Response to EPL referee B report on manuscript EPL G41974

I thank the referee for reviewing my paper. I would like to respond to this report and ask the referee to consider my response.

The first paragraph of the referee (up to "*was prepared*") is entirely correct.

On the second paragraph of the referee about magnetic systems: ("*First I should mention... I strongly doubt that.*"):
I have not studied these issues for the case of magnetism, so I don't know it for sure but suspect the same problem doesn't arise there. There are important differences between ferromagnetism and superconductivity. (i) There is hysteresis in ferromagnets, there is none in type I superconductors; (ii) The ferromagnetic transition is 2nd order, the superconducting one (type I in a magnetic field) is first order; (iii) The Clausius-Clapeyron equation applies to superconductors, not to ferromagnets. So the superconducting transition is more analogous to the water-ice or water-vapor transition than to the ferromagnetic transition; (iv) in magnetic systems there are necessarily other dissipation mechanisms at play: if a magnetic field is applied to a magnetic moment not parallel to the field, the magnetic moment will precess around the magnetic field direction, and its component along the field will not change, hence the magnetization will not change, unless there is a damping mechanism, which will generate entropy. So it is possible that the Joule heating from the Faraday field and this other dissipative mechanism combine to give a total change in entropy that depends only on initial and final states and not on the speed of the process. (v) Finally, the fact that there may be other physical systems that we don't understand is not a good argument for rejecting the explanation I am proposing for one particular system (superconductor). A good argument would be to point out what is it in my argument that is wrong.

That is in fact the subject of the third and last paragraph of the referee, *"As the author writes himself... So there is no any contradiction with the laws of thermodynamics."* I will explain why the referee is wrong, interspacing my response into the referee's comments (referee's comments in italic):

"*As the authors writes himself the cooling of superconductor is irreversible process due to appearance of this Joule heating.*" No, if the cooling of the superconductor proceeds infinitely slowly the process is reversible; if it proceeds at a finite rate it is irreversible.
"*It also would be irreversible in a gedanken experiment suggested in Fig 3 and in chapter IV of the manuscript since the heat conductance is not a reversible process.*" Yes, the process in Fig. 3 and Sect. IV is irreversible, whether there is Joule heating or not, because it involves heat transfer between systems at different temperatures. Therefore, the change in entropy of the universe is finite, as given by Eq. (14).
"*For irreversible processes entropy and heat are not directly related.*" That is correct. *Second law of thermodynamics (Clausius inequality) states that the change of entropy is bigger than the heat divided by temperature.*" That is correct. "*So there is no any contradiction with the laws of thermodynamics.*" That is incorrect. Let me explain why.

Please consider Sect. V. I have to admit I was not sufficiently careful. Right after Eq. (21) I said "Second, the transfer of the heat ΔQ from the system to the reservoir generates the same entropy as given by eq. (17)". That is not quite right, because of the Clausius inequality pointed out by the referee. The correct statement is:
(1) The transfer of heat ΔQ into the reservoir increases the entropy of the reservoir by $\Delta Q/T_2$
(2) The transfer of heat ΔQ out of the system decreases the entropy of the system by $\Delta Q/T$ *or less, due to Clausius inequality.*
Therefore, the change in entropy of the universe due to the transfer of heat ΔQ from the system to the reservoir is *at least* - $\Delta Q/T+ \Delta Q/T_2$. Instead, the paper said it was equal. But of course the conclusion doesn't change. To this entropy change we need to add the entropy generation due to Joule heat, $\Delta Q_J /T$, Eq. (21). So Eq. (22) is correct except that the first equal sign should be replaced by a larger or equal sign. The conclusion that "the second law of thermodynamics is violated by Eq. (22)" stands unchanged.

I hope the referee will consider this argument and either say what's wrong with it in his/her view, or agree it is right. If the latter, I suggest it is grounds for modifying the report's recommendation.

Thank you for considering this response.