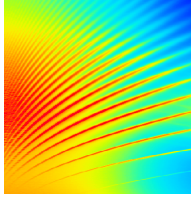


Heliosismology: an introduction

T. Appourchaux

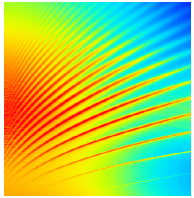
Institut d'Astrophysique Spatiale, Orsay



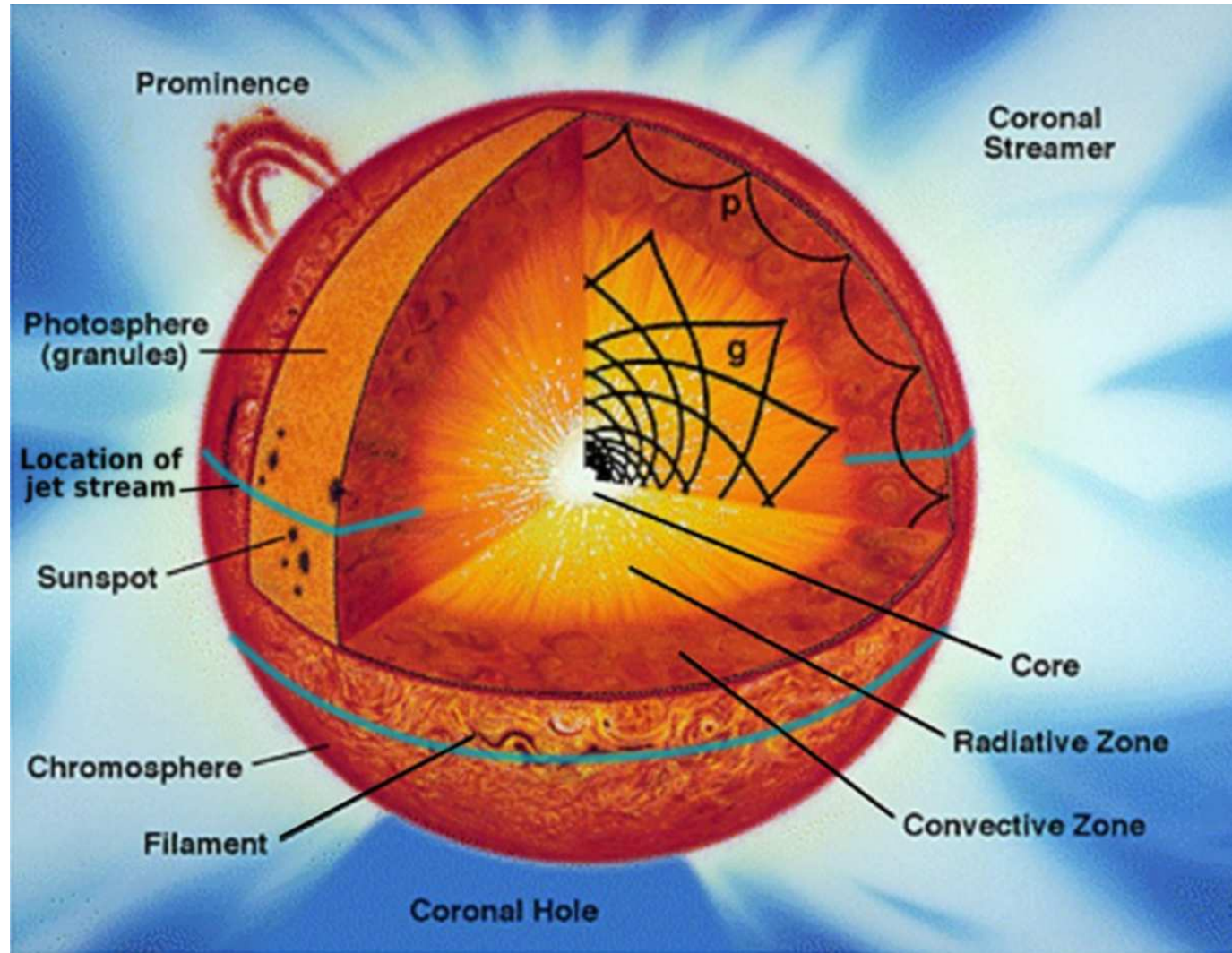
What can we do with PICARD?

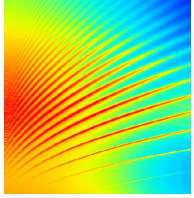


- Global helioseismology:
 - Internal structure and stellar model
 - Internal rotation and dynamics
 - Excitation and convection
- Telechronoseimology:
 - Active region emergence and evolution
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 - Seismic radius (f mode)
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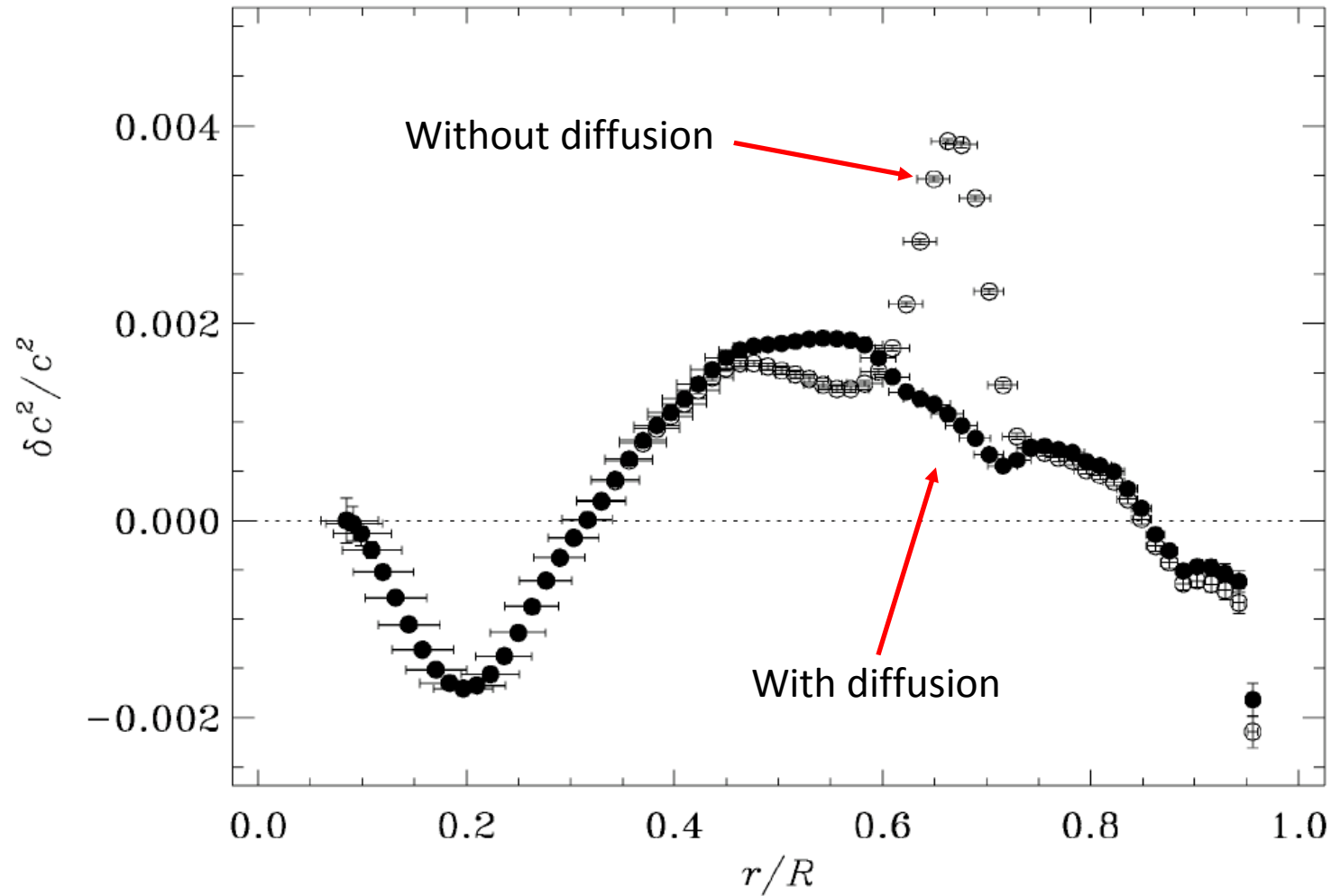


