

# CARMA AND ME

PREPARED FOR  
CRM/UWS OPENING 28-05-2014  
(AND CARMA ANNUAL RETREAT)

**Jonathan M. Borwein** FRSC FAA FBAS FAAAS

Laureate Professor & Director of CARMA, University of Newcastle

URL: <http://carma.newcastle.edu.au/jon/vc-visit13.pdf>

NEWS: <http://carma.newcastle.edu.au/carmanews.shtml>

**Priority Research Centre for**  
**Computer Assisted Research Mathematics and its Applications**

Revised: May 22, 2014



## Title with apologies to:

Michael Moore: *Roger and Me* (1989)

Paul Erdős: *Ramanujan and Me* (1987)



- 4. Who we are
- 7. CARMA's Remit
- 15. About CARMA
- 21. Conclusions

## Congratulations to All



# Contents

*we will sample*

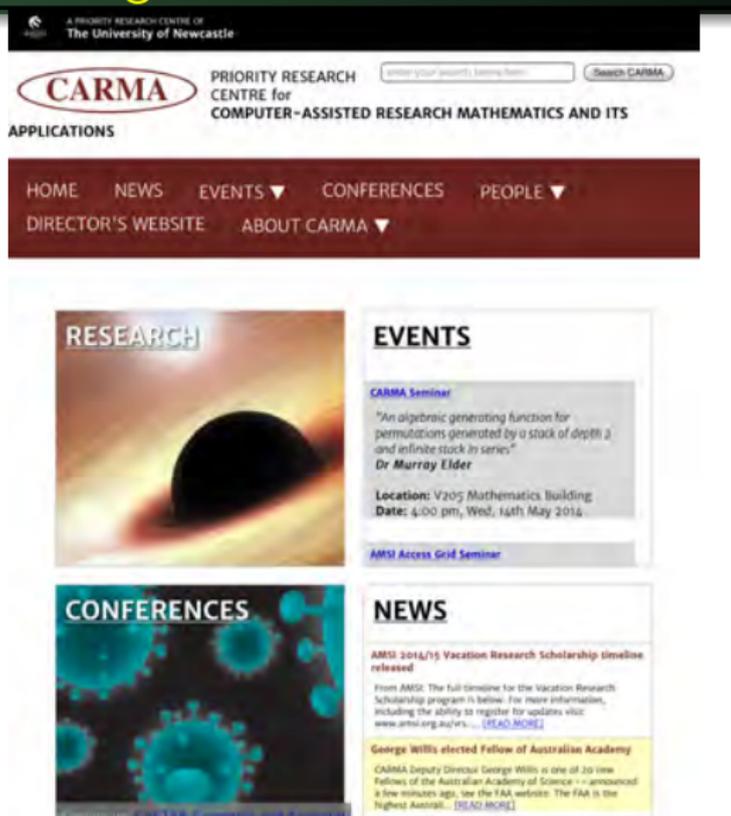
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4. Who we are  
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# CARMA Home Page



The screenshot shows the CARMA website interface. At the top, it identifies itself as a Priority Research Centre of The University of Newcastle. The main header includes the CARMA logo and the text "PRIORITY RESEARCH CENTRE for COMPUTER-ASSISTED RESEARCH MATHEMATICS AND ITS APPLICATIONS". A navigation menu lists: HOME, NEWS, EVENTS, CONFERENCES, PEOPLE, DIRECTOR'S WEBSITE, and ABOUT CARMA. Below the menu are four content boxes: RESEARCH (with a sphere image), EVENTS (with a "CARMA Seminar" announcement), CONFERENCES (with a molecular image), and NEWS (with two news items: "AMSI 2016/15 Vacation Research Scholarship timeline released" and "George Willis elected Fellow of Australian Academy").

A PRIORITY RESEARCH CENTRE OF  
The University of Newcastle

**CARMA** PRIORITY RESEARCH CENTRE for COMPUTER-ASSISTED RESEARCH MATHEMATICS AND ITS APPLICATIONS

HOME NEWS EVENTS ▼ CONFERENCES PEOPLE ▼  
DIRECTOR'S WEBSITE ABOUT CARMA ▼

**RESEARCH**

**EVENTS**

**CARMA Seminar**

"An algebraic generating function for permutations generated by a stack of depth 2 and infinite stack in series."

