# Renewable Energy for Radio Astronomy

**Lourdes Verdes-Montenegro**
**Juande Santander Vela**
Instituto de Astrofísica de Andalucía-CSIC
Granada
On behalf of CTAER, IT-Portugal,
ASTRON-Netherlands, MPIfR-Germany

AERAP Workshop: AERAP Framework Platform Discussion Workshop
Brussels, March 6th 2013

# Talk Outline

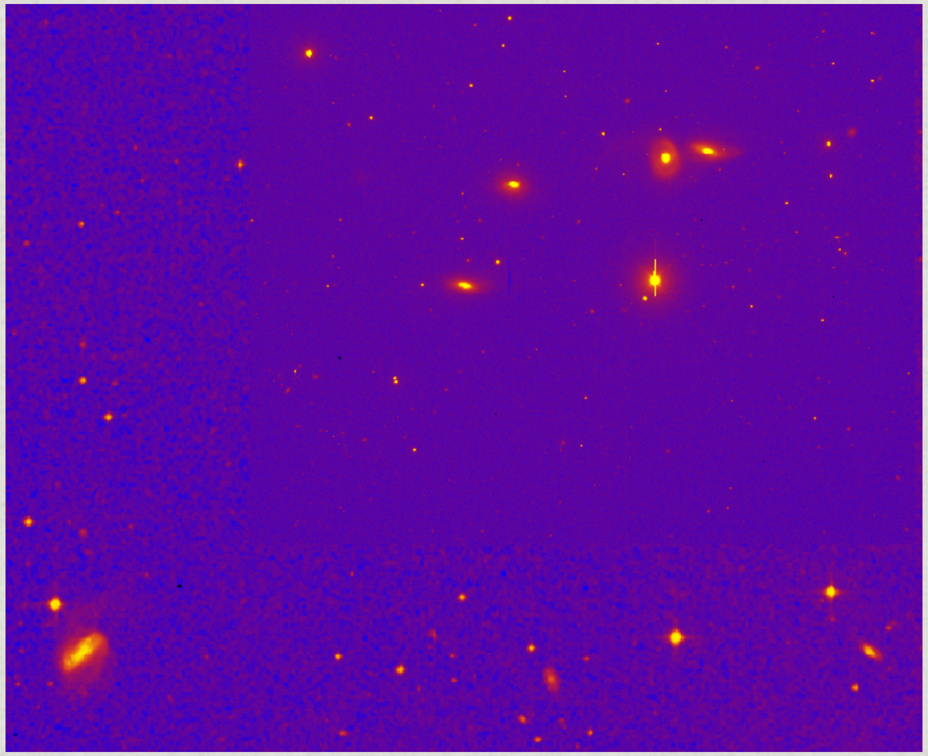
(…a Spanish radioastronomer)

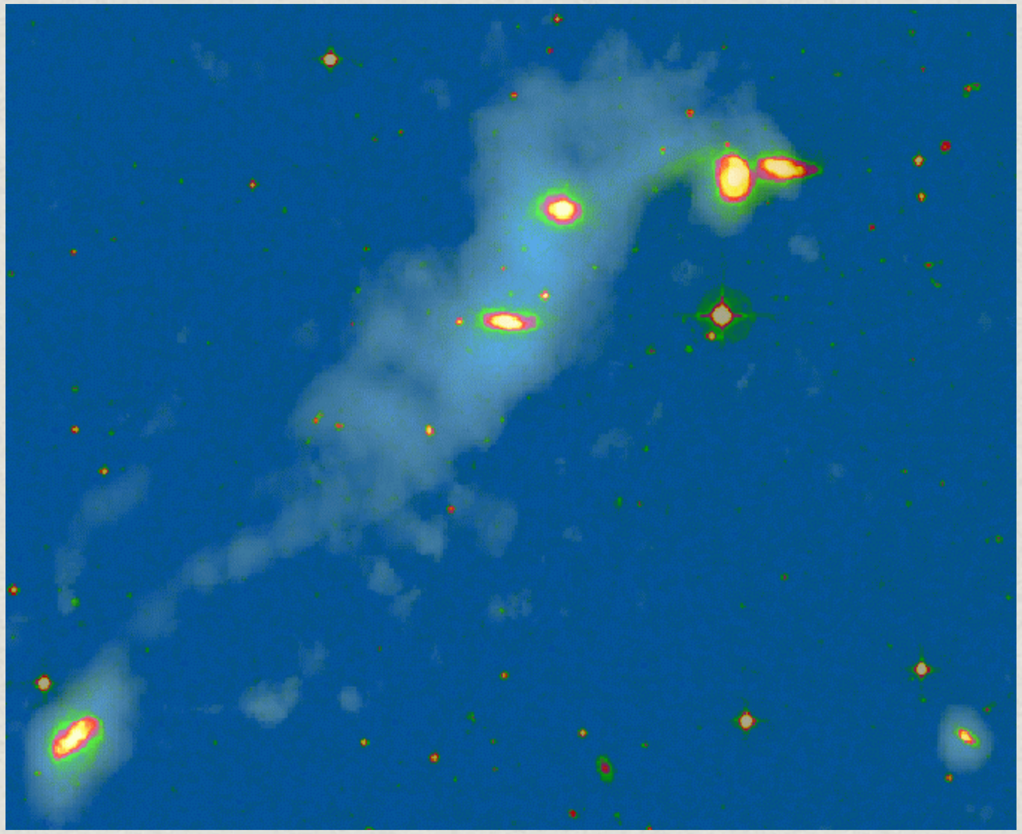
- What has Radioastronomy to do with Renewable Energy?
- Current challenges
- A 1st step: EC funded project BIOSTIRLING4SKA
- Benefits for Africa
- Benefits for Europe
- Key actions

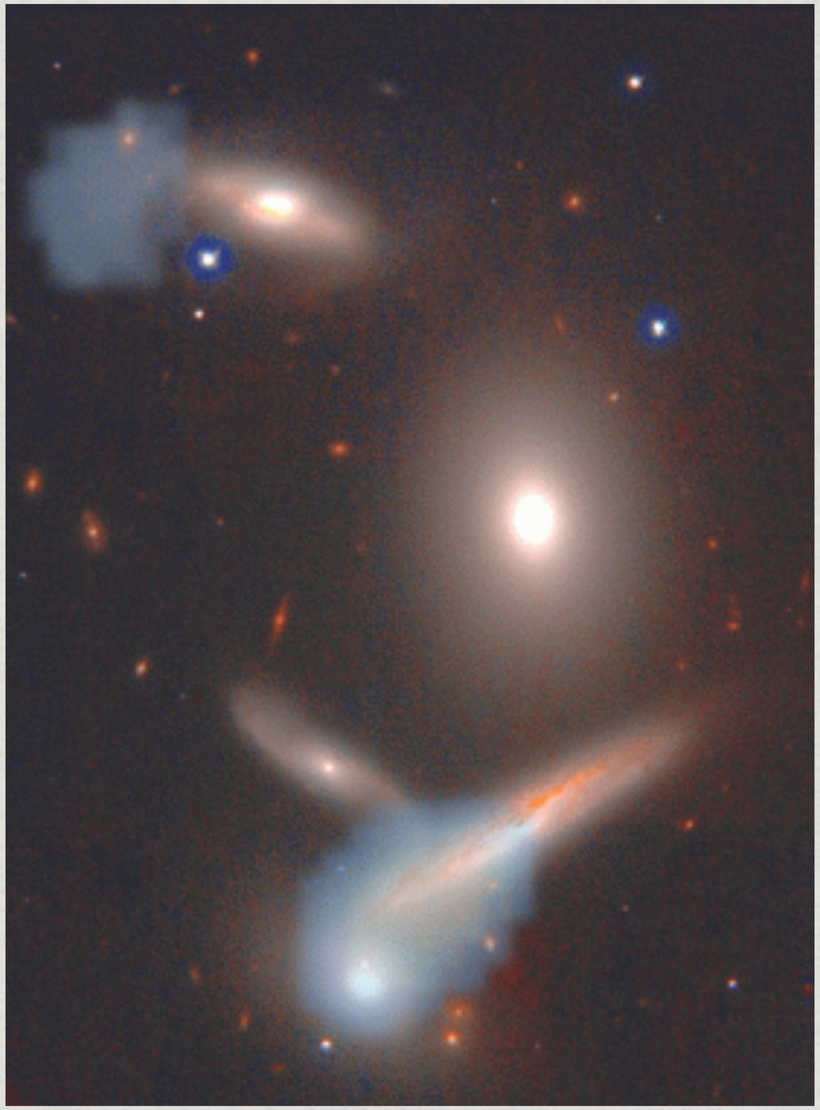
(do we need to separate them?)

