Cosmic Ray Tomography of the Milky Way
using Synchrotron Emission

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Observing Galactic Cosmic ray emissivity using HII regions in the Milky way

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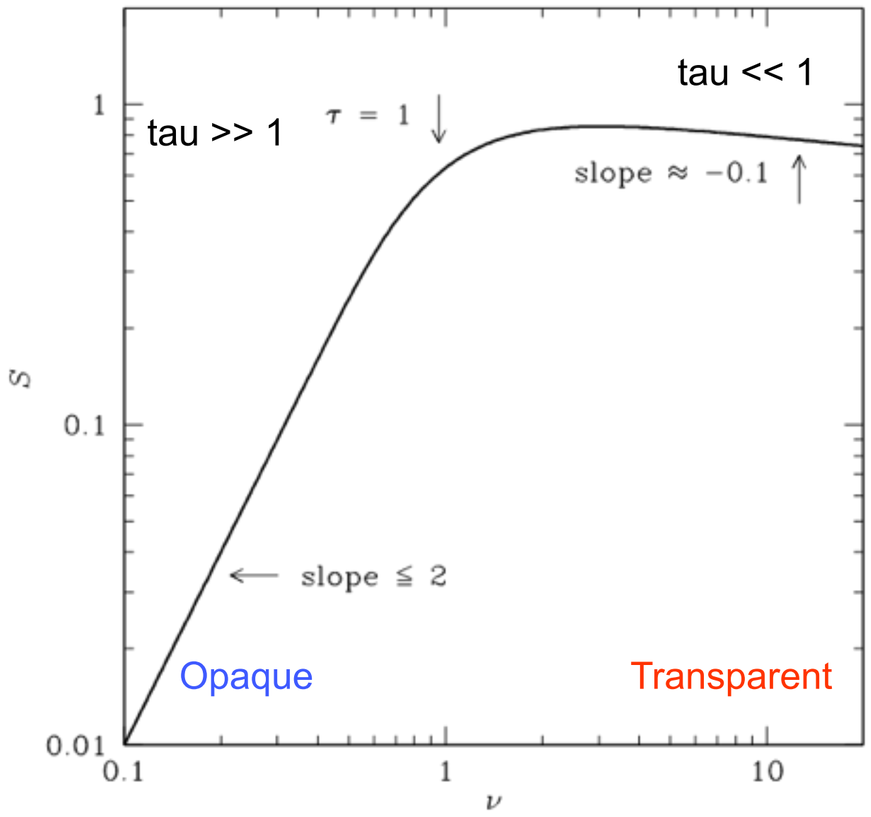
HII regions

Hydrogen (HI) cloud surrounding young stars gets ionized
Strömgren Radius: border where photo-ionization rate equals rate of recombination
Sizes up to a few parsecs + typical lifetimes of 3 - 10 Myr
Observation by

