



Imagining X-ray science in 2050

Sakura Pascarelli

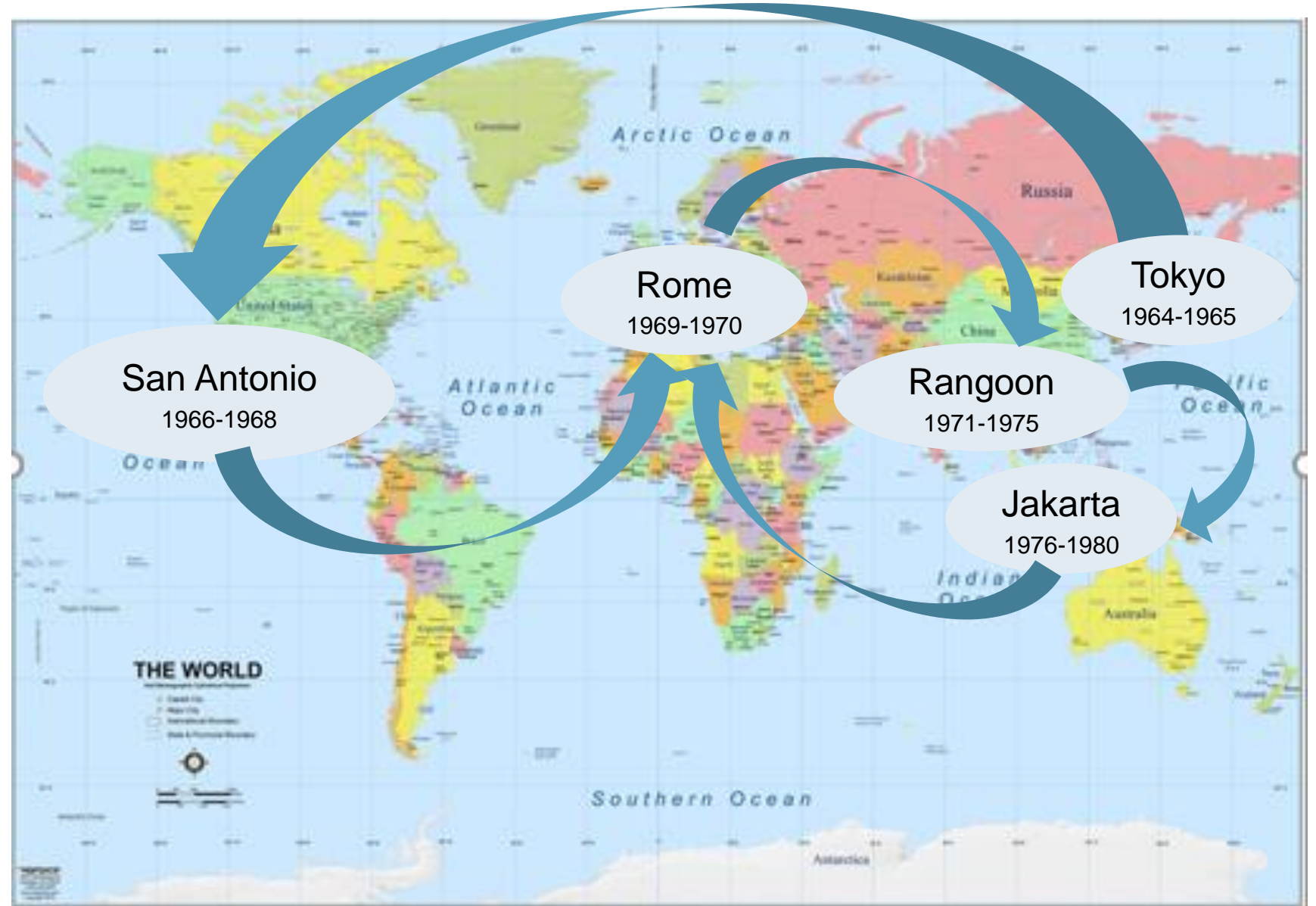
European XFEL

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The Innova XN Plenary Event

ESRF, 6-7 July 2022

Sakura 桜



2019

- Scientific Director @ EuXFEL

2015

- Head of Matter at Extremes Group @ESRF

2012

- Head of Electronic Structure and Magnetism Group @ESRF

2000

- Permanent appointment

1997

- Beamline Responsible @ESRF

1993

- Beamline Scientist @ESRF

1990

- Post Doc @INFN



Looking back 30 yrs

- No 3rd generation synchrotron sources ...
 - No exploitation of coherence properties of SR
 - The dawn of time-resolved, in-situ, operando studies