What is helioseismology ?

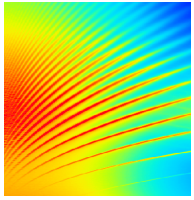




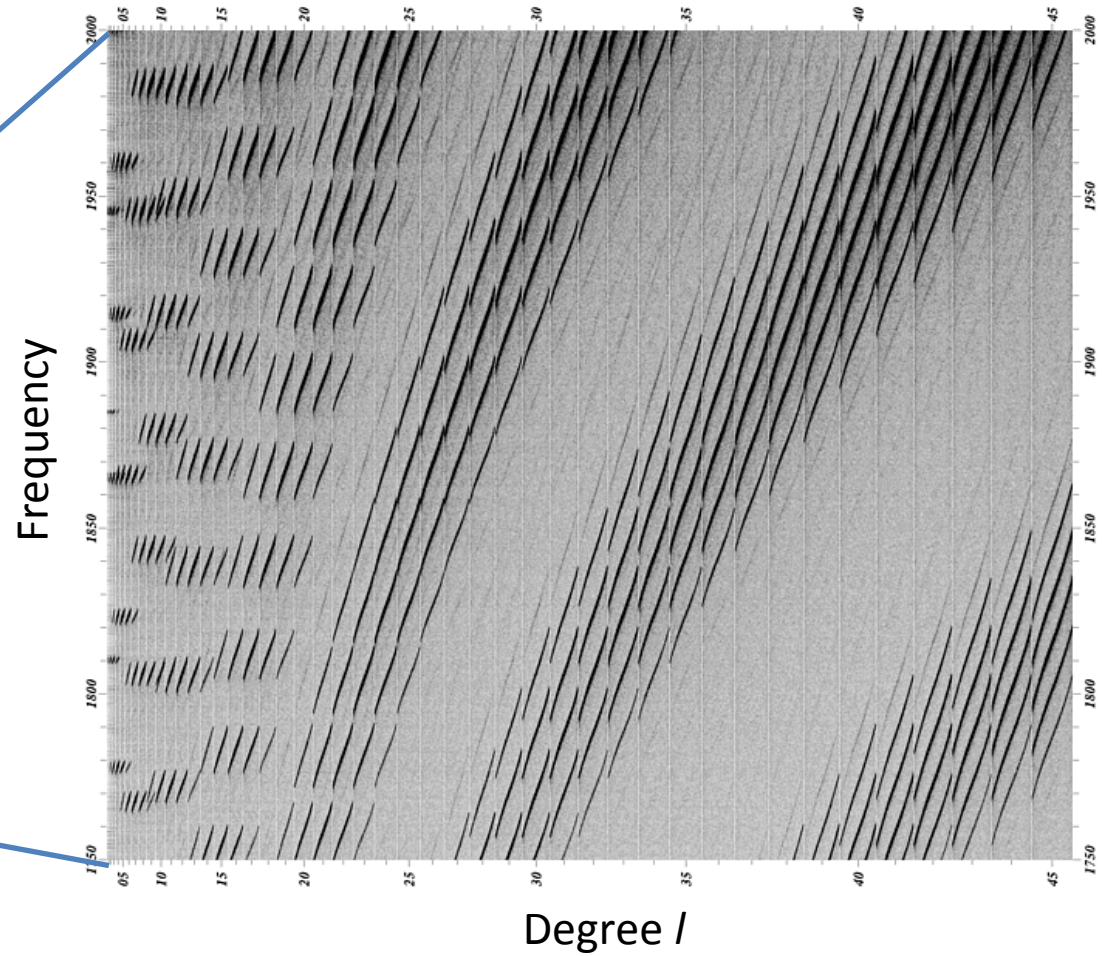
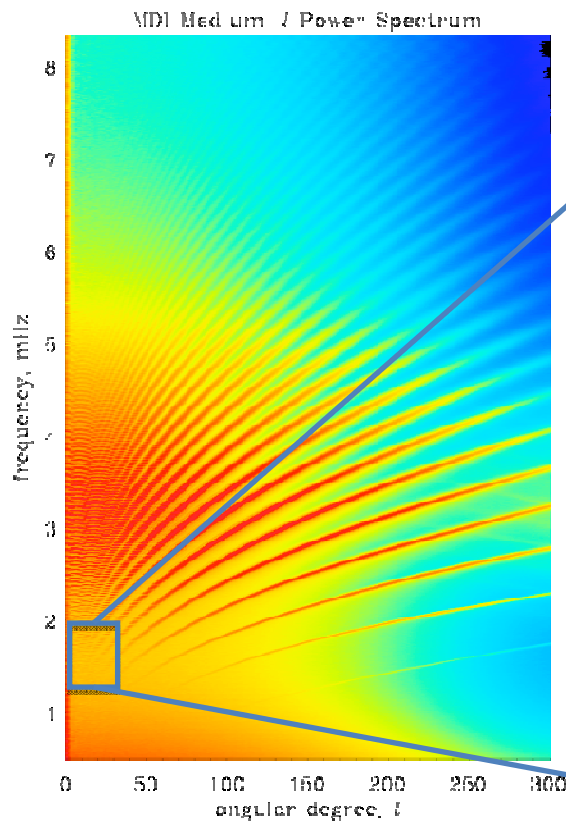
Internal structure

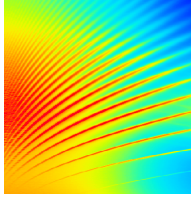


Christensen-Dalsgaard and Di Mauro (2007)

