Asteroseismology and exoplanets: a lesson from the Sun *

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- Can we learn on exo-planets from asteroseismology?
- Metallicity of stars with planets
- The origin of metals in the Sun photosphere and helioseismology.

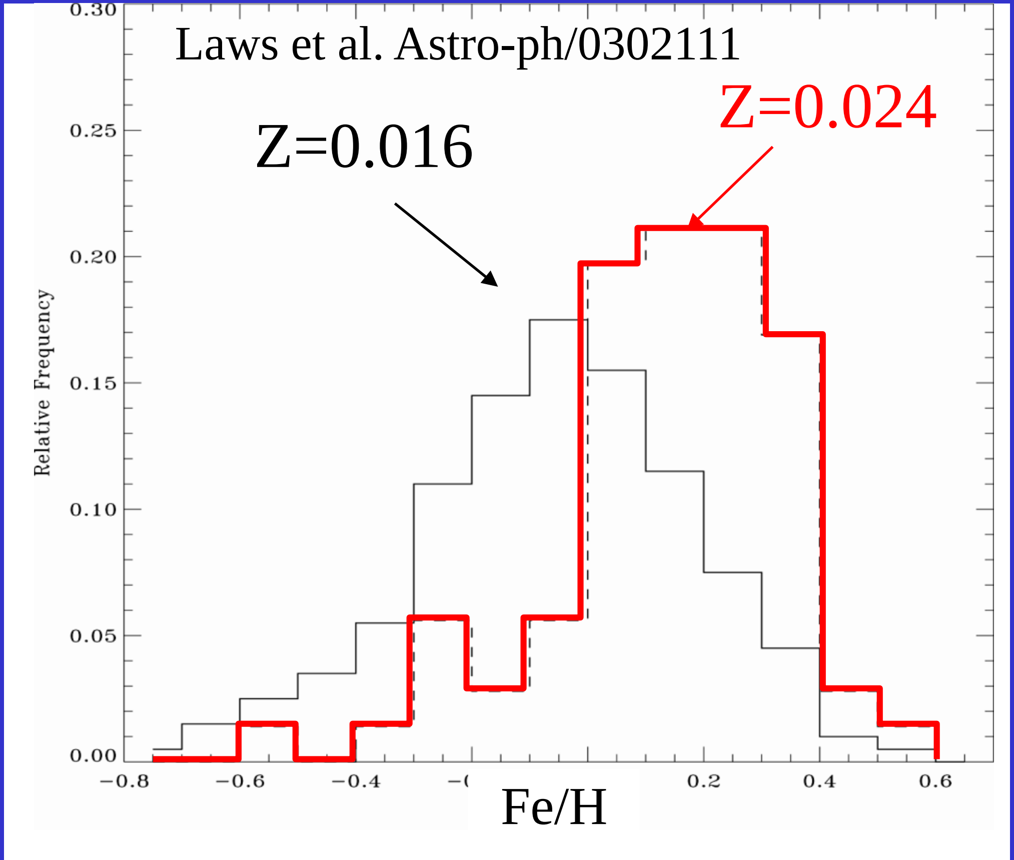
*based on: A. Zanzi, Master Thesis, Ferrara University (2003) and discussions with Castellani Ortolani Paterno'

The Chicken and the Egg dilemma

- Stars hosting planets look more metal rich.
- The metal content in the convective envelope of a solar type star with Z=0.016 is

  ΔM_Z=120 M_{earth}

- To reach Z=0.024 an extra 60 M_{earth} are needed.
- Is the excess metallicity primordial or a result of accretion?

