Dust from galactic chemical evolution and SED model

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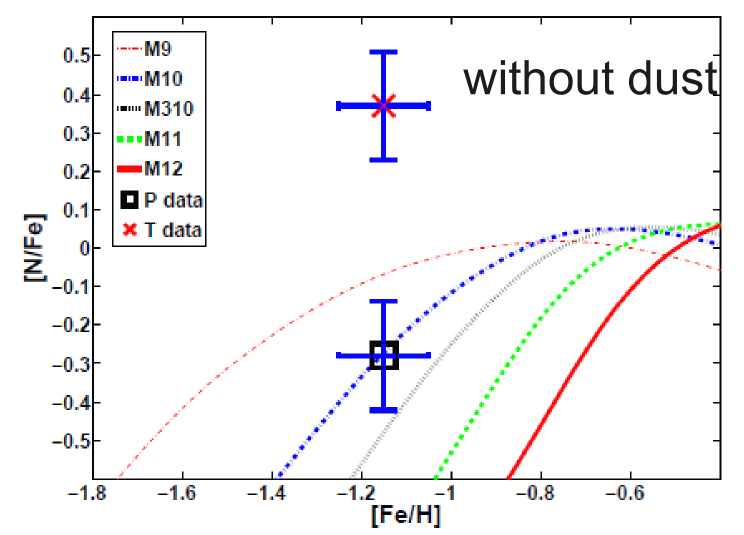
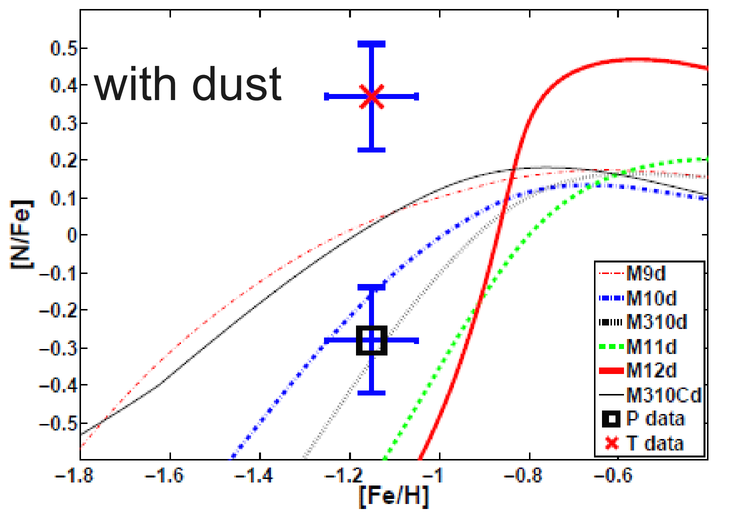
Outline

- Dust in galactic chemical evolution model:
  - What are the sources of high redshift dust ? QSO J1148+5251 at z≈6.4, dust mass ranges from $2 \times 10^8 M_\odot$ to $7 \times 10^8 M_\odot$ (e.g. Bertoldi et al. 2003a; Robson et al. 2004; Carilli et al. 2004; Beelen et al. 2006).
  - How dust evolve in ISM ?
- Dust in SED model: preliminary results

Why galactic chemical evolution model

- Dust information is necessary to study chemical evolution (up to 90% Fe locked into dust)
- Abundance is measured in gas phase
- More Fe depleted into dust, higher [N/Fe]





data: cB58 from Pettini et al. (2002) and Teplitz et al. (2000)
lines: predications of our models for ellipticals of different mass
(Pipino et al. 2011)

Our model ingredients

- An updated model based on Calura et al. (2008)
- SFH (downsizing: shorter and more intense SF in massive objects)
- IMF (Salpeter)
- Yields : *van den Hoek & Gronewegen (1997)*, Francois et al. (2004), Maeder (1992).
- Dust sources : *low and intermediate mass stars*, supernovae Ia, supernovae II, QSOs
- Dust elements : C, O,Si,Fe,Mg,Ca,S
- Dust evolution :dust destruction and accretion processes in ISM=gas+dust

$$\frac{dG_{dust,i}(t)}{dt} = -\psi(t)X_{dust,i}(t)$$

subtracted from the ISM by the SF process.

