**Reviewer A**  
  
**Comment 1:**

Reviewer’s comment: “*The theoretical merit, claimed by the Abstract, is the "laboratory verification of the objective classical world" emerging from the quantum. In conclusion, the authors claim to have shown that emergent "objective classical systems", as defined by QD, exist [] in "small environments". This, I'm afraid, is incorrect. First, because - to my best knowledge - QD requests a l a r g e n u m b e r of environmental subsystems each sharing the same information about the central system. One can not interpret "proliferation of information" over a "small environment". The full-scale phenomenon (emergence of classicality a la DW) never happens in a small environment. It is misleading to claim the objective classicality of the NV-center even in a perfect 1+4-spin GHZ state.*“

Authors answer: We thank the reviewer for this important comment. We agree that we cannot claim to have observed classicality. We do see, though, classicality emerging, i.e., the beginnings of redundancy and the first steps that lead to classicality.

Changes made: In the abstract, we now stress that redundancy *begins* to form so there is no confusion. In particular, we use the term “incipient classical objectivity” to emphasize that this is just the start of the quantum-to-classical transition. We have also made similar changes to the conclusions.

**Comment 2:**

Reviewer’s comment: “*I wonder if a revised main text contains the 4 parallel couplings (now in SI), leading to the following approximate periods in microsecs: 10, 20, 20, 40. Guess that cca t=15 is (14.7 in the ms) yields the best classicality although spin 1 contains no information, so proliferation is defective. Then t=20 might give the worst classicality, since all spins return to their initial states. Fig. 3c confirms this for the single spin environment; 2-3-4 spins contain more and more information respectively (this does not fit to my phenomenology, I must admit). The case t=10 is symptomatic, spin 4 performs its maximum, the other three are completely useless, "proliferation" fails again.* “

Authors answer: It is correct that the optimal interaction time is connected to the strength of the hyperfine interaction. When a single nuclear spin is considered, the optimal time would be an odd multiple of half the interaction period. In this case, the nuclear spin states projected into the sublevels ms=0 and ms=-1 of the NV center are orthogonal and therefore a maximal amount of information about the NV state is acquired. A good time is therefore t=15us, since all nuclear spins nearly go through half an interaction cycle. At t=20us, only spin four rotates half a cycle and carries a maximal possible amount of information. Because nuclear spin four carries one bit, the mutual information stays at one bit when all nuclear spins are intercepted, even when the other spins carry no information.

Changes made: The strength of the parallel hyperfine coupling strength of the four strongest coupled nuclear spins is now presented in the caption of figure two. Also, the changes made in comment 1 are also relevant.

**Reviewer B**

**Comment 1:**

Reviewer’s comment: “*Abstract: The term “evolving naturally” is used. However, the meaning of this term is not clear to me. I expect that the authors mean that the N-V—quantum state evolves without any engineered electromagnetic perturbations apart from those contributed by the background spin bath and thermal reservoir of the natural isotope crystal lattice environment. This should be made clear.*“

Authors answer: We thank the reviewer for this comment. “Evolving naturally” means here that the NV spin evolves under the presence of its natural nuclear spin environment. No artificial engineering of the environment was therefore used.

Changes made: In the abstract we have clarified this by saying clearly that our NV system interacts with its nuclear spin environment, which is naturally given by the appearance of 13C atoms in the diamond lattice.

**Comment 2:**

Reviewer’s comment: “*First paragraph: The term “Quantum Darwinism” is perhaps a popular topic in advanced level quantum mechanics or philosophy classes, however many readers may not be completely familiar with the concept. The impact of the paper could be increased if a very short description of the concept is included, especially to define what is meant by a “pointer state” in this context. A reference could be inserted after the first mention of “pointer state” in the text.* “

Authors answer: We agree, as this will be helpful to a wider audience.

Changes made: We implemented both suggestions in the first paragraph.

**Comment 3:**

Reviewer’s comment: “*Fig 1: This is a very nice diagram but does not convey the fact that the four spins shown interacting with the central spin will have very different interaction strengths depending on their distance and crystallographic orientation relative to the central spin. This fact is important to the experimental method and could be mentioned in the caption.*“

Authors answer: The reviewer is correct, the schematic does not give information about the interaction strength.

