"... something so simple as a Star."

an exploration

Pontecorvo Seminar; 21 Feb /2018

The story so far:

" In the beginning the Universe was created. This has made a lot of people very angry and has been widely regarded as a bad move." Douglas Adams, *The Restaurant At The End Of The Universe*

Some history

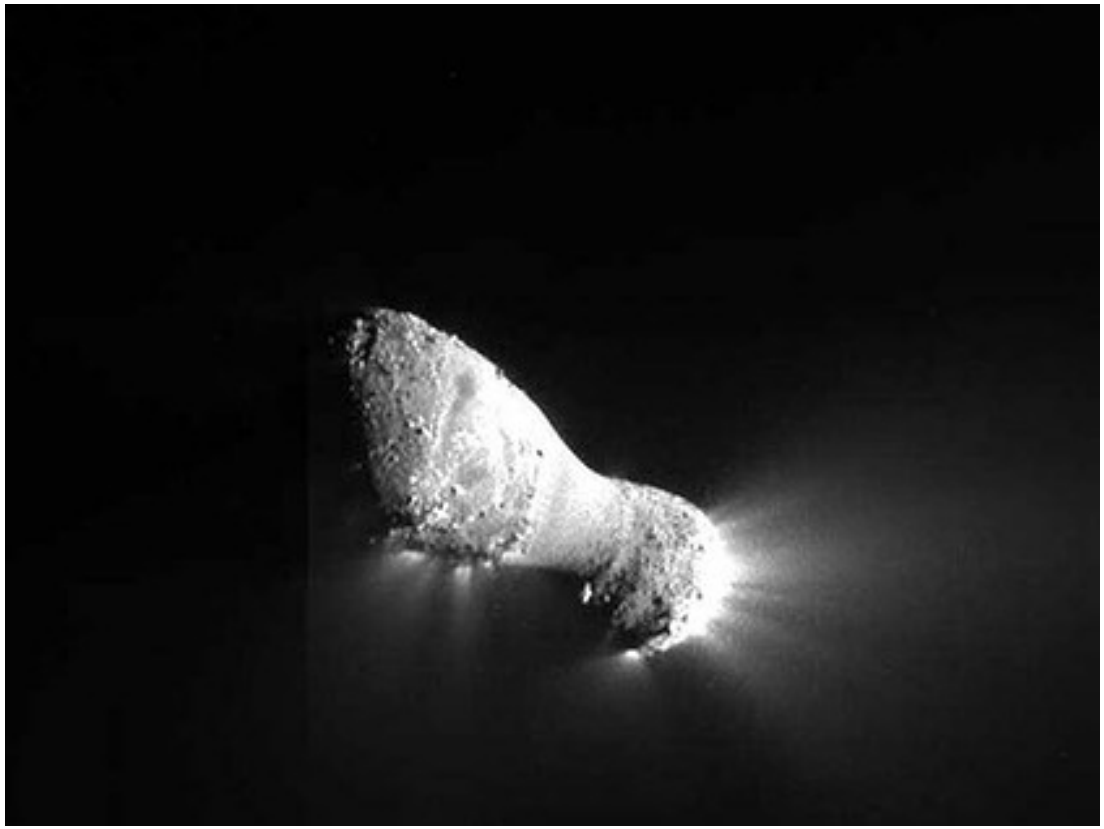
- 18th century: celestial mechanics
- 19th century: binary stars, equilibrium of incompressible bodies, potential theory, and stability
- late 19th century: compressible gas laws, spectroscopic diagnostics (Stark effect, Zeeman effect) and the age of taxonomy
- 1900-1927: radiative transfer
- 1930s: thermonuclear processes, degenerate gases, periodic (pulsational) instability, secular instabilities, rotation, composiion
- early-mid 20th century: the Standard Model later mid-mid-20th century: the Standard Model is wrong, evolution, nucleosynthesis, the first views of the nursery and the graveyard
- late-late 20th century: the cosmological connection
- 21st century ...

Local empirics: What do we know?

- orbit of the Earth an the distance to the Sun (several methods, including speed of light)
- radius and mass of the Sun (relative to whatever we can locally determine as the mass of the Solar System)
- selective (terrestrial atmospheric window) and bolometric luminosity (the "Solar Constant")
- mean density of the Sun
- the evolution of like since the *K-Tec* event (65 Myr)
- age of the Earth (more on this in a bit)
- laboratory measurements (e.g., physical constants, spectroscopy, chemistry)

