

Aron and me:  
a wonderful journey  
in the flatland (1996-2022)

Vittorio Pellegrini  
*Bedimensional Spa, Genova (Italy)*

# Collapse

1996-1998

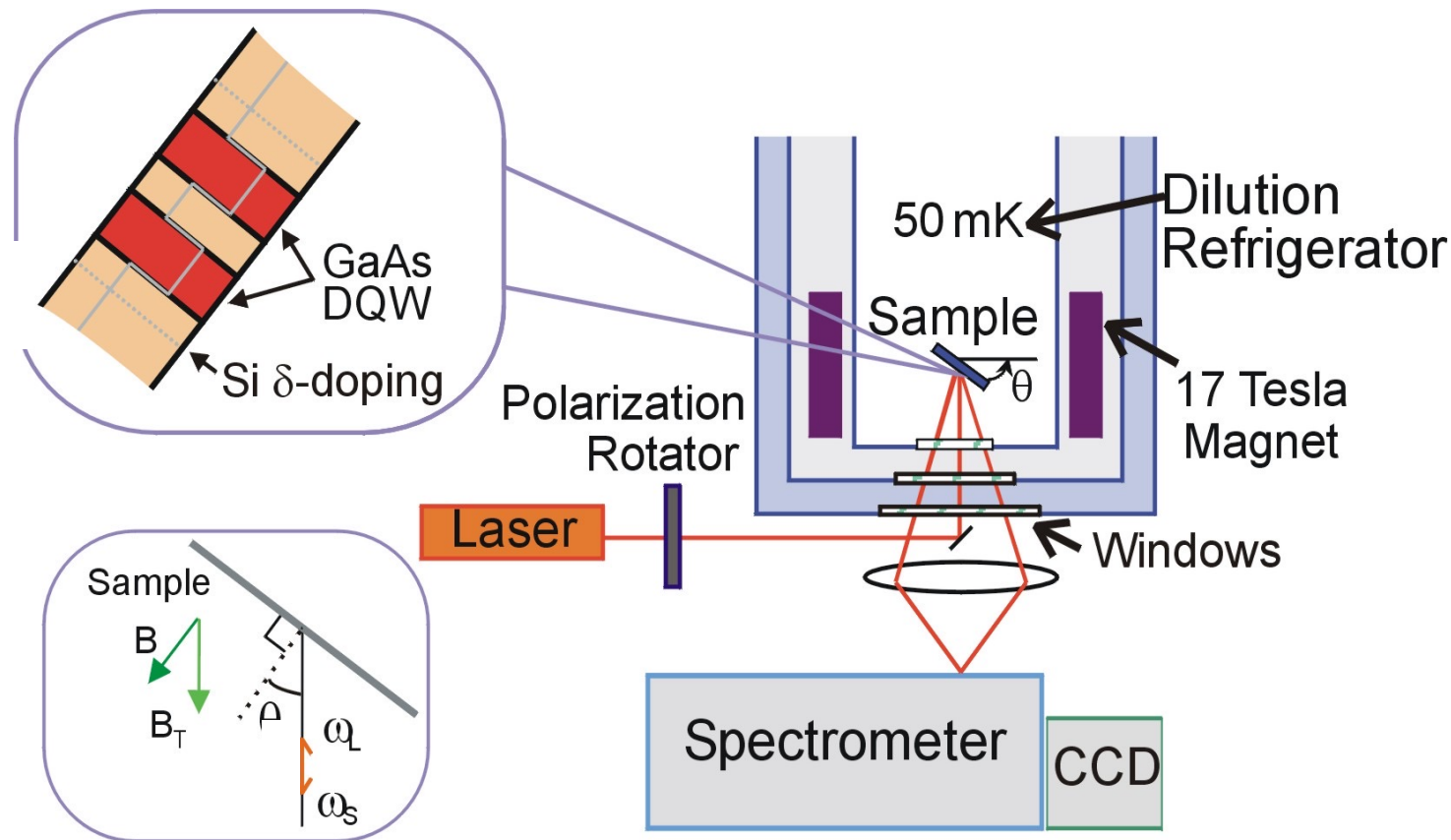
Bell labs

12 hours per day

PhD

Ice-creams and chocolate

# Resonant inelastic light scattering



$$\omega_L - \omega_S = \pm \omega(q) \quad q = |\mathbf{k}_{//}|$$

Translational invariance  $\Rightarrow \mathbf{q} = \mathbf{k}_{L//} - \mathbf{k}_{S//} = (k_L - k_S) \sin \theta < \sim 10^5 \text{ cm}^{-1}$

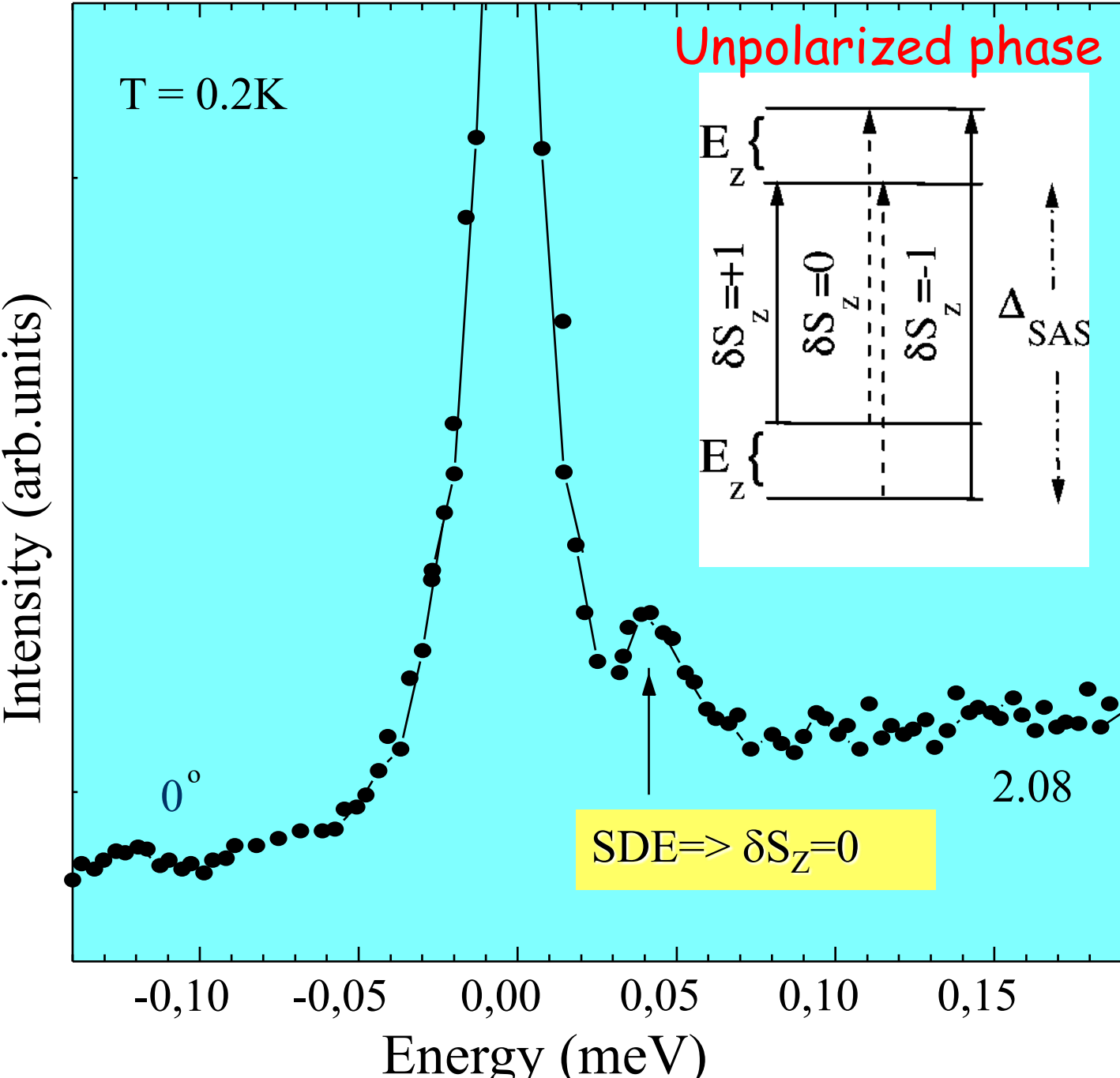
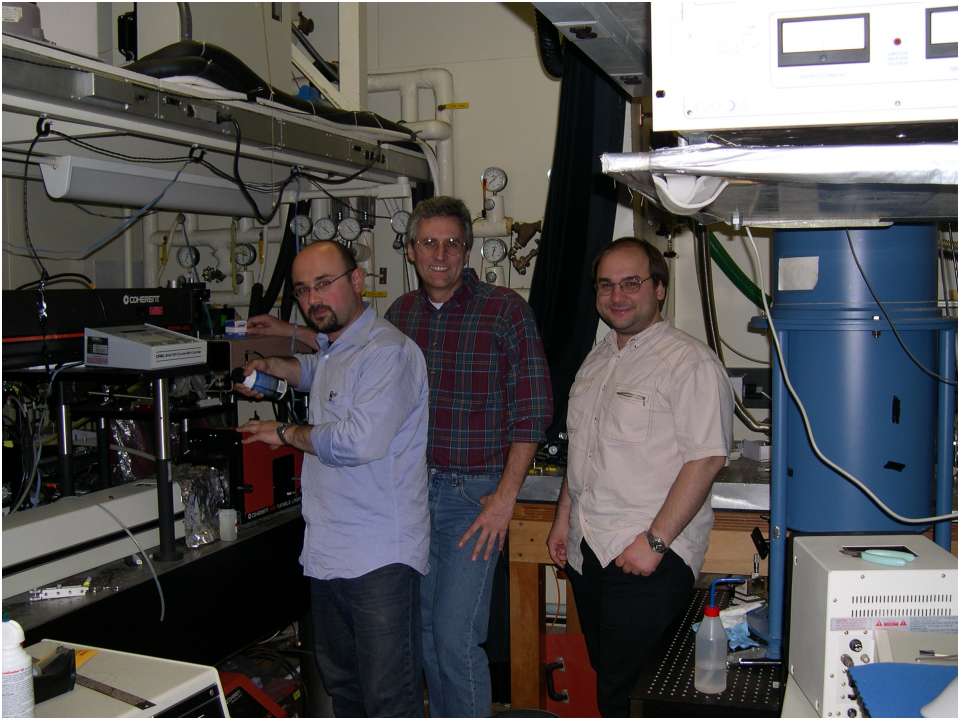


