The BIG Bang

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TYBIS
March 23, 2018

Philippe's Check-List

Content

[ ] I am glad to participate, but I prefer not to talk at all

[ ] I am willing to give a talk but I do not know yet what I shall be talking about

[ ] I already know the title of my talk---but I want anyway to keep the privilege to later change my mind.

My current title is:

Several binary questions!

The topic of your talk is of your own choosing. Here are a few suggestions.

- It can relate (or not) personally to Michael Unser.
- It can have (or not) something to do with splines.
- It can reminisce (or not) about your time at BIG.
- It can disclose (or not) what became of you after leaving BIG.
- It can be related (or entirely unrelated) to BIG.
- It can illustrate (or not) how your current interests extend (or differ from) those of yore.
- It can involve new (or old) topics.
- It can be educational/academic/scientific/technical/entrepreneurial (or not).
- It can deploy theory, or practice, or something else altogether.
- It can offer solution(s) or ask open question(s).
- It can contain all (or few, or none) of the above.

These are mere suggestions for you to consider. You're welcome to innovate!

Binary CS?

Michael's First Visit to India
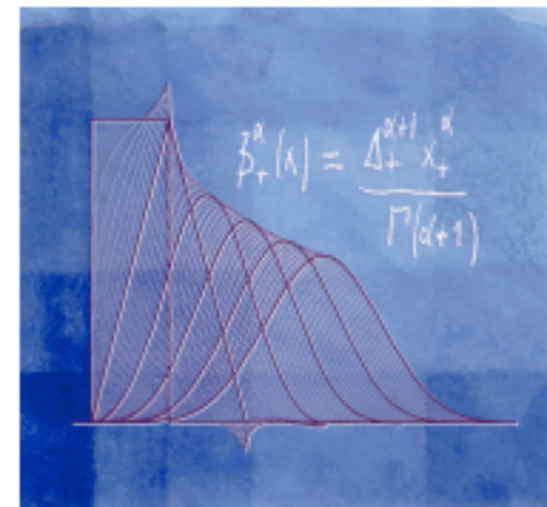
Michael's Plenary Talk at SPCOM 2004

EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Think analog, act digital

Michael Unser
Biomedical Imaging Group
EPFL
Lausanne, Switzerland

$$\beta_r^\alpha(x) = \frac{\Delta_+^{\alpha+1} x_+^\alpha}{\Gamma(\alpha+1)}$$

SPCOM'04, December 11-14, 2004, Indian Institute of Sciences, Bangalore, India

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Think Analog, Act Digital

Is continuous-time signal processing dead ?

- **Arguments in favor of its suppression:**
  - The modern world is discrete (CDs, DVDs, WEB, etc...)
  - Modern SP courses concentrate on digital signal processing
  - Most processing is discrete (DSPs, PCs, etc...)
  - Students don't like the Laplace transform...

- **However...**
  - Real-world signals are continuous
  - Often, the end product is analog: control systems, sound reproduction systems, etc.
  - Don't forget the interface: A-to-D and D-to-A
  - Some discrete algorithms require continuous-time thinking

2

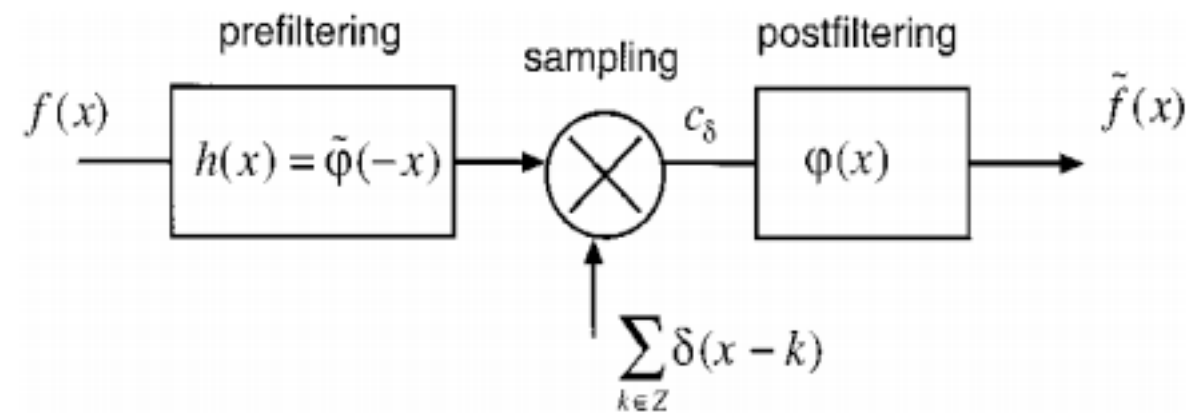M. Unser, SPCOM 2004

Promoting Continuous-Time Thinking

Revival of continuous-time thinking

- **Recent trends in SP**
  - Wavelet theory, multiresolution analysis
  - Self-similarity, fractals, analysis of singularities
  - Partial differential equations
  - Spline-based signal processing

