Chasing the Cosmic Dawn with LEDA

Marta Spinelli

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ISTITUTO NAZIONALE DI ASTROFISICA INAF
UNIVERSITY of the WESTERN CAPE
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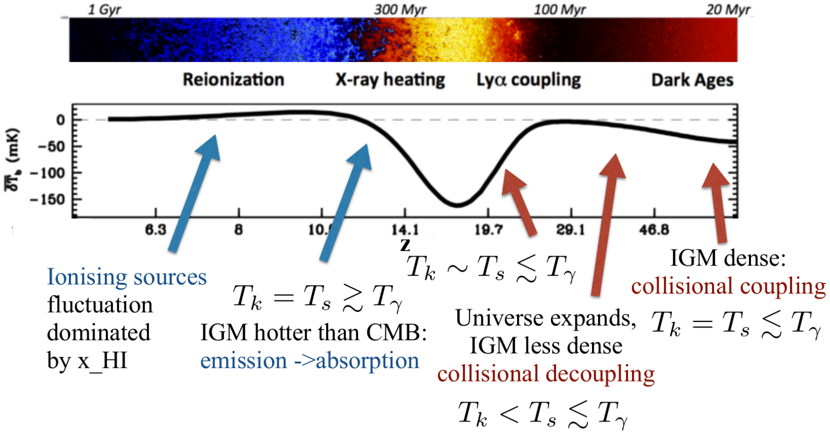
ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

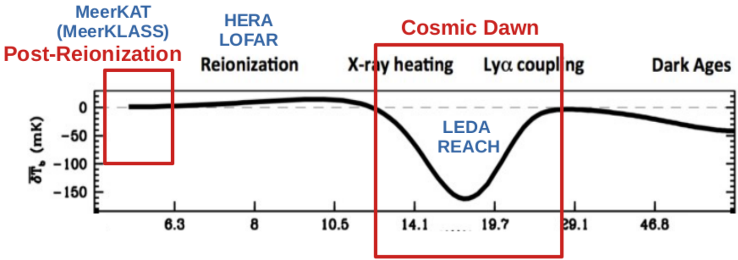
21 cm signal

Mesinger, Greig & Sobacchi (2016)

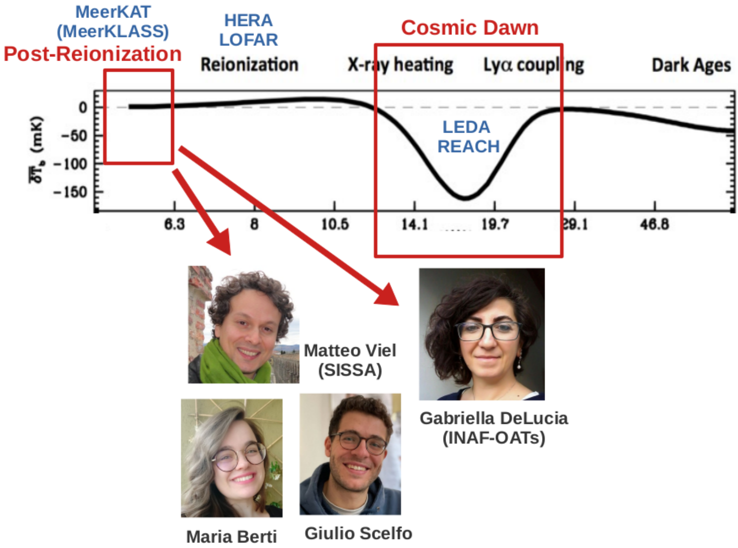
$$\delta T_b \propto x_{HI}(1+\delta)(1-\frac{T_\gamma}{T_s})\ \mathrm{mK}$$



