

Astrophysics in the LOFAR era

EMMEN, 23 – 27 April 2007



Foregrounds Simulations for **LOFAR** – **EoR** Experiment



Vibor Jelić

Collaborators: **S. Zaroubi** (supervisor), G. Bernardi, G. de Bruyn, G. Harker, L. Koopmans, P. Labropoulos, V. Pandey, R. M. Thomas, S. Yatawatta

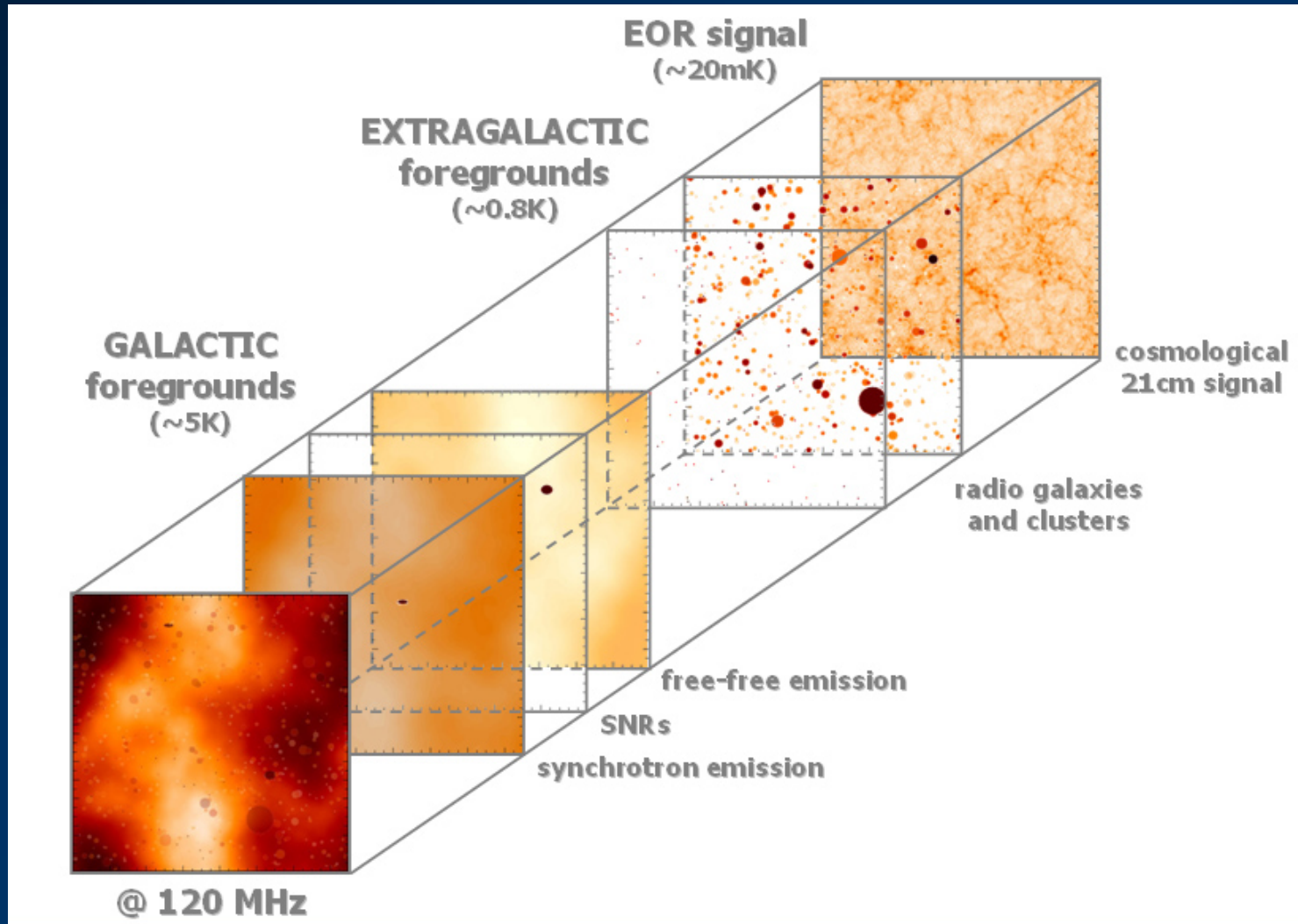
Outline



- **Introduction**
- **Galactic foregrounds**
 - diffuse synchrotron emission
 - supernovae remnants
 - free – free emission
- **Extragalactic foregrounds**
 - radio galaxies
 - clusters of galaxies
- **Extraction of 21cm EOR signal from FGs**
- **Plans for the future**



