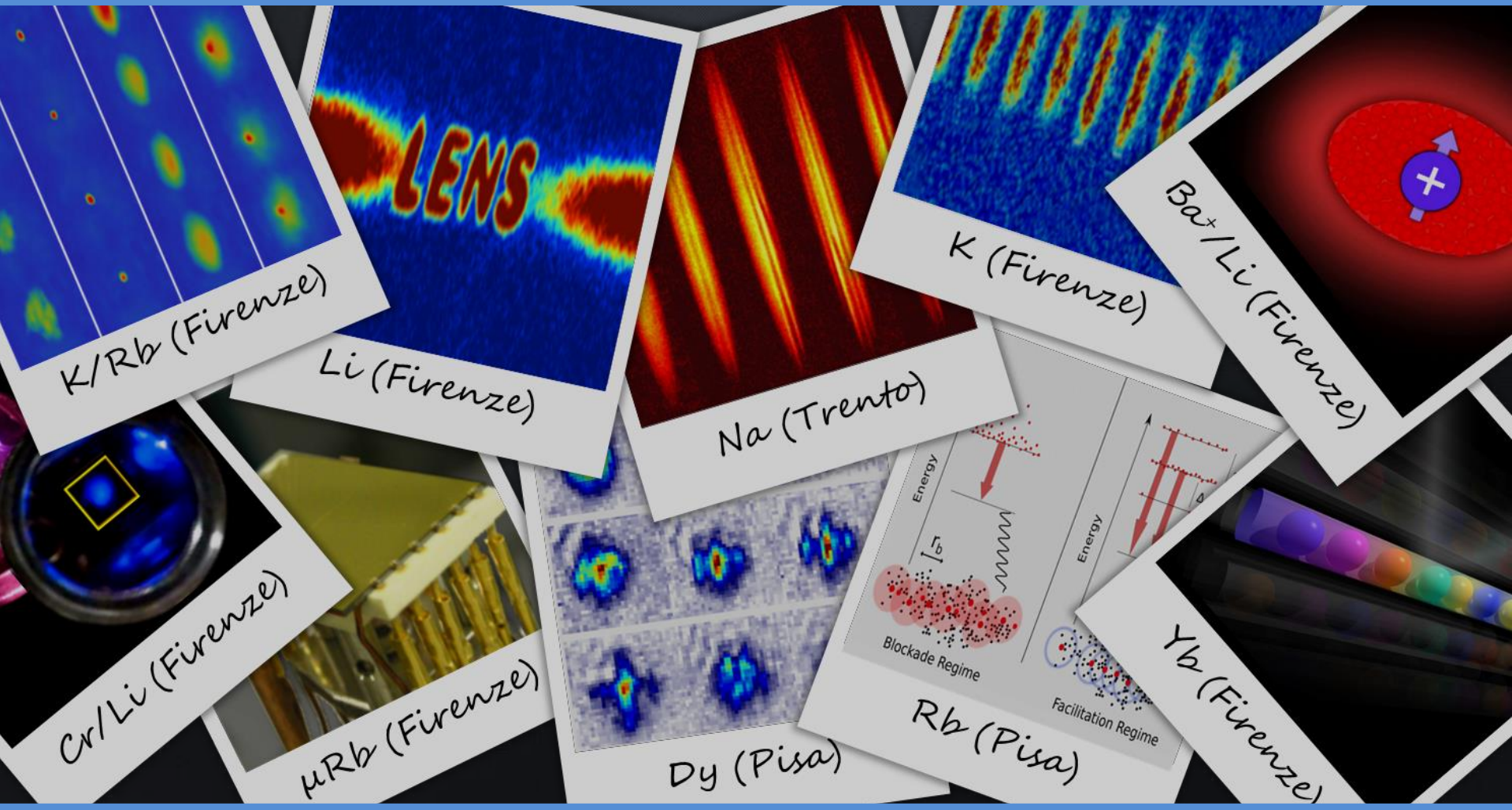
25 years of quantum degenerate atomic gases at INO-CNR-LENS: just a first step



Massimo Inguscio

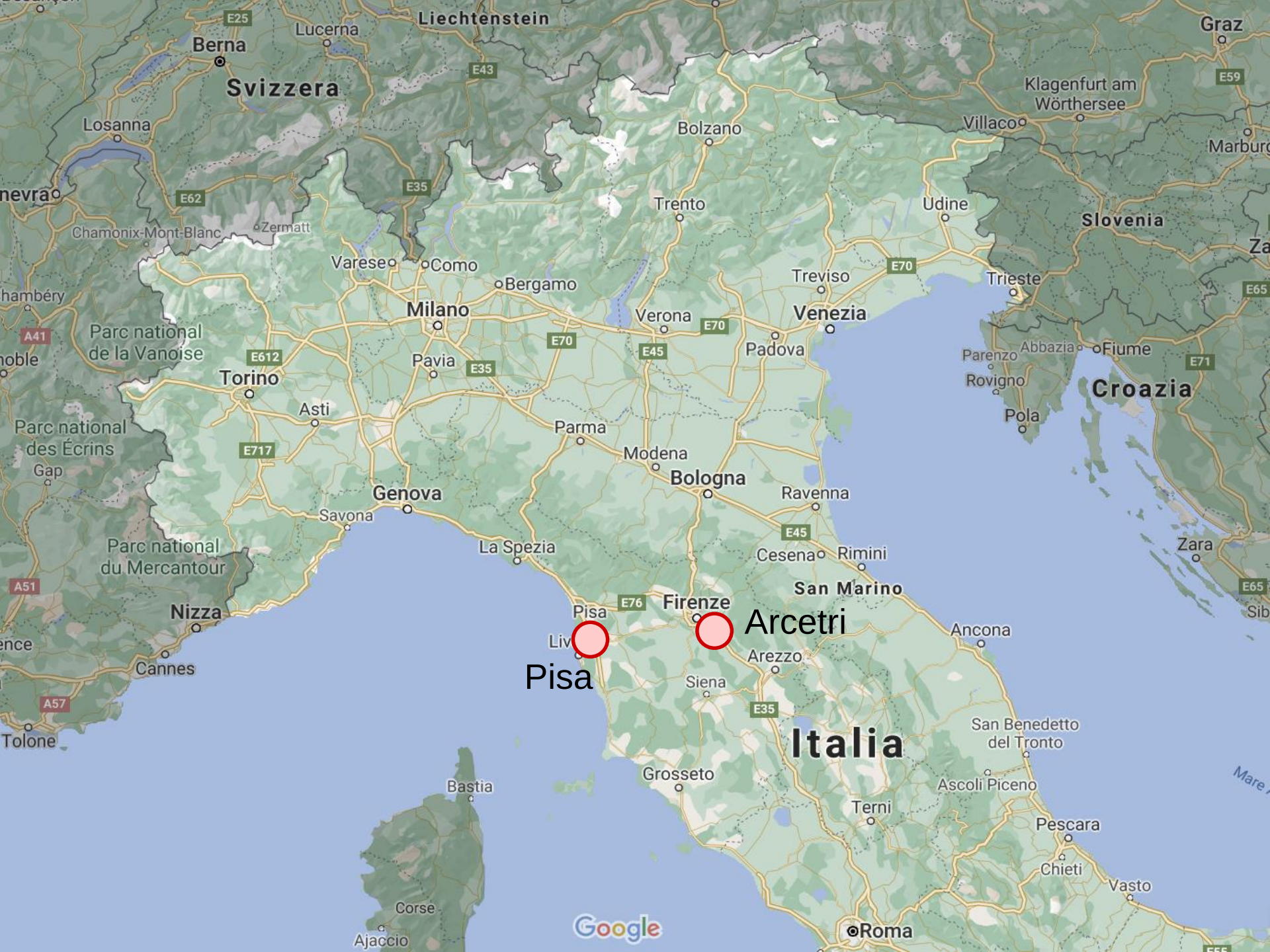
CNR INO Annual Symposium, November 23rd 2020

1995 June 11th-16th, Capri (Italy)
20th International Conference on Laser Spectroscopy

BEC Announcement

1998, Varenna (Italy)
CXL Summer School «Bose-Einsten Condensati ases»