  - Global benefits

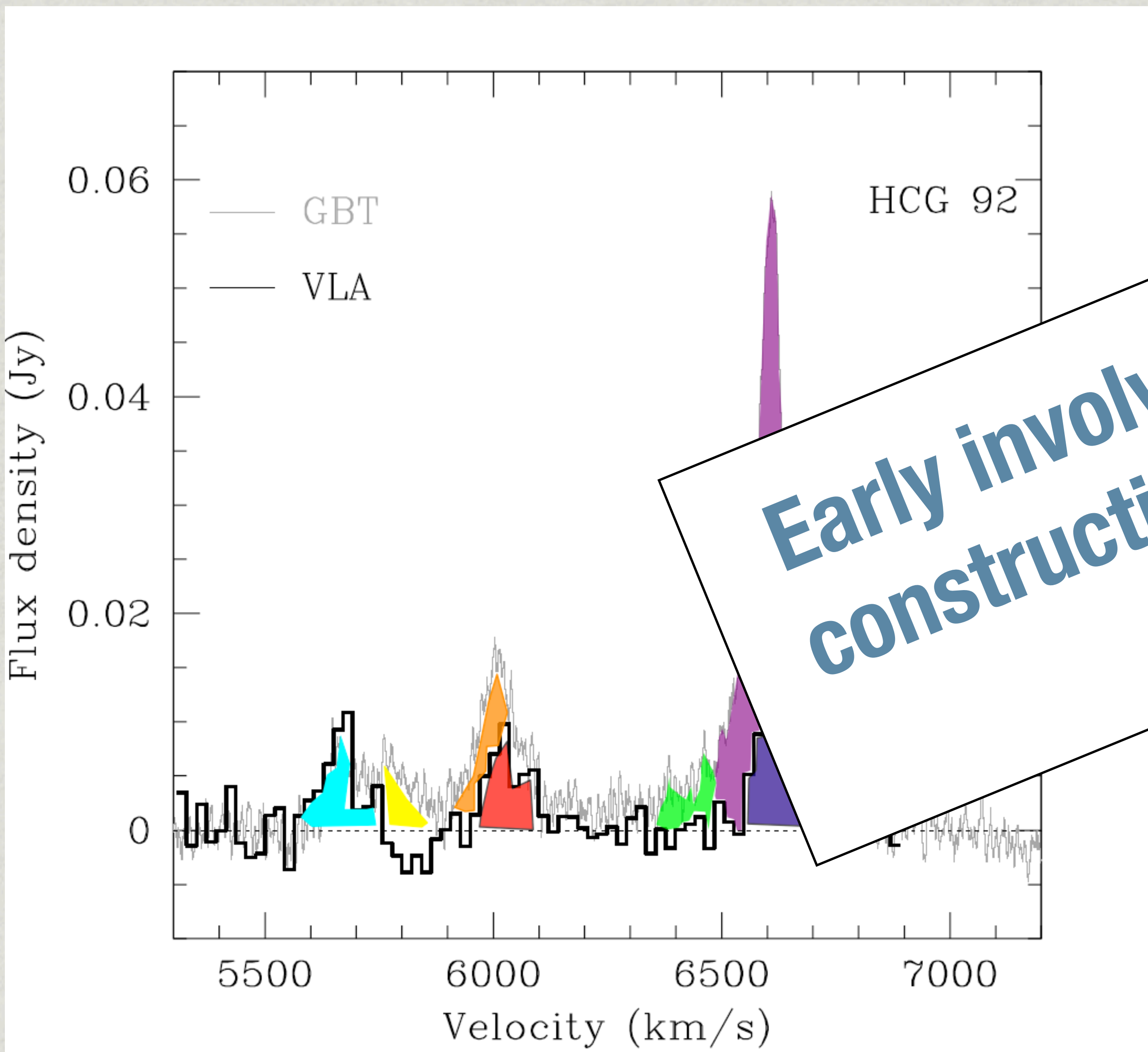
# Looking for the faintest gas







# The faintest gas escapes to the current radiointerferometers




**Early involvement in design and construction crucial for the best science**

- MINECO-**funded** ***Scientific Network***

UV, IAA, CAB, OAN, UB, IEEC, UGR, UJ, IAC, IFCA, UPTC

- **June 2011:** kick-off meeting in CSIC showed broad and strong scientific interest of Spanish researchers in SKA
- **September 2011**: MICINN request Spain to participate in SKA as an Observer

- MINECO-**funded** ***Feasibility Study for Spanish Technological Participation in the SKA***

- 14 organisations: 7 research institutions (4 from CSIC) + 8 Universities (all over Spain)

- Close collaboration with

  - Fractal (Astronomy & Instrumentation Industry)

  - Induciencia (Science & Technology Industry Association)

  - CTAER (Centro Tecnológico Avanzado de Energías Renovables)

As part of mapping of Spanish industrial capabilities with SKA technologies:

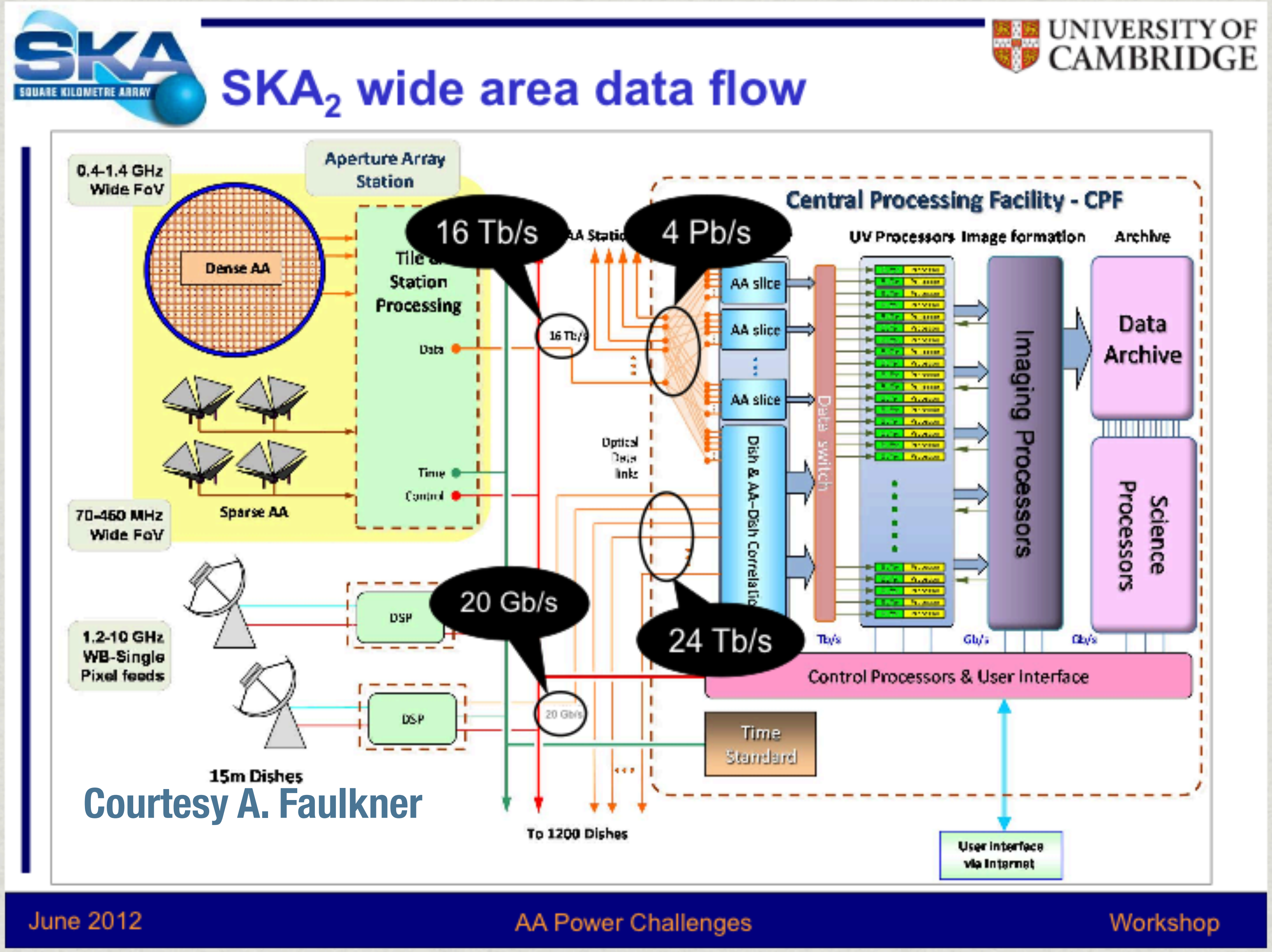
# Key area: Power

| EMPRESAS<br>ÁREAS TECNOLÓGICAS | ACITURRI | AIDO | ALTRAN INNOVACIÓN | ARIEMA | ASTURFEITO | CRISA | CRYOVAC | DEIMOS | EMPRESARIOS AGRUPADOS | FRACTAL | GMV | GTD | HTS | IDOM | IK4-TEKNIKER | INSA | INTEGRASYS | ISOFOTON | IXION Industry & Aerospace | JEMA | LIDAX | PROCON SYSTEMS | SCHWARTZ-HAUTMONT | SENER | SEVEN SOLUTIONS | TAFCO METAWIRELESS | TECNOBIT | TELSTAR Vacuum Solutions | THARSIS TECHNOLOGY | TTI | VINCI ENERGIA | VLC Photonics |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Analog ASIC design | | | | |x| | | | | | | | | | | | | | | | | | | | |x| |x| | | |
| Analog beamforming hardware | | | | | | | | | | | | | | | | | | | | | | | | | | | |x| | |x|
| Analog beamforming SW | | | | | | | | | | | | | | |x| | | | | | | | | | | |x| | | |
| Analog filterbank design | | | | | | | | | | | | | | |x| | | | | | | | | | |x| | | | | |
| Analog sensors | |x| | | | | | | | | | | |x|x| | | | | | | | |x| |x| |x| | | |
| Analog signal processing | | | | |x| | | | | | | | |x|x|x| | | | | | |x|x| |x| |x| | | |
| Antenna system beam profile measurement |x| | | | | | | | | | | | | | | |x| | | | | | | | | | | | | | | |
| Antenna system sensitivity measurement |x| | | | | | | | | | | | | | | |x| | | | | | | | | | | | | | | |
| Cabling | | | | |x| | |x| | | | | | | | | | | | | | | | | | | |x| | | |
| Civil engineering | | | | | | | |x| | | | |x| | | | | | | | | |x| | | | | | | | |
| Control system design |x| | | | |x| | | |x| |x| |x|x| |x| |x| | |x| |x| | |x| |x|x| | |
| Cooling: Cryogenics | | | | |x|x| | | | | |x|x|x| | | | | |x| | | | | | |x| |x| | |
| Cooling: Heat recovery | | | | | | | |x| | | |x|x|x| | | | | |x| | | | | | |x| |x| | |
| Cooling: Thermal insulation | | | | | |x| | | | | |x|x| | | | | | |x| | | | | | |x| | | | |
| Cost modelling | | | | | | | | | | | | |x|x|x| | | | | | | | | | | | | | | | |
| Cryogenic LNAs (450MHz-2GHz) | | | | | | | | | | | |x| | |x| | | | |x| | | | | | | | |x| | |
| Digital ASIC design | | | | |x| | | | | | | | | | | | | | | | | | | | |x| |x| | | |
| Digital beamforming | | | | |x| | | | | | | | | |x| | | | | | | | | | | | | |x| | |
| Digital Fieldbuses | | | | |x| | | | | | | | | | | | | | | |x| | | | | | | | | | |
| Digital filterbank design | | | | | | | | | | | | | | |x| | | | | | | | | | |x| | | | | |
| Digital sensors | |x| | | |x| | | | | | | |x|x| | | | | | | | |x| |x| | | | | |
| Digital signal processing | |x| | | |x| | | | |x| | | |x|x|x| | | | | | | |x| |x| | |x| | |
| Digital signal transport networks | | | | |x| | | | |x| | | |x| | | | | | | | | | | |x| | | | | |
| Dipole antenna array construction |x| | | |x| | | |x| | | |x|x| | | | | | | | | | | | | | |x| | |
| Dipole antenna array design |x| | | | | | | |x| | | |x|x| | | | | | | | | | | | | | |x| | |
| Dish antenna construction |x|x| | |x| | | |x| | | | |x| | | | | | | | |x| | | | | | |x| | |
| Dish antenna design |x| | | | | | | |x| | | |x|x| | | | | | | | | | | | | | |x| | |
| Electro-magnetic compatibility design | | | | |x| | |x| | | | | |x| | | | | | | | | | | |x| | | | | |
| FFT digital signal processing | | | | |x| | | | |x| | | |x|x| | | | | | | |x| | |x| | |x| | |
| FPGA computing | | | | |x| | | | |x| | | |x|x| | |x| | |x| |x|x| |x| | |x| | |
| FPGA design | | | | |x| | | | |x| | | |x|x| | |x| | |x| |x|x| |x| | | | | |
| High Performance Computing: event-based computing | | | | | | |x| | |x|x| | | | | | | | | | | | |x|x| | | | | | |
| High Performance Computing: GPU computing | | | | | | |x| | |x|x| | | | | | |x| | | | | |x| | | | | | | |
| High Performance Computing: grid computing | | | | | | |x| | |x|x| | | |x| | | | | | | | | | | | | | | | |
| High-accuracty timing systems | | | | |x| |x| | |x|x| | | |x|x| | | | | | | |x| | | |x| | | |
| High-voltage electrical engineering | | | | |x| | | | | | | | | | | | | |x| | | |x| | | | |x| | | |
| Logistics engineering | | | | | | | | | | | | |x| | | | | | | | | |x| | | | | | | | |
| Low-RFI Power conversion | | | | | | | | | | | | | | | | | | | | | | | | | | | | |x| | |
| Mecatronics | |x|x| | | | | | | | |x|x|x|x| | | | | |x| | |x| | | |x|x| | | |
| Mechanical engineering |x|x|x| | | | | |x| | | |x|x|x| | | | | |x| | |x| | | |x|x| | | |
| Mechanical tooling |x|x|x| | | | | | | | | |x|x|x| | | | | |x| | |x| | | |x| | | | |
| Monitoring SW and systems |x|x| | | |x| |x| |x|x|x| | |x| | | |x| | | | | | | | | | | | | |
| Non-cryogenic LNAs (70MHz-450MHz) | | | | | | | | | | | | | | |x| | | | | | | | | | | | | |x| | |
| Photovoltaic solar thermal energy |x|x| | | | | | | | | | | |x| | |x| |x| | | | | | | | | | | | |
| Power engineering | | | |x| |x| | |x| | |x| |x| | | | | |x| | | |x| | |x| | | |x| |
| Power engineering: budgeting | | | |x| |x| | |x|x| | | |x| | | | | | | | | |x| | | | | | | | |
| Project management | |x| |x| |x| |x| | |x|x|x|x|x|x| | | | |x| | |x| |x| | | |x| | |
| RF engineering 0,03-0,15 m (2-10GHz) | | | | | | | | | | | |x| | |x|x| | | | | | | | |x| | | |x| | |
| RF engineering 0,12-0,30 m (10-25GHz) | | | | | | | | | | | | | | |x|x| | | | | | | | |x| | | |x| | |
| RF engineering 0,15-0,7 m (450MHz-2GHz) | | | | | | | | | | | | | | |x|x| | | | | | | | | | | | |x| | |
| RF engineering 0,7-4 m (70-450MHz) | | | | | | | | | | | | | | |x|x| | | | | | | |x| | | | |x| | |
| RF engineering: risk assessment | | | | | | | | | | | | | | |x| | | | | | | | | | | | | |x| | |
| RF Interference measurement | | | | | | | | | | | | | | | |x| | | | | | | | | | | | |x| | |
| RF Interference sensitivity | | | | | | | | | | | | | | | |x| | | | | | | | | | | | |x| | |
| RF optical design | |x| | | | | | | | | | | | |x| | | | | | | | | | | | | | | |x|
| RF optical simulation | |x| | | | | | | | | | | | |x| | | | | | | | | |x| | | | | |x|
| RF system simulation | | | | | | | | | | | | | | |x| | | | | | | | | | | | | |x| | |
| RFI shielding | | | | |x| | | | | | | | | |x| | | | | | | | | | | | | |x| | |
| Risk assessment | | | | |x| |x| | | |x| |x|x|x| | | | | | | | | | | | | | | | |
| Sensor networks | | | | | | | | | | |x| | |x| |x| | | | | | |x| |x|x| |x| | | |
| SW engineering | |x| | | |x| |x| |x|x|x| | | | |x| |x| | |x| |x|x|x|x| |x| | | |
| SW engineering: behavioural modelling | | | | |x| |x| | |x|x| | | | | | |x| | | | | | | |x| | | | | |
| SW engineering: data modelling | | | | |x| |x| | |x|x| | | | | | |x| | | | | | | |x| | | | | |
| SW engineering: high-performance computing algorithms | | | | |x| |x| | |x|x| | | | | | |x| | | | |x|x| |x| | | | | |
| SW engineering: human-computer interaction | |x| | | |x| |x| | |x|x| | | | | | |x| | | | |x| | |x| | | | | |
| SW engineering: quality assurance | | | | |x| |x| | |x|x| | | | | | |x| | | | | |x| |x| | | | | |
| SW engineering: requirements analysis | | | | |x| |x| | |x|x| | | | | | |x| | | | |x|x| |x| | | | | |
| SW engineering: risk assessment | | | | |x| |x| | |x|x| | | | | | |x| | | | | |x| |x| | | | | |
| SW engineering: structural modelling | |x| | | |x| |x| | |x|x| | | | | | |x| |x| | | | | |x| | | | | |
| SW engineering: system simulation | |x| | | |x| |x| | |x|x| | | | | | |x| |x| | | | | |x| | | | | |
| Synchronisation and timing equipment | | | | |x| | | | | | | | | | | |x| | | | |x| | | | | | | | | | |
| System engineering | |x|x| | |x| |x| |x|x| | |x|x|x|x| | | |x| | |x|x| | | | |x| | |
| Thermal-electric compatibility | | | | |x| | | | | | | | | | | | | | |x| | | | | |x| | | | | |
| Wavelet digital signal processing | | | | | | | | | | | | | | | | | | | | | | | | | |x| | | | | |
| Wideband receiver design | | | | | | | | | | | | | | |x| | | | | | | | | |x| | | |x| | |