**Dr Murray Elder**

**Location:** V205 Mathematics Building  
**Date:** 4:00 pm, Wed, 14th May 2016

**AMSI Access Grid Seminar**

**CONFERENCES**

**NEWS**

**AMSI 2016/15 Vacation Research Scholarship timeline released**

From AMSI: The full timeline for the Vacation Research Scholarship program is below. For more information, including the ability to register for updates visit: [www.amsi.org.au/vis...](http://www.amsi.org.au/vis...) [\[READ MORE\]](#)

**George Willis elected Fellow of Australian Academy**

CARMA Deputy Director George Willis is one of 20 new Fellows of the Australian Academy of Science -- announced a few minutes ago, via the FAA website. The FAA is the highest honour. [\[READ MORE\]](#)

## CARMA's Leadership

... diversity



George Wills  
Deputy director

Judy-anne Osborn  
Advancement and  
Outreach

Mike Meylan  
Events

Braley Sims  
Memory

Michael Coons  
Exec member  
without portfolio

Lijana Brankovic  
Liaison with other  
schools and  
institutions



David Bailey

Tony Guttman

Gerard Joseph

- Government, Industry and Academia: Australia and Overseas
- All have close connections with Newcastle



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## CARMA's Support Staff

... commitment

### CARMA SUPPORT STAFF



Mrs Juliane Turner (EA)    Dr David Allingham (Scientific officer)    Andrew Danson ('AGR')

- They make our activities possible
  - with unfailing good grace, imagination and energy
  - **AGR** (Access Grid Room) is a misnomer: it is really an **ACE CARMA**

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## Computer Assisted Research Mathematics:

what it is?

*Experimental mathematics is the use of a computer to run computations—sometimes no more than trial-and-error tests—to look for patterns, to identify particular numbers and sequences, to gather evidence in support of specific mathematical assertions that may themselves arise by computational means, including search.*

*Like contemporary chemists—and before them the alchemists of old—who mix various substances together in a crucible and heat them to a high temperature to see what happens, today's experimental mathematicians put a hopefully potent mix of numbers, formulas, and algorithms into a computer in the hope that something of interest emerges. (JMB-Devlin, 2008, p. 1)*

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# Top Ten Algorithms:

all but one well used in CARMA

## Algorithms for the Ages

"Great algorithms are the poetry of computation," says Francis Sullivan of the Institute for Defense Analyses' Center for Computing Sciences in Bowie, Maryland. He and Jack Dongarra of the University of Tennessee and Oak Ridge National Laboratory have put together a sampling that might have made Robert Frost beam with pride--had the poet been a computer jock. Their list of 10 algorithms having "the greatest influence on the development and practice of science and engineering in the 20th century" appears in the January/February issue of *Computing in Science & Engineering*. If you use a computer, some of these algorithms are no doubt crunching your data as you read this. The drum roll, please:

1. **1946: The Metropolis Algorithm for Monte Carlo.** Through the use of random processes, this algorithm offers an efficient way to stumble toward answers to problems that are too complicated to solve exactly.
2. **1947: Simplex Method for Linear Programming.** An elegant solution to a common problem in planning and decision-making.
3. **1950: Krylov Subspace Iteration Method.** A technique for rapidly solving the linear equations that abound in scientific computation.
4. **1951: The Decompositional Approach to Matrix Computations.** A suite of techniques for numerical linear algebra.
5. **1957: The Fortran Optimizing Compiler.** Turns high-level code into efficient computer-readable code.
6. **1959: QR Algorithm for Computing Eigenvalues.** Another crucial matrix operation made swift and practical.
7. **1962: Quicksort Algorithms for Sorting.** For the efficient handling of large databases.
8. **1965: Fast Fourier Transform.** Perhaps the most ubiquitous algorithm in use today, it breaks down waveforms (like sound) into periodic components.
9. **1977: Integer Relation Detection.** A fast method for spotting simple equations satisfied by collections of seemingly unrelated numbers.
10. **1987: Fast Multipole Method.** A breakthrough in dealing with the complexity of n-body calculations, applied in problems ranging from celestial mechanics to protein folding.

From *Random Samples*, Science page 799, February 4, 2000.



## Experimental Mathematics:

**Secure Knowledge without Proof.** Given real numbers  $\beta, \alpha_1, \alpha_2, \dots, \alpha_n$  Ferguson's **integer relation method (PSLQ)**, finds a nontrivial linear relation of the form

$$a_0\beta + a_1\alpha_1 + a_2\alpha_2 + \dots + a_n\alpha_n = 0, \quad (1)$$

where  $a_i$  are integers—if one exists and provides an **exclusion bound** otherwise.

- If  $a_0 \neq 0$  then (1) assures  $\beta$  is in rational vector space generated by  $\{\alpha_1, \alpha_2, \dots, \alpha_n\}$ .
- $\beta = 1, \alpha_i = \alpha^i$  means  $\alpha$  is algebraic of degree  $n$
- **2000** *Computing in Science & Engineering*: PSLQ one of **top 10 algorithms** of 20th century (2001 CISE article on *Grand Challenges* (JB-PB))

## Integer Relation Methods



PROFILE: HELAMAN FERGUSON

### Carving His Own Unique Niche, In Symbols and Stone

By refusing to choose between mathematics and art, a self-described "misfit" has found the place where parallel careers meet

### CMS D. Borwein Prize



Madlung constant (2013 book)

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## Experimental Mathematics:

PSLQ is core to CARMA

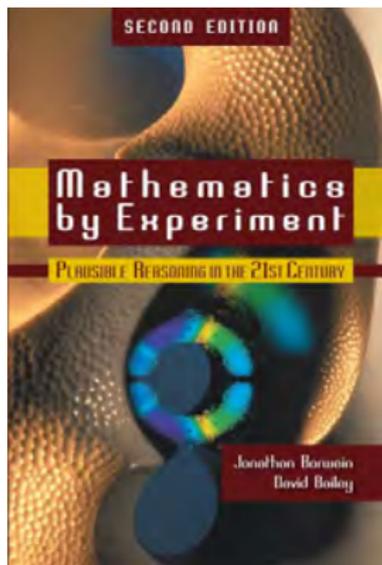
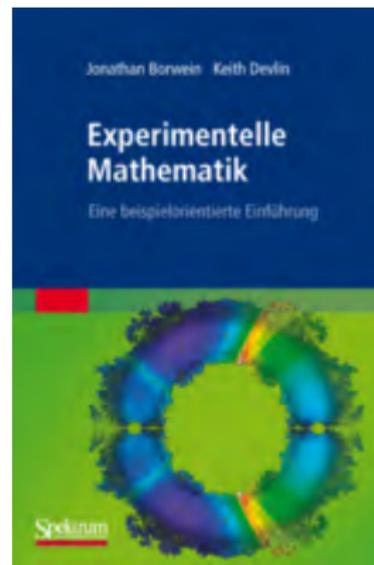
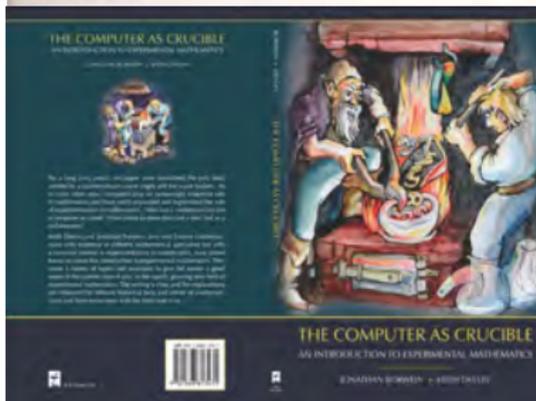


Figure 6.3. Three images quantized at quality 50 (L), 48 (C) and 75 (R). Courtesy of Mason Macklein.



Experimental Mathematics (2004-08, 2009, 2010)



# Notices of AMS 2011: ... and hundreds of online re-publications

## Exploratory Experimentation and Computation

David H. Bailey and Jonathan M. Borwein

The authors' thesis—once controversial, but now a commonplace—is that computers can be a useful, even essential, aid to mathematical research.

—Jeff Shallit

Jeff Shallit wrote this in his recent review [10] of [16]. As we hope to make clear, Shallit was entirely right in that many, if not most, research mathematicians now use the computer in a variety of ways to draw pictures, inspect numerical data, manipulate expressions symbolically, and even sometimes. However, it seems to us that there has not yet been substantial and intellectually rigorous progress in the way mathematics is presented in research papers, textbooks, and classroom instruction as to how the mathematical discovery process is organized.

### Mathematicians Are Humans

We share with George Pólya (1887–1985) the view [23, 26, 2, p. 126] that, while learned, intuition comes to us much earlier and with much less outside influence than learned rigor.

David H. Bailey is Chief Technologist of the Computational Research Department at Lawrence Berkeley National Laboratory. He email dave@lbl.gov. His work was supported by the director, Office of Computational and Technology Research, Division of Mathematical, Information, and Computational Sciences of the U.S. Department of Energy, under contract number DE-AC02-05OR21400. Jonathan M. Borwein is Associate Professor at the Centre for Computer Assisted Research Mathematics and its Applications (CARMA) at the University of Newcastle, Australia. His email address is jborwein@newcastle.edu.au.

Pólya went on to explain, nonetheless, that proof should certainly be taught in school.

We turn to observations, many of which have been found in our researched books such as *Mathematics by Experiment* [16] and *Experimental Mathematics in Action* [2], in which we have posed the changing nature of mathematical knowledge and in consequence ask questions such as “How do we teach what and why to students?”, “How do we come to believe and create pieces of mathematics?”, and “Why do we wish to prove things?” An answer to the last question is “That depends.” Sometimes we wish insight and sometimes, especially with subsidiary results, we are more than happy with a certificate. The computer has significant capacities to assist with both.

Sokal [27, p. 11] writes:

the large human brain evolved over the past 1.7 million years to allow individuals to negotiate the growing complexities posed by human social living.

As a result, humans find various means of argument more palatable than others and are more prone to make certain kinds of errors than others. Likewise, the well-known evolutionary psychologist Steven Pinker observes that language [24, p. 9] is founded on

the essential notions of space, time, causation, possession, and goals that appear to make up a language of thought.