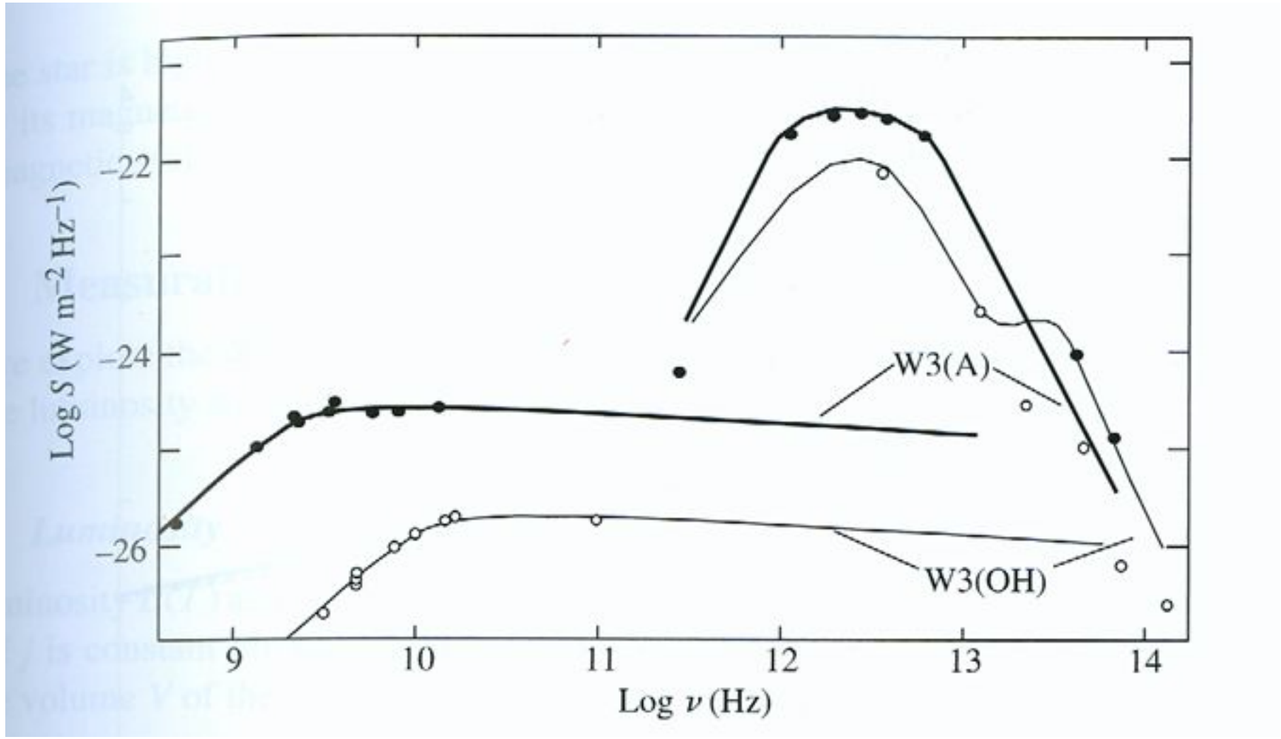
- Free-free emission (radio)
- Emission lines (radio, optical, IR)

Rosette Nebula, H-alpha observed with INT La Palma. Courtesy: Nick Wright & IPHAS collaboration