**Collapse of Spin Excitations in Quantum Hall States of Coupled Electron Double Layers**

Vittorio Pellegrini,<sup>1,\*</sup> Aron Pinczuk,<sup>1</sup> Brian S. Dennis,<sup>1</sup> Annette S. Plaut,<sup>2</sup> Loren N. Pfeiffer,<sup>1</sup> and Ken W. West<sup>1</sup>

<sup>1</sup>*Bell Laboratories, Lucent Technologies, Murray Hill, New Jersey 07974*  
<sup>2</sup>*Department of Physics, University of Exeter, Exeter EX4 4QL, United Kingdom*  
(Received 24 September 1996)

Remarkable softenings of long wavelength intersubband spin excitations of dilute electron double layers are observed at even integer quantum Hall states. These excitations in coupled GaAs double quantum wells were probed by resonant inelastic light scattering. Their softening is attributed to enhanced exchange vertex corrections (excitonic binding) in the quantum Hall states. The collapse of the spin-density mode with  $\delta S_z = 0$  to an energy close to the Zeeman splitting suggests the existence of unstable spin-flip intersubband excitations with  $\delta S_z = 1$ . [S0031-9007(96)02143-6]

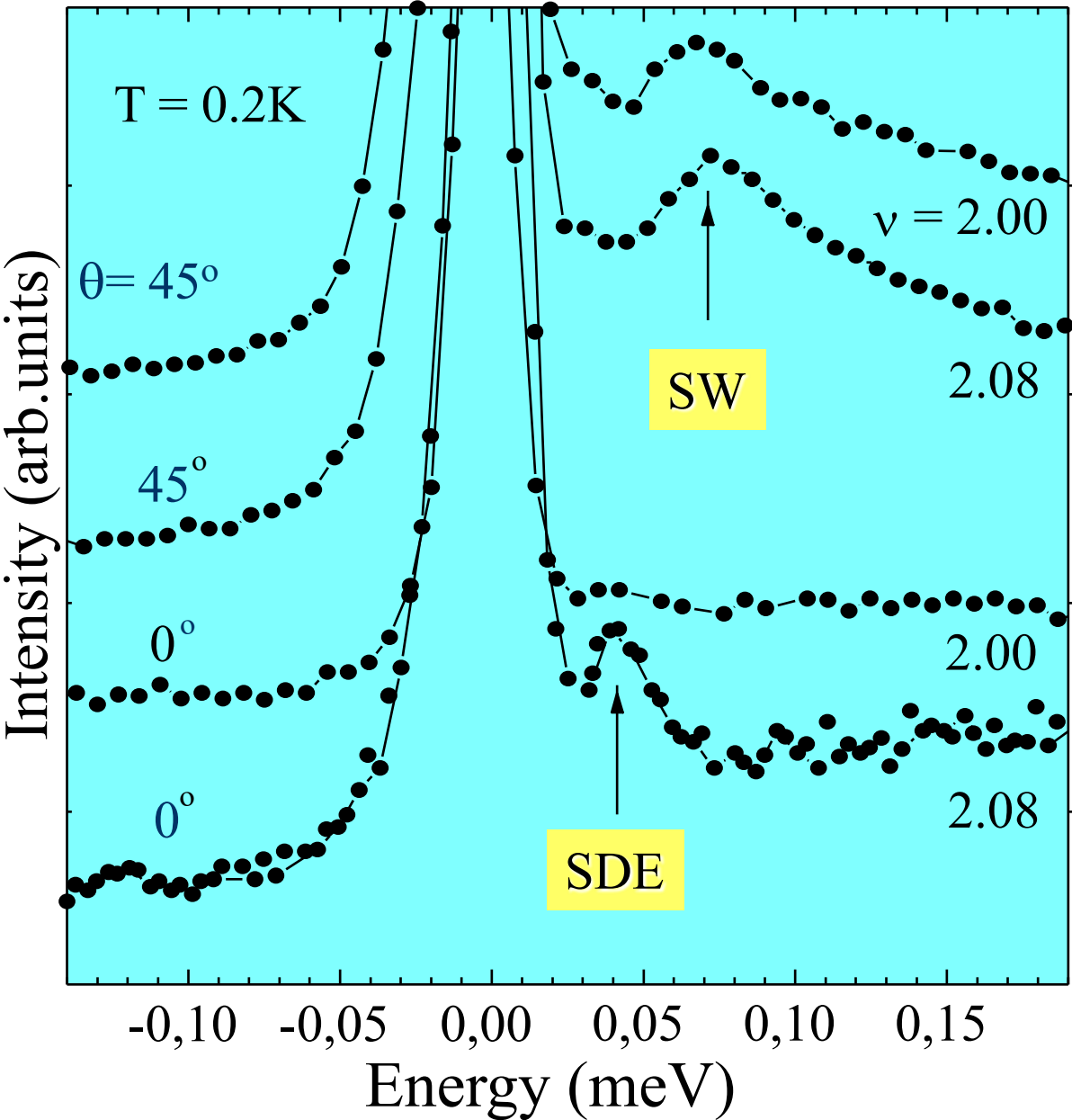
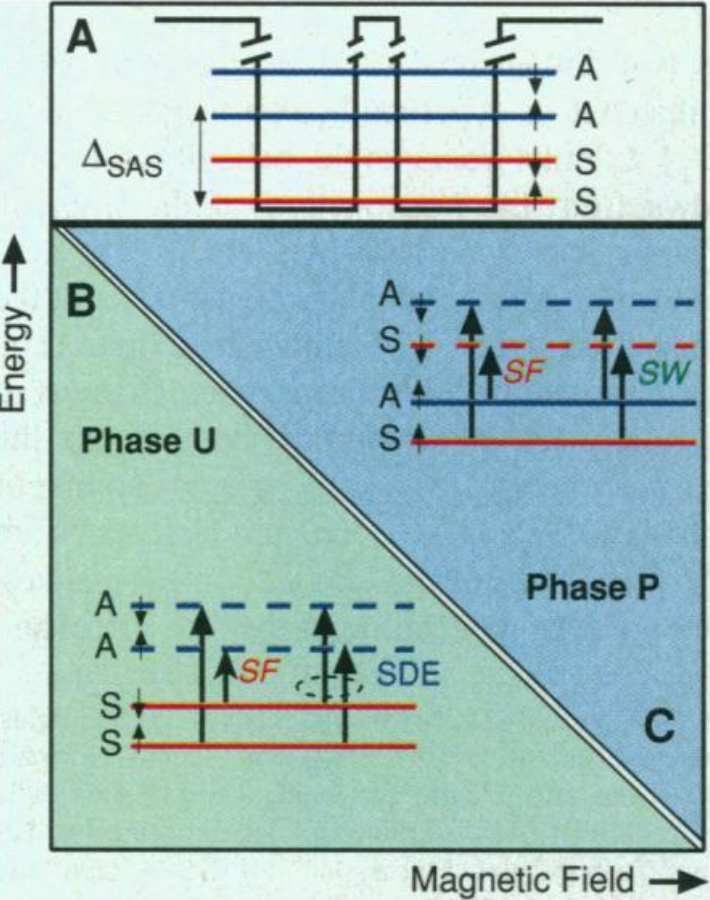


