PRELIMINARY PROGRAMME OF ERCA 2010

I - FIRST FOUR WEEKS IN GRENOBLE (11 JANUARY - 7 FEBRUARY 2010)

1.1. LECTURES (about 125 hours ; the duration of each lecture is 1.5 h) **AND SEMINARS**

N.B. *Please note that lectures may be given in a different order to the listing in the preliminary programme, and that there will be some mixing of lectures from the four different parts of the programme. In addition, some lectures will be given during the final week at Observatoire de Haute-Provence.*

The solar system and beyond

- Earth : evolution of a habitable world (J. Lunine, 1 lecture)
- Titan's methane cycle and lessons for Earth (J. Lunine, 1 lecture)
- Climates of Mars and Venus (J. Lunine, 1 lecture)
- Photochemistry of planetary atmospheres (V. Vuitton, 1 lecture)
- Trends and groupings in the solar system (M. Coradini, 1 lecture)
- Small bodies and dwarf planets in the Kuiper Belt (E. Schaller, 1 lecture)
- Comets and their variable atmospheres (E. Schaller, 1 lecture)
- Detecting and characterizing extrasolar planets (G. Tinetti, 2 lectures)
- Climate of exoplanets : habitability at the extremes (R. Pierrehumbert, 1 lecture)

Physics and chemistry of the atmosphere of the Earth

- Atmospheric chemistry - an overview from the bottom to the top of the atmosphere (J. Plane, 1 lecture)
- Radiative transfer : basics and examples (A. Macke, 1 lecture)
- Radiation in clouds and aerosols (A. Macke, 1 lecture)
- Clouds and precipitation physics – an introduction (M. Quante, 1 lecture)
- From deserts to rainforests : a global perspective on dust sources, processes and impact (Y. Rudich, 1 lecture)
- Optical properties of aerosols : theory and new measurement methods (Y. Rudich, 1 lecture)
- Physical, chemical and optical properties of biomass burning particles (R. Balasubramanian, 1 lecture)
- Satellite measurements of the troposphere - principles, results and challenges for the future (A. Richter, 1 lecture)
- Nitrogen oxides in the troposphere - sources, distributions, impacts and trends (A. Richter, 1 lecture)
- Halogen chemistry in the marine boundary layer – an example of DOAS in action (J. Plane, 1 lecture)

- Global biogeochemical cycles (K. Noone, 1 lecture)
- Natural biogeochemical cycles of trace elements (C. Barbante, 1 lecture)
- The role and fate of heavy metals emitted by human activities (C. Barbante, 1 lecture)
- Dynamic processes of mercury on regional and global scale (N. Pirrone, 1 lecture)
- Emission sources, regional and global distribution of classical Persistent Organic Pollutants (POPs) (R. Ebinghaus, 1 lecture)
- Detecting emerging organic pollurants – environmental chemistry in the forefront of monitoring and legislation (R. Ebinghaus, 1 lecture)
- Multicompartment models as tools for analyzing the environmental fate of chemicals (M. Scheringer, 1 lecture)
- Atmospheric long-range transport of chemicals and related risks to environment and human health (M. Scheringer, 1 lecture)
- Overview of air pollution in Megacities (R. Balasubramanian, 1 lecture)
- Using stable isotope analyses in environmental sciences (C. Brenninkmeijer, 1 lecture)
- Tracing atmospheric CO2, CH4, H2, N2O and other gases using stable isotope information (C. Brenninkmeijer, 1 lecture)
- The design and construction of environmental chambers for atmospheric chemistry studies (P. Seakins, 1 lecture)
- The use of environmental chambers for understanding the mechanisms of gas phase and heterogeneous processes in the atmosphere (P. Seakins, 1 lecture)
- The stratosphere (M. Chipperfield, 1 lecture)
- Polar stratospheric ozone depletion (M. Chipperfield, 1 lecture)
- The mesosphere (J. Plane, 1 lecture)
- The thermosphere (J. Plane, 1 lecture)
- The weather of the Sun : observation and exploration (H. Lundstedt, 1 lecture)
- Living with the space (solar) weather (H. Lundstedt, 1 lecture)
- Cosmic ray atmospheric transport and dosimetry (C. Mertens, 1 lecture)
- Satellite infrared remote sensing of upper atmospheres under non local thermodynamic equilibrium (C. Mertens, 1 lecture)

