Status report about charge instability

May 29, 2017

Abstract

We collect some results obtained by means of different implementations of fRG equations using a full frequency dependent vertex. It emerges a very peaked structure in the charge-channel for finite frequency-transfer, that in some region of the parameter space becomes divergent. Such a divergence has no obvious physical interpretation. The peaked structure seems to be characteristic of the frequency dependence of the vertex, as it is shown by means of simpled diagrams. On the other hand the *divergence* of this structure may be very sensitive to the detailed structure of the Green's function used in the calculation, i.e., very sensitive to the use, or not, of dressed propagators, even when the correction to the self-energy appear to be small (i.e., self-energy Fermi liquid-like).

1 fRG without self-energy

The results shown in this section are obtained in standard fRG using an interaction cutoff: $G_0^\Lambda = \Lambda G_0$. The calculations are performed on the Matsubara frequency axis for temperature $T = 0,08t$, where t is the nearest neighbors hopping.

Besides the vertex, we have computed the susceptibilities, whose divergences follow the vertex ones.

Technicalities

- The vertex was decomposed in channels (magnetic, density, and superconducting) as usual in the literature.
- We have previously shown that the full frequency dependence of the vertex can change drastically the resutls (as opposed for example to a bosonic frequency transfer decomposition), and hence we kept all the frequencies in a finite box.
- The momentum dependence of the vertex is treated by means of a form factor decomposition, while keeping 29 patches in the respective

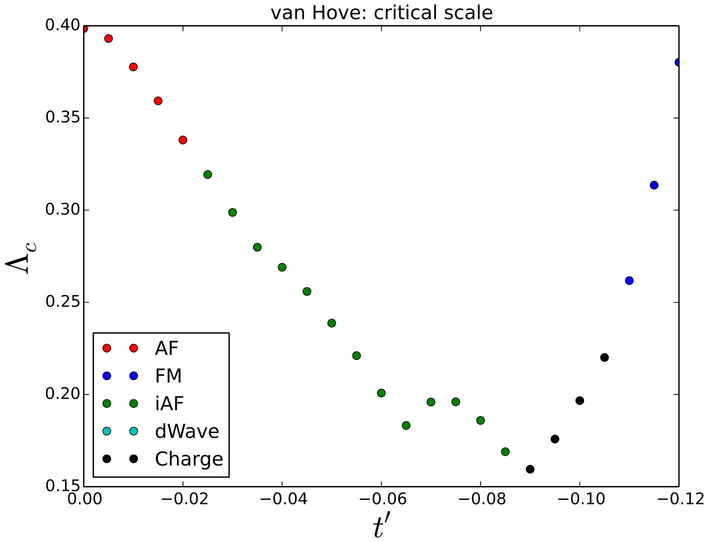

Figure 1: Critical scale in full frequency fRG (interaction cutoff) as a function of the nearest neighbors hopping and for van Hove filling. The color of the symbol indicates the kind of instability that is realized.

bosonic momentum transfer . The critical scale is fixed by the condition that the absolute value of one of the channels exceeds a value of $300D$, $D = 4t$.

- In all the calculations in this section we did not include any self-energy feedback. The calculation of the self-energy, with a full frequency dependence vertex is ongoing work, and needs more testing. Some results are presented in the following paragraphs.

  If not otherwise specified we measure energies in units of $D = 4t$, i.e., $t' = 0.1$ corresponds to $t' = 0.4t$.

Results In Fig 1 and 3 we show a putative phase diagram, for, respectively, van Hove filling, and van Hove filling plus 7%.

The fininte temperature acts as a cutoff for divergencies in the bare bubble.

In the spirit of the "interaction cutoff" the critical scale can be associated with the maximal value of the interaction $U_{\text{flow}} \approx (1-\Lambda)^2 U$ **check if there is the square** for which the flow would converge. In a purely weak coupling scenario one can assume a monothonic relation between the interaction value and the critical temperature, and hence we can qualitatively associate the critical scale whith a critical temperature. In this sense our results are consistent with those reported in the literature.