Changes made: In the caption we now mention that the coupling between the central spin and the nuclear spin is mediated by the hyperfine interaction, which is different for each nuclear spin due to a different relative location.

**Comment 4:**

Reviewer’s comment: “*Page 2 paragraph 1: The use of the term “weird” in the context of quantum superposition is not clear. I question if this word is appropriate. To a practitioner in the field there is nothing “weird” happening. I recommend using a different expression to make the meaning clear. Perhaps the authors mean “fundamentally non-classical quantum superposition of states”?*“

Authors answer: We thank the reviewer for this comment.

Changes made: In the revised manuscript, we changed the wording from “weird” quantum superposition to “non-classical quantum superposition”.

**Comment 5:**

Reviewer’s comment: “*Page 2 paragraph 3: This paragraph is dense with jargon that may obscure the essential physics to the non-specialist reader. I believe the paper could have more impact if a few additional words of explanation, or a suitable reference, are provided to expand on the use of the terms “Holevo quantity”, the concept of “quantum discord” and “classical objectivity”.* “

Authors answer: We agree with the reviewer.

Changes made: We have made several changes. We added a reference to the Holevo quantity (in addition to the other reference already present which explains its role in quantum Darwinism). We substantially rearranged the discussion, emphasizing what the orthogonality of the conditional states means, giving in generic terms what “Holevo” represents (an upper bound of classical information communicated by a quantum channel), and separate the paragraph in two.

**Comment 6:**

Reviewer’s comment: “*Page 2 second column: Here the authors discuss the physical mechanisms for coupling of the central spin with the spin bath provided by what turns out to be the 13-C nuclear spins in the environment. It is my understanding that prior to measurement, the coherence of the central spin becomes shared by the surrounding nuclear spins while maintaining an overall coherent state except that the system now consists of the central spin plus the spin bath. This is therefore not decoherence as such until measurements are performed on the spins in the system, however the shared state represents a high entropy configuration of the coherent state, the transition to which is irreversible. I therefore do not understand how the single nuclear spins in the bath can be considered as copies of the original central spin. Readers such as myself would be grateful for a few additional words of explanation here.* “

Authors answer: We thank the reviewer for pointing out this potential source of confusion. After the system interacts with the environment spins, if you look at the system’s state (i.e., it’s density matrix), it will be decohered. However, the reviewer is correct that the full state of the system plus environment is still coherent. Regarding the nuclear spins being copies of the original system spin, they are not. Rather, they are copies of the pointer states of the system.

Changes made: We have now emphasized that after the *generation* of the entangled state, the system’s state alone is decohered and each environment spin carries a record of the pointer state (in the case of a GHZ state).

**Comment 7:**

Reviewer’s comment: “*Fig 2c: The “light blue/red shaded regions” mentioned in the caption were not visible in the manuscript presented for review.*“

Authors answer: We thank the reviewer for this comment.

Changes made: To improve the visibility of the shaded regions, we changed the transparency.

**Comment 8:**

Reviewer’s comment: “*Page 3 second paragraph: A few additional words explaining what is lost by omission of the higher harmonics would be useful along with reassurance that no artifacts are introduced into the data as a result.* “

Authors answer: In general and especially in our case, contributions from higher harmonics are neglectable because they are far detuned. For example in our case they are separated by about 1 MHz and the width of the dynamical decoupling filter window is on the order of a few kHz. Therefore, the resonances of higher harmonics can be well differentiated and artefacts can be neglected.

Apart from this, other groups (mentioned/referenced in the main text) use higher harmonics so far to reduce the effective coupling between NV and individual nuclear spins. Instead of using a time duration of tau=1/(2T) between pi-pulses, where T is the Larmor period of the nuclear spin, one increases then the time tau to tau’ = (2k+1)/(2T). k is here the order of the harmonic. In our case this is not necessary because by adjusting the timings incorporated into the composite pi-pulses, the effective coupling can already be reduced. This is in general more robust, because the effect of decoherence as well as contributions from pulse errors increase when a larger interpulse spacing is used. The successful implementation of the AXY sequence is confirmed by experiments performed with various filter coefficients, which are presented in section one of the SI.