The elementary inputs

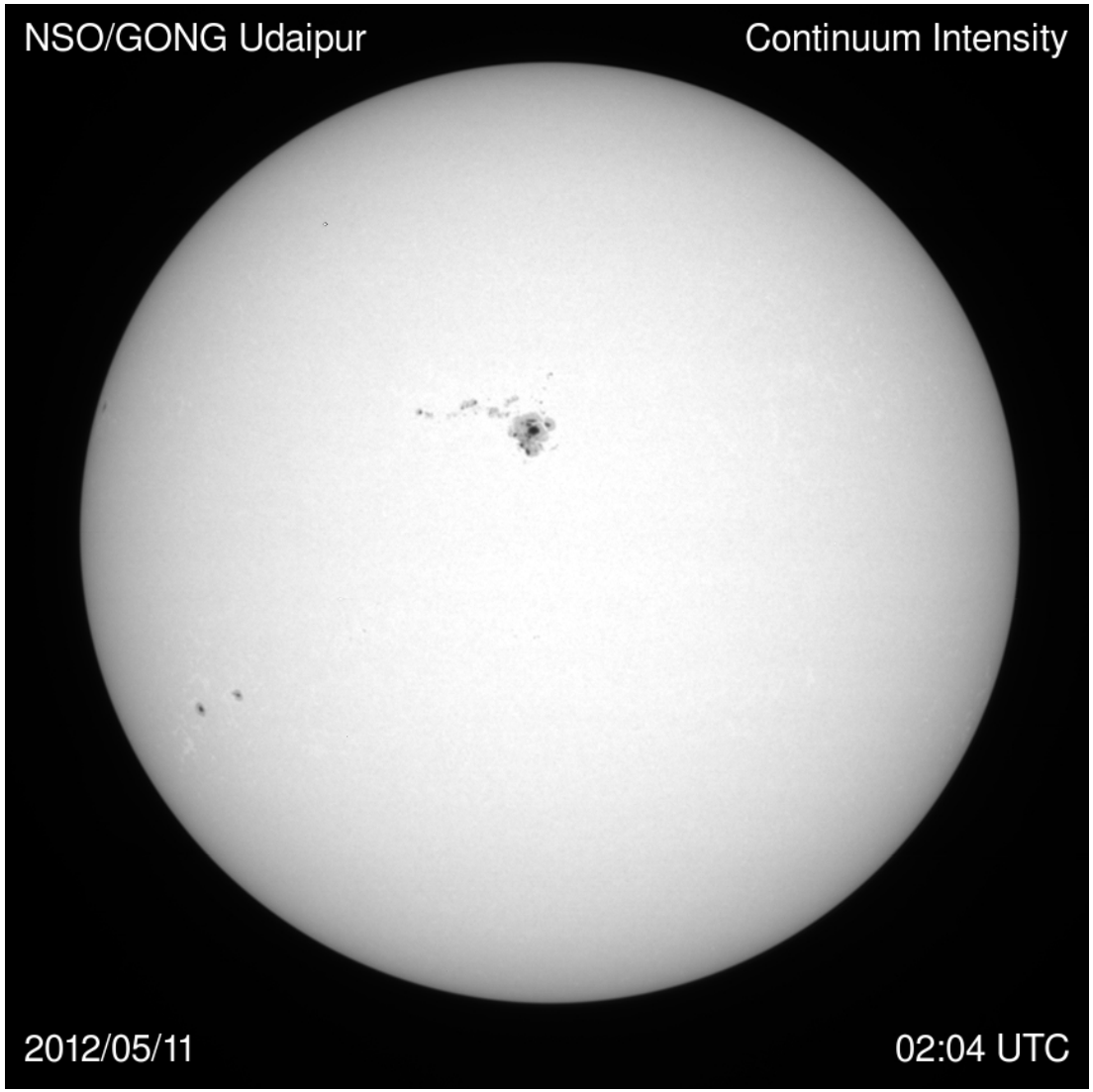
Abundances from the most primitive objects - comets (Hartley 2), meteorites (carbonaceous chondrites, pre-solar grains



"al di la" empirics: What do we know of the stars?

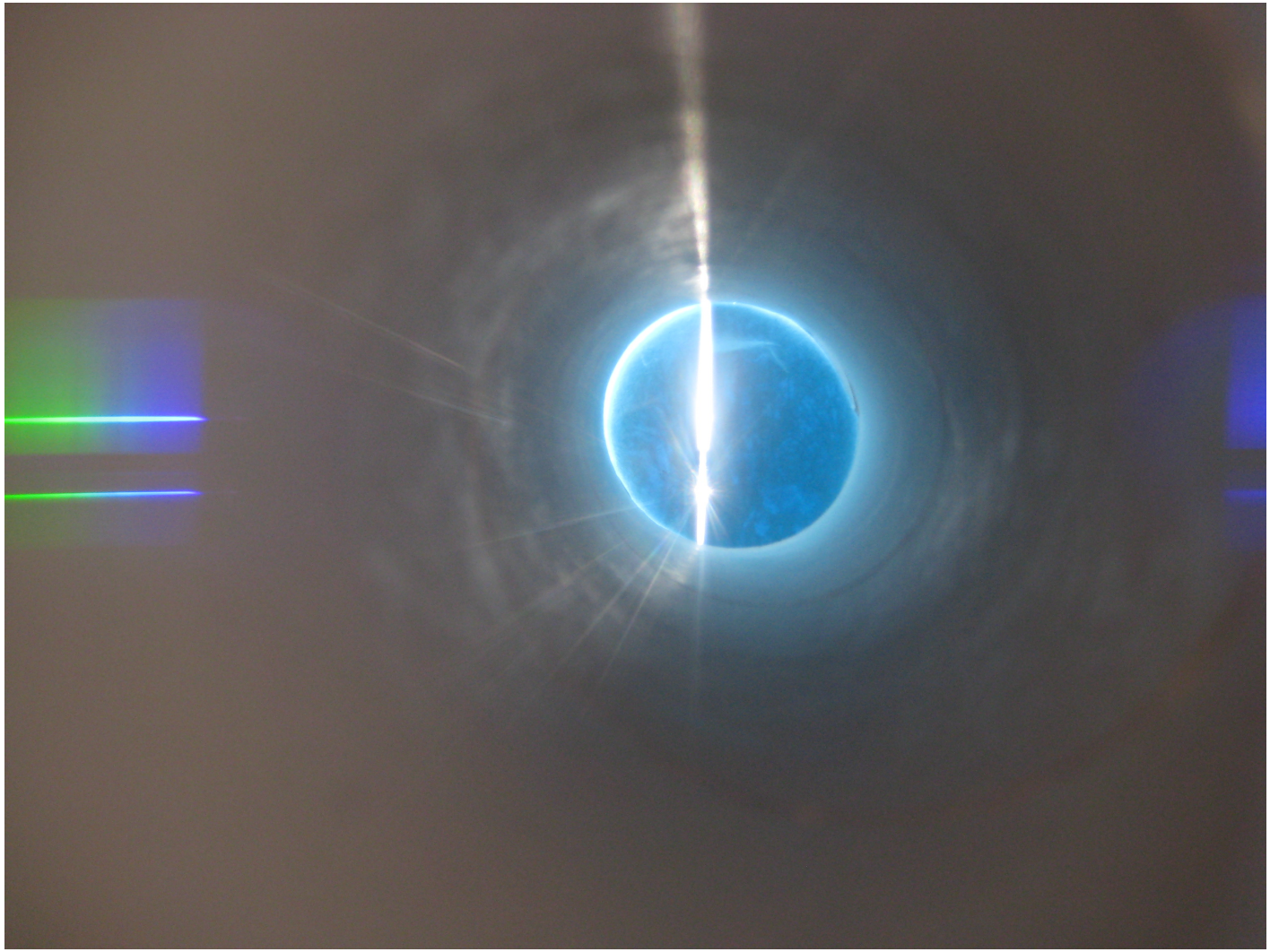
- parallax, angular motions, radial velocities
- mass and luminosity ratios
- selective (terrestrial atmospheric window) and bolometric luminosity (the "Solar Constant")
- mean density of the Sun and ratios for stars
- the evolution of like since the *K-Tec* event (65 Myr)
- age of the Earth (more on this in a bit)