Free Free Emission and Free Free Absorption



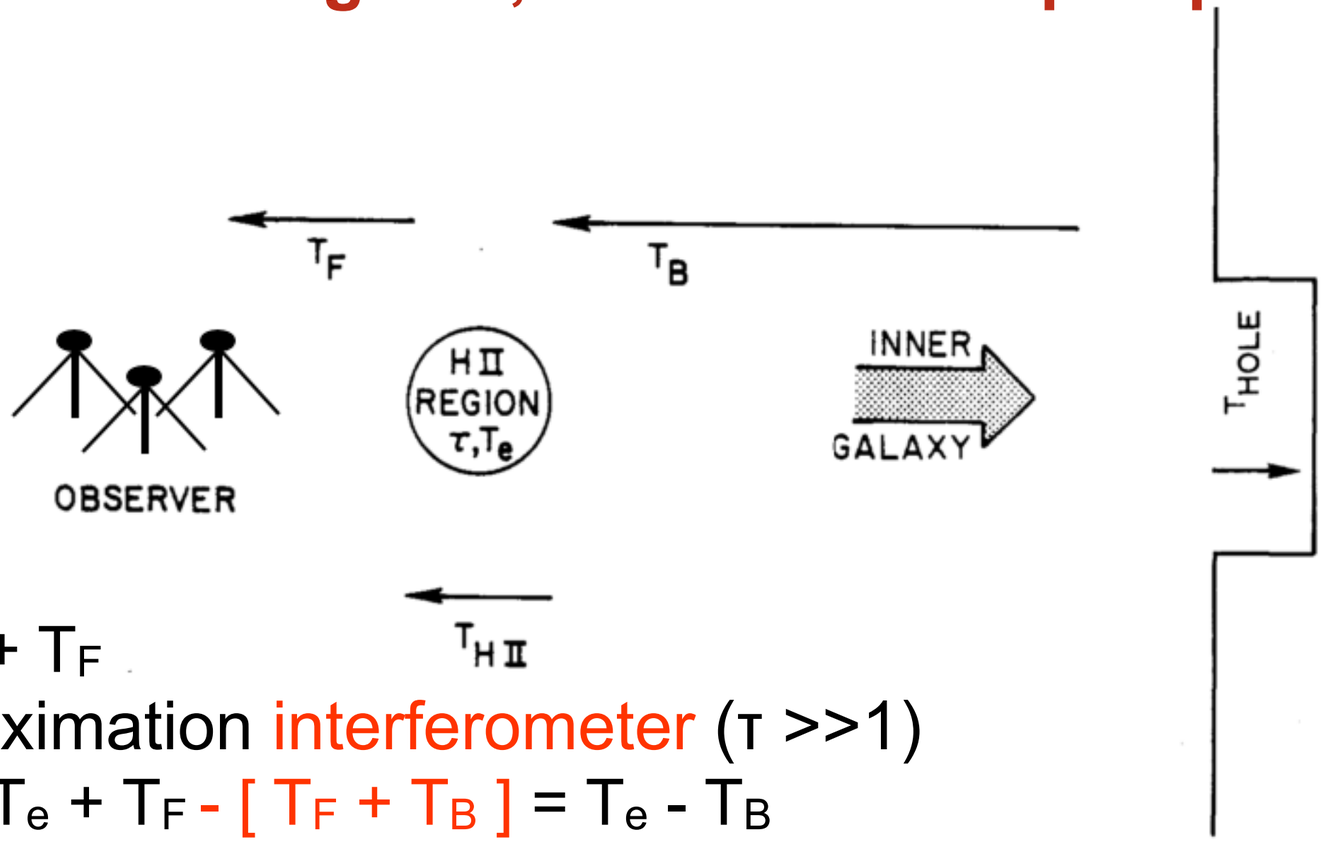
courtesy: NRAO, online course, free-free emission



courtesy: Krügel et al.,1975

Free-free absorption in HII regions, interferometer perspective

source: Kassim (1990)



$T = T_e(1 - e^{-\tau}) + T_B\, e^{-\tau} + T_F$

Low frequency approximation interferometer ($\tau >> 1$)