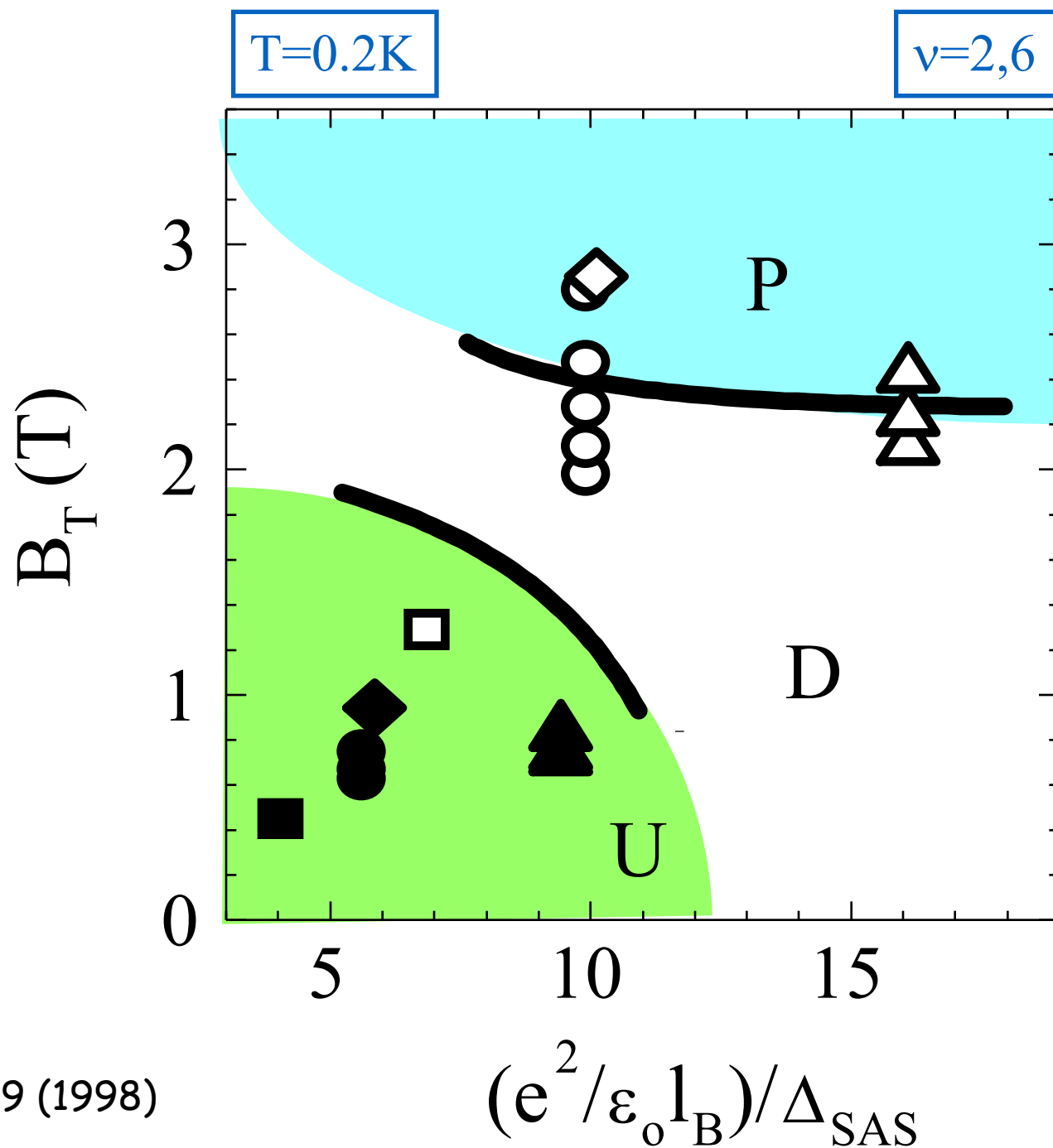


# Evidence of Soft-Mode Quantum Phase Transitions in Electron Double Layers

Vittorio Pellegrini, Aron Pinczuk, Brian S. Dennis, Annette S. Plaut, Loren N. Pfeiffer, Ken W. West

*Science* 281, 799 (1998)





*Science* **281**, 799 (1998)



17 July 1997

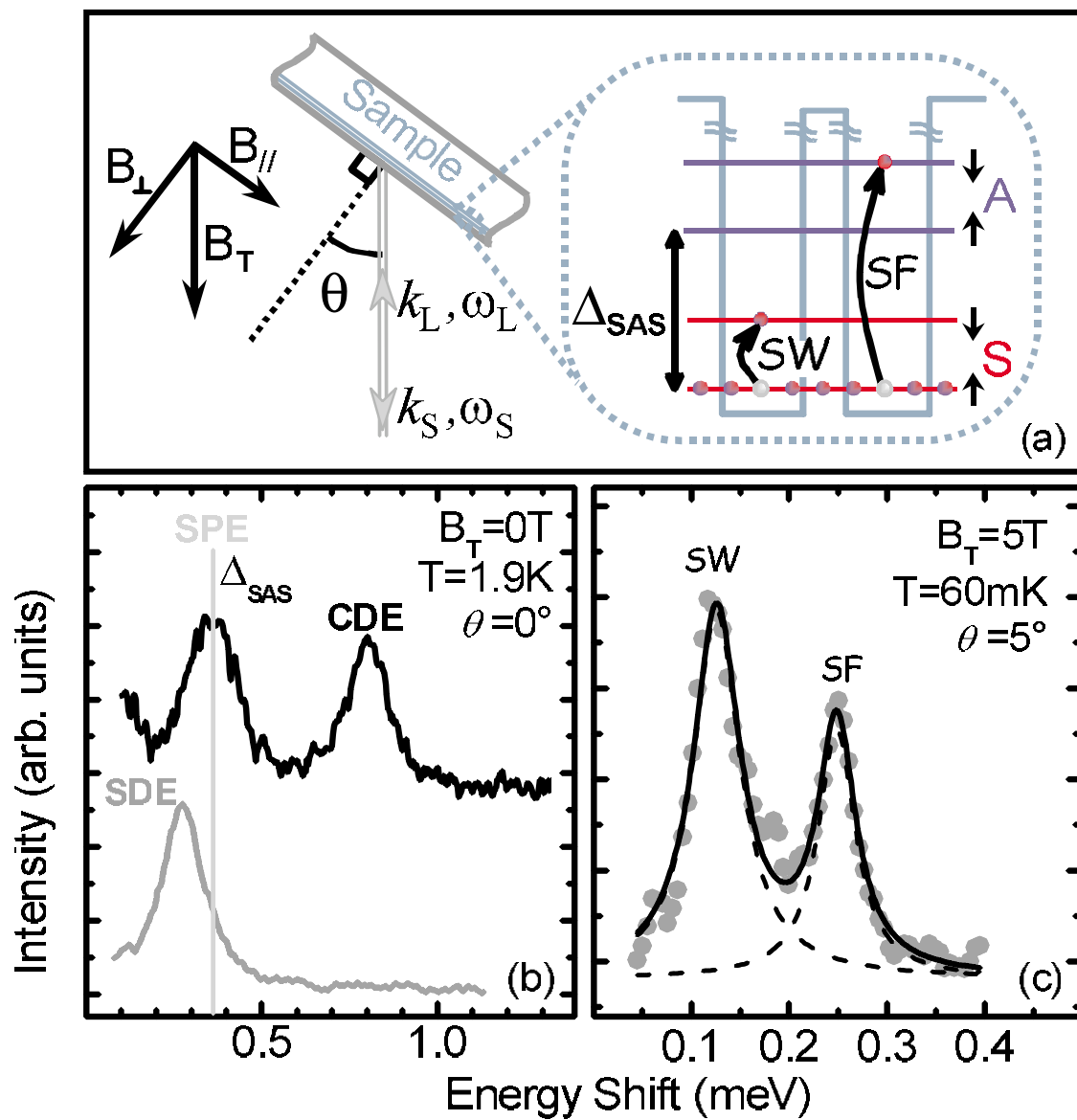




# Collapse again

2003-2005

Pisa Columbia London Paris  
Ice-creams and chocolate



Hartree-Fock prediction

$$E_{SW} = E_Z$$

$$E_{SF} = E_Z + \Delta_{SAS}$$











# Observation of Collapse of Pseudospin Order in Bilayer Quantum Hall Ferromagnets

Stefano Luin,<sup>1,2</sup> Vittorio Pellegrini,<sup>1</sup> Aron Pinczuk,<sup>3,2</sup> Brian S. Dennis,<sup>2</sup> Loren N. Pfeiffer,<sup>2</sup> and Ken W. West<sup>2</sup>

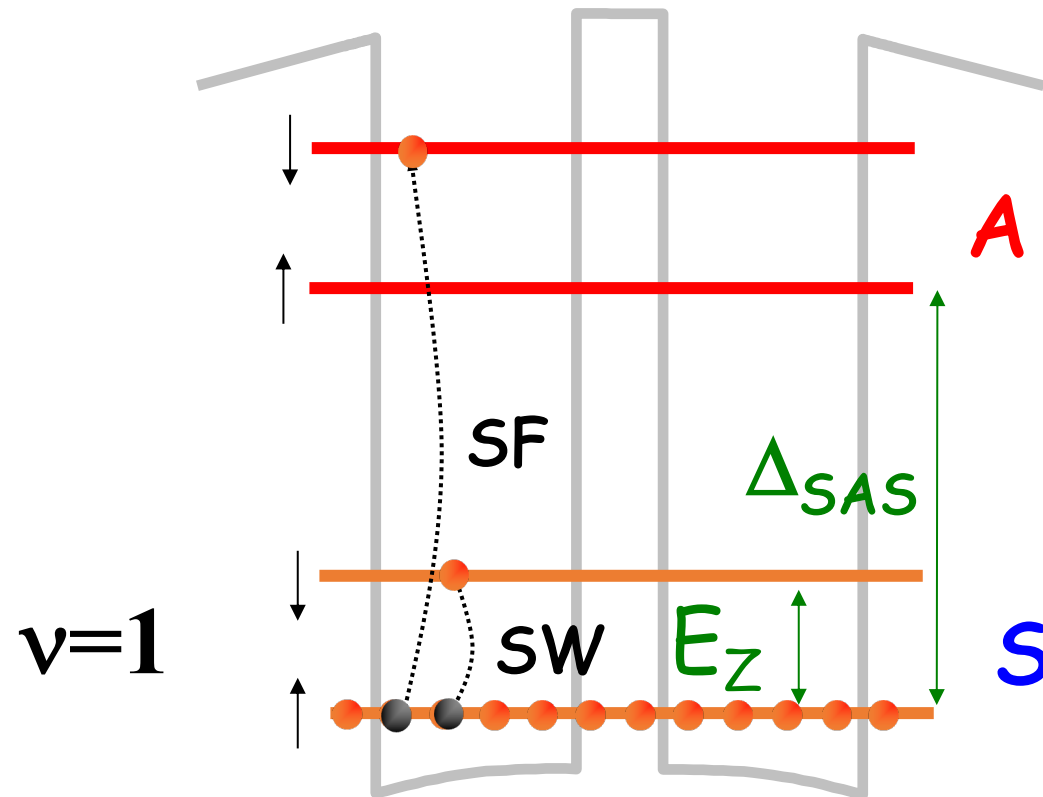
<sup>1</sup>*NEST-INFM and Scuola Normale Superiore, Piazza dei Cavalieri 7, I-56126 Pisa (Italy)*

<sup>2</sup>*Bell Laboratories, Lucent Technologies, Murray Hill, New Jersey 07974, USA*

<sup>3</sup>*Dept. of Physics, Dept. of Appl. Phys. and Appl. Math, Columbia University, New York, New York 10027, USA*

(Received 29 November 2004; published 13 April 2005)

The Hartree-Fock paradigm of bilayer quantum Hall states with finite tunneling at filling factor  $\nu = 1$  has full pseudospin ferromagnetic order with all the electrons in the lowest symmetric Landau level. Inelastic light scattering measurements of low energy spin excitations reveal major departures from the paradigm at relatively large tunneling gaps. The results indicate the emergence of a novel correlated quantum Hall state at  $\nu = 1$  characterized by reduced pseudospin order. Marked anomalies occur in spin excitations when pseudospin polarization collapses by application of in-plane magnetic fields.



