UNIVERSITY OF PISA
DEPARTMENT OF PHYSICS «ENRICO FERMI»

# MAGIA-ADVANCED PISA CONTRIBUTION

**NATIONAL COORDINATOR: GUGLIELMO TINO (LENS, FI)**


**Maria Luisa Chiofalo, Dept. of Physics and INFN, University Pisa (Italy)**
**Michele Barsanti Dept.Engineering and INFN, University Pisa (Italy)**
**Giorgio Carelli Dept. of Physics and INFN, University Pisa (Italy)**
**Davide Rossini INFN and University of Pisa (Italy)**
**Oliver Morsch INO-CNR and University of Pisa (Italy)**
**Carla Signorini PhD student UniPi [Formerly ESA, Head of Electrical Engineering Dept.]**

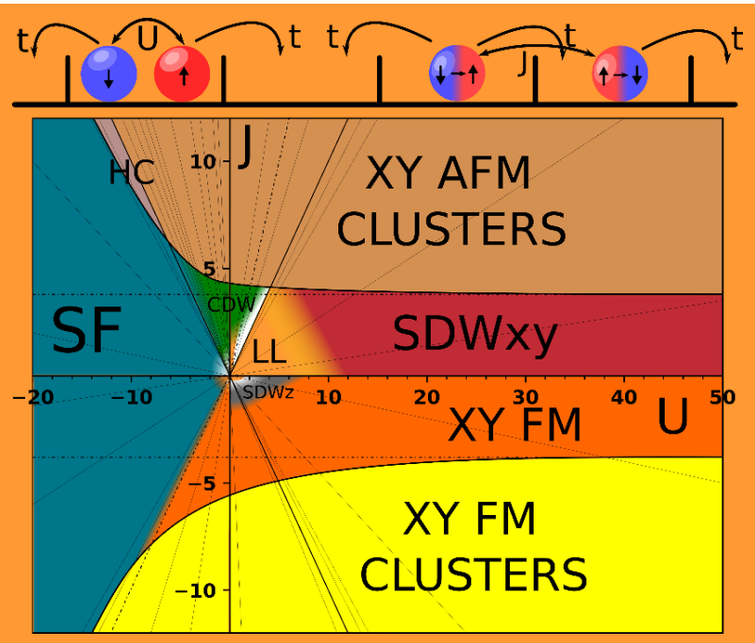
**Students**
**Fabrizio Varchetta Graduating Student @Dept. Of Physics, University of Pisa (Italy)**

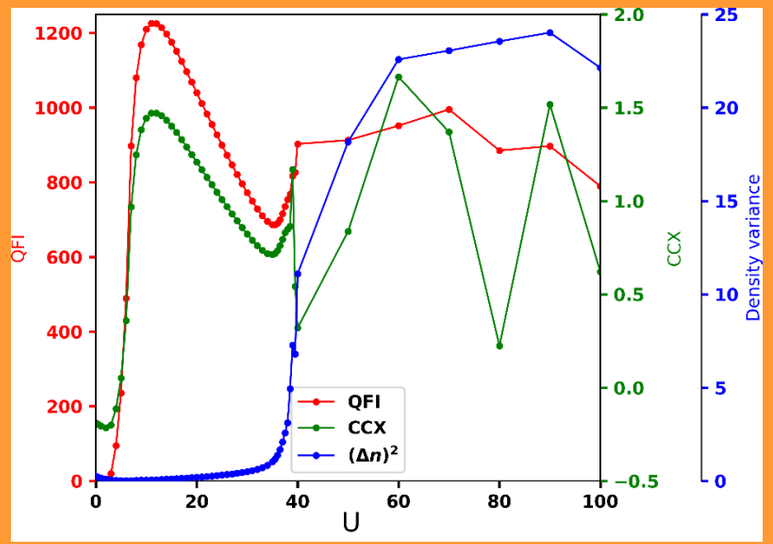
**Active collaborations focused on this problem**
**Vladan Vuletic @Dept. Of Physics, MIT (USA)**
**Murray Holland @JILA+UCB @ Boulder (USA)**
**Andrew Daley @University of Strathclyde (UK)**
**Benjamin Lev @University of Stanford (USA)**
**Jonathan Keeling @University of St. Andrews (UK)**
**Andrea Trombettoni @ SISSA (Trieste, Italy)**
**Augusto Smerzi @ INO, Florence (Italy)**
**Luca Lepori PD@ SNS, Pisa (Italy)**