Varenna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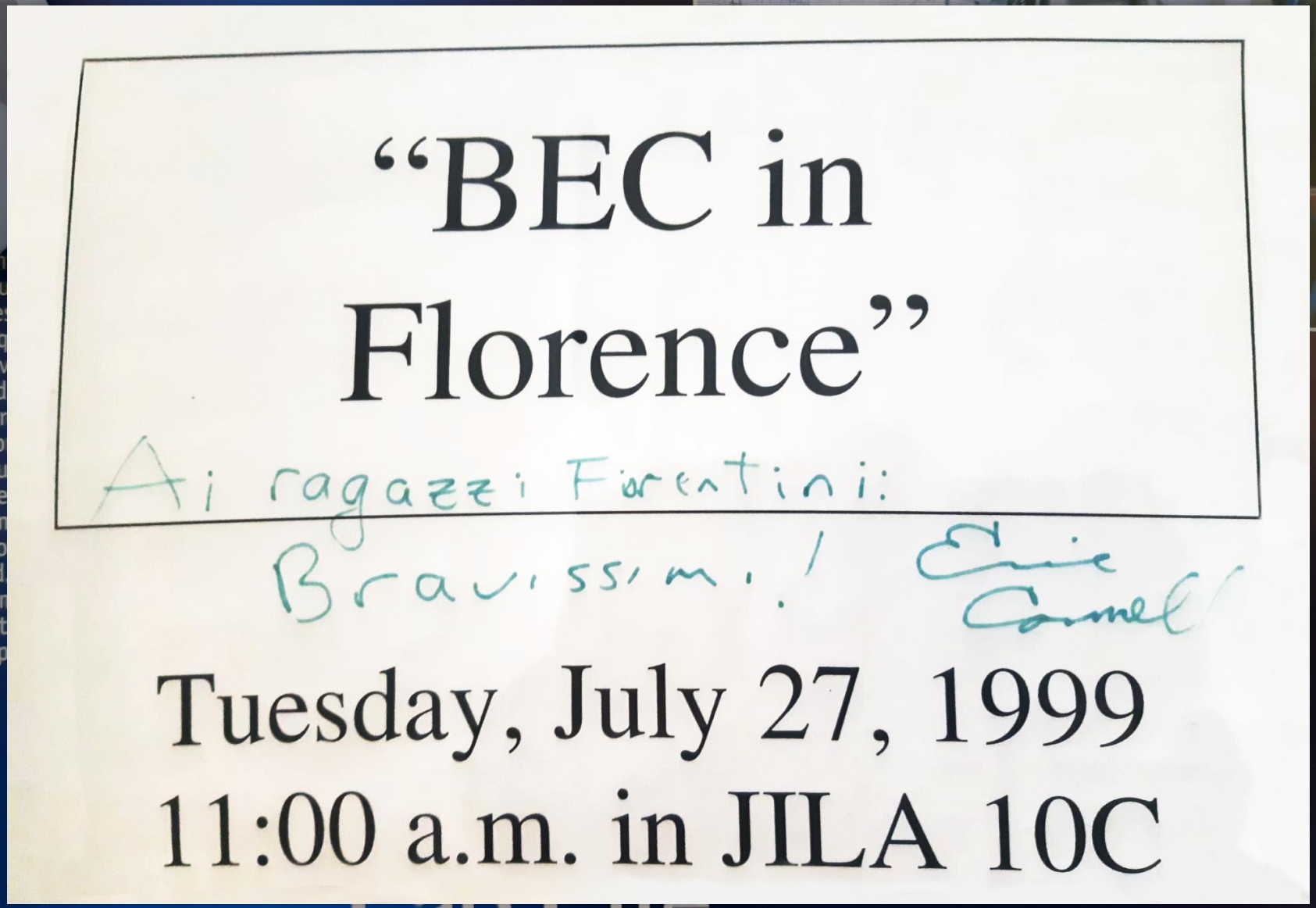
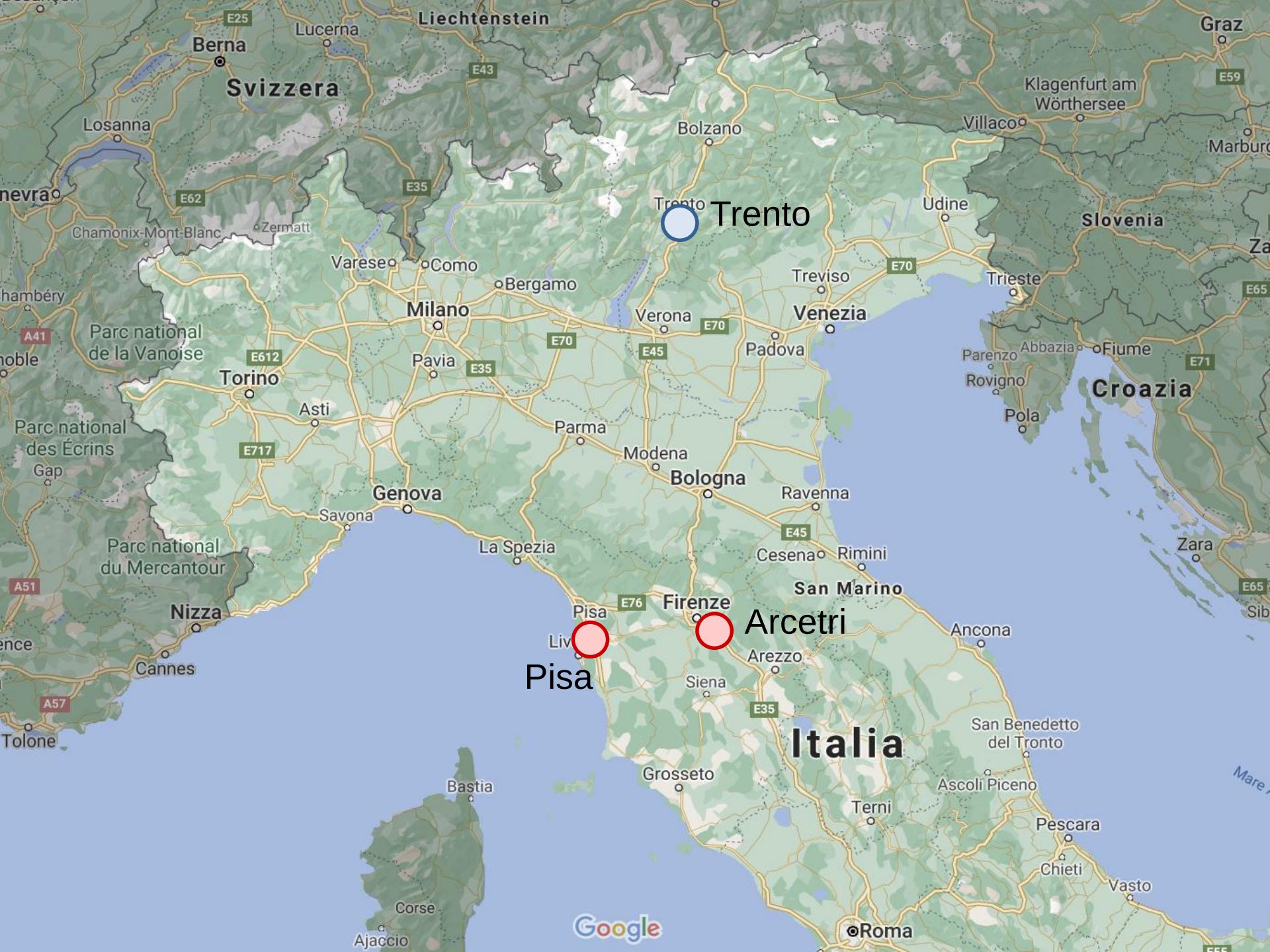
1997, Arcetri (Firenze)
Cataliotti, Tino, Prevedelli, Inguscio, Fort, Marin, Ricci

Setting up for BEC

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BEC Center CNR-INO Trento

F. Dalfovo, S. Giorgini,
L. Pitaevskii, S. Stringari

Theory of Bose-Einstein condensation in trapped gases

Rev. Mod. Phys. **71**, 463 (1999)

Highly cited paper:
at present ≈4200 WoS citations

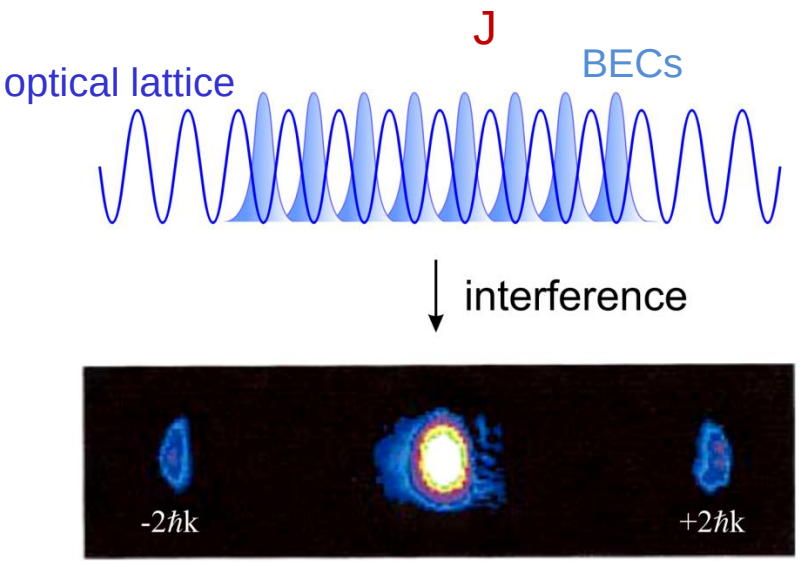
*F. S. Cataliotti et al., Science **293**, 843 (2001)*