$T_{HOLE} = T_e + T_F - T_T = T_e + T_F - [\, T_F + T_B \,] = T_e - T_B$

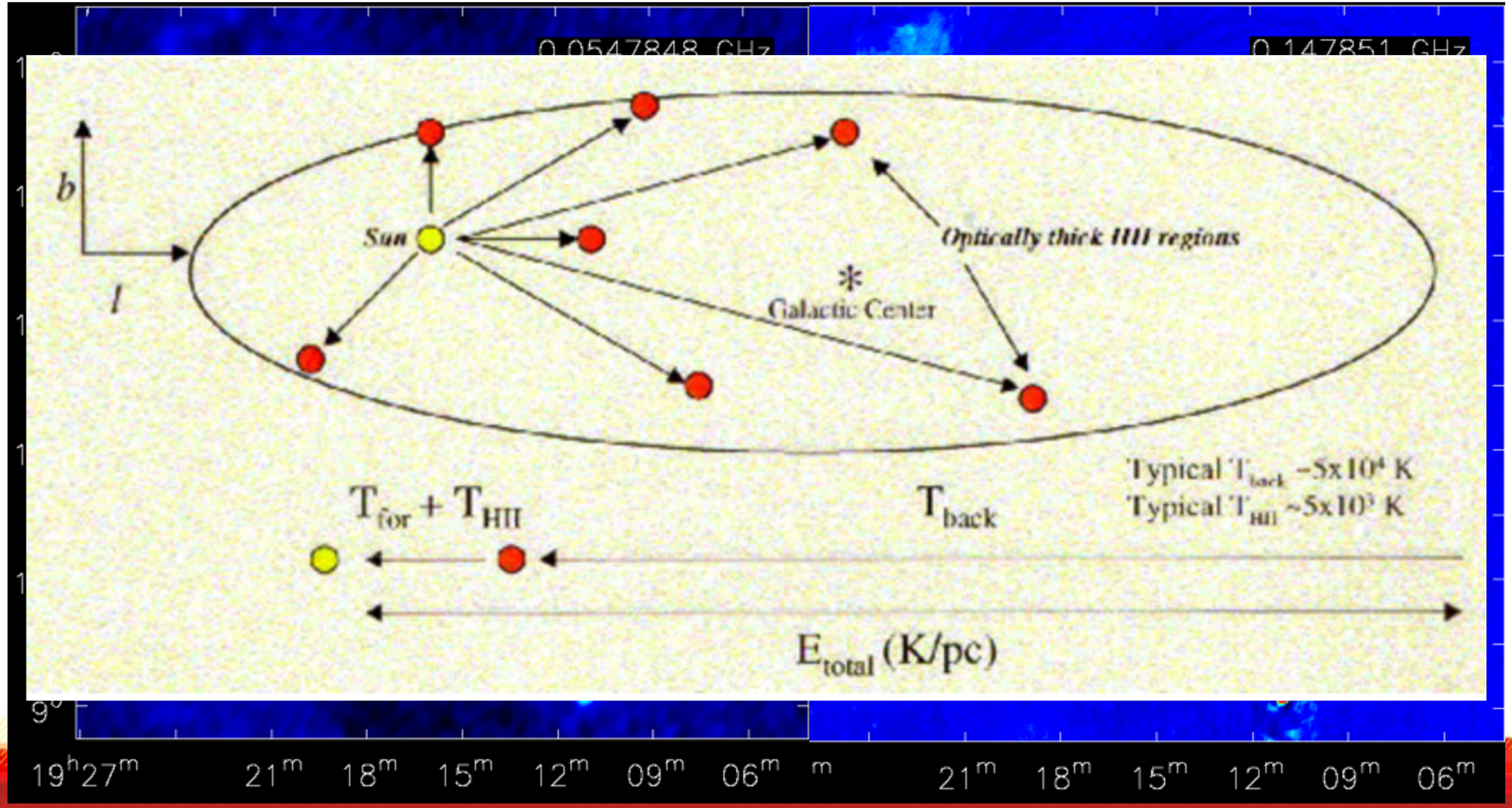
$T_{HOLE} = T_e - T_B < 0$

LOFAR

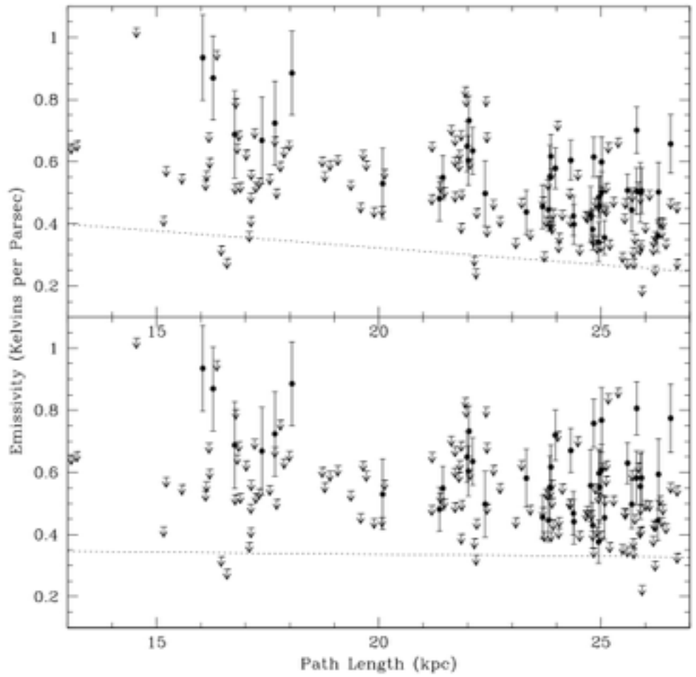
LBA: Low Band Antenna dipoles
10 - 90 MHz