- **Continuous/discrete formulation**
  - "Think analog, act digital"
  - Applications:
    - Fractional delays, sampling rate conversion
    - Discretization of differential operators
    - Interpolation
    - ...
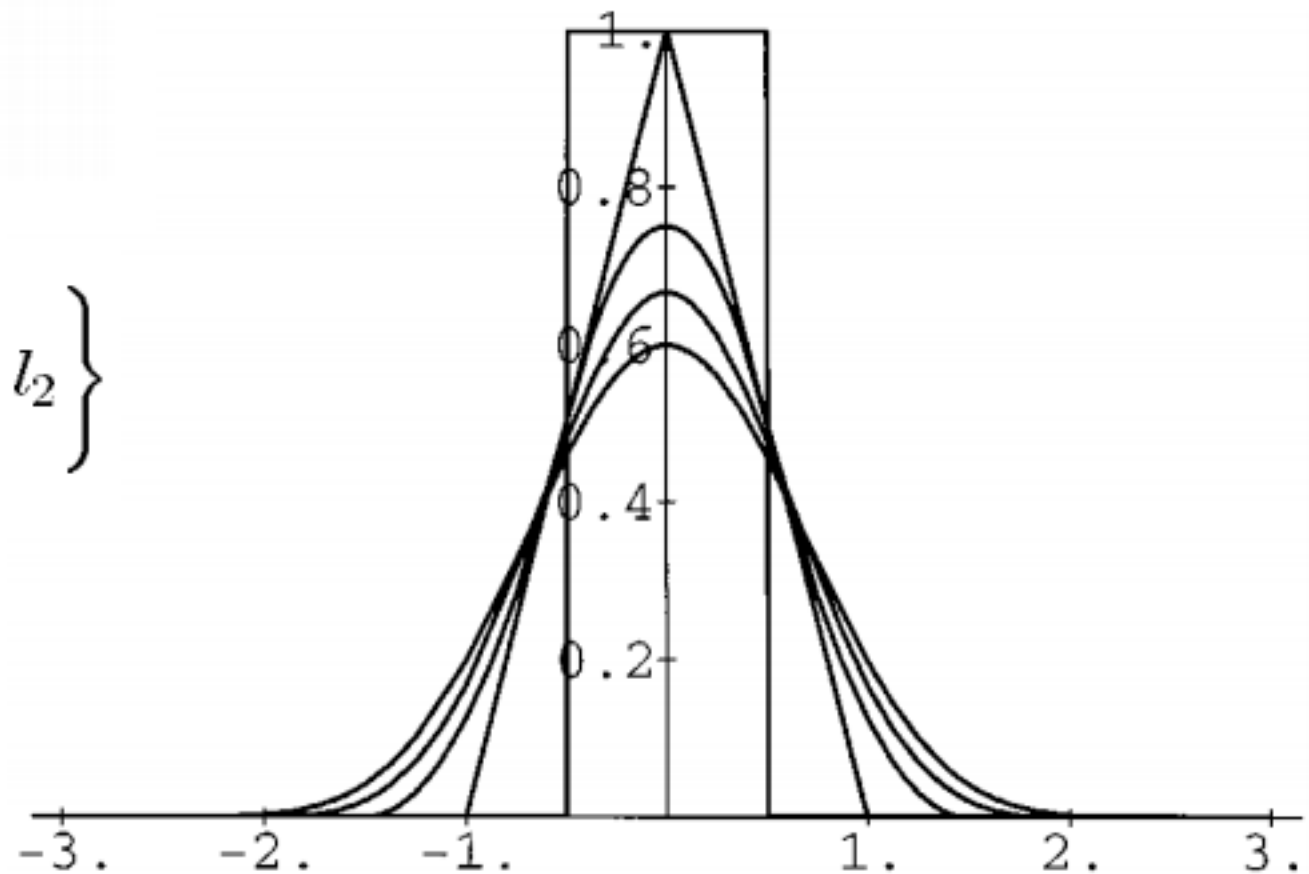
3

M. Unser, SPCOM 2004

Sampling—50 Years After Shannon
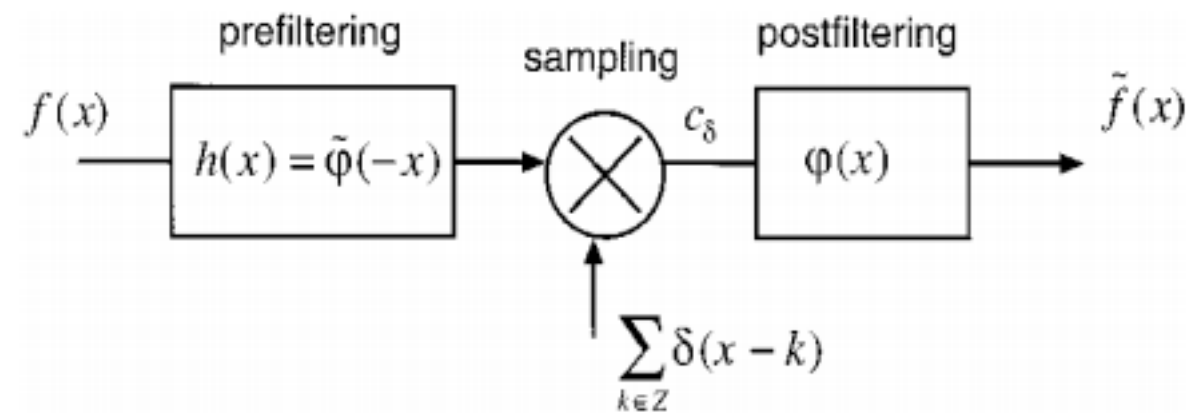

$$V(\varphi) = \left\{ s(x) = \sum_{k \in Z} c(k)\varphi(x - k) : c \in l_2 \right\}$$

Fig. 3. The centered B-splines for $n = 0$ to 4. The B-splines of degree n are supported in the interval $[-((n+1)/2), ((n+1)/2)]$; as n increases, they flatten out and get more and more Gaussian-like.
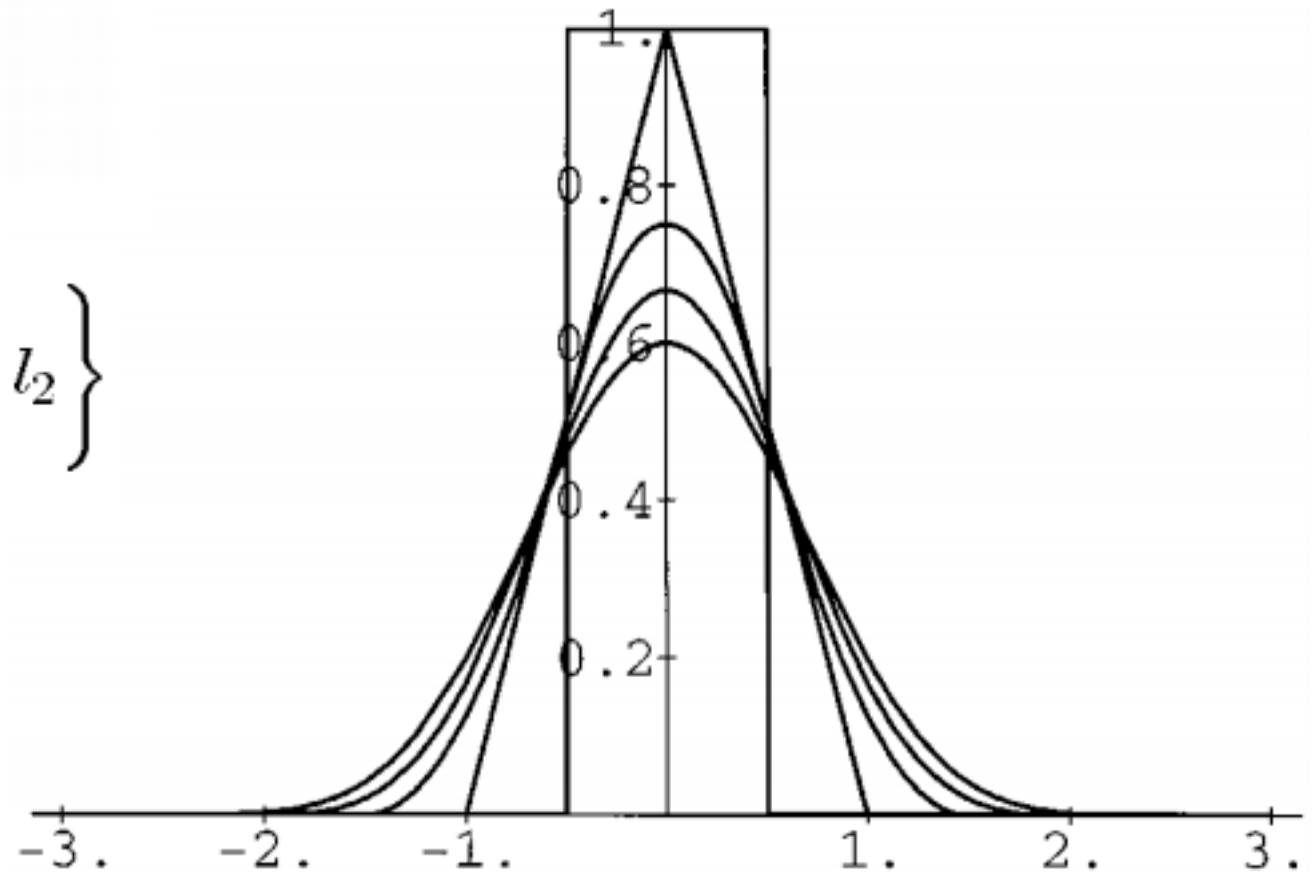
M. Unser, Proc. IEEE, 2000

