Swiss SKA Days 2021-09-08
SETI on SKA, some ideas

Another approach to the Search of Extraterrestrial Intelligence with SKA?

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Presentation Outline

- SETI history
- Why no pertinent signal candidate yet?
- The inverse problem
- History of radio on Earth
- The assumptions
- Exoplanet selection
- How to calculate with exoplanets

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SETI History

- Some experiments
  - SETI on Arecibo dish
    - 300m diameter, HII frequency
    - Crowdsourcing of data crunching (SETI@home, BOINC)
    - Very little availability for SETI (<5% in total)
  - Allen Telescope Array (ATA)
    - Dedicated to SETI
    - Low cost 6m dishes
    - 0.5 to 9.5GHz
    - Baseline: few km, large number of dishes (up to 10000m2)
- Why did they get no relevant signal candidate?
  - “Wrong” frequency band?
  - “Wrong” direction?
  - “Wrong” moment?
  - Background noise (suns etc)? ➔ **Antenna aperture?**

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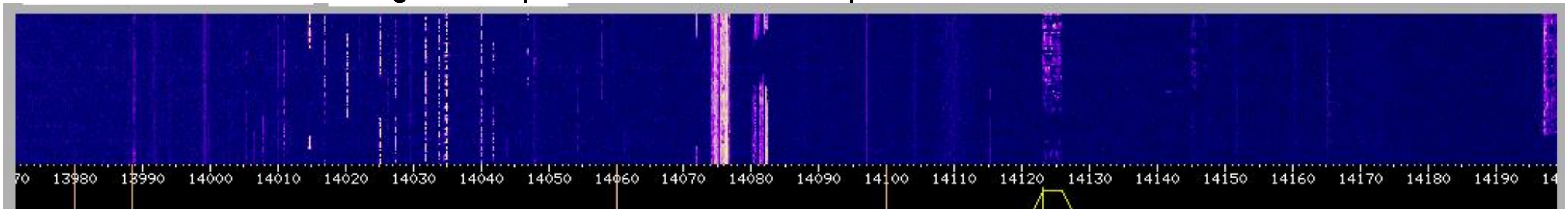
The inverse problem

- **Could an SKA radiotelescope situated on an exoplanet detect our RF signals? (present and past)**
- How to differentiate?
  - Natural source:
    - wideband «noise»
    - not modulated (except pulsars) ➔ 3bits are enough
  - Artificial signal:
    - Narrowband
    - Modulated, BW/data rates from Hz to MHz
    - «Randomly» switched on/off (personal comms…), or at regular intervals (broadcast…), or never (broadcast, bulk telecom…)
    - High density modulations (OFDM…) appear as narrowband noise.
    - High number of sources
    - ➔ higher amplitude resolution required

http://websdr.ewi.utwente.nl:8901/



Rayleigh's criterion

- Interferometer baseline is considered without sensitivity issues (total pickup area)

- Rayleigh's criterion for interferometer angular resolution with baseline length B: $R = \frac{\lambda}{B}$

- SKA MID phases:
  - 1: baseline 150km (200 dishes)
  - 2: baseline 3500km (2000 dishes)

- For comparison:
  - Arecibo 0.3km (one dish)
  - FAST 0.5km (one dish)
  - ATA dedicated to SETI: few km (up to 350 dishes)
  - VLBI 8600km (10 dishes)

Is the spot small enough?

- Spot dimension (interferometric pattern, actually):

SKA phase1	0.35	1.00	2.40	5.00	15.00	24.00	GHz
EPFL -New York	42.83	14.99	6.25	3.00	1.00	0.62	m
Earth-moon	2284	799	333	160	53	33	m
Alpha Centauri	234 300 000	82 000 000	34 200 000	16 400 000	5 500 000	3 400 000	km
Wolf 1061c	755 800 000	264 500 000	110 200 000	52 900 000	17 600 000	11 000 000	km

SKA phase2	0.35	1	2.4	5	15	24	GHz
EPFL -New York	1.84	0.64	0.27	0.13	0.04	0.03	m
Earth-moon	97.9	34.3	14.3	6.9	2.3	1.4	m
Alpha Centauri	10 000 000	3 500 000	1 500 000	700 000	200 000	100 000	km
Wolf 1061c	32 400 000	11 300 000	4 700 000	2 300 000	800 000	500 000	km

- SKA MID phase 1:
  - At low frequencies (MID band 1), spot covers several AU
  - At high frequencies (MID band 6), it may be possible to «isolate» the planet from its sun
- SKA MID Phase2:
  - At relatively low frequencies, the spot may allow isolating the planet from its sun
  - At high frequencies, the beam could can be aimed at a single planet
- **➔ This is a long term project (2030+, 2040+)**

Resolution limitations (B/65536: ~40kHz)?

Another possibility: LOW-MID Interferometry?

- There may be some overlap between the upper frequency range of SKA-LOW and the lower end of MID band 1
- Observe a few MHz (up to 10-20?) of frequency range at around 350MHz (little atmospheric perturbation)
- Large Baseline distance for interferometry:
  - ~10000km: ~3x smaller spot size than SKA phase 2
  - Alpha Centauri: 3M km, Wolf 1061: 10M km
- **Shorter term** experiment using current Meerkat and SKA-LOW
- Other 350MHz observatories in southern hemisphere?
- ?Less resolution issues (300MHz/65536 channels: ~5kHz)
- Issues and constraints:
  - Is there an usable overlap?
  - Target exoplanet must >>horizon for both/all facilities involved
  - This “ad hoc” solution *may* of course be not optimal
    - loss of system gain on the “slopes” of each passband
    - Relative lack of antenna area
  - Requires inter-continental time synchronization for interferometry
  - Less sensitivity (“small“ number of antenna): Noise/sensitivity issues to be researched
  - ?quiet band? (military satellites?)

