Women in Geometry 3

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1 Overview of the workshop

Women in Geometry 3 was a collaborative research workshop organized at Banff International Research Station (BIRS) that followed the model of the previous Women in Geometry 1 and 2 workshops. Specifically, the workshop hosted seven different collaborative research teams of five to seven women in the following areas: Geometric Flows, Riemannian Geometry, Mathematical General Relativity, Homogeneous Geometry, Symplectic Geometry, Spin Geometry and Special Geometric Structures, and Variational Problems in Geometry.

The WIG 3 workshop was timely and important because the overall representation of women in mathematics in general, and in geometry in particular, remains low. As of 2017-18, roughly 29% of all mathematics PhDs in the United States were awarded to women, while in the same year, women represented only 18% of the PhDs awarded in the United States in geometry/topology. Furthermore, at each successive academic career stage, the percentage of mathematicians who identify as female decreases. For example, as of 2017, the percentage of tenured math faculty members at PhD-granting institutions in the Unites States identifying as female was only 12%. (Statistics from the Mathematical and Statistical Sciences Annual Survey.) The WIG 3 workshop was designed to support, through research activity and mentorship, the retention and promotion of women at all stages of their mathematical careers.

The program structure was designed to maximize productive research exchanges during the five days of the workshop so that the discussions would lead to concrete outcomes such as published articles and future funding for ongoing research activity. The areas of geometry featured in the WIG 3 program were intentionally chosen because they are interrelated, thus ensuring strong potential for cross-collaboration. Furthermore, the program aimed to both strengthen the existing network of women mathematicians that had been established by the WIG 1 and WIG 2 workshops, and to extend the reach of these workshops to include more areas of geometry and more female geometers. The workshop had 42 participants, with 37 attending in person and 5 joining remotely. These women mathematicians came from different institutions, career stages, countries and continents, creating a vibrant and collaborative environment. A few months before the program, team leaders provided participants with a comprehensive overview of the research problems and essential background reading materials. Due to this advance preparation, it was possible to dedicate the majority of the workshop time to collaborative research. Seven plenary talks were scheduled over the first four mornings in the program, featuring one speaker from each group. These talks aimed to build a sense of community, and to foster discussion and collaboration within and between groups. Afternoons, with the exception of just one, were allocated to research collaboration. On the final day of the program, each team presented a

10-minute report to the full workshop, summarizing progress made and outlining future goals. This provided a comprehensive overview of the collective achievements and set the stage for continued collaboration. The program concluded with the remaining two hours devoted to research collaboration.

In addition to the scientific program, two insightful discussion sessions were conducted using different formats, enriching the overall workshop experience. The first event was a panel discussion titled "Collaboration in Mathematics," which took place on Tuesday evening. Both the moderators and the audience posed questions to a panel of 5 mathematicians, delving into the dynamics of collaboration, exploring effective collaboration models and offering guidance to junior researchers on initiating and maintaining healthy collaborations while avoiding common difficulties. The panel further addressed strategies to counteract power and gender dynamics within collaborative endeavors. The second discussion session on Thursday evening focused on community building. It began with breakout group discussions in which groups of 5 to 7 participants discussed specific topics in a more relaxed setting and shared experiences on topics such as how to build community, combat bias when starting new jobs, and mentor women in the early stages of their careers. The participants then all joined together to share highlights of earlier discussions, get further feedback from the larger group, and converse further.

2 Presentation Highlights

There were seven hour-long plenary talks scheduled on the first four mornings of the workshop: A senior member from each team gave a colloquium-style lecture related to their team's research area and the problem they were working on together. The talks were designed to be accessible to all WIG 3 participants. An important goal of the WIG workshops is for participants to not only come together to work with their own team, but also to learn more about the other participants' research areas and the important problems therein. WIG 3 aimed to establish strong working relationships within and between teams. These lectures reached beyond this to lay the groundwork for possible cross-team collaboration.