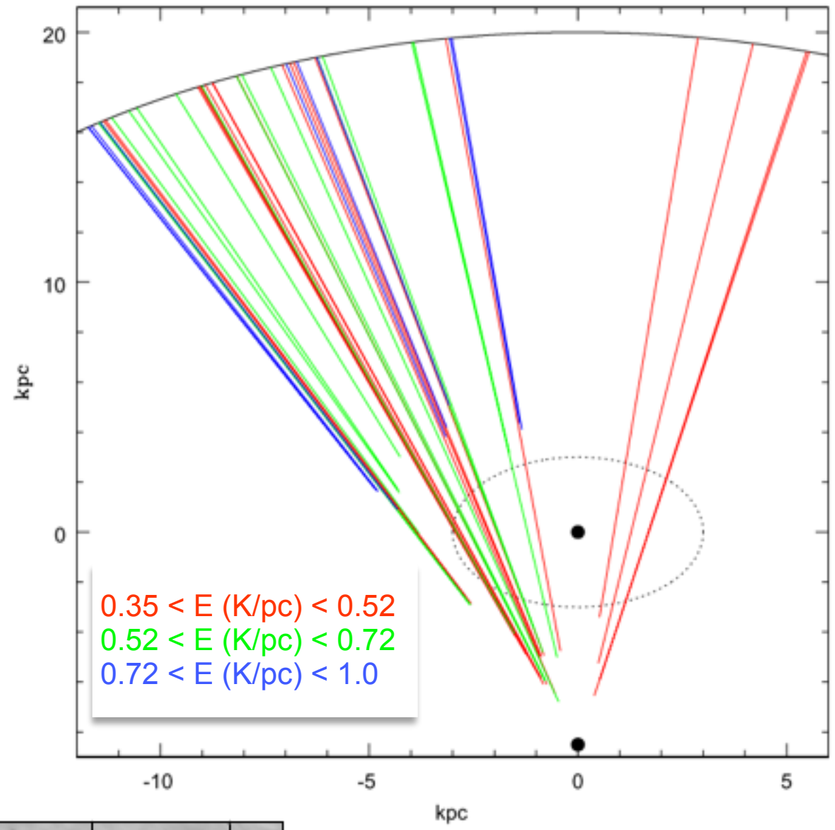
- HBA: High Band Antenna
- tiles
- 110 - 240 MHZ

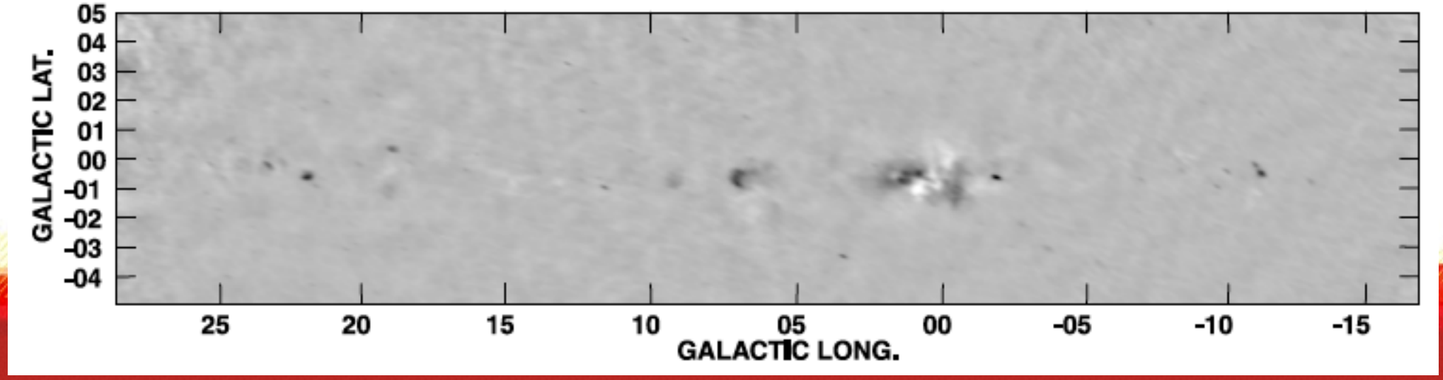
Free-free absorption in HII regions and cosmic ray tomography