Introduction



Galactic foreground



- **SYNCHROTRON EMISSION ($\sim 70\%$)**

- **sources:** electrons trapped in the magnetic fields of discrete galactic supernovae remnants and diffuse emission from interaction of cosmic-ray electrons with galactic magnetic field
- DGSE as a probe of galactic magnetic field and distribution of relativistic electrons in the galaxy

- **DIFFUSE SYNCHROTRON EMISSION**

- spectrum is close to a **featureless power law** with a gradual **variation in spectral index** with a position on the sky and frequency
- average spectral index (100 MHz) $\beta = -2.55$, with position dispersion $\sigma(\beta) \sim 0.1$ (Shaver et al. 1999)



Galactic foreground



▪ DIFFUSE SYNCHROTRON EMISSION

$$T(x, y, \nu) = \int T_0(x, y, z) \left(\frac{\nu}{\nu_0} \right)^{-\beta(x, y, z)} dz$$

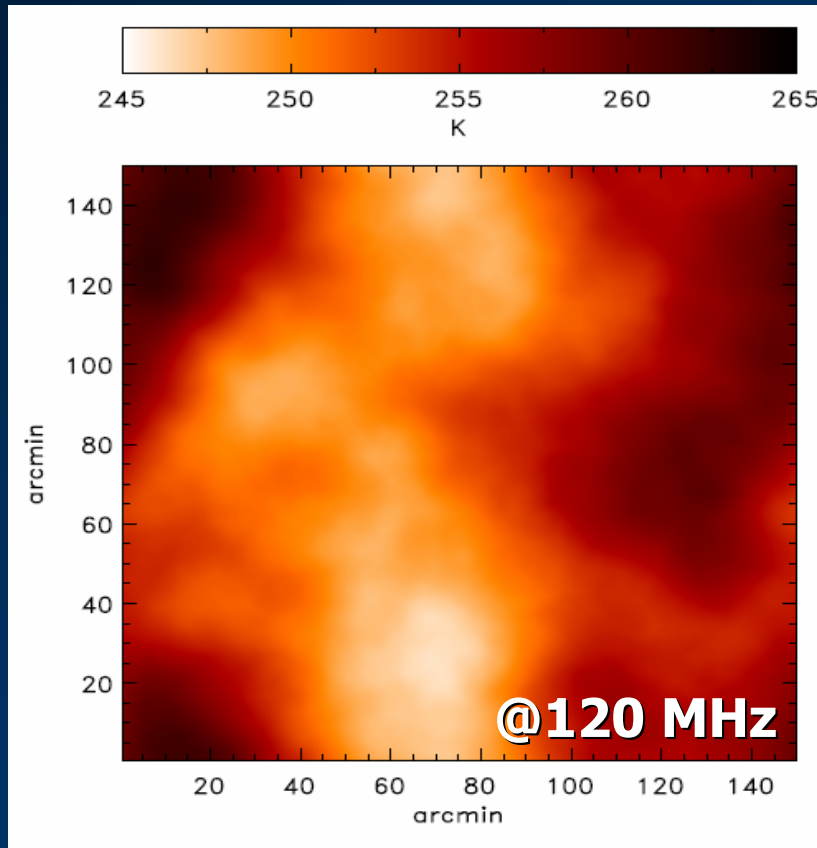
@ frequency ν_0

- ⇒ 2 random Gaussian fields with power law spectrum (index = -3)
- ⇒ normalize mean and rms of RGF according to observed maps (Reich & Reich 1988)