The plenary talks were as follows:

- Laura Starkston from UC Davis, representing the Symplectic Geometry group, spoke on *Symplectic and contact geometry: geometric properties, dynamics and invariants.*
- Meera Mainkar from Central Michigan University, representing the Homogeneous Geometry group, spoke on *Geometry of solvmanifolds.*
- Ruth Gregory from King's College London, representing the Mathematical General Relativity group, spoke on *Cosmic strings and spacetime singularities.*
- Ines Kath from Universität Greifswald (Germany), representing the Spin Geometry and Special Geometric Structures group, spoke on *Holonomy groups contained in the non-compact* G_2.
- Megan Kerr from Wellesley College, representing the Riemannian Geometry group, spoke on *Compact homogeneous Einstein manifolds.*
- Melanie Rupflin from Oxford University, representing the Variational Problems in Geometry group, spoke on *Quantitative estimates for geometric variational problems.*
- Julie Clutterbuck from Monash University, representing the Geometric Flows group, spoke on *The shape of solutions of elliptic problems in curved spaces.*

3 Scientific Progress Made: Reports from Research Groups

3.1 Report from Team 1 (Geometric Flows)

Group Members: Min Chen (McGill University), Julie Clutterbuck (Monash University), Yi Lai (Stanford University), Alina Stancu (Concordia University), and Valentina Wheeler (University of Wollongong), Mariel Sáez (P. Universidad Católica de Chile)

Research Synopsis and Progress: The most well-known curvature flow of hypersurfaces in Euclidean space is the flow by mean curvature (MCF). Without getting into technical details, mean curvature flow's equation is $X_t = -H\nu$ and describes an evolving hypersurface moving inward with a normal speed equal to its mean curvature. This flow has numerous features that have led to many applications.

Among the properties of the mean curvature flow, note that the flow admits a monotonicity formula proved by Huisken, first for compact hypersurfaces, then extended to noncompact hypersurfaces with certain decay at infinity. Huisken's monotonicity formula says that for any hypersurface Σ_t evolving by MCF the $(n+1)$-dimensional backward heat kernel ρ_{x_0,t_0}, centered at some point $x_0, t_0)$, decreases in time along Σ_t and stays constant on, and only on, the hypersurfaces that evolve self-similarly:

$$\int_{\Sigma_t} \rho_{x_0,t_0}(X,t) d\mu_t = -\int_{\Sigma_t} \left(H - \frac{X^\perp}{2t} \right)^2 \rho_{x_0,t_0}(X,t) d\mu_t.$$

Therefore, the monotonicity formula can be used to classify self-similar solutions of the mean curvature flow. In fact, more generally, as x_0 and t_0 are chosen as the time and position of a singularity of the evolving surface, the monotonicity formula is used to analyze the behavior of the surface as it evolves towards this singularity. Our project proposes to investigate the existence of monotonicity formulas for fourth order curvature flows, MCF being a second order parabolic partial differential equation for X or, roughly speaking, a heat equation. To start, we considered Willmore's flow which, without technical details, is $X_t = -\Delta_{\Sigma_t} H\nu$ and made preliminary calculations for non-compact hypersurfaces for which self-similar solutions exist (in the compact case there exist only stable solutions) with a bi-harmonic heat kernel as density. Further analysis is needed to conclude if the behavior of this convolution is monotone, possibly under a modified density. We intend to pursue this question during the coming months.

3.2 Report from Team 2 (Riemannian Geometry)

Group Members: Isabel Beach (University of Toronto), Erin Griffin (Northwestern University), Haydee Contreras Peruyero (UNAM Morelia), Megan Kerr (Wellesley College), Regina Rotman (University of Toronto), and Catherine Searle (Wichita State University)

Research Synopsis and Progress: The question of when a manifold M admits an Einstein metric, that is, a metric of constant Ricci curvature, is wide open. In dimensions greater than 4, there are no known obstructions, yet finding examples of Einstein metrics has historically been a piecemeal process. In the presence of symmetries, however, the search for examples has been more fruitful. Our group is working in the setting of compact homogeneous spaces, $M = G/H$, where $H \subset G$, and G and H are compact, connected Lie Groups. A key fact is that Einstein metrics are critical points of the Hilbert action. Graev used this fact to prove that for such compact homogeneous spaces G/H, if the nerve $X_{G/H}$ is non-contractible, then G/H admits a G-invariant Einstein metric.