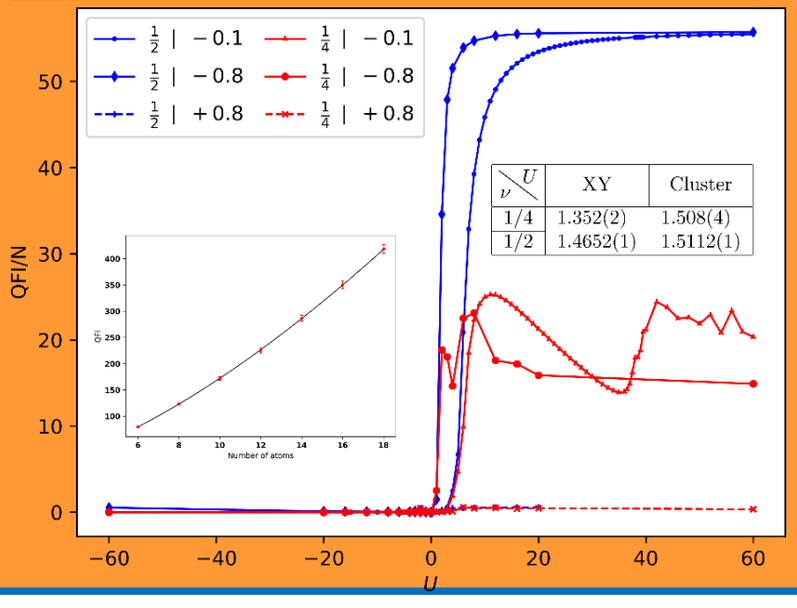

## OUTLINES

- Activities 2019
- Activities 2020
- Personnel data+ Financial requests
- Services etc.