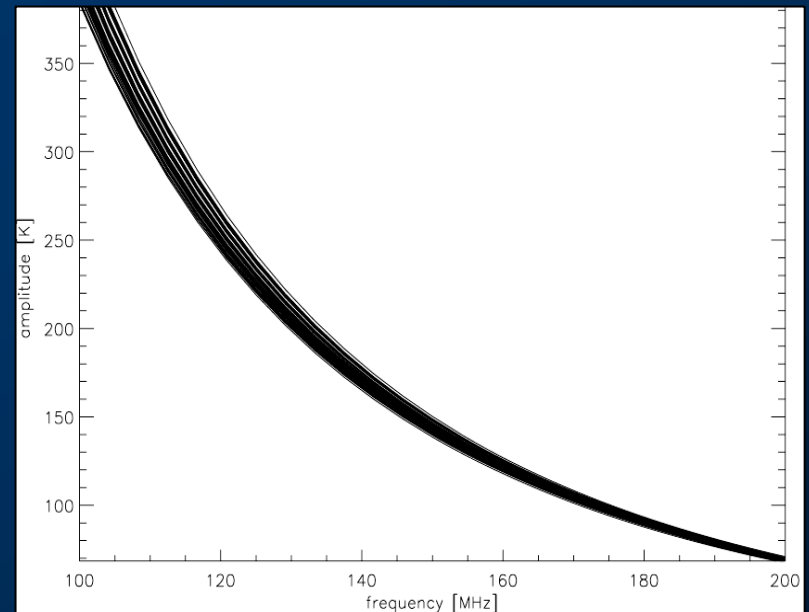
⇒ maps of DGSE @ different frequencies



Galactic foreground



▪ DIFFUSE GALACTIC SYNCHROTRON EMISSION

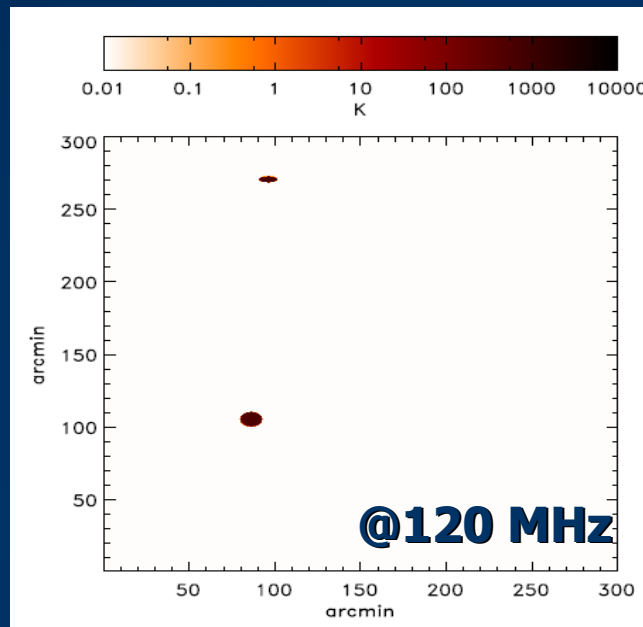


Galactic foreground



• SUPERNOVAE REMENANTS

- based on **observed statistical properties** of SNRs
 - e.g. Caswell & Lerche 1979, Trushkin 1998
- **A Catalogue of Galactic Supernova Remnants**
 - D. A. Green, 2006
 - low frequency observations with VLA (Brogan et. al., 2006)



- **surface brightness**
- **spectral index**
- **angular size**
 - ⇒ **power law, normalized according observations**



Galactic foreground



- **FREE - FREE EMISSION ($\sim 1\%$)**

- arises from interaction of free electrons with ions and consists of thermal bremsstrahlung radiation
- at intermediate and high galactic latitudes $H\alpha$ is a good tracer of diffuse galactic free-free emission, since both are emitted by the same ionized medium and have intensities proportional to emission measure ($\propto \int N_e^2 dl$)

- spectrum can be approximate as power law with $\nu^{-2.15}$ that scales as $C_l \sim l^{-3.0}$ (Tegmark et al. 2000)

- **simulated in a same manner as galactic synchrotron emission, but with different spatial and frequency indexes**



Extragalactic foreground



• RADIO GALAXIES

- based on radio sky simulations by Jackson 2005
 - **3 TYPES OF SOURCES**: FRI, FRII (Fanaroff & Riley 1972) & star forming (SF) galaxies
 - predicted **source surface density distribution @151 MHz**
 - predicted **number of sources per square degree @151 MHz**
 - random distribution on the map
 - random size distribution between 50 – 800 kpc for FRs galaxies and between 10 – 100 kpc for SF galaxies
- **power law** with temp. spectral index **-2.7**