Sampling—50 Years After Shannon

$$V(\varphi) = \left\{ s(x) = \sum_{k \in Z} c(k)\varphi(x-k) : c \in l_2 \right\}$$

The Great Revelation!
The BIG Bang!

Fig. 3. The centered B-splines for $n = 0$ to 4. The B-splines of degree n are supported in the interval $[-((n+1)/2), ((n+1)/2)]$; as n increases, they flatten out and get more and more Gaussian-like.

M. Unser, Proc. IEEE, 2000

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Postdoc at BIG

- April 1, 2006 - July 15, 2009
- One of the teaching assistants for the Image Processing tutorials and ImageJ sessions, and Signaux et Systèmes course
- Working mostly on
  - Optical-Coherence Tomography
  - Digital Holographic Microscopy
  - Splines and snakes
  - Finite-rate-of-innovation sampling

- Joined back Indian Institute of Science in July 2009
- Tenured, and on my way to becoming a full professor

My BIG Contemporaries

My BIG Contemporaries

Thierry Blu
A genius French mathematician
Always amazes people with his sharp intellect
Very inspiring and friendly

My BIG Contemporaries

Daniel Sage
Software expert
Very cordial
1st liaison with the French-speaking administration

My BIG Contemporaries

Manuelle Borruat
Efficient secretary
My first French tutor
2nd liaison with the French-speaking administration

My BIG Contemporaries

Philippe Thévenaz
An example of Swiss perfectionism
Corrected my manuscripts and taught me Java
Badminton partner

Malley badminton club

Philippe's Certainty Principle

When will you arrive in Lausanne?
[ ] Thursday March 22, 2018
[ ] Other

You will travel
[ ] By car
[ ] By train
[ ] By plane
[ ] Other

[ ] You already have a place to stay in Lausanne
[ ] You want us to find accommodation for you

I also have to ask again about the social event. The plans will need to be finalized at the end of this month, with hotel reservations and everything.

Will you participate to Chamonix?
[ ] Yes, but not to the Vallée Blanche
[ ] Yes, including the Vallée Blanche
[ ] No

When do you want to leave Chamonix?
[ ] Monday March 26, 2018
[ ] Other

Philippe.

P. Thévenaz
EPFL/STI/IMT-LS/LIB/BM.4.137
Station 17
CH-1015 Lausanne VD
Switzerland
===

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Philippe's Certainty Principle

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Uncertainty is not an option!

Will you participate to Chamonix?
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Philippe.

P. Thévenaz
EPFL/STI/IMT-LS/LIB/BM.4.137
Station 17
CH-1015 Lausanne VD
Switzerland
===

My BIG Contemporaries

Dimitri Van De Ville
Highly professional and diplomatic
Master of collaboration

My BIG Contemporaries

Pouya Dehghani-Tafti
Deep thinker and a patient office-mate
Worldly discussions

My BIG Contemporaries

Kunal Narayan Chaudhury
Café-à-la-coupole partner
Discussions on the Hilbert transform

My BIG Contemporaries

François Aguet
Café-à-la-coupole partner
Discussions on Optics

My BIG Contemporaries

Sathish Ramani
Weekend Indian party mate

My BIG Contemporaries

Cedric Vonesch　　　　**Ildar Khalidov**

Pizza and movie organizers ("Mon Oncle")

My BIG Contemporaries

Simona Maggio
Tiramisu mate

My BIG Contemporaries

Torsten Moeller
Beer-mate
Movie mate: "The Wind That Shakes The Barley"!