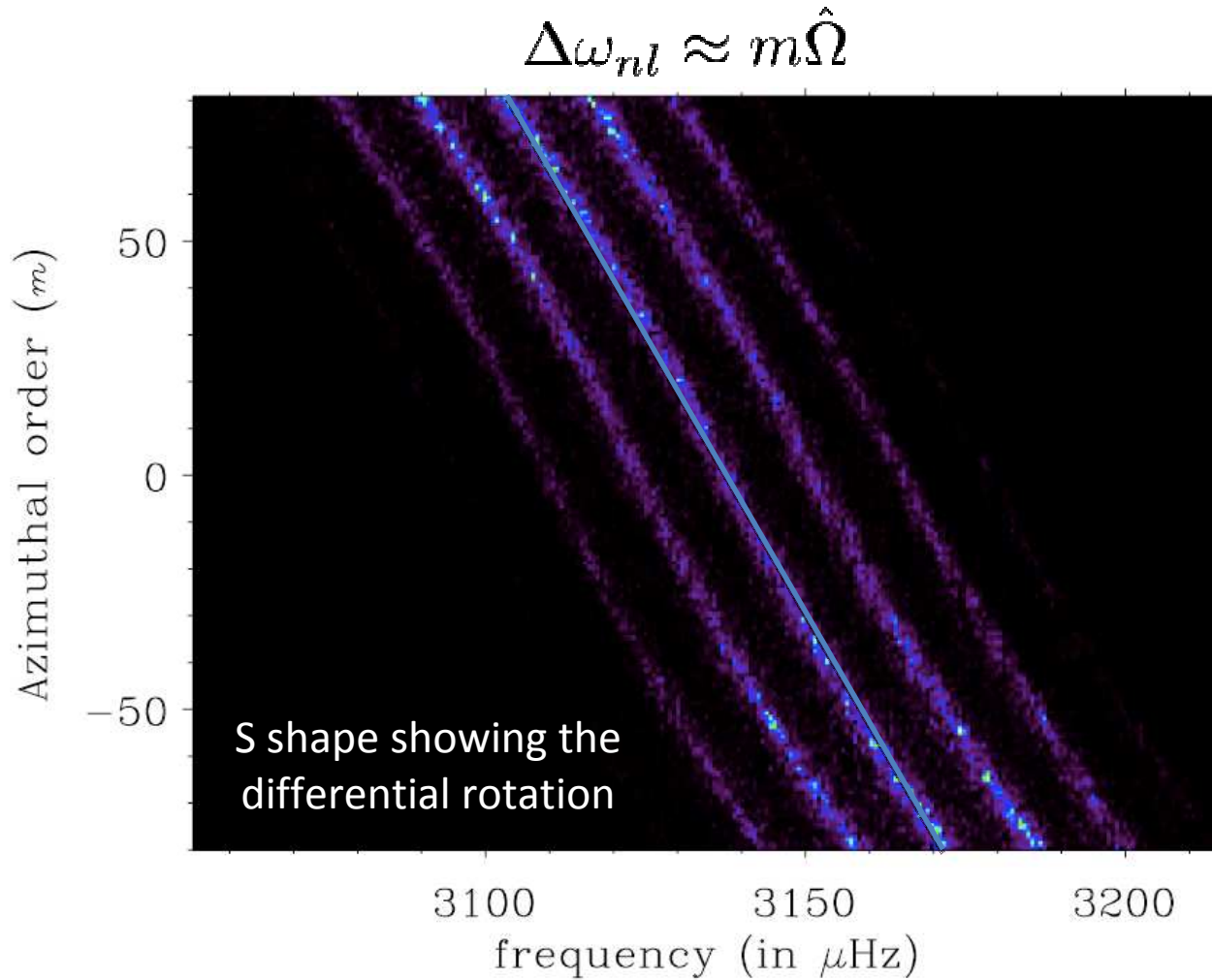


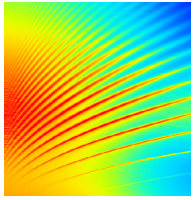
Hyperfine structure



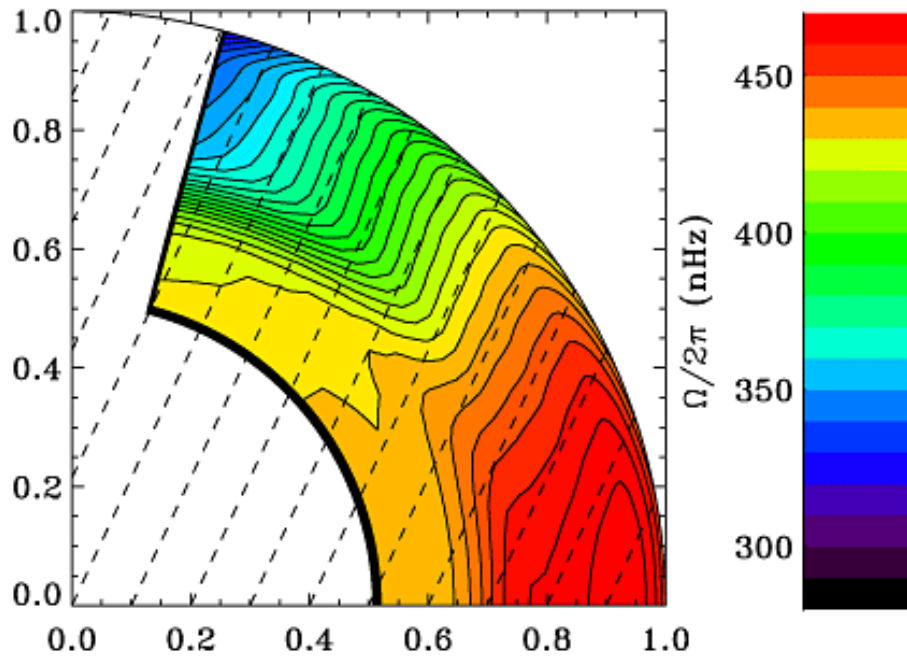


Hyperfine structure: rotation

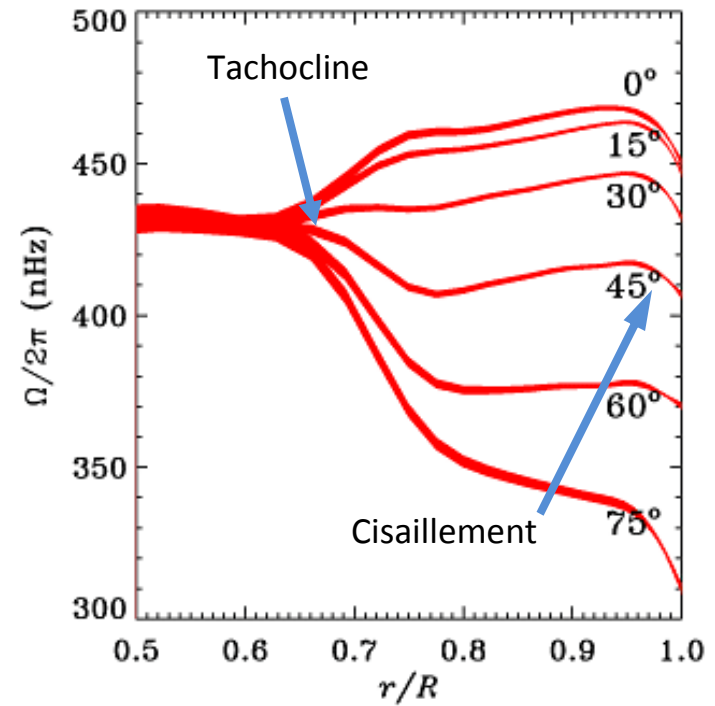




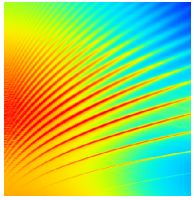
The internal rotation



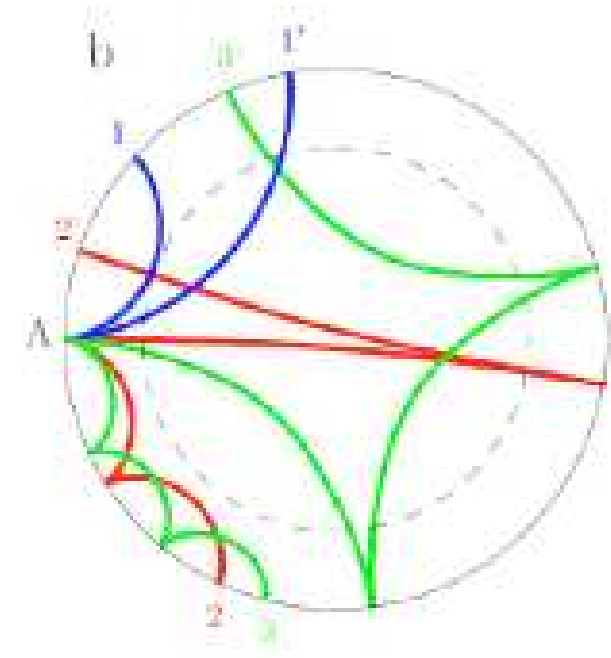