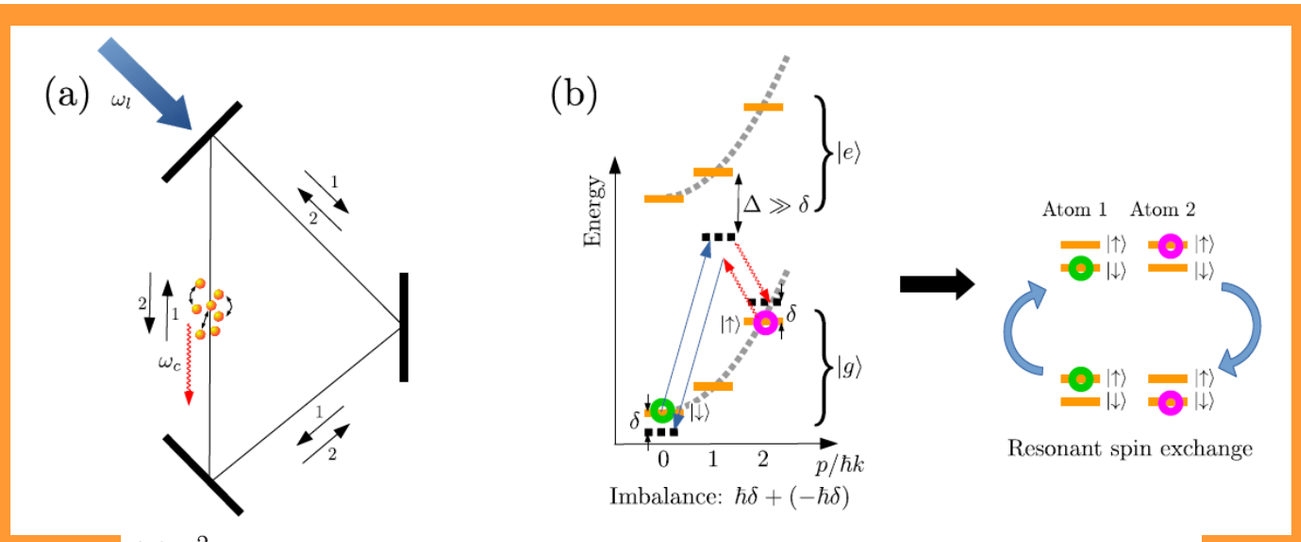
**INFN Pisa, July 4th 2019**

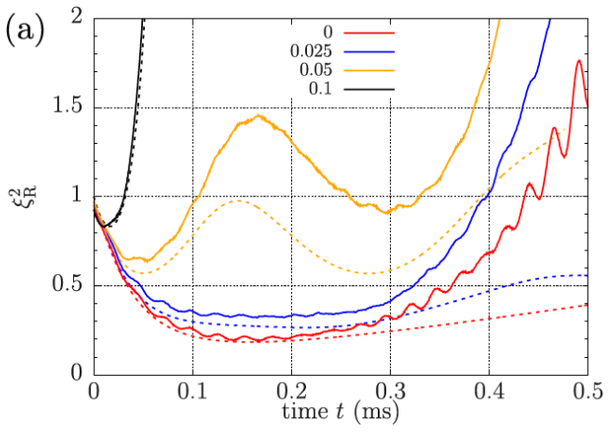


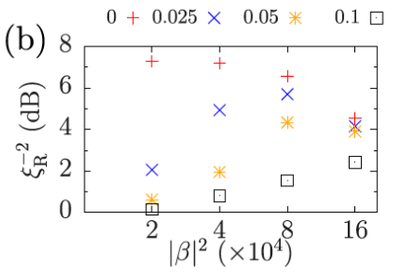



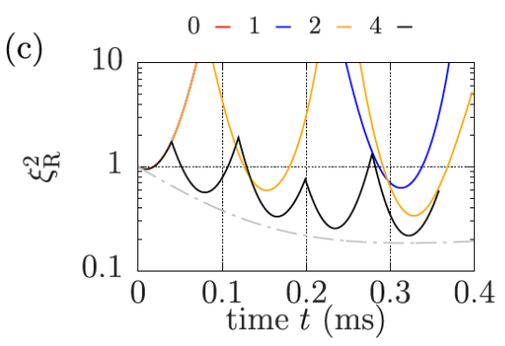



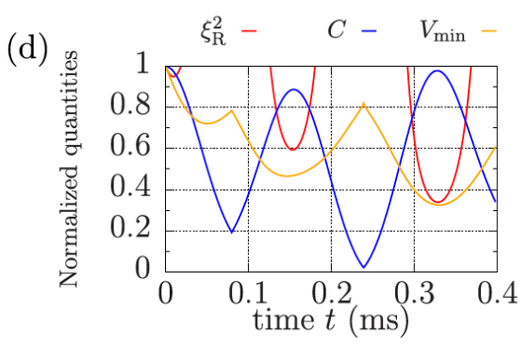

| $\nu$ \ $U$ | XY | Cluster |
|---|---|---|
| 1/4 | 1.352(2) | 1.508(4) |
| 1/2 | 1.4652(1) | 1.5112(1) |

