Combining ground-based and space-based radio observations

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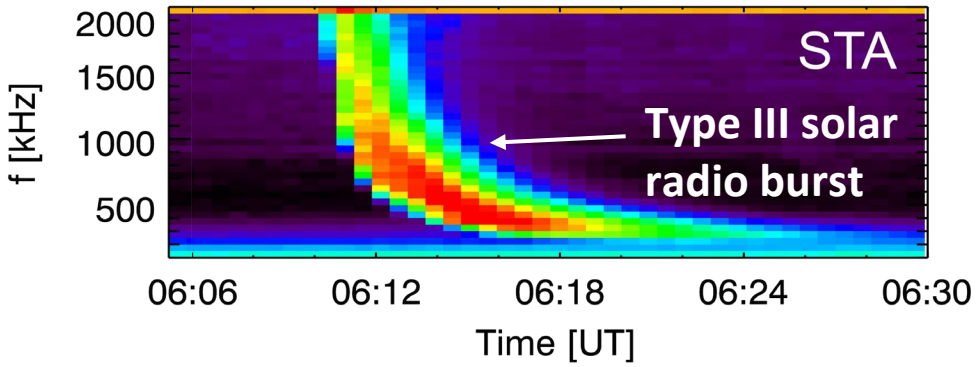
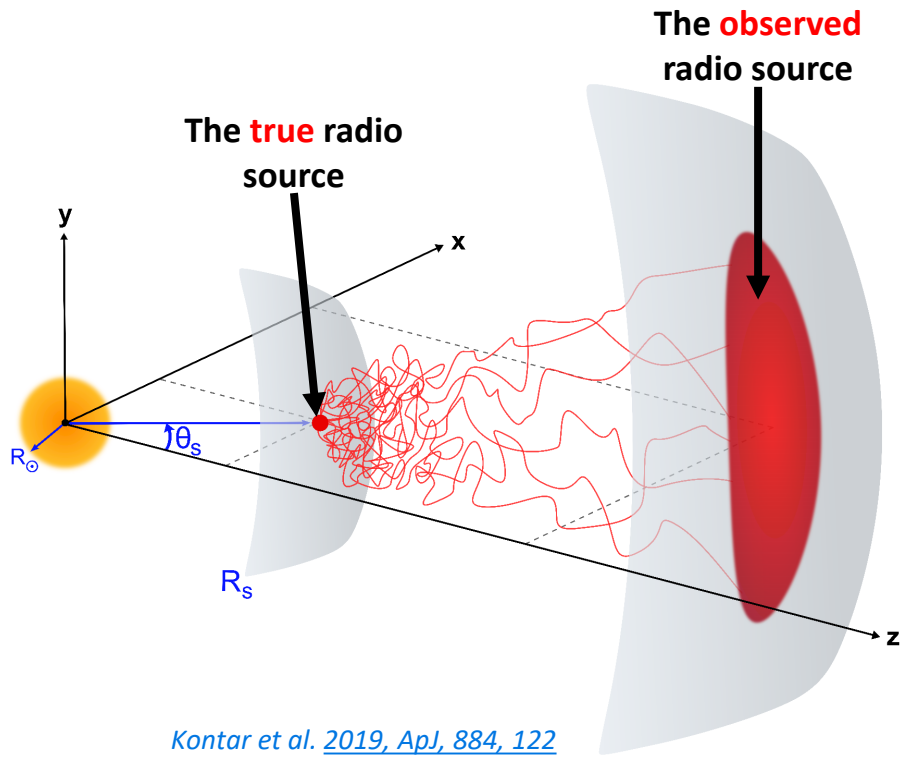
A bit about me

- IPI Postdoctoral Research Fellow (Sorbonne University, Paris, France)
- Primary research focus:
  - Solar radio emissions (radio bursts)
  - Radio-wave propagation effects due to anisotropic heliospheric density turbulence
  - Quantification through comparison of observations with ray-tracing simulations
- Radio instruments used:
  - Space-based: Solar Orbiter (SolO), Parker Solar Probe (PSP), STEREO, WIND
  - Ground-based: LOFAR, CALLISTO, NenuFAR, NDA, NRH, ORFEES, …
- Involvement:
  - Solar Orbiter Radio and Plasma Waves (RPW) Consortium
  - LOFAR Solar and Space Weather Key Science Project
  - NenuFAR Long-Term Program Team (LT11: Sun)
  - SKA Solar, Heliospheric & Ionospheric Physics Working Group