The climate system and climate change

- Global climate modelling – basic ideas and concepts of General Circulation Models (M. Werner, 1 lecture)
- Global climate modelling – advantages and limitations of General Circulation Models (M. Werner, 1 lecture)
- Global atmospheric reanalyses : motivation, design and quality (D. Dee, 1 lecture)
- Key ocean processes in climate (J. Marotzke, 1 lecture)
- Monitoring the Atlantic meridional overturning circulation at 26.5°N (J. Marotzke, 1 lecture)
- Chemical aspects of the marine CO2 system and the intricacies of air-sea exchange (A. Körtzinger, 1 lecture)
- Marine oxygen and carbon cycles and their responses to anthropogenic forcing (A. Körtzinger, 1 lecture)
- The greenhouse effect (A. Berger, 1 lecture)
- Human impacts on climate (what do we know and what do we know less ?) (A. Berger, 1 lecture)
- The astronomical theory of paleoclimates (A Berger, 1 lecture)
- The role of clouds in climate and environment (M. Quante, 1 lecture)

- Present-day sea level rise : observations and climate causes (A. Cazenave, 1 lecture)
- Observing terrestrial waters from space (A. Cazenave, 1 lecture)
- Climate of the polar regions (M. Van den Broeke, 1 lecture)
- Recent changes in the mass balance of Greenland and Antarctica (M. Van den Broeke, 1 lecture)
- Different proxies in paleoceanography (B. Malaizé, 1 lecture)
- Major Quaternary climatic events seen through the ocean, from orbital to millennial time scales (B. Malaizé, 1 lecture)
- Ice cores: introduction to a climate archive (H. Fischer, 1 lecture)
- Ice cores: particles and gases (H. Fischer, 1 lecture)
- Causes of decadal and centennial variability (T. Crowley, 1 lecture)
- Climate change over the last three million years (T. Crowley, 1 lecture)
- Climate dynamics of snowball Earth and the post-glacial hothouse (R. Pierrehumbert, 1 lecture)
- Global projections of hydrological effects of climate change (J.Kwadijk, 1 lecture)
- Regional climate modelling : status and perspectives (F. Giorgi, 1 lecture)
- Climate change in the Mediterranean region (F. Giorgi, 1 lecture)
- Science progress on cryosphere and climate in China and Asia (D. Qin, 1 lecture)

Human dimensions of environmental changes

- From regional to global : the role of UNEP in managing the emerging challenge of Atmospheric Brown Clouds (ABC) (S. Shrestha, 2 lectures)
- Earth System Science (K. Noone, 1 lecture)
- Pasteur's Quadrant : Science for a global society (K. Noone, 1 lecture)
- Gambling with the climate – collective climate protection as a social dilemma (J. Marotzke, 1 lecture)
- Climate ethics, climate justice and the bankruptcy of cost-benefit analysis (R. Pierrehumbert, 1 lecture)
- The latest scientific findings on climate change – a perspective from the last Assessment Report of IPCC (D. Qin, 1 lecture)
- The use of climate scenarios in development of water management climate adaptation strategies (J. Kwadijk, 1 lecture)
- European and international legislations and programs on mercury (N. Pirrone, 1 lecture)
- The solar radiation management approach to geoengineering (J. Feichter, 1 lecture)
- CO2 sequestration in the ocean (D. Wolf-Gladrow, 1 lecture)
- Energy and environment : research and development and technological challenges for TOTAL (J.F. Minster, 1 lecture)
- Climate and environment changes in China and sustainable development (D. Qin, 1 lecture)
- Air pollutants and their health impact (P. Brimblecombe, 1 lecture)
- Indoor air pollution (P. Brimblecombe, 1 lecture)
- Effects of air pollutants on materials (P. Brimblecombe, 1 lecture)