This resonates so within mathematics. The computer offers scaffolding both to enhance mathematical reasoning, as with the recent computation connected to the Liu group  $\mathbb{Z}_6$ , see <http://www.amsrh.org/ER/compute-erleas14.html>, and to constrain mathematical error.

### Experimental Mathematics

Justine Fritter-Borwein's famous 1954 comment, “I know it when I see it,” in the quote with which

The Computer as Crutch [13] starts, A bit less informally, by experimental mathematics: we intend [10]

- (a) gaining insight and intuition;
- (b) visualizing math principles;
- (c) discovering new relationships;
- (d) testing and especially falsifying conjectures;
- (e) exploring a possible result to see if it merits formal proof;
- (f) suggesting approaches for formal proof;
- (g) comparing replacing lengthy hand derivations;
- (h) confirming analytically derived results.

Of these items, (a) through (e) play a central role, and (f) also plays a significant role for us but connotes computer-assisted or computer-derived proof and this is quite distinct from formal proof as the topic of a special issue of the *Notices* in December 2008; see, e.g., [24].

Digital integrity: I. For us, (g) has become ubiquitous and we have found (h) to be particularly effective in ensuring the integrity of published mathematics. For example, we frequently check and correct identities in mathematical manuscripts by computing particular values on the LHS and RHS to high precision and comparing insights—and then if necessary using software to repeat directly.

As a first example, in a current study of “character sums” we wished to use the following result derived in [14]:

$$(1) \sum_{n=1}^x \frac{(-1)^{n-1}}{(2n-1)(n+1)^3} = \frac{1}{2} 4\ln\left(\frac{1}{2}\right) - \frac{51}{2880} \pi^4 - \frac{1}{6} \pi^2 \log^2(2) + \frac{1}{2} \log^4(2) + \frac{7}{2} \log(2)\zeta(3).$$

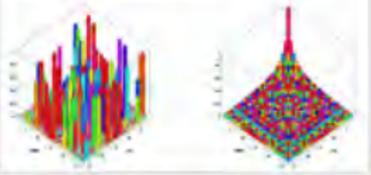
Here  $\ln(\frac{1}{2})$  is a polylogarithmic value. However, a subsequent comparison to check results disclosed that, whereas the RHS evaluates to  $-0.872929289\dots$ , the LHS evaluates to  $2.599330815\dots$ . Puzzled, we computed the sum, as well as each of the terms on the RHS (note that coefficients), to 500-digit precision, then applied the “PSQ” algorithm, which searches for integer relations among a set of constants [16]. PSLQ quickly found the following:

$$(2) \sum_{n=1}^x \frac{(-1)^{n-1}}{(2n-1)(n+1)^3} = 4\ln\left(\frac{1}{2}\right) - \frac{51}{2880} \pi^4 - \frac{1}{6} \pi^2 \log^2(2) + \frac{1}{2} \log^4(2) + \frac{7}{2} \log(2)\zeta(3).$$

In other words, in the process of transcribing (1) into the original manuscript, “151” had become “51”. It is quite possible that this error would have gone undetected and uncorrected had we not been

### Caption for attached graphic:

Mathematicians often work with matrices, which are arrays of numbers. When written on a page, a matrix can look like a sea of numbers, so any patterns that might occur in the numbers can be difficult to discern. More and more, mathematicians are turning to graphic representations of matrices, like the two examples here. By using color and form to indicate the values of the numbers in the matrix, these graphical representations can instantly give a sense of the patterns in the data. The first picture is a representation of a matrix in which the numbers exhibit a clear pattern; the second picture, by contrast, is a matrix in which the numbers are random. (Graphic by David Bailey and Jonathan Borwein. Request their permission before reproducing the graphic.)

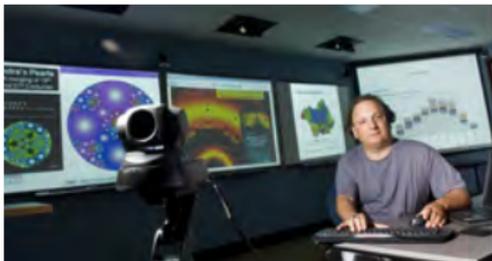


AMS Embargoed PR



## CARMA's Mandate

*Mathematics, as “the language of high technology” (Tom Brzustowski) which underpins all facets of modern life and current **Information and Communication Technology** (ICT), is ubiquitous. No other research centre exists focussing on the implications of developments in ICT, present and future, for the practice of research mathematics. CARMA fills this gap.*



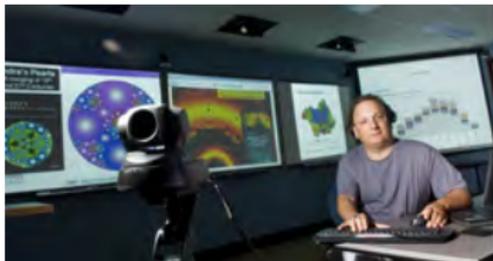
CARMA's Access Grid Room (2008)

Through exploitation and development of techniques and tools for computer-assisted discovery and disciplined data-mining including mathematical visualization.