➔ A good start?

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History of radio on earth

- Maxwell, Faraday
- The wired telegraph
- First radio experiments (Marconi)
  - Spark gap transmitters
  - “Crystal” rectifiers
  - “long-wave wideband” km-wave
- Vacuum tubes (Lee De Forest)
  - Hectometric/decametric waves
  - Across planet ionospheric transmission
  - LW/MW/SW broadcasting
- Discrete semiconductors
  - Metric bands (“FM”, TV) broadcasting
  - Short range transmission
  - “optical propagation”
- Integrated circuits
  - Personal transmissions devices (dec<u>i</u>metric waves)
  - … centimeter, millimetre waves

- **What drives this: device size decreases (antenna size), data rate increases, so does the carrier frequency**

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What would be «visible» from space?

- Ionospheric cutoff depends on atmospheric plasma density:
  - Earth: «high pass» filter with varying 7..60MHz cutoff
  - Depends on sun's ionizing radiation flux
  - Brown dwarf: little ionizing radiation, low cutoff high pass ➔ needs observation from space/moon
- How did the earth appear in RF from space at various stages of technological development:
  - Before the use of electricity
  - from 1837: wired telegraph
  - from 1890-1920: Marconi experiment, spark gap transmitters
  - from 1930: vacuum tube electronics, intercontinental shortwave telecommunications, AM broadcasts (MW, LW, SW)
  - Around 1960: terrestrial TV, FM broadcasts. Satellite TV
  - From 1970: satellite communications
  - 2000-2021: billions of mobile phones, millions of cellular base stations, diminishing hertzian broadcasts
  - 2021+: Future 5G high-band millimetric communications, Ka-band telecom satellite constellations, IoT, deep space comms…

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Assumptions

- Technological development on an exoplanet similar to Earth would follow a similar path
- Technological evolution:
  - Could be as short as on earth (2 centuries, disruptive exponential growth fueled by fossil fuels = “old” planet)
  - or a society could stay stable for a much longer period: less resources, “techno-conservative” society
  - Or could never happen at all

- Drake’s equation

➔ So, how do we select “good” planet candidates for observation?

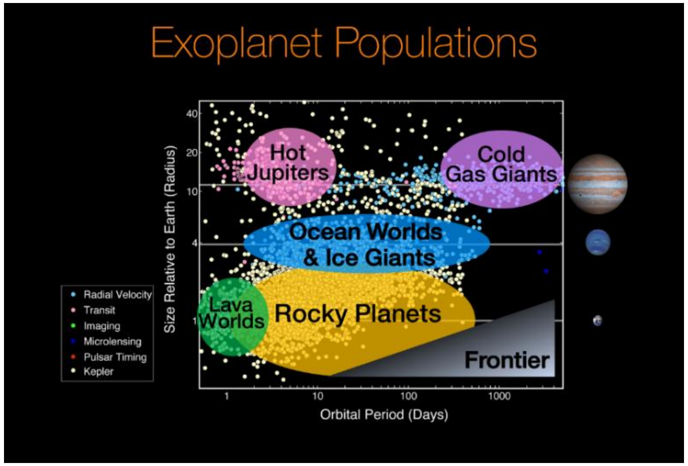
Exoplanet candidate selection

- Visible from SKA (southern hemisphere)
- Closest candidates first ($1/d^2$ propagation loss)

- What materials are needed for a radio?
  - Wires: a good conductor, Cu or other ductile conductive metals, possibly Al?
  - Bobbin cores and capacitors: conductor, air, ceramic, electrochemical
  - Insulators: natural or artificial source
  - Glass (SiO_2 derivatives)
  - Si, and/or other semiconductor materials
- Energy source?
  - Batteries: Cu, Ni, Zn, salts, water; later: Na, K, Li
  - Electrical generators and transformers: Cu, laminated Fe + rectifiers (Se, others) + capacitors + voltage stabilisation
- Transformation Processes?
  - C needed for smelting the minerals (bio/fossil)
  - vacuum technology, metal to glass welding
  - Semiconductor technology (purification, vacuum, CVD, lithography, etc..)

Exoplanet selection wrt surface conditions

- The minerals required determine the type of planet:
  - Solid core
  - Atmosphere containing oxygen (for smelting)
  - Current Vegetation (for charcoal, and just for sustaining life)
  - Past vegetation (fossil carbon)
  - Liquid water (some, and just for sustaining life)
  - Magnetic field (to keep an atmosphere, and ionosphere)
  - Similar surface temperature range as earth
- Distance to earth
  - The closer the better (starting with alpha centauri)



https://www.nasa.gov/image-feature/ames/kepler/exoplanet-populations

Exoplanets selection tools and method

- PyExoplanet database and other exoplanet tools
- Select the closest exoplanets visible from SKA (southern sky)
- Compute noise and sensitivity issues (**is detection really feasible? What are the limitations?)**
- Compute U, V parameters
- Check whether angular resolution allows «separating» the planet from its sun, select observation time
- Compute pointing parameters for SKA
- Are SKA stored data already available that could be processed further?

➔ Requires a lot more (collaborative) work before asking for SKA observation time!

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