## Hartree-Fock prediction

$$E_{SW} = E_Z$$

$$E_{SF} = E_Z + \Delta_{SAS}$$

+ correlations

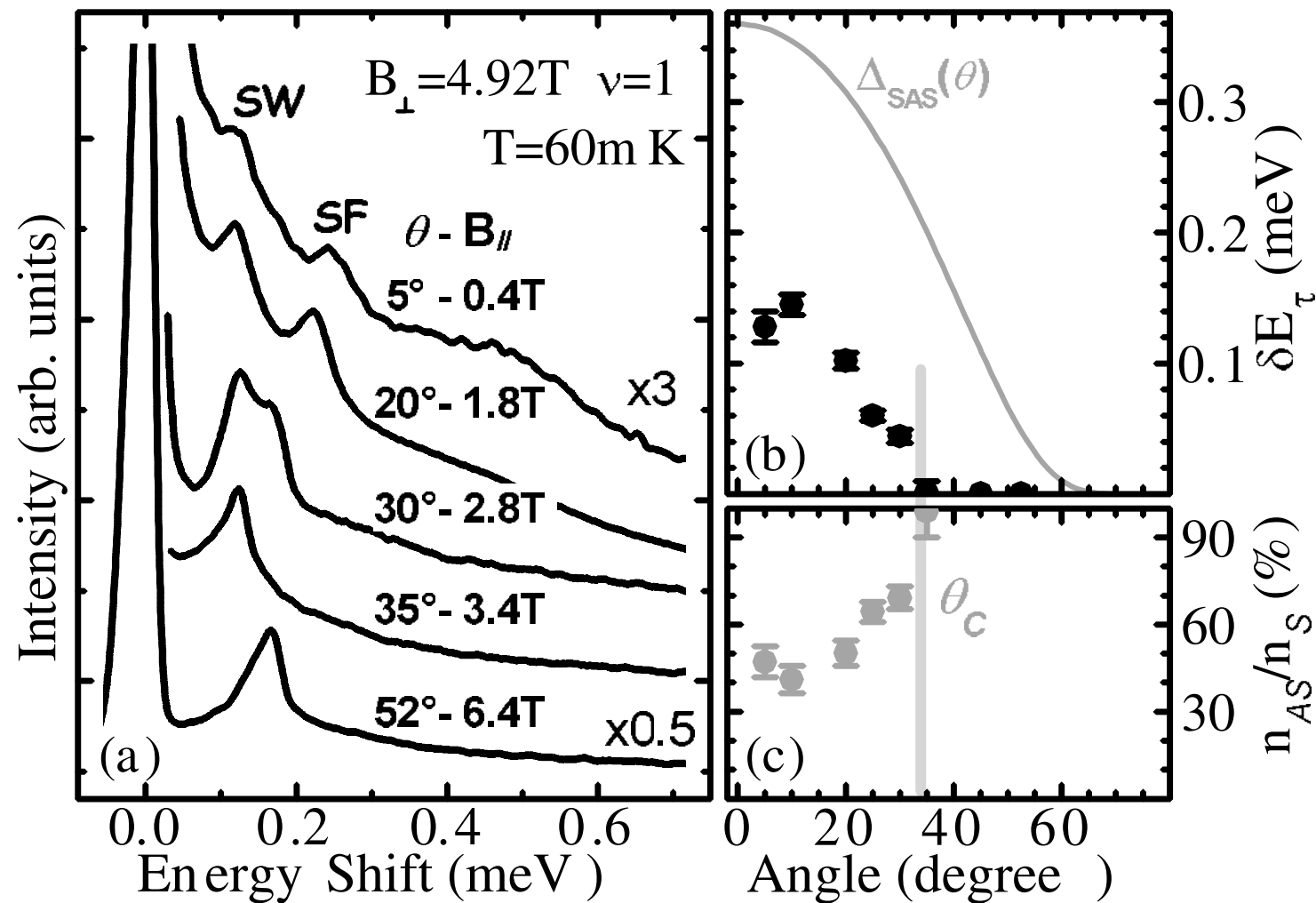
$$E_{SW} = E_Z$$

$$E_{SF} = E_Z + \Delta_{SAS} \cdot \langle \tau^x \rangle$$

$$(E_{SF} - E_{SW}) / \Delta_{SAS} = \langle \tau^x \rangle$$

# COLLAPSE OF PSUDOSPIN ORDER $\langle \tau_x \rangle < 1$

$$\langle \tau_x \rangle = (n_S - n_{AS}) / (n_S + n_{AS}) = 1 - 2n_{ex} / n_T$$





# Collapse again and again

2005-2010

Pisa Columbia London Paris

Zero dimensional

Ice-creams and chocolate

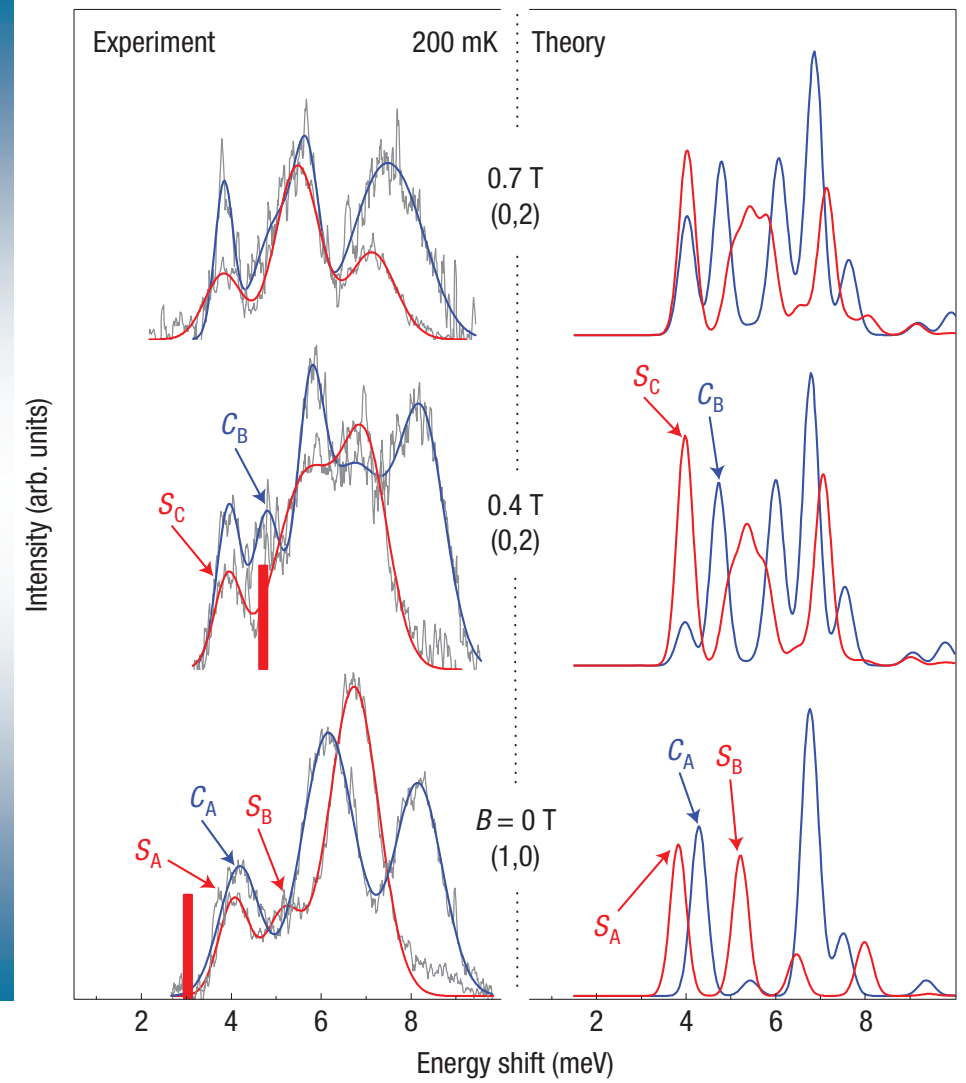
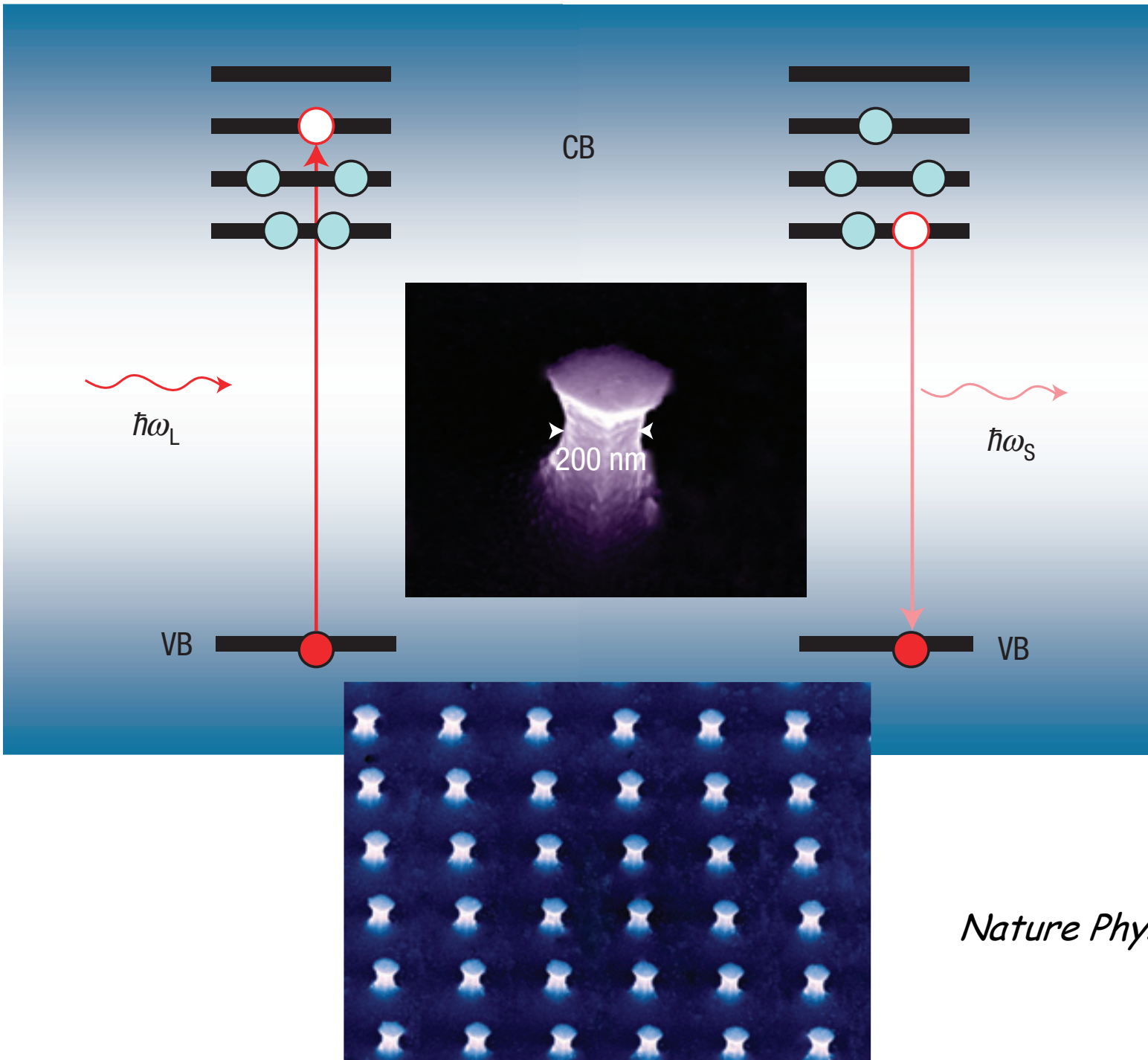