- X-ray Free Electron Lasers not invented yet...
 - Motions of electrons, atoms, molecules in time-domain observed only indirectly (optical lasers)



ESRF construction site, 1990

Symmetry of Matter from Molecules to CrystalsJ. Sivadine
Pages: 1-21**Single Crystal Structure Analysis**G. Heger
Pages: 23-49**Surfaces and Interfaces: X-Ray Studies**M. Sauvage-Simkin
Pages: 51-73**Surfaces and Interfaces: Neutron Studies**R. K. Thomas
Pages: 75-95**Neutron Scattering and Magnetic Structures**J. Schweizer
Pages: 97-117**Magnetic form Factors and Magnetization Densities**J. Schweizer
Pages: 119-130**Excitations and Phase Transitions**R. A. Cowley
Pages: 147-165**NEUTRON
AND SYNCHROTRON RADIATION
FOR CONDENSED
MATTER STUDIES****APPLICATIONS TO
SOLID STATE PHYSICS AND CHEMISTRY**Edited by:
J. BARUCHEL, J.L. HODEAU, M.S. LEHMANN
J.R. REGNARD, C. SCHLENKER**HERCULES**

Higher European Research Course for User of Large Experimental Systems

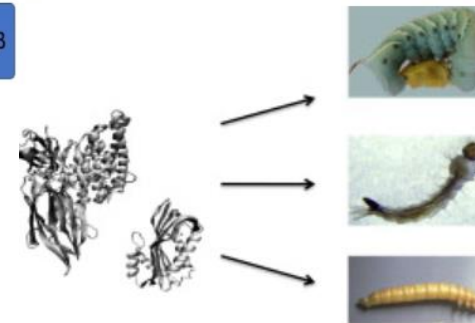
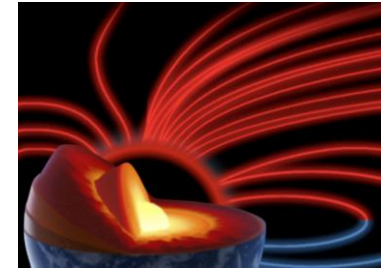
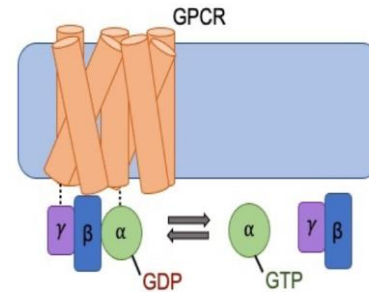
SPRINGER-VERLAG BERLIN HEIDELBERG GMBH

Non-Periodic Systems (Amorphography)Adrian C. Wright
Pages: 187-198**Quasicrystals**C. Janot
Pages: 197-211**Stereo Chemistry and Electronic Structure XAFS Spectroscopy: Data-Analysis and Applications**D. C. Koningsberger
Pages: 213-244**Low Dimensional Conductors**J. R. Fouquet
Pages: 245-260**Layers — Multilayers — Superlattices**S. Ferrer, J. L. Martínez
Pages: 261-287**Magnetic Excitations in High- T_c Superconductors**J. Rossat-Mignod
Pages: 289-306**Measurement of the Energy Gap in High T_c Superconductors by Electron Spectroscopies**Y. Petroff
Pages: 307-317

