Convergent Evolution....

In evolutionary biology, convergent evolution is the process whereby organisms that are not monophyletic (not closely related) independently evolve similar traits as a result of having to adapt to ecological niches or similar environments.

Wikipedia
EC Framework7 “RadioNet”
Joint Research Activity

APRICOT:

All Purpose Radio Imaging Cameras On Telescopes
The APRICOT strategy: produce design studies and develop sub-systems to allow future cost-effective construction of large-format (100 beams) mid-frequency (30-50 GHz) horn arrays.
Some European telescopes for 30-50 GHz

Effelsberg-100m (new active 2nd mirror)
The APRICOT Partners

UMAN, IRA, MPIfR, CAY, TCfA
(& MECSA) (& Cantabria)

- Operate the target telescopes
  - With extensive receiver operations experience

- Long-established RF design expertise
  - Of active and passive sub-systems in proposed band

- Established MMIC design & testing expertise
  - With one “foundry” within the partnership
Moving on from current array receivers

- Increase the array size: to improve productivity
- Choose the ideal operating range: 30-50 GHz is spectrally rich and many continuum applications
- Increase the level of MMIC integration: reduce cost
- Provide both continuum and spectroscopic modes: operational efficiency
- Go digital as early as possible: Having the data in digital form offers maximum flexibility

18-26 GHz 7 beams
Spectroscopy (IRA)

26-36 GHz 16-beams
Continuum (UMAN)

9-mm 7-beam (MPIfR)
Molecular Line Spectroscopy

- Star-forming regions & circumstellar envelopes
  - Imaging plus modelling $\rightarrow$ temperature & density
  - Many carbon-chain species in the 30-50 GHz band ($\text{HC}_n\text{N} n=3,5,7; \text{C}_n\text{H} n=5,6; \text{C}_n\text{S} n=1,3,5$) diagnostic of cold dense quiescent gas
  - Other species:
    - $\text{SiO}$ (shock tracer); $\text{OCS}$ (sulphur sink)
    - $\text{CH}_3\text{CN}$ (hot core species); $\text{SO}$ (Zeeman sensitive)
    - $\text{SiO}$ masers in CSEs close to the star
  - With large format cameras could survey complete clouds in one day

- Blind surveys in redshifted CO (1-0)
  - Distances & mass estimates of dusty galaxies
Continuum Studies

• Surveys for discrete sources (in polarisation)
  • Find new types of AGN e.g. youngest CSOs
    • follow-up with mm-VLBI & VSOP-2 imaging
    • follow-up of GLAST transients
  • Provide net of calibration sources for EVLA and mm-VLBI
  • Support of Planck and all high-sensitivity CMBR experiments

• Surveys for/of clusters of galaxies via the S-Z effect

• Surveys of diffuse Galactic emission (in polarisation)
  • Synchrotron; free-free; anomalous dust; thermal dust
  • Need to dissect out the contributions: for ISM astrophysics and CMBR polarised foregrounds
  • In compact regions e.g. YSOs - diagnostics of dust agglomeration in protoplanetary disks
Technology: WP1 Architecture

- Combine continuum and spectroscopic capabilities with multiple-pixels: high reliability & low cost
  - Modular design with well-defined interfaces
  - Design for mechanical and cryogenic stability
  - Optimise layout for maintenance/fault-fixing
  - Design of monitor, control and calibration systems
  - Integration of direct detection and heterodyne systems
  - LO generation and distribution
  - Design, packaging and integration of RF, IF, LO systems
  - Establish capability to batch-produce RF, IF modules

Deliverables are mainly design study reports
Technology: WP2 passive components

- Highly integrated chain with OMT, hybrids, transmission sections etc
- Low-loss, low size/weight, low cost, ease of manufacture
  - Standard waveguide technology too expensive
  - Needs technology shift
    → Planar technology, microstrip transmission lines and filters etc

Deliverables - design study reports
- Few pixel hardware comparing performance of conventional and innovative approaches
  (with WP1 and WP3)
Technology: WP3 MMICs

- To develop and secure European supply of world-standard MMIC devices for astronomy

- To seek improved noise performance in the band 30-50 GHz - performance gains will translate to other bands.