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Through exploitation and development of techniques and tools for **computer-assisted discovery** and **disciplined data-mining** including **mathematical visualization**.

## CARMA's 2008 Objectives:

largely met

To perform R&D relating to the informed use of computers as an adjunct to mathematical discovery (including current advances in cognitive science, in information technology, operations research and theoretical computer science)



- Of mathematics underlying computer-based support systems and to undertake mathematical modelling of such activities
- To promote and advise on use of appropriate tools (hardware, software, databases, learning object repositories, mathematical knowledge management, collaborative technology) in academia, education and industry [Global quick success, locally slower]
- To make University of Newcastle a world-leading institution for Computer Assisted Research Mathematics and its Applications<sup>1</sup>

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<sup>1</sup>ERA: UofN only 2010 '5' in Appl. Maths & only real 2012 '5' (CARMA)  
2013 Top 200 Maths Dept (Shanghai) 2014 3 FAA (9 at UofN)

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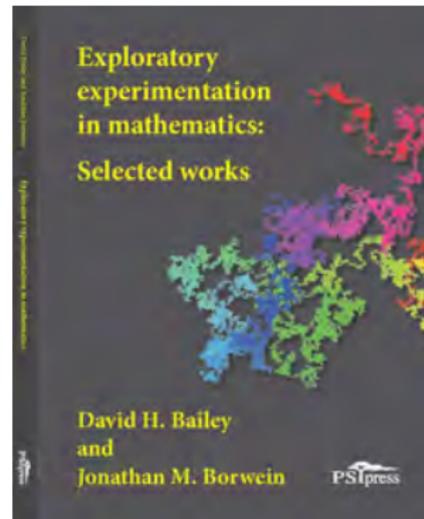
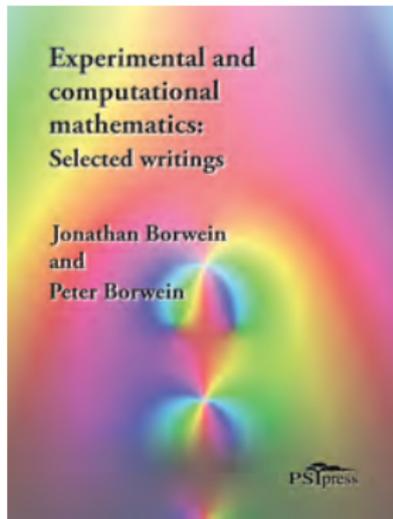
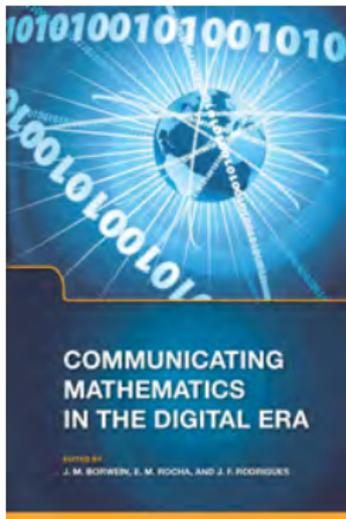
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## Communication and Computation:

are entangled



### Communicating Mathematics (2008, 2010, 2012)

- 2012 *Science Communication* paper on AG seminars at <http://www.carma.newcastle.edu.au/jon/c2c11.pdf>



# CARMA's 'Deep' History

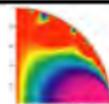
(Daniel Lord Smail)

toc

▶ SKIP

A co-evolution of symbolic/numeric (hybrid) computation, experimental maths, collaborative technology and HPC.

Experimentally-found modular fractal took three hours to print in 2003



1982 PBB & JMB 'minor' work on fast computation at Dalhousie; experimental mathematicians before term was current.<sup>2</sup>

1993-03 Moved to SFU to found Centre for Experimental & Constructive Maths [www.cecm.sfu.ca](http://www.cecm.sfu.ca) (Shrum & CRC)

1995 Organic Mathematics Project: [www.cecm.sfu.ca/organics](http://www.cecm.sfu.ca/organics)

2004-09 JMB opens D-Drive (Dalhousie Distributed Research Institute and Virtual Environment) with Canada Research Chair funding

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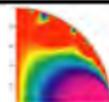
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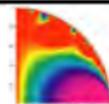
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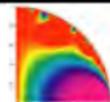
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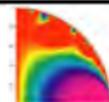
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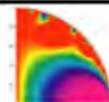
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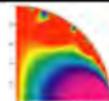
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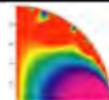
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- taking (reasonable) **risks**—intellectual and managerial
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# CARMA's Structure and Membership

Currently **36** Members, **8** Associates, **7** Student Members:

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- External Advisory Committee (IBM (GAJ chair), Melb, LBL)
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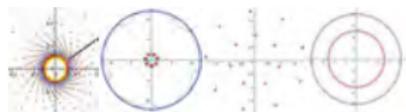


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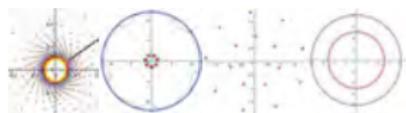


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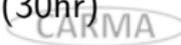
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**V205** for **dis-located** collaboration;

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**HPC** 104 core **MacPro x-grid** Cluster; 144-core **HTCondor** cluster (64 GB) (RedHat); 12-core (24 hyperthreaded) Linux server (192 GB RAM) + access to NSW/National compute services.

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<http://vis.carma.newcastle.edu.au/>

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<b>4. Symbolic Latent Analysis</b> A book discussing various clusters and their characteristics, tracing cause functions in both Euclidean and Riemannian spaces. <a href="#">View...</a>	<b>5. Iterative Projection Method</b> Iterative projection methods form the basis of a number of algorithms used to solve optimisation problems. <a href="#">View...</a>	<b>6. Protein Reconstruction</b> Reconstruction of the protein SP1Q using the Douglas-Peucker algorithm. <a href="#">View...</a>
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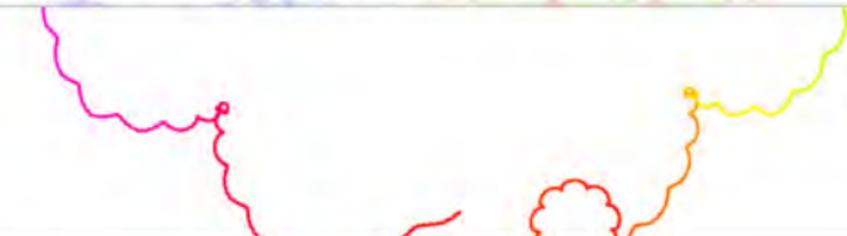
- 1 Remember there is seed funding and help for all good projects: (<http://carma.newcastle.edu.au/reads/>)
- 2 Bookmark the Home page
- 3 Regularly monitor Events and make sure they are advertised
- 4 Report Issues to David Allingham and Juliane Turner
- 5 Suggest Additions and Enhancements



## Walking on Real Numbers

A Multiple Media Mathematics Project

CARMA



Visit our extensive WALKS gallery



### PUBLICATIONS

View our article from the *Mathematical Intelligencer*, as well as related publications, in this section.

### PRESENTATIONS

This section contains presentations related to our research.

### PRESS COVERAGE

We have received coverage in the popular press for our work! It all started with the original "Wink" article and news has grown from there.

### GALLERY

Our extensive gallery of research images.

### GIGAPAN IMAGES (external link)

Clicking here will take you to our very hi-res research images of number walks.

### LINKS

Our page of links that are associated with the project.

MOTIVATED by the desire to visualize large mathematical data sets, especially in number theory, we offer various tools for representing floating point numbers as planar (or three dimensional) walks and for quantitatively measuring their "randomness". This is our homepage that discusses and showcases our research. Come back regularly for updates.

**RESEARCH TEAM:** Francisco J. Aragón Artacho, David H. Bailey, Jonathan M. Borwein, Peter B. Borwein with the assistance of Jake Fountain and Matt Skerritt.

**CONTACT:** [Fran Aragon](mailto:Fran.Aragon@carma.newcastle.edu.au)



Turtle plots of  $\pi$  and paper-folding

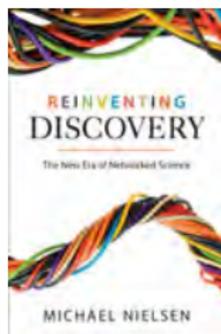


CARMA

## Member Services

Allingham, Danson, & Turner

- We offer a variety of services to our members and their students (and to many others)
  - some are forced upon us by problems with UofN Academic Computing support
  - taking money from research
  - relying on significant subsidy from the Director's other funds



See details at:

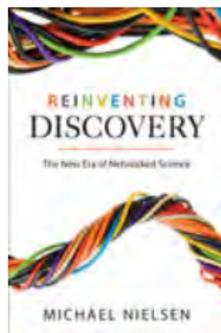
<http://www.carma.newcastle.edu.au/jon/MemberServices.pdf>