Trends 1

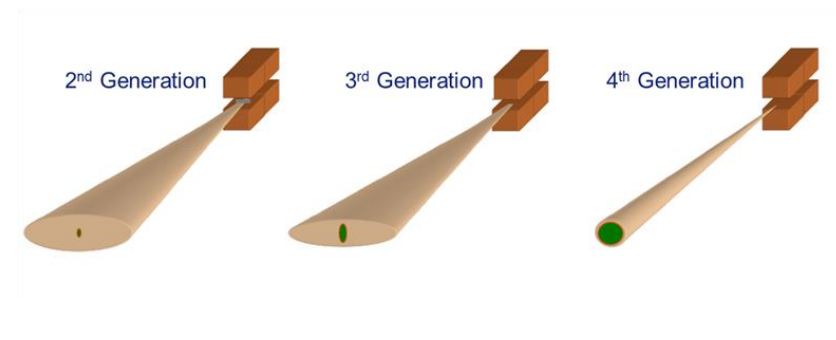
The development of X-ray user facilities, providing access to a large community of multidisciplinary scientists, has been a determinant in solving scientific and societal problems over the ~ 50 yrs, and this will continue for many decades and even centuries to come.

- ***water purification***
- ***geophysical processes of our planet***
- ***fundamental processes important for human health***