BIG 2007
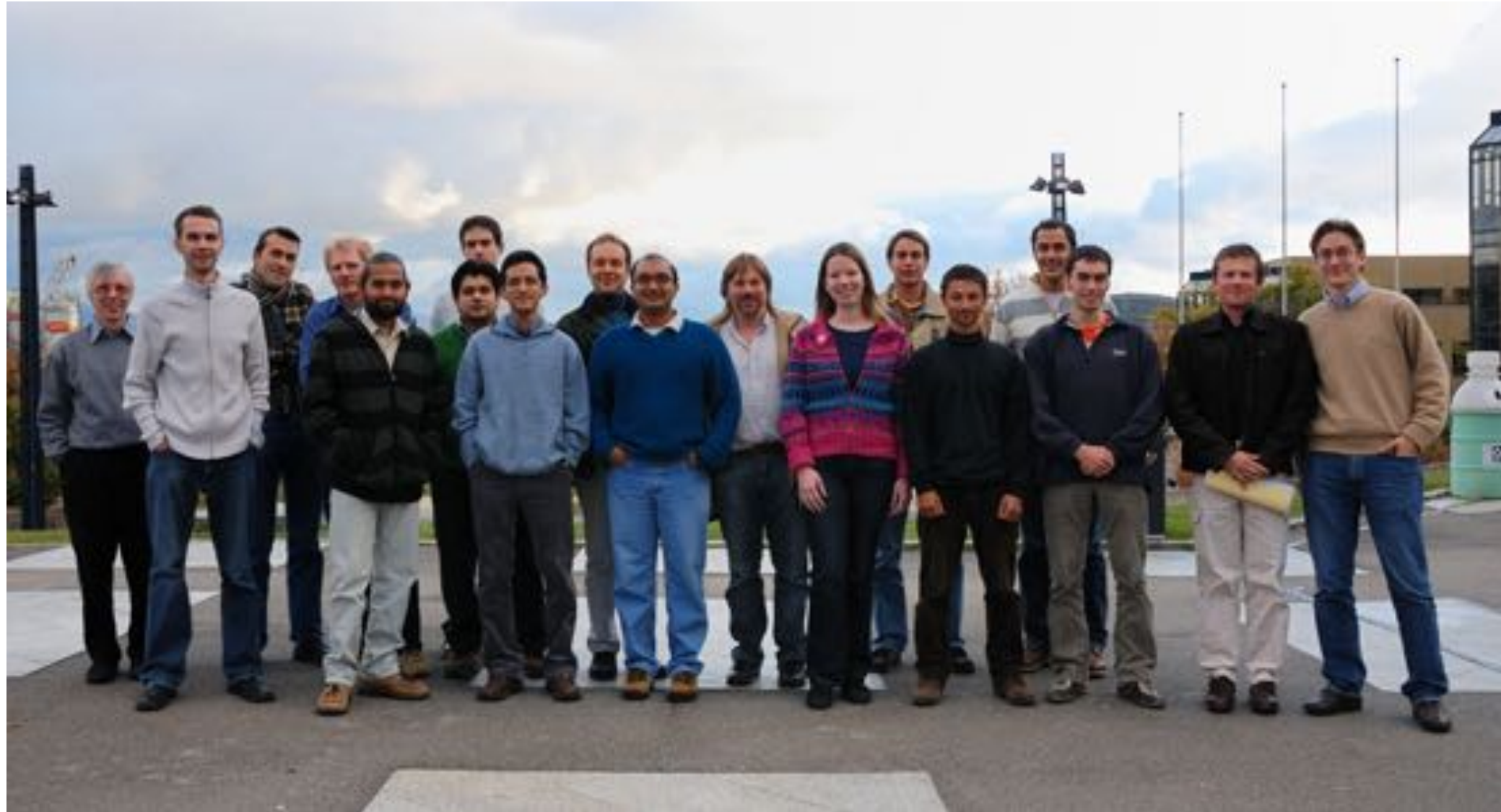
Little BIG at the Indian Institute of Science

Muthuvel Arigovindan
BIG PhD, 2005

Kunal Chaudhury
BIG PhD, 2011

Chandra
BIG Postdoc, 2009

My Team at the Indian Institute of Science

March 19, 2018

Michael

- Highly dynamic group leader

- Hardworking and inspiring

- Amazing intuition and intellect

Michael's Advice

- Never give up!

- Jump at opportunities.

- Promote your students.

Michael's Advice

- Never give up!

- Jump at opportunities.

- Promote your students.

6 Doctor of Philosophy
7 Master of Philosophy
15 Masters Projects

3 Best Student Medals
3 Best Thesis Awards

Glimpses Into Four Recent Research Problems

1. Super-Resolved Nuclear Magnetic Resonance Spectroscopy

Super-Resolved NMR (FRI-NMR)

- Free induction decays

- Fast NMR; Minimal no. of samples

- Estimate chemical shifts accurately

- Finite rate of innovation (FRI) sampling approach

- Study of Ubiquitin gold nanorod interactions

Nature Scientific Reports, 2017
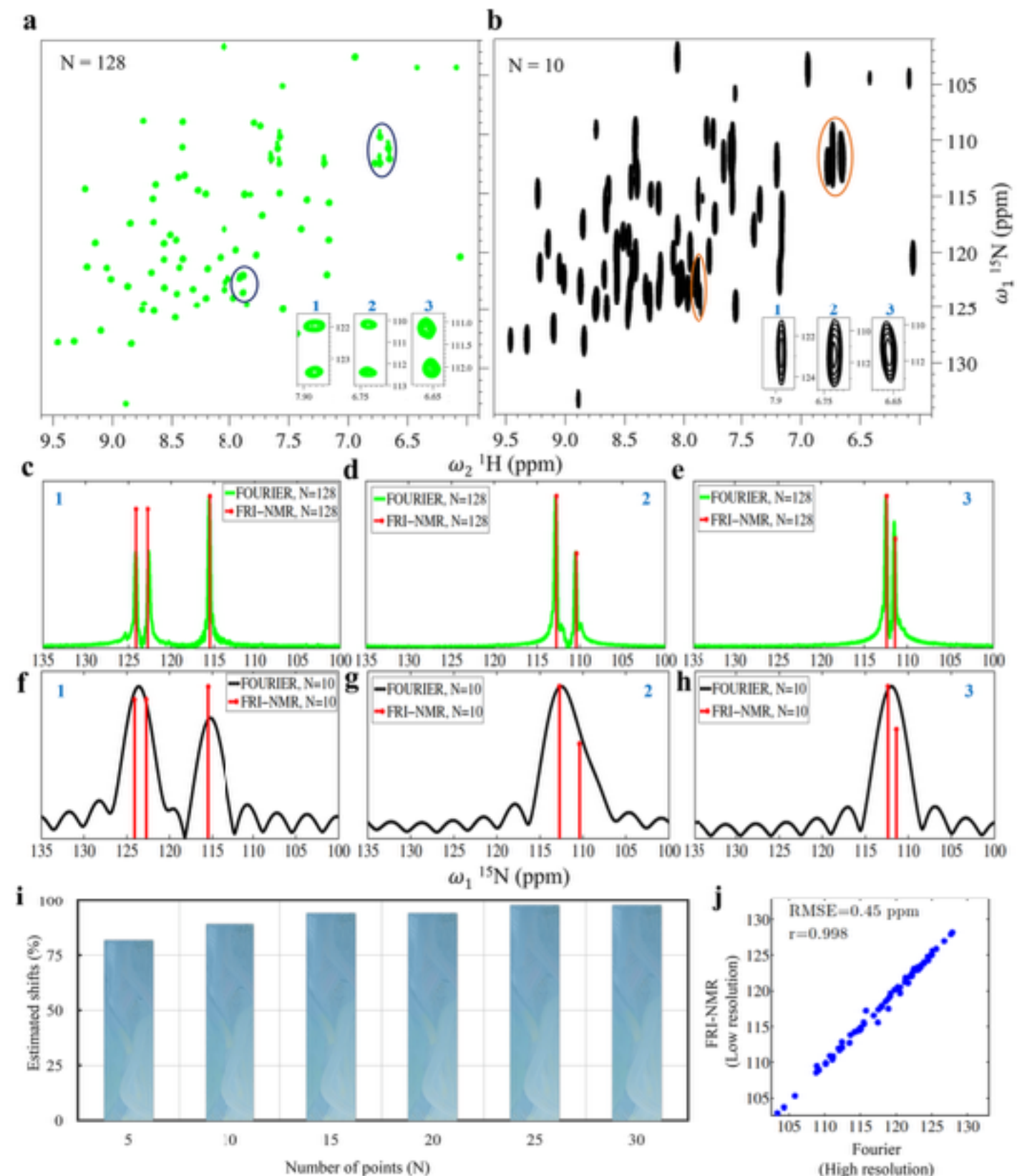
2. Phase Retrieval