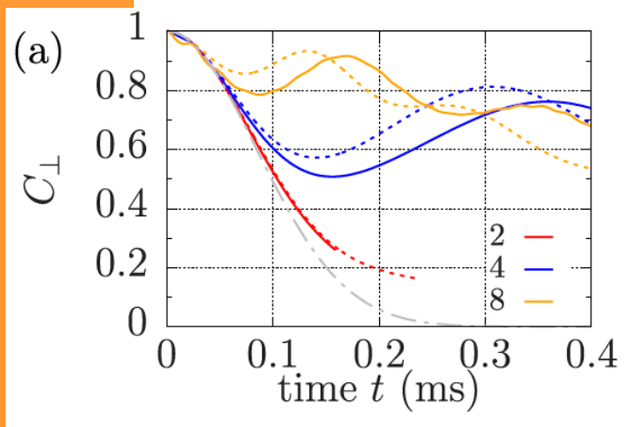


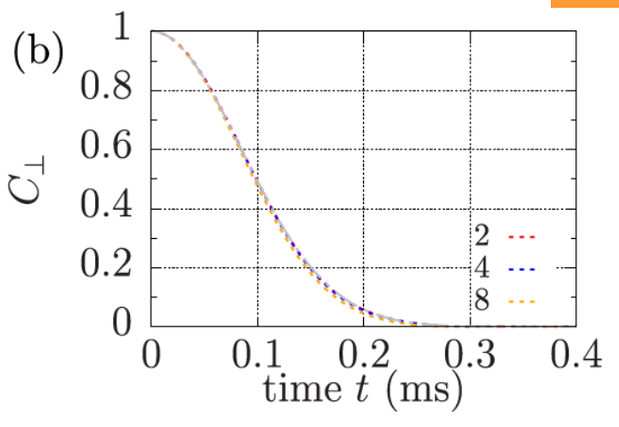



## PUBLICATIONS

[1] E. COLELLA, M. L. CHIOFALO, M. BARSANTI, D. ROSSINI, AND R. CITRO, Fluid structure of 1D spinful Fermi gases with long-range interactions, JPB, in press
[2] L. LUCCHESI AND M. L. CHIOFALO, Many-body Entanglement of Fermi Gases with Short-Range Interactions, SUBM. TO PRL
[3] A. SHANKAR, L. SALVI, M.L. CHIOFALO, N. POLI, M.J. HOLLAND, Squeezed state metrology with Bragg interferometers operating in a cavity, IN COURSE TO SUBM.
[4] SAGE COLL., SAGE: A Proposal for a Space Atomic Gravity Explorer, IN COURSE SUBM.
[5] P. BONETTI AND M. L. CHIOFALO, Local-Field Theory of the BCS-BEC Crossover, IN COURSE OF SUBM.

## INVITED TALKS

[T1] HARVARD [5]
[T2] STRATHCLYDE [2+THE UNIVERSE IN 4 SQUARES METERS]
[T3] CNR-INO PISA [THE UNIVERSE IN 4 SQUARED METERS]
[T4] UNI. MESSINA [THE UNIVERSE IN 4 SQUARED METERS]
[T5] PISA [Tailoring Quantum States of Matter for Many-Body Physics and Precision Measurements ]
[T6] ECT@TRENTO [5]

## POSTERS

[P1] Jin fest@JILA [Tailoring Quantum States of Matter for Many-Body Physics and Precision Measurements I+II]
[P2] TRENTO, WORKSHOP ON QUANTUM MIXTURES [5]
[P3] KITP, WORKSHOP ON OPEN QUANTUM SYSTEMS DYNAMICS & QUANTUM SIMULATORS [5]
[P4] ECAMP19 [3] AND [5]

## VISITING

[V1] INNSBRUCK
[V2] JILA (FELLOWSHIP)
[V3] HARVARD
[V4] STRATHCLYDE
[V5] KITP
[V6] ECT TRENTO

## ORGANIZATION CONF

[C1] QFC19 (Chair)
[C2] ECAMP19

## PROPOSALS

[PR1] A RYDBERG QUANTUM SIMULATOR (COLL.) SUBM. TO QUANTERA CALL (PI O. MORSCH)
[PR2] THE QBIT WOMAN (PI)