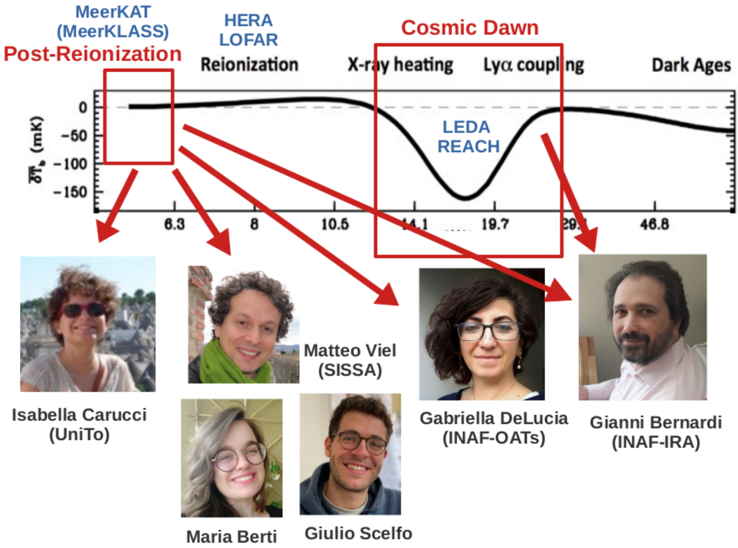
Scientific projects



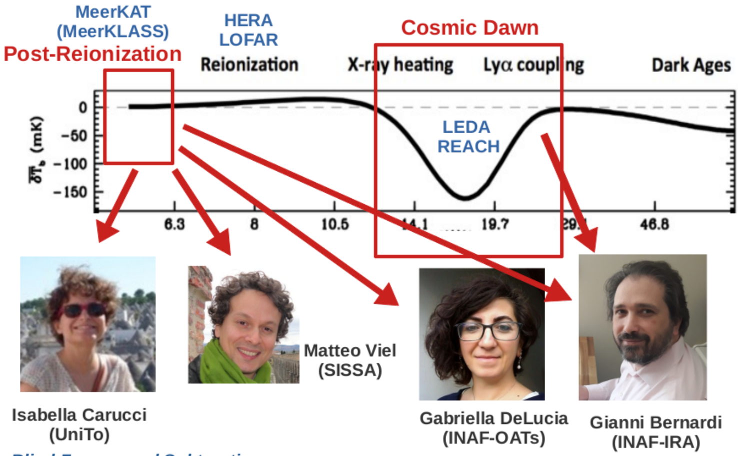
Scientific projects



Scientific projects



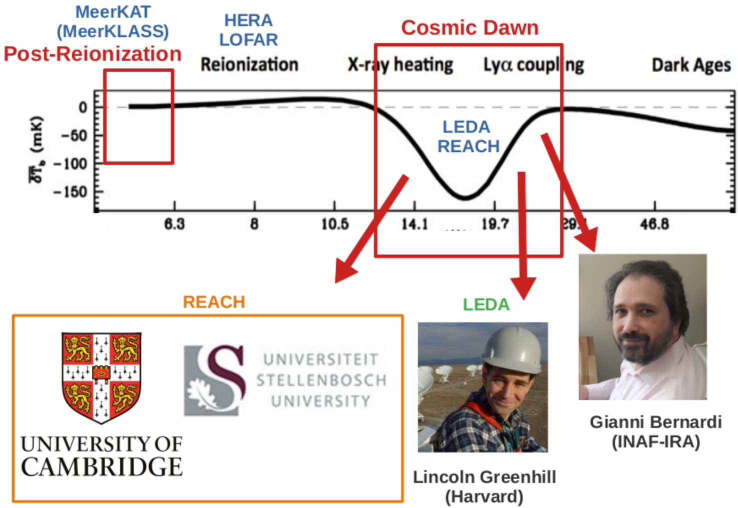
Scientific projects



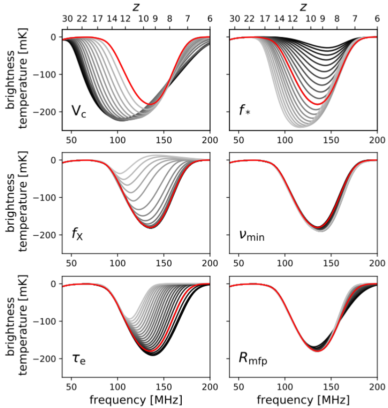
Blind Foreground Subtraction Challenge
arXiv:2107.10814