Seminars

- Atmosphere, water and astrobiology (A. Brack)
- Origin of inner planet atmospheres : contributions from the Stardust and Genesis missions (B. Marty)
- Mercury emissions from industrial source area in former GDR – a case study (R. Ebinghaus)
- Methane hydrates : the sleeping giant in climate change ? (K-C. Emeis)
- The vulnerability of the Nile basin to climate change (J. Kwadijk)
- Geoengineering climate – an overview on suggestions and objections under discussion (M. Quante)
- From mercury thermometers to satellite : how we observe the large complex Earth system ? (C. Brenninkmeijer)
- Aeronomy of upper atmospheres from auroral infrared emission (C. Mertens)

The lecturers will include (list subject to changes) : **F. ADAMS** (University of Antwerpen, Belgium) ; **J.M. ANE** (CEA Cadarache, France) ; **R. BALASUBRAMANIAN** (National University of Singapore) ; **C. BARBANTE** (University Ca' Foscari of Venice, Italy) ; **A. BERGER** (Catholic University of Louvain, Belgium) ; **A. BRACK** (CNRS Orléans, France) ; **C. BRENNINKMEIJER** (Max Planck Institute for Chemistry, Mainz, Germany) ; **P. BRIMBLECOMBE** (University of East Anglia, Norwich, United Kingdom) ; **A. CAZENAVE** (CNES Toulouse, France) ; **M. CHIPPERFIELD** (University of Leeds, United Kingdom) ; **M. CORADINI** (European Space Agency, Paris, France) ; **T. CROWLEY** (University of Edinburgh, United Kingdom) ; **D. DEE** (European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom) ; **R. EBINGHAUS** (GKSS, Geesthacht, Germany) ; **K-C. EMEIS** (University of Hamburg, Germany) ; **J. FEICHTER** (Max Planck Institute for Meteorology, Hamburg, Germany) ; **H. FISCHER** (University of Bern, Switzerland) ; **F. GIORGI** (Abdus Salam International Center for Theoretical Physics, Trieste, Italy) ; **P. KECKHUT** (CNRS/IPSL Verrières, France) ; **A. KOERTZINGER** (Leibniz Institute of Marine Sciences, Kiel, Germany) ; **J. KWADIJK** (Delft Hydraulics, Delft, The Netherlands) ; **H. LUNDSTEDT** (Swedish Institute of Space Physics, Lund, Sweden) ; **J. LUNINE** (University of Arizona, Tucson, USA) ; **A. MACKE**

(Leibniz Institute of Marine Sciences, Kiel, Germany) ; **B. MALAIZE** (University of Bordeaux, France) ; **J. MAROTZKE** (Max Planck Institute for Meteorology, Hamburg, Germany) ; **B. MARTY** (Ecole Nationale Supérieure de Géologie, Nancy, France) **C. MERTENS** (NASA Langley Research Center, Hampton, USA) ; **J.F. MINSTER** (Total S.A., Paris, France) **;** **K. NOONE** (University of Stockholm, Sweden) ; **J. PATRIS** (University Paul Cezanne of Aix-Marseille, France) ; **A. PAZMINO** (CNRS/IPSL Verrières, France) ; **R. PIERREHUMBERT** (University of Chicago, USA) ; **N. PIRRONE** (CNR, Rome, Italy) ; **J. PLANE** (University of Leeds, United Kingdom) ; **D. QIN** (China Meteorological Administration, Beijing, China) ; **M. QUANTE** (GKSS, Geesthacht, Germany), ; **A. RICHTER** (University of Bremen, Germany) ; **Y. RUDICH** (Weizmann Institute, Rehovot, Israel) ; **A. SARKISSIAN** (CNRS/IPSL Verrières, France) ; **E. SCHALLER** (Institute of Astronomy, Honolulu, USA) ; **M. SCHERINGER** (Swiss Federal Institute of Technology, Zurich, Switzerland) ; **P. SEAKINS** (University of Leeds, United Kingdom) ; **S. SHRESTHA** (UNEP, Nairobi, Kenya) ; **G. TINETTI** (University College, London, United Kingdom) ; **M. VAN DEN BROEKE** (Utrecht