The elementary inputs
imaging, photometry



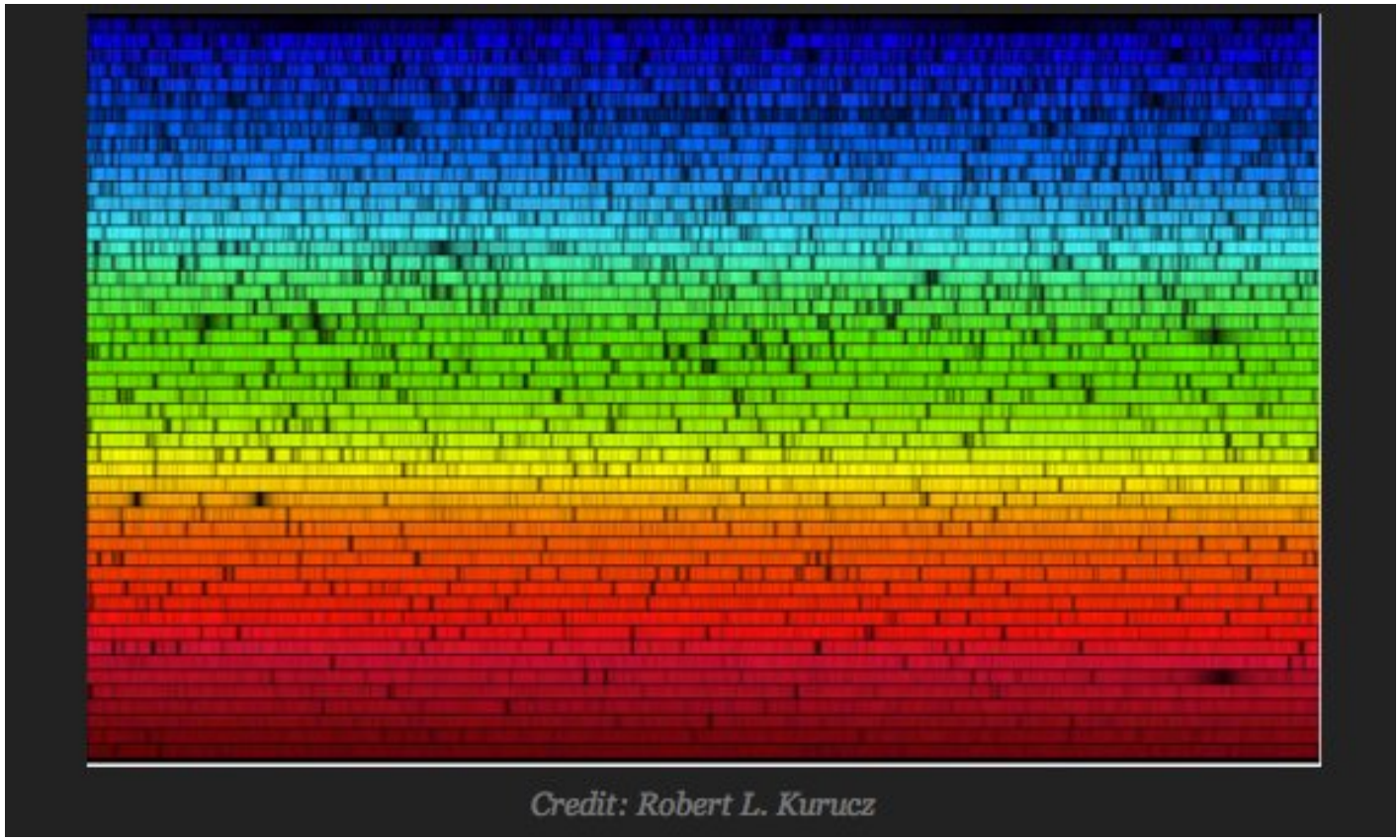
The elementary inputs

spectroscopy: as Secchi understood it



The elementary inputs

spectroscopy: the Sun, precision astrophysics with a connection with the laboratory



Theoretical: What do we know?(esami superate)

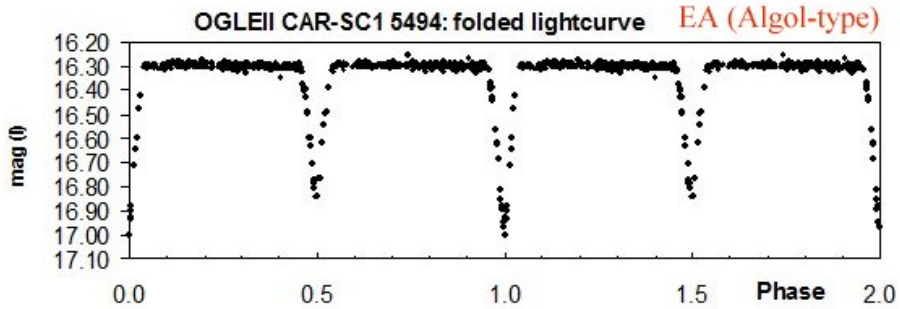
- thermodynamics, gravitational mechanics, gas laws (Fisica 1)
- electromagnetic processes (Fisica 2)
- gas laws, atomic and molecular processes, nuclear (Fisica 3, Mecc. statistica. Mecc. quant., Nucleare e subnucleare)
- hydrodynamics and continuous media, photonics, interaction of radiation with matter (Struttura della materia)

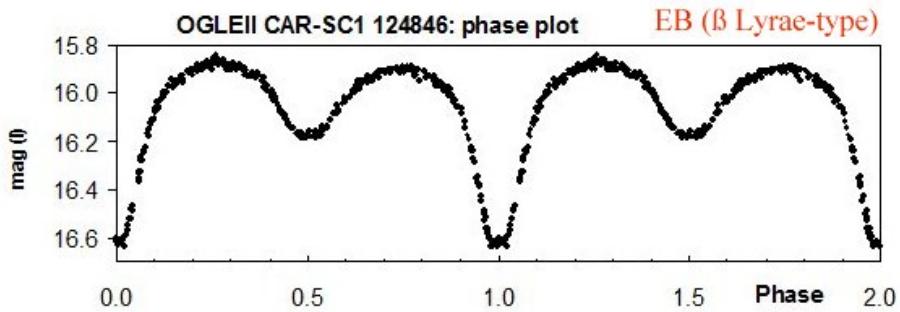
the audacity of it all:
we observe the "experiment", we *don't* perform it