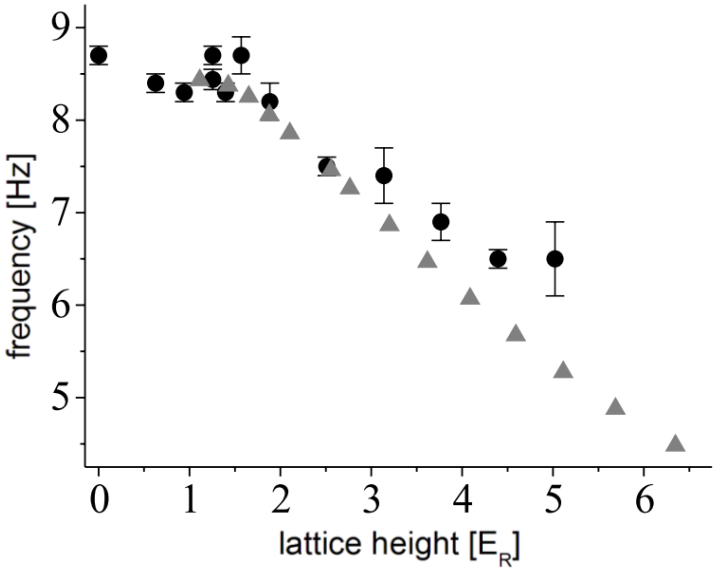
BEC Josephson junctions

Josephson Junction Arrays with Bose-Einstein Condensates

F. S. Cataliotti,[1,2,3] S. Burger,[1,2] C. Fort,[1,2] P. Maddaloni,[1,2,4] F. Minardi,[1,2] A. Trombettoni,[2,5] A. Smerzi,[2,5] M. Inguscio[1,2,3]*

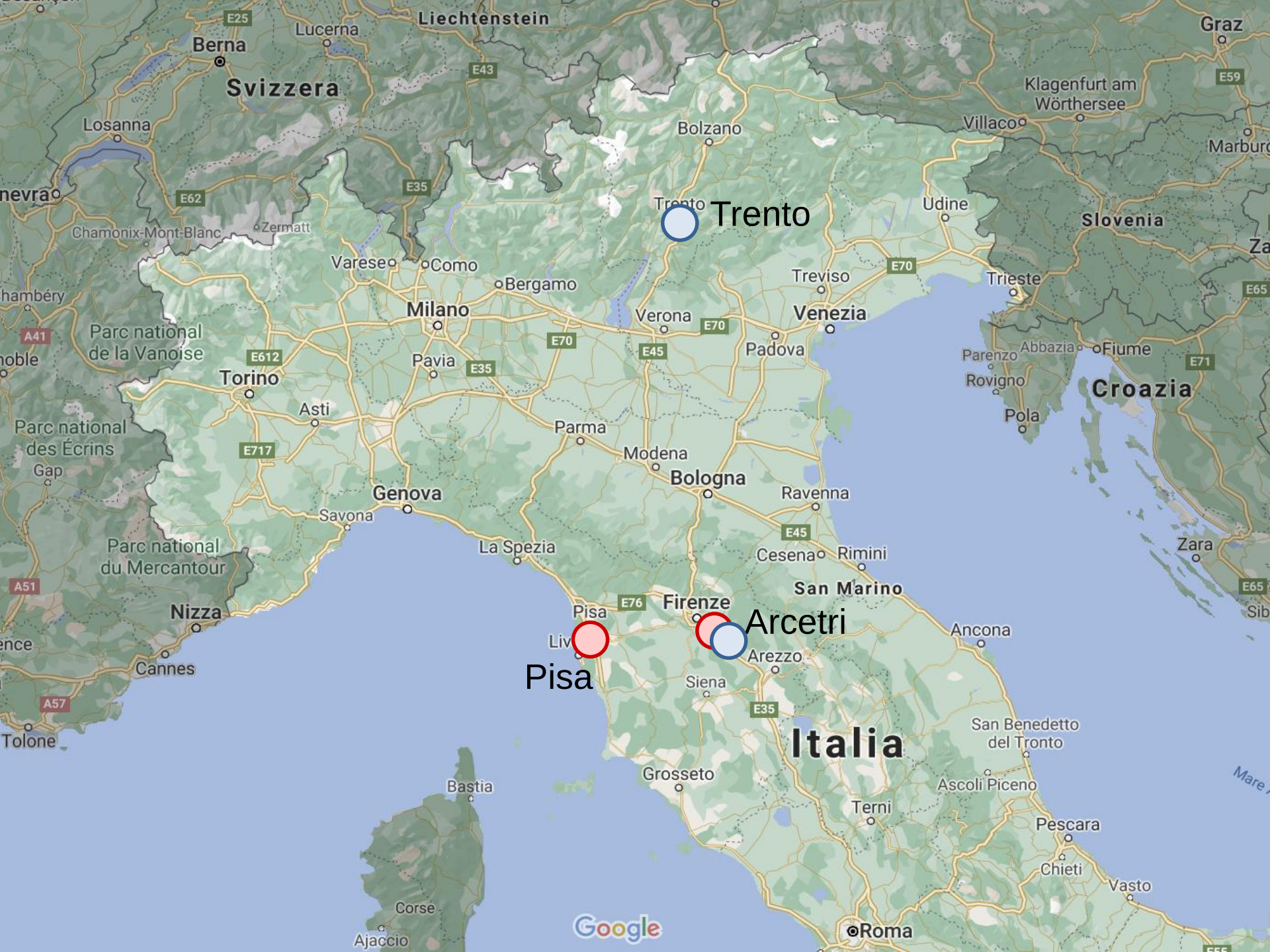
We report on the direct observation of an oscillating atomic current in a one-dimensional array of Josephson junctions realized with an atomic Bose-Einstein condensate. The array is created by a laser standing wave, with the condensates trapped in the valleys of the periodic potential and weakly coupled by the interwell barriers. The coherence of multiple tunneling between adjacent wells is continuously probed by atomic interference. The square of the small-amplitude oscillation frequency is proportional to the microscopic tunneling rate of each condensate through the barriers and provides a direct measurement of the Josephson critical current as a function of the intermediate barrier heights. Our superfluid array may allow investigation of phenomena so far inaccessible to superconducting Josephson junctions and lays a bridge between the condensate dynamics and the physics of discrete nonlinear media.





Atomic Josephson junctions arrays with BECs in optical lattices

Coherence, superfluid transport, superfluidity breakdown…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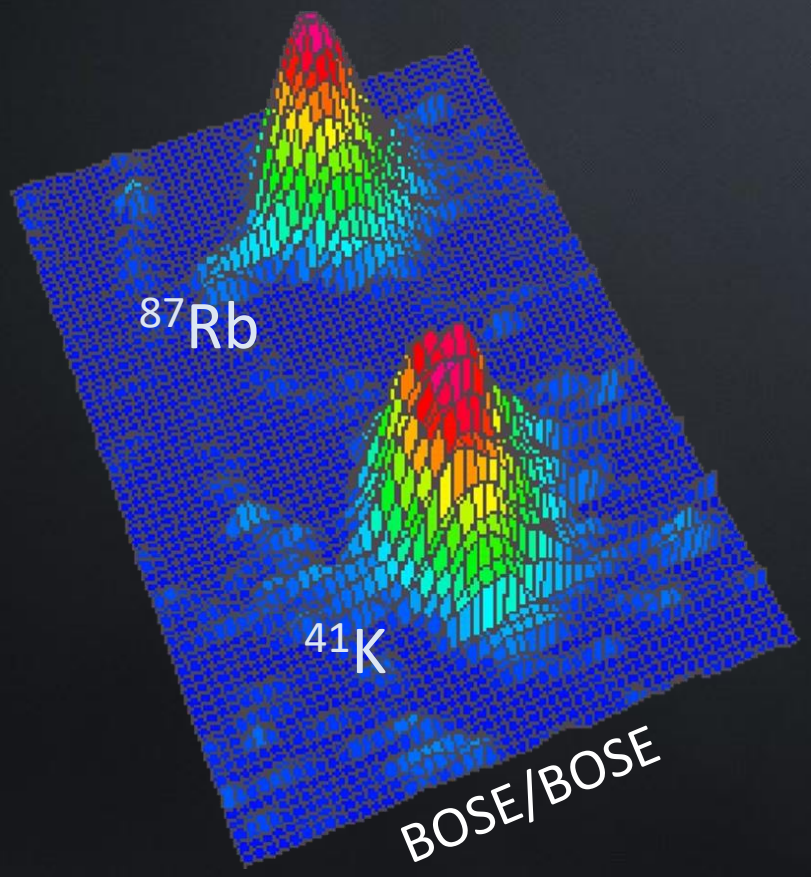
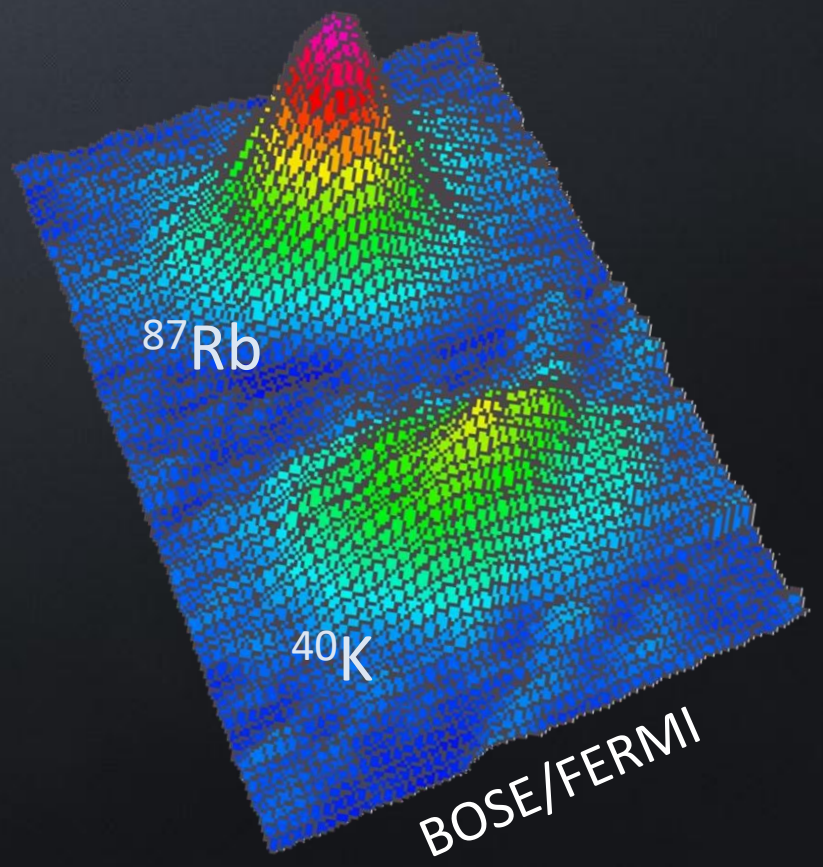
More degenerate gases in Arcetri