## MD THESIS

[T1] P. M. BONETTI
[T2] L. LUCCHESI

## REFEREEING

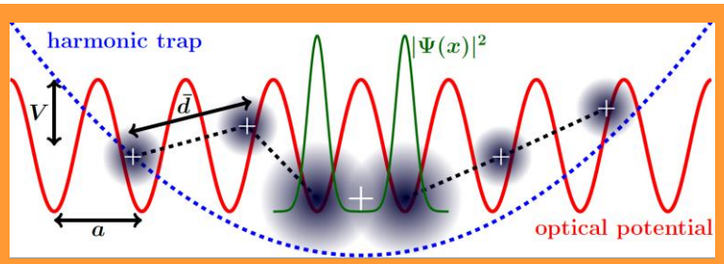
[R1] HARVARD
[R2] ERC

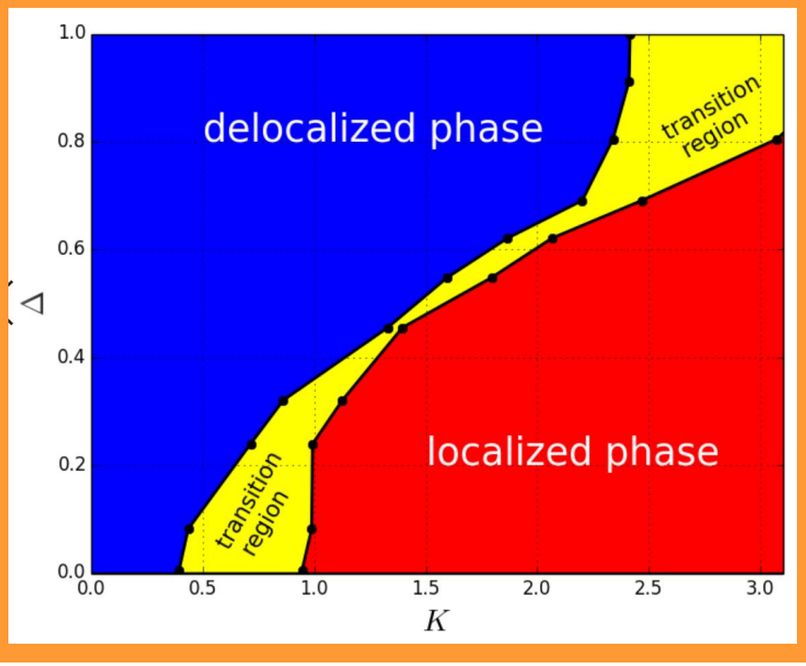
## PhD THESIS

[T3] CARLA SIGNORINI ON FUZZY DARK MATTER, CO-SV A. FERRARA + COLL. WITH D. GRASSO

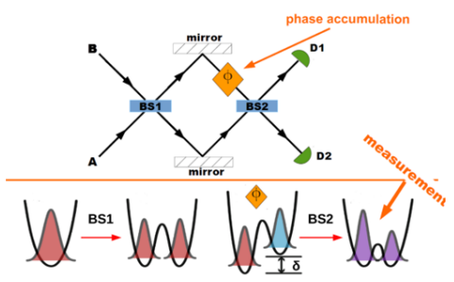
## OUTREACH

[O1] BRIGHT 2018 AND 2019
[O2] SCHOLE (LECTURES FOR HIGH-SCHOOL STUDENTS+PUBLIC COLLOQUIUM)
[O3] MLC, L. SALVI, G. TINO, “FISICA DELLA MATERIA”, BOOKLET FOR CORRIERE DELLA SERA
[O4] DIRE DONNE (ON WOMEN AND SCIENCE)
[O5] REPUBBLICA (COLLAB. ON CULTURE AND SOCIETY TOPICS)
[O6] PIANETA GALILEO 2018-2019 (4 MEETINGS)
[O7] COSMOS PRIZE FOR POPULAR SCIENCE (COMMITTEE MEMBER)
[O9] AGGIORNAMENTI (INFN) FOR HIGH-SCHOOL TEACHERS
[O10] MASTER PUBLIC SPEAKING CIBA (2011-) WORDS OF PHYSICS
[O11] PARTECIPATION TO UNIPI GROUP ON RESPONSIBLE RES. AND INNOVATION (CISP)
[O12] CAFRE: TALK @ WORKSHOP ON LEARNING&TEACHING INNOVATION PROCESSES