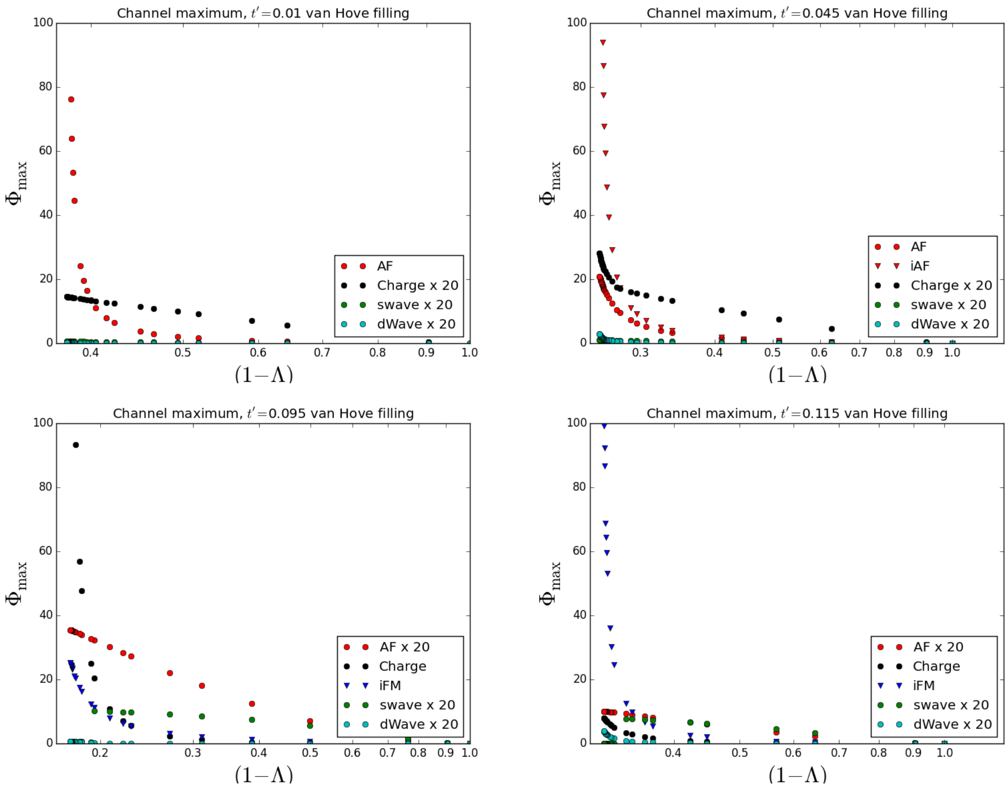

Figure 2: Flow of the maximum of the absolute value of each channel for differnt values of t' and at van Hove filling.

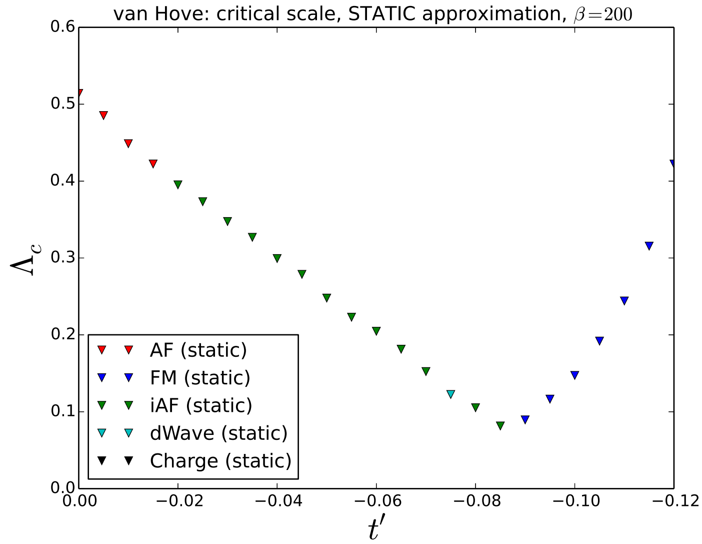

Figure 3: Critical scale in static fRG (interaction cutoff) as a function of the nearest neighbors hopping and for van Hove filling. The color of the symbol indicates the kind of instability that is realized.

We hava double-checked the consistency of our results by also considering a frequency selective cuffoff, which substitutes: $i\omega \to i\mathrm{sign}\omega\sqrt{\omega^2+\Lambda^2}$.

Charge instability problem We call *charge instability problem* the divergence of the charge component of the vertex for a finite bosonic frequency transfer, i.e. $\Omega_{ph} = 2\pi/\beta$, as already reported in the literature by Husemann *et al.*

- The charge channel diverges for a region of filling/next neighbors hopping between iAF and FM. In static fRG in this region one can find $d$wave superconductivity, usually at much lower scales (see Figs. 1, 3, 2).
- The divergence of the charge channel seems to appear at the transition between iAF and FM instabilities. In the "phase diagram" the charge divergence line seems to be continued by the FM line.
- The *divergence* of the channel is associated with a very specific *frequency-structure*. The frequency-structure can be explained (section about perpendicular ladders), it's divergence instead is unphysical. The frequency structure of the magnetic channel is rather flat, which can be interpreted in terms of RPA terms, with very little effect from other channels.