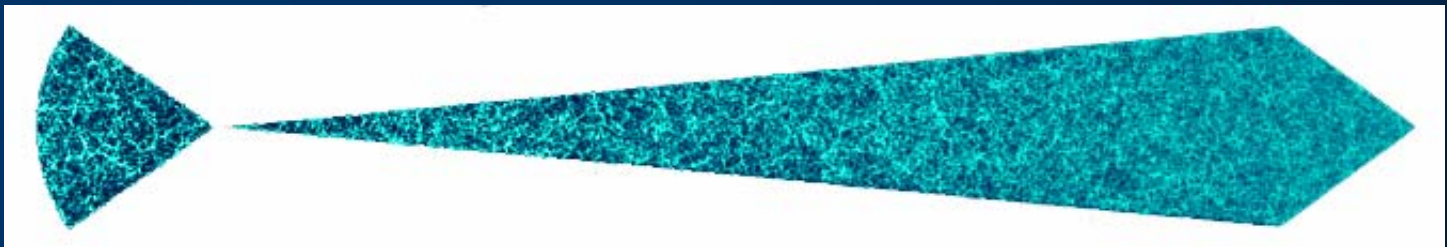


Extragalactic foreground



• CLUSTERS OF GALAXIES

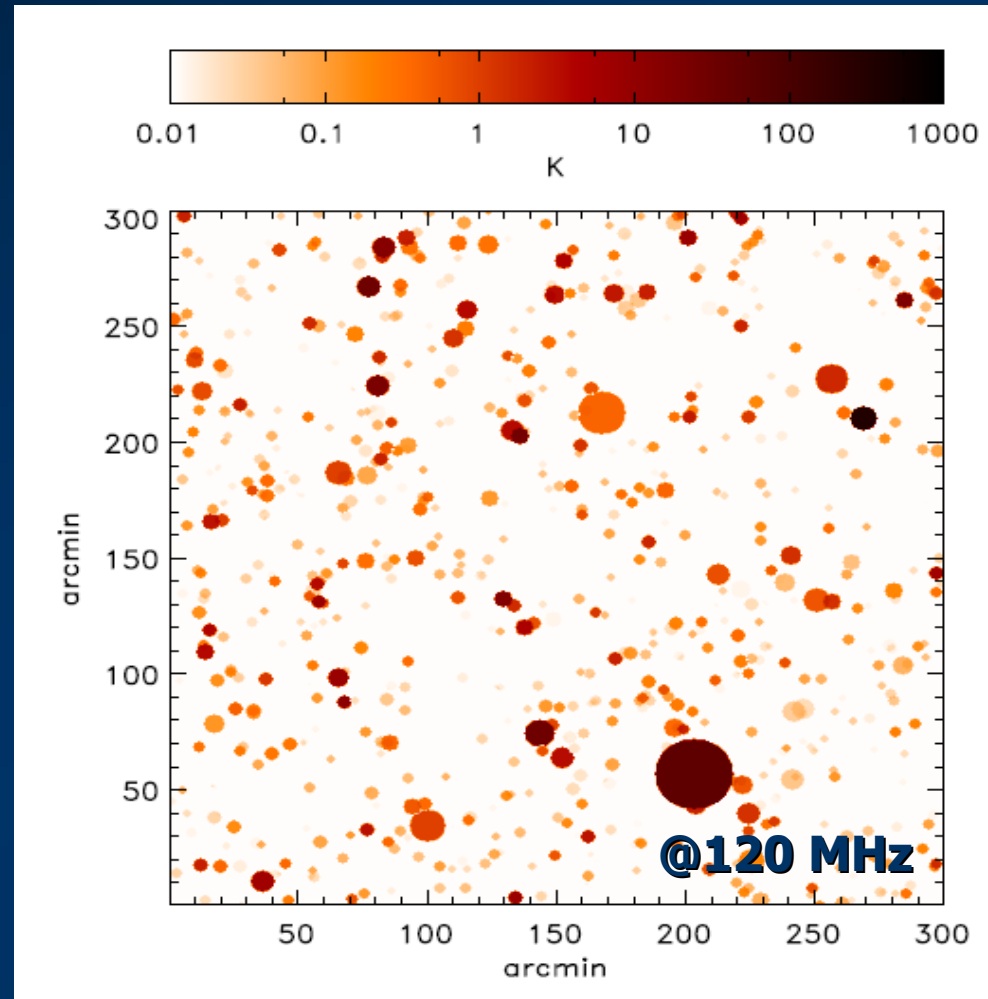
- **The Hubble Volume Simulation (10x10 degree)**
 - **Cluster Catalogue** (Virgo Consortium, 2002)
- **mass DMH – X ray luminosity correlation** (Jenkins et al., 2001)
- **X ray – radio luminosity correlation** (Enßlin & Röttgering, 2002)
 - ~ 30% with radio properties (from observations)
- redshift, virial radius \Rightarrow **angular size**
- power law with spectral index distribution from Cohen et al. 2004