$$+\int_{M_L}^{M_{Bm}} \psi(t-\tau_m)\delta_i^{SW} Q_{mi}(t-\tau_m)\phi(m)dm$$

$$+(1-A)\int_{M_{Bm}}^{8M_\odot} \psi(t-\tau_m)\delta_i^{SW} Q_{mi}(t-\tau_m)\phi(m)dm$$

restored into the ISM by low and intermediate mass stars

$$+A\int_{M_{Bm}}^{M_{BM}} \phi(m)$$

$$\cdot\left[\int_{\mu_{min}}^{0.5} f(\mu)\psi(t-\tau_{m2})\delta_i^{Ia} Q_{mi}(t-\tau_{m2})d\mu\right]dm$$

restored into the ISM by SNe Ia

$$+(1-A)\int_{8M_\odot}^{M_{BM}} \psi(t-\tau_m)\delta_i^{II} Q_{mi}(t-\tau_m)\phi(m)dm$$

$$+\int_{M_{BM}}^{M_U} \psi(t-\tau_m)\delta_i^{II} Q_{mi}(t-\tau_m)\phi(m)dm$$

restored into the ISM by SNe II

$$-\frac{G_{dust,i}}{\tau_{destr}} + \frac{G_{dust,i}}{\tau_{accr}} + \delta_i^{qso} X_i \psi t$$

QSO dust

dust destruction and accretion in ISM

Dust sources I

- In low and intermediate-mass stars, dust is produced during the Asymptotic Giant Branch (AGB) phase (Ferrarotti & Gail 2006)
- Our model: as suggested by Dwek (1998), we adopt the condensation efficiencies: δ_i^{SW}, δ_i^{Ia} and δ_i^{II}.

  $M_{ej,i}(m) \propto m \times Q_{mi}(t)$

  1) C rich stars: carbon dust

  2) O rich stars: silicate dust composed by O, Mg, Si, S, Ca, Fe.
- SNIa and SNII: condensation efficiencies decreased by a factor of 10 with respect to the Calura et al.'s fiducial case: **a typical 20 $M_\odot$ star now produces nearly 0.08 $M_\odot$ dust.**

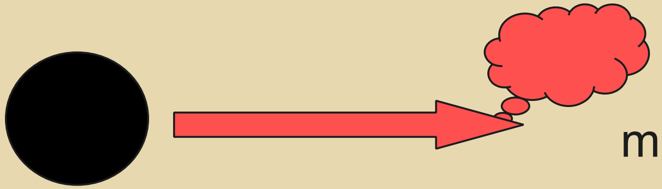
$$M_{\mathrm{d},i}(m) = \delta_i^{\mathrm{Ia}} M_{\mathrm{ej},i}(m) \propto \delta_i^{\mathrm{Ia}} Q_{\mathrm{mi}}, \; M_{\mathrm{d,O}}(m) = 16 \sum_i \delta_i^{\mathrm{Ia}} M_{\mathrm{ej},i}(m)/\mu_i .$$

Dust sources II

- Smoking QSO (Elvis et al. 2002): physical conditions in the clouds of the Broad Emission Line (BEL) regions may become similar to the conditions of AGB stellar envelopes.
- Our fiducial model:

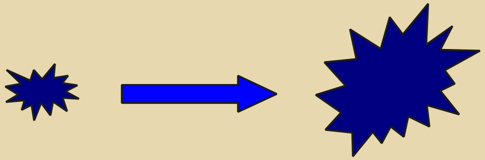
BH grow at the Eddington rate (Padovani & Matteucci 1993)

$M_{bh} \sim 0.003\, M_L$
(Ferrarese & Cote 2007)



mass flow rate from QSO wind

$\psi(t) = 0.5 \times 10^{-8} M_{bh}(t)$ in units of $M_\odot$/yr
(Proga et al. 2000)



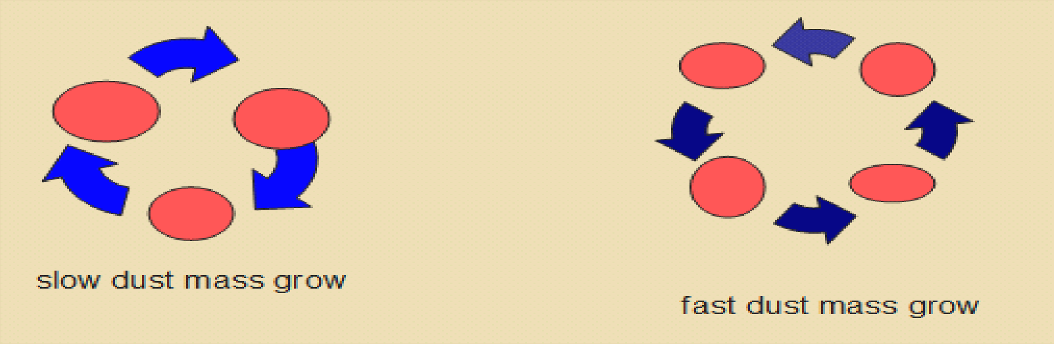
$\delta_i^{qso} X_i \psi_f(t)$

dust grow in smoking QSO

Dust evolution in ISM

- **Dust accretion occurs in dense molecular clouds**, where volatile elements can condensate onto pre-existing grain cores, originating a volatile part called mantle (Dwek 1998; Inoue 2003).
- **Dust destruction is due to** the propagation of **SN shock waves** in the warm/ionized interstellar medium (McKee 1989; Jones et al. 1994).
- Timescales for the accretion and destruction of dust as Dwek (1998) with **two new effects**:

  1)The **more frequently** the single regions of the ISM collapse into clouds (in more massive galaxy), form stars and become diffuse ISM again, **the faster** the dust mass grows.