Phase Retrieval in Principal Shift-Invariant Spaces

- Causal, delta-dominant (CDD) sequences:

$$x[n] = \delta[n] + c[n]u[n]; \|c\|_1 < 1$$

- Exact phase retrieval up to a global phase factor

- New class of "phase-retrievable" signals

- Finite-length CDD sequences are minimum-phase

- Magnitude-Phase Hilbert integral relations

CDD

Min. Phase

IEEE TSP 2016
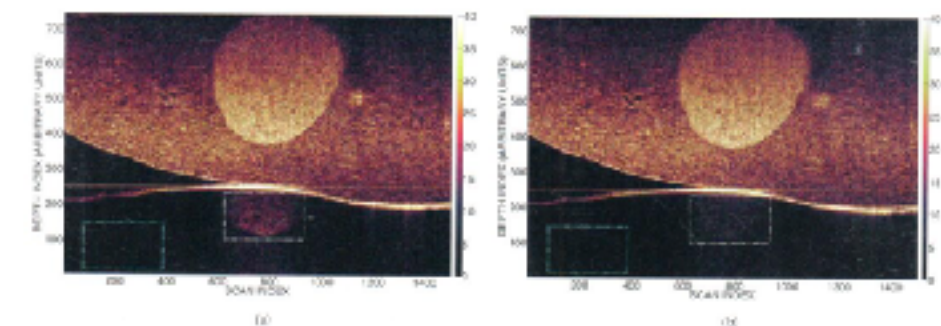
3. DSP

DSP = Deep Signal Processing

- Rapidly emerging research frontier at the interface of deep learning and signal processing

- Link between sparse coding and deep learning (Gregor and LeCun, 2010; McCann et al., 2017; Mallat, etc.)

Central objective: To learn priors in a data-driven fashion
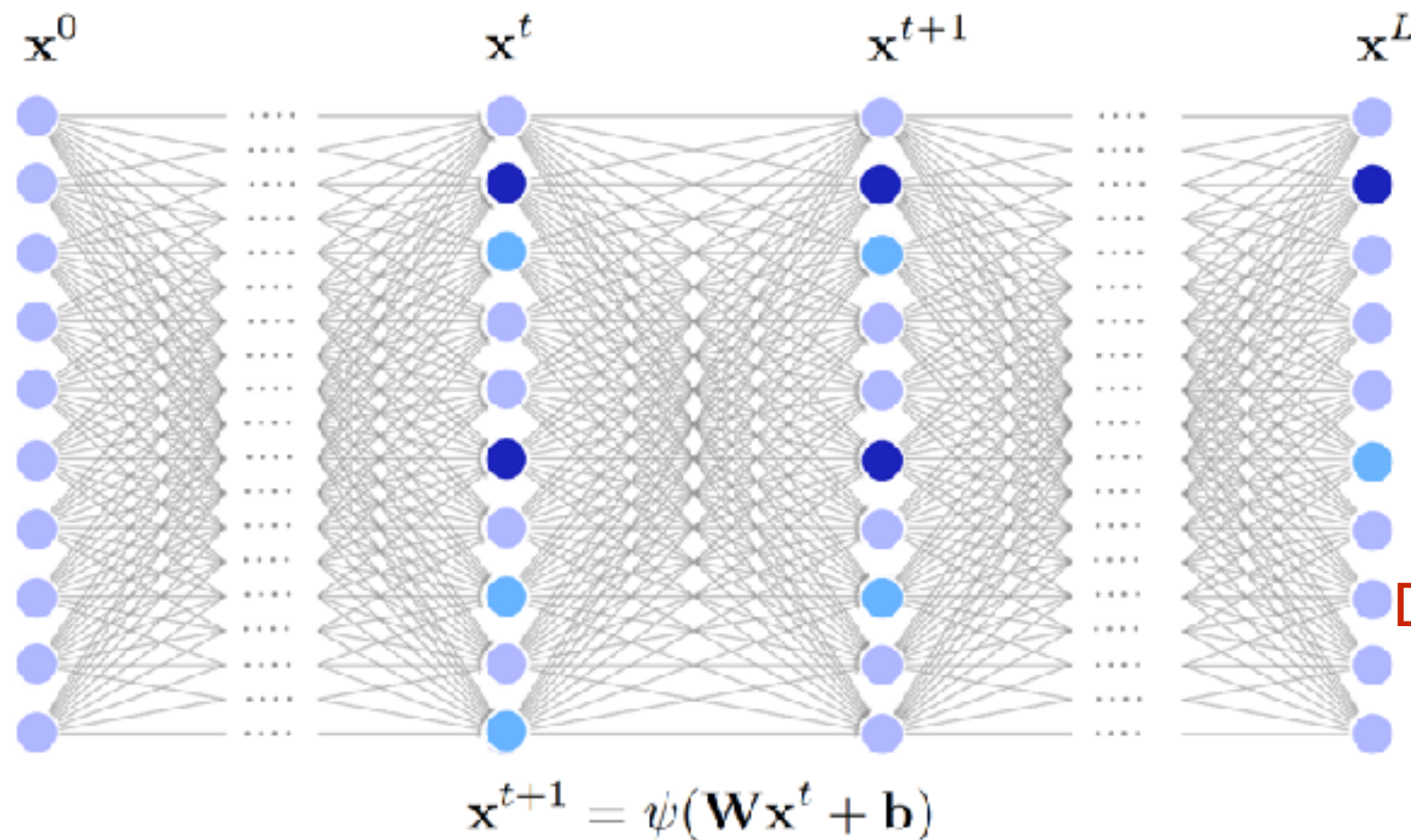
Deep Sparse Coding