07.09.2009 21:18









*Nature Physics* 4, 467 (2008)





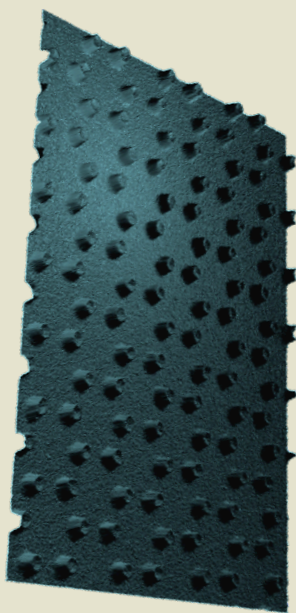
# Being artificial not superficial

2018-2021

Email and zoom

Artificial graphene

Ice-creams and chocolate



$$V_0 \approx 10 \text{ K}$$

$$d \approx 20 - 100 \text{ nm}$$

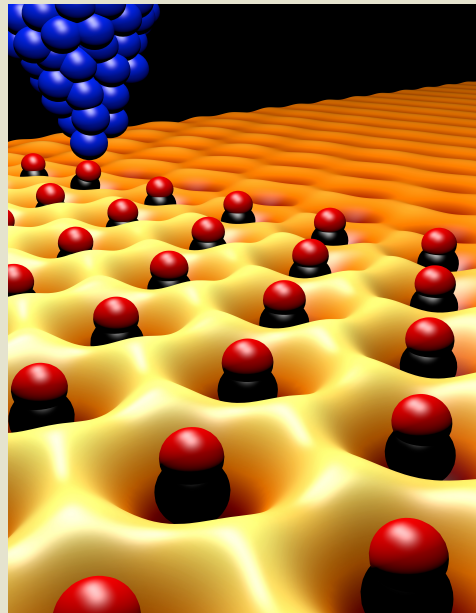
$$N \approx 10 - 10^7$$

$$U \approx 10 \text{ K}$$

$$V \approx 1 \text{ K}$$

$$t \approx 1 - 10 \text{ K}$$

$$T_F \approx 0.1 - 100 \text{ K}$$



$$V_0 \approx 10^3 \text{ K}$$

$$d \approx 1 - 3 \text{ nm}$$

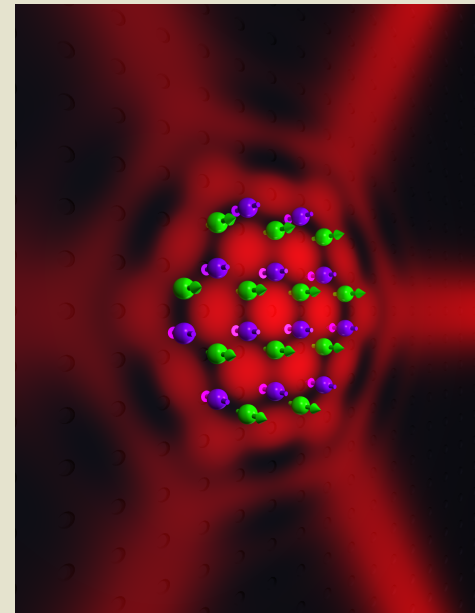
$$N \approx 10^2 - 10^3$$

$$U \approx 600 \text{ K}$$

$$V \ll U$$

$$t \approx 10^3 \text{ K}$$

$$T_F \approx 5 - 500 \text{ K}$$



$$V_0 \approx 10 \text{ mK}$$

$$d \approx 500 \text{ nm}$$

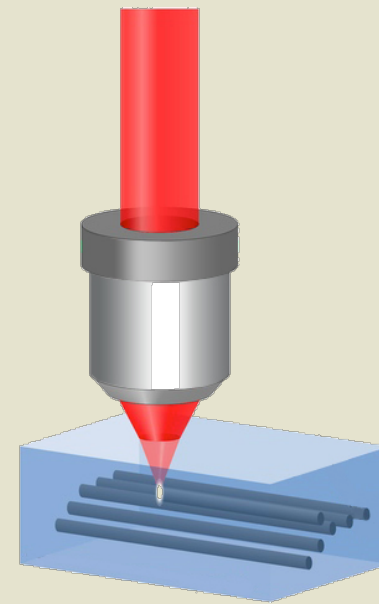
$$N \approx 10^5$$

$$U \approx 100 \text{ nK}$$

$$V \ll U$$

$$t \approx 0.1 - 10^3 \text{ nK}$$

$$T_F \approx 100 \text{ nK}$$



$$\Delta n \approx 10^{-3}$$

$$d \approx 15 \text{ mm}$$

$$N \approx 10 - 10^3$$

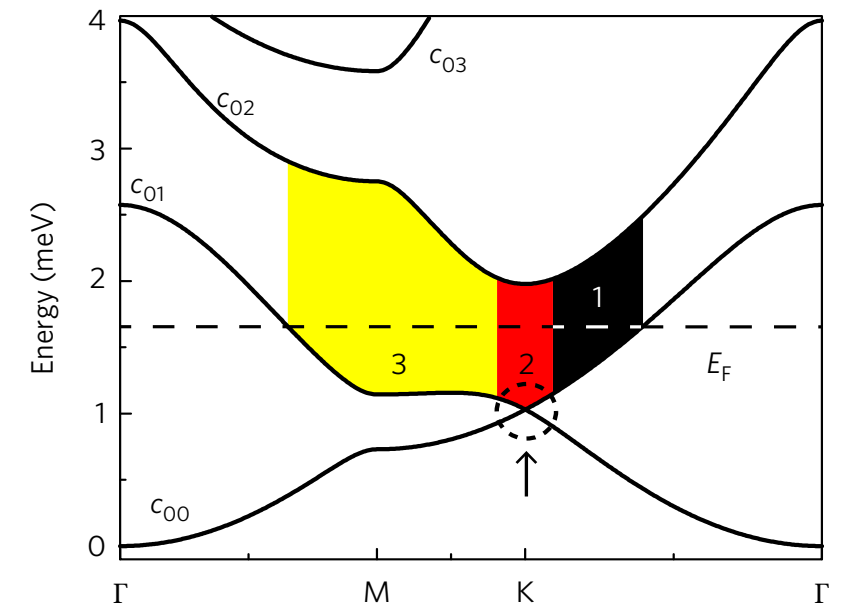
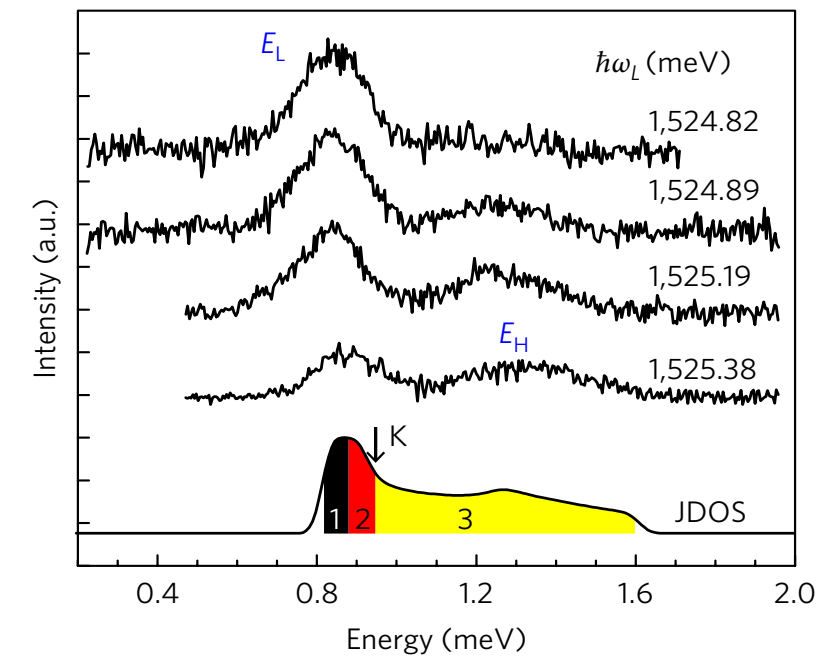
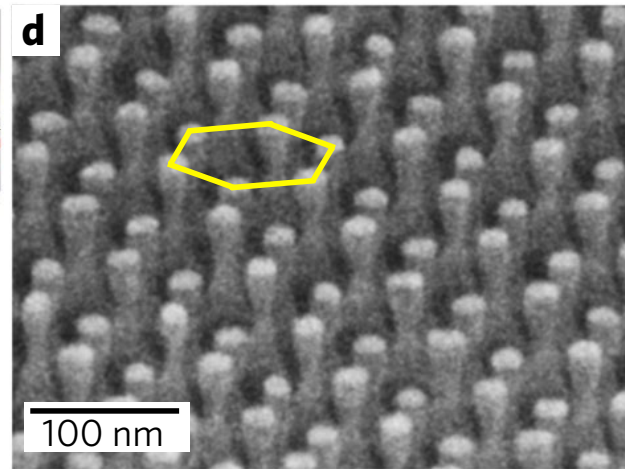
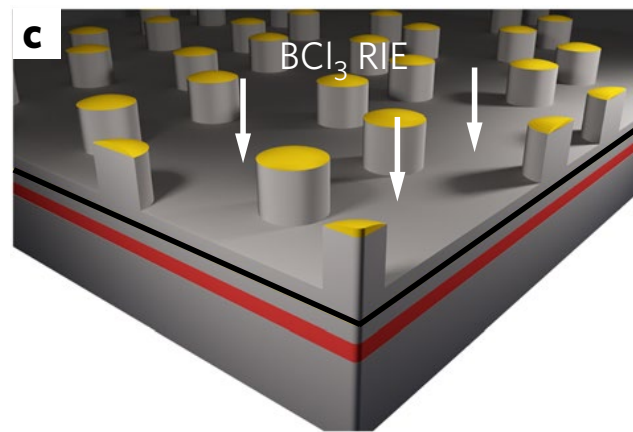
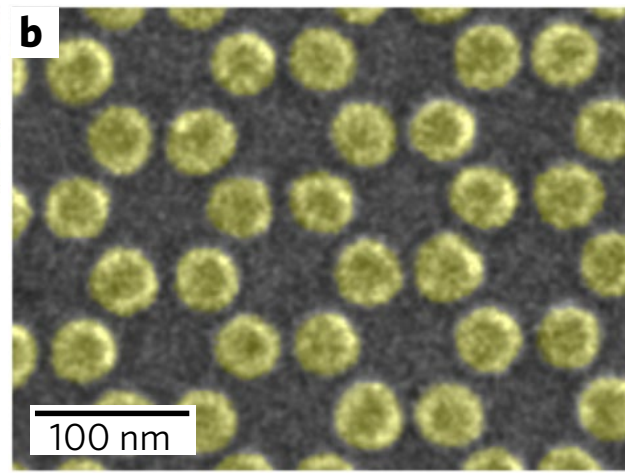
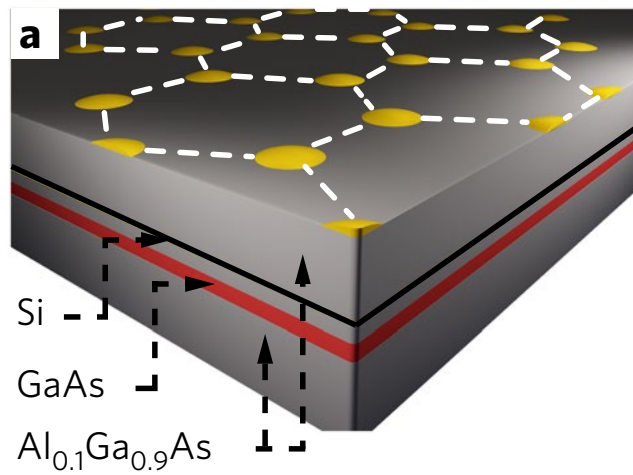
$$n/a$$

$$n/a$$

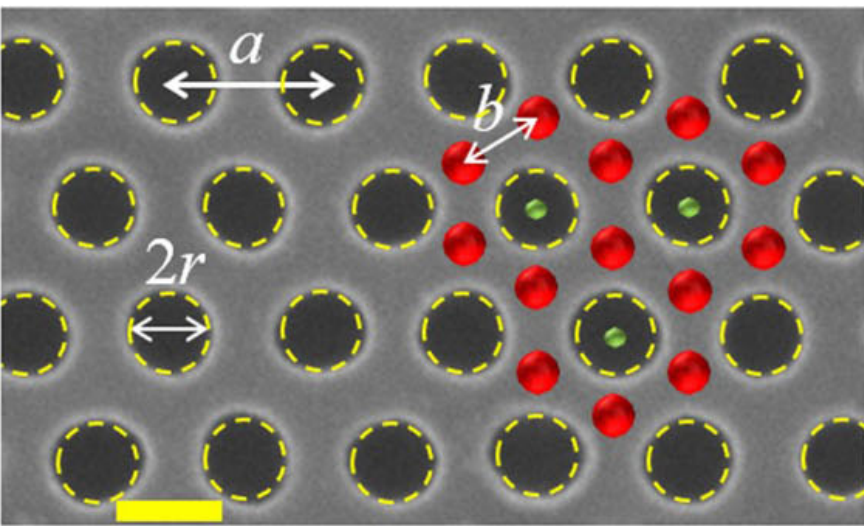
$$c_0 \approx 1/\text{cm}$$

$$n/a$$





*Nature Nanotech* 13, 29 (2018)



PHYSICAL REVIEW LETTERS **126**, 106402 (2021)

## Observation of Flat Bands in Gated Semiconductor Artificial Graphene

Lingjie Du,<sup>1,2,\*</sup> Ziyu Liu<sup>3</sup>, Shalom J. Wind,<sup>2</sup> Vittorio Pellegrini,<sup>4</sup> Ken W. West,<sup>5</sup> Saeed Fallahi,<sup>6</sup> Loren N. Pfeiffer,<sup>5</sup> Michael J. Manfra,<sup>6</sup> and Aron Pinczuk<sup>2,3,†</sup>

<sup>1</sup>*School of Physics, and National Laboratory of Solid State Microstructures, Nanjing University, Nanjing 210093, China*

<sup>2</sup>*Department of Applied Physics and Applied Mathematics, Columbia University, New York, New York 10027, USA*

<sup>3</sup>*Department of Physics, Columbia University, New York, New York 10027, USA*