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- Timescales for the accretion and destruction of dust as Dwek (1998) with **two new effects**:

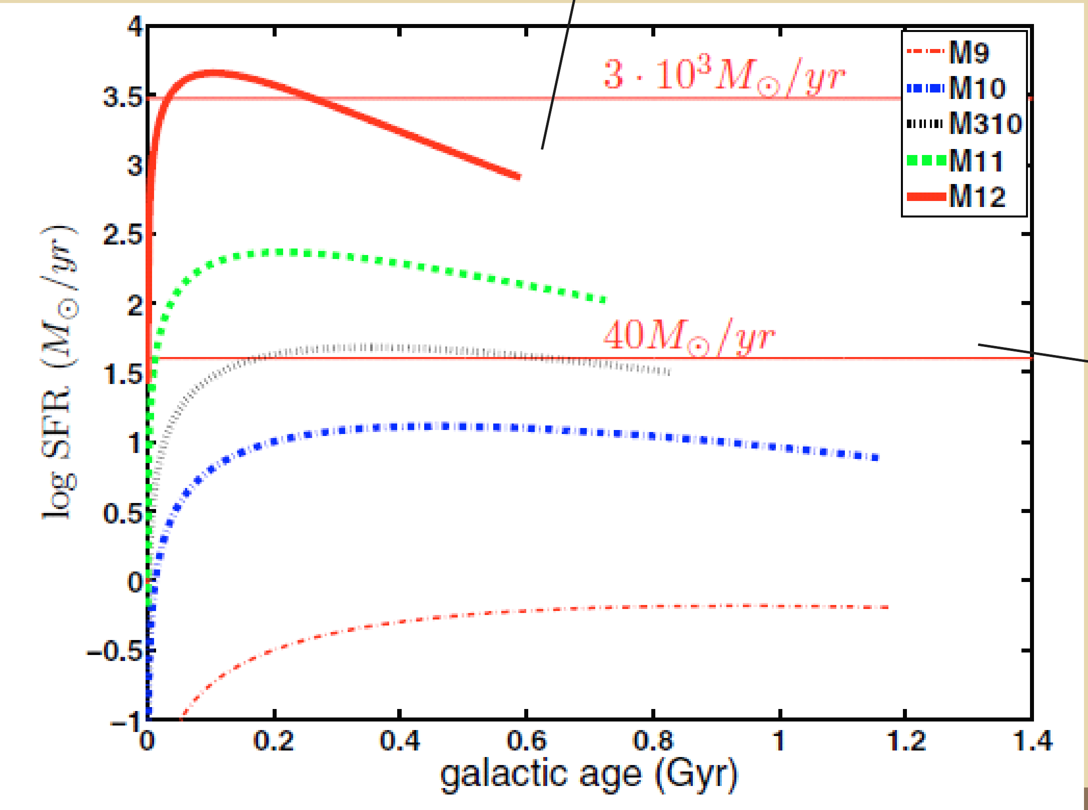
2)**Multiple SNe II explosions strongly suppress the destruction** of the interstellar dust with respect to the case in which all SNe could be treated as isolated and random explosions (McKee 1989). **the mean efficiency per SNII is a factor of 0.05–0.2 the efficiency of an isolated explosion.**

Isolated and random explosions

Multiple SNe II explosions

Overall results:Star formation history

- SFH downsizing: shorter and more intense SF in massive objects. Quenching of SF by galactic wind

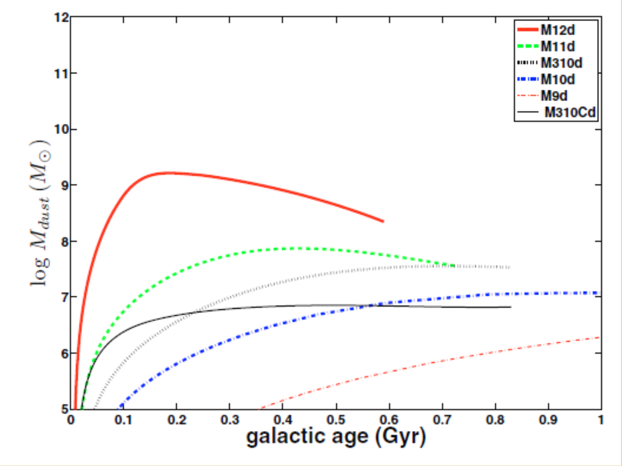


SFR of QSO J1148 (Bertoldi et al. 2003b; Carilli et al. 2004)

SFR of LBG cB58 (Pettini et al.2002)