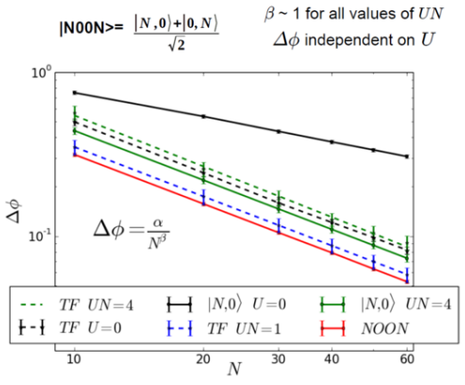



## INTERACTION EFFECTS IN PREFORMANCE OF ATOMIC INTERFEROMETERS

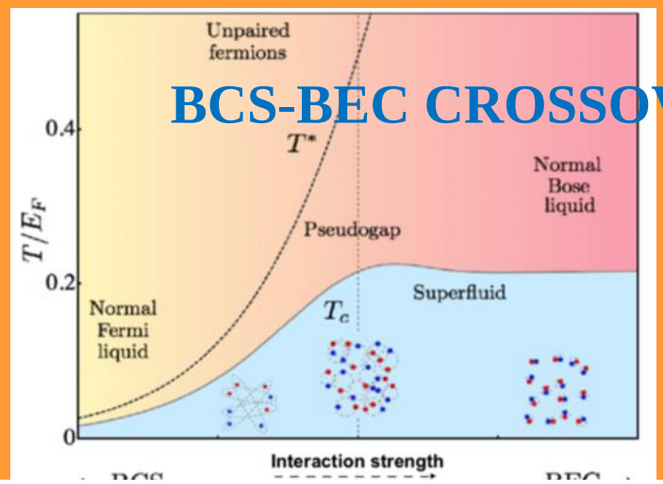


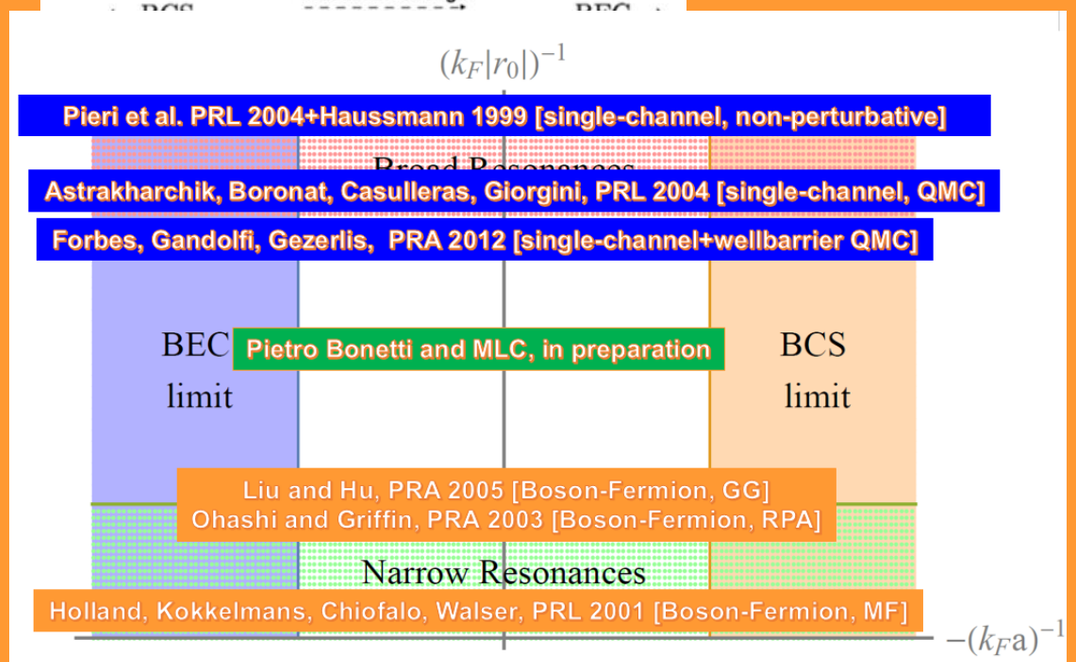

| | z measurements<br>for specific holding time intervals a sensitivity equal or better than in the non interacting case is found, even with the simplest set-up. | Phase probability distribution<br>for specific holding time intervals a better sensitivity is found with respect to the non interacting case. |
|---|---|---|
| Twin Fock \|N/2,N/2> | $\Delta\delta_{U\neq 0} \sim \Delta\delta_{U=0}$ only for small values of $UN$ | $\beta \sim 1$ for all values of $UN$<br>$\Delta\phi_{UN=1} < \Delta\phi_{U=0} < \Delta\phi_{UN=4}$ |
| \|N,0> | $\Delta\delta_{U\neq 0} < \Delta\delta_{U=0}$ better by increasing $UN$ thanks to non linearities $\rightarrow$ larger $\delta$-derivative. Further improvement possible thanks to squeezing | $\Delta\phi_{UN\neq 0} < \Delta\phi_{U=0}$ better by increasing $UN$ At the self trapping $\beta \sim 1$ |