- ***designing heterostructures for future nano-optoelectronics***
- ***more efficient bacterial insecticides for agriculture and medicine***
- ***promising candidates for future high-density magnetic data storage media***
- ***new materials for greener and more sustainable energy solutions and improved energy efficiency***

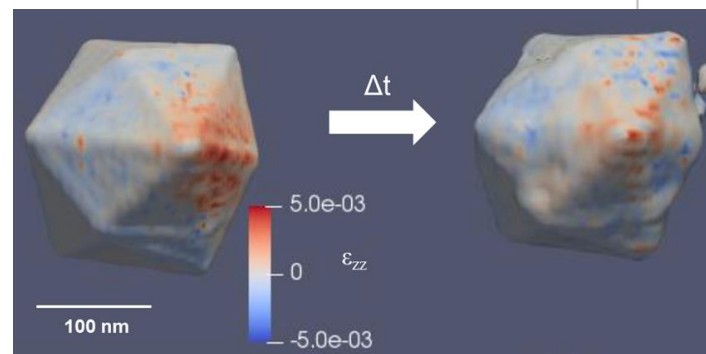
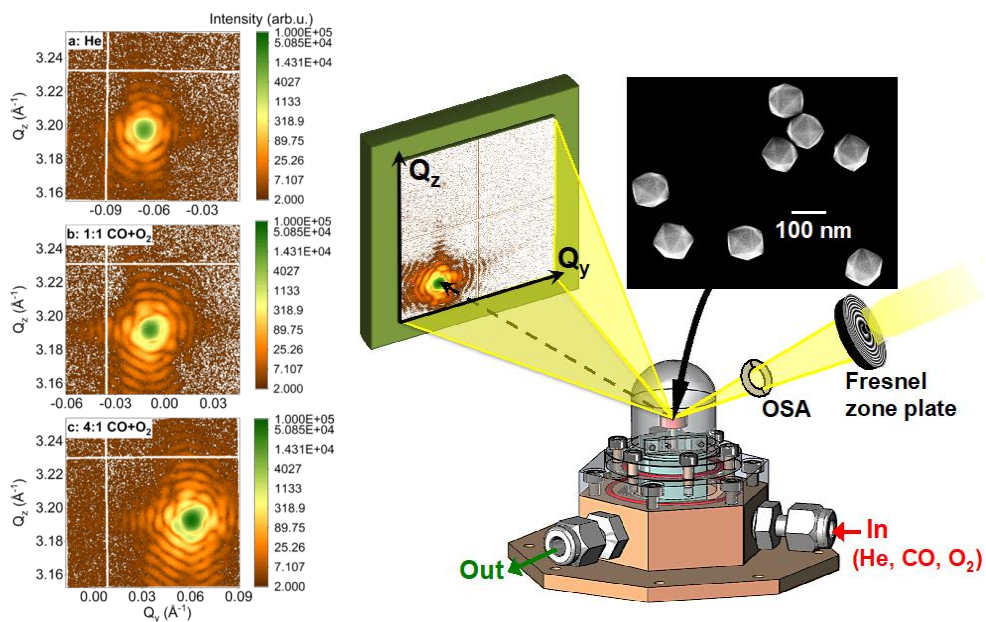
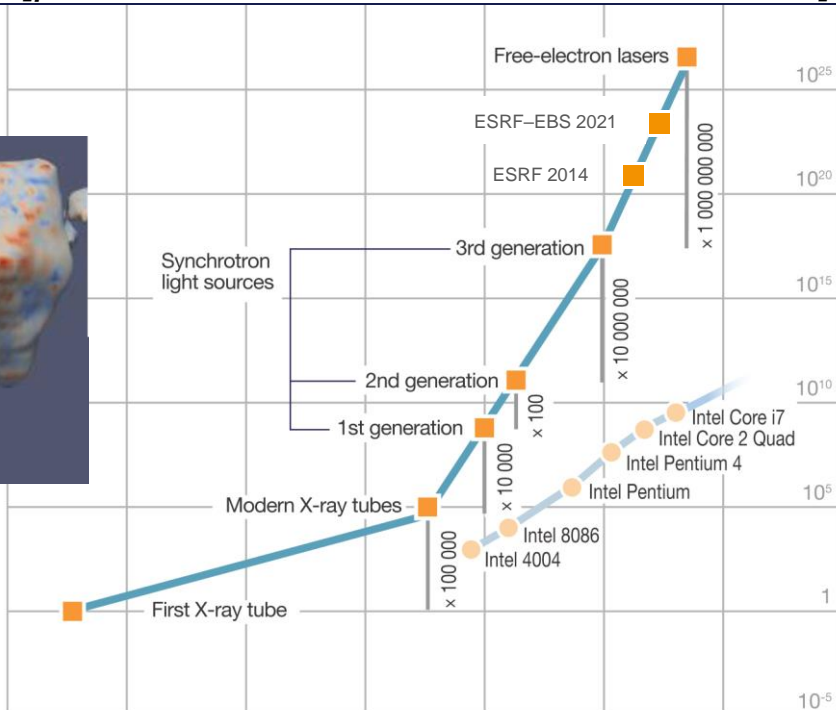