Overall results:dust mass

- dust mass-galaxy mass relation : dust content is higher and increases faster in more massive galaxies
- dust mass at the peak



$$\mathrm{Log}(M_{\mathrm{dust,peak}}/M_\odot) = 0.98(\mathrm{Log}M_{\mathrm{lum}}/M_\odot) - 2.75$$

- dust mass after 0.5 Gyr of evolution

$$\mathrm{Log}(M_{\mathrm{dust,05}}/M_\odot) = 1.07(\mathrm{Log}M_{\mathrm{lum}}/M_\odot) - 4.01$$

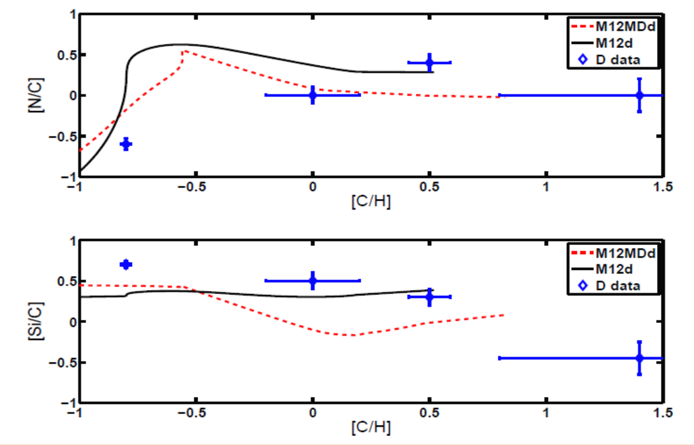
The high mass case

- Our massive $10^{12}\ M_\odot$ elliptical model predictions are in **agreement with** the observations of QSO J1148:

1) a **stellar mass** of ~ $10^{11}\ M_\odot$ and a **gas mass** of ~ $10^{10}\ M_\odot$ within 2.5 kpc (e.g. Wang et al. 2010).

2) The predicted **BH mass** at the onset of the galactic wind is ~ $2\times10^{9}\ M_\odot$ (e.g. Barth et al. 2003).

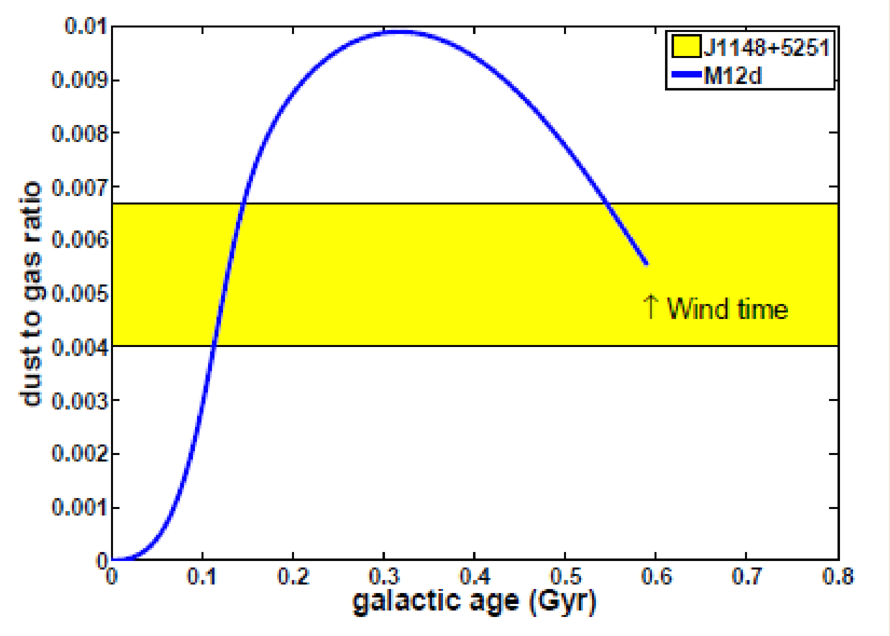
- narrow line region **abundances ratios** :

