Mathematical Physics applied to Engineering

Modeling of Climate and Complex Systems

Advanced solutions for small accelerators

Synchrotron X-source

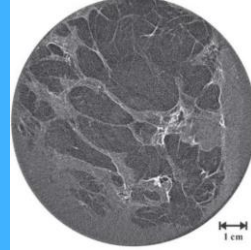Compact X-source

CXS

Four is our magic number.
Each of our projects has
four components.

Mathematical Physics
Advanced Computing

Multidisciplinary Advanced Imaging

⭐ **MEDICAL DIAGNOSTICS**

Breast tissue

⭐ **NON-DESTRUCTIVE INDUSTRIAL TESTS**

⭐ **CULTURAL HERITAGE SCIENCE**

Ostuni Mother, Ostuni, Italy

⭐ **ACADEMIC RESEARCH**

⭐ **FLASH RADIOBIOLOGY**

Imaging with tunable monochromatic partially coherent X-rays

**Conventional and ICS X-rays replicate the light of a bulb and of a laser pointer.
The energy/color of ICS X-rays can be tuned, that of a laser pointer is fixed.**

light bulb

laser pointer

Light

X-rays

X-ray tube
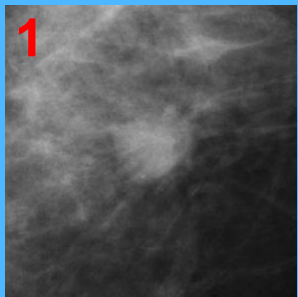
ICS source
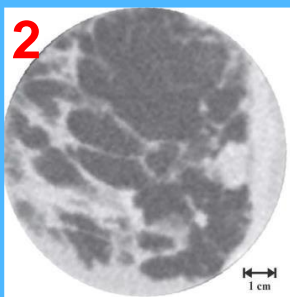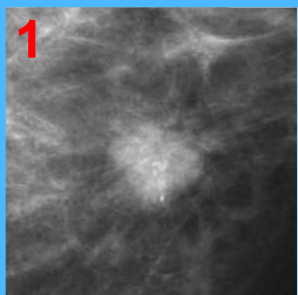
https://lynceantech.com

Standard X-ray Absorption Imaging (AI) vs Synchrotron light X-rays and phase contrast (PCI)

1

2

3 vertical striations

(a)

AI

AI

AI

1

2

3 vertical striations

PCI
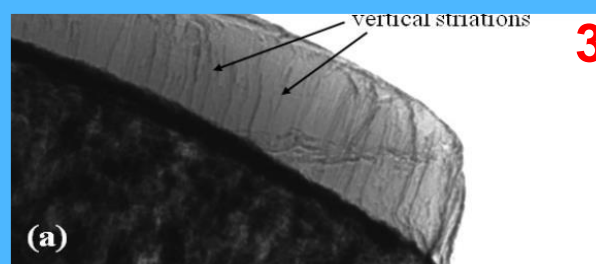
PCI

PCI

trabecular bone   subchondral bone
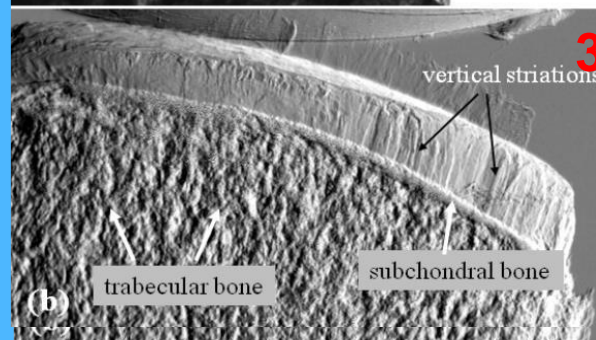
(b)
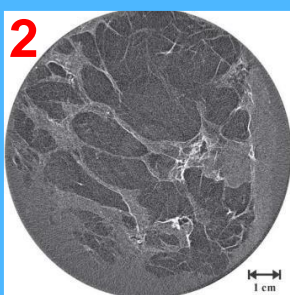
**AI vs PCI
soft tissue imaging**

1 Mammography

2 Breast tissue

3 Joint cartilage
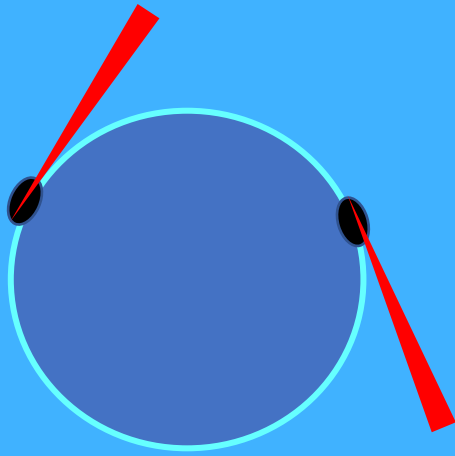
Courtesy: G. Tromba@SYRMEP

CXS: a Compact X-ray Source

4 m

S-band Photo-injector

C-band *e-* linac

e-

(e-)