NIPS BDL 2017

$$\mathbf{x}^{t+1} = \psi(\mathbf{W}\mathbf{x}^t + \mathbf{b})$$

LET parameterization

$$\psi^t(u) = \sum_{k=1}^{K} c_k^t \phi_k(u), \text{ where } \phi_k(u) = u\,e^{-\frac{(k-1)u^2}{2\tau^2}}$$
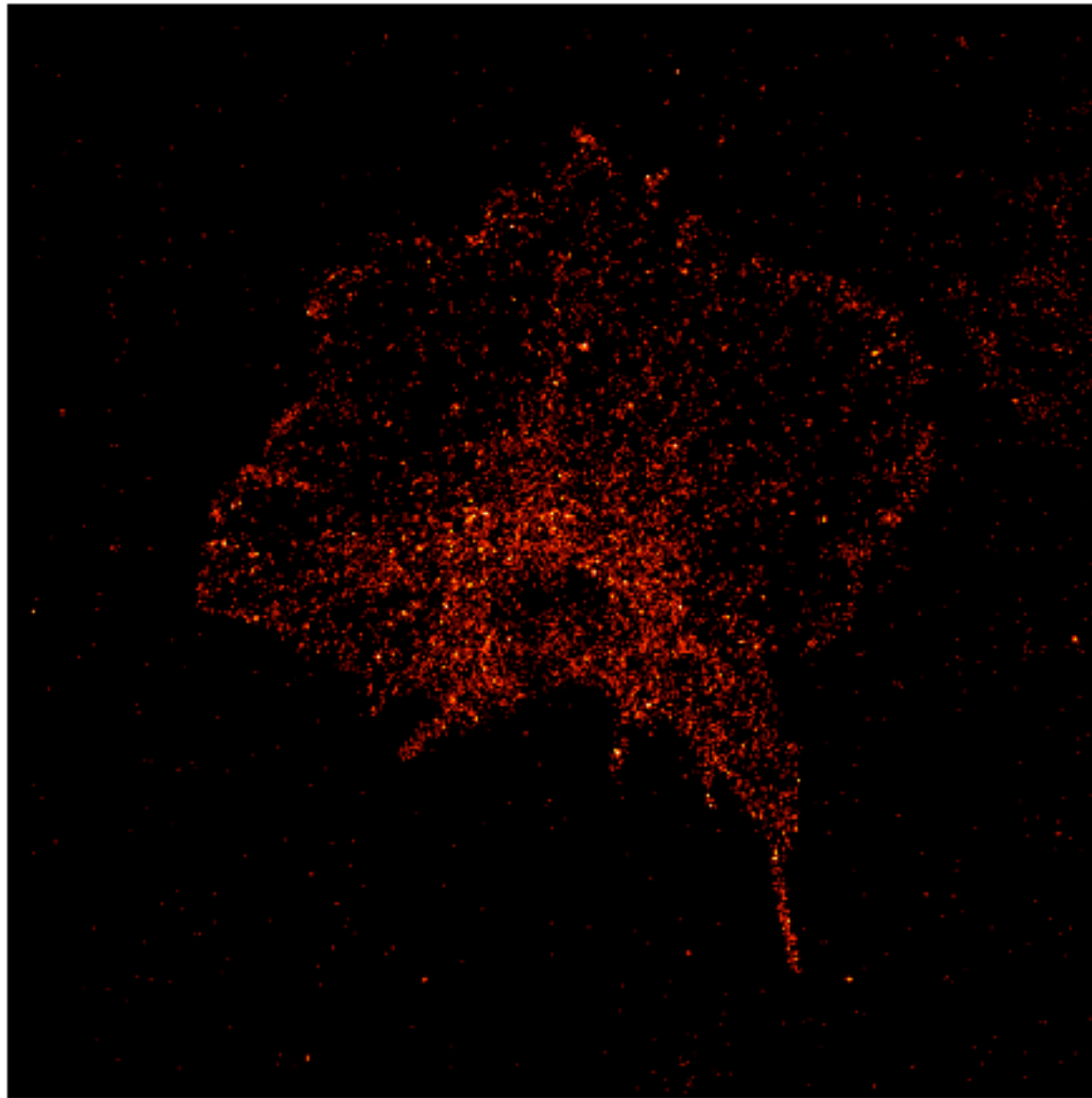
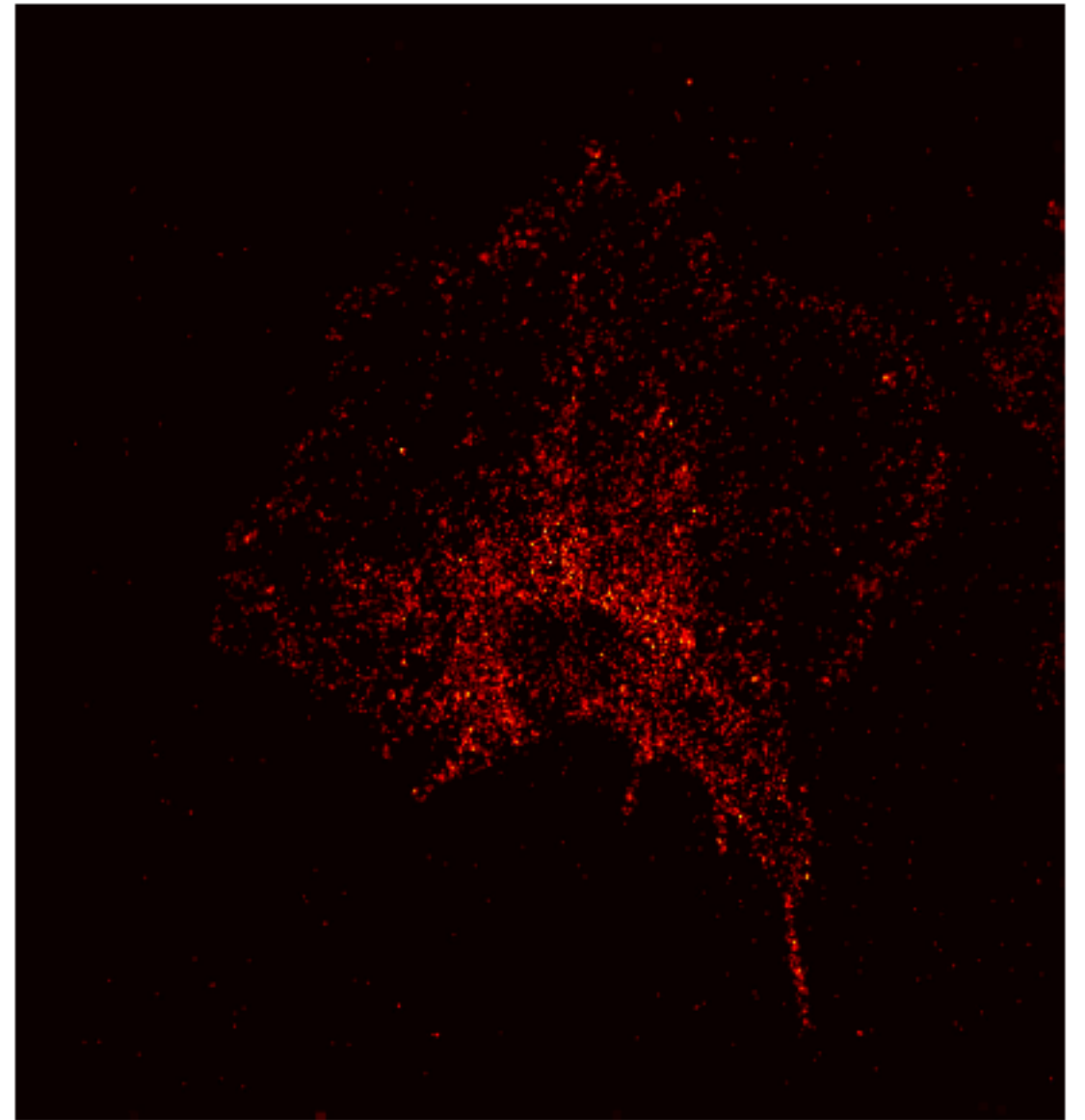Blu et al. (several papers)