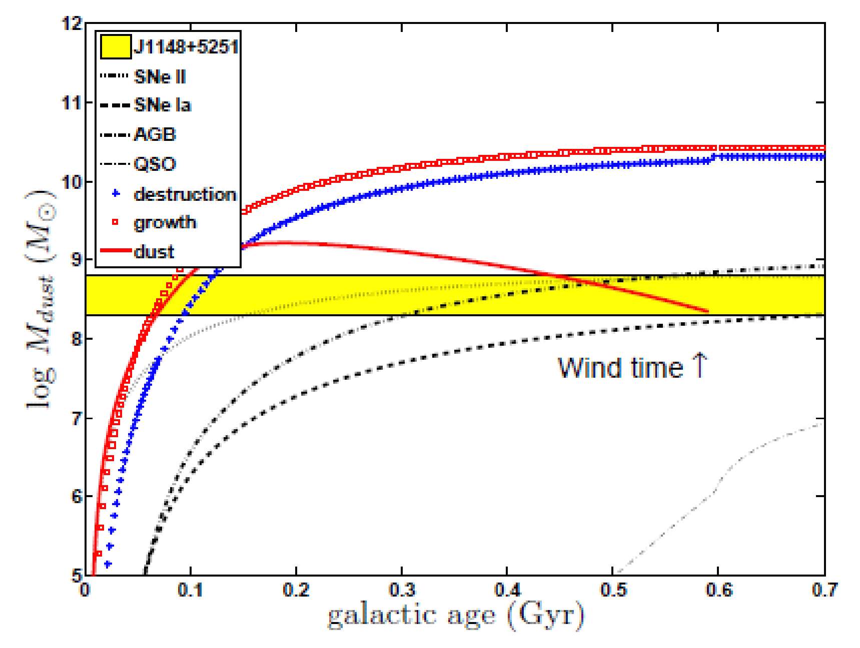


Data: NLR by D'Odorico et al. (2004)
dotted lines:the predictions in which the metallicity dependent yield from Woosley & Weaver (1995) + Maeder (1992).

Dust in J1148 host galaxy I

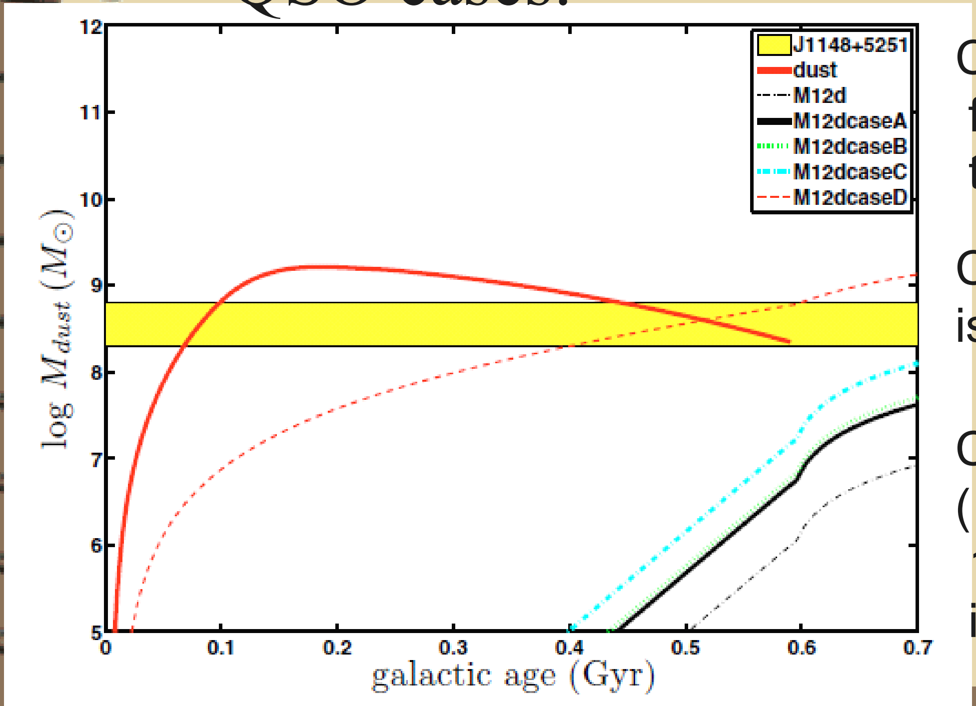
- z=6.4 (massive10^{12} $M_\odot$ elliptical model)
- dust growth and destruction dominate the cumulative mass at times larger than 0.1 Gyr.
- QSO dust is relatively unimportant.





Dust in J1148 host galaxy II

- The channels for dust production are many, and their relative role cannot be constrained by using only the observed dust mass.
- QSO cases:



Case A: the metallicity of the dust forming regions is 0.8 dex higher than the average.

Case B and C: BH-stellar mass ratio is a factor of 2 and 4 than the local value

Case D: a quite high seed mass (10^8 $M_\odot$) and the accretion timescale is 10 times longer than the adopted one in the fiducial case

Conclusions

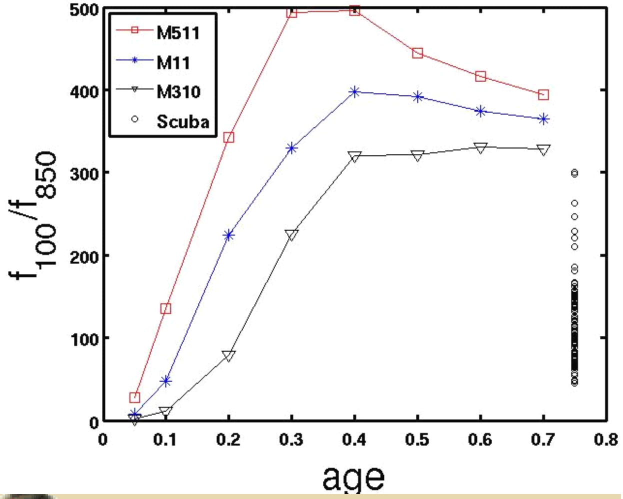
- Dust content is higher and increases faster in more massive galaxies
- Dust growth and destruction dominate the cumulative dust mass of a high redshift star-burst galaxy
- QSO itself can produce dust but this production appears negligible compared to that from stellar sources, unless one focuses on the very central regions at times very close to the galactic wind onset.