<sup>4</sup>*Istituto Italiano di Tecnologia, Graphene Labs, Via Morego 30, I-16163 Genova, Italy*

<sup>5</sup>*Department of Electrical Engineering, Princeton University, Princeton, New Jersey 08544, USA*

<sup>6</sup>*Department of Physics and Astronomy, and School of Materials Engineering, and School of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana 47907, USA*



(Received 17 October 2020; accepted 15 February 2021; published 12 March 2021)

Flat bands near  $M$  points in the Brillouin zone are key features of honeycomb symmetry in artificial graphene (AG) where electrons may condense into novel correlated phases. Here we report the observation of van Hove singularity doublet of AG in GaAs quantum well transistors, which presents the evidence of flat bands in semiconductor AG. Two emerging peaks in photoluminescence spectra tuned by backgate voltages probe the singularity doublet of AG flat bands and demonstrate their accessibility to the Fermi level. As the Fermi level crosses the doublet, the spectra display dramatic stability against electron density, indicating interplays between electron-electron interactions and honeycomb symmetry. Our results provide a new flexible platform to explore intriguing flat band physics.



# Enjoying staying with Aron

2018-2021

Conferences

All around the world

Ice-creams and chocolate



Genova  
20 July 2007









# EMERGENT PHENOMENA IN QUANTUM HALL SYSTEMS

## Founders

**Jim Eisenstein** (Caltech, Pasadena, CA, USA)

**Sankar Das Sarma** (University of Maryland, College Park, MD, USA)

**Jainendra Jain** (Penn State University, University Park, PA, USA)

**Vittorio Pellegrini** (NEST-CNR-INFN & Scuola Normale Superiore, Pisa, Italy)

**Aron Pinczuk** (Columbia University, New York, NY, USA)

**Steve Simon** (Rudolf Peierls Centre for Theoretical Physics, Oxford, UK)

1. Taos, New Mexico (USA) 2005
2. Penn State University (USA) 2007
3. Lucca (Italy) 2009
4. Beijing (China) 2011
5. Weizmann (Israel) 2014
6. TIFR Mumbai (India) 2016
7. Beijing (China) 2019
8. Princeton (USA) 2021