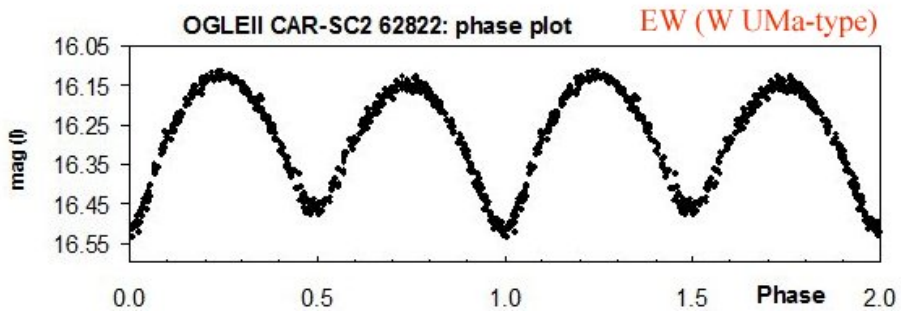
and a nod to our founder (a century of interdisciplinarity)

let's see how far we can get ...

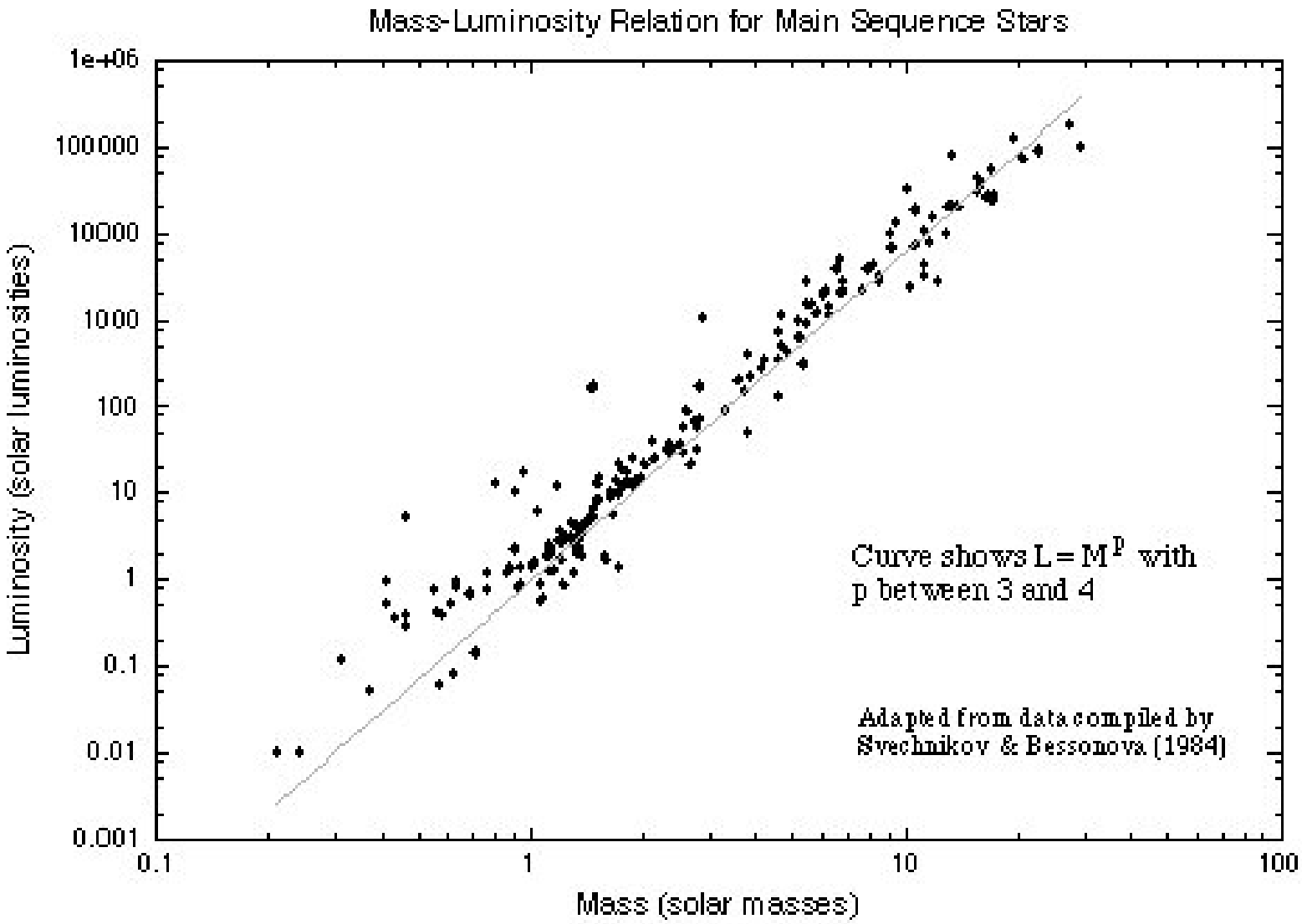
calibrations: applications of gravitational mechanics and photometry