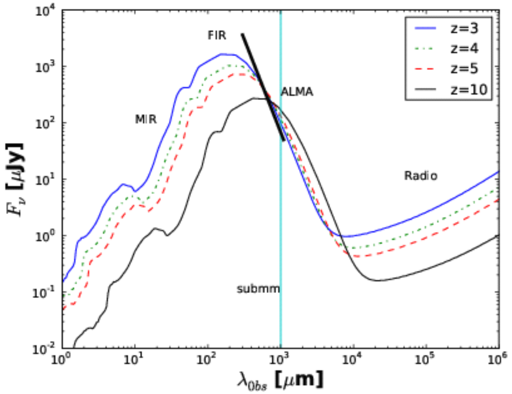
dust in SED model: results for high redshift data

- SED is the most direct observational information
- Dust change SED a lot (~30% UV absorbed)
- Our approach combining two models:
  - chemical evolution model: self-consistent SFH, chemical (21 elements) and dust evolution information
  - spectro-photometric model GRASIL: UV-radio, radiative transfer, geometry
  - available for all morphological galaxies
  - tested for local data

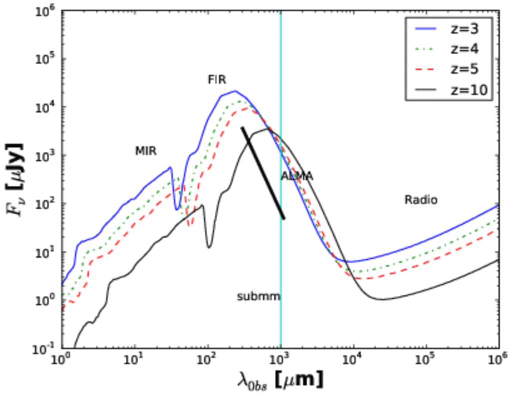
dust in SED model: results for high redshift data

- The mass fraction of the warm and the cold dust in galaxies
- SEDs of galaxies located at different redshift (NOT local template Arp 220)





(a) SED of 0.5Gyr $10^{11}M_\odot$ galaxy located at different redshift. ALMA sensitive curve is for an integration time of 60 seconds.

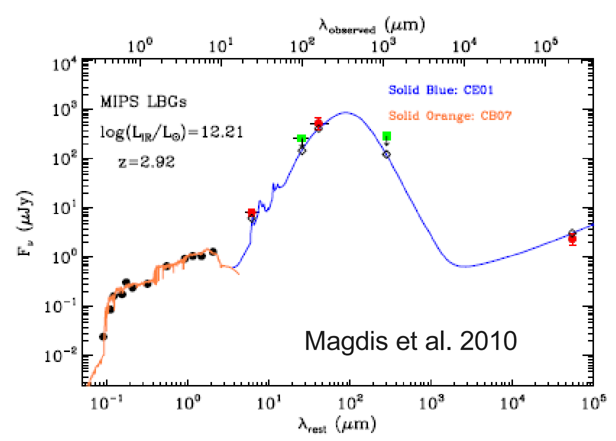


(b) SED of 0.5Gyr $10^{12}M_\odot$ galaxy located at di
ferent redshift. ALMA sensitive curve is for an in
tegration time of 60 seconds.

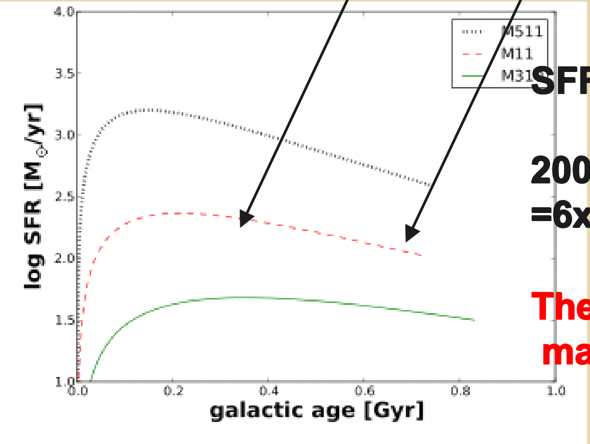
data:SCUBA local galaxies
(Dunne et al. 2000)

MIPS-LBGs at z ~3

- MIPS-LBGs are likely young (~0.3- 0.7 Gyr) elliptical galaxies.