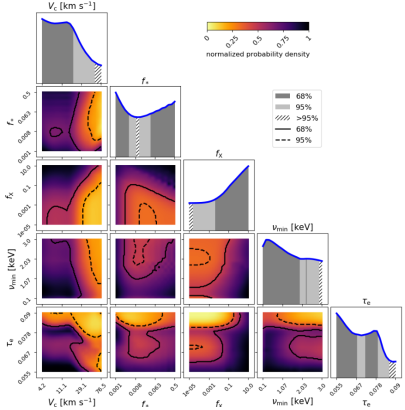
Spinelli, Carucci et al. (2021)

Scientific projects



High redshift astrophysics (e.g. Monsalve et al. (2019))





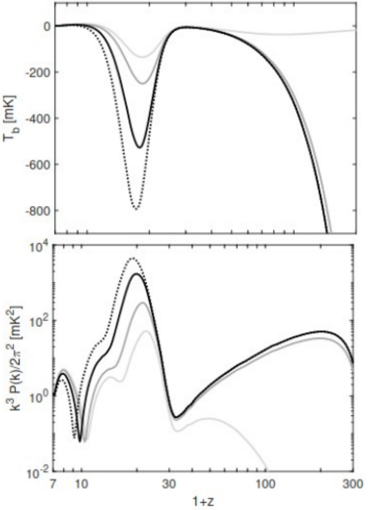
An ongoing experimental effort

partial summary from last year **3rd Global 21cm signal** workshop (**4th** upcoming next week)

- EDGES: Bowman et al (2018) *Nature*
  new results from Mid-Band and Low-Band3,
  lst analysis, full Bayesian treatment of calibration
- SARAS3: deployed on lake water (3 papers out, main result under revision)
- LEDA: Bernardi et al. (2016), Price et al. (2018), Spinelli et al. 2021
- REACH (Cambridge): Karoo Desert
- MIST (McGill): Chile & Canadian Arctic
- PRIZM (McGill +): Marion Island
- PRATUSH (India), DAPPER (Usa): lunar orbit

Connection to interferometry (and SKA)

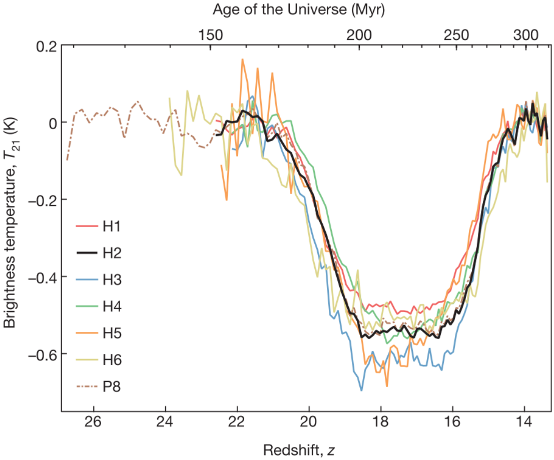
- LEDA (OVRO-LWA) has also interferometric data
  Eastwood et al (2019), Garsden et. al (2021)
- Global signal can drive data taking
  e.g. AARTFAAC Cosmic Explorer
  Gehlot et al (2020)
- contributes with early constraints for modeling future SKA data



Fialkov & Barkana (2019)

EDGES result

Bowman et al. (2018)



New physics?

$$\delta T_b \propto (1 - \frac{T_\gamma}{T_s})$$

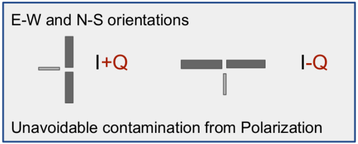
T_γ higher than expected

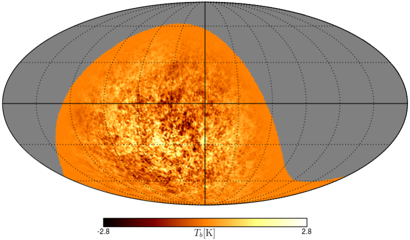
- early black holes? Ewall-Wice et al 2018
- connection with ARCADE2 excess (Feng & Holder 2018)? (probably not)

