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Agency Name: National Science Foundation

Agency Tracking Number: **2154250**

Organization:

NSF Program: Combinatorics

PI/PD: Williams, Nathan

Application Title: Independence Posets and Dynamical Algebraic Combinatorics

Review 1

Rating:

Excellent

Review:

Summary

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to intellectual merit.

This proposal addresses problems in dynamical algebraic combinatorics which is a new subfield of combinatorics that the PI spearheaded. The project outlined in the proposal builds on the PI's work of independence posets, independence polytopes, and semidistrim lattices to unify and generalize these settings in several directions, including piecewise-linear and birational directions, as well as a lattice-theoretic directions.

The proposal is well written and contains many helpful examples and illustrations. One point that could be improved is to point out which problems would be suitable for students to work on.

Overall the intellectual of the proposal is very strong. The problems are all interesting and the PI seems well-qualified to approach all of them.

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to broader impacts.

The PI plans yearly online workshops for early graduate and undergraduate students.
An innovative idea is to write a browser-based interactive discrete math textbook using the software he developed/used for his FPSAC poster in 2020. In addition, the PI plans to continue to organize conferences. His past conferences at AIM and BIRS on dynamical algebraic combinatorics had a big impact on the community.
In addition, the PI plans to compile a library of combinatorially-relevant graphs and their independent sets and to integrate them into SageMath.

Based on the PI's track record, the broader impact promises to be very strong. Especially the browser-based interactive textbook fills a much needed demand!

Overall the broader impact of this proposal is excellent!

Please evaluate the strengths and
weaknesses of the proposal with respect to any additional solicitation-specific review criteria, if applicable

Summary Statement

This proposal is excellent both on its intellectual merits and on its broader impacts.
This proposal ranks roughly in the top third of all proposals assessed by this reviewer.

Review 2

Rating:

Very Good

Review:

Summary

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to intellectual merit.

This proposal concerns a variety of problems involving posets and polytopes, from the perspective of dynamical algebraic combinatorics. Most of the proposed problems center on recently defined objects (independence posets, semidistrim lattices, ...), with the hope that studying their properties will unify and generalize results about other families, and in some cases lead to progress on significant open problems (e.g., uniform sampling of independent sets of a graph). Broadly the PI seems well qualified for the proposed problems; however, some of them are sufficiently open-ended that it's either not clear what would constitute success, or not entirely clear why success is likely. That said, the intellectual merit of this proposal is very strong.

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to broader impacts.

The proposal includes a wide variety of mentorship and outreach activities, as well as more routine professional duties. Not all of these ideas are equally compelling, but collectively they represent a strong package, particularly for an early career PI.

Please evaluate the strengths and
weaknesses of the proposal with respect to any additional solicitation-specific review criteria, if applicable

Summary Statement

Overall this is a very strong proposal in both intellectual merit and broader impacts -- I would rate it in the top half of proposals I reviewed.

Review 3

Rating:

Good

Review:

Summary

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to intellectual merit.

Broadly speaking, the main problems proposed by the PI fall into the new field, Dynamical Algebraic combinatorics.
The PI is a leader in developing new techniques for dynamical algebraic combinatorics, and, in general, for popularizing the field.
In particular, the PI will provide two different generalizations of the notion of an independence poset (a potentially transformative concept first introduced in joint work by the PI in 2019).

With Striker, the PI built connections between rowmotion and jeu-de-taquin, and this connection has been used explored by many in the field, including---very recently---Patrias and Pechenik, who used the connection to resolve a 25 year old conjecture of Cameron and Fon-Der-Flaass.

The notion of a independence polytope---a generalization of independence posets and chain polytopes---would connect Erhart Theory and Dynamical Algebraic combinatorics (in ways that are distinct from other proposals this reviewer read).

The main issue is to define a combinatorial object (ideally a poset structure) that encodes the number lattice points inside the m-dilations of the independence polytope.
The PI has a conjectural object (see Definition 4), and some partial results and computational evidence to support their conjecture.

In the last section, the PI also proposes problems related to random sampling of independence sets of a graph.
The questions are interesting and the idea of using independence posets to possibly improve efficiency is creative.

The one general weakness is that the problems (especially in section 2 and section 4)---while worthwhile---are missing a good strategy.
The most compelling proposals state a general question upfront, and then refine it with more specific known results and specific open questions, giving a good impression that at least some elements of the general question are within reach.

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to broader impacts.

The PI is currently advise two PhD students and has supervised four summer research projects, including undergraduate research.
The PI has organized several conferences and workshops, and has been a leader in establishing a new research area, Dynamical Algebraic combinatorics.
The PI has developed a browser-based interactive poster for presentations during the pandemic, and is continuing efforts along this line to develop interactive textbooks to be used at his institution.

Please evaluate the strengths and
weaknesses of the proposal with respect to any additional solicitation-specific review criteria, if applicable

Summary Statement

The review is good, and ranks in roughly in the top half of proposals.
The PI is a pioneer in their field, and has been a leader in popularizing dynamical algebraic combinatorics.
The problems presented here represent a innovative direction.
The one weakness here is that most of problems presented are very general. It would be better to describe both a general open problem, then smaller problems that chip away at the bigger question.

Relative to other proposals, the broader impacts described here fall in the bottom half the proposals reviewed by this reviewer.