- To achieve increased levels of integration

- Previous un-coordinated procurements with Euro foundries
- APRICOT will coalesce the effort within a coherent strategy with AMSTAR+
The MMIC Foundries

- **U. Manchester**
  - 100nm InP HEMT technology
  - Innovation in materials and architecture for low-noise
  - Rapid response to new design inputs

- **Fraunhofer Institute (IAF) Freiburg**
  - 100 nm GaAs mHEMT technology
  - Multi-function MMICs
  - Established 50 nm and experimental 35nm processes
  - Now interested in low-noise at cryo temps

- **OMMIC company**
  - 70nm GaAs mHEMT technology
IAF: Two-Stage W-Band MHEMT Low-Noise Amplifier

- Gate width: 2 x 30 µm
- Gate length: 50 nm
- Coplanar waveguide technology

- Gain: 23 dB @ 94 GHz
- Noise figure: 2.4 dB @ 94 GHz
- Power dissipation: 36 mW
WP4: Device Testing

- Accurate measurement of noise temperature and gain fluctuation of devices at cryo temperatures is not easy!

- Results from well-respected labs often differ!

- MMIC assessment requires the precise inter-comparison of devices from different foundries and of different designs

APRICOT partners will pool knowledge and work with a standard testing site (CAY)
WP5: Data handling

- Spectroscopic data rates are high!
  - Combination of spatial and spectral resolution will produce $>>10\times$ more data than existing systems

- Spectrometer hardware NOT part of APRICOT
  - R&D in “UNIBOARD” FP7 JRA

- Mapping in lines and continuum
  - “On the fly” gridding and mapping
  - Use of multi-pixels for atmospheric WV subtraction
  - Observing strategies and data presentation in images
  - Back-end and computational hardware scalability

How the data are produced and how the user interacts with them is a vital part of the overall design picture.
WP Leadership

WP1: Receiver Architecture
• MPIfR; IRA, UMAN, CAY, TCfA

WP2: Passive Components
• IRA; MPIfR, UMAN

WP3: MMIC Procurement
• UMAN; IRA; MPIfR; CAY

WP4: Device Testing
• CAY; UMAN; MPIfR, IRA

WP5: Data Handling
• TCfA: UMAN, IRA, MPIfR
Summary: FP7 JRAs

APRICOT: Technology readiness for multi-purpose large format cameras in 30-50 GHz band
  - Development of European low-noise MMIC capability for astronomy
  - Deliverables are studies and sub-systems

[ AMSTAR+: develop 90 GHz heterodyne FPA technology with IAF for MMICs]

[ UNIBOARD: general purpose digital board - 4Tops]

EC funding from 1 Jan 2009 - 31 Dec 2011
[Proposed] Centre for Radio and TeraHertz Technology (CRT$^2$) in Manchester

Aims: to develop, build and test complete and highly integrated source/receiver sub-systems and systems involving:

Innovative development of generic technologies
- Active Devices - designed for purpose
- Passive components and systems
- High-speed digital signal processing

Overall system design
- Mechanical design and construction
- Rapid testing

- Close analogy with Caltech/JPL thinking
- Good environment for graduate research training
## Technological Symbioses

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<tr>
<th>Astronomical Applications</th>
<th>Wider Economy Applications</th>
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| Square Kilometre Array - large format digital phased arrays “software radio” (decimetre wavelengths) | • New generation of low-noise systems for mobile telecoms  
• Intelligent arrays for satellite TV and mobile ground-sat equipment  
• Space-ground communications  
• Ultra-Wide Band comms systems |
| Large format radio “cameras” (mm and sub-mm wavelengths) the “THz” regime | • e-THz security and inspection applications both passive and active (with additional high power sources)  
• Advanced car radars  
• Point-to-point broad-band comms systems within cities  
• Biological/medical non-ionising inspection |
Summary: FP7 JRAs

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- [AMSTAR+: develop 90 GHz heterodyne FPA technology with IAF for MMICs]
- [UNIBOARD: general purpose digital board – 4Tops]

EC funding: 36 months from 1 Jan 2009
Basic Science Strategy

• “Cameras” enable these telescopes to make new surveys at 30-50 GHz - scientifically rich range

• In “intermediate” gap between SKA and ALMA

• Follow-up with EVLA, VLBI, VSOP-2

• Continuum and spectroscopy: observations in different weather conditions