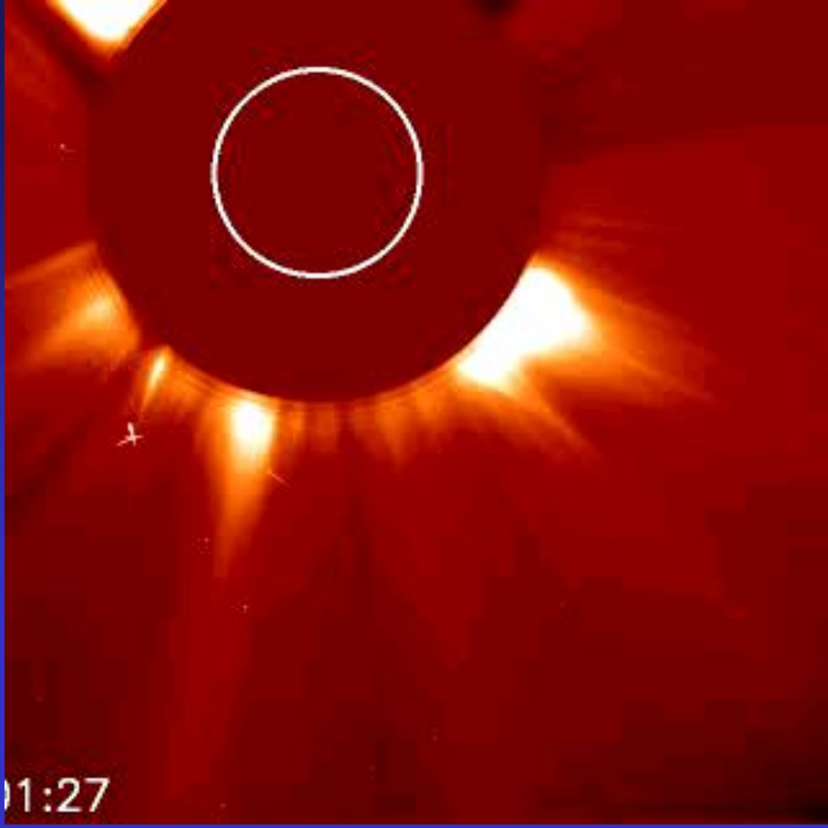


- Is it a surface/ bulk effect ?

  Z_{int} < or > Z_{ph}

- Need a look at the stellar interior: asteroseismology is the natural tool

Dirty solar models



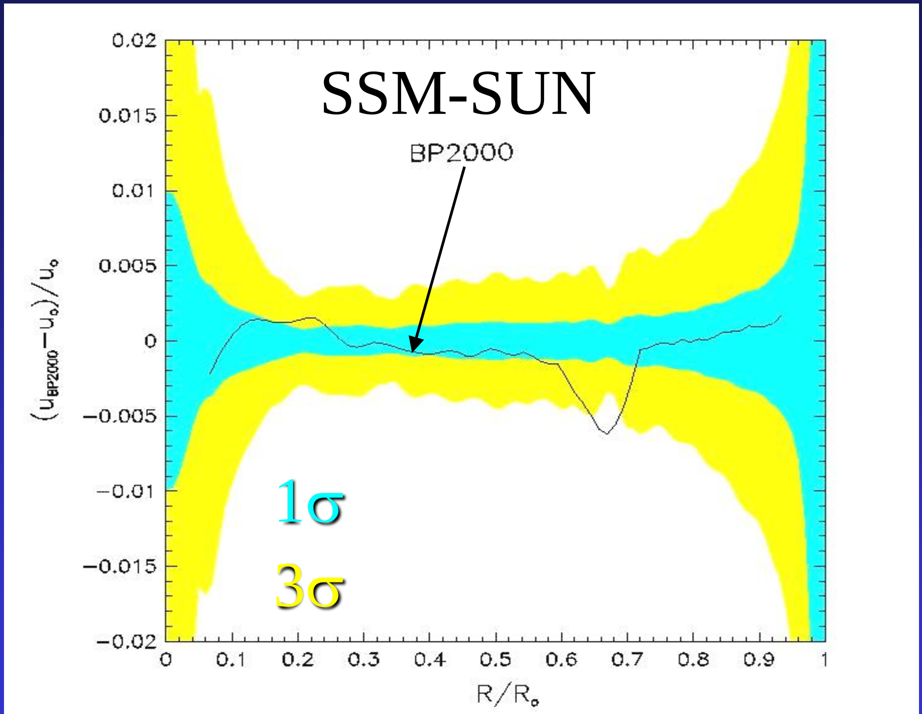
- The Sun is a natural laboratory
- Matter is falling onto the Sun (and presumably more was falling in the past)
- The SSM (without accretion) has been accurately tested with helioseismology (& neutrinos)
- Build solar models starting wih a lower metacillity and assume metal accretion occurs (shortly) after ZAMS.

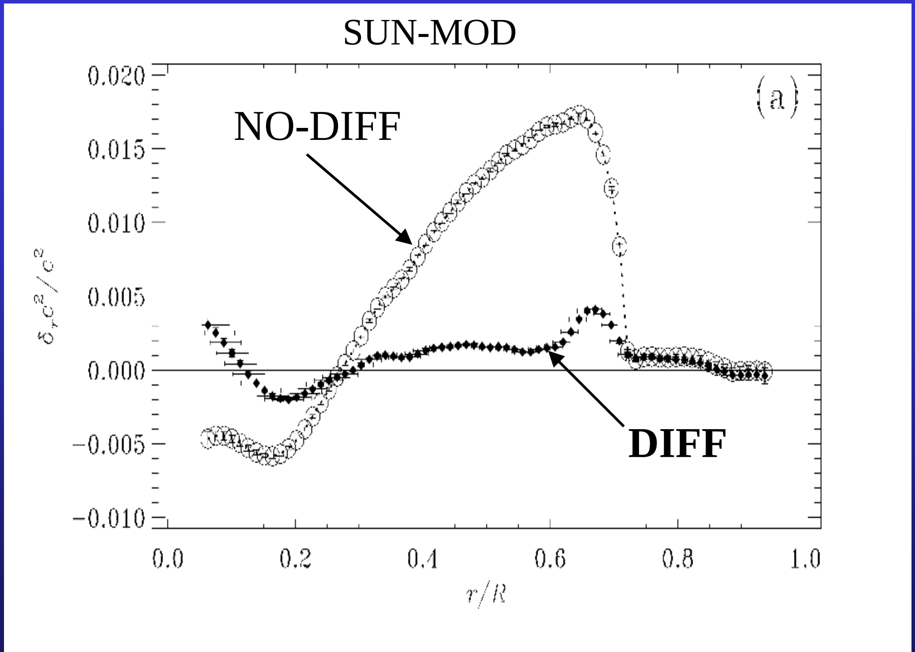
- How much material can have accreted without spoiling the agreement with helioseismology (& neutrinos) ?