Taos July 2005





英杰交流中心

# The 4<sup>th</sup> International Workshop on Emergent Phenomena in Quantum Hall Systems

July 2011





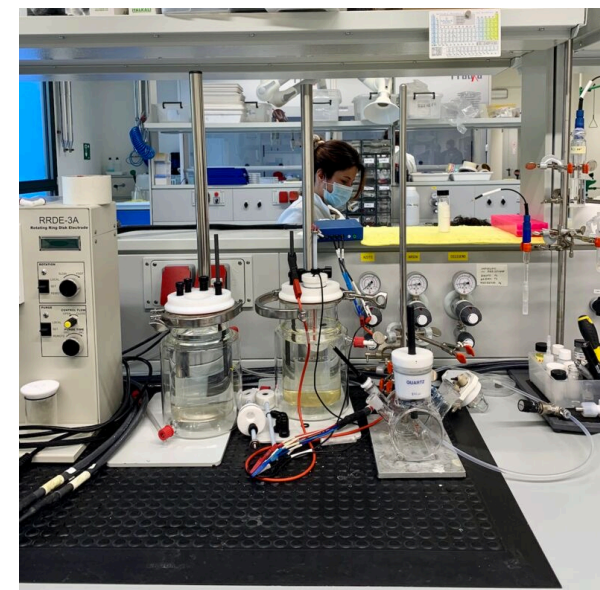
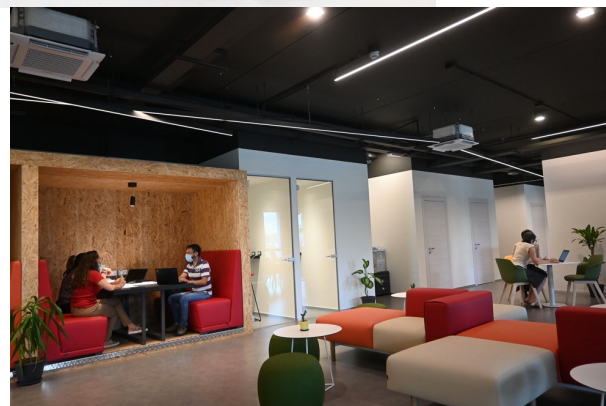
# BeDimensional



BE DIMENSIONAL

BeDimensional is a spin-off company of IIT - Istituto Italiano di Tecnologia founded in 2016 and dedicated to the production and exploitation of innovative materials obtained via the use of two-dimensional crystals including graphene

*spin-off*  
**iit**  
ISTITUTO  
ITALIANO  
DI TECNOLOGIA





[European Commission](#) > [Strategy](#) > [Shaping Europe's digital future](#) > [News](#) >

Shaping Europe's digital future

NEWS ARTICLE | 23 March 2020

## A pinch of graphene to increase batteries' lifetime and capacity

Graphene combines with Silicon to replace graphite:  
+25% in Li-ion performances





**Da:** Aron Pinczuk ap359@columbia.edu  
**Oggetto:** Note from Aron  
**Data:** 27 dicembre 2021, 15:57  
**A:** Vittorio Pellegrini v.pellegrini@bedimensional.it  
**Cc:** apinczuk PNAS ap359@columbia.edu

---

Hi Vittorio,  
Many thanks for email. I am very pleased you reached out to me.  
This year my Holiday Season is complicated. This fall our teaching has been in-person.  
I am now very busy with calculating final grades and related activities. In this work I neglected conventional contacts of the season.

Of course, we wish you and your family had a Buon Natale.

Shall we do a Zoom session? I will set it up.

With kind regards,  
Aron

On 12/26/21 12:43 PM, Vittorio Pellegrini wrote:

Hi Aron  
I trust you are doing fine.

It has been a long time since our last meeting ! I wish you and your family happy holidays! We can get over skipe in the next days.

All the best  
Vittorio



I first met Aron on January 15<sup>th</sup> 1994, late afternoon, in front of the Bell labs in Murray Hills. Before that day Aron was for me like a “star” in the semiconductor physics community. I was a 25<sup>th</sup> year old PhD student at Scuola Normale in Pisa, It was my first trip to the US. Aron came to pick me up with his volvo car and when he saw me he just smiled and brought me to the “Office” in Summit to get a sandwich. When I remember that precise moment I always feel something special in my heart.

After spending one year in Bell labs in 1994, we collaborated over the years and we met regularly often in airports (our typical meeting started on Saturday morning ending on Monday morning). Paris, Madrid, London, Rome, Munich. On top of that I was regularly flying to New Jersey 2-3 times per year. He also came to Scuola Normale Superiore a few times. The first visit was in July 1997 when he attended my PhD degree dissertation. During the years many students of mine came to New York to work with him for some periods of time. In 2008 he helped me to spend a semester at Columbia University.

Every meeting with Aron was unique, full of discussion and pleasant breaks looking for some chocolate! We also organized together several conferences in Italy Erice and Lucca and in the US (I remember a beautiful one at Penn state). They were all fantastic experiences with many colleagues and friends. He introduced me to that community of great people and of course to Eli Burstein who I first met during the March meeting in 1994.

Aron had an influential and humble lifestyle, He was brilliant ironic simple crisp. Life is a path. I’m proud and feel fortunate that Aron gave to me the opportunity to bring my path close to him for such a long time.

I will never forget Aron.

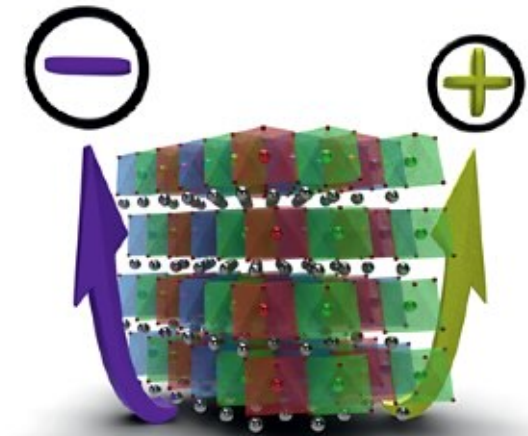


*Aron and SSC*

# Aron Pinczuk

and

## Solid State Communications



Submit On-line: [www.elsevier.com/locate/ssc](http://www.elsevier.com/locate/ssc)



The journal was established 1963, when the *Journal of Physics and Chemistry of Solids* split its letters section to create *Solid State Communications* which is published bimonthly.

*Elias Burnstein* served as founding chief editor until 1992.

He was succeeded by *Manuel Cardona* until 2004.

*Aron Pinczuk* took over until 2020 when *François Peeters* became Editor-in-Chief.



Professor Aron Pinczuk  
Editor in Chief of Solid State Communications  
(2005-2019)

# SPECIAL ISSUE OF SSC IN HONOR OF ARON PINCZUK D

Handling Editors: *François Peeters and Vittorio Pellegrini*

Submission open date: 15 September 2022  
Final manuscript submission deadline: 15 January 2023

Type of manuscripts (no page limit):

- Original work
- Review paper
- Outlook of a research area that is related to the work of Aron

Practical:

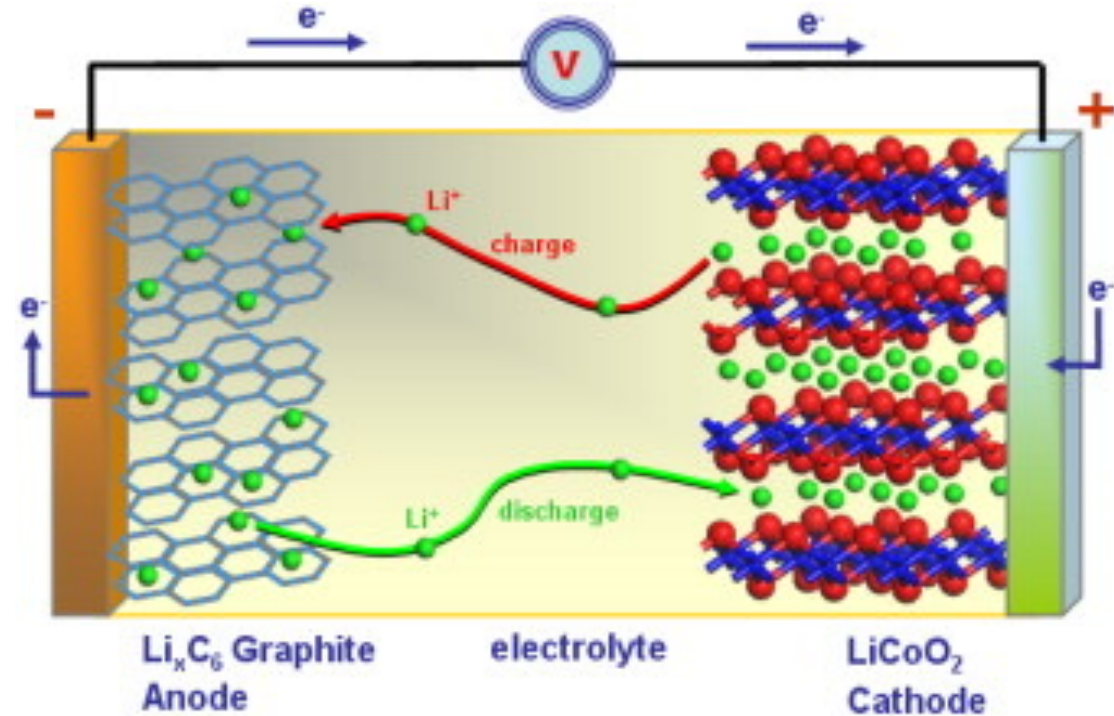
- submission website is located at SSC: [Editorial Manager®](#)
- authors select **VSI: Pinczuk** when reaching the "Article Type" step in the submission process