Nord, et al. 2006. Proof of Concept





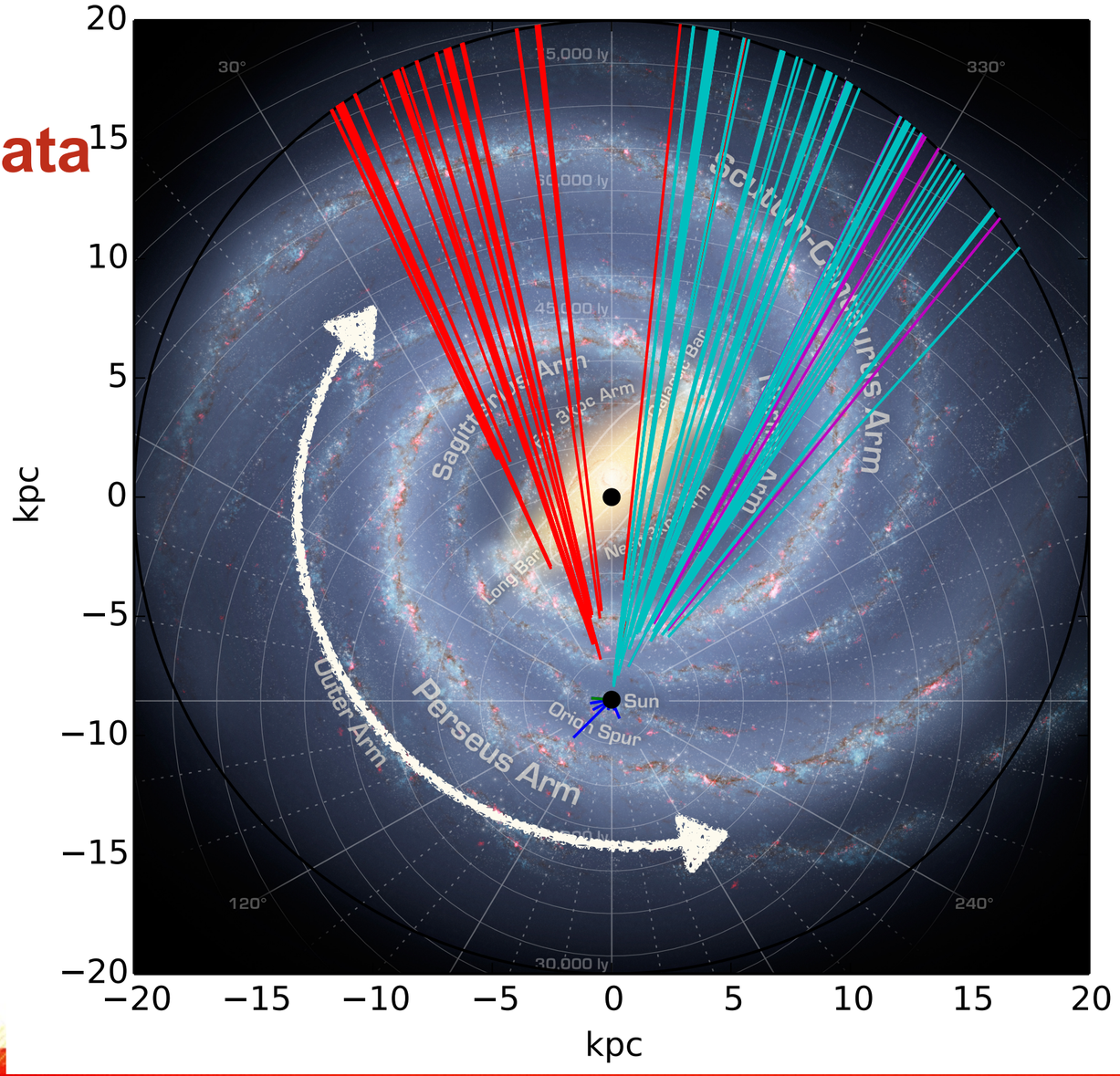


Nord, et al. (2006)