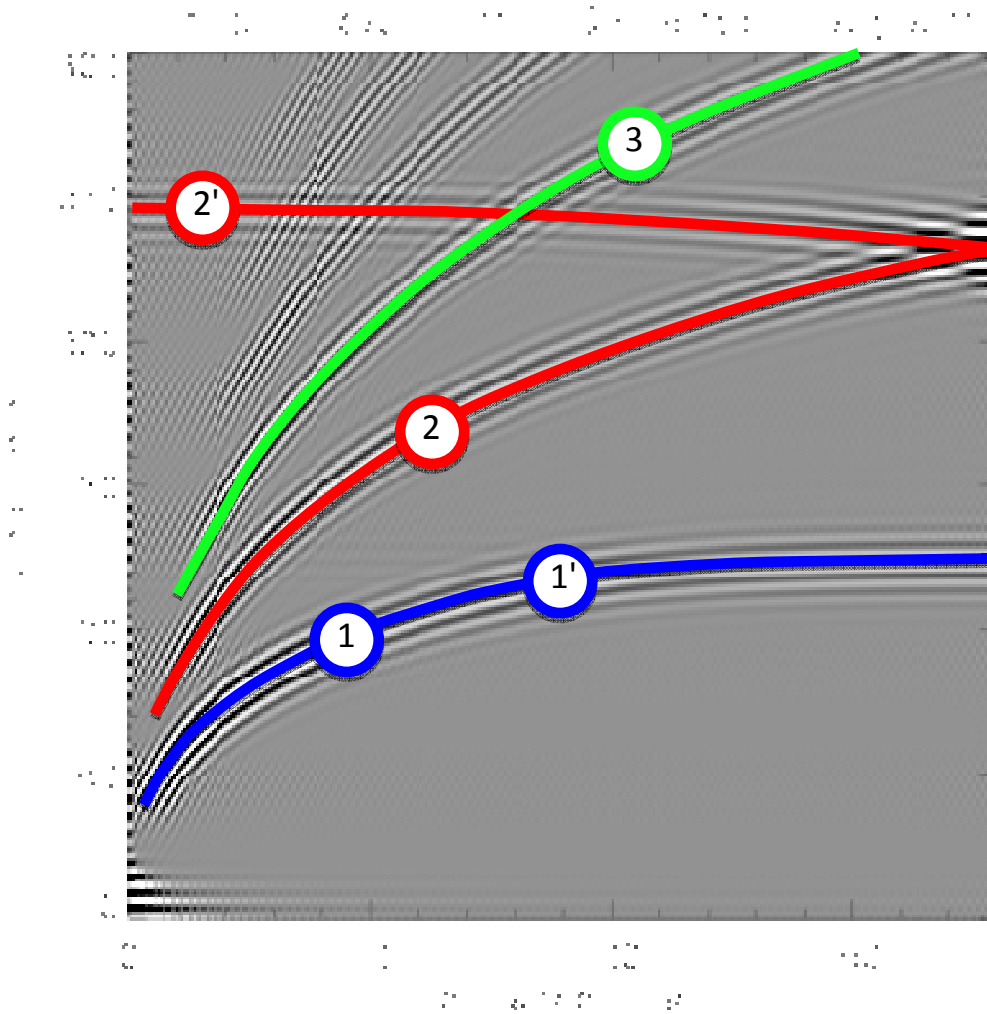
25 degree inclination lines



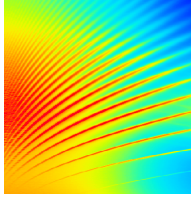
After Schou et al (1998)



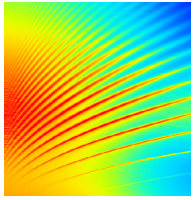
Time-distance diagramme



After Gizon et al (2009)



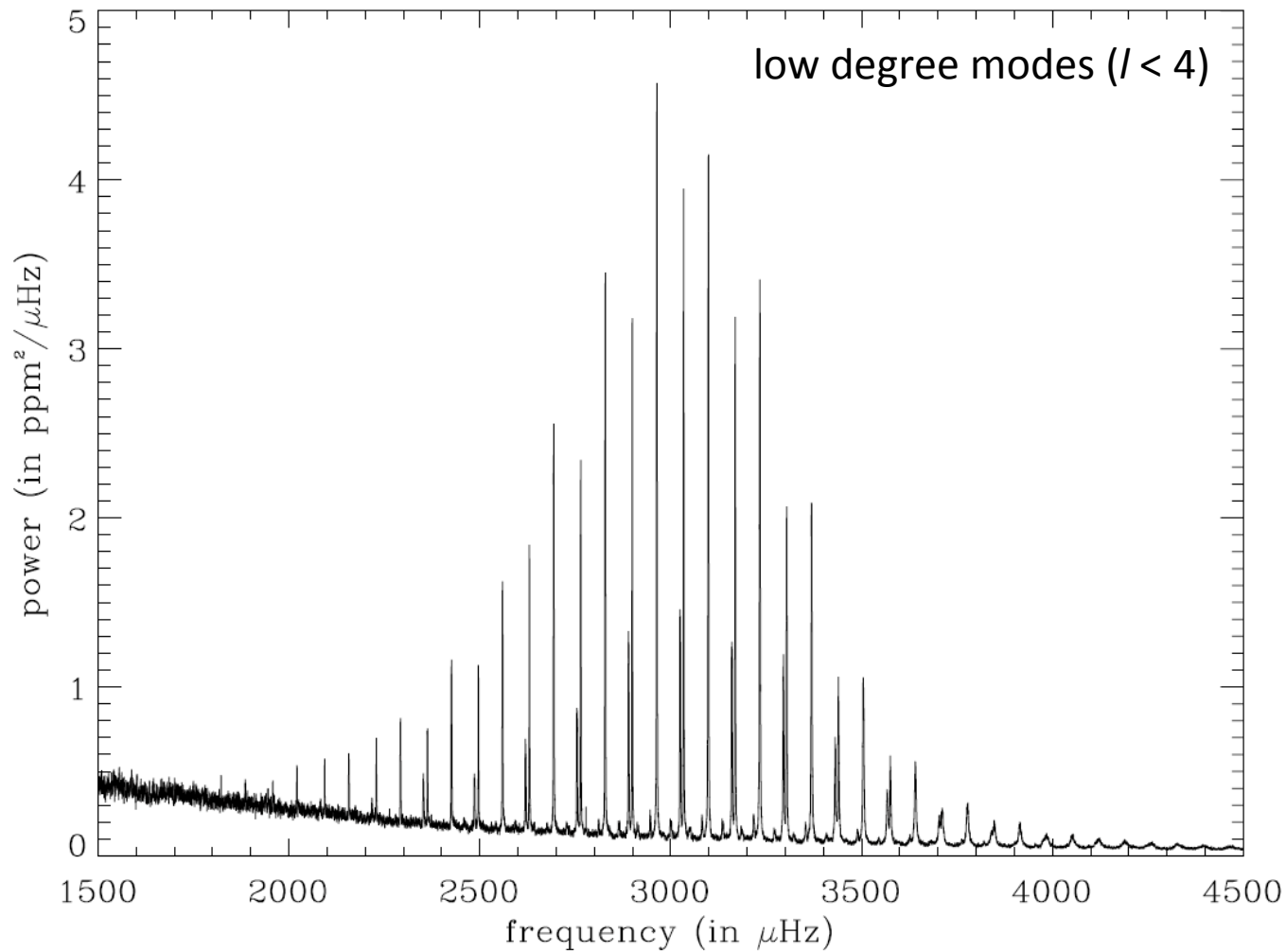
The Luminosity Oscillations Imager of VIRGO: a low resolution SODISM !