| EMPRESAS<br>SKA Work Packages | ACITURRI | AIDO | ALTRAN INNOVACIÓN | ARIEMA | ASTURFEITO | CRISA | CRYOVAC | DEIMOS | EMPRESARIOS AGRUPADOS | FRACTAL | GMV | GTD | HTS | IDOM | IK4-TEKNIKER | INSA | INTEGRASYS | ISOFOTON | IXION Industry & Aerospace | JEMA | LIDAX | PROCON SYSTEMS | SCHWARTZ-HAUTMONT | SENER | SEVEN SOLUTIONS | TAFCO METAWIRELESS | TECNOBIT | TELSTAR Vacuum Solutions | THARSIS TECHNOLOGY | TTI | VINCI ENERGIA | VLC Photonics |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dish-array element | |x|x| |x| |x| |x| | | |x|x|x| | | | | |x| |x|x| |x| | | |x| |x|
| Low Frequency Aperture Array | | |x| |x| |x| |x| | | |x|x|x|x| | | | |x| | | | |x| | | |x| | |
| Signal and Data Transport / Sync and Timing | | | | |x| | | | | |x| | | |x|x| | | | |x| |x|x| |x|x|x| | |x|
| Central Signal Processor | |x| | | |x| |x| | |x|x| | | |x|x| | | | | | |x|x|x|x| |x|x| | |
| Science Data Processor | | | | |x| |x| |x|x|x| | | |x| | |x| | | | |x| |x|x| | | | | |
| Telescope Manager |x| | | | | | |x| |x|x|x| | |x|x| | |x| | | | | | | | | | | | | |
| Power | |x| |x|x|x| | | | | |x| |x| | | |x| |x| | | | | | | | |x| |x| |
| Site and Infrastructure | |x| | | | | | |x| | | | |x| |x| | | | | | | |x| | |x| | | | | |
| Science | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Management and Engineering |x| |x| | |x| |x|x|x|x| |x|x| |x|x| | | | | | |x| | | | |x| | | |

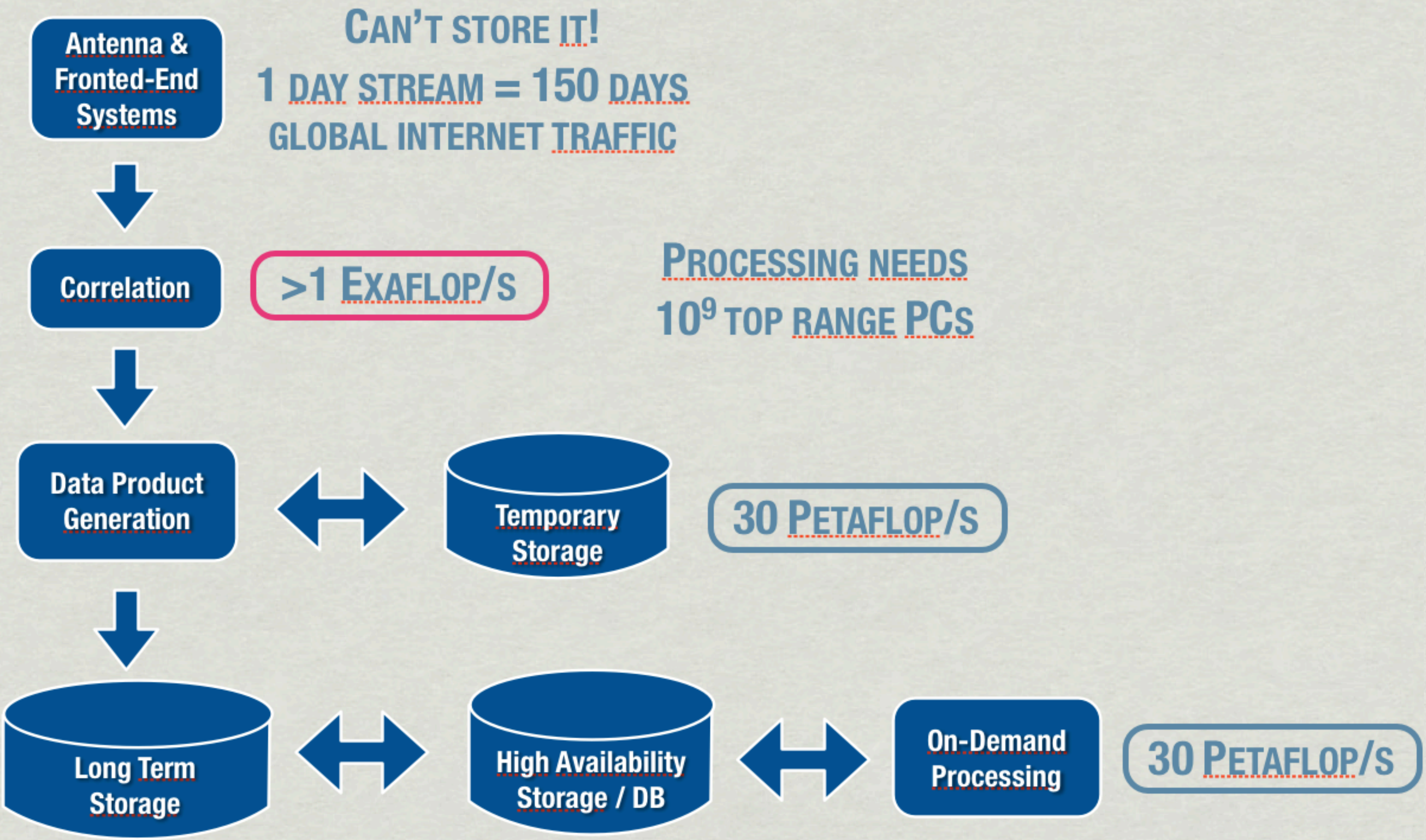
## Areas of expertise vs SKA WPs of the registered companies