the most basic fact: the virial (gravothermal) isn't enough

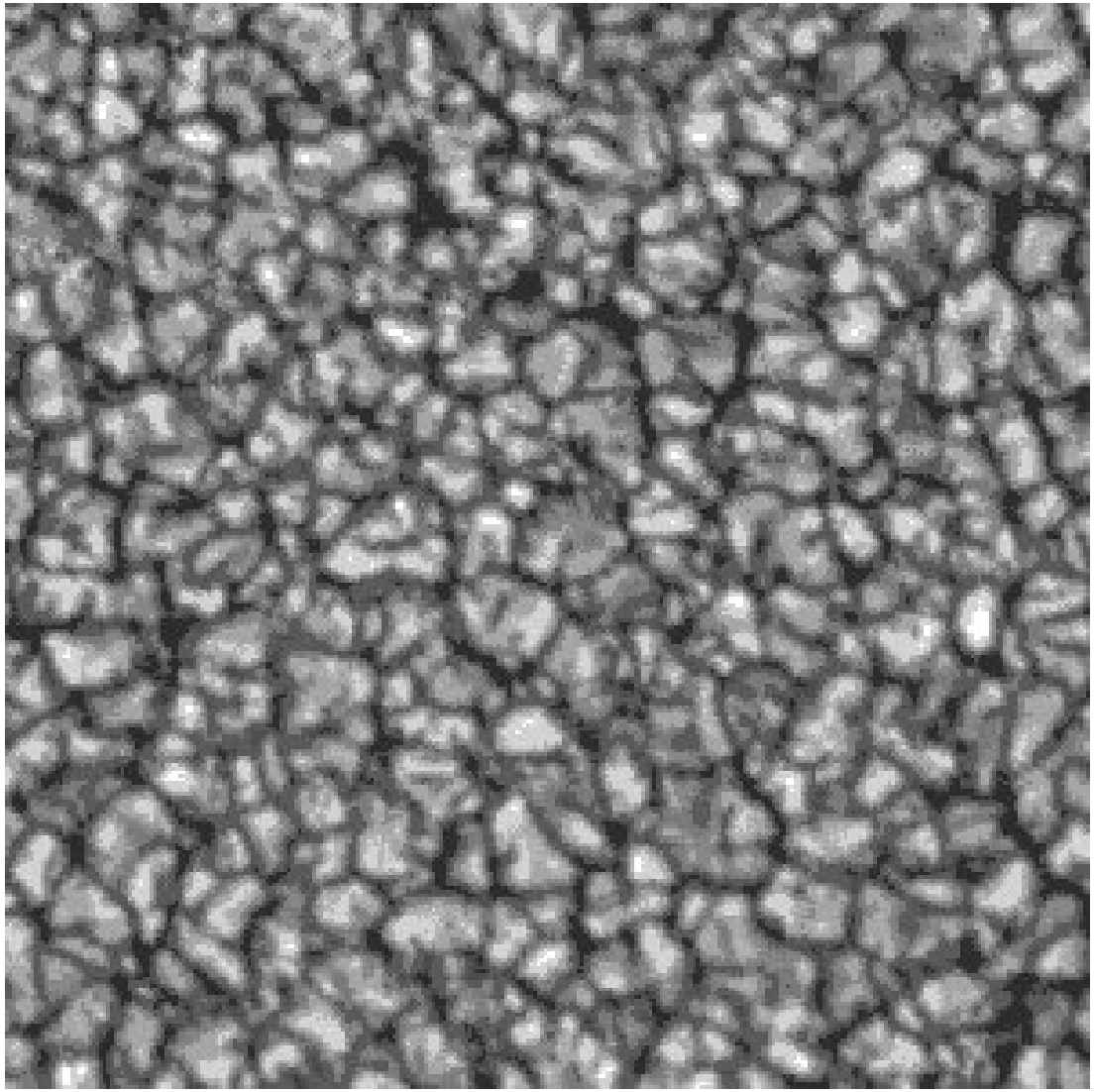


so what does this imply?

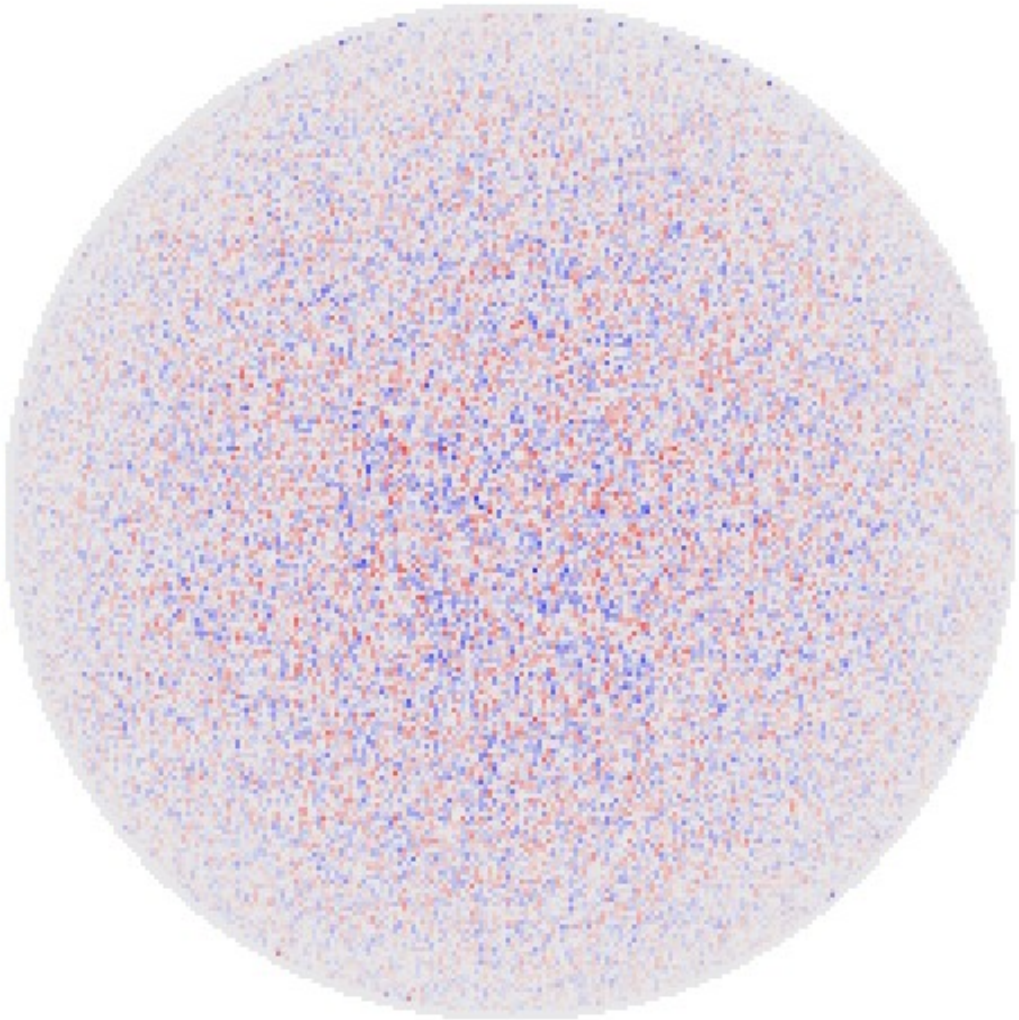
kitchen convection

pizzeria convection

and the reality is ...

