Zeeman Effect and Line Mixing in ARTS 2.2

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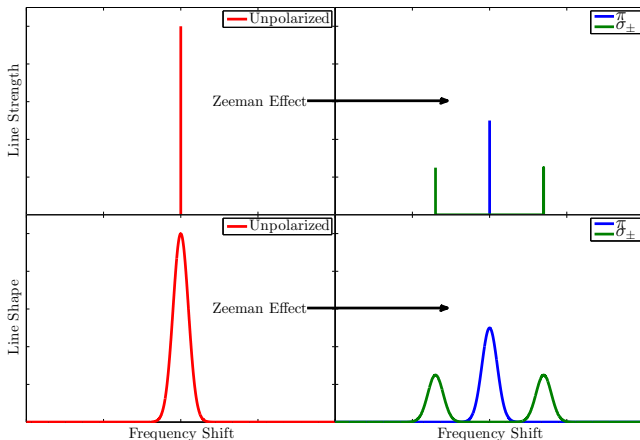
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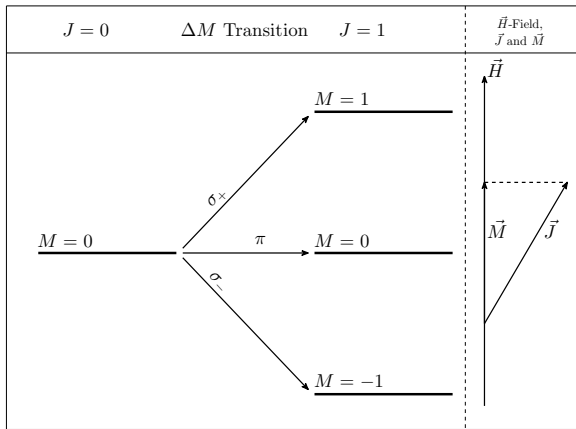Kiruna, Sweden

June 11, 2014

What is the Zeeman Effect?

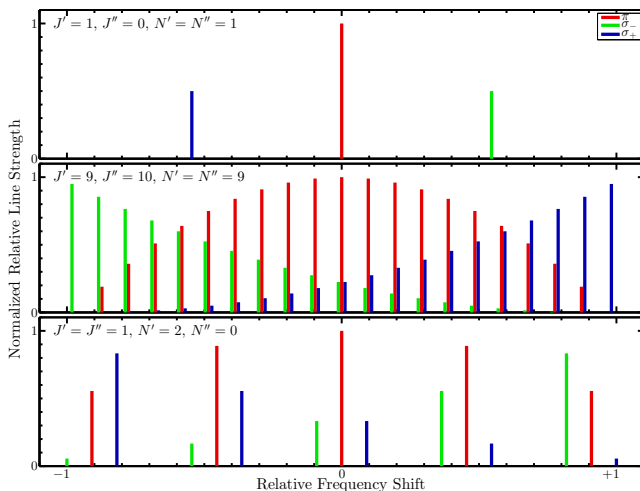Magnetic field strength and direction gives polarization and splitting,

How is the Line Split?

Coupling of the rotational angular momentum to the magnetic field,

What is the Zeeman Effect?

Quantum number configuration gives the Zeeman pattern,

Propagation Equations

Simple unpolarized absorption coefficient:

$$\alpha_{jl}(\nu) = n_j \ S_l \ F(\nu)$$

Propagation matrix (no Zeeman effect):

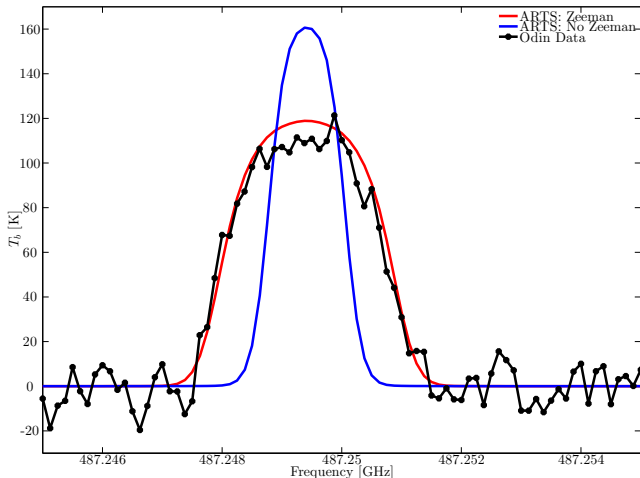$$\mathbf{K}_{jl}(\nu) = \alpha_{jl}(\nu)\mathbf{I}$$