Deconvolutional Neural Networks

Super-Resolution Localization Microscopy

Standard Reconstruction

Deep Reconstruction

NIPS BDL 2017; FoM 2018

4. Statement Proving

Example: Michael can produce papers on splines.

A Universally Accepted Statement

IEEE SP Magazine, 1999   SIAM Review, 2000

Proof by numerous examples!

Is the Converse True?

Is the Converse True?

Can splines produce Michael on paper?

What are the Constraints?

- Pass through all the "landmark" points — Interpolation

- Shortest path

- Minimum curvature

- No breaks, maintain continuity — A single closed curve

- The optimal interpolating function with minimum curvature is the cubic B-spline (Brigger et al., 2000)

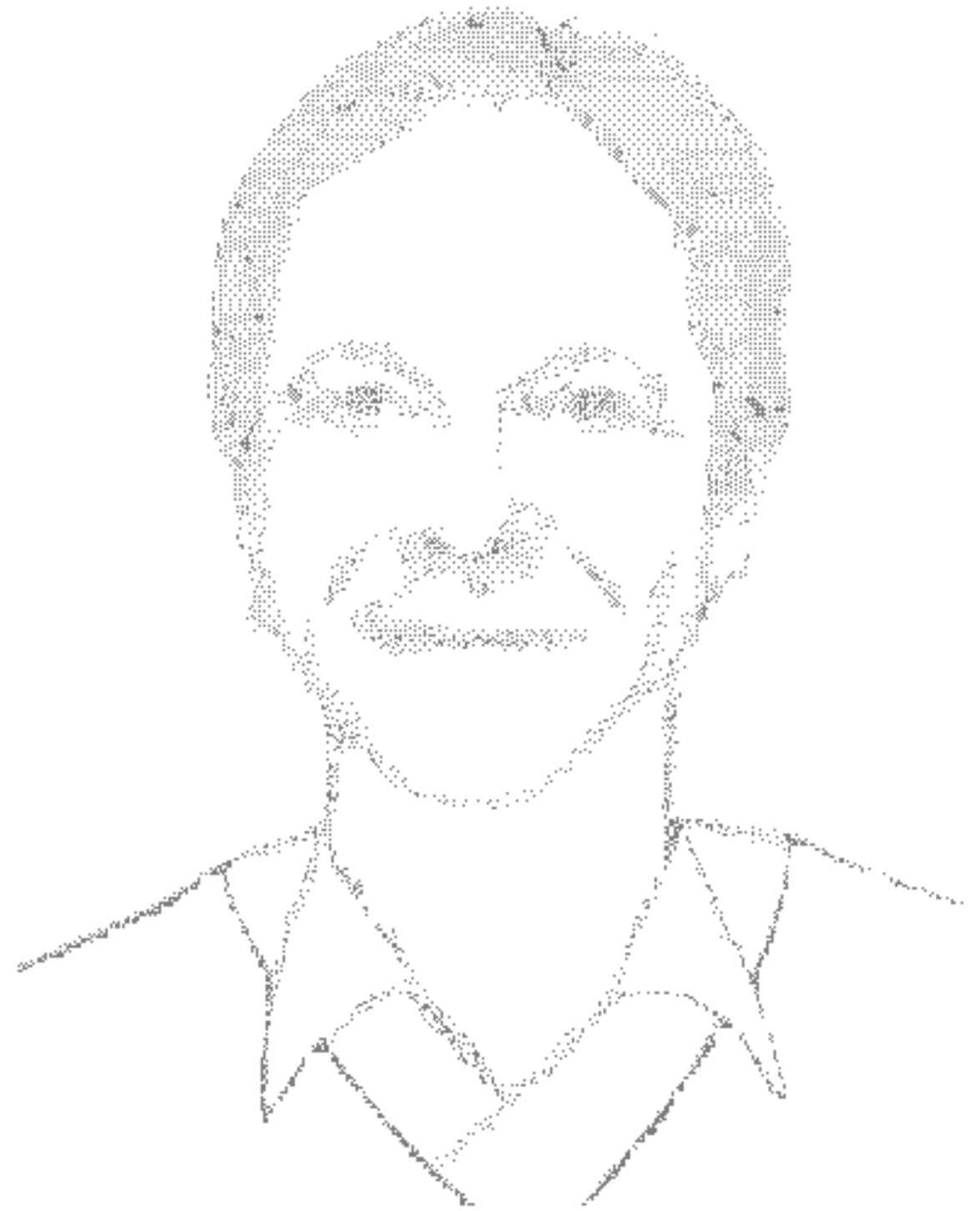$$\beta^{(3)}(t)$$
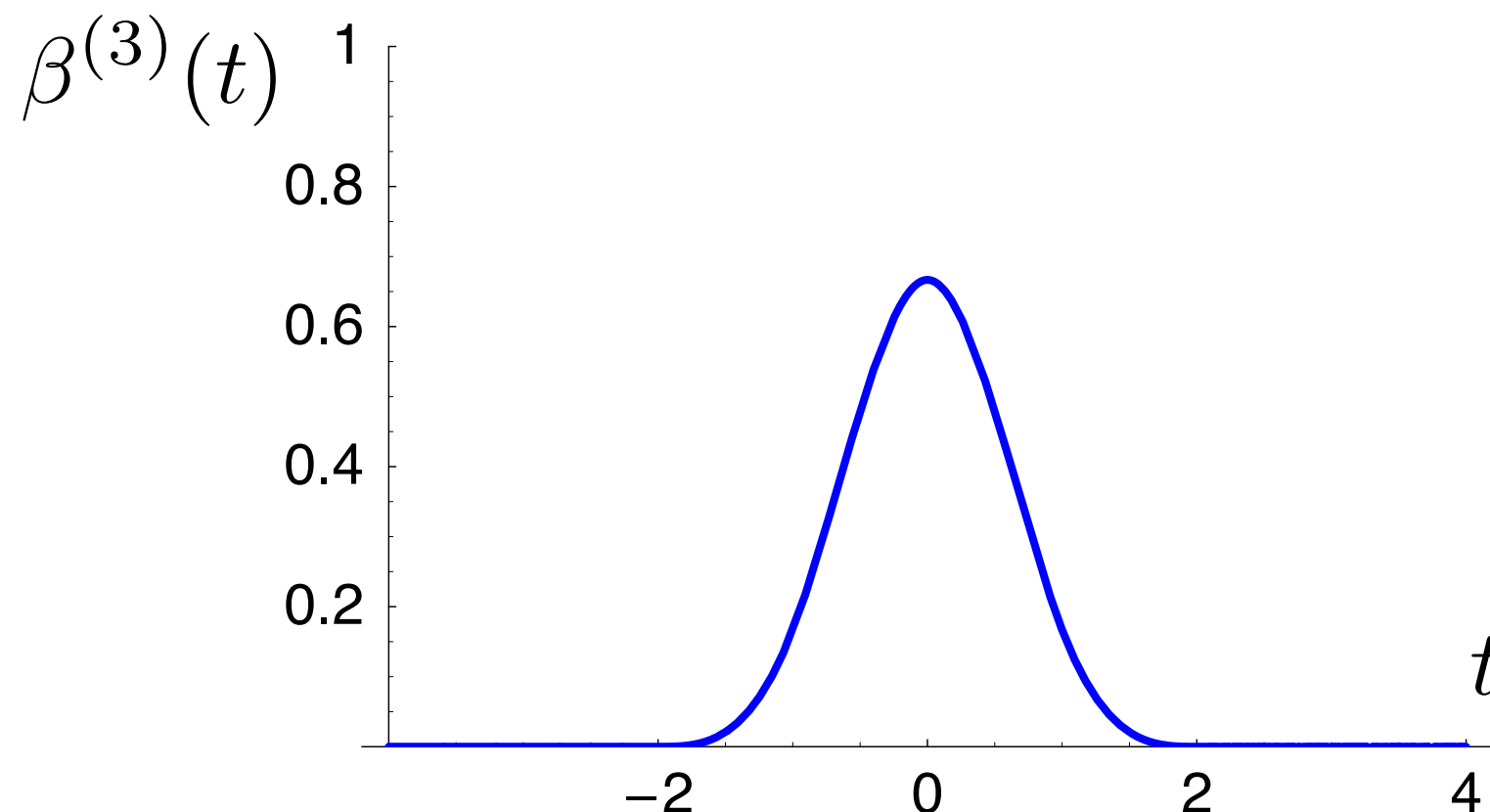
Here's a "Sketch" of the Proof!