Magdis et al. 2010



SFR~ 250$M_\odot$/yr

200 $M_\odot$/yr * 0.3Gyr =6x10^{10} $M_\odot$

The total dust mass ~ 7 × $10^7 M_\odot$

average SFR~ 250 M☉/ yr.
stellar mass ~7.9×$10^{10} M_\odot$
no AGN signature
PAH signature (Magdis et al. 2010)

dust mass ~ 5.5x 10^8 $M_\odot$ (Rigopoulou et al. 2010) based on single temperature grey-body fitting

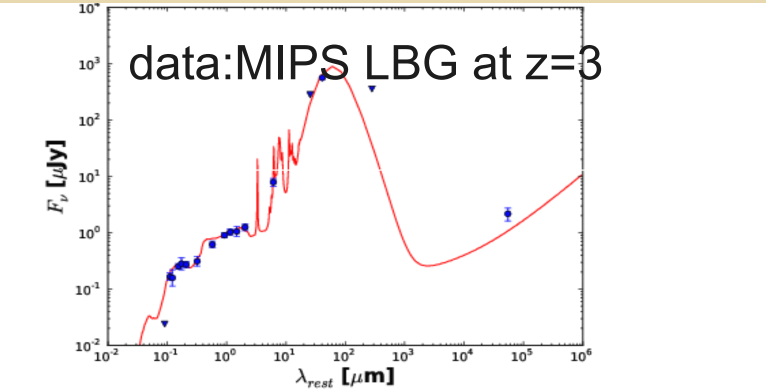


Fig. 9. best-fitting Rest-frame SED of $10^{11} M_\odot$ galaxy at 0.5 Gyr. Data are from Magdis et al. (2010b)

Dust mass estimation

- The uncertainty of galaxy mass estimation is related to the model parameters. The dust mass estimation in this work for 2 x 10^{11} $M_\odot$ galaxy at 0.5 Gyr produces dust mass M_d ~ 2 x 10^8 $M_\odot$
- The uncertainty of single temperature grey-body fitting parameter, such as the rest frame dust mass absorption coefficient k . e.g. a factor ~ 7 at 800μ m estimated by Hughes et al. 1997

$$M_{\mathrm{d}} = \frac{S_\nu D_{\mathrm{L}}^2}{\kappa(\lambda_{\mathrm{rest}}) B_\nu(\lambda_{\mathrm{rest}}, T_{\mathrm{d}})},$$

- The well known degeneracy of dust temperature T_d and slope β_d in single temperature grey-body fitting: A higher β_d will result in lower dust temperature derived from single temperature grey-body fitting , therefore higher dust mass will be estimated.

$$F_\nu \propto \frac{\nu^{3+\beta_{\mathrm{d}}}}{\exp(h\nu/kT_{\mathrm{d}}) - 1}.$$

dust intrinsic properties ?

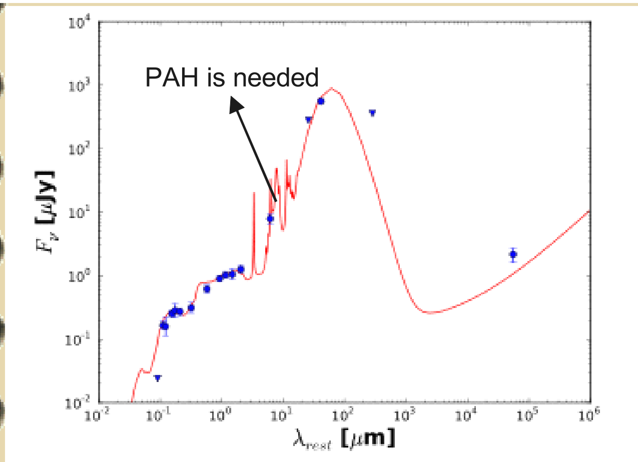
- Dust optical properties:

  silicate and graphite grains from Laor & Draine (1993).

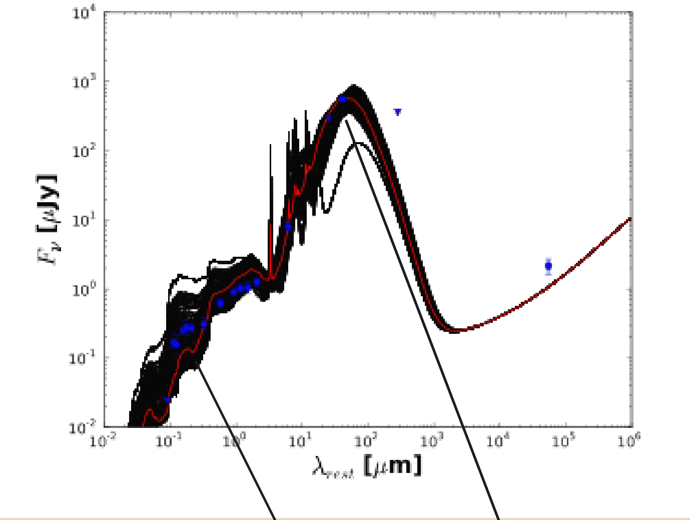
  PAH molecules from Draine & Li (2007).