This result, an extension of an earlier result of Böhm, often provides quick data indicating that a space must admit an invariant Einstein metric. However, there are many compact homogeneous spaces that have a contractible nerve $X_{G/H}$, and yet admit a G-invariant Einstein metric. Our project is to address this gap. We consider the set of compact homogeneous spaces G/H for which the isotropy representation has 3 or more irreducible summands, contractible simplicial complex, and rank(G) = rank(H), and denote this class of manifolds by $\mathcal{N}_{0,\geq 3}$. We note that in the two-summand case, there is an algebraic marker, a discriminant, that tells us precisely when there are Einstein metrics. We expect that a better understanding of those spaces in $\mathcal{N}_{0,\geq 3}$ which admit an Einstein metric will help us to identify an underlying algebraic marker for the existence of invariant Einstein metrics in this case.

At BIRS, we began work on the following problem.

Problem. Which of the manifolds in $\mathcal{N}_{0,\geq 3}$ admit a G-invariant homogeneous Einstein metric?

While at BIRS, we worked to identify the full list of homogeneous spaces in $\mathcal{N}_{0,\geq 3}$, for which there are no more than 4 isotropy summands, and we calculated the critical points of the scalar curvature functional for many examples in $\mathcal{N}_{0,\geq 3}$. We have continued to have regular online meetings since BIRS to move our project forward. In the short term, we all met at the JMM in San Francisco in January 2023 to collaborate in person. We have also applied to several research centers in order to meet in person in the near future. We recently heard that our application to the IAS, Princeton Summer Collaborators program for summer 2024 was accepted.

3.3 Report from Team 3 (Mathematical General Relativity)

Group Members: Ghazal Geshnizjani ((Perimeter Institute and University of Waterloo), Melanie Graf (University of Hamburg), Ruth Gregory (King's College London), Sharmila Gunasekaran (Fields Institute), Christina Sormani (Lehman College, CUNYGC), and Ivonne Zavala (Swansea University)

Research Synopsis and Progress: Our team has been investigating the geometric properties of cosmic strings, gravitational anomalies resulting from symmetry-breaking processes in the early universe, such as phase transitions as the universe cools down. In the context of the simplest model of space-time, flat Minkowski space, which is a fusion of Euclidean space with time, endowed with a Lorentzian metric tensor, we consider a metric of the form:

$$-dt^2 + dx^2 + dy^2 + dz^2 = -dt^2 + dz^2 + dr^2 + r^2 d\theta^2.$$

The standard static straight cosmic string exhibits local flat Minkowski space characteristics. However, it possesses a conical singularity along the z-t space-time plane, referred to as its world sheet, with a metric tensor given by:

$$-dt^2 + dz^2 + dr^2 + \alpha^2 r^2 d\theta^2.$$

where α is less than 1.

The understanding of other types of cosmic strings remains limited. Although they may adhere to the Nambu-Goto action, resolving the complete Einstein gravity around them is not straightforward due to the nonlinearities of the Einstein equations. Unlike in linearized Einstein gravity, defining curvature with a delta function value along the string is challenging. To grasp the geometry of these strings, understanding their conical singular geometry is crucial.

Our team is pursuing two approaches. First, we have developed a coordinate system for the cosmic string's neighborhood, showing the standard static cosmic string as the sole solution to full Einstein equations on Minkowski spacetime with z-axis removal. Next, we plan to explore more freedom by removing certain symmetries. Some cases we are considering are situations where we assume the metric tensor is the metric tensor of Minkowski space plus an extra $(1-\alpha^2)d\theta^2$ term where α is allowed to be a function depending on z.

Secondly, we have started to study initial data sets for cosmic strings using Einstein Constraint Equations. In the time symmetric setting, these are Riemannian manifolds with nonnegative scalar curvature or even the vacuum cases where the scalar curvature is 0. We can investigate various possible settings like R^3 with a line removed or a circular ring. Again imposing symmetries along a line that has been removed, in the vacuum case, the only possibility satisfying certain limits is a cone crossed with a line. We are investigating the ring case using toroidal coordinates and imposing rotational symmetry along the ring. We will try similar ideas to those mentioned above for the spacetime setting in this simpler spacelike case. Once initial data sets are understood it may be possible to solve the equations forward in time using numerical General Relativity or at least study the existence and properties without explicitly finding a solution.