Bose/Bose and Bose/Fermi mixtures with heteronuclear sympathetic cooling





G. Modugno et al., Science **294**, 1320 (2001)
G. Ferrari et al., PRL **89**, 053202 (2002)

G. Roati et al., PRL **89**, 150403 (2002)

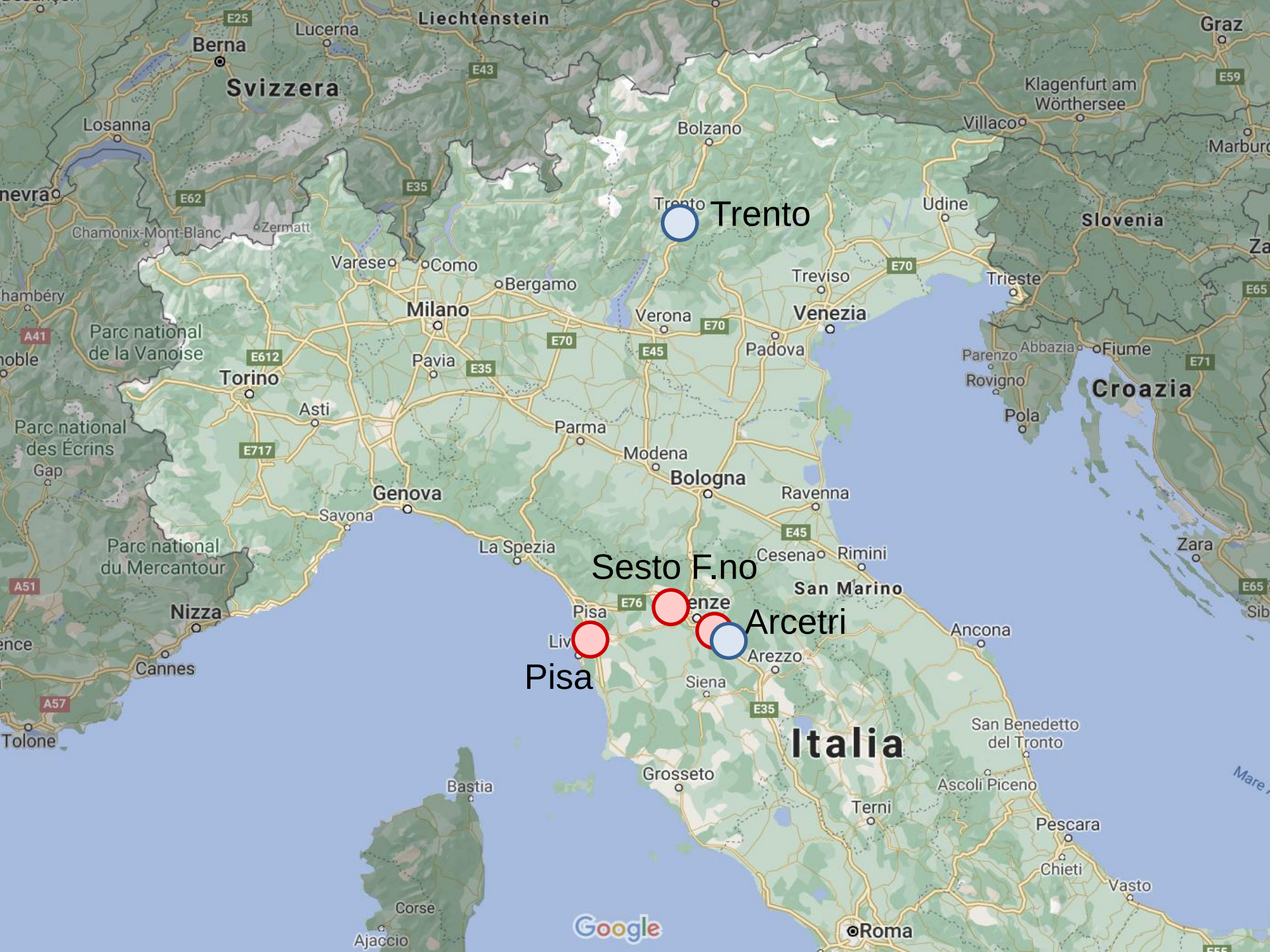
2005, Arcetri (Firenze)

More degenerate gases in Arcetri

2006, Varenna (Italy)
CLXIV Summer School «Ultracold Fermi gases»

Varenna again

LENS moves to Sesto Fiorentino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2005, Sesto Fiorentino (Firenze)

At the new campus

*G. Modugno et al., PRA **68**, 011601(R) (2003)*

Fermions in optical lattices

First trapping of atomic Fermi gases in optical lattices

RAPID COMMUNICATIONS

PHYSICAL REVIEW A **68**, 011601(R) (2003)

Production of a Fermi gas of atoms in an optical lattice

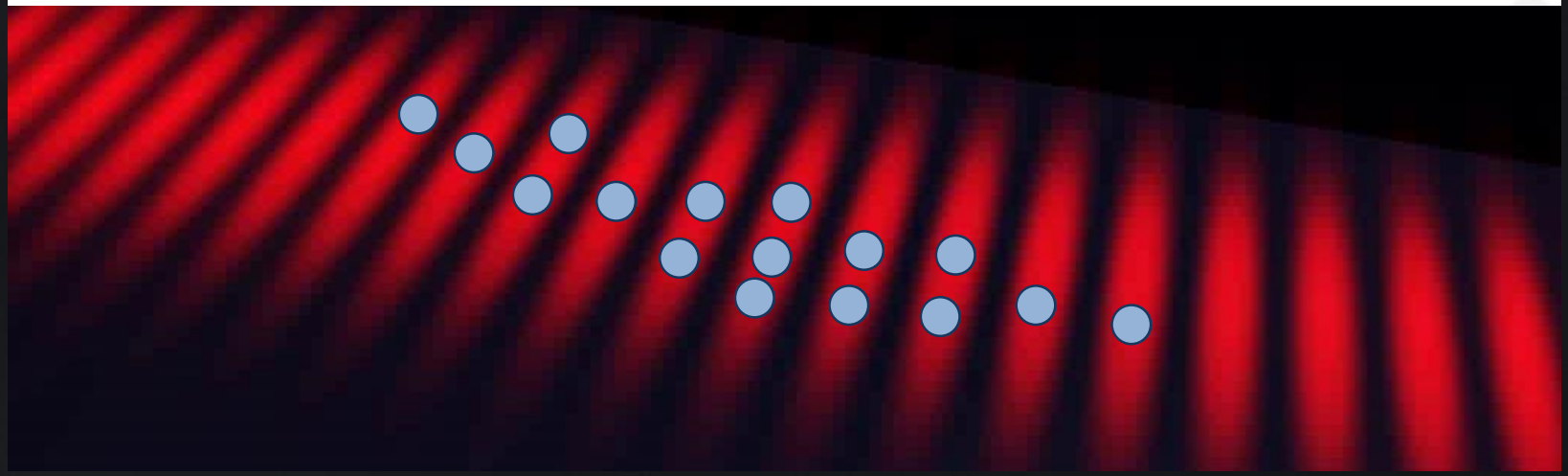
G. Modugno, F. Ferlaino, R. Heidemann,* G. Roati, and M. Inguscio

LENS and Dipartimento di Fisica, Università di Firenze, and INFM, Via Nello Carrara 1, 50019 Sesto Fiorentino, Italy

(Received 10 April 2003; published 7 July 2003)

We prepare a degenerate Fermi gas of potassium atoms by sympathetic cooling with rubidium atoms in a one-dimensional optical lattice. In a tight lattice, we observe a change of the density of states of the system, which is a signature of quasi two-dimensional confinement. We also find that the dipolar oscillations of the Fermi gas along the tight lattice are almost completely suppressed.