Trends 2

Step increase in brightness and coherence with MBA is an enabler for applying 3D microscopy with nanometer spatial resolution as a routine analytical tool, using dedicated sample environments for *in situ* and *operando* studies, in a broad range of research fields, with time resolution as a fourth dimension.



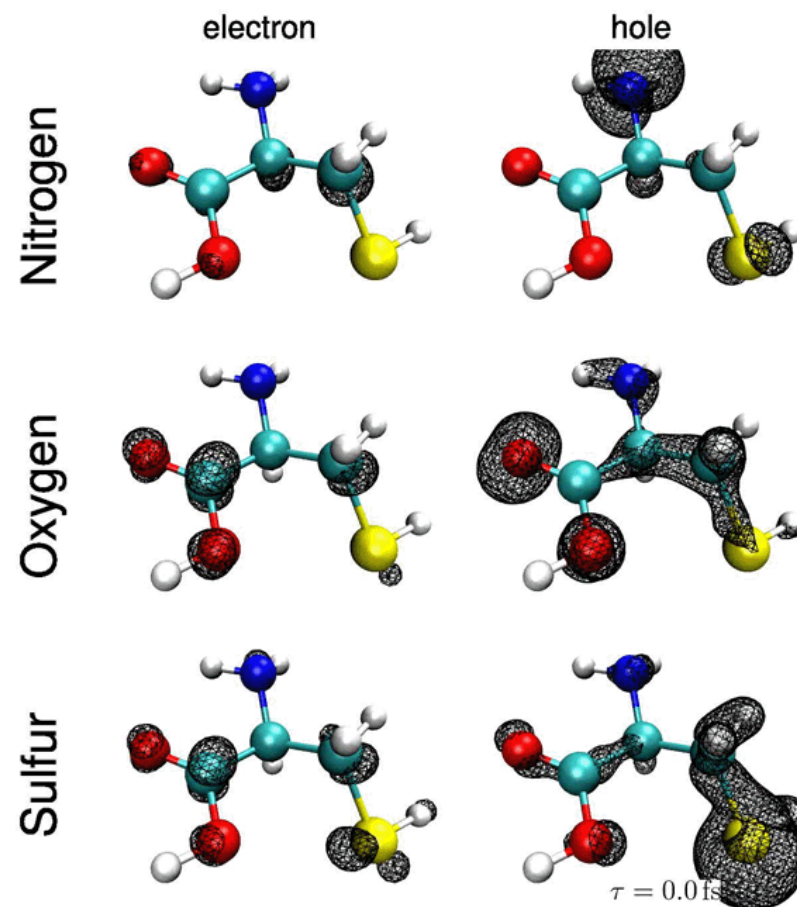
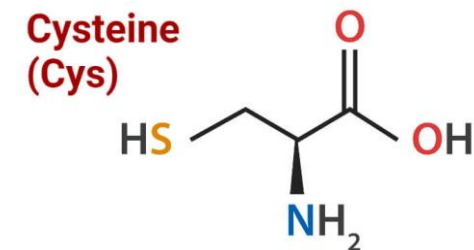
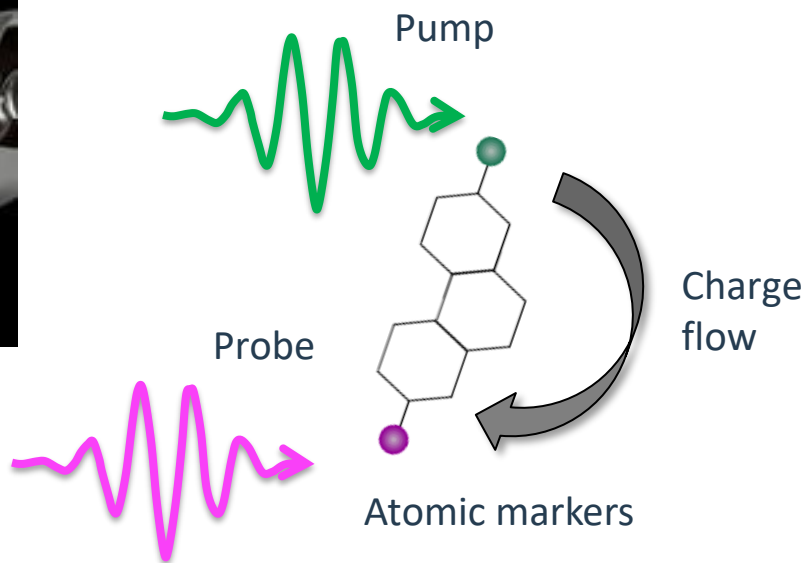
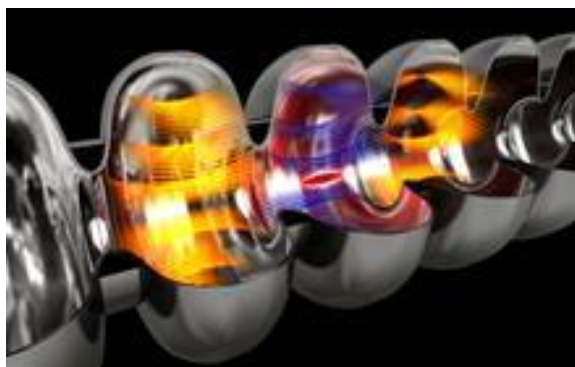
PEAK BRILLIANCE
[photons / s / mrad² / mm² / 0,1% bandwidth]



J. Carnis & M.I. Richard

Trends 3

We are well on track towards fully coherent and controllable XFEL pulses that will enable filming atomic scale movements of electrons and ions at the relevant timescales (attoseconds), visualizing rapid electronic structure changes, for example during a chemical reaction, a phase transition of a material, or a magnetic recording.



Opportunities and Challenges

- Growing scientific community, expansion of research fields
- Remote access: facilities become more open, accessible and inclusive
 - **A new era in access to SR and XFEL radiation based research**
- Large scale facilities will
 - **strengthen their role as places of inter- and multi-disciplinary work, intrinsically fostering brain circulation and cooperation**
 - **advance international integration, inclusion, and training of researchers who are not able to travel**
- Data Deluge & Data Science Technology
- How to develop cost-effective, green facilities?
- Machine Learning & Artificial Intelligence

2050 is yours to create!