The lesson of diffusion

- SSM are in excellent agreement with helioseismology (for u, Y_{ph}, R_b...) when diffusion is included.
- The effect of diffusion is that

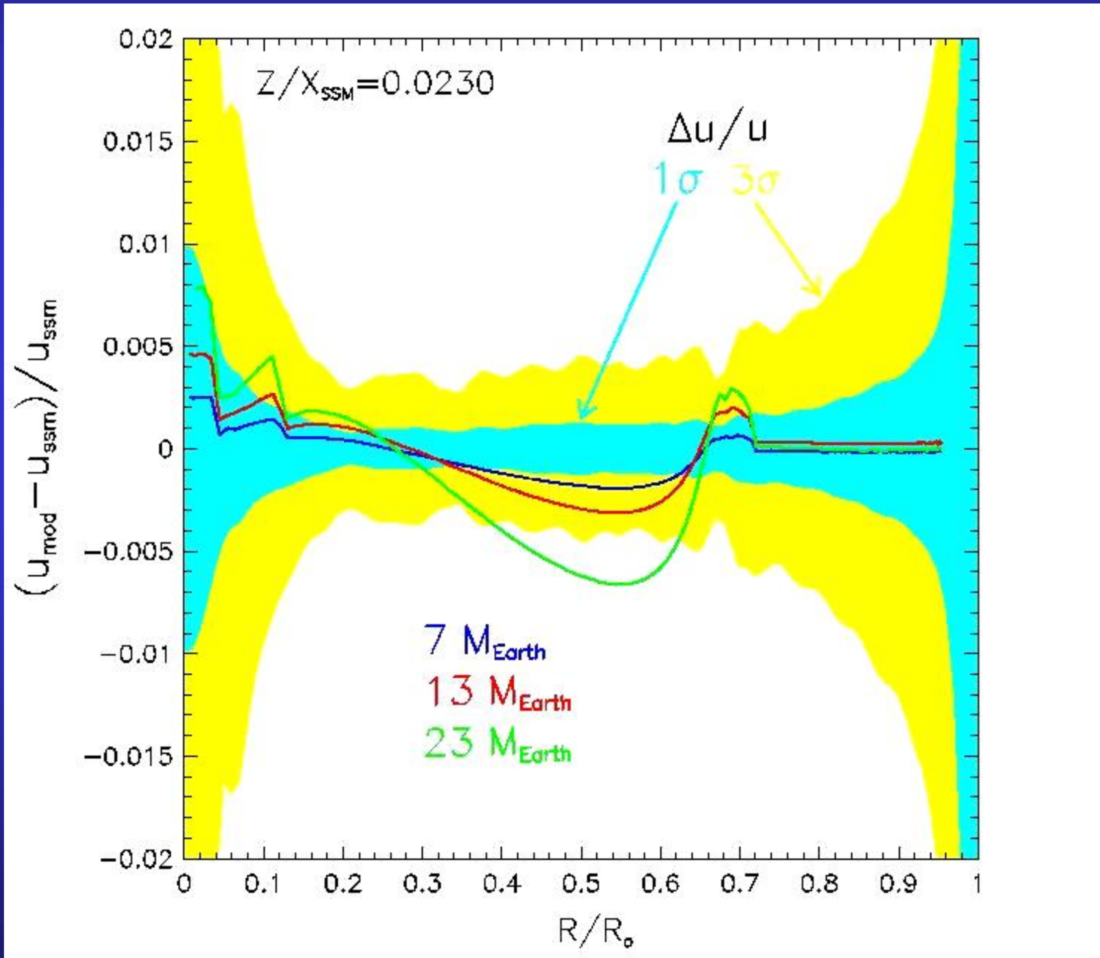
  $Z_{ph}=0.9\ Z_{int}$.
- This means that helioseismology is sensitive to changing by 10% the metal mass in the convective envelope, i.e. to $12M_{earth}$