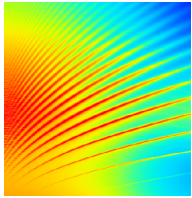


The Sun as a star from SoHO / LOI

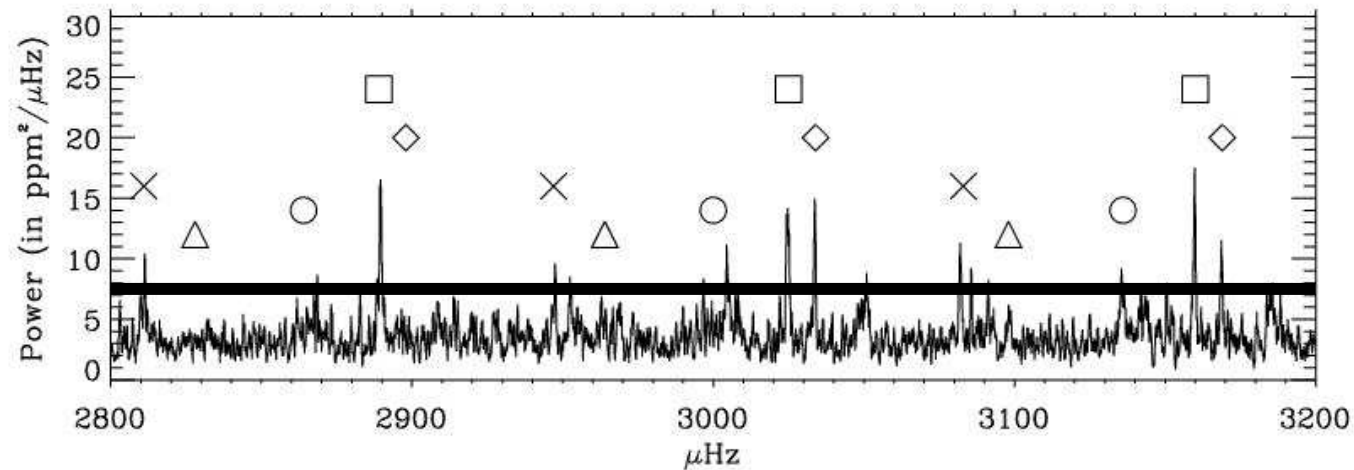
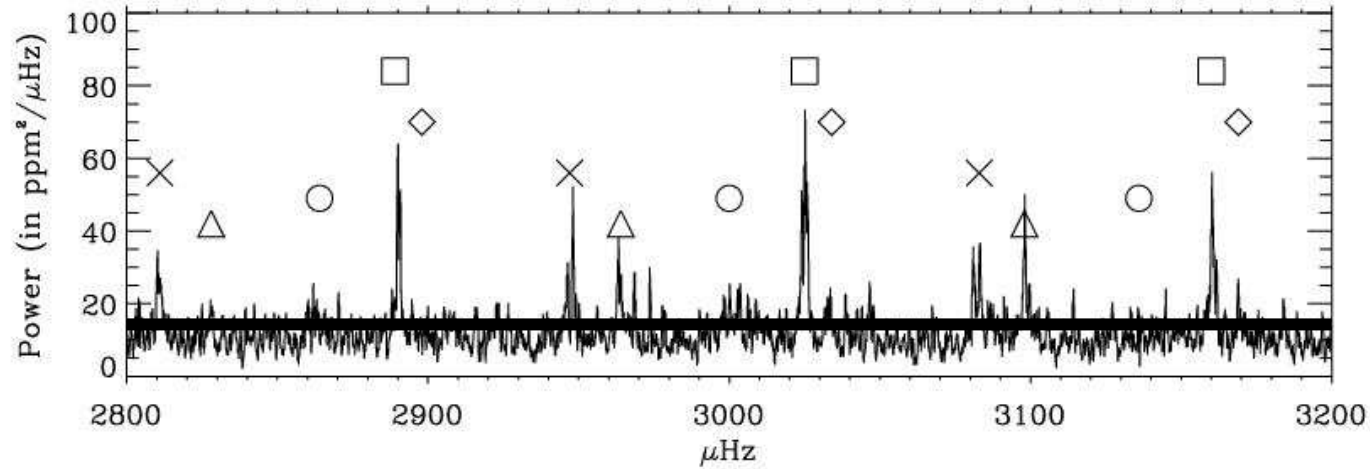


16 years of Luminosity Oscillations Imager (LOI / VIRGO on SOHO)

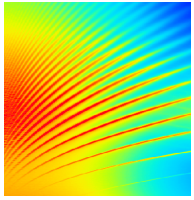




Limb observation with the LOI



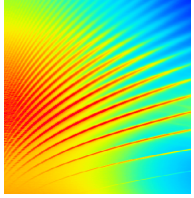
Appourchaux & Toutain (1998)



Synergy with SDO / SoHO



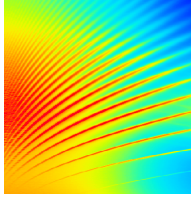
- Homogenous inversion using SODISM / LOI in intensity comparable with that of HMI (reduction of systematic errors, coeval)
- Internal rotation in intensity using SODISM / LOI comparable with that of HMI (reduction of systematic errors, coeval)
- Telechronoseismology in intensity comparable with that of HMI (reduction of systematic errors, coeval, solar noise reduction)



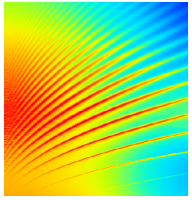
What can we do with PICARD?