3.4 Report from Team 4 (Homogeneous Geometry)

Group Members: Romina M. Arroyo (University of Cordoba, Argentina), Karen Butt (University of Chicago), Karla García (National Autonomous University of Mexico), Ruth Gornet (University of Texas–Arlington), Meera Mainkar (Central Michigan University), Tracy Payne (Idaho State University)

Research Synopsis and Progress: Homogeneous spaces with nonpositive sectional curvature are locally modelled on solvmanifolds. A solvmanifold is a simply connected solvable Lie group endowed with a left-invariant Riemannian metric. The general study of the geometry of solvmanifolds is quite difficult: the algebraic expressions for the curvature operator are complicated and messy, and solvable Lie groups do not have the nice structure that semisimple ones do. Research in this area tends to focus on studying nice families of solvmanifolds with special algebraic or geometric properties, or asking general qualitative questions.

Our group studies the sectional curvature and the eigenvalues of the curvature operator for nice families of negatively curved homogeneous spaces. We started meeting online before the workshop. During this time, we completed a literature review and typed up a set of preliminary calculations. On the first day of the workshop, we made a list of seven interrelated research questions about nonpositively curved solvmanifolds, and we decided to go through the list question by question, and feel out the difficulty of each problem, test out possible approaches to the problems, and discuss how the different strengths of group members were aligned with requirements of each problem. In some cases, discussion opened up new questions that we had to clarify by re-examining references and discussing.

As we discussed the potential problems, in parallel, we identified several classes of solvmanifolds of interest, which we formally defined, and we did preliminary geometric computations for these. Discussion during preliminary computations led us to decide on the right questions for us to work on. We removed four of the questions from consideration, keeping three interrelated questions to focus on.

We were able to completely answer our questions in the simplest class. In another class, which has more complicated geometry, we almost completed a full analysis of all of our questions. In doing these calculations, we discovered some general principles that we aim to frame as theorems as we progress.

On the last day, we reviewed our accomplishments from the week. We made plans for future collaboration and we decided on expectations for working together as a group going forward. After the workshop, we applied to AIM for an AIM Squares grant to meet in person at AIM to continue work on our project. We recently heard that our proposal was accepted.

3.5 Report from Team 5 (Symplectic Geometry)

Group Members: Members: Aleksandra Marinkovíc (Belgrade University), Jo Nelson (Rice University), Ana Rechtman (University of Grenoble), Laura Starkston (University of California–Davis), Shira Tanny (Institute for Advanced Study, Princeton), Luya Wang (Stanford University)

Research Synopsis and Progress:

Symplectic and contact structures arose in the study of classical mechanical systems, leading to the development of global Floer theoretic invariants, which encode structural aspects of Hamiltonian and Reeb flows. Symplectic geometry also has key ties to subtle phenomena of smooth 4-manifolds. This has motivated the study of symplectic 4-manifolds and their contact 3-dimensional boundaries. A symplectic manifold is a smooth manifold which admits a closed nondegenerate differential 2-form, which measures signed area, forces the symplectic manifold to be even-dimensional, and whose n-fold wedge product is a volume form. A contact structure is a maximally nonintegrable hyperplane field, meaning it can be described as the kernel of a differential 1-form λ, which forces any contact manifold to be odd-dimensional and admit a volume form given by $\lambda \wedge (d\lambda)^n$. There is a close connection between symplectic and complex manifolds, as well as subtle interplay between the dynamics on the contact boundary of a symplectic manifold and the underlying topology of the latter. We studied the contact dynamics of 3-manifolds that are motivated by complex algebraic geometry and singularity theory. Complex curves and singular symplectic surfaces in symplectic 4-manifolds have standard symplectic neighborhoods, which under certain conditions have a convex or concave structure, inducing a contact form on the boundary 3-manifold. In some cases, these contact 3-manifolds are also links of surface singularities. We studied the dynamical properties of these contact manifolds and investigate connections to symplectic fillings and cappings. We worked on understanding the Floer theoretic invariant known as the order of algebraic torsion as defined using embedded contact homology, to obstruct the symplectic fillability of boundaries of certain concave plumbings of disk bundles over surfaces. Embedded contact homology is a three dimensional gauge theory which is equivalent to monopole Seiberg-Witten Floer cohomology, but defined in terms of contact dynamics and holomorphic curves. Prior to our time at the Banff International Research Station, we had regular weekly online meetings, and had made significant progress on understanding the background on embedded contact homology and constructions of the Reeb vector field of boundaries of concave plumbings. During our time intensively working in person at BIRS, we were able to construct and sort out the details of a heuristic argument to compute the order of algebraic torsion in a model example. Through this model example, we developed key lemmas and arguments that we expect to need in more general examples. We are continuing to meet regularly and are writing up the details of the proof, which we are also working to generalize to all linear plumbings. In the linear plumbing case, we expect to recover results which could also be proven less directly using results of Lisca and McDuff, and possibly generate some unknown results. More generally, we will work with treelike plumbings, with the hope of establishing new classes of tight nonfillable contact manifolds, possibly with interesting values of algebraic torsion. We are currently investigating the additional tools we will need to handle these non-linear plumbing examples. We are making plans to meet again in person this summer, for example, applying for the IAS Summer Collaborators program as well as utilizing our personal grants.