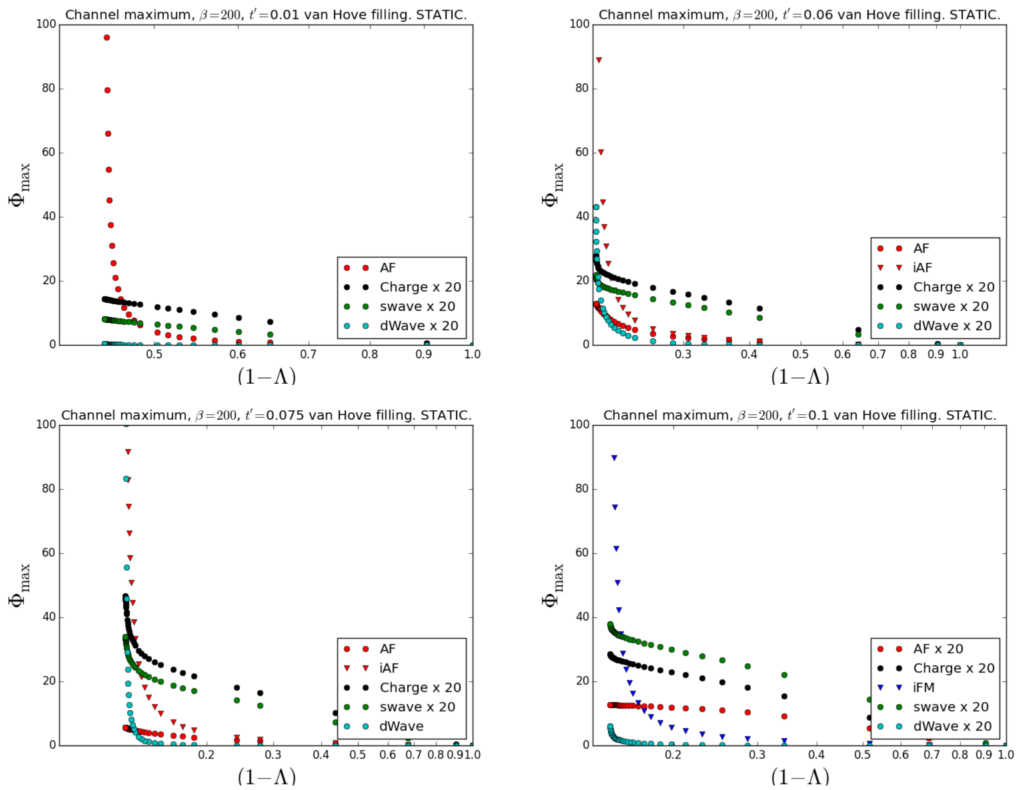

Figure 4: Flow of the maximum of the absolute value of each channel for different values of t' and at van Hove filling, in the static approximation for the vertex.

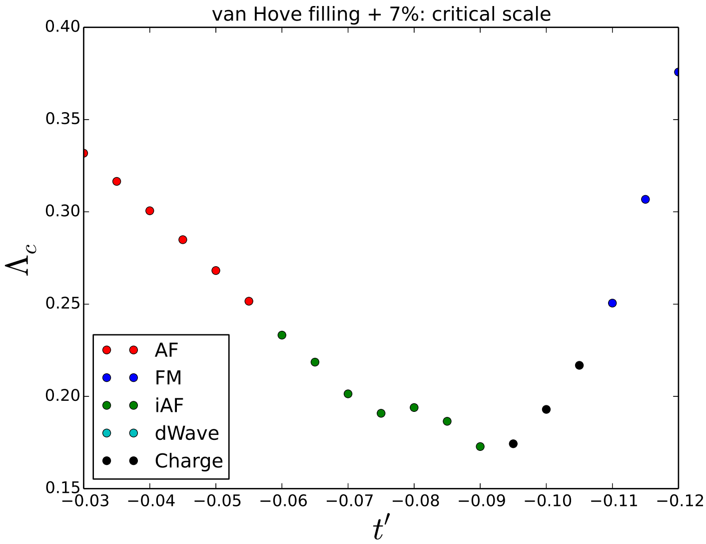

Figure 5: Critical scale in full frequency fRG (interaction cutoff) as a function of the nearest neighbors hopping and for van Hove filling + 7 %. The color of the symbol indicates the kind of instability that is realized.