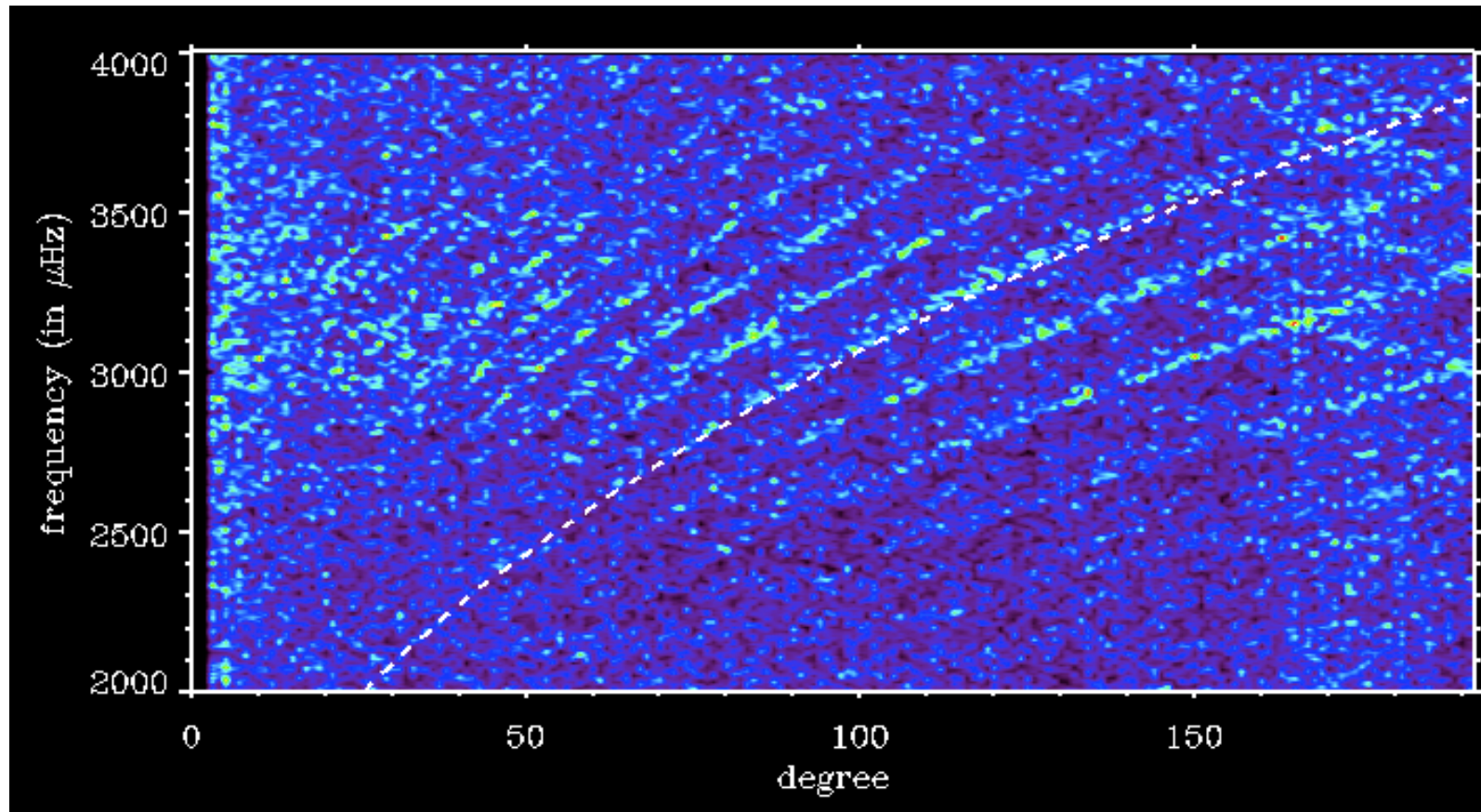
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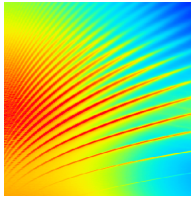