# What has Power to do with Radioastronomy beyond other Research Infrastructures?




**Massive Data Flow, Storage & Processing**

# Massive Data Flow, Storage & Processing

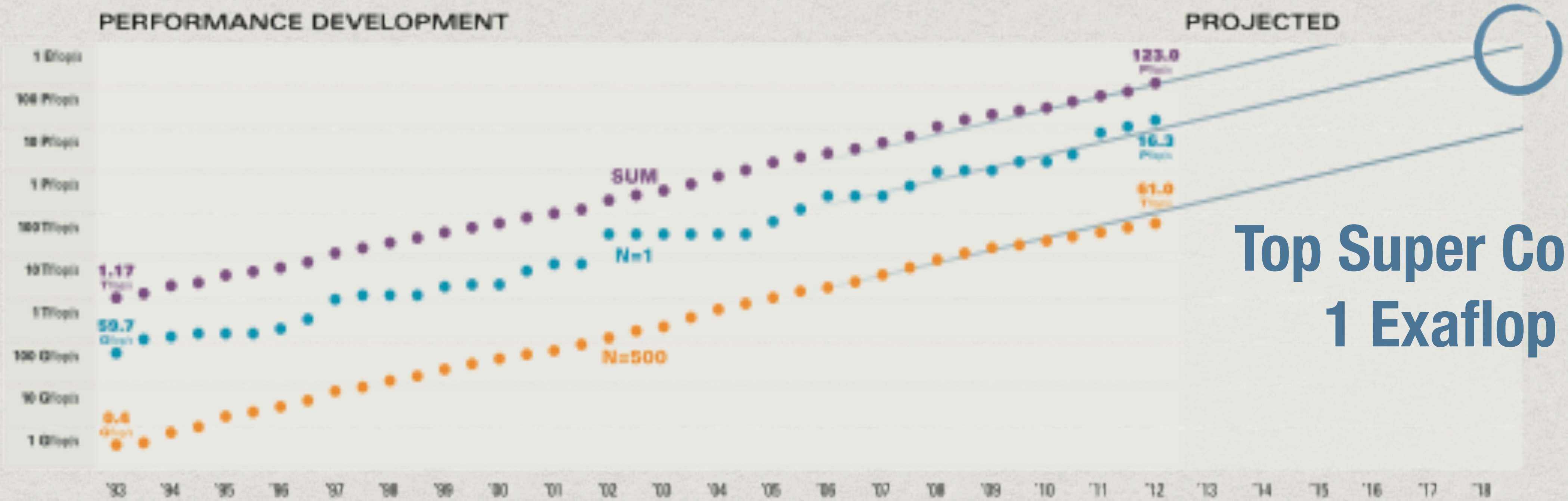


TOP500 JUNE 2012

PRESENTED BY UNIVERSITY OF MANNHEIM

FIND OUT MORE AT www.top500.org

| | NAME | SPECS | SITE | COUNTRY | CORES | $R_{max}$ Pflop/s |
|---|---|---|---|---|---|---|
| 1 | **Sequoia** | IBM BlueGene/Q, Power BQC 16C 1.60 GHz, Custom interconnect | DOE / NNSA / LLNL | USA | 1,572,864 | 16.33 |
| 2 | **K computer** | Fujitsu SPARC64 VIIIfx 2.0GHz, Tofu interconnect | RIKEN AICS | Japan | 705,024 | 10.51 |
| 3 | **Mira** | IBM BlueGene/Q, Power BQC 16C 1.60 GHz, Custom interconnect | DOE / SC / ANL | USA | 786,432 | 8.153 |
| 4 | **SuperMUC** | IBM iDataPlex DX360M4, Xeon E5-2680 8C 2.70GHz, Infiniband QDR | Leibniz Rechenzentrum | Germany | 147,456 | 2.897 |
| 5 | **Tianhe-1A** | NUDT YH MPP, Xeon X5670 6C 2.93 GHz, NVIDIA 2050 | NUDT/NSCC/Tianjin | China | 186,368 | 2.566 |




## Top Super Computer, 1 Exaflop in 2018

## 1 Gigaflops = 0,5W

## 1 Exaflops = 500MW

## Target: 50MW

# Current challenges

## Not Only How Much, but How

- Far from man-made radio frequency emission → away from power supplies (**Energy production, distribution**)
- Geographically distributed (**Distributed energy generation**)
- 24/7 operation (**Storage**)
- Cooling of digital electronics in a hot climate
- Reliable
- Affordable

**With renewable energy**

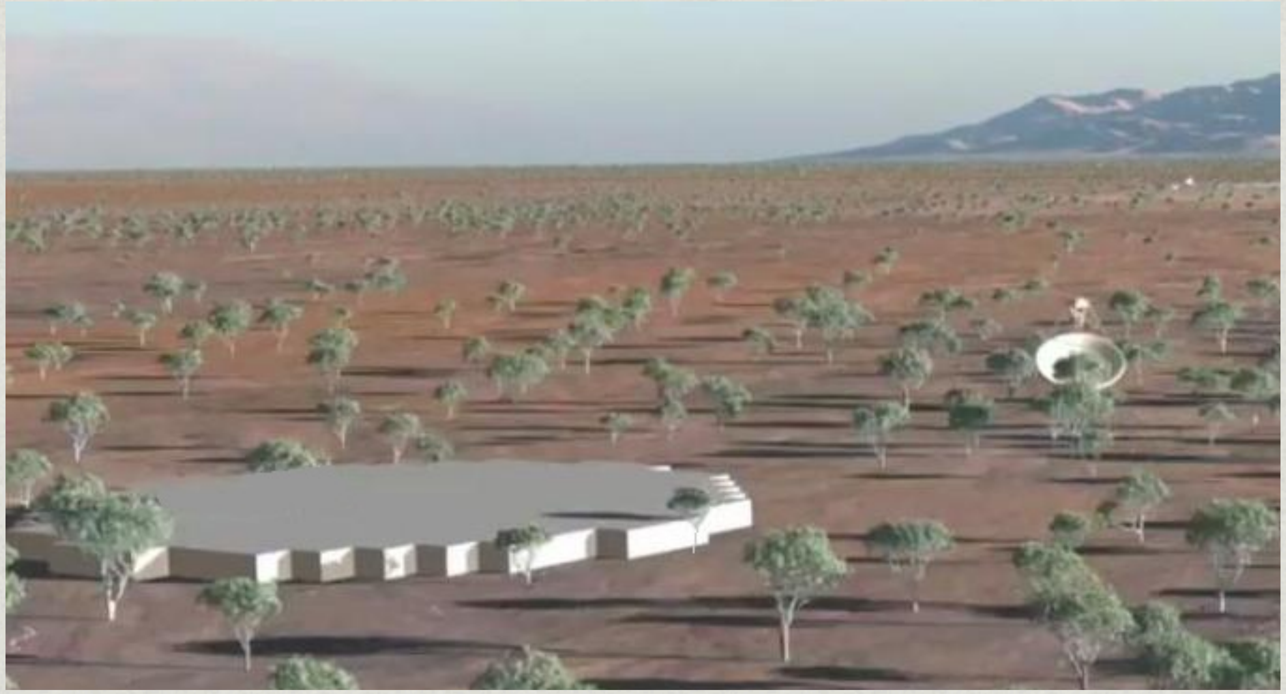
**Radioastronomy is already challenging industry**

## VLBI Antenna

Energy Consumption:
~ 1 GWh/year

~ several 300 People Villages
(with European assumptions!)