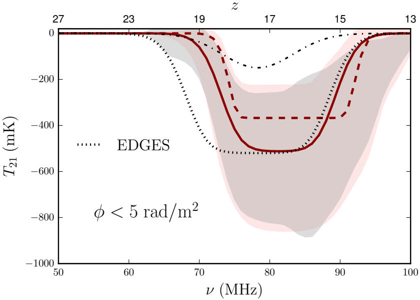
$T_s \sim T_k$ lower than expected

- baryon-dark matter fluid slowest it will ever be
- "mini-charged" dark-matter (Barkana 2018, Munoz & Loeb 2018)

Contamination from polarization?







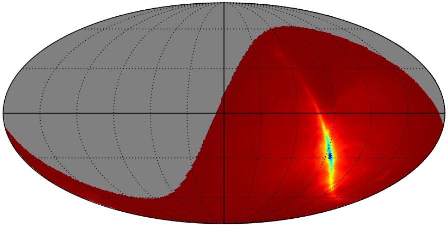
- contaminant is non smooth and may complicate the signal extraction
- enhanced signal may mitigate the need for exotic physics

Spinelli,Bernardi,Santos (2019)

Global signal observations

$$T(\hat{\boldsymbol{r}}_0, \nu, t) = \frac{\int_\Omega A(\hat{\boldsymbol{r}}', \nu)\, T_{\rm sky}(\hat{\boldsymbol{r}}', \nu, t)\, d\hat{\boldsymbol{r}}'}{\int_\Omega A(\hat{\boldsymbol{r}}', \nu)\, d\hat{\boldsymbol{r}}'} + T_N(\nu, t)$$

- $\hat{\boldsymbol{r}}_0$: e.g. EDGES location
- Different sky at different LST
- Noise varies with integration time and frequency resolution (400 h, 1 MHz)
- Need a beam model $A(\hat{\boldsymbol{r}}, \nu)$ (chromaticity complicates the analysis)



$$T_{\rm sky} = T_{\rm foregrounds} + T_{\rm signal}$$

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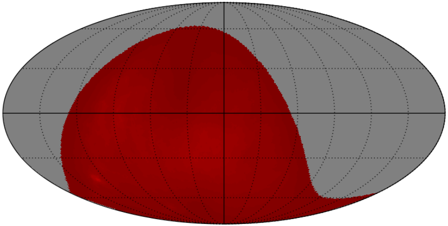

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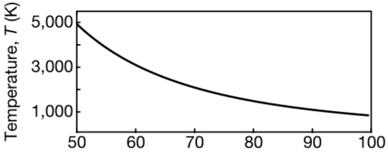
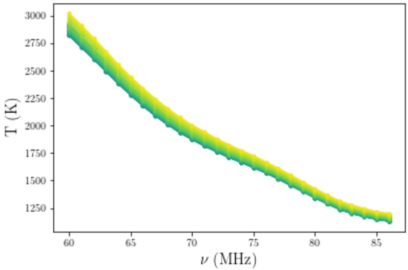
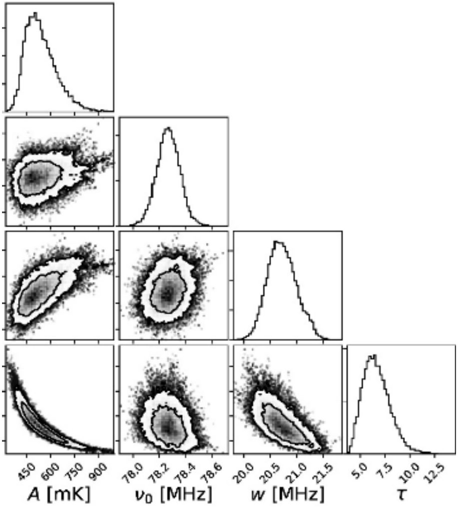


Bowman et al. (2018)



Extracting the signal



Bowman et al. (2018)