3

e-

laser

X

X

1

2

12 m
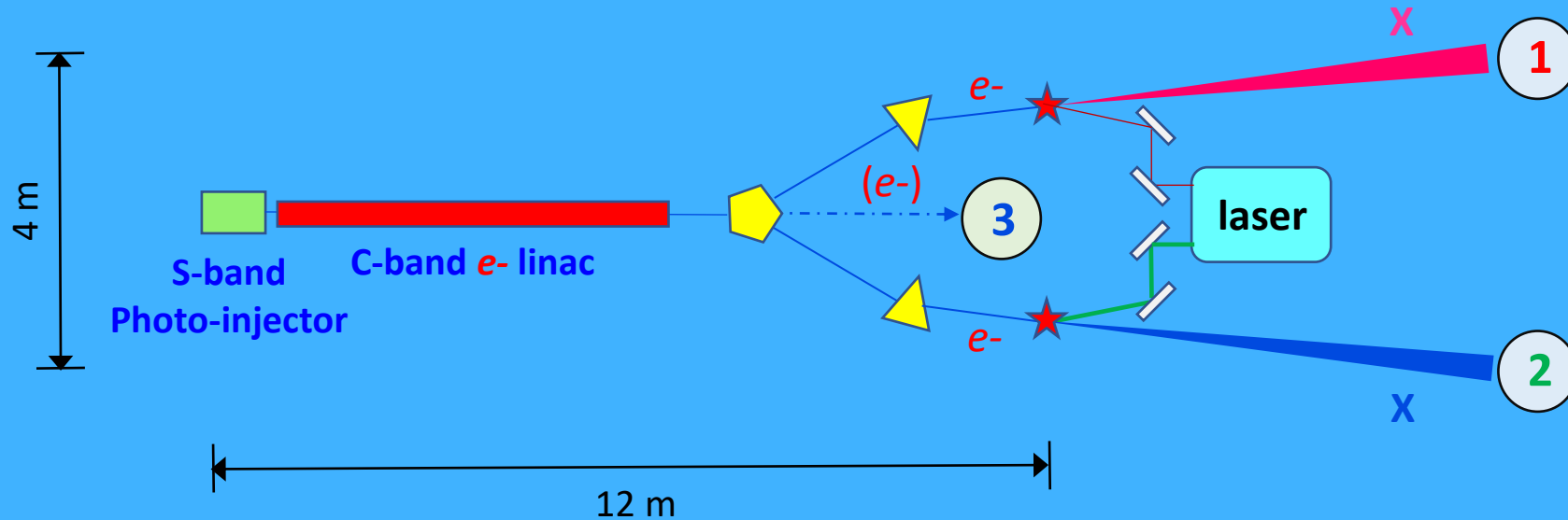
1 *X-ray* energy $E_X \leq 500\ keV$

2 *X-ray* energy $E_X \leq 1\ MeV$

3 *e-* energy $E_e \leq 165\ MeV$

Pulse duration $1 \div 5\ ps$

ICS principle

Energy of photons emitted by relativistic electrons
in Accelerator Dipoles and Undulators
has the same expression as for photons produced via the
Inverse Compton Scattering (ICS) process

Accelerator Dipoles

Undulator

ICS

$$\gamma = \frac{E_e}{m_e c^2}$$

$$E_X \propto hc\frac{\gamma^2}{\lambda_u}$$

$$E_X \propto hc\frac{\gamma^2}{\lambda_{ph}}$$

$\lambda_u \sim 15\ mm$
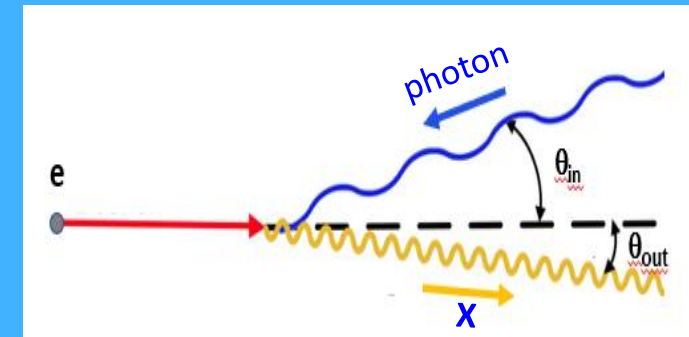
$\lambda_{ph} \sim 1\ \mu m$