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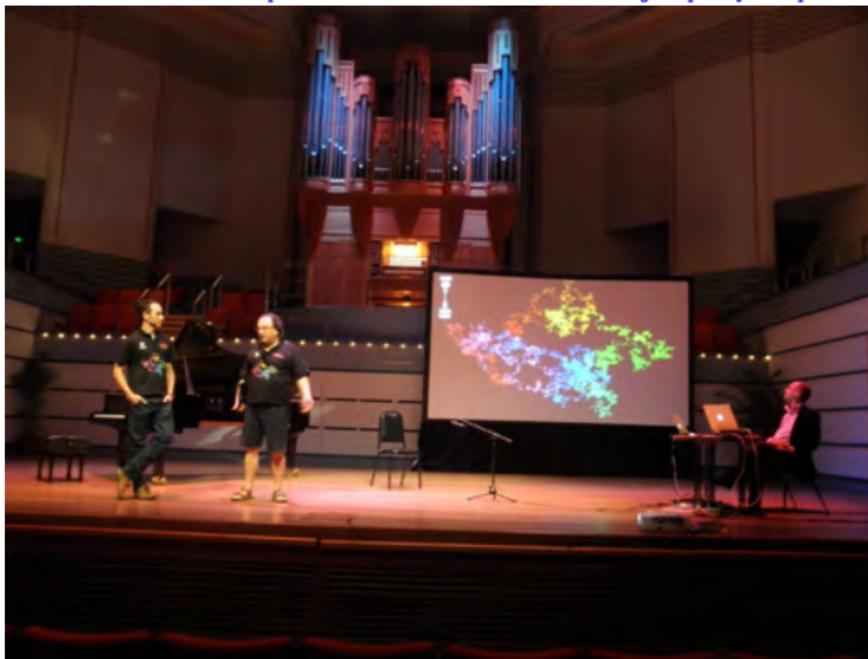
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## Non-traditional Publication

video and audio

Learn about Pi at <http://www.carma.newcastle.edu.au/jon/piday-14.pdf>



October 25 2012: Music and Maths Concert

[http://carma.newcastle.edu.au/pdf/music\\_maths.pdf](http://carma.newcastle.edu.au/pdf/music_maths.pdf)

Hear Pi at <http://carma.newcastle.edu.au/walks/>

Jonathan Borwein, 2014

CARMA and Me

<http://www.carma.newcastle.edu.au/jon>



## Conclusions

We are (mainly) having fun

- We are **Pragmatic Dreamers**
  - always aiming slightly too high
- The members' enthusiasm and work ethos is superb. We all *own* CARMA
- We cover all bases – research, applications, outreach and education
  - *We can not fund education. I am, however, strongly in favour of early introduction to research.*  
(Eliot Phillipson, former CFI and CIHR President)
  - an AMSI 'maths hot spot' (one of two). Very strong participation at AustMS, ANZIAM and AMSI conferences



2012 CARMA shirts (Ballarat AMS)

ANIMATION



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## Not Bad for the First Five Years ... and we have big plans

Given *real* support from P/VC for:

- hiring next CARMA Director/HoS;
- to make Pure Maths an ERA '5'; Maths a top 100 department.

### RELATED MATERIAL

- 1 FEASIBILITY METHODS: DIVIDE AND CONCUR  
<http://carma.newcastle.edu.au/DRmethods/>
- 2 EXPERIMENTAL MATHEMATICS: FOR EVERYTHING  
<http://www.carma.newcastle.edu.au/expmaths/>
- 3 PI DAY:  
<http://carma.newcastle.edu.au/jon/piday.pdf>
- 4 WALKING ON NUMBERS: A VIRAL SUCCESS  
<http://walks.carma.newcastle.edu.au/>
- 5 LATTICE SUMS: THEN AND NOW  
<http://www.carma.newcastle.edu.au/jon/LatticeSums/index.html>
- 6 THE DIRECTOR'S BLOGS  
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2010: Communication is not yet always perfect



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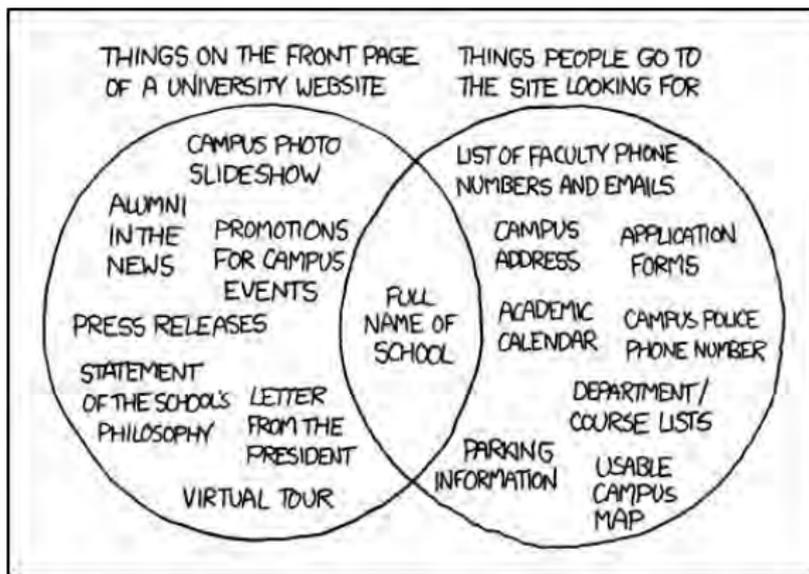
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## Building a new research centre