Follow-up:
literature search and LOFAR data

Literature:
5 papers with emissivity values
127 catalog entries

LOFAR data:
2 fields processed
5 fields unprocessed



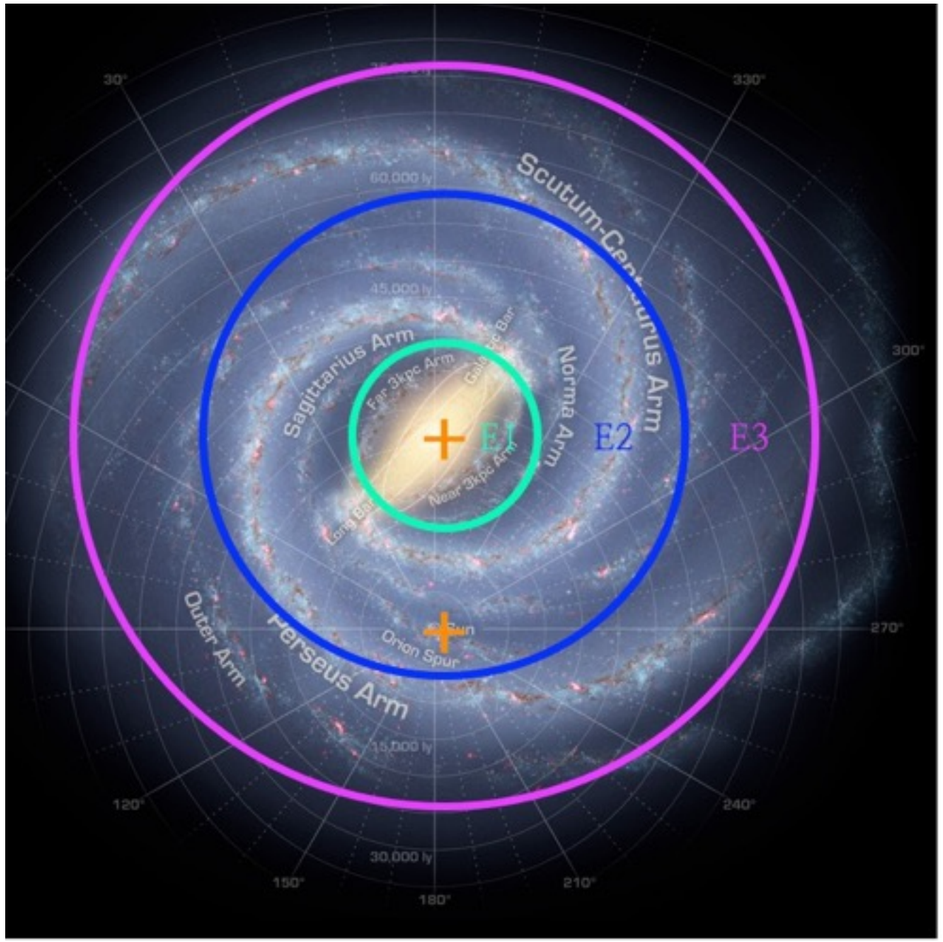
Emissivity modelling

4 different models
- Emissivity as function of Galactic radius
- more data
- better constraints on fitting values