CXS to epX: four beam lines

1. *X-ray* energy $E_X \leq 500 \, keV$
2. *X-ray* energy $E_X \leq 1 \, MeV$
3. *e-* energy $E_e \leq 165 \, MeV$
4. *p* energy $E_p \leq 5 \, MeV$

Pulse duration $1 \div 5 \, ps$

Proprietary open source beam dynamics software

Micromaps – 2D Tracking code with exact linear optical functions computation

Halodyn – 2D-3D Tracking code with space charge

AlaDyn – 2D and 3D Maxwell-Vlasov code

Earth – centaurus

Four spheres: atmosphere, hydrosphere, lithosphere, biosphere

Software development

Variational and reversibility indicators. Poincaré recurrences and extreme events

Koopmann-EDMD dynamic interpolation, Artificial Intelligence and Deep Learning techniques

Analysis of climate models and data

Agreement to be established with the UNIBO center ALMA CLIMATE

1

2

3

4

https://centri.unibo.it/climate/en

Complex – centaurus

Four levels: complex atoms, organs, automata, networks of automata
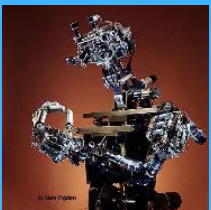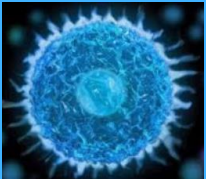
A complex atom is a self-replicating Von Neumann automaton

Theoretical and software development for complex systems analysis

Electromagnetic waves modeling and control

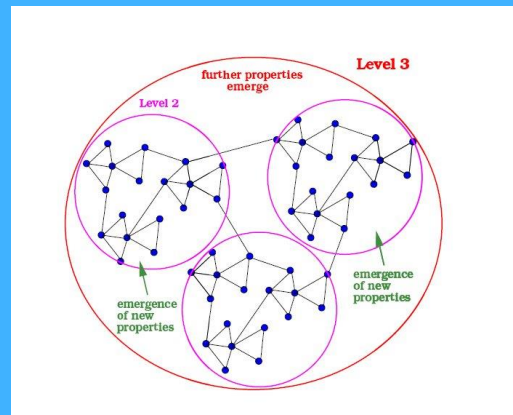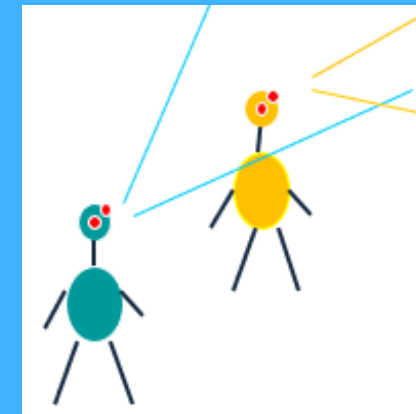### Biosystems modeling, mobility models and data analysis©

Non-Newtonian gas of automata

https://iopscience.iop.org/article/10.1209/0295-5075/78/58003   (2007)
https://www.maggiolieditore.it/9788838744617-la-citt-liquida.html   (2010)

Founders profile

Giorgio Turchetti
CV

Chair of Mathematical Physics

Bologna University until 2012

Dynamical and Complex Systems

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http://www.physycom.unibo.it/index.php
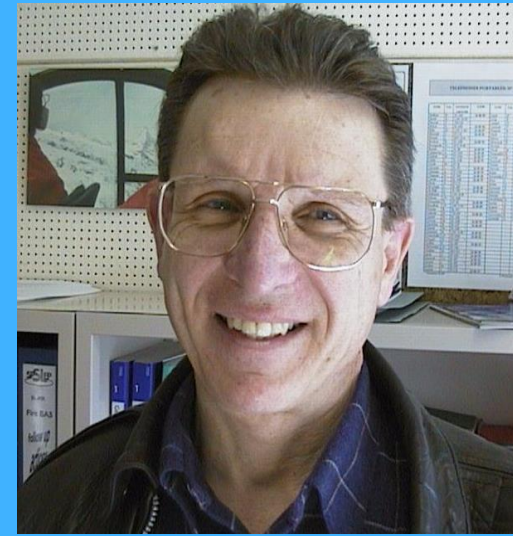
Massimo Placidi
CV

Accelerator Physicist

LNF & CERN until 2003

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