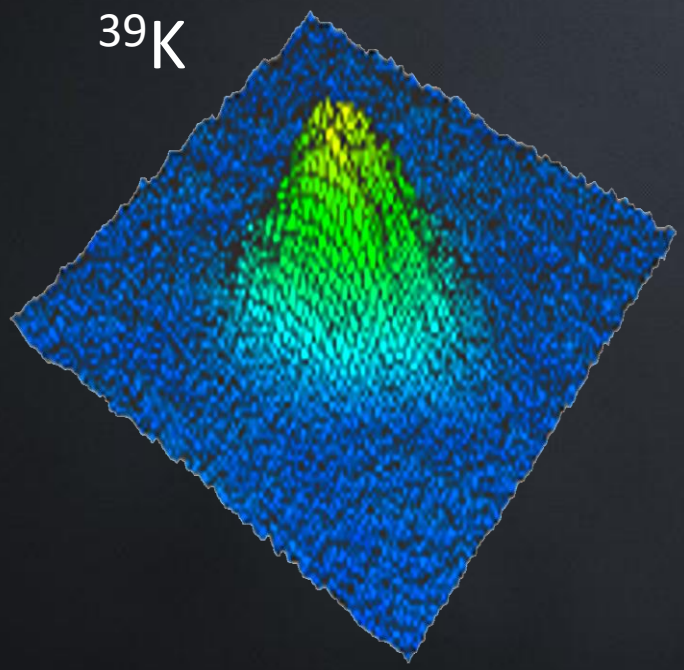
DOI: 10.1103/PhysRevA.68.011601 PACS number(s): 03.75.Ss, 03.75.Lm, 71.10.Pm



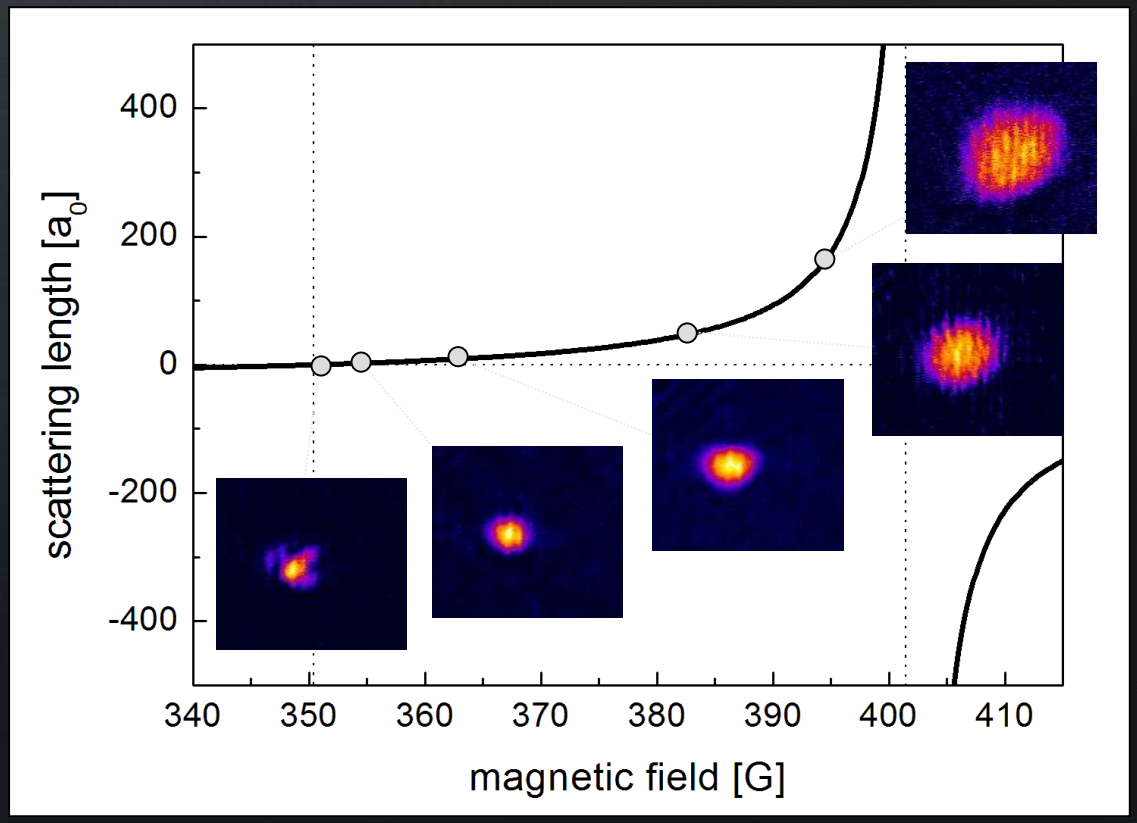
Completing the K degenerate family

The last stable alkali isotope:

^{39}K



^{39}K Feshbach resonance



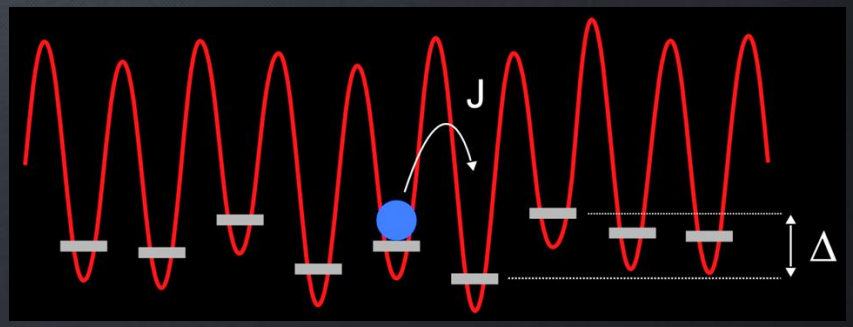
*G. Roati et al., PRL **99**, 010403 (2007)*

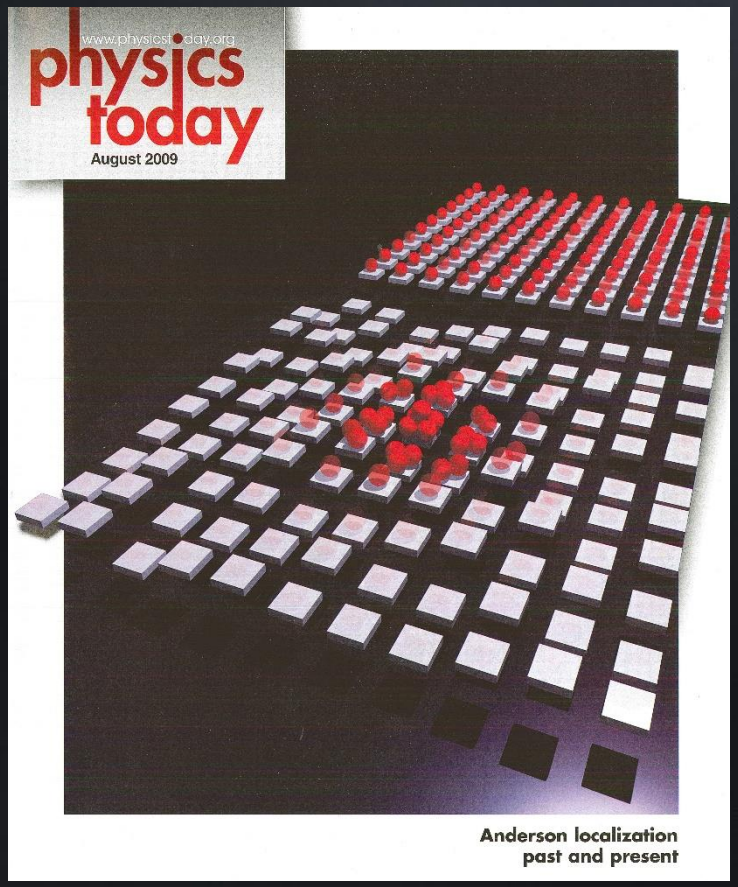
*M. Fattori et al., PRL **100**, 080405 (2008); PRL **101**, 190405 (2008)*

