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Title: Critical scaling of the mutual information in two-dimensional disordered

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Referee report

Re Manuscript "Critical scaling of the mutual information in two-dimensional disordered Ising models "

The manuscript addresses the relation between mutual Renyi entropy and phase transitions in disordered 2d spin models. I read the paper with interest. I am a physicist working in information theory. As such I know there is very little work on actual predictions of physical quantities using information theory. This paper does not do prediction but it illustrates a methodology which might be useful in the future.

The authors conduct numerical simulations of ground states for varying temperature in three classes of disordered 2d spin models. They identify the critical temperature for two of these systems using a function of the Renyi mutual information.

The results are convincing, the method is interesting as it illustrates nicely the relation between the physics of phase transitions and Shannon / Renyi information theory.

My main concern is that it is unclear to me how much this work adds to the work reported in references 11-19. I suggest the authors clarify this.

I agree with the authors that the unsuccessful study of the RCF system in Eq 5 is important to include. However, it would be illuminating if the authors added some comments on the reason of this failing. Why do they think the Monte-Carlo optimization fails here but not for the other models?

I recommend the authors add a few sentences on the background of RMI and phase transitions, explaining why a crossing of the RMI curves indicates

a phase transition. This would help bring the communities of information theorists and physicists closer together.

In the introduction, a classification of universality classes is promised but this is not taken up later in the paper. Unless I have missed something, the authors should either take out the promise or add this to the paper.

More minor comments:

Is it worth explaining what a 'glassy phase' is? (page 2)

Why is J set to 1 in Eq (4) but not in Eq (6)?

Should it be $\beta = 1/k_B T$ rather than $\beta = 1/T$ on page 3?

3rd paragraph in Results: point to Fig 2.

Last paragraph of Results: Give exact results from Eq 7 for comparison.

The lower-value crossing points are never clearly visible. Maybe an inset with a zoom? I suspect this will show that they are hidden in the noise.

Why is Renyi entropy of order 2 used and not any other order? (Why is it called second Renyi entropy rather than Renyi entropy of order 2?)