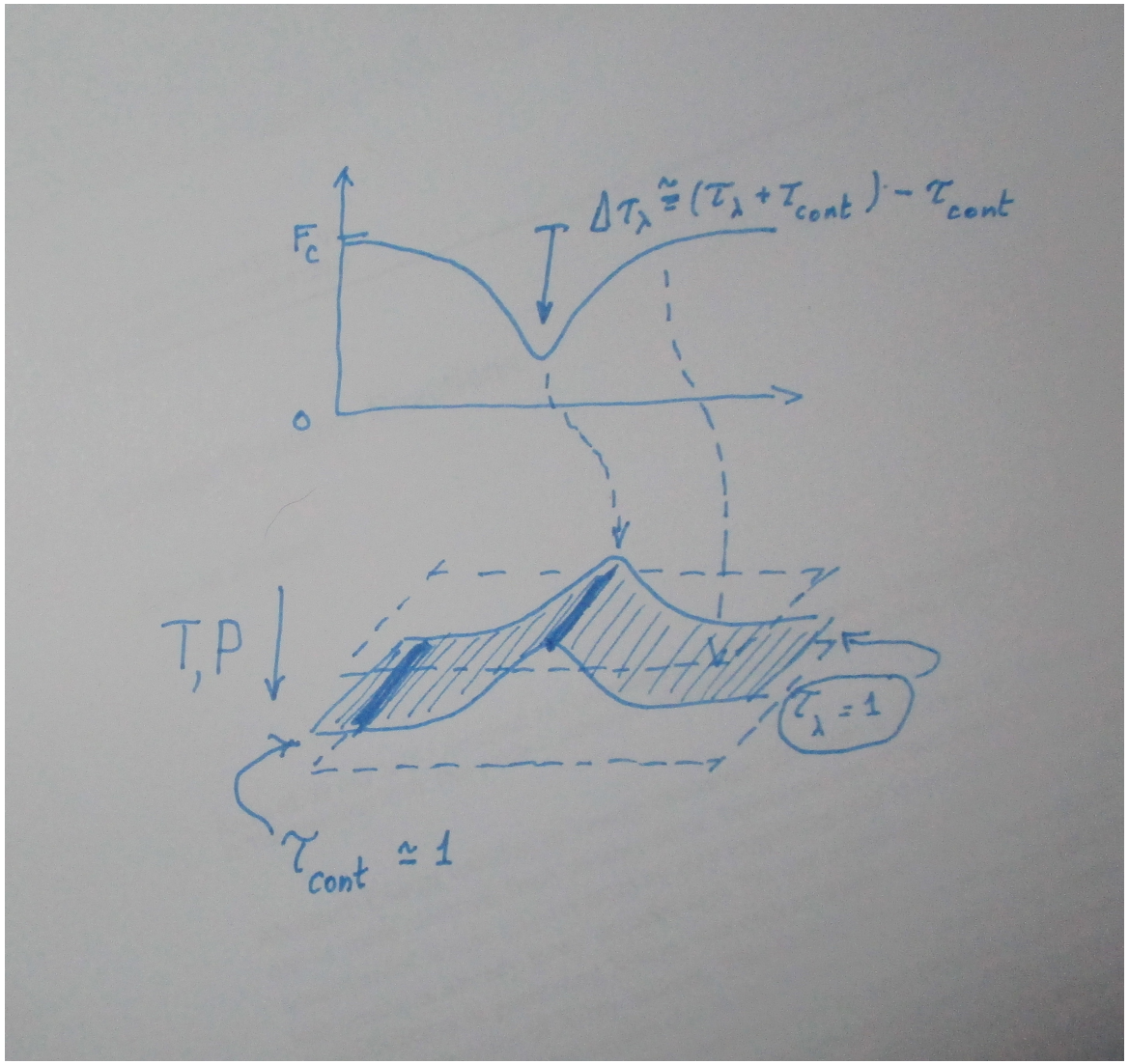


and the deeper reality is ...



and what it implies about the structure: mixing, turbulence, and transport processes

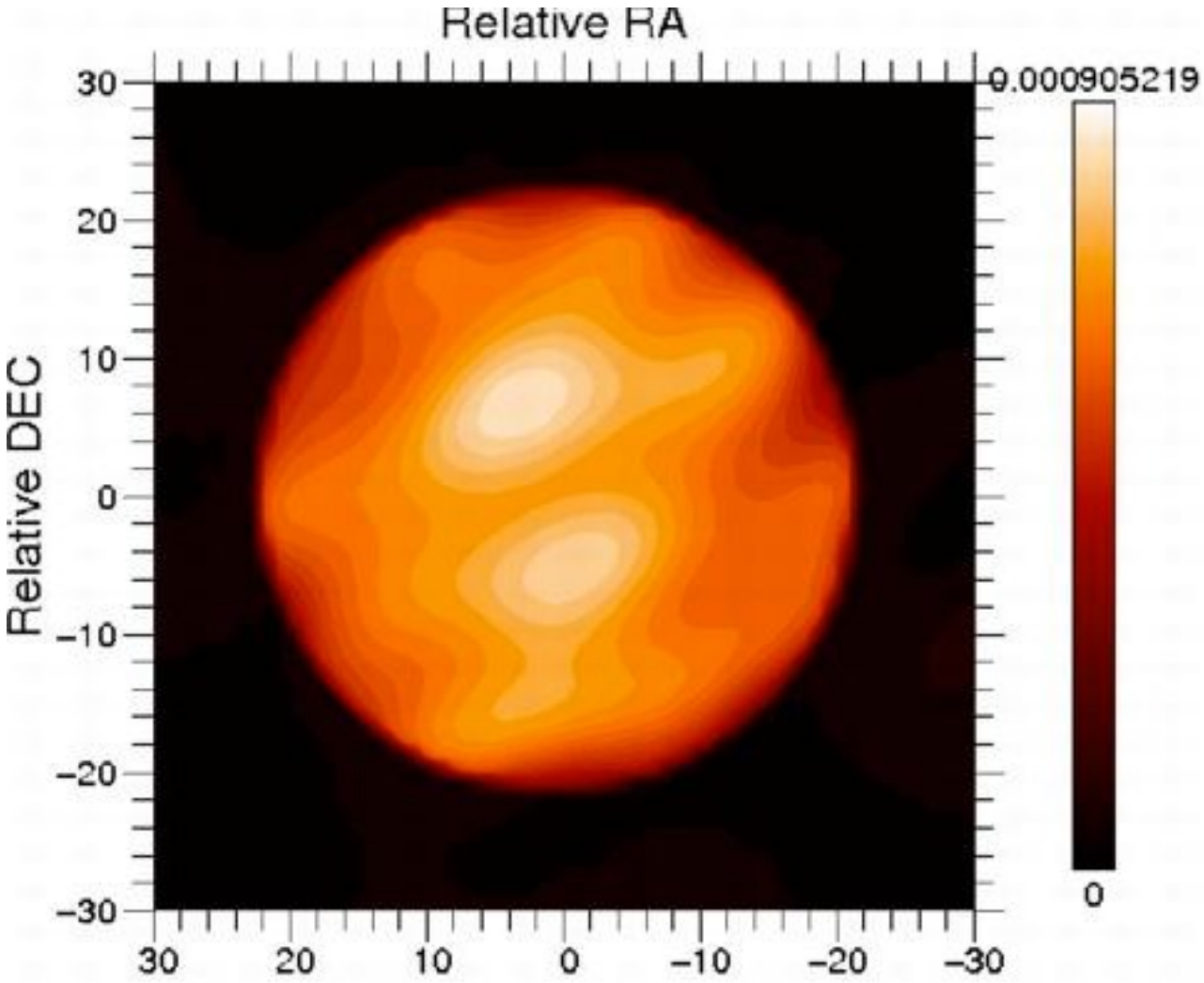
how we understand the outer layers and what's being probed?