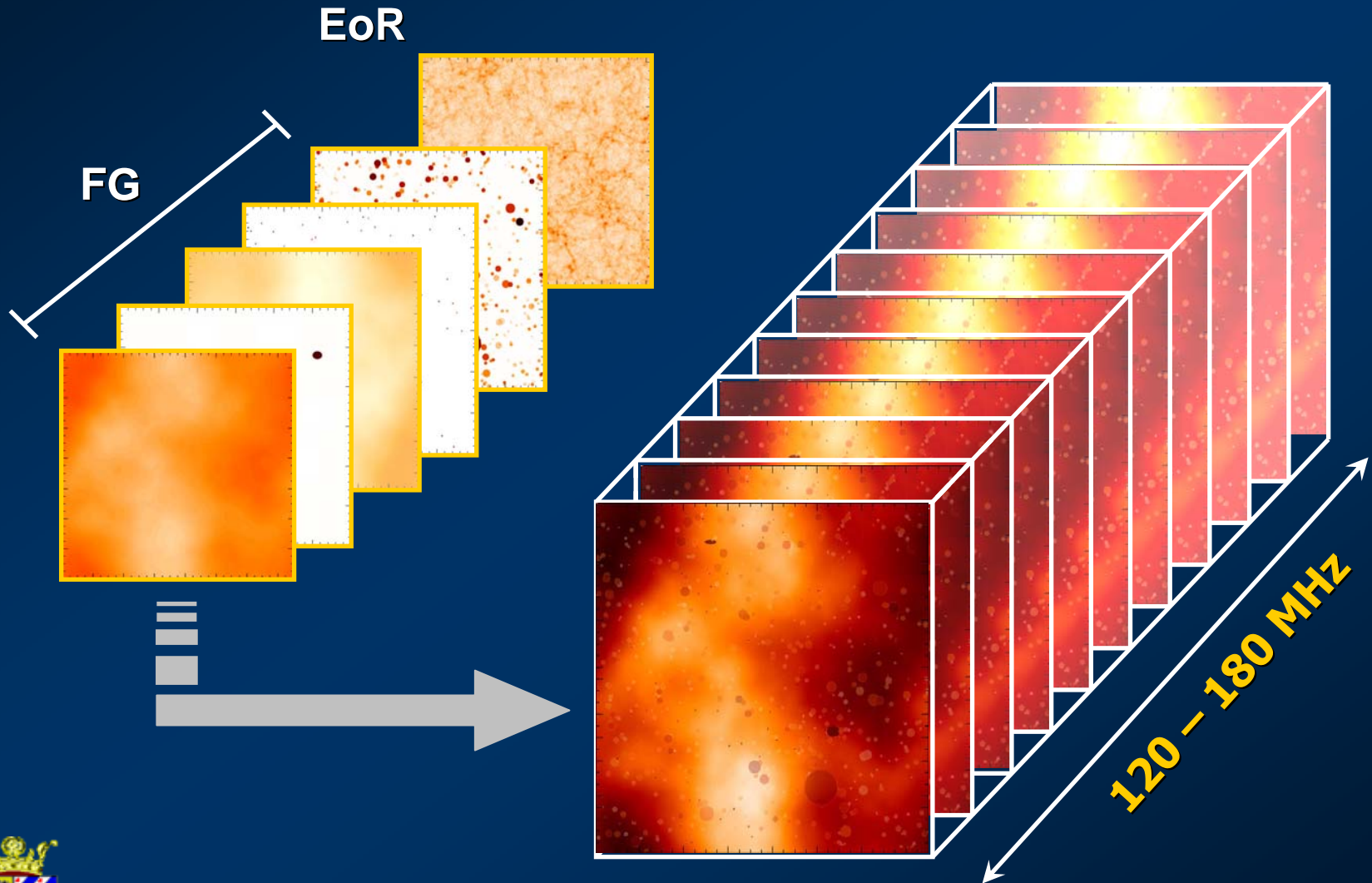
Extragalactic foreground



- CLUSTERS OF GALAXIES