- The divergence in the charge channel is very localized in frequency space. Nevertheless, it is sufficient to induce large values of the charge susceptibility, with a maximum at finite frequency transfer. The magnetic susceptibility is anyway larger due to the flat frequency structure of the magnetic vertex.
- The charge-channel divergence arises also in DMF^{2}RG, where the DMFT self-energy is already included in the flow equations.
- Introducing a *full* self-energy feedback the in DMF^{2}RG the problem seems to be suppressed.
- Similar observations in fRG, with major approximations on the self energy feedback.

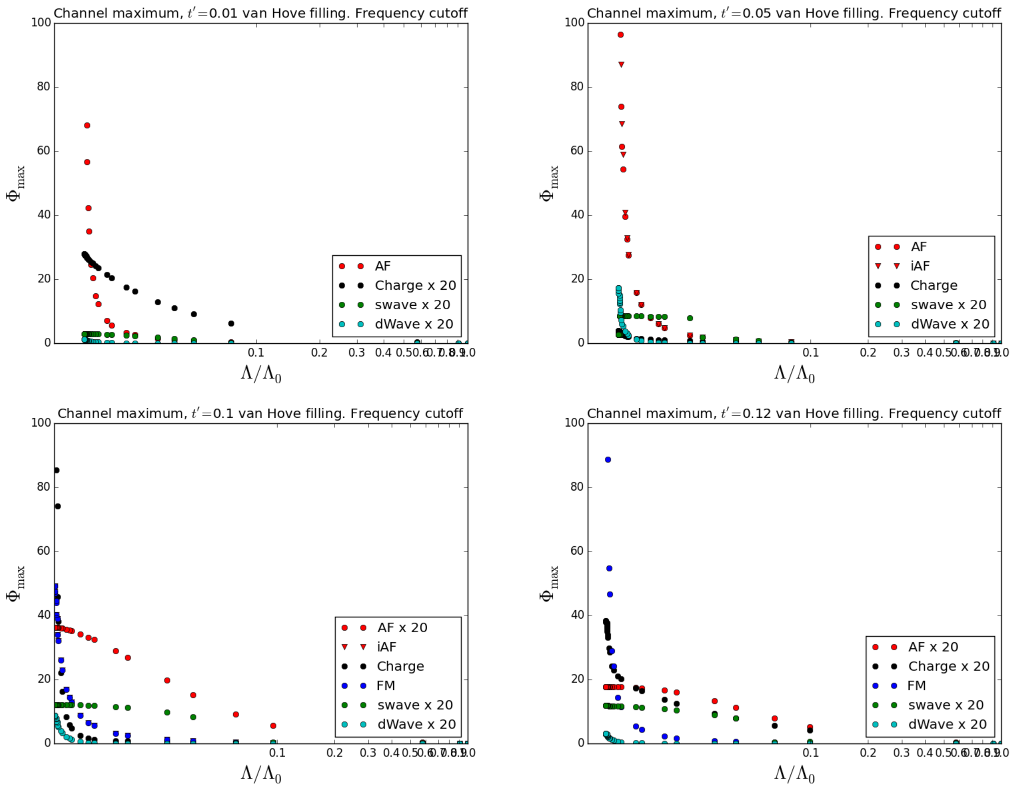

Figure 6: **frequency cutoff** Flow of the maximum of the absolute value of each channel for differnt values of t' and at van Hove filling.