and what are we attempting to resolve?

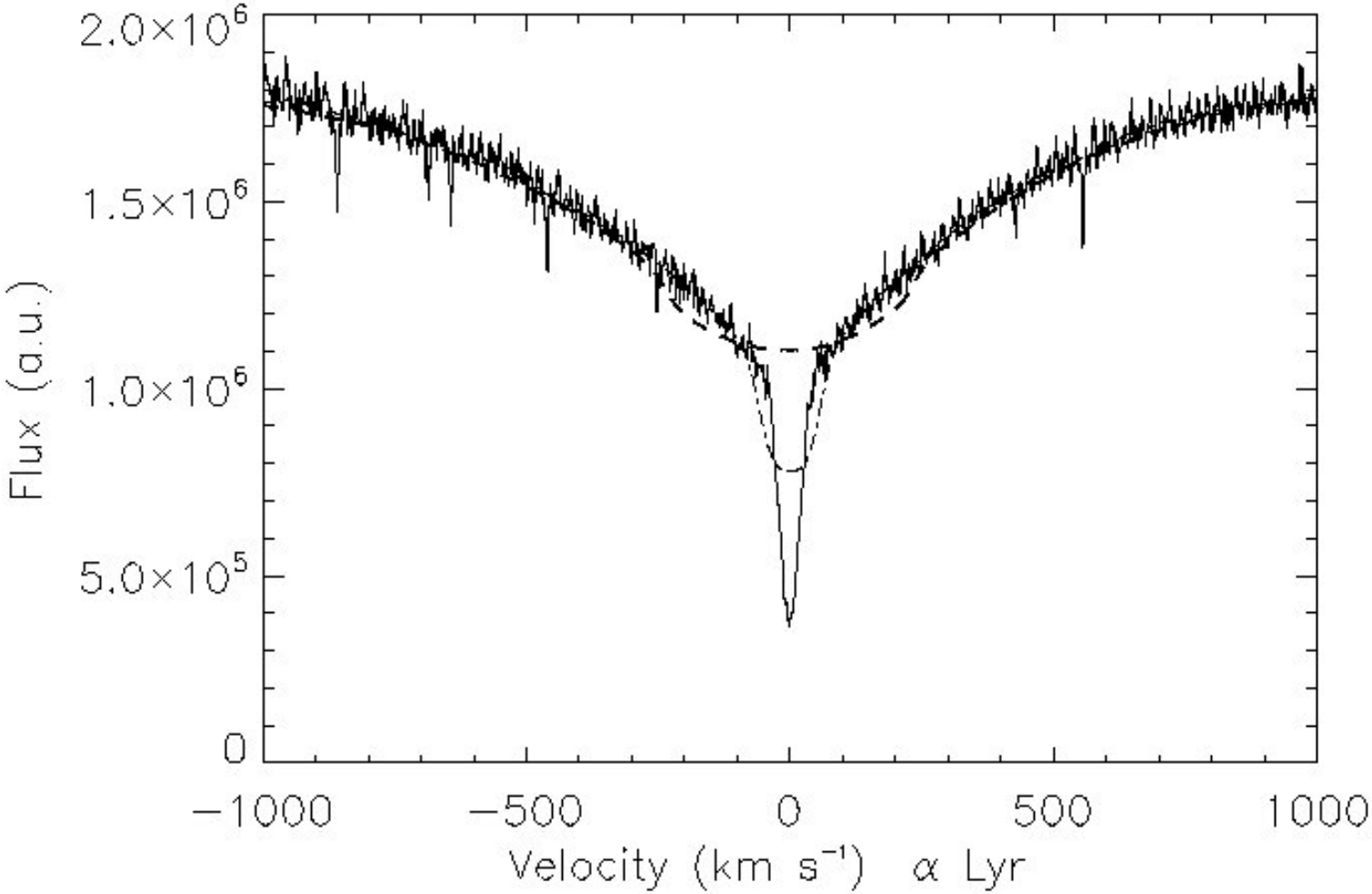
How can we use this?