SKA Remote Station

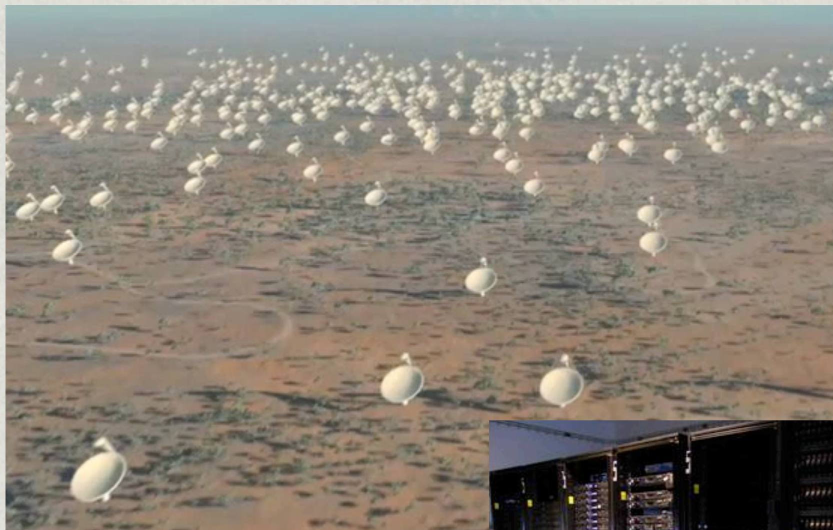


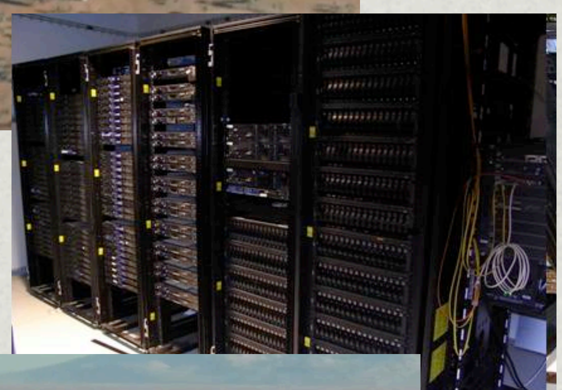
Energy Consumption: ~ 20 GWh/year

Mount Fletcher, Eastern Cape

5000 People Town

## SKA Core





**Energy Consumption:**
**~ 400 GWh/year**

## Brugge

**100.000 People City**

# BIOSTIRLING4SKA

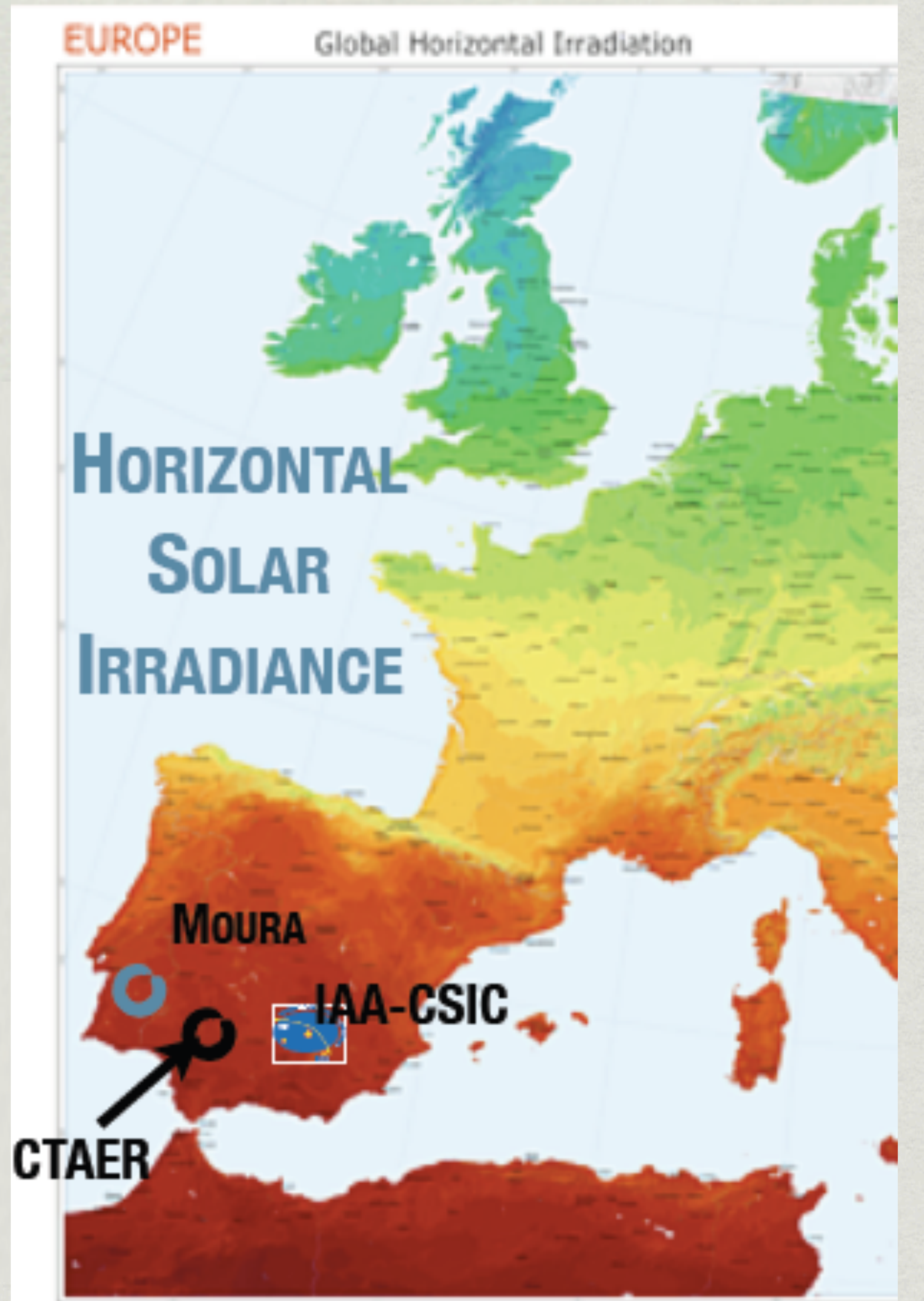
## Dish Stirling systems for SKA

- FP7-ENERGY-2012-1 Collaborative Project
  - *Cost Effective and Efficient Approach for a New Generation of Solar Dish-Stirling Plants Based on Storage and Hybridization*
- 14 Partners all over Europe: 6 in Spain (**PI**), 8 in Iberia
- Total budget: 6.191.682 € (36 months)
  - Requested contribution from EC: ~4 M€

ENERGY.2012.2.5-1: Research, development and testing of solar dish systems

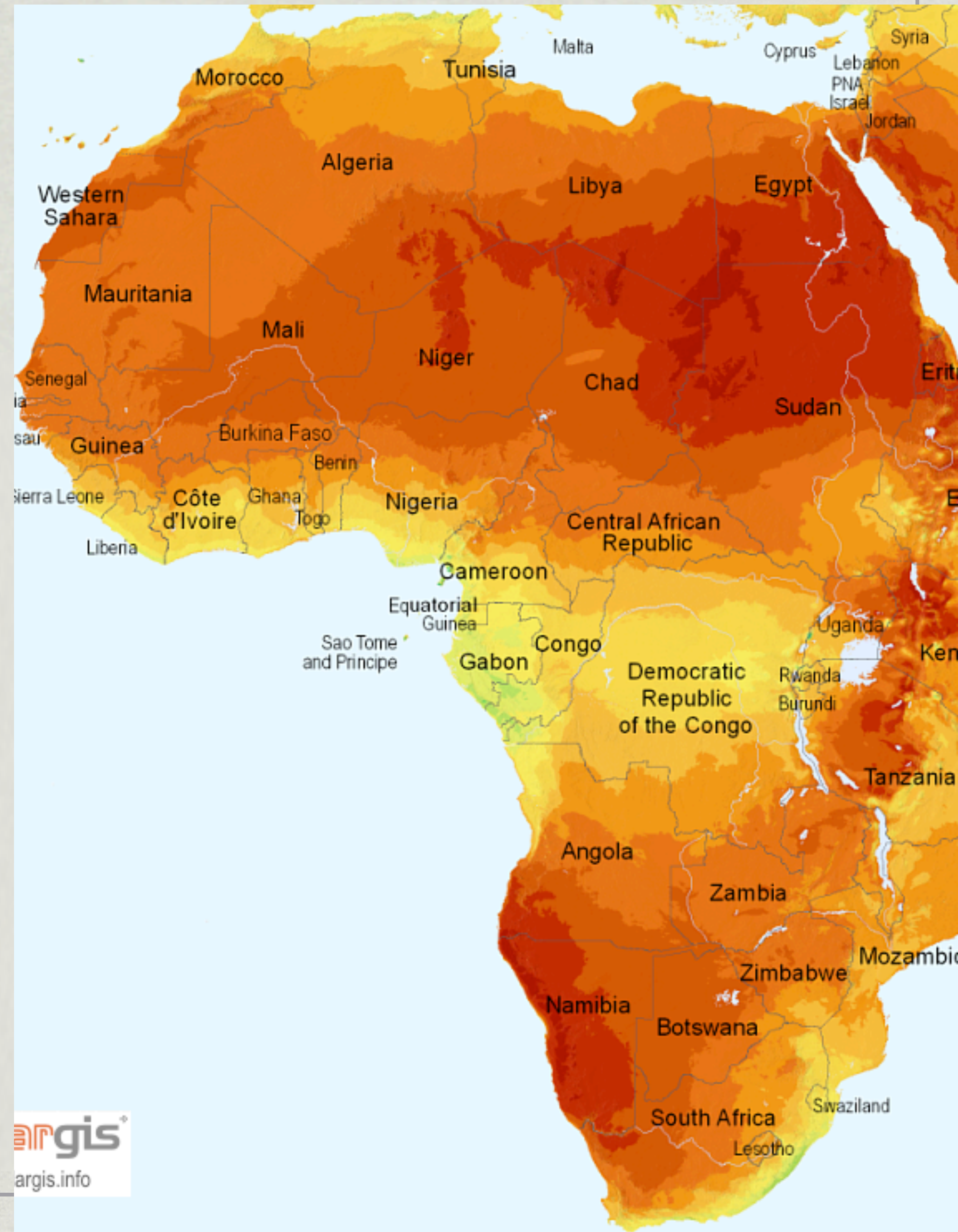
# BIOSTIRLING --> 4SKA

1. Gestamp Renewable Industries (GRI)
2. Alener Solar
3. Cleanergy
4. AGC Glasseurope
5. University of Jyväskylä (JYU)
6. Centro Tecnologico Avanzado de Energias Renovables (CTAER)
7. U. Seville (US)
8. CSIC-IAA
9. Astron
10. IT Aveiro
11. MPIfR
12. Fraunhofer-ISE
13. Lógica
14. Gestamp Solar Steel (GSS)



# BIOSTIRLING --> 4SKA

1. Gestamp Renewable Industries (GRI)
2. Alener Solar
3. Cleanergy
4. AGC Glasseurope
5. University of Jyväskylä (JYU)
6. Centro Tecnologico Avanzado de Energias Renovables (CTAER)
7. U. Seville (US)
8. CSIC-IAA
9. Astron
10. IT Aveiro
11. MPIfR
12. Fraunhofer-ISE
13. Lógica
14. Gestamp Solar Steel (GSS)