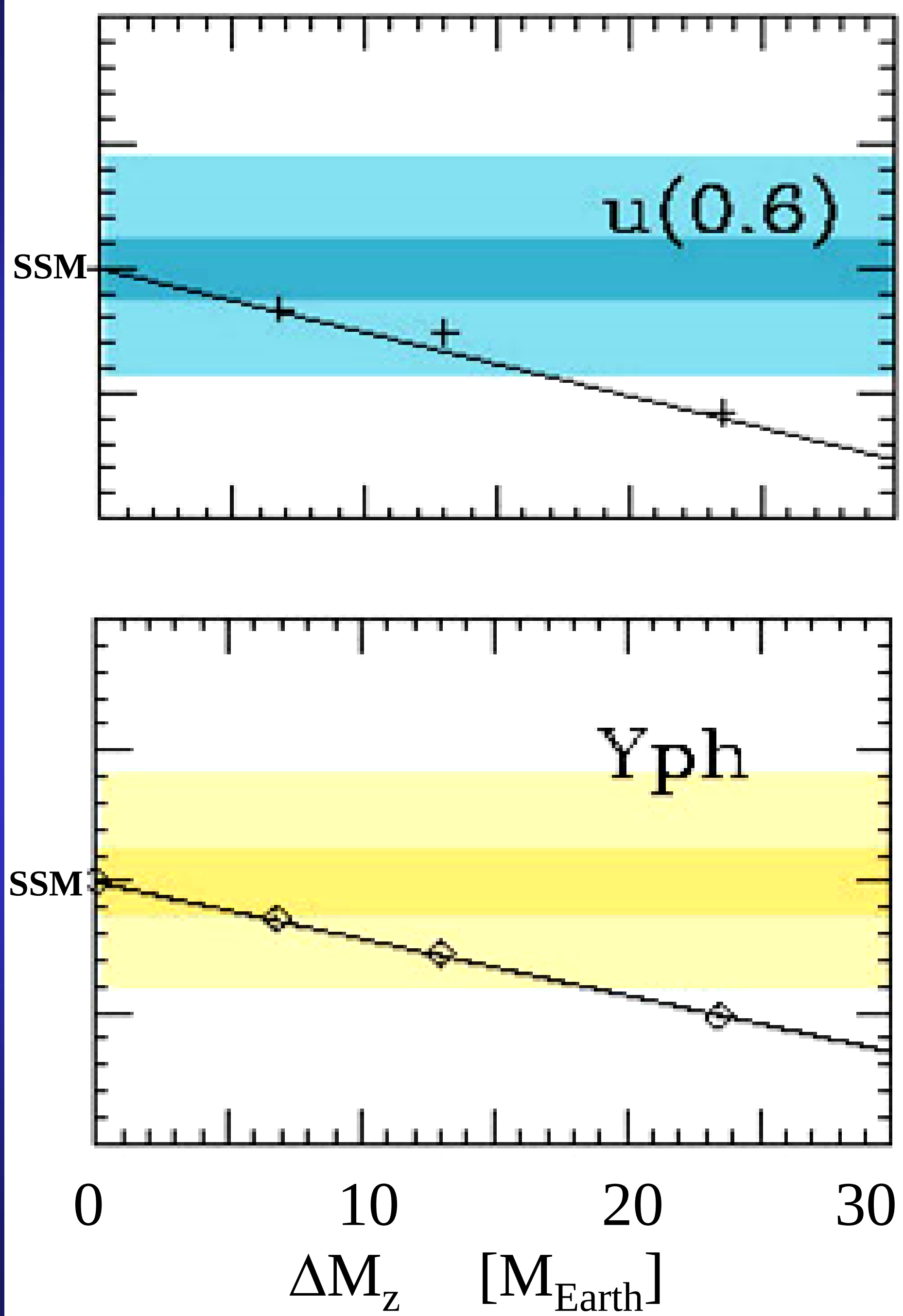
Dirty solar models

- With respect to SSM, a dirty Sun is metal poor in the interior.
- molecular weight and opacity are changed
- Temperature, sound speed, Y_{ph} (& Φ_ν) can be changed



Constraints from helioseismology and neutrino

- Can study the changement of several observables (sound speed, Y_{ph}, R_b, Tc)
- Helioseismic observables imply:
  $\Delta M_Z < 20\ M_{Earth}$ (at 3σ)
- [Boron neutrino flux gives $\Delta M_Z < 30\ M_{Earth}$]



Helioseismology and Asteroseismology

- Heliosesimology is sensitive to O(10) M_{earth}
- For asteroseismology we need sensitivity to O(100) M_{earth}
- We are planning simulations (which frequencies? Which accuracy ?)
- Asterosesismology can prove accretion theory:

  $$Z_{int} < Z_{ph}$$

- Howevever it cannot disprove it (if accretion occurred before ZAMS) .