Slides pour PaB and TC

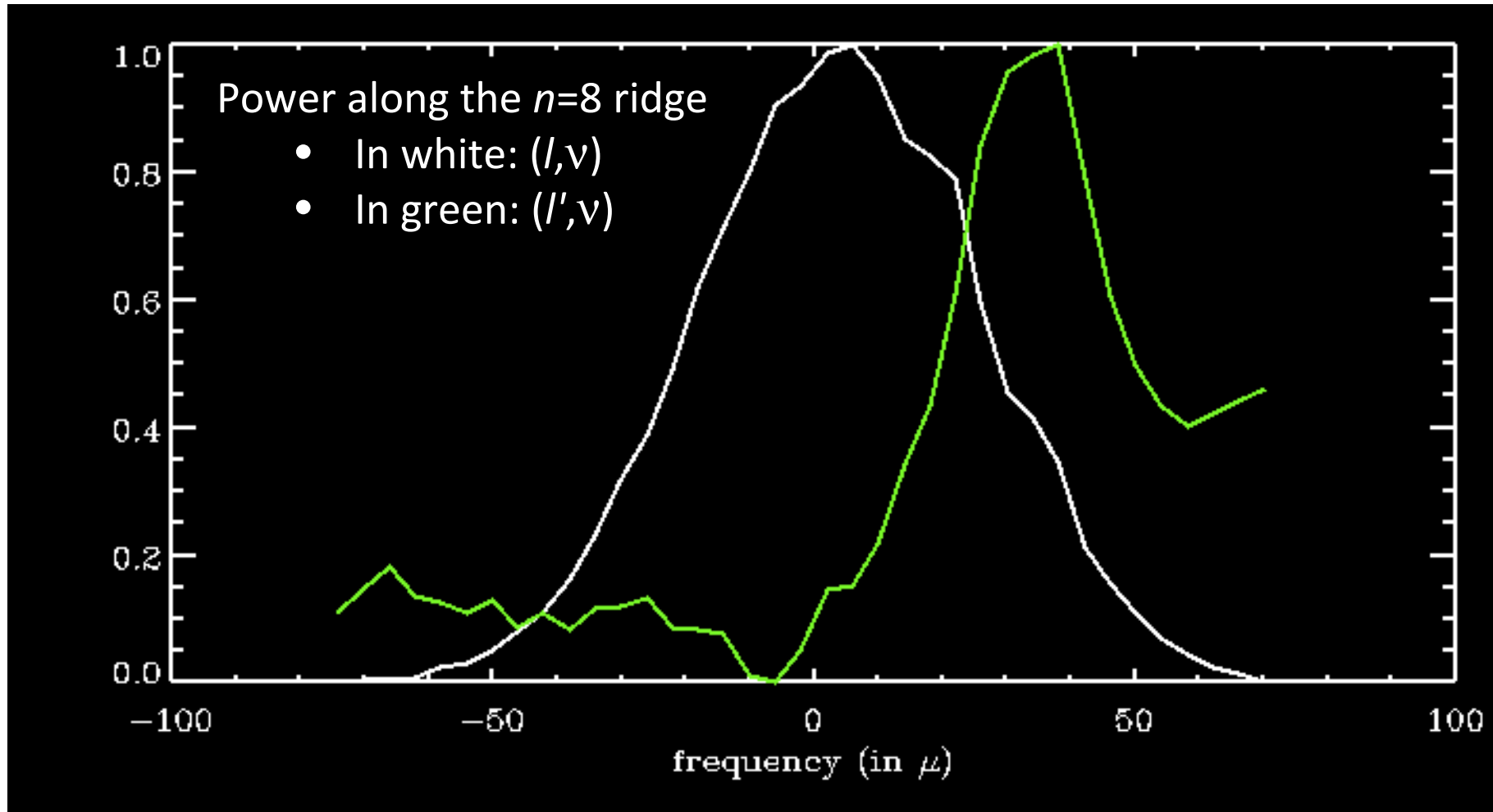


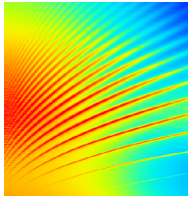
(l', ν) diagram of the LPs



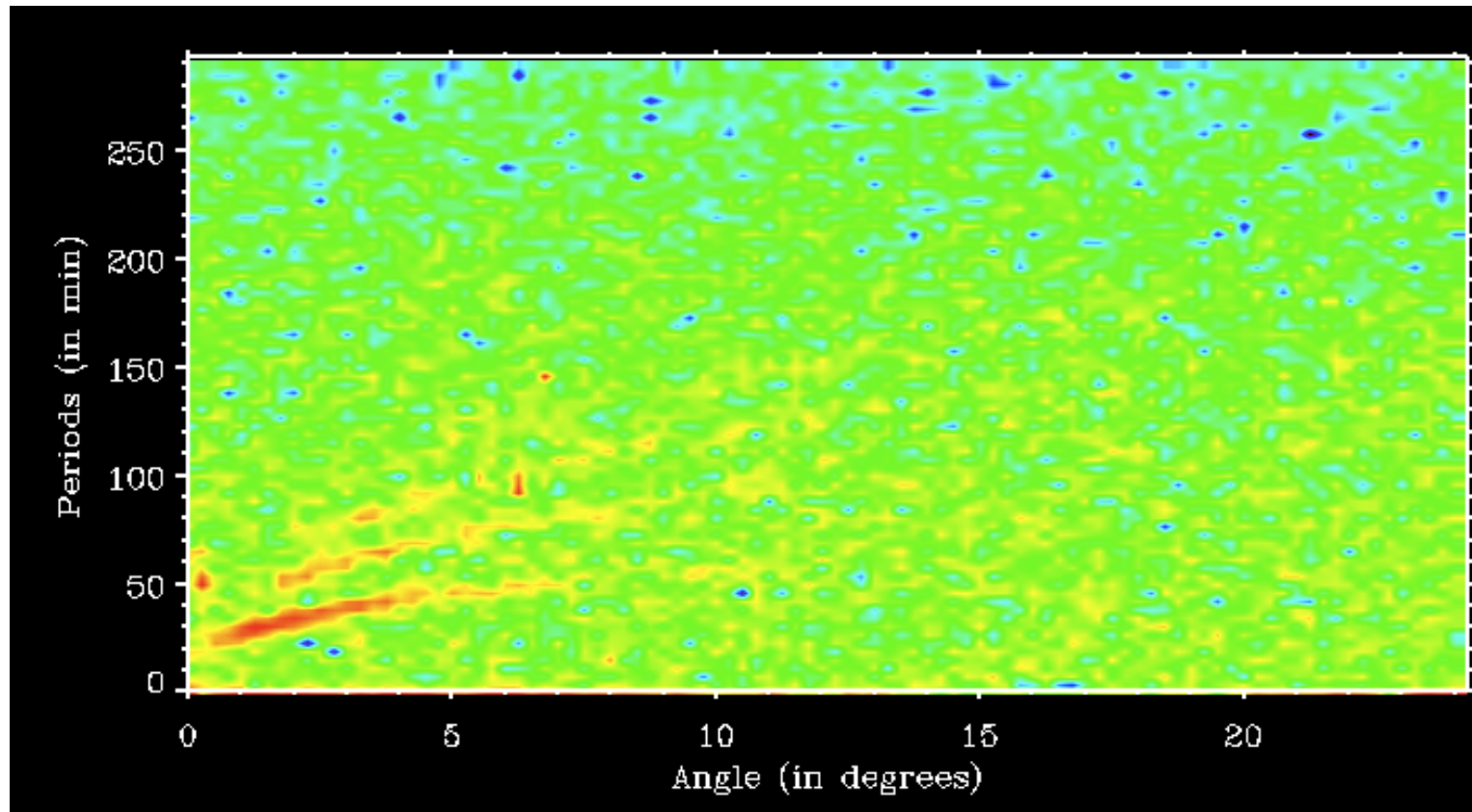


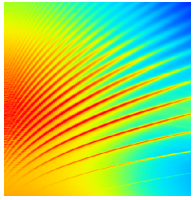
Shift between ridges



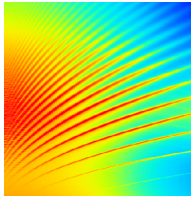


Time-distance with the LPs

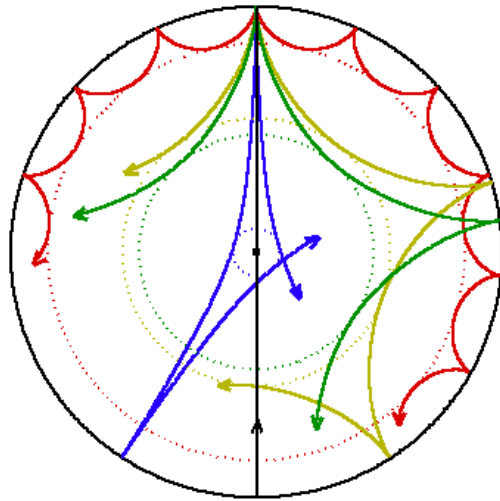




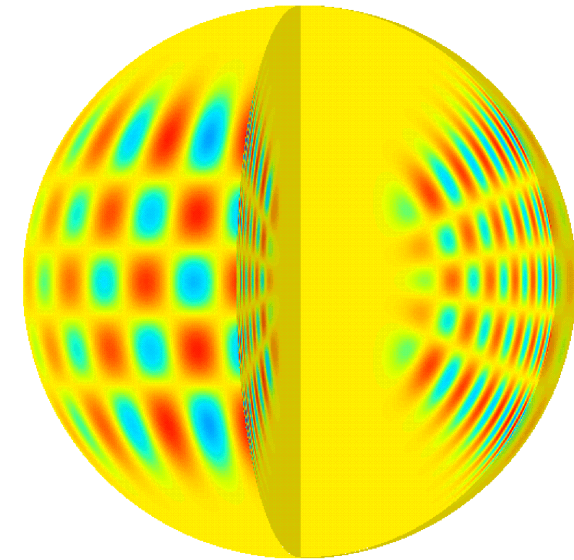
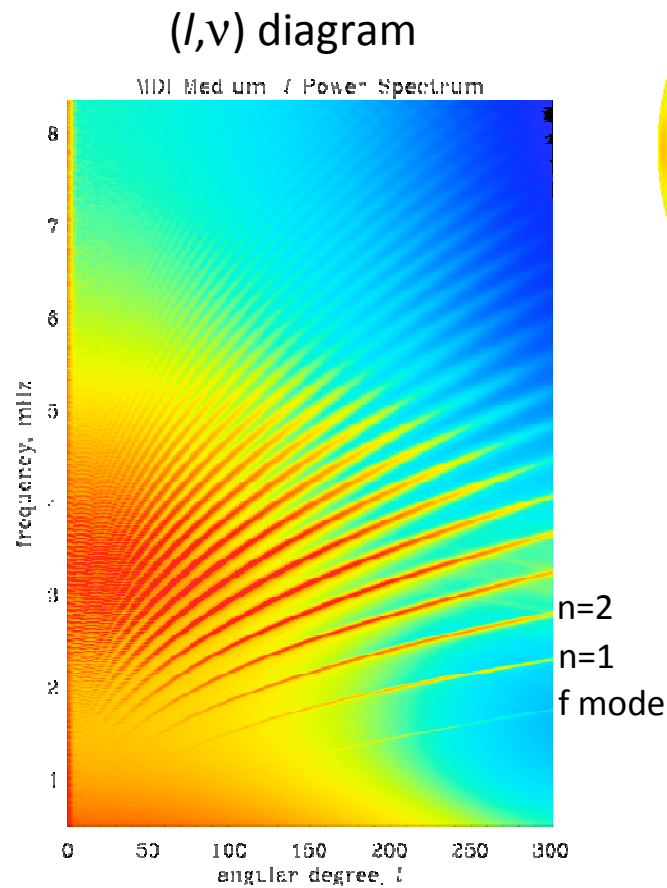
Reserve