Constant: E = E1 for every Rgal

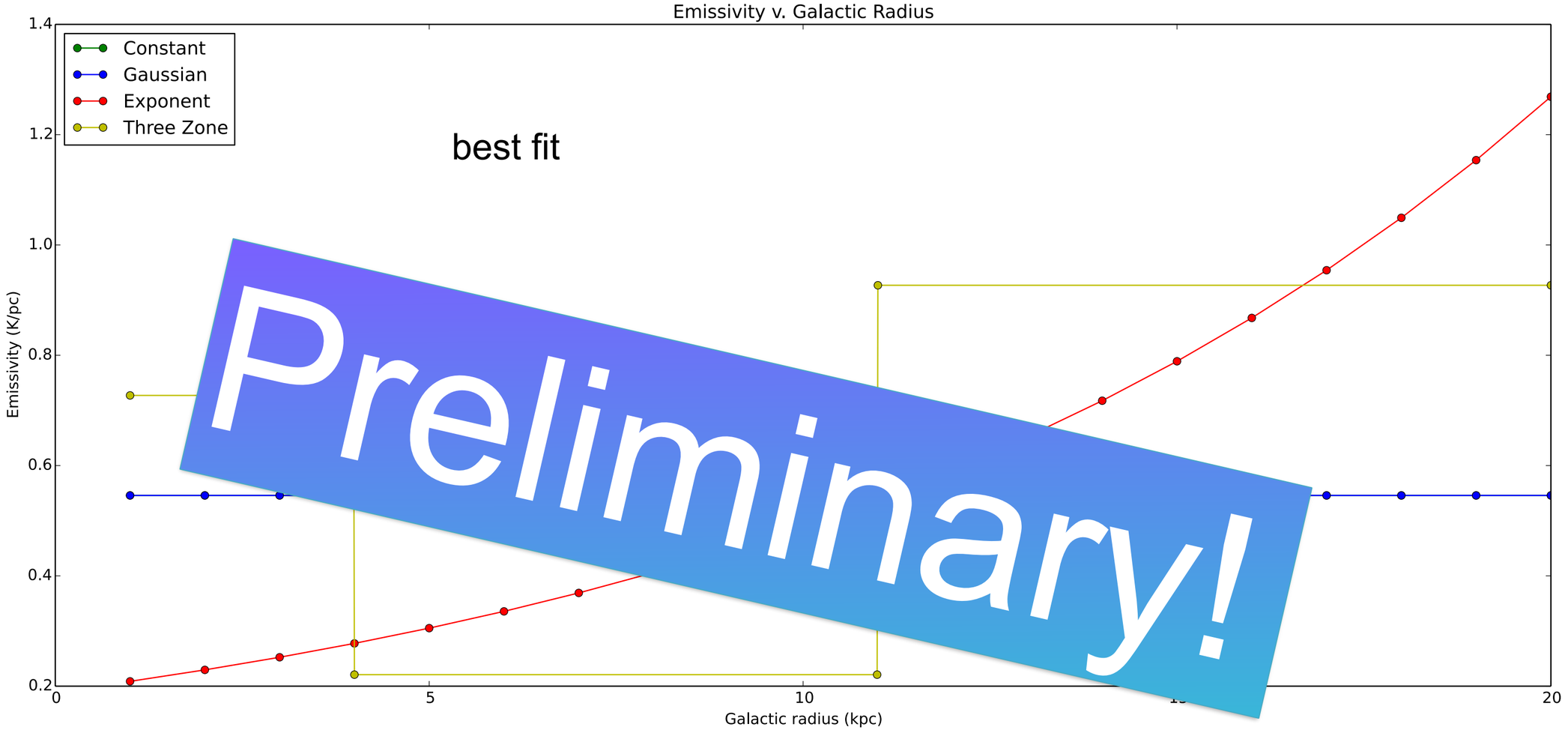
Gaussian: E = alpha x $e^{-Rgal/2*beta**2}$

Exponent: E = alpha x $e^{-beta*Rgal}$



Three Zone model

CatalogDataCRModelInput_Backgrounds.csv



Future Work

This project:
More informative plotting methods
Include foregrounds in modelling
Physics based modelling :

- realistic CR distribution (GALPROP)
- emissivities and magnetic fields (Imagine and Hamurabi)

Next projects:
Processing of data for more HII regions to add to the catalog
Inclusion of other processed low-frequency data
Using LOFAR LBA and HBA data to study HII region properties
(Turn over frequency, spectral index, emission measure, electron density,…)

To Be Continued