Chrysaphi et al. 2024, A&A, 687, L12





Kontar et al. 2019, ApJ, 884, 122

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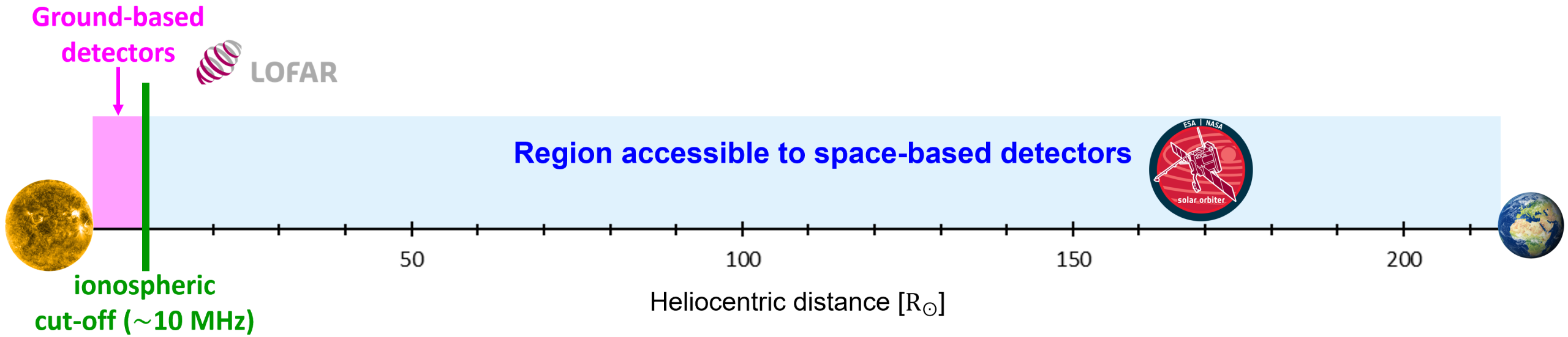
Ground- and Space-based Observations

- Combination of both **ground-based and space-based** instruments needed to cover the heliosphere → continuous tracking of particles
- **Multi-vantage observations** crucial for understanding impacts of radio-wave propagation effects
- Need dedicated **coordinated observing campaigns** → e.g. LOFAR + NenuFAR observing during SolO/PSP perihelia
- Observation challenges:
  - Non-solar dedicated instruments (and no ground-based observations during the night) → good coordination needed
  - Quality of ground-based observations depends on time of the year
  - Sometimes few ground-based observing hours per year (e.g. LOFAR + NenuFAR)
  - Contamination of protected radio frequencies (e.g. Starlink)



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Challenges (user's perspective)

STEP 1: Finding/Reading Data

1) Issues finding instruments → list of possible **sources**? (see e.g. CESRA website for ground-based instruments)
2) Lack of openly-accessible **quick-looks** (do I even need this data? – multiple radio bursts a day to go through)
3) Lack of information on **observational setup** (time, resolutions, pointing, imaging?, calibration?, issues with antennas?)
4) Storage issues (see LOFAR, SKA)
5) Proprietary data (varying time limits) → LOFAR, SolO/RPW, PSP/FIELDS
6) Handling **varying data formats + metadata**
   - Data formats vary a lot (some difficult to handle):
     *.hdf5 (LOFAR)
     *.cdf (SolO/RPW; PSP/FIELDS)
     *.spectra (NenuFAR)
     *.dat (WIND/WAVES; I-LOFAR)
     *.B3E (STEREO/SWAVES)
     *.fits (CALLISTO)
   - Even if datafile formats are the same, the variable/attribute names can vary (e.g. WIND vs STEREO L3 files)
7) Insufficient **documentation** (if available), or tricky to find

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Challenges (user's perspective)

STEP 2: Analysis

1) Calibration is not straight-forward → e.g. LOFAR data calibrated (I hope) by individual users
2) Pipelines developed separately by individuals → sometimes little transparency, no cross-checks (can they be trusted by third parties if/when shared?)
3) Large datasets → computationally demanding to store/analyse → analyses repeated by several individuals (waste of resources/time)
4) Space-based instruments:
   - Calibration delays → e.g. officially-calibrated SolO/RPW L3 data not yet publicly released
   - Calibrated data from different (unofficial) sources have discrepancies

Side notes

- Radio is a powerful tool (especially when combined with other wavelengths) → should not be overlooked
- We have a lot of data from many instruments → need more hands on deck! (better community coordination + involvement) → What do we need to do?
- But: is the (solar) radio community really here? → how do we reach it and encourage interactions across EHC?