Propagation matrix (with Zeeman effect):

$$\mathbf{K}_{jl}(\nu) = \alpha_{jl}(\nu) \sum_Z S_Z \ F\left(\nu + \Delta \ \nu_Z\right) \ \mathbf{\Phi}_Z(\vec{r}, \vec{H}),$$
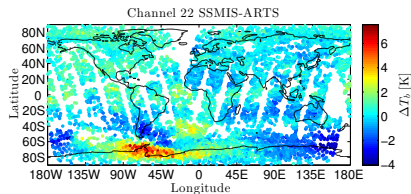
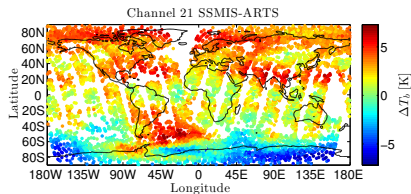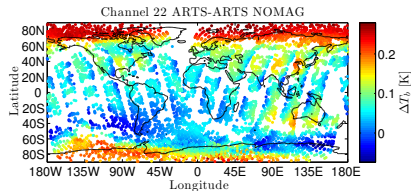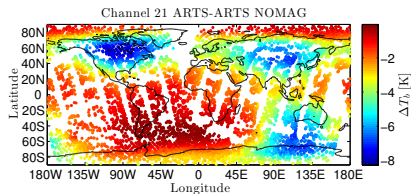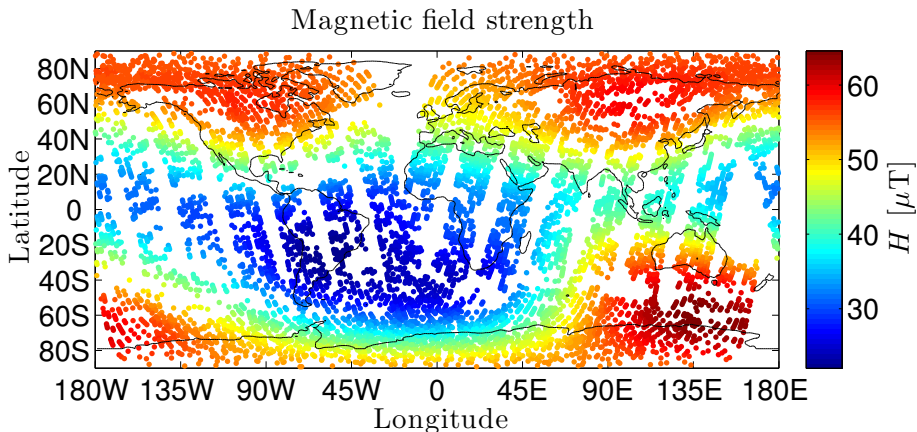where $\Delta \ \nu_Z$ is a few MHz at most for Earth.

Satellite Comparison

Comparison with Odin-SMR,

Satellite Comparison

Comparison for two channels of SSMIS (ongoing project),

Earth Magnetic Field

For reference,

Magnetic field strength

How to Use the Zeeman Module

- In `propmat_clearsky_agenda`, add `propmat_clearskyAddZeeman`

- `abs_species` must contain species with `Z` to activate the Zeeman module
  - `O2-Z`
  - `O2-Z-66`
  - `O2-Z-66-61e9-62e9`

- `isotopologue_quantum` must be set with species information
  - The relativistic splitting constant g_s
  - Quantum number S

- Gridded magnetic field (pressure, latitude, and longitude)
  - Three x-y-z variables `mag_0_field` (where `0` is the direction)

What is Line Mixing?

For O_2, line mixing narrows the 60 GHz band,
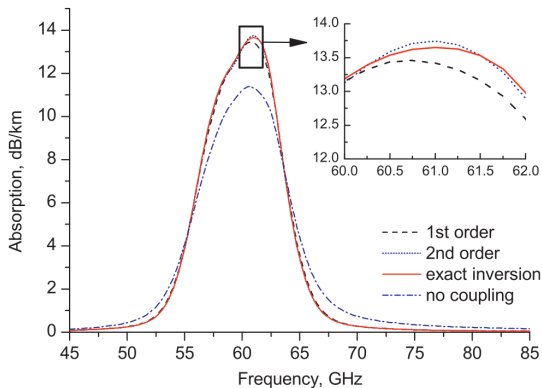
(From Makarov et al. 2013)

Line Shape Change

Simple Lorentzian line shape:

$$F(\nu) = \frac{1}{\pi} \frac{1}{\nu - \nu_0 - i\Delta \nu_p}$$

Line shape with first order line mixing (e.g., Rosenkranz's model):

$$F(\nu) = \frac{1 - iY}{\pi} \frac{1}{\nu - \nu_0 - i\Delta \nu_p}$$

Line shape with second order (e.g., Makarov et al. 2011):

$$F(\nu) = \frac{1 - iY + G}{\pi} \frac{1}{\nu - \nu_0 - \Delta \nu' - i\Delta \nu_p}$$

How to Use the Line Mixing Module

- abs_species must contain species with LM_2NDORDER to activate the Zeeman module
  - O2-LM_2NDORDER
  - O2-66-LM_2NDORDER
  - O2-Z-66-LM_2NDORDER

- Input the line mixing data
  - line_mixing_dataInit
  - ArrayOfLineMixingRecordCreate(lm_o2)
  - ReadXML(lm_o2,$PATH)
  - line_mixing_dataMatch(species_tag=$TAG,
    line_mixing_records=lm_o2)

- Line shape must handle imaginary part (ARTS imaginary line shape means dispersion)

Questions?