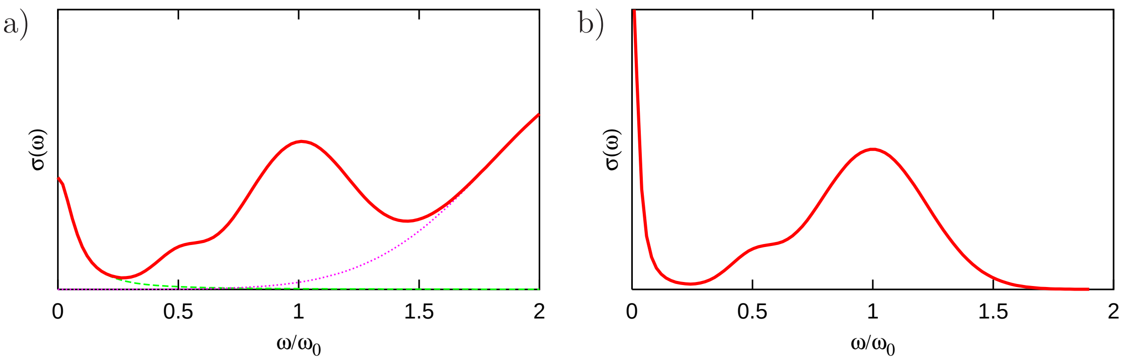

Figure 4.4: Scheme for $\sigma(\omega)$: Effects of disorder/phonons as well as interband excitations which would be seen in experiment (**a)**, solid line) have to be identified (dashed and dotted lines) and subtracted when comparing to **b)** results of a "clean" valence electron calculation.

abstractions and approximations can violate the f-sum rules; then, the plasma frequency may become dependent on parameters of the model or even on temperature. Before we treat transport properties and the conductivity sum rule on a microscopic level in the next sections, we want to discuss the qualitative impact of the neglect of lattice degrees of freedom and of a reduction to a few valence bands. Furthermore, we sketch the generic overall behavior of $\sigma(\omega)$ for the Hubbard model.

In Fig. 4.4 a, we show schematically the optical conductivity of a typical strongly correlated metal (solid line). One can distinguish a relatively broad Drude peak near $\omega = 0$ and an incoherent peak at finite frequencies $\omega \approx \omega_0$ with a shoulder (here at $\omega \approx \omega_0/2$). In a single-band picture, $\hbar\omega_0$ roughly corresponds to the local Coulomb interaction U. Then, the contributions at $\omega \gg \omega_0$ have to be interpreted as interband contributions. Therefore, they have to be quantified (dotted line) and subtracted in order to define an effective valence electron contribution as shown in Fig. 4.4 b. Often, the width of the Drude peak (dashed line in Fig. 4.4 b) is dominated by lattice degrees of freedom which are not taken into account in purely electronic models. Therefore, this contribution has been replaced by a much narrower Drude peak with the same weight in Fig. 4.4 b. Clearly, this mapping is somewhat ad-hoc and not generally reliable.[7] Still, the example given here illustrates that results obtained for an electronic valence-electron model will not in general yield meaningful estimates for the plasma frequency (not even in the sense of partial sum rules) and that even the shape of the low-frequency part of $\sigma(\omega)$ may be unrealistic.

In the remainder of this section, we will classify the qualitative behavior of $\sigma(\omega)$ for electronic models which are defined in the continuum or on a Bravais lattice. Then, electronic states may be labeled by their (crystal) momentum $\boldsymbol{k}$, band index ν, and spin σ. The associated paramagnetic current density operator $\hat{\boldsymbol{\jmath}}$ and Fermi

[7] Our example is very similar to an analysis of experimental data for $CaVO_3$ by Rozenberg, Inoue, Makino, Iga, and Nishihara (1996).