Alessandro Volta  
1799



John B.  
Goodenough



Akira  
Yoshino



M. Stanley  
Whittingham

Nobel prize  
2019





1 liter of gasoline = 6000Wh

Full charge  
50 liters 3-4 minutes



1 kg of Li-ion battery = 200-250 Wh

Full charge 100 kWh  
> 500 kg > 30 minutes



Our technology is to use silicon/graphene

Silicon is 10 times better than graphite

3579 mAh g<sup>-1</sup> vs 372 mAh g<sup>-1</sup>

Li<sub>15</sub>Si<sub>4</sub> vs LiC<sub>6</sub>

Alloying vs Intercalation



Silicon is not stable

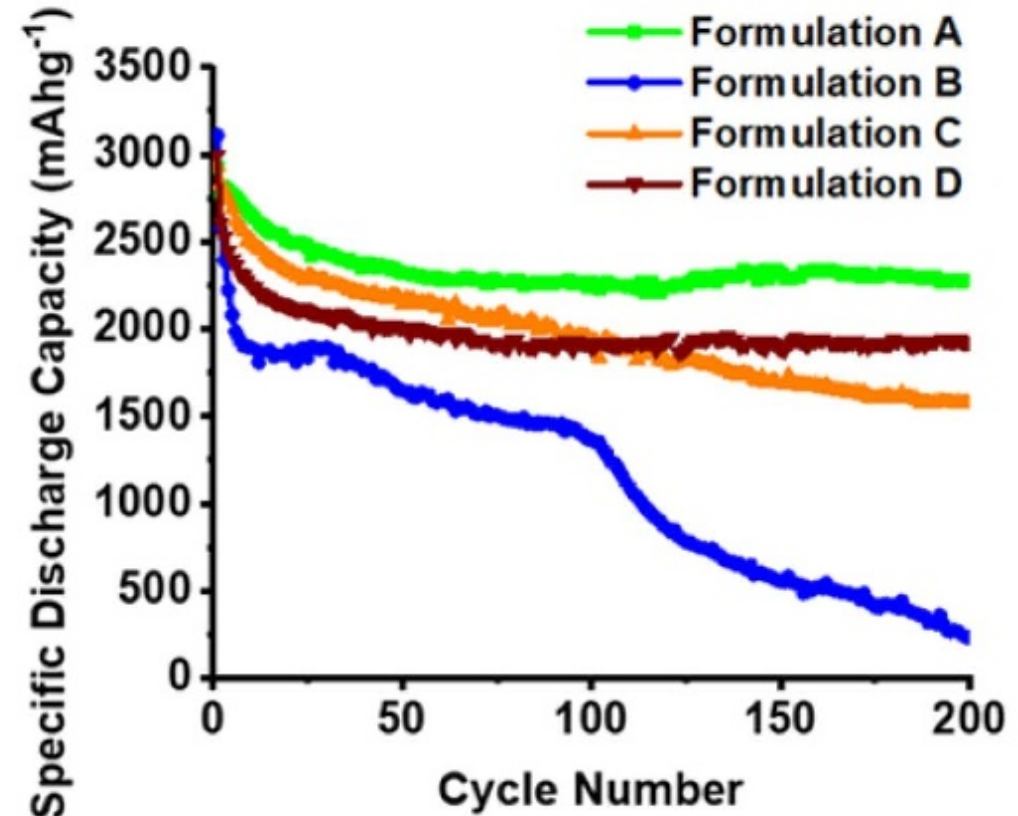
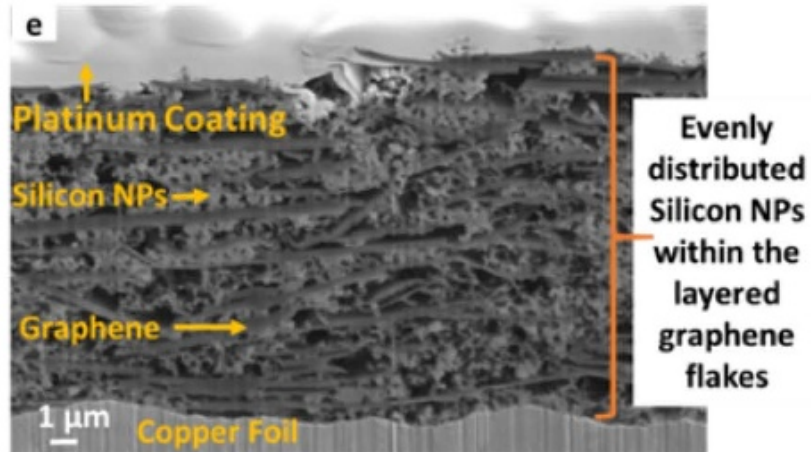
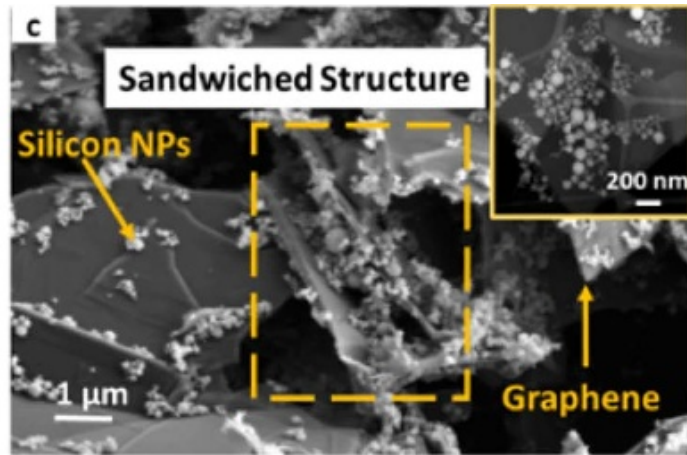


By combining Silicon with a small amount of graphene we make the composite material stable



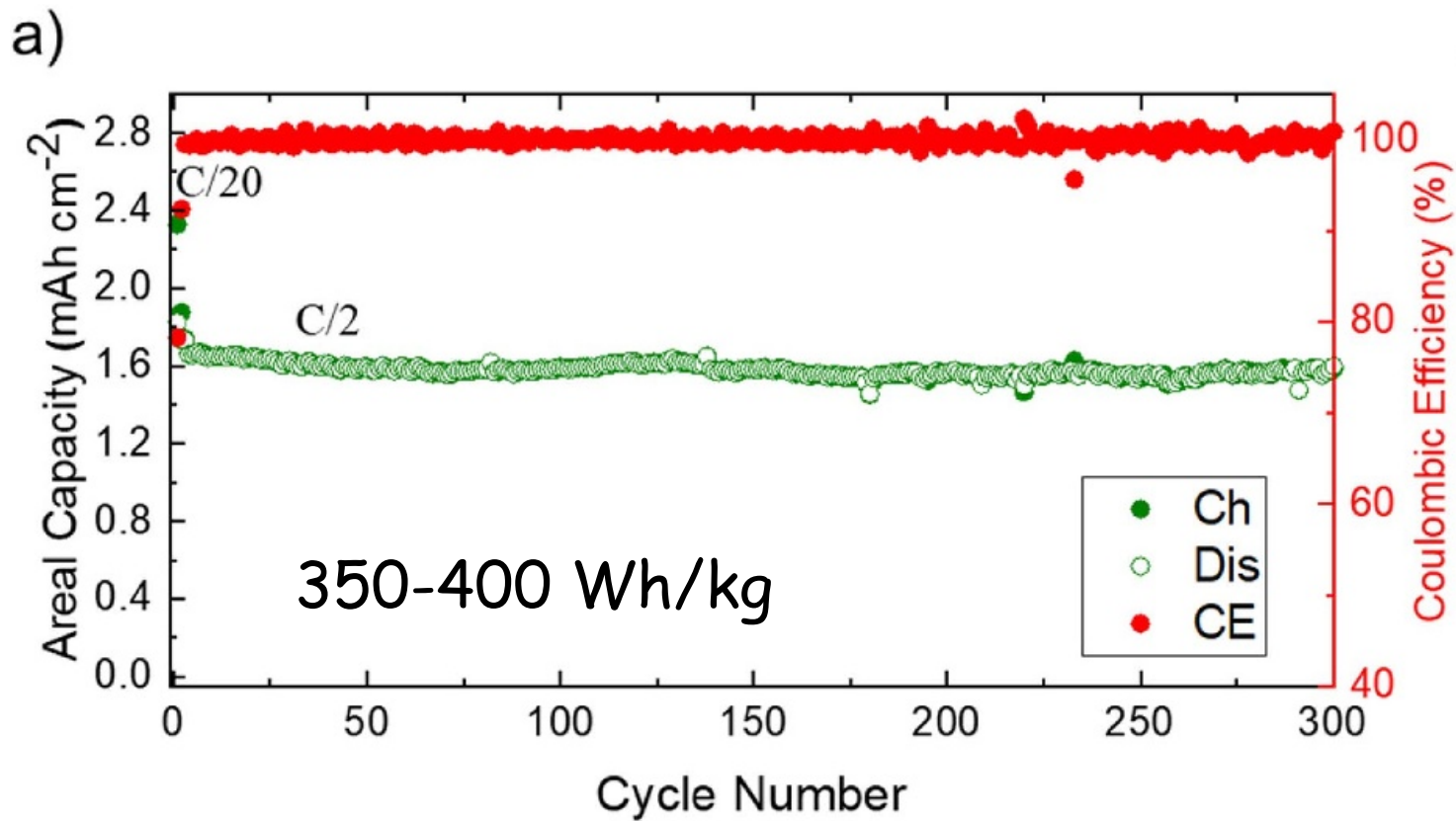


# SILICON/GRAPHENE ANODE IN LI-ION BATTERIES

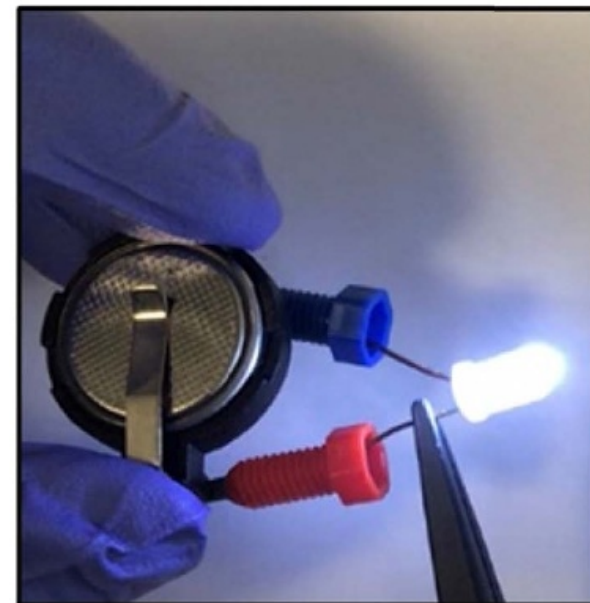


*2D Materials* 8, 015012 (2021)

# SILICON/GRAPHENE FULL LI-ION BATTERY PROTOTYPE



b)



*2D Materials* 8, 035014 (2021)