[Cosetta Baroni, Giacomo Gori, MLC, A. Trombettoni, in preparation]

## BCS-BEC CROSSOVER




| | Quantum Gases | Neutron Stars | Quark-Gluon Plasma |
|---|---|---|---|
| T $\approx$ | $10^{-6}$ -$10^{-9}$ K | $10^{6}$ K | $10^{12}$ K $\approx$ $10^{2}$ MeV |
| Interaction strength $\approx$ | $k_Fa$ in (-oo,+oo)<br>$1/k_Fa \approx$ 100 Bohr | $k_Fa \approx$ -13<br>$1/k_Fa \approx$ 1.4 fm | $g \approx 1/2$ |
| Range $\approx$ | $k_FR_e$ <<1 (broad)<br>$k_FR_e \approx 1$ (-> narrow) | $k_FR_e \approx 2$ | ------- |

## PUBLICATIONS IN FIERI

[1] L. LEPORI, L. LUCCHESI AND M.L. CHIOFALO, Quantum-Fisher Information scaling of Fermi Gases with Short-Range Interactions, IN PREP.

[2] C. BARONI, G. GORI, M.L. CHIOFALO, AND A. TROMBETTONI, Effect of interactions on the performance of ultracold quantum interferometers and application to gyroscopes, IN PREP.

[3] A. VENEGAS-GOMEZ, M. L. CHIOFALO, AND A. DALEY, Adiabatic State Preparation and Quantum Fisher Information, IN PREP.

[4] P. BONETTI, M. BARSANTI, AND M. L. CHIOFALO, Critical Behavior of Fermi Gases with large effective range, IN PREP.

[5] P. BONETTI, A. RUCCI, V. VULETIC, AND M. L. CHIOFALO, Quantum Effects in the Aubry Transition, IN PREP.

## WORK IN PROGRESS

[W1] F. VARCHETTA, A. DALEY, J. KEELING, B. LEV, AND MLC, DISSIPATIVE EFFECTS IN ENTANGLEMENT-BASED QUANTUM METROLOGY

[W2] FOLLOW-UPS OF MOMENTUM STATES SQUEEZING AND SIMULATION OF THE ATOMIC INTERFEROMETER

[W3] S. LIBERATI, A. TROMBETTONI, D. GRASSO, M.L. CHIOFALO, ON ANALOGUE GRAVITY PROBLEMS

## OUTREACH

[O1] COSMOS PRIZE FOR POPULAR SCIENCE (COMMITTEE COMPONENT)

[O2] METAORIZZONTI (CON M. SOZZI, A. FERRARA, E. MARINAI, S. LISCHI, IN COURSE OF PLANNING)

[O3] MASTER PUBLIC SPEAKING CIBA (2011-) LE PAROLE DELLA FISICA

[O4] PARTECIPATION TO UNIPI GROUP ON RESPONSIBLE RESEARCH AND INNOVATION (CISP)