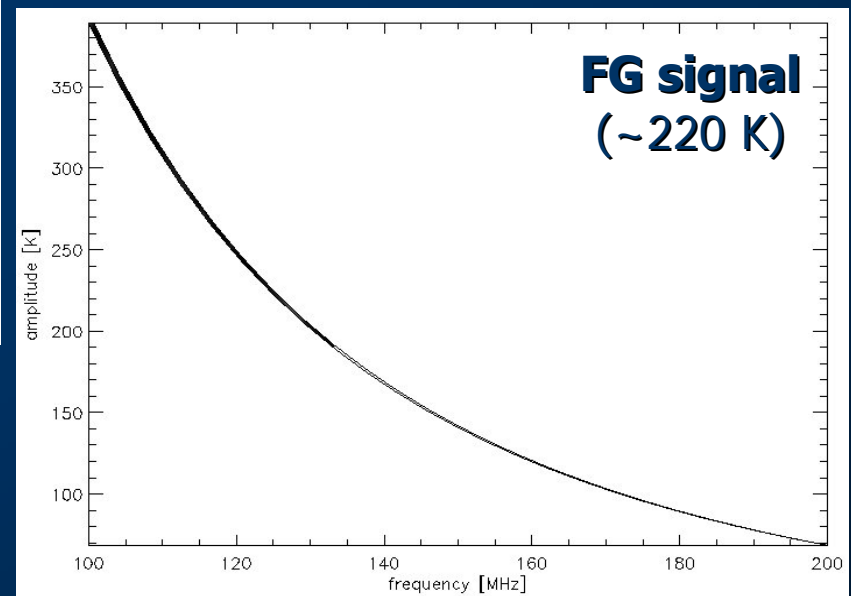
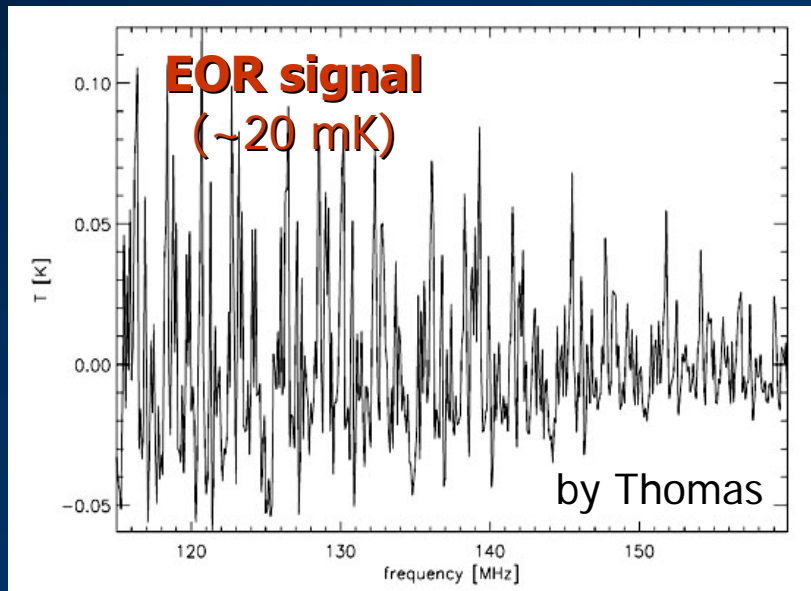
Extraction of EoR from FGs