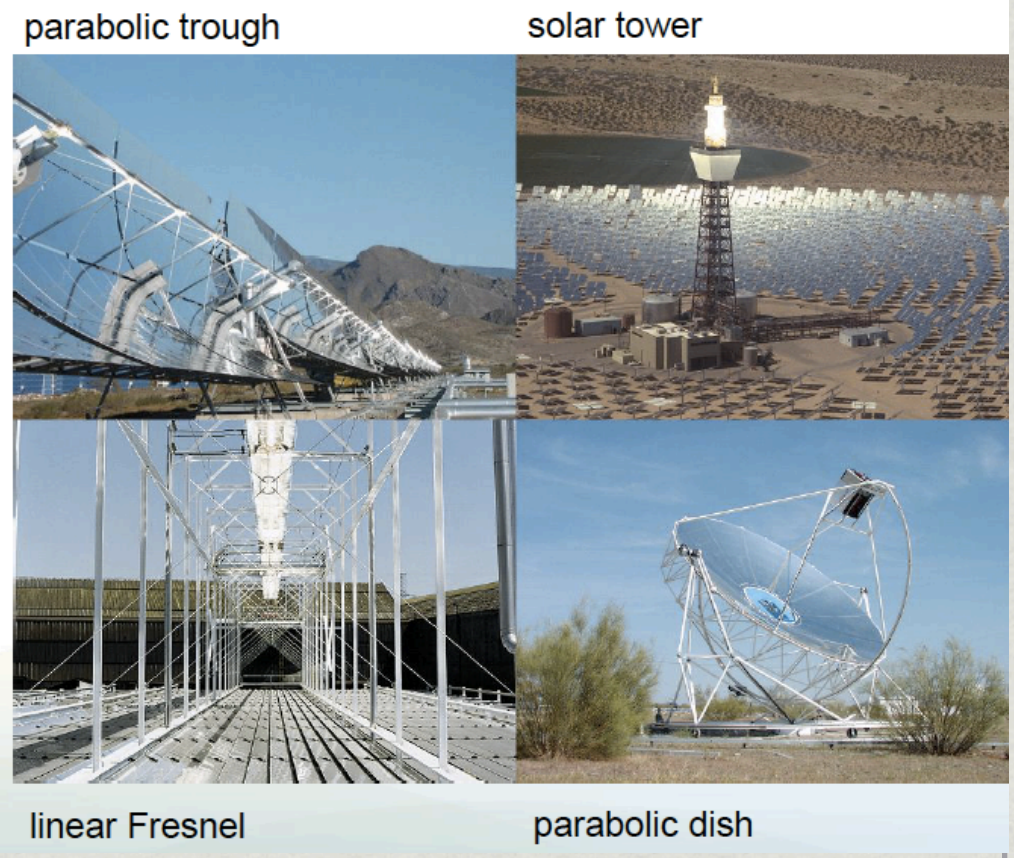



A 1st step: BIOSTIRLING4SKA

# BIOSTIRLING4SKA

**Dishes with Stirling engines:**

Highest efficiency of solar power generation system




- **Not yet fully commercialized**:
  Reduce costs for mass manufacturing
- 24h/7d
  Hybridization: Biomass / Energy Storage
- Life time
  Innovative Materials

**Interdisciplinary approach required**

# Key solution for remote antennas

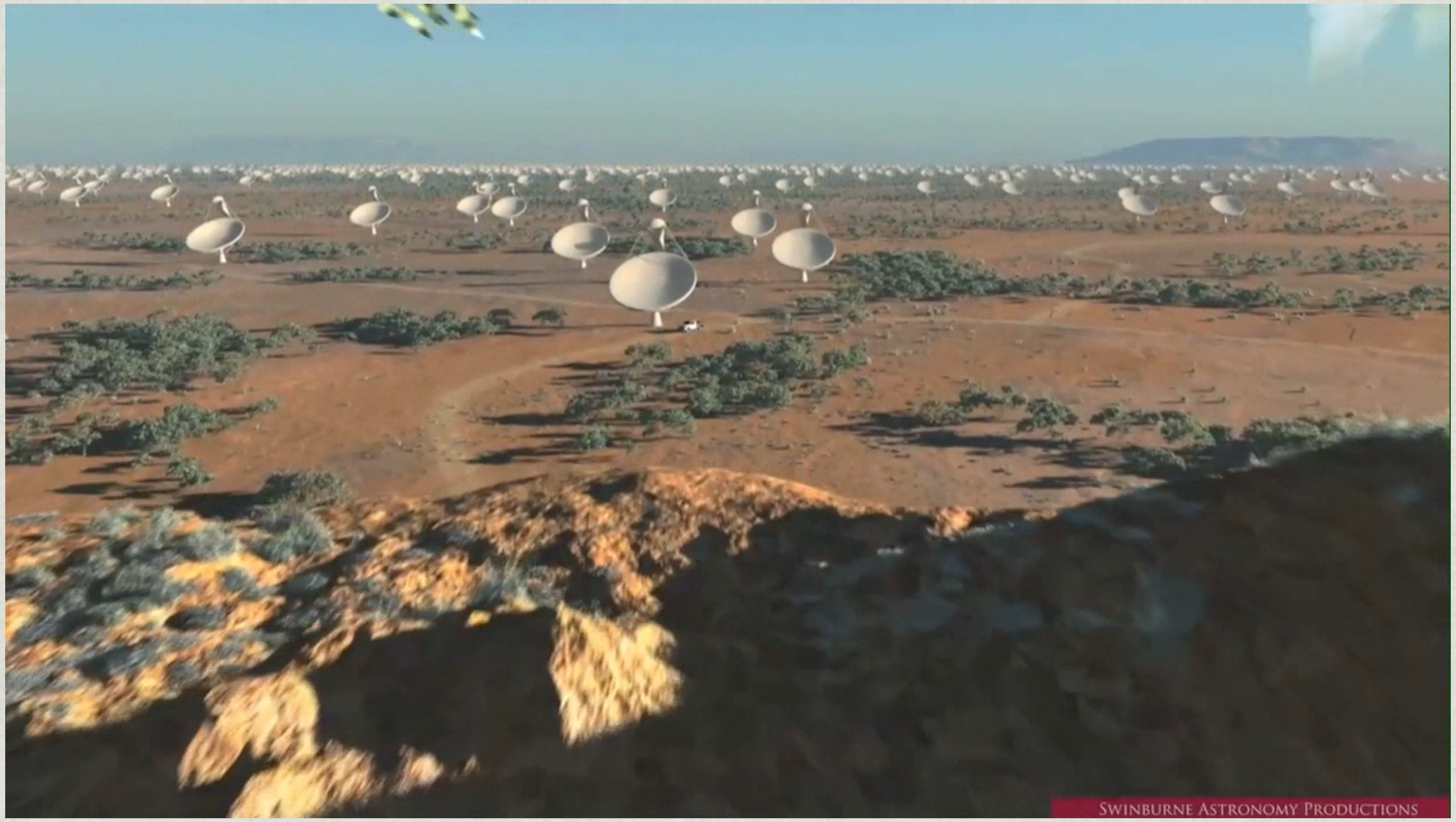
(=areas)

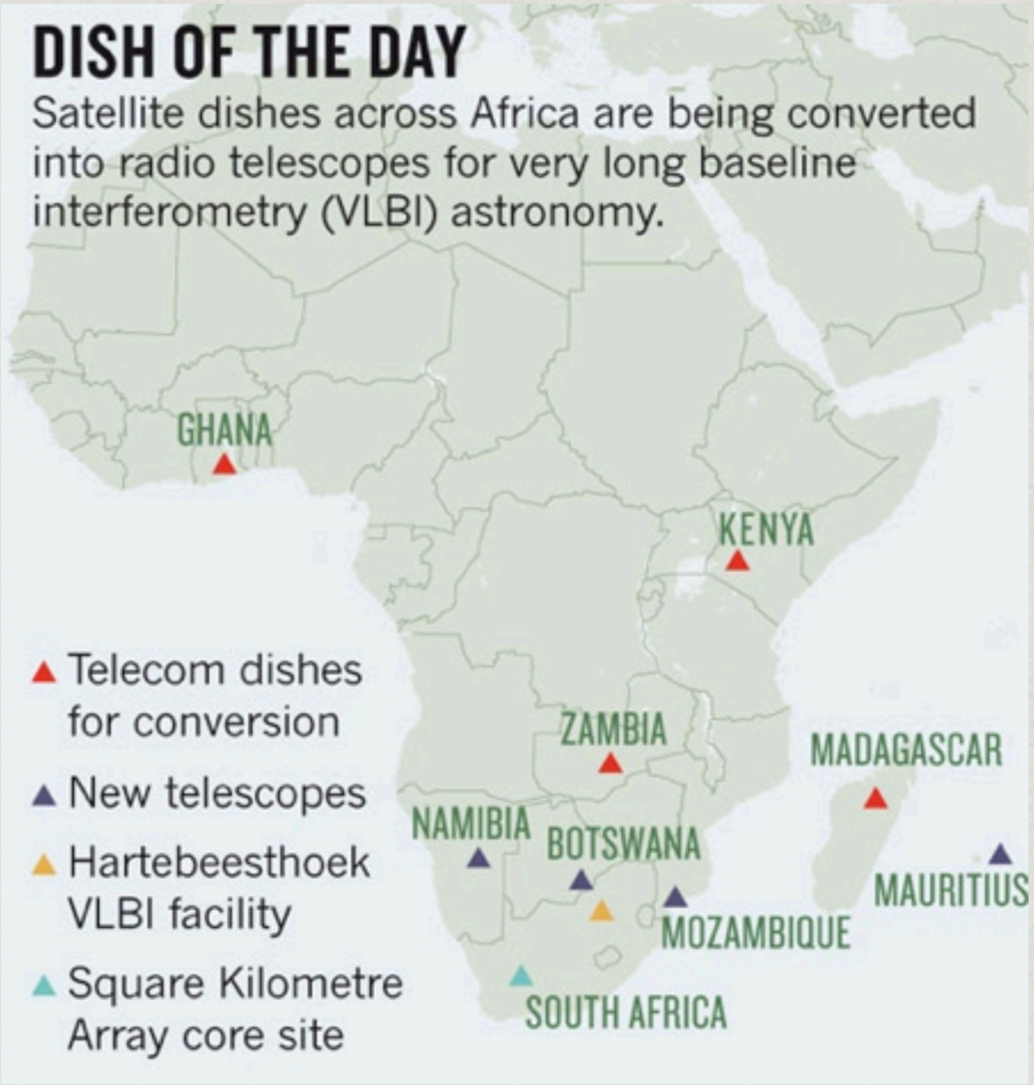
- Different load profiles at different locations:
  - Modular power generators
  - Only water requirements are for the collectors' cleaning