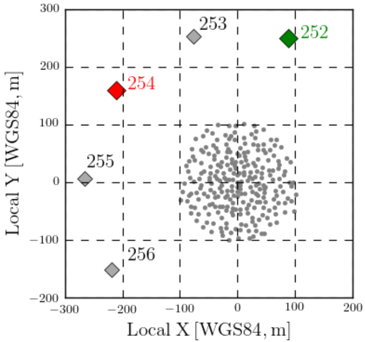
Methods

- Bayesian analysis with simplified modeling
  e.g. Bernardi et al (2015,2016), Bowman et al (2018)
- Maximally smooth functions
  e.g. Singh et al (2019)
- Methods more robust to chromaticity and systematics
  e.g. Anstey et al. (2021), Tauscher et al. (2020,2021)

LEDA

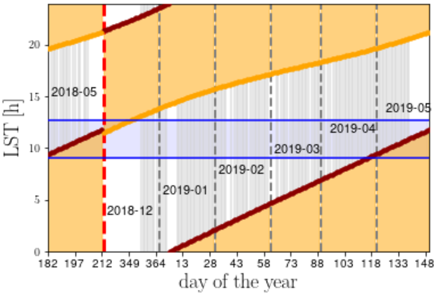
Large-aperture Experiment to detect the Dark Ages

- outriggers of LWA stations at Owens Valley Radio Observatory
- for this analysis: 254 and 252
  E-W orientation (polarization A)
- frequency range: 30-87 MHz
- instrument overview, RFI flagging and calibration: Price et al. (2018)



LEDA observations

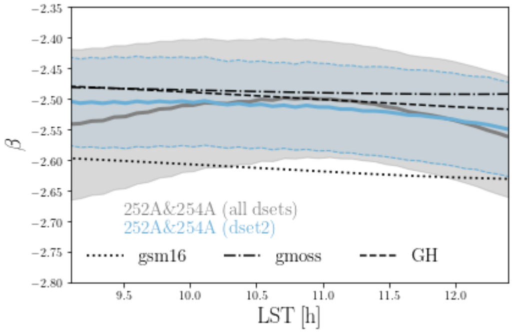
- 137 *days*: Dec 2018 to May 2019
  (+ May 2018)
- best window: *night-time* (less RFI and ionospheric disturbance) and *avoid galactic plane* (less chromaticity)
- *Dec/Jan* (dry soil)
- δlst $\sim$ 15sec, $\delta\nu$ $\sim$24 kHz, $\nu > 50$MHz
- final spectra: rebin with δlst $\sim$ 10min, $\delta\nu = 1$MHz



Spectral index

$$T_{\rm model}(\nu) = {\rm T}_{75}(\frac{\nu}{\nu_{75}})^{\beta} + T_{\rm CMB}$$

- combined 254A and 252A results
- evolution with LST in agreement with models and available data
- ground screen and soil condition due to weather are important



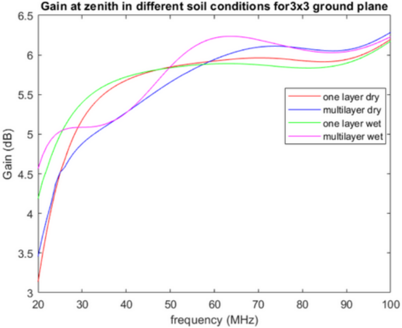
Spinelli et al. 2021

Work in progress

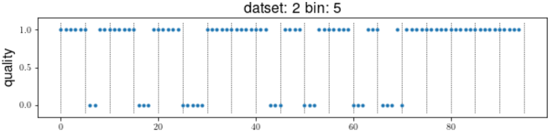
Improving antenna sims

with Georgios Kyriakou and Pietro Bolli (Arcetri)

Refining data selection and understanding of systematics
Goal: set upper limit on the absorption feature



Funding secured to open better site in 2022 (very clean)
PI: Greenhill



Global (Signal) Conclusions

- 21cm Global signal experiments have the potential to unveil the high redshift Universe
- Need to treat foregrounds (and their coupling with the antenna) properly!
- EDGES measurement has triggered further investigations both theoretically and for the analysis pipeline
- An independent measurement is needed to convince the scientific community

Available data to be used to understand systematics, constraint foregrounds (and the 21cm signal) in preparation for SKA