University, The Netherlands) ; **V. VUITTON** (University Joseph Fourier, Grenoble, France) ; **M. WERNER** (Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany) ; **D. WOLF-GLADROW** (Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany)

1.2. PANELS

Panels will be organised. The topics that might be considered include :

- Climate change,
- Geoengineering – should we control the thermostat ?
- The future of exploration of the cosmos and the Earth from space

1.3. POSTER PRESENTATIONS

Each participant will prepare a poster in which he describes his own research work. About 15 posters will be presented each week. The participants will also be asked to prepare in advance a one page summary of their poster, and to give a five minute oral presentation (powerpoint presentation or overheads).

1.4. VISITS OF RESEARCH INSTITUTES

The participants will visit several research institutes in Grenoble : the European Synchrotron Radiation Facility (ESRF), the Laboratory of Glaciology and Geophysics of the Environment (UJF/CNRS) and the Coriolis Platform (Grenoble INP/UJF/CNRS).

The ***European Synchrotron Radiation Facility*** *(ESRF) is a research institute funded by twelve European countries. Its main task is to produce hard X-rays with high brilliance using synchrotron radiation emitted by very high energy electrons (6 GeV). The electrons beam is produced in a linear accelerator and then a synchrotron. It is then injected into a 844 m storage ring. The experimental hall around the storage ring can house up to 50 beamlines tangential to the ring. Each beamline is specialised either for a technique or for a field of research. The different fields of research include for instance : materials science, surface science, biology, medicine, high pressures, chemistry, magnetism and industrial applications.*
They also include research fields of relevance for ERCA such as the analysis of atmospheric
particulate matter using X-ray microfluorescence. The visit will begin by a presentation of ESRF by ***Mrs D. Cornuejols*** *(ESRF Information Officer) and a lecture by* ***Prof. F. Adams*** *(University of Antwerpen) on the use of synchrotron radiation in atmospheric chemistry. The participants will then visit several beamlines in the experimental hall.*

The ***Laboratory of Glaciology and Geophysics of the Environment*** *(LGGE) is a laboratory of the University Joseph Fourier of Grenoble and the French National Center for Scientific Research (CNRS). Its scientific reputation is based on outstanding research achievements related to the reconstruction of past changes of climate and atmospheric composition during the last climatic cycles from polar ice cores. These studies are based on the well preserved frozen atmospheric archives which have been obtained by ice drilling in the central plateau areas of Antarctica and Greenland. The time periods under investigation now include the last nine climatic cycles as well as the Holocene and the last few centuries. Current investigations* *also include the study of the physical and mechanical properties of the ice, modelling of ice caps, chemical exchanges between the low atmosphere and snow and ice fields, remote sensing of snow and ice covered areas in polar and temperate regions, mass balance of Alpine and Andean glaciers as well as high latitude climate modelling and atmospheric chemistry modelling. Research carried out at LGGE combines technological and analytical approaches. Of particular i mportance are polar field campaigns organised in the frame of international programmes such as the European Programme for Ice Coring in Antarctica (EPICA), as well as field parties in the Alps, in the Arctic and in the Andes. Research conducted at LGGE contributes to a better understanding of important scientific issues which are fundamental to our society as a whole, such as the greenhouse effect, climate and environmental changes, atmospheric pollution at global and regional scales, as well as risks associated with glaciers.*