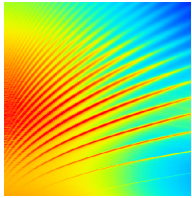
Characteristics of p modes



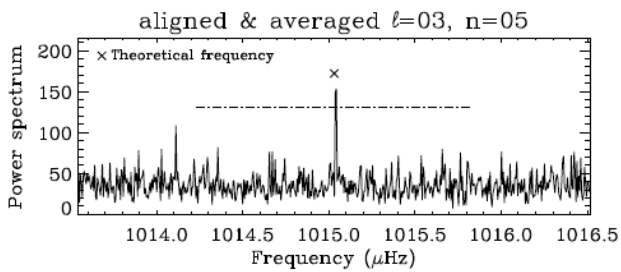
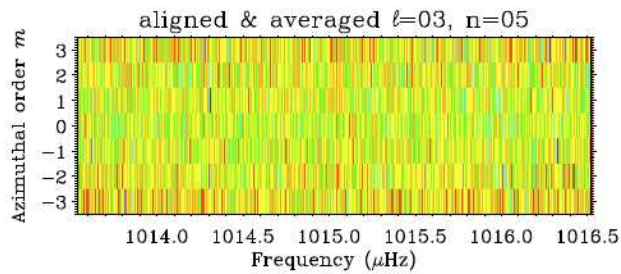
Ray tracing



Eigenfunction

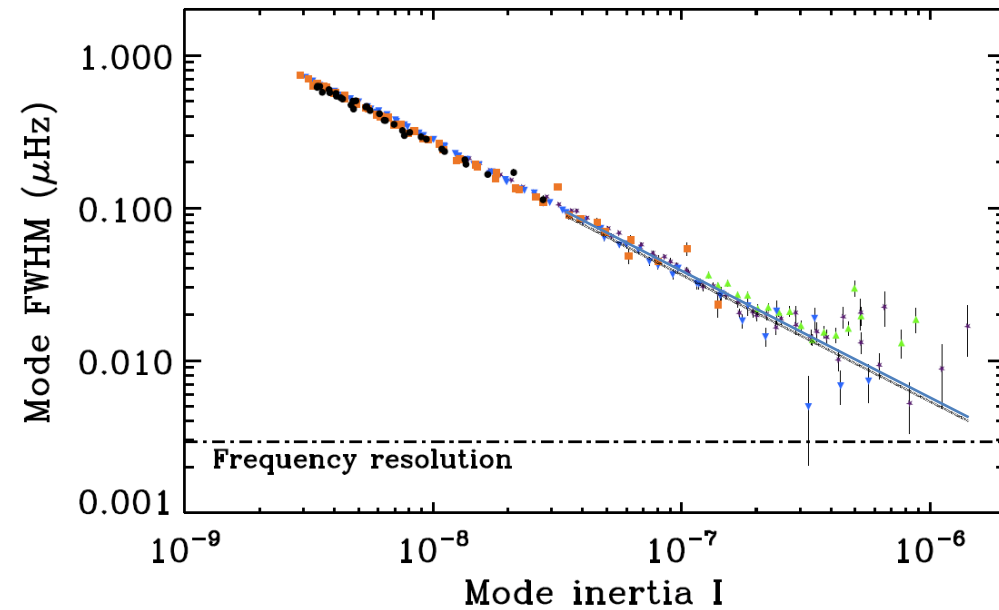


...and long lifetimes

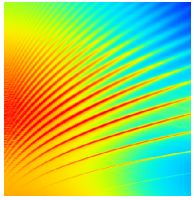


10GONG data

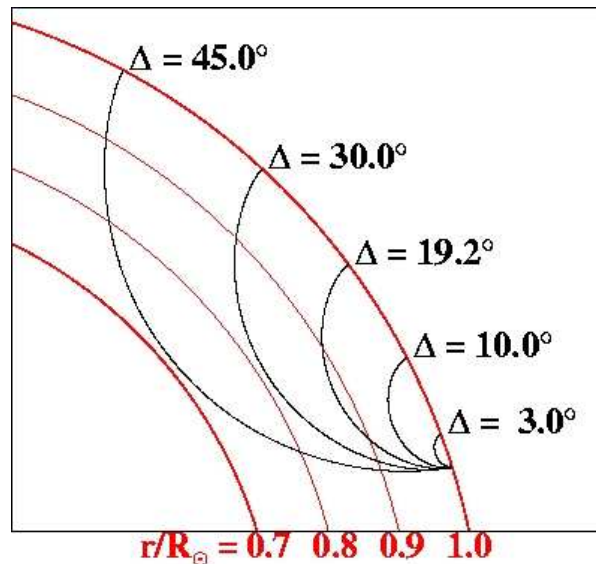
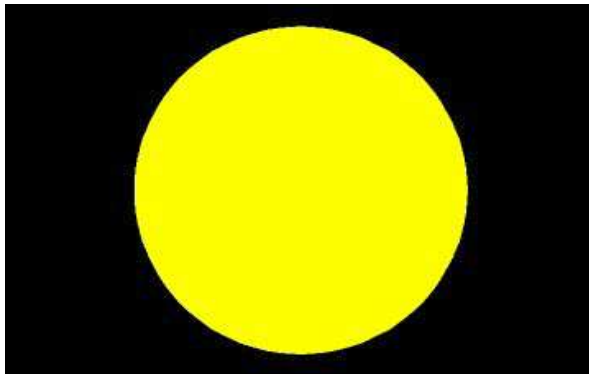
lifetime from a few days to > 1 year !



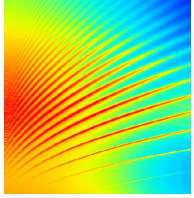
Salabert et al (2009)



Telechronoseismology



- Propagation time of wave packets between 2 points A and B at the surface of the Sun
- Differences occurs between $A \rightarrow B$ et $B \rightarrow A$ coming from different perturbations
- 3D map of motion and temperature below the solar surface



The helioseismic Sun



- Internal structure
- Depth of convection zone
- Helium and heavy element diffusion
- Internal rotation and dynamics
- Mode physics (excitation and damping)
- Active region emergence