3.6 Report from Team 6 (Spin Geometry and Special Geometric Structures)

Group Members: Ilka Agricola (University of Marburg, Germany), Viviana Del Barco (State University of Campinas, Brazil), Jordan Hofmann (King's College, UK), Ines Kath (University of Greifswald, Germany), Marie-Amelie Lawn (Imperial College London, UK), Ana Cristina Ferreira (University of Minho)

Research Synopsis and Progress: The project of our team is part of the study of special geometries on pseudo-Riemannian manifolds. A special geometry exists if the holonomy group is a proper subgroup of the special orthogonal group. We studied pseudo-Riemannian manifolds of signature $(4,3)$ whose holonomy group is contained in the non-compact Lie group of type G_2, which we denote by G_2^*. The Lie algebras of the possible holonomy groups were classified by Fino and Kath [FK18, FK19]. All corresponding simply-connected Lie groups can indeed be realised as the holonomy group of a metric [Vol19a, Vol19b], but only some of them by a left-invariant metric. Since up to now there exist only sporadic examples of such left-invariant metrics, our aim is to start a systematic search for left-invariant, or more generally, homogeneous metrics with holonomy contained in G_2^*. Two different approaches were tried in parallel:

Strategy I In order to get some intuition for which Lie groups can occur, we wrote an appropriate Maple program which checks holonomy groups of left-invariant metrics that have a 3-dimensional socle (Type III holonomies). In this way we already found new examples of such metrics. Moreover, it led us to a conjecture how we can characterise the holonomy groups of Type III that can be realised by a left-invariant metric by the holonomy representation on the socle. We will continue this project and try to prove our conjecture.

Strategy II Our second approach was to inspect all existing constructions for Riemannian holonomy groups inside G_2 and to investigate which methods could be transferred to our particular pseudo-Riemannian case. It turned out that in the end, only cone constructions over 6-dimensional nearly pseudo-Kähler manifolds can be considered suitable, and hence promising [CLSSH11, Sch17]. Of these, very little is understood; since we must exclude pseudo-Riemannian analogues of a Riemannian 'sibling' as they do not yield manifolds with holonomy representation of the type we are looking for, we are left with only one known candidate. This manifold is a solvable Lie group with a left invariant nearly pseudo-Kähler structure constructed by Alekseevsky, Kruglikov, and Winther in [AKW14]. Although very interesting, this particular example has sectional curvature -1 and therefore it follows that the cone over it has vanishing holonomy. It was decided that it would be an interesting, but separate, project to try to construct further examples of nearly pseudo-Kähler manifolds.

References

[AKW14] D. V. Alekseevsky, B. S. Kruglikov, and H. Winther. Homogeneous almost complex structures in dimension 6 with semi-simple isotropy. *Ann. Global Anal. Geom.*, 46(4):361–387, 2014.

[CLSSH11] V. Cortés, T. Leistner, L. Schäfer, and F. Schulte-Hengesbach. Half-flat structures and special holonomy. *Proc. Lond. Math. Soc. (3)*, 102(1):113–158, 2011.

[FK18] Anna Fino and Ines Kath. Local type I metrics with holonomy in G_2^*. *SIGMA, Symmetry Integrability Geom. Methods Appl.*, 14:paper 081, 28, 2018.

[FK19] Anna Fino and Ines Kath. Holonomy groups of G_2^*-manifolds. *Trans. Am. Math. Soc.*, 371(11):7725–7755, 2019.

[Sch17] Lars Schäfer. *Nearly pseudo-Kähler manifolds and related special holonomies*, volume 2201 of *Lect. Notes Math.* Cham: Springer, 2017.

[Vol19a] Christian Volkhausen. Local Type II metrics with holonomy in G_2^*. *Abh. Math. Semin. Univ. Hamb.*, 89(2):179–201, 2019.