The ***Coriolis Platform*** *is the largest rotating turntable in the wold (diameter : 13 m). It belongs to the " Laboratoire des Ecoulements Géophysiques et Industriels (Grenoble- Institut National Polytechnique/University Joseph Fourier of Grenoble/CNRS. The instrument can be accessed by European researchers in the frame of the EU funded "Hydralab" Program. The facility is designed for physical modelling of geophysical flows influenced by rotation and stratification, and reproduces meso-scale processes in the ocean or the atmosphere with very good dynamical similarity. The rotation period ranges from 18 to 1000s and the tank can be filled over 1m with homogeneous, multilayered or linearly stratified fluids. It is equipped with 2D and 3D particle imaging velocimetry systems (PIV) adapted to the large size of measurement volumes. Current research activities are : stability of density currents : appearance and growth of instabilities, entrainment, interactions with a topography boundary layers in laminar and turbulent regimes*

Ekman layer and lateral layer near a vertical wall or a topography turbulence in homogeneous or stratified rotating fluid : wake of isolated obstacles vortex structure and vortex pair interaction ; internal waves : generation and breaking processes, induced mixing ; internal solitary waves ; sediment transport and morphodynamics.

II - LAST FIVE DAYS (7-12 FEBRUARY 2010)

The participants will stay for five days at "Observatoire de Haute-Provence" (OHP), near the small city of Forcalquier (about 170 km south of Grenoble). OHP is one of the main French astronomical observatories, with several large optical telescopes and various other instruments. Its location is renowned for the clarity of its sky.

OHP is part of the "Observatoire Astronomique de Marseille-Provence " (OAMP), together with the " Laboratoire d'Astrophysique de Marseille" and the "Laboratoire d'Interférométrie Stellaire et Exoplanétaire"

OHP *was created in 1937 as a national facility for French astronomers. It is located in southeast France on a limestone plateau at an altitude of 650m and lies 90km East of Avignon and 100km North of Marseille. The main telescopes have diameters of 1.93m, 1.52m and 1.20m and date from 1957, 1967 and 1943 respectively. Six smaller telescopes are also located on the site, three of them being remote- controlled. The main instruments used on the 1.93m telescope are the ELODIE and SOPHIE échelle spectrographs. ELODIE was* *used by Mayor and Queloz in 1995 to discover 51 Peg-B, the first planet around another star than the Sun. Thirty other extra-solar planets have since been found with these instruments. The 1.52m telescope is equipped with the high- resolution (R=100000) AURELIE spectrograph for detailed stellar studies. The 1.20m telescope is used for direct imaging to monitor the brightness of different types of objects (natural satellites, asteroids, stars, X-ray sources, etc.).*

OHP also hosts one of the largest geophysical observatories in the world, the "Station Gérard Mégie" of the Institut Pierre Simon Laplace (IPSL). The station has important experimental facilities for atmospheric measurements: temperature, wind and ozone lidars, UV-visible spectrometers, balloon sounding, etc..., developed by scientists of the "Laboratoire Atmosphère, Milieux, Observations Spatiales" (LATMOS) (CNRS/ University of Versailles Saint-Quentin /University Pierre et Marie Curie of Paris/ /IPSL). Station Gérard Mégie is a primary station of the Network for Detection of Stratospheric Changes (NDSC). It allows to obtain long term high accuracy measurements important for climate change and stratospheric ozone studies.

OHP, Station Gérard Mégie and the various instruments will be presented in lectures by ***P. Keckhut, J. Patris, A. Pazmino and A. Sarkissian***. The participants will then be split into several groups to see detailed technical parts of the temperature, wind and ozone lidars,

and of the SAOZ and Dobson spectrometers. They will also participate in the ozone sounding balloon launch. If the weather is good, they will also use the 0.80 and 1.20 m optical telescopes for observations.

The participants will also visit the **Cadarache Research Center of the French Atomic Energy Commission (CEA)** in St-Paul-les Durance, about 40 km from Forcalquier.Special emphasis will be given to current international research on fission and fusion nuclear energy, especially to the **International Thermonuclear Experimental Reactor (ITER) project**, developped jointly by China, the European Union, India, Japan, South Korea, Russia and the United States.

Important : Access to the Cadarache Research Center of the French Atomic Energy Commission (Commissariat à l'Energie Atomique) is subject to prior authorization due to the sensitive nature of some of the research carried out at the center. Authorization to certain participants may thus be refused.