Disorder

Optical potentials with controlled disorder

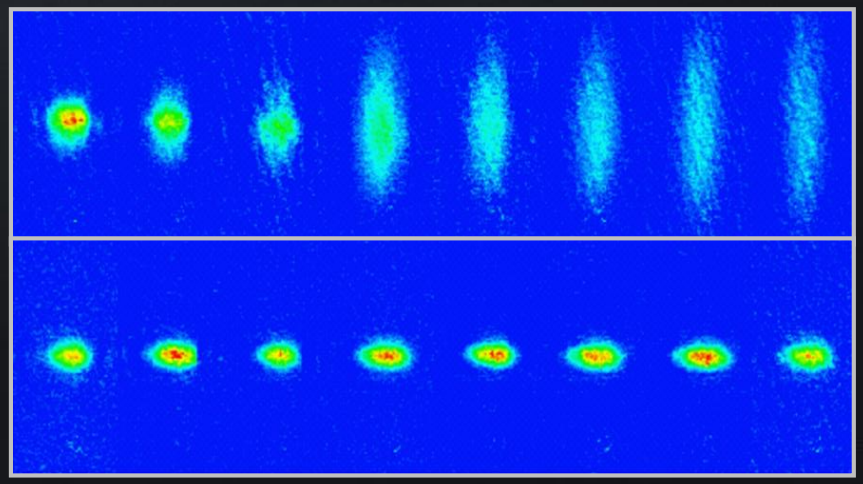
*J. E. Lye et al., PRL **95**, 070401 (2005)*
*C. Fort et al., PRL **95**, 170410 (2005)*
*L. Fallani et al., PRL **98**, 130404 (2007)*





Anderson localization of matter waves with 39K with tunable interactions

*G. Roati et al., Nature **453**, 895 (2008)*



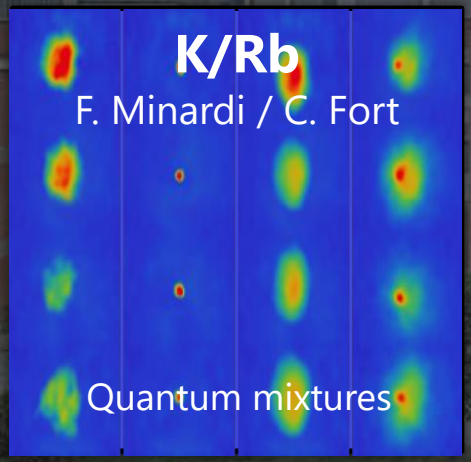
$\Delta/J = 0$

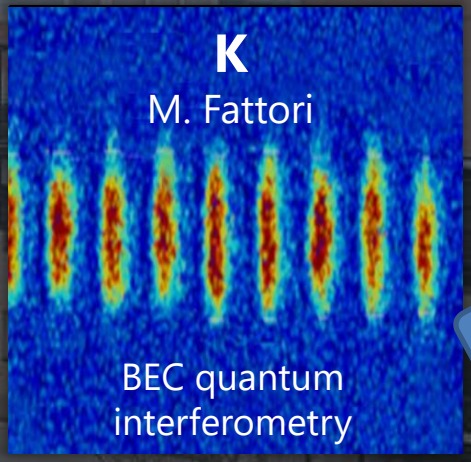
$\Delta/J = 7$

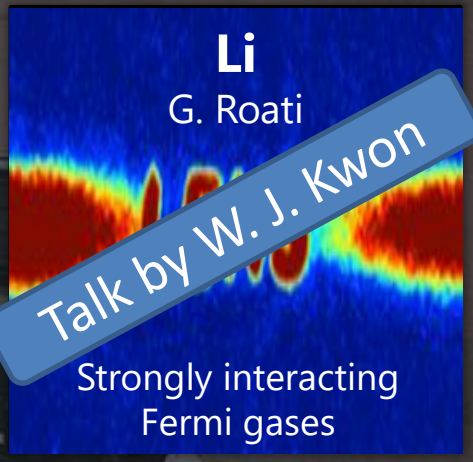
2007, LENS

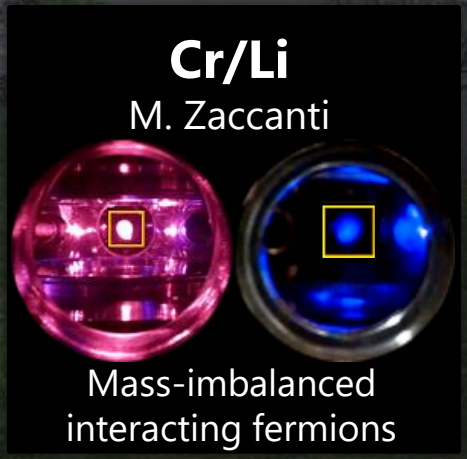
Anderson localization

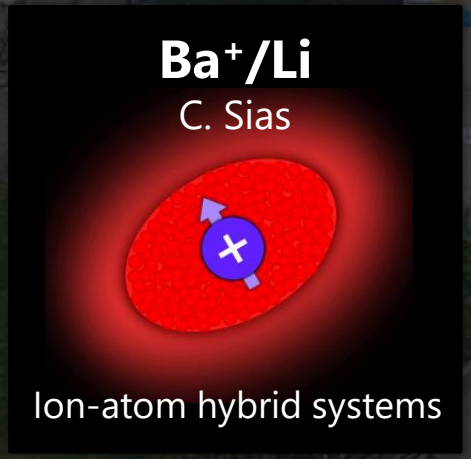
New species and adventures in Sesto

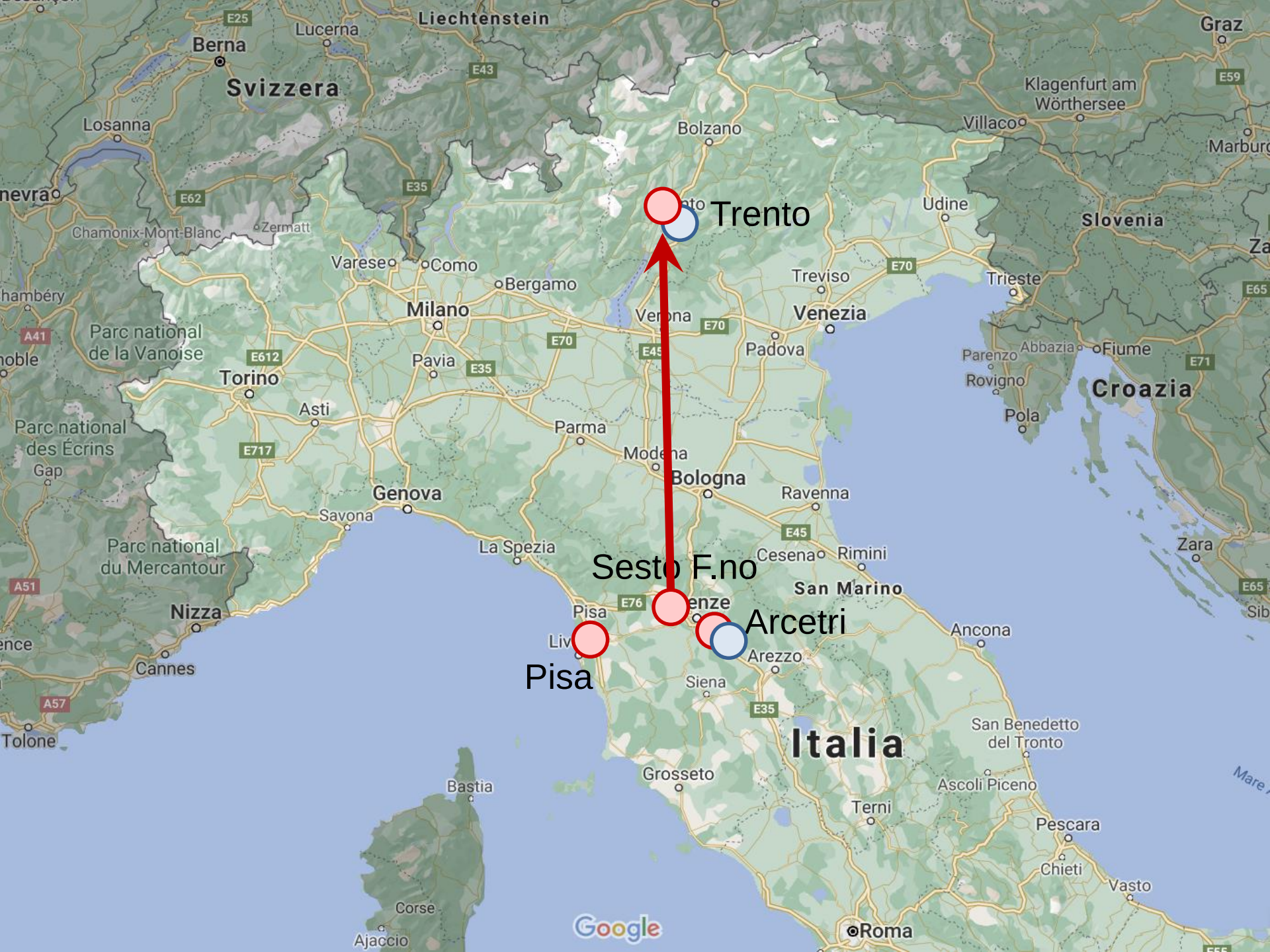








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2012, Trento
Trento-Firenze Joint Meeting