Changes made: We mention now that contributions from higher harmonics can be neglected because they are far detuned and say that further experiments with different filter coefficients (which are presented in the SI) confirm the successful implementation of the adaptive XY8 sequence.

**Comment 9:**

Reviewer’s comment: “*Page 3 second paragraph: It is not immediately clear which of the 13-C nuclear spins resonant peaks from Fig 2c are selected for the experiments (if I understand the text correctly), perhaps the relevant peaks could be starred to make it clear. The selection criteria for the selected peaks needs to be clarified. Is it just signal to noise ratio? Is this in proportion to the proximity of the 13-C nuclear spin to the central N-V- spin?*“

Authors answer: We selected the four strongest coupled nuclear spins to study the correlations between the central electron spin and the nuclear spin environment.

Changes made: In the revised text we now mention that we focused on the four strongest coupled nuclear spins, because the main effect of the nuclear spin bath on the central spin is mainly attributed to them. In addition, the selected nuclear spins are marked by stars and corresponding numbers in the spectrum presented in Figure 2c.

**Comment 10:**

Reviewer’s comment: “*Page 3 last paragraph: The expression “natural interaction” is used but it is not clear what is meant by this and it should be defined.*“

Authors answer: We thank the reviewer for this comment.

Changes made: We now explicitly mention that it is the dipolar hyperfine interaction, which is defined by the register geometry.

**Comment 11:**

Reviewer’s comment: “*Page 4 paragraph 3: The second sentence of his paragraph is not clear*

*and should be reworded. Do the authors mean “The dark green data shows the results when an error due to imperfect polarization and tomography are corrected”? Then “When errors happen …”?* “

Authors answer: Yes, what the reviewer indicates is what we mean.

Changes made: We reformulated the sentence and the sentence following.

**Comment 12:**

Reviewer’s comment: “*Page paragraph 4: The expression “uptick” is imprecise in this context and should be clarified.*“

Authors answer: We agree that this is worded in a way that is not clear unless other quantum Darwinism papers are consulted.

Changes made: We now define what is meant: “The ``uptick'' is a sharp upward turn of the mutual information on the plateau when the fragment size near the total environment size.”

**Comment 13:**

Reviewer’s comment: “*Page 4 paragraph 5: See earlier comment about the use of the word “weird”.*“

Authors answer: We thank the reviewer for this comment.

Changes made: We reformulated the sentence and do not use “weird” anymore.

**Comment 14:**

Reviewer’s comment: “*Page 4 paragraph 5: The use of the word “dustbin” is not appropriate, and this statement should be clarified. Perhaps the authors mean “a high entropy state”?* “

Authors answer: We agree with the reviewer.

Changes made: We reformulated the paragraph and removed the word “dustbin”.

**Comment 15:**

Reviewer’s comment: “*Page 4 end of page: I believe the final sentence in this paragraph makes an assertion which is too strong. Or do the authors mean that gravity-induced wavefunction collapse is not necessary to explain the phenomena observed here? I am not an expert on the gravitational theories that involve single spin quantum systems, but for a central spin fixed in proximity to a discrete spin-bath of nuclear spins then surely the magnetic interaction is sufficient to explain the observed decoherence as expected? Why should we expect gravity may play a role?* “

Authors answer: We agree with the reviewer that the way this was worded can be a source of confusion. We did indeed mean that gravitational collapse is not necessary.

Changes made: We now use this wording, “This straightforward and purely quantum account of the origins of the classical in our quantum Universe suggests other approaches to the quantum-to-classical transition (gravitational collapse, etc.) are not necessary to describe the emergence of our objective, classical world.”

**Comment 16:**

Reviewer’s comment: “*Supplementary material: I note the important sample information that appears in section I. The expression “a native (un-implanted) NV center” needs to be clarified because this is implicit context to previous work by some of the co-authors that rely on ion implanted N to form their N-V-centers. As pointed out above, the concept of “natural” or “native” is not clear in this context. Perhaps the authors mean “adventitious” or “introduced from residual N2 in the CVD plasma from the vacuum system”. I also believe this important detail warrants inclusion in the introduction to the sample on page 1 of the paper itself rather than being relegated to the SI.*“

Authors answer: The reviewer is right, we thank them for this comment.

Changes made: In the SI, as well as in the revised paper, this additional information about the sample preparation in now included.