... is hard work



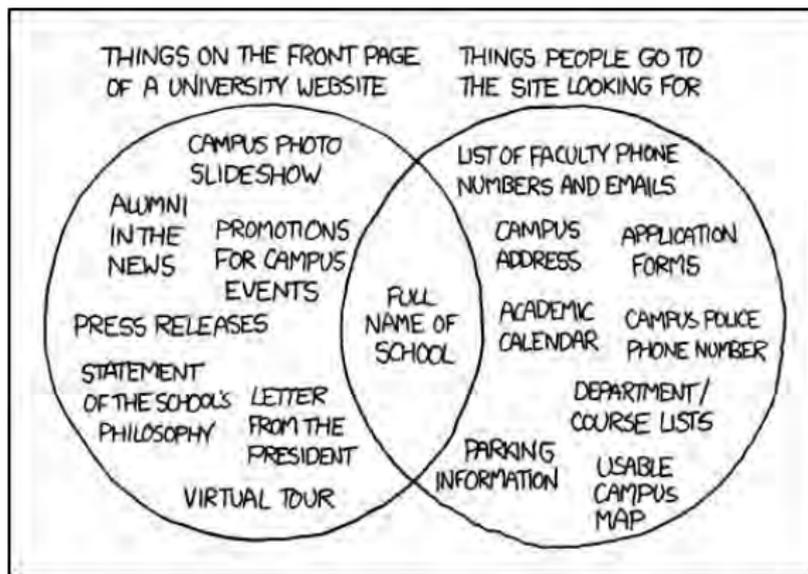
with many **hurdles**, and lots of **details** to get right.  
But it *can* be very rewarding.

# Thank you



## Building a new research centre

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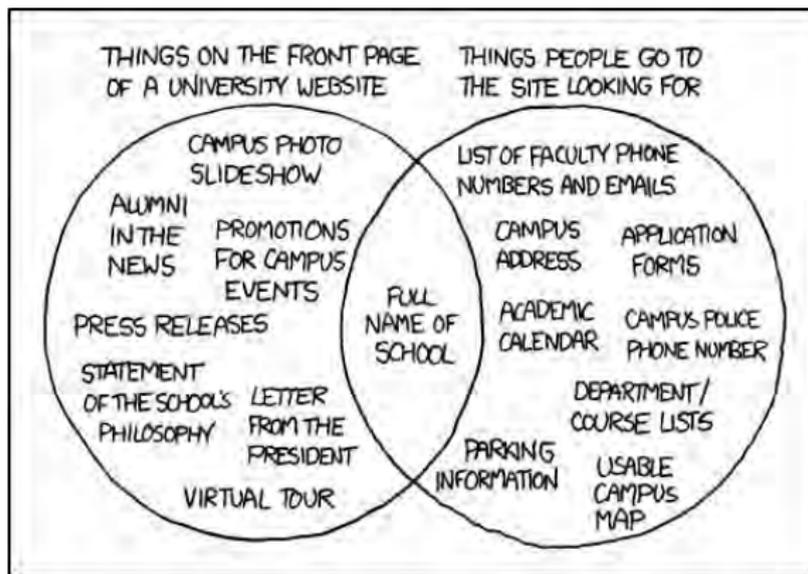
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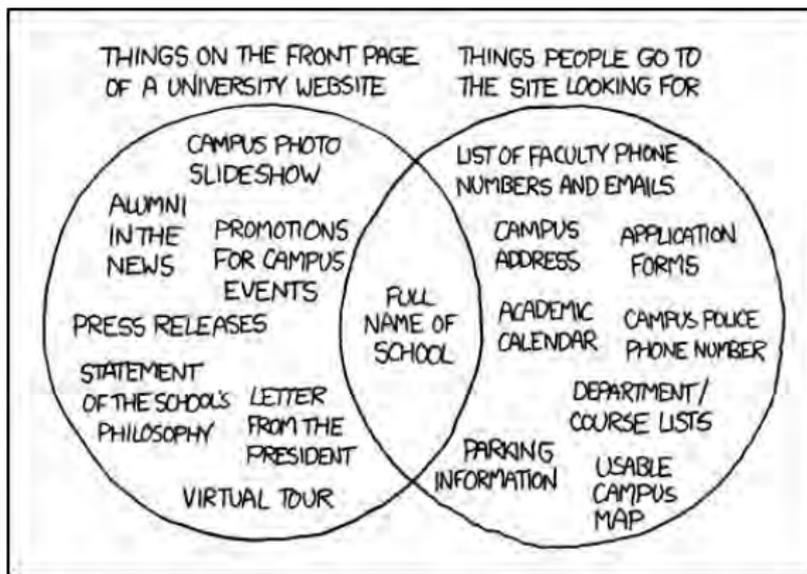


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