of at least one typical source with **D/M ~ 5 × 10^{-3}** at z > 7. For **S ≳ 1 μJy** and **ΔΩ ≲ 10 deg^2**, **higher than typical D/M** are required to detect at least one individual source at z > 7. The observability of model galaxies is also affected by the size distribution of dust grains, specially towards higher z.*

See De Rossi & Bromm (2017, 2019), for more details about this work.

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VB acknowledges support from NSF grant AST-1413501. MEDR is grateful to PICT-2015-3125 of ANPCyT (Argentina).