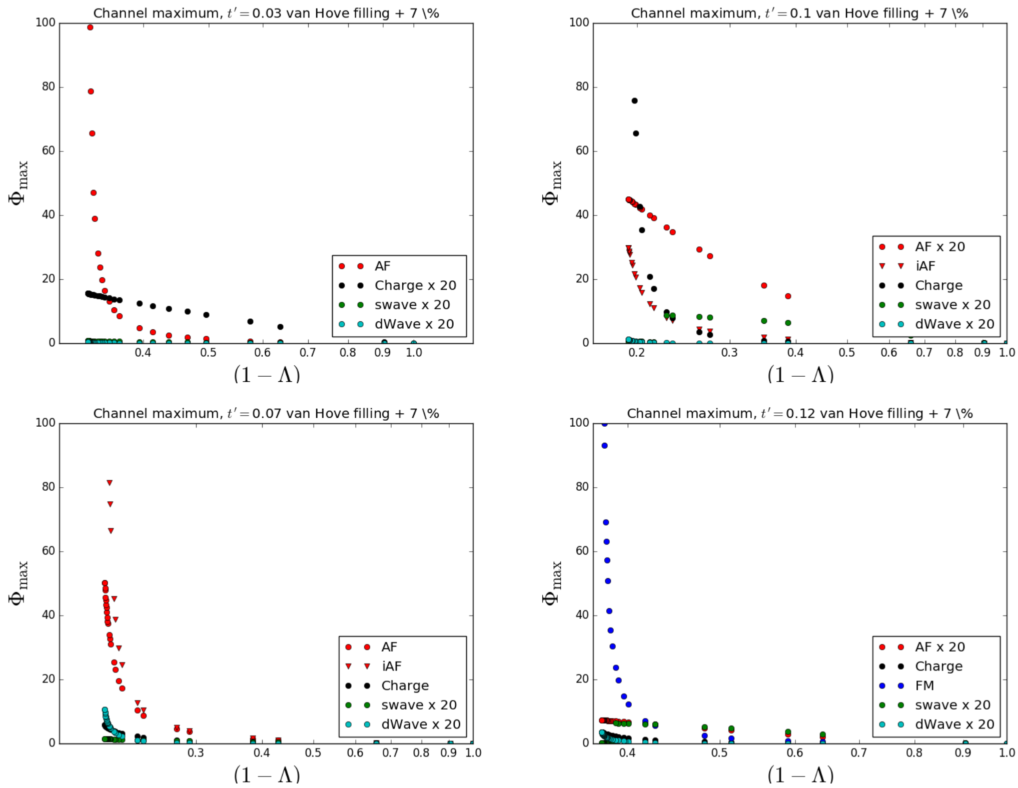

Figure 7: Flow of the maximum of the absolute value of each channel for diffrent values of t' and at van Hove filling $+7\%$.

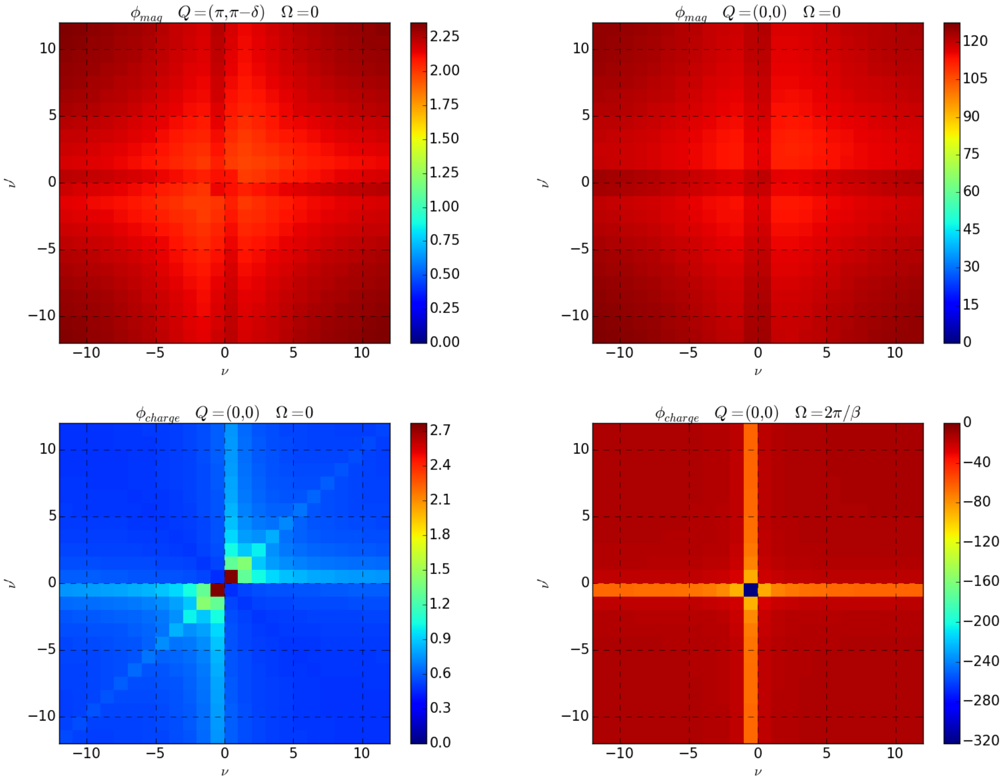

Figure 8: Frequency structure of the channels. Top left: magnetic channel for momentum closet to π, π where the vertex has a local maximum, top right: magnetic channel for momentum close to $0, 0$, in both cases external frequency transfer $\Omega = 0$. Bottom left: charge channel for external frequency transfer $\Omega = 0$ and transfer momentum $0, 0$, bottom right: the same but for *finite* frequency transfer $\Omega = 2\pi/\beta$.