we know the surfaces of other stars: the extreme supergiant α Ori

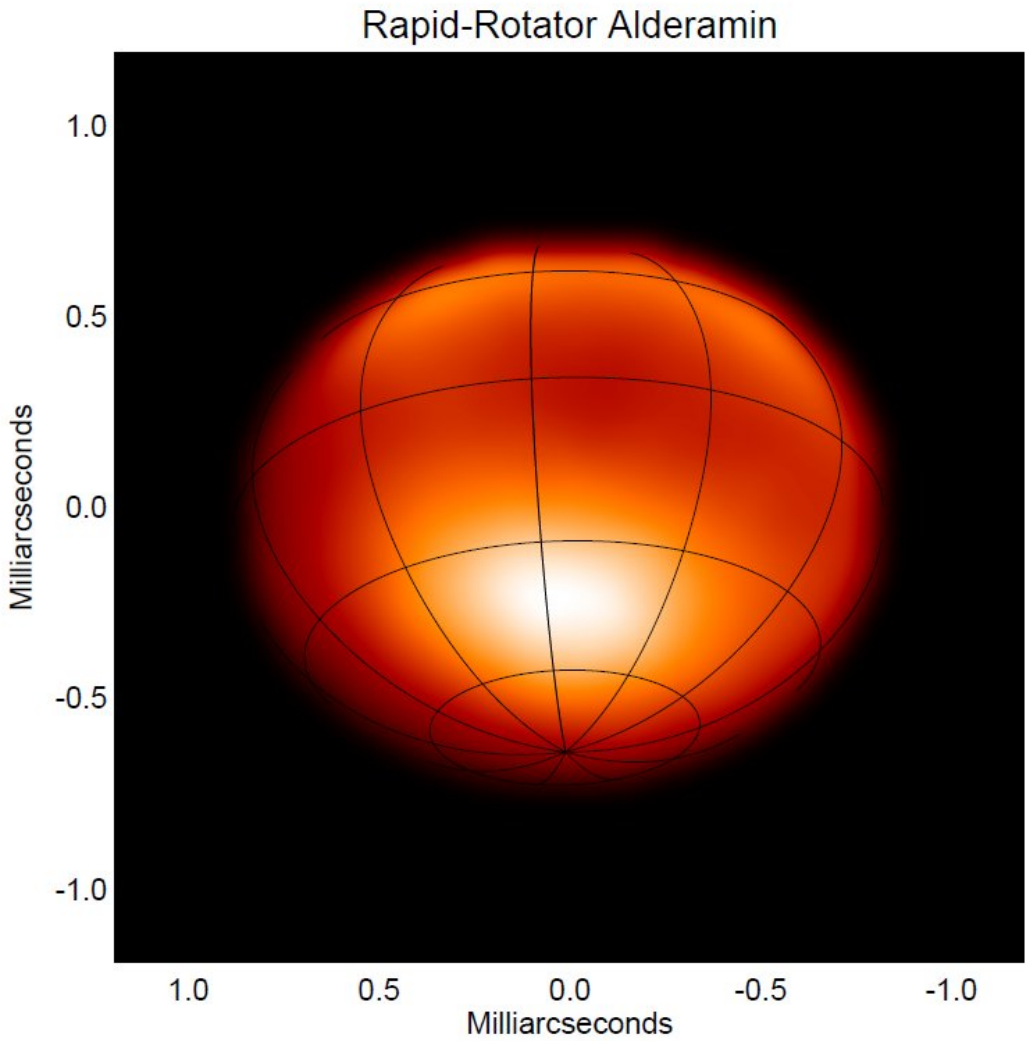


Up to now, what might be missing?

rotation and Doppler imaging

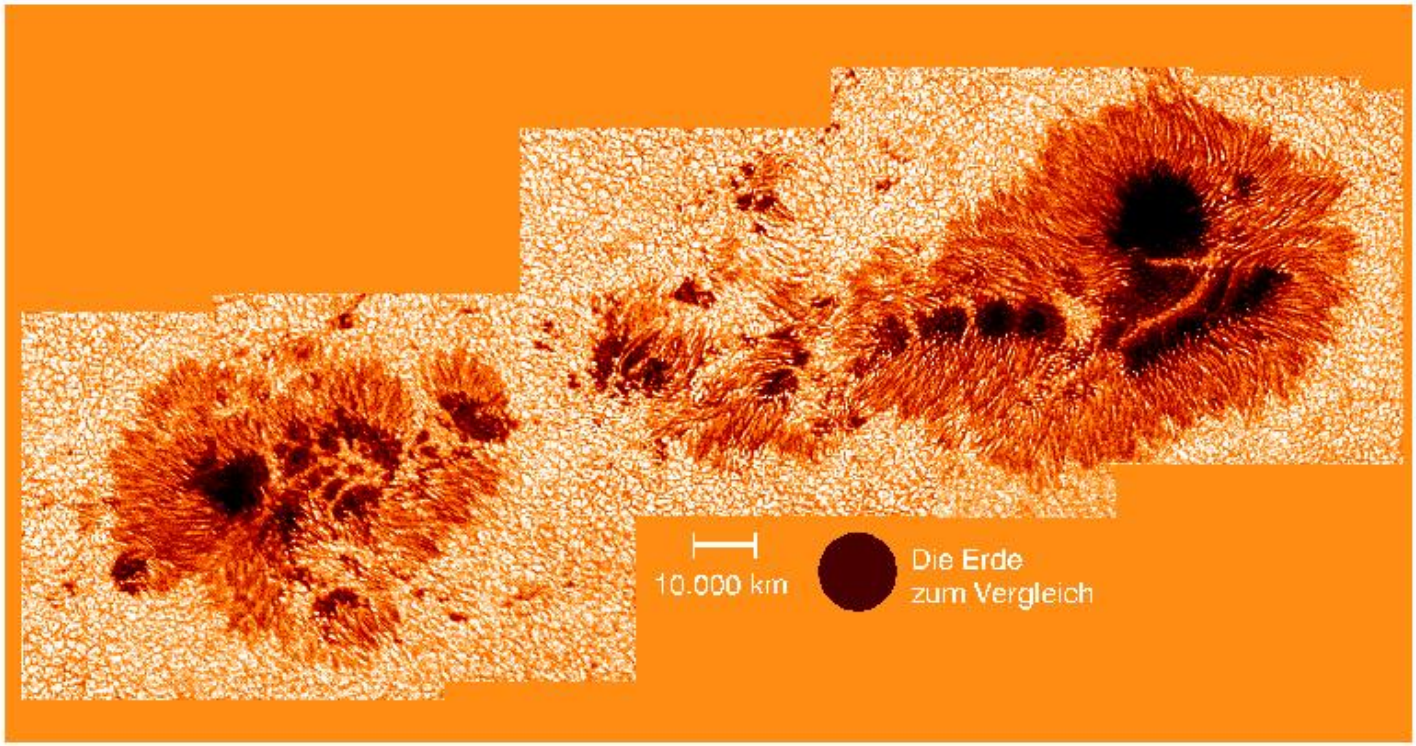


rotation *in extremis*