The visit will begin by a general tour of the Cadarache Research Center with **A. Boulet** (CEA Cadarache). It will continue with a presentation "Is nuclear energy sustainable ? Can nuclear energy contribute to solve the energy and climate crisis ?" by **J.M. Ané** (CEA Cadarache) about current research on fission and fusion energy, and a visit to the Tore Supra Tokamak.

The evidence for adverse effects of massive release of greenhouse gases (GHGs) to the atmosphere is clear. The consensus of the scientific community overwhelmingly backs this position (e.g. fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007). The Kyoto Protocol shows that politicians are aware of the risks and willing to *address the problems. But there is no consensus on what the responses should be and practical responses fall short of what is necessary.*

One of the main challenges will be to manage the transition towards a sustainable energy system. In 2000 about 80% of the world 10 Gtep primary energy was produced from GHG emitting fossil energies. If the future warming is to be limited to 2°C in 2100, our energy system has to be radically changed. More than 80% of the 20-30 Gtep energy which will have to be produced at the end of the century will have to be GHG free.

The part nuclear energy could play in the transition to a sustainable energy system is debated. Energy sources are usually split into renewable and non renewable. Such a simple classification leads to the evident conclusion that a sustainable energy system can only rely on renewable energies. Nuclear energy is usually restricted to fission and is considered as non renewable due to the limited resources of uranium. Nuclear energy then appears to be incompatible with a sustainable energy system.

However "renewable energy" is an oxymoron. The mass-energy content of a closed system is conserved and energy can't be "renewed". Mass may convert to energy, and vice versa but neither may disappear without compensation in the other quantity (first law of thermodynamics). Mass has to disappear to produce energy, and mass-energy transformations come at a cost which is a loss of useful energy (second law of thermodynamics). The concept of "renewable energy" should be replaced by the one of "sustainable energy" and energy sources should be split into sustainable and non sustainable i.e. compatible or not compatible with sustainable development. This change of paradigm in the classification of energy sources and the inclusion of both fission and fusion in nuclear energy radically change the perception of the contribution nuclear energy could make to a sustainable energy system.

Availability of nuclear fuels is a prerequisite topic to be dealt with when the sustainability of nuclear energy is discussed. Both fission and fusion fuels resources should be surveyed. Nuclear reactions either by the nuclear fission (splitting) of elements of high atomic number or by the nuclear fusion (joining) of elements with low atomic number release huge quantities of energy. Concerning fission fuel, total identified and undiscoverered conventional resources of uranium amount to respectively 5.5 and 10.5 million tons (MtU) at a cost inferior to USD 130/kgU. An additional 22 MtU could be recovered as a by product of phosphate mining even if the uranium ore is not rich enough to justify mining it by itself. An extra 4500 MtU could eventually be extracted from the oceans if it can be done at a reasonable price in spite of the very low concentration of uranium (about 3 parts per billion).

In terms of years of world energy consumption in 2000 (yWEC) these uranium resources, used in non-breeder fission reactors, would produce at a minimum an energy equivalent to 5 yWEC (identified resources), 10 yWEC (undiscovered resources), 20 yWEC (phosphates resources) and 900 yWEC (oceans resources), i.e. almost a thousand years in total.

Non-breeder fission reactors only burn about 1% of the energy content of uranium. Breeder reactors can extract up to 100 times more energy from uranium than non-breeder reactors do. Breeder reactors can also burn thorium. The concentration of thorium in the earth's crust is roughly three times larger than the concentration of uranium; however thorium concentration in the oceans is negligible. The assessment of thorium resources differs from that of other commodities (coal, uranium etc) in that there is no current large-scale demand for thorium;

thorium resources are preliminarily assessed at about 2.5 MtTh, at a cost inferior to USD 80/kgTh.