Experiments in Trento

Experiments in Trento

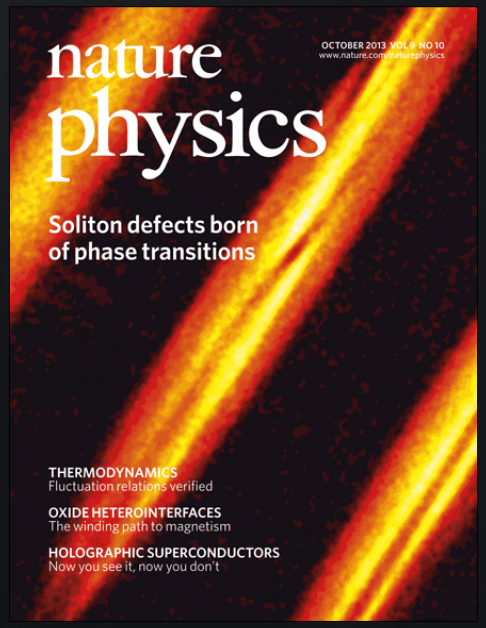
Starting from 2011: New **experimental** activity at the Trento CNR-INO BEC Center (G. Ferrari and G. Lamporesi)

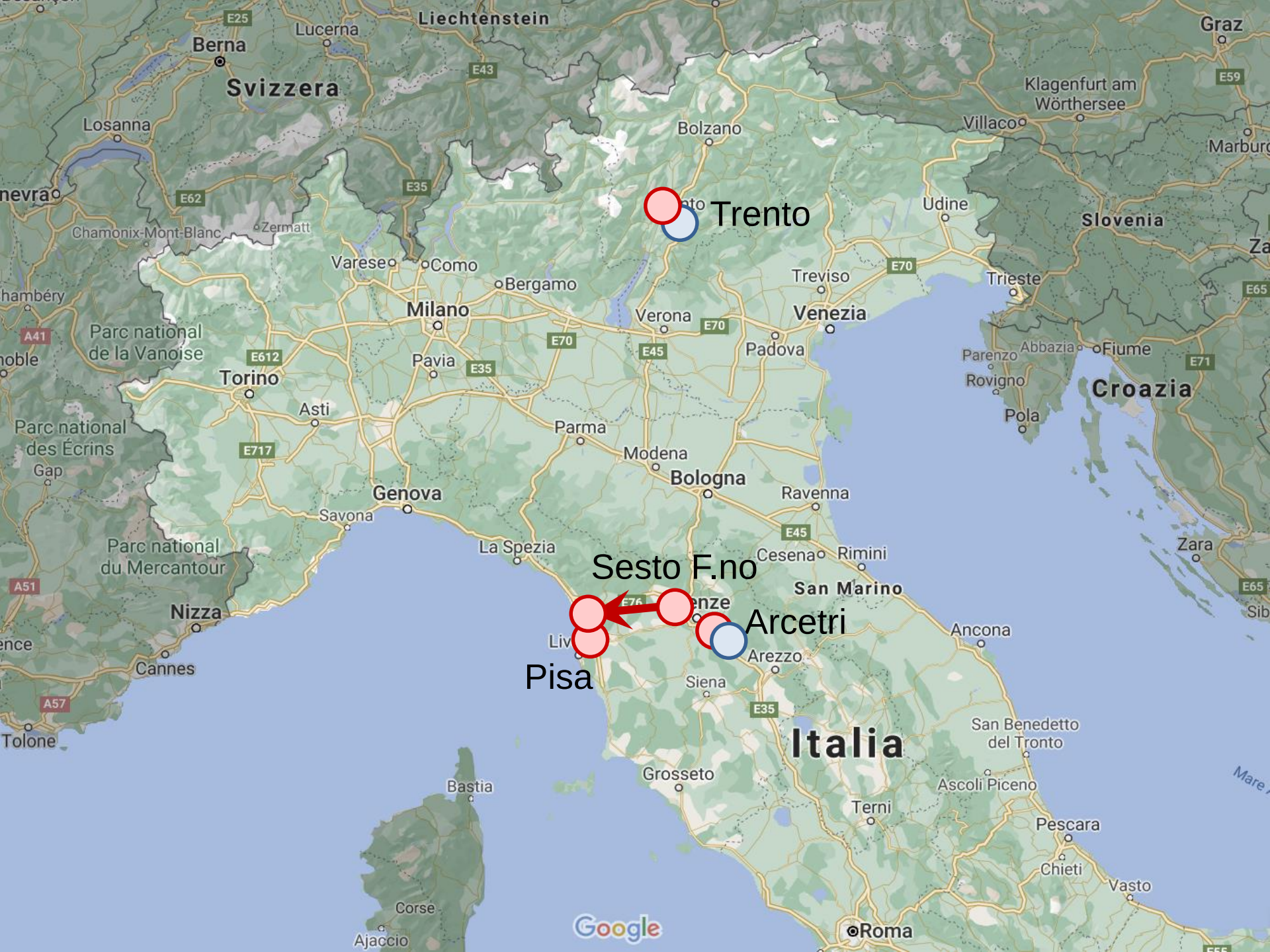
Talk by G. Lamporesi

BEC with Na atoms

Spontaneous creation of **Kibble-Zurek solitons** in a Bose-Einstein condensate

G. Lamporesi et al., Nature Phys. ***9****, 656 (2013)*

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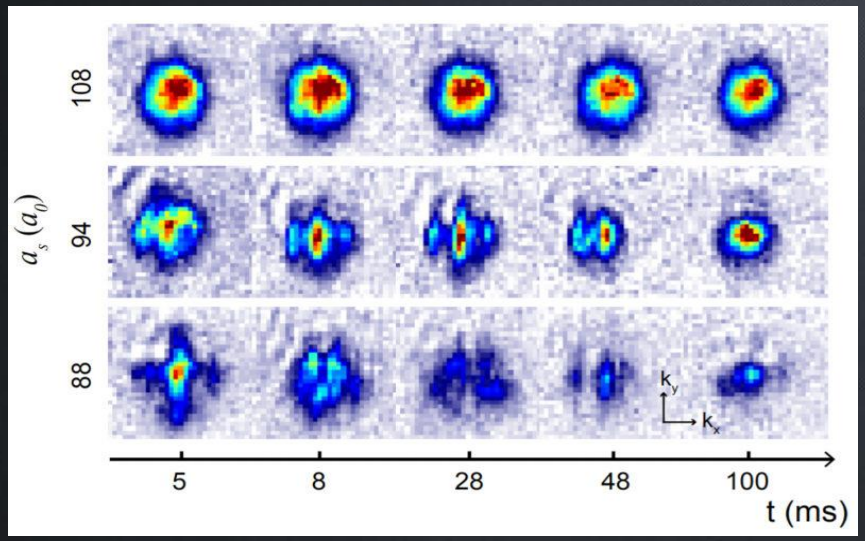
A new lab in Pisa



