SDSS J1148+5251: a hyperluminous high metallicity galaxy, in the early universe

**An exceptionally high star formation rate**

The rest frame IR luminosity of this quasar (right panel; Dwek et al. 2006) indicates that it is an HYLIR (LIR=10^12 L☉).

- A naive conversion of LIR into star formation rate (hereafter SFR) gives SFR=3500-5000 M☉/yr.
- This estimation is consistent with the value of ~3000 M☉/yr usually quoted in the literature.

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**When massive stars control dust evolution**

- SDSS J1148+5251 is a very young system. Assuming that it began its star formation at the reionization (z=10), its age at z=6.42 is ~400 Myr, which is the average lifetime of an AGB star.
- We can neglect the contribution of AGB stars to the evolution of the galaxy.
- Massive stars dominating the elemental evolution, we can simplify the gas and dust evolution equations, by considering instantaneous recycling

\[
\frac{dM_{\text{gas}}}{dt} = -\frac{SFR}{\text{gas}}\times\text{gas return to the ISM}
\]

\[
\frac{dM_{\text{dust}}}{dt} = \frac{SFR}{\text{dust}}\times\text{dust production by SN} + \text{dust destruction in the ISM}
\]

**A reasonably high star formation rate**

- The relation between the gas content and the star formation rate required to solve the equations above is given by the Kennicutt (1998) law (right panel).
- Adopting a total gas mass of (2-5)×10^10 M☉, this relation gives a star formation rate of SFR=400-800 M☉/yr (Dwek et al. 2004), which is significantly lower than the estimation from the IR luminosity.

**Star formation or nuclear activity?**

The SED of SDSS J1148+5251 is remarkably flat (figure below, Dwek et al. 2006), especially the rest frame near-IR observations (Charmandaris et al. 2004; Spitzer/IRS). Several origins are possible for this excess:

- Emission from low-mass stars: this explanation would require ~10^4 M☉ of stars, in order to match the 2 μm flux.
- Emission from the AGN: this solution is shown on the figure below. The AGN spectrum is a Taken as a power-law. The stellar component has been synthesized with PEGASE (Rocca & Rocca-Velumparange 1997), with a star formation scenario consistent with our dust evolution modelling.

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**A short-term memory dust content**

- In SDSS J1148+5251, massive stars are responsible for dust production and destruction → the dust lifetime is independent of the star formation history.

\[
T_{\text{dust,SN}} = \frac{R_{\text{SN}}}{\text{mass}} \times \frac{M_{\text{SN}}}{M_{\text{dust}}}
\]

- Consequently, the measure of the dust mass provides an estimation of the average dust yield per SNe:

\[
M_{\text{dust}}(t) \times Y_{\text{SN}} \approx f(t)
\]

- The two left figures (Dwek et al. 2004) show the evolution of the gas and dust masses, in SDSS J1148+5251. On each panel, 2 solutions are shown: 1) a closed-box model, and 2) a model with an inflow of gas.

**She must produce a lot of dust**

- The solution of the dust evolution equations (left figures), in the case of SDSS J1148+5251, indicates that the dust yield per SNe must be high, in order to explain the amount of dust observed (Dwek et al. 2004):

\[
Y_{\text{dust}} = 0.3-1 M_{\odot}/SN
\]

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**Summary and conclusion**

- SDSS J1148+5251 is a distant quasar at z=6.42. It is a nearly solar metallicity hyperluminous IR galaxy, in the early universe. It challenges our understanding of dust formation in extreme environments → how could such a high mass of dust have formed in only a few 100 Myr ?
- The dust production by low-mass stars can be neglected since the age of J1148+5251 is high, indicating that the dust yield per SNe must be high (Y≈0.3-1 M☉/SN).
- Two independent star formation tracers, indicate that the total energy budget of this galaxy is dominated by the central black hole → the previous studies overestimated the star formation rate by a factor of ≈3-4.

**References**

Fan, Strauss, Schneider et al. 2003, AJ, 125, 1649