**Stirling Dish system**

**1st step**

# Radioastronomy will change the landscapes of Africa



# But only the landscape?

The African VLBI Network expected to encourage co-location of:

**GPS** stations,
automated **climate change monitoring**
**weather** stations
**seismic** activity warning systems.

Dr Tshepo Seekoe, Chief Director, Radio Astronomy Advances at the Department of Science and Technology

Conversion work on the dish in Ghana

## .. And Power supply?

To use the increasingly available broadband infrastructure for research and economic benefits."

*Former Minister Pandor*

# But only the landscape?

- Opportunity for **remote local populations** to get direct benefits by:

  - **Access to energy** supply
  - **Maintaining** the facilities
  - Getting **feedback to solve domestic problems**

Give me fish

  - **Stimulating interest in education** into technical domains
  - **Training** in new skills
  - Creation of **new local jobs** and businesses.
  - Potential for **fair-trade and cross-sectorial economy**

Teach me to fish

# Why Europe? Green Excellence

* Renewable energies as an area for European leadership:

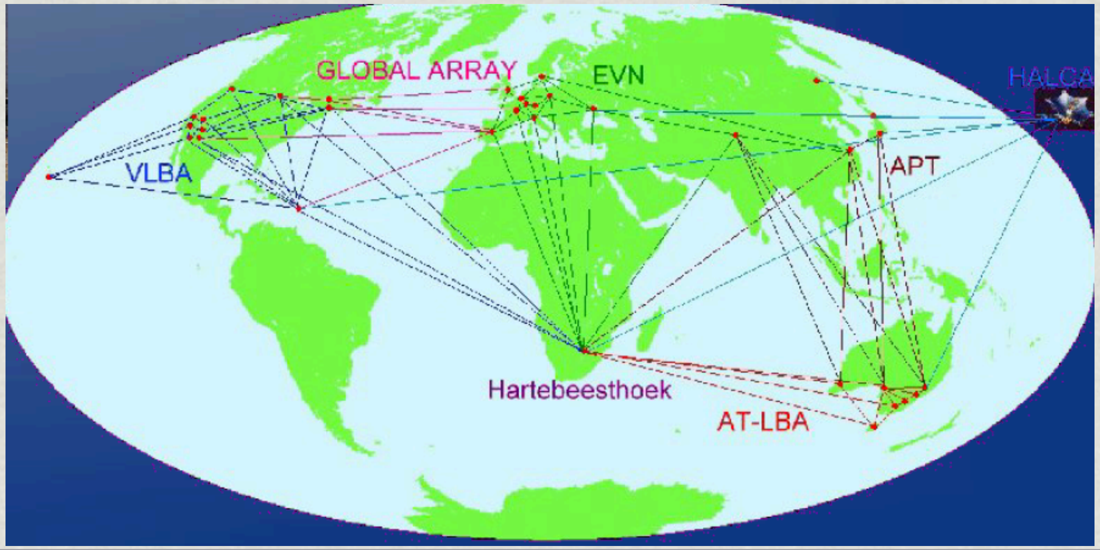
- Establishing a roadmap for sustainable energy
    - **Reducing global CO2 emissions**

# Why Europe? Green Excellence

- Renewable energies as an area for European leadership:
  - Research with **Industry/Academia** partnership (e.g BIOSTIRLING)
  - **Consolidation** of leadership

**Radioastronomy as a shuttle to export European expertise**

**VLBI international network**

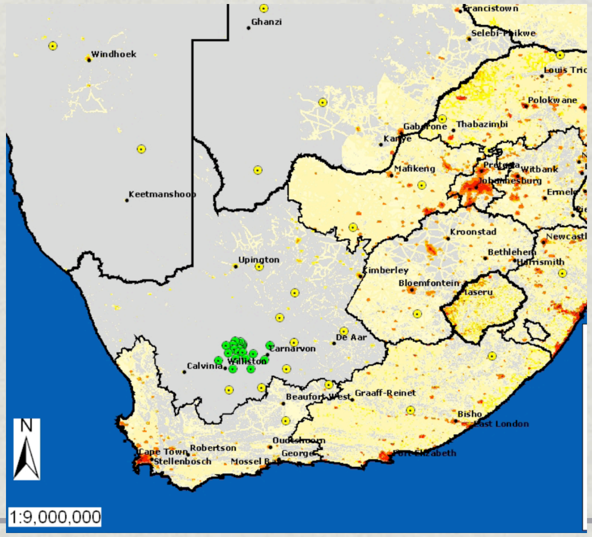


# Why Europe? Green Excellence

* Renewable energies as an area for European leadership:
  - Research with **Industry/Academia** partnership (e.g BIOSTIRLING)
  - **Consolidation** of leadership

**Radioastronomy as a shuttle to export European expertise**

**MeerKAT**



# Why Europe? Green Excellence

- Renewable energies as an area for European leadership:
  - Research with **Industry/Academia** partnership (e.g BIOSTIRLING)
  - **Consolidation** of leadership

**Radioastronomy as a shuttle to export European expertise**

**Only global project on ESFRI list:**

+67 institutes in +20 countries participating (and increasing)

SKA
SQUARE KILOMETRE ARRAY

# Key actions

- **R**esearch and **D**evelopment of technologies

  • Key for 24h/7d supply (**storage, hybridization, H2 fuel cells**)

  • According to **requirements** of the installations +**local** renewable energy resources

  • Avoiding radio frequency interference

# Key actions

- With a vision of:

  - **Impact analysis** in the sites
  - Potential for **excess** power
  - R&D aspects for **large scale implementation** and use
  - Uplifting the skills levels **in local communities**:
    - Joint bursary programs with industry

# Global benefits

* Direct technology transfer:
    * Computing resources consume **1.5% of the world energy**. This percentage should <u>double in 5 years</u> *(source: European Codes of Conduct for ICT / 2009)*

* 2012 International Year of Sustainable Energy **for All**

  **1.6 billion people could benefit from radioastronomy developments AND facilities**

**Synergies between ICT and Power** for more efficient matching of local power needs and power generation capabilities (**smart-grids**)

# Global benefits

**Radioastronomy facilities as Prototype/demonstrator for sustainable Mega Science Infrastructures with 0% Carbon Footprint**

Research Infrastructures: have both **responsability** and **need** for reduced (sustainable) energy consumption

**Explore the Cosmos using Green energies while bringing down to Earth:**

- **Access** to the **means** (energy, internet)
- But even more important: innovative **access to knowledge**

*La ventura va guiando nuestras cosas mejor de lo que acertáramos a desear, porque ves allí, amigo Sancho, donde se descubren treinta, o pocos más, desaforados gigantes, con quien pienso hacer batalla [...] que esta es buena guerra.*

# Key actions

- Characterise the power and energy requirements of radio astronomy installations
- Develop impact analysis of renewable power scenarios on radio telescopes sites
- This includes aspects of radio interference and potential for excess power
- Identify R&D aspects for large scale implementation and use
- Promote joint bursary programs with industry engaging on teaching of sustainable energy, energy efficiency and resource conservation. Energy has a long term investment cycle. Hence, it presents a unique opportunity to promote market and company fidelities via education.
- Developing a training programme for the construction and maintenance of renewable energy plants that can be used to train local engineers and technicians

# Specific goals

- Support the development of the key technologies (storage, hybridization, H2 fuel cells)

- Identification of candidate renewable energy technologies according to requirements of the installations and local renewable energy resources
- Development of technologies and techniques to avoid or shield radio frequency interference of power plants and equipment
- Uplifting the skills levels in local communities to participate in the operations and maintenance of any infrastructure deployed in their immediate vicinities

# But only the landscape?

The African VLBI Network expected to encourage co-location of:

- **GPS** stations,
- automated **climate change monitoring**
- **weather** stations
- **seismic** activity warning systems.

*Dr Tshepo Seekoe, Chief Director, Radio Astronomy Advances at the Department of Science and Technology*

**.. And Power supply?**

**Conversion work on the dish in Ghana**

To use the increasingly available broadband infrastructure for research and economic benefits,"

*Former Minister Pandor*