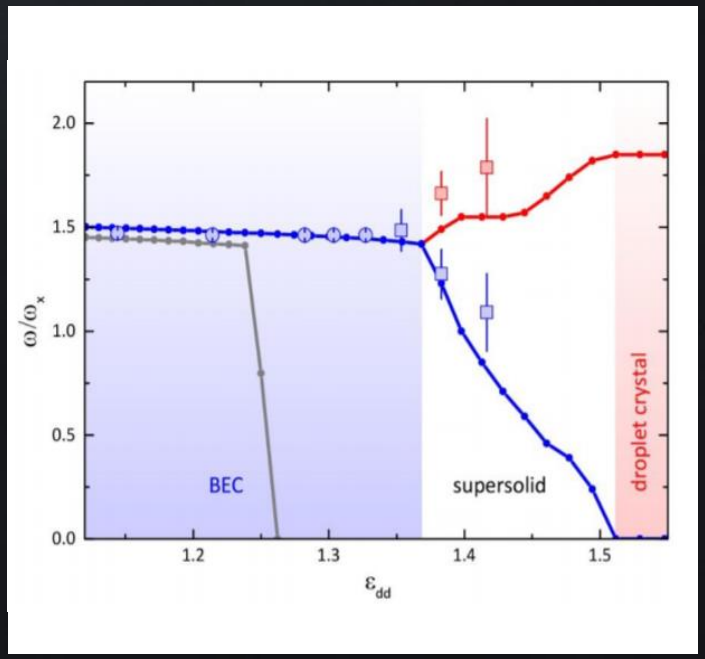
Dy dipolar quantum gases

Long-range anisotropic inte
Supersolidity

Talk by C. Gabbanini

Collective excitation modes and supersolid symmetry breaking in a dipolar BEC

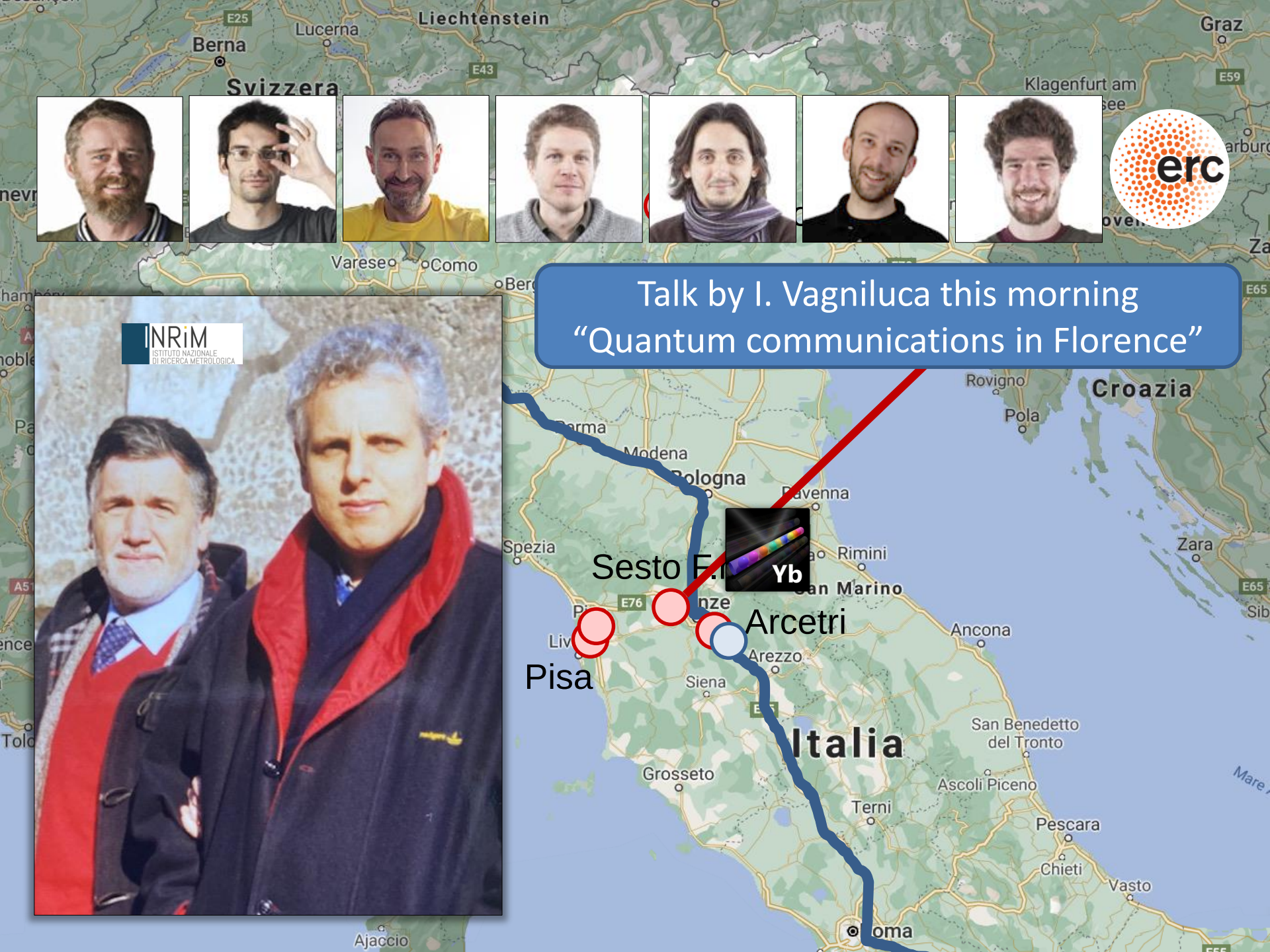
L. Tanzi, S. M. Roccuzzo, E. Lucioni, F. Famà, A. Fioretti, C. Gabbanini, G. Modugno, A. Recati, S. Stringari
Supersolid symmetry breaking from compressional oscillations in a dipolar quantum gas
Nature **574**, 382 (2019)



Lens QuantumGases

2018, Arcetri (Firenze)
LENS Quantumgases internal workshop

The story continues…


Talk by I. Vagniluca this morning
“Quantum communications in Florence”
INRiM
ISTITUTO NAZIONALE DI RICERCA METROLOGICA
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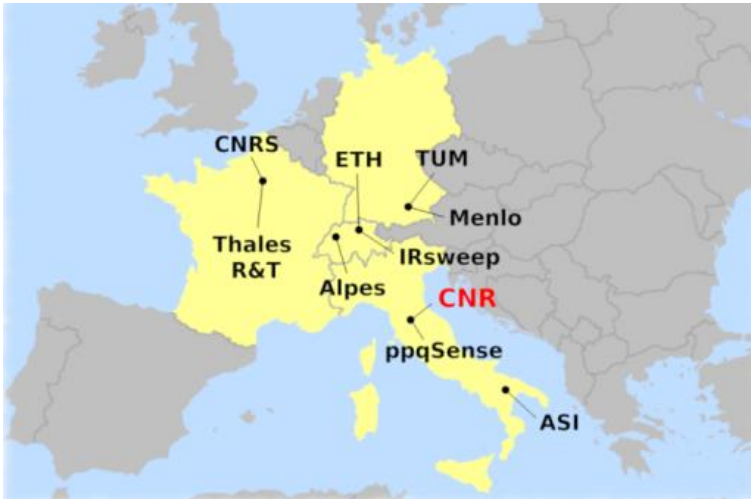
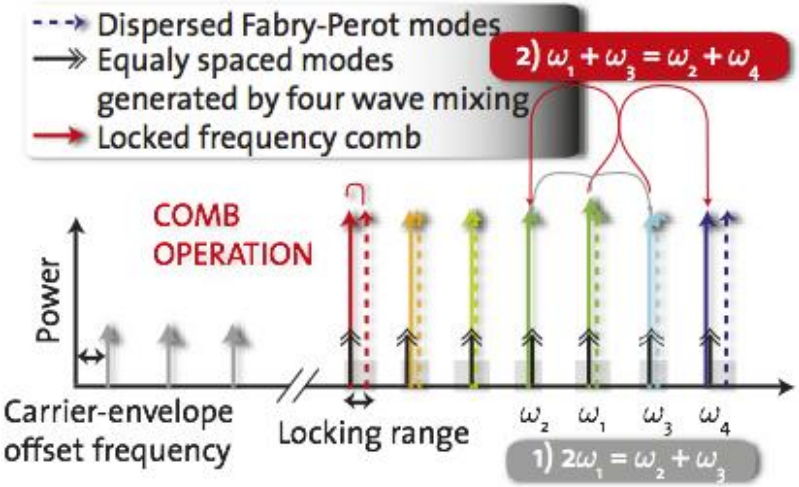
Mixing atoms with light

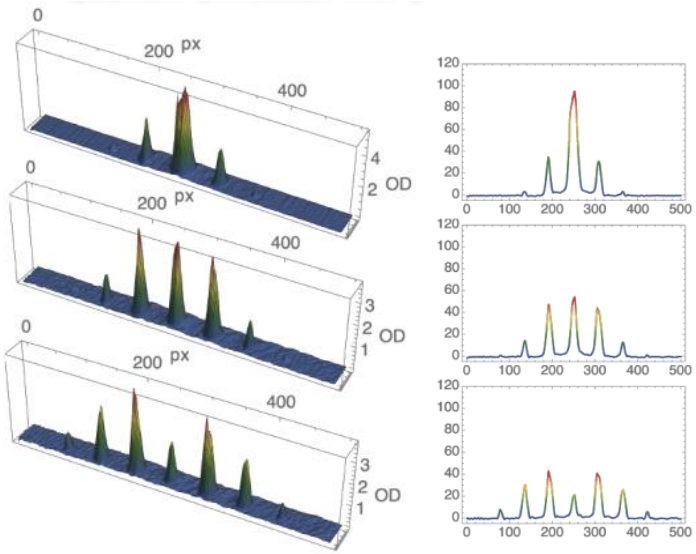
EU QUANTUM Flagship project
Coordination by CNR-INO



Quantum Cascade Laser (QCL)
Frequency combs



Quantum simulators of new devices
with atoms and optical lattices



7 years ago…

2013, Arcetri (Firenze)
CNR-INO Annual Symposium

…many other suprises to come!