- Dust size distribution

$$\frac{dn_i}{da} = \begin{cases} A_i n_H a^{\beta_1}, & \text{if } a_b < a < a_{max}, \quad (2) \\ A_i n_H a_b^{\beta_1-\beta_2} a^{\beta_2}, & \text{if } a_{min} < a < a_b. \quad (2') \end{cases}$$

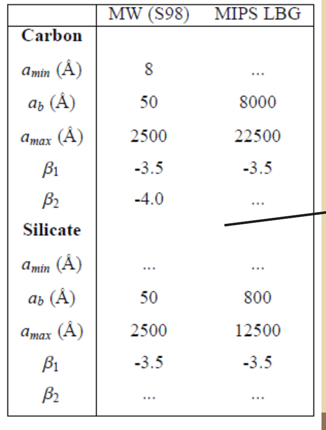


PAH is needed



the slope of optical

the peak of FIR

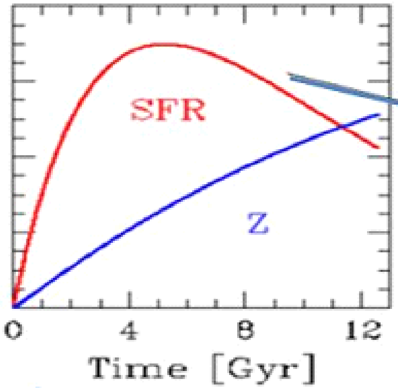


	MW (S98)	MIPS LBG
Carbon		
a_{min} (Å)	8	...
a_b (Å)	50	8000
a_{max} (Å)	2500	22500
β_1	-3.5	-3.5
β_2	-4.0	...
Silicate		
a_{min} (Å)	...	...
a_b (Å)	50	800
a_{max} (Å)	2500	12500
β_1	-3.5	-3.5
β_2	...	...

dust size distributions in MIPS LBGs may be flatter than it in the MW

Thanks !

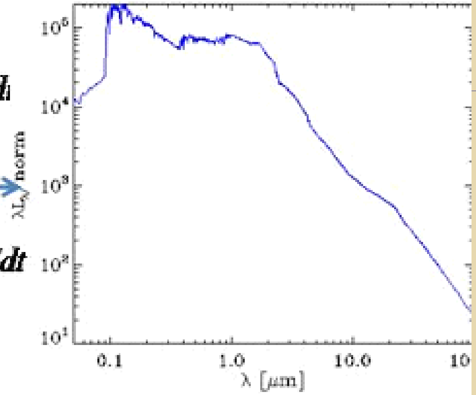
1) SFR(t), Mgas(t), Z(t),…



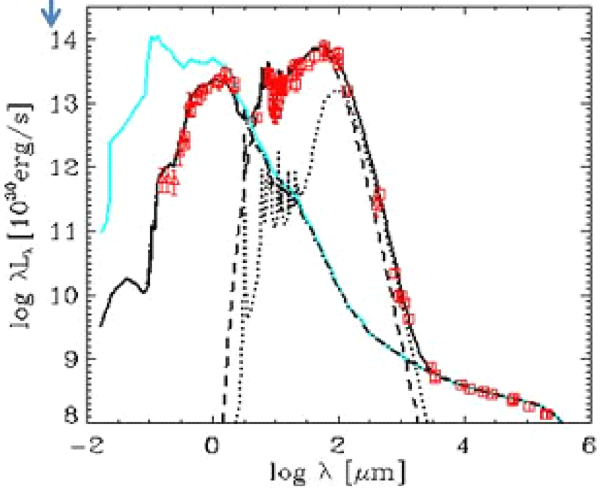
$$L_\lambda(T)=\int_0^T SFR(t)\cdot L_\lambda^{SSP}(T-t,Z(t))\cdot d$$

$$L_\lambda(T)=\int_0^T\int_0^1 SFR(t,Z)\cdot L_\lambda^{SSP}(T-t,Z)\cdot dZdt$$

2) Stellar population synthesis



RT code/Empirical treatment



3) UV/optical attenuation and IR emission

***Semi-empirical:** attenuation curve for L_{IR} + IR shape.
Pros: non time consuming - statistical analysis of large data sets.
Cons: not great predictive power

***Theoretical:** Explicit computation of RT and dust emission
Pros: broader interpretative/predictive power
Cons: time consuming

Silva 2009