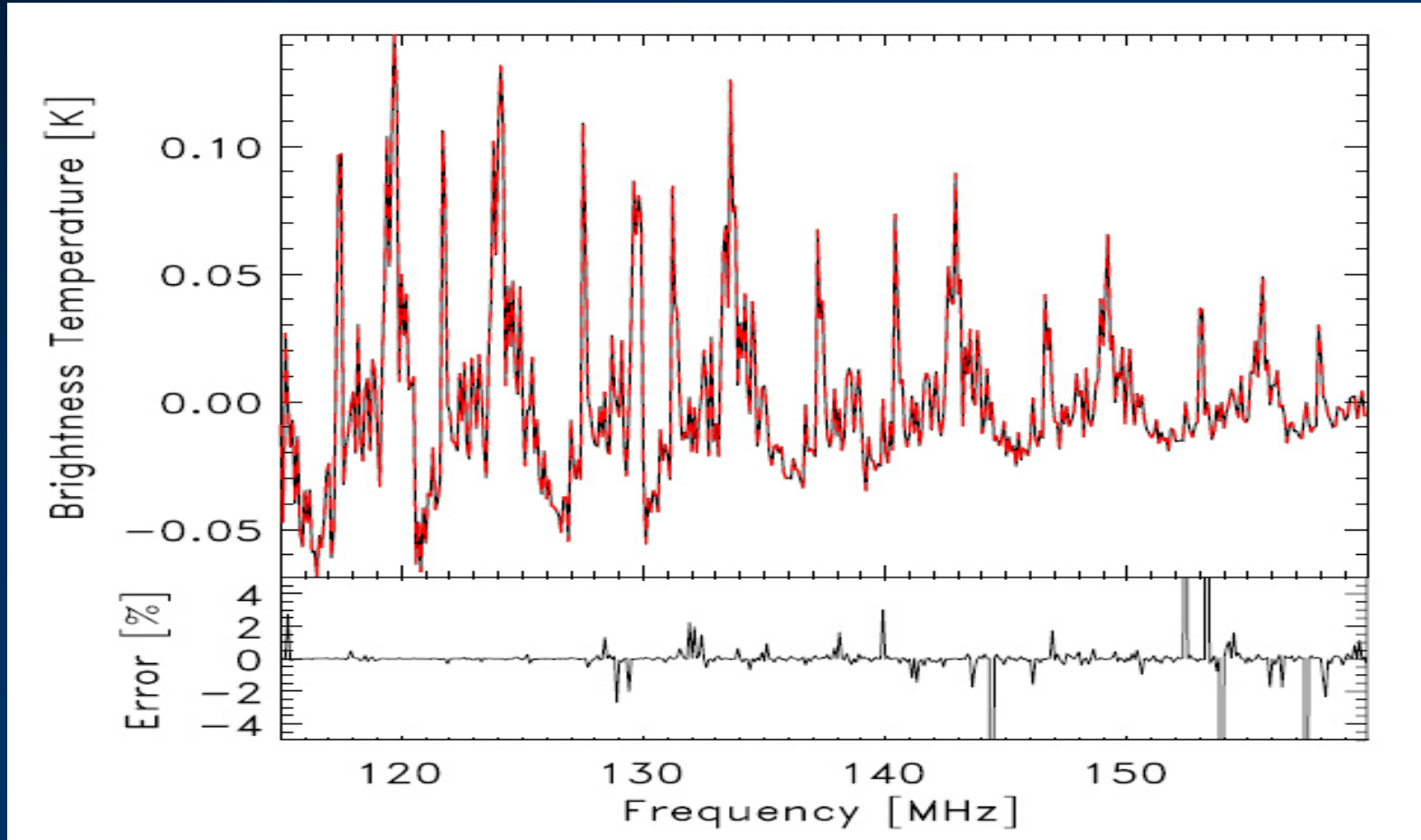
Extraction of EoR from FGs



- **proposed methods:**
 - for one pixel (**frequency domain**)
 - **polynomial fit**, PCA, Wiener filter, wavelets



Extraction of EoR from FGs



Plans for future



- add polarization character of galactic foregrounds
 - **Galactic synchrotron polarization is linearly polarized**
- normalize FG maps according LFFE observations

questions ?