## VISITING (planned)

[V5] KITP ON BLACK HOLES AS OPEN QUANTUM SYSTEMS

## ORGANIZATION CONF

[C1] KITP20 ON BLACK HOLES AS OPEN QUANTUM SYSTEMS

## THESIS

[T1] FABRIZIO VARCHETTA (WITH STRATHCLYDE) MD

[T2] GUGLIELMO LAMI (WITH SISSA) MD

[T3] CARLA SIGNORINI PhD

## PROPOSALS- FOLLOW UP

SAGE: A Proposal for a Space Atomic Gravity Explorer

G. M. Tino[1], A. Bassi[2], G. Bianco[3], K. Bongs[4], P. Bouyer[5], L. Cacciapuoti[6], S. Capozziello[7], X. Chen[8], M. L. Chiofalo[9], A. Derevianko[10], W. Ertmer[11], N. Gaaloul[11], P. Gill[12], P. W. Graham[13], J. M. Hogan[13], L. Iess [14], M. A. Kasevich[13], H. Katori[15], C. Klempt[11], X. Lu[16], L.-S. Ma [17], H. Müller[18], N. R. Newbury[19], C. Oates[19], A. Peters[20], N. Poli[1], E. Rasel[11], G. Rosi[1], A. Roura[21], C. Salomon[22], S. Schiller[23], W. Schleich[21], D. Schlippert[11], F. Schreck[24], C. Schubert[11], F. Sorrentino[25], U. Sterr[26], J. W. Thomsen[27], G. Vallone[28], F. Vetrano[29], P. Villoresi[28], W. von Klitzing[30], D. Wilkowski[31], P. Wolf[32], J. Ye[33], N. Yu[34], and M. S. Zhan[35]

| NAME | AFFILIATION | FTE |
|---|---|---|
| MARIA LUISA CHIOFALO | PA DEPT PHYSICS UNIPI | 100% |
| MICHELE BARSANTI | RC DEPT ENGINEERING (CIVILE E INDUSTRIALE) UNIPI | 70% |
| GIORGIO CARELLI | RC DEPT PHYSICS UNIPI | 25% |
| DAVIDE ROSSINI | RTDB DEPT PHYSICS UNIPI | 10% |
| OLIVER MORSCH | PI INO-CNR | 20% |
| CARLA SIGNORINI | PhD UNIPI | 100% |
| FABRIZIO VARCHETTA | UNDERGRAD PHYSICS DEPT UNIPI | 100% |
| | | 3.25 |

## PISA UNIT PERSONNEL DATA & FINANCIAL REQUESTS

| FOR WHAT | HOW MUCH (EUROS) |
|---|---|
| COLLABORATION -AIMED TRIPS | 3500 (+2000 SJ) |
| | |

| NAME | AFFILIATION |
|---|---|
| VLADAN VULETIC | HEAD DIVISION CM/AMO AND DEPT. PHYS. MIT (USA) |
| MURRAY HOLLAND | JILA AND UNIVERSITY OF COLORADO @BOULDER (USA) |
| ANDREW DALEY | STRATHCLYDE UNIVERSITY (UK) |
| BENJAMIN LEV | STANFORD |
| JONATHAN KEELING | ST. ANDREWS (UK) |
| AUGUSTO SMERZI | INO, FLORENCE (ITALY) |
| LUCA LEPORI | SNS, PISA (ITALY) |
| ANDREA TROMBETTONI | SISSA, TRIESTE (ITALY) |
| DARIO GRASSO | INFN – PISA (ITALY) |
| STEFANO LIBERATI | SISSA, TRIESTE (ITALY) |
| SABRINA MANISCALCO | TURKU (FINLAND) |
| LINCOLN CARR | COLORADO SCHOOL OF MINES (USA) |
| ANDREA FERRARA | SNS, PISA (ITALY) |
| ALESSANDRO SILVA | SISSA, TRIESTE (ITALY) |
| GIOVANNA MORIGI | SAARBRUCKEN (GERMANY) |
| BILAL TANATAR | BILKENT UNIVERSITY (TURKEY) |

### PISA UNIT COLLABORATIONS

- ON THIS SUBJECT
- ON RELATED SUBJECTS
- SOON ON THIS SUBJECT

- **SERVICES** ●

| FOR WHAT | HOW MUCH (EUROS) |
|---|---|
| COMPUTING RESOURCES | For DMRG simulations |
| SECRETARIAT AND ADMINISTRATIVE FUNCTIONS QFC19 | (+ FINANCIAL SUPPORT OBTAINED: THANKS!) |

- **LOGISTICS** ✘
- **INFRASTRUCTURES** ✘

**THANKS FOR YOUR ATTENTION!**

# QFC2019 - Quantum gases, fundamental interactions and cosmology

23-25 October 2019
Aula Gerace
Europe/Rome timezone

https://agenda.infn.it/event/QFC2019

**TAKE TWO ☺**

**MORE INFN IN LOC !!**

**+ DARIO GRASSO**
**+ GIANCARLO CELLA**
**+ DARIO BUTTAZZO**