[Vol19b] Christian Volkhausen. Local type III metrics with holonomy in G_2^*. *Ann. Global Anal. Geom.*, 56(1):113–136, 2019.

3.7 Report from Team 7 (Variational Problems in Geometry)

Group Members: Theodora Bourni (University of Tennessee-Knoxville), Elena Mäder-Baumdicker (Darmstadt University), Robin Neumayer (Carnegie Melon University), Jiewon Park (Korea Advanced Institute of Science and Technology), Raquel Perales (National Autonomous University of Mexico (UNAM) at Oaxaca), Melanie Rupflin (Oxford University)

Research Synopsis and Progress:

We worked on the following problem: Asymptotic behaviour of free boundary area preserving curve shortening flow.

Curve shortening flow is the one dimensional analogue of mean curvature flow, which is the gradient flow of the area. Area preserving curve shortening was introduced by Gage, who described it as the L^2-gradient flow of the length under an enclosed area constraint. With the term 'free boundary' we mean that the evolving curves have a boundary and we require that the evolving curves intersect a given support curve orthogonally at their boundary. In our setting, we consider a bounded convex domain $\Omega \subset \mathbb{R}^2$ and study area preserving curve shortening flow in the exterior domain $\mathbb{R}^2 \setminus \Omega$ with free boundary on $\partial\Omega$. This problem has been extensively studied by one of the members in our group, Elena Mäder-Baumdicker, who among other things, proved long time existence under natural geometric hypotheses. In particular, starting with an embedded convex curve that satisfies a certain natural length bound, the flow exists for all time and it subconverges to an arc of a circle.

Given a gradient flow whose solution exists for all times, a natural question that arises is whether one can expect that it converges to a unique limit, as $t \to \infty$. In general, solutions might exhibit winding behavior where the flow approaches a continuous set of critical points, and do so in a way that the total distance travelled is infinite, which could lead to different limits via different subsequences $t_j \to \infty$. In our project we investigate this and related questions concerning the structure of the set of critical points for the free boundary area preserving curve shortening flow.

During the time at BIRS we have already made progress on a model problem and have now started to have regular online meetings to take the next steps on our project. We have also discussed several possible opportunities to meet in person in the near future. We plan to manage this by meeting in smaller teams via personal grants or through "Research in Pairs" at Oberwolfach or BIRS. We have also discussed applying to the SWiM and/or SRiM program at SLM/MSRI and SQuaREs program at AIM, which will give us the opportunity to meet all together.

4 Outcomes of the Meeting

Each of the research teams made important progress on their research problems during the workshop. All teams have plans to continue their collaborations. Some teams are holding Zoom meetings regularly and in order to meet again are applying to research in teams programs, such as SWiM at MSRI; SQuaRE at AIM; Research in Pairs; and programs at the Max Planck Institute for Mathematics in Bonn, and the MFO, Oberwolfach Research Institute for Mathematics.

The feedback on the workshop that we have received from participants is quite positive and publications resulting directly from this workshop are expected.

Participants benefited on the individual level by building background knowledge on a new problem, by strengthening and broadening their research programs, and, in some cases, by being provided with a re-entry point after being sidetracked by any or all of family responsibilities, high service loads, or high teaching loads. By building teams that included women at all career stages, from advanced graduate students and recent PhDs to associate professors seeking to invigorate their research programs to senior researchers, the workshop formed mentoring and collaborative networks that will strengthen the careers of all participants.

All attending gained an overview of seven exciting areas of current research in geometry, and all contributed to progress in their own area.

The community of women geometers was strengthened by the supportive research community, mentorship of women just beginning or at the middle of their research careers, and the new collaborative links forged between women geometers working within and between their respective areas of specialization at WIG3. It is important to note that the areas of geometry featured in the WIG3 program are strongly interrelated, so the potential for cross-area collaboration is high. The visibility of the community of women geometers was increased by highlighting the work of established female leaders in geometry, by bringing attention to the work of outstanding new women geometers, and, very simply, by having this many women together to do geometry research.

Finally, it bears mentioning that ten research articles resulted so far from the first two Women in Geometry workshops, the first held at the Banff International Research Station in Banff and the second at the Casa Matématica Oaxaca. Based on the preliminary information we have received from the participants of this third Women in Geometry workshop, we believe that at least as many, if not more, may be expected from WIG3.

5 Acknowledgments

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