Uranium resources used in breeder reactors could provide a total energy spanning from 500 yWEC (identified resources) to 90 000 yWEC (oceans resources) i.e. almost a hundred thousand years of world energy consumption in total. Thorium in breeder reactors could probably provide an energy equivalent to the conventional resources of uranium.

Concerning the availability of fuels for fusion reactors, lithium extracted from the oceans which contain 230 billion tons of lithium limits the reserves of deuterium-tritium (D-T) fusion fuels to tens of millions of yWEC. The capacity to build a fusion reactor capable to burn only deuterium using the deuterium-deuterium (D-D) fusion reactions is questionable. It supposes that the plasma core is heated up at 700 million degrees i.e. four times the temperature needed for a D-T fusion reactor. However the D-D reaction could extend the fuel availability of fusion to billions of YWEC, which corresponds to the time when our neighbour fusion reactor, the sun, will eventually run out of fuel: the end of sustainable development on earth…

But the question of the sustainability of nuclear energy cannot be restricted to the availability of nuclear fuels even if it is a prerequisite. Other sustainability constraints such as social acceptance, resistance to weapon proliferation, safe management of nuclear waste, safety of operation, security of energy supply, impact of fuel extraction and conservation of fuels for the future generations have to be considered.

What are the differences between fission and fusion in terms of waste, safety, proliferation, availability of fuel, security of energy supply? What are the key technical challenges to be faced to develop breeders and fusion reactors? Which key results will deliver the next step nuclear machines?

Generation IV *test reactors (~ 2020?) probably breeding reactors to be built by the Generation IV International Forum partners (Argentina, Brazil, Canada, China, Euratom, France, Japan, South Korea, South Africa, Switzerland, Russia, UK, USA)*

JHR *(Jules Horowitz Reactor CEA/Cadarache 2014) material testing reactor (Belgium, Czech Republic, India, Finland, France, Japan, The Netherlands)*

ITER *(International Thermonuclear Experimental Reactor Cadarache 2018) will be the largest tokamak ever built, it will produce 500 MW of fusion power and is intended to demonstrate the feasibility of magnetic fusion as a future energy source (China, EU, India, Japan, South Korea, Russia, USA)*

LMJ *(Laser MegaJoule CEA/CESTA 2014) NIF (National Ignition Facility Lawrence Livermore laboratory 2009)* **HiPER** *(High Power laser Energy Research facility EU 2025?) intended to demonstrate the feasibility of laser driven inertial fusion*

IFMIF *(International Fusion Materials Irradiation Facility 2018?) accelerator for fusion material testing (EU, Japan, Russia, USA under the auspices of the International Energy Agency)*

We shall try to analyze how the sustainability of nuclear energy evolutes through the four stages of nuclear energy: non-breeding fission, breeding fission, D-T fusion, D-D fusion and how nuclear energy can contribute to provide a response to the imminent energy and climate crisis.

A visit of the Tore Supra superconducting tokamak will follow the presentation by ***Jean-Marc Ané****. Tore Supra is the largest superconducting tokamak in the world. In most tokamaks, the plasma duration is limited by the capacity of the copper magnetic field coils to maintain the high magnetic field needed to confine the plasma, as well as the capacity of the vacuum vessel walls to extract the high heat flux emitted by the plasma and finally by the capacity to maintain a high current in the plasma.*

Tore Supra holds the world record of high power plasma discharge duration (6 minutes) because it implements cutting edge technologies. The niobium-titanium superconducting coils of Tore Supra are cooled at 1.8 K by super fluid helium so that a steady state high magnetic field can be maintained. The actively cooled carbon walls of the vacuum vessel that contains the 25 cubic meter plasma can sustain very high thermal flux (up to 10 $MW\ m^{-2}$*). Klystrons generating waves at 3.7 Ghz can drive a plasma current of about 500kA.*

The duration of the plasma discharge is presently mostly limited by the klystrons which were designed in 1986 to only operate for about 1 min. Upgraded CW klystrons are presently installed and Tore Supra should set a new record of plasma discharge duration in the coming years…

A **sightseeing tour** will also be organized.