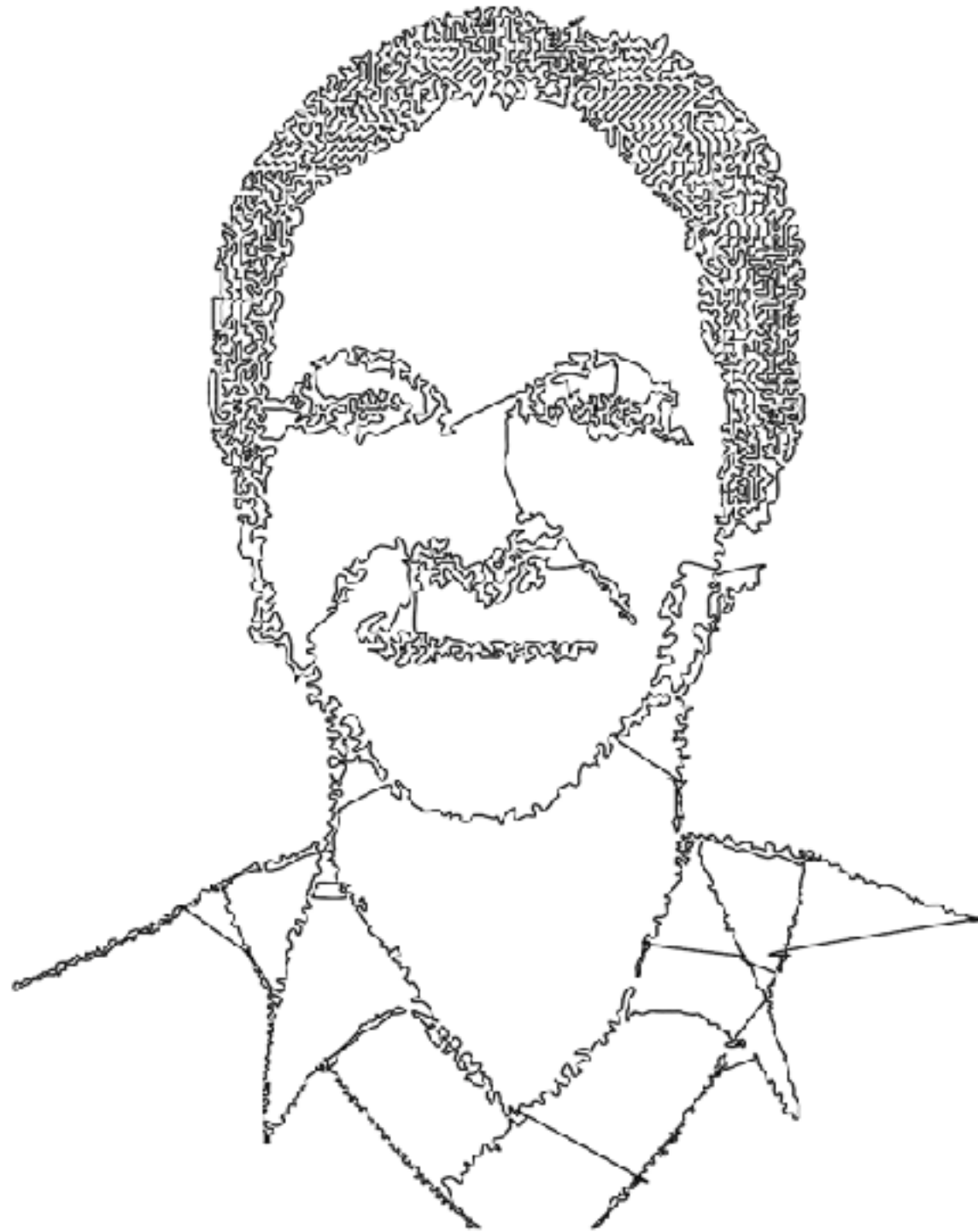25,000 cubic B-splines at work

Splinetoning!

App and paper coming soon!

Inspired by Robert Bosch, PNAS, 2016

Happy 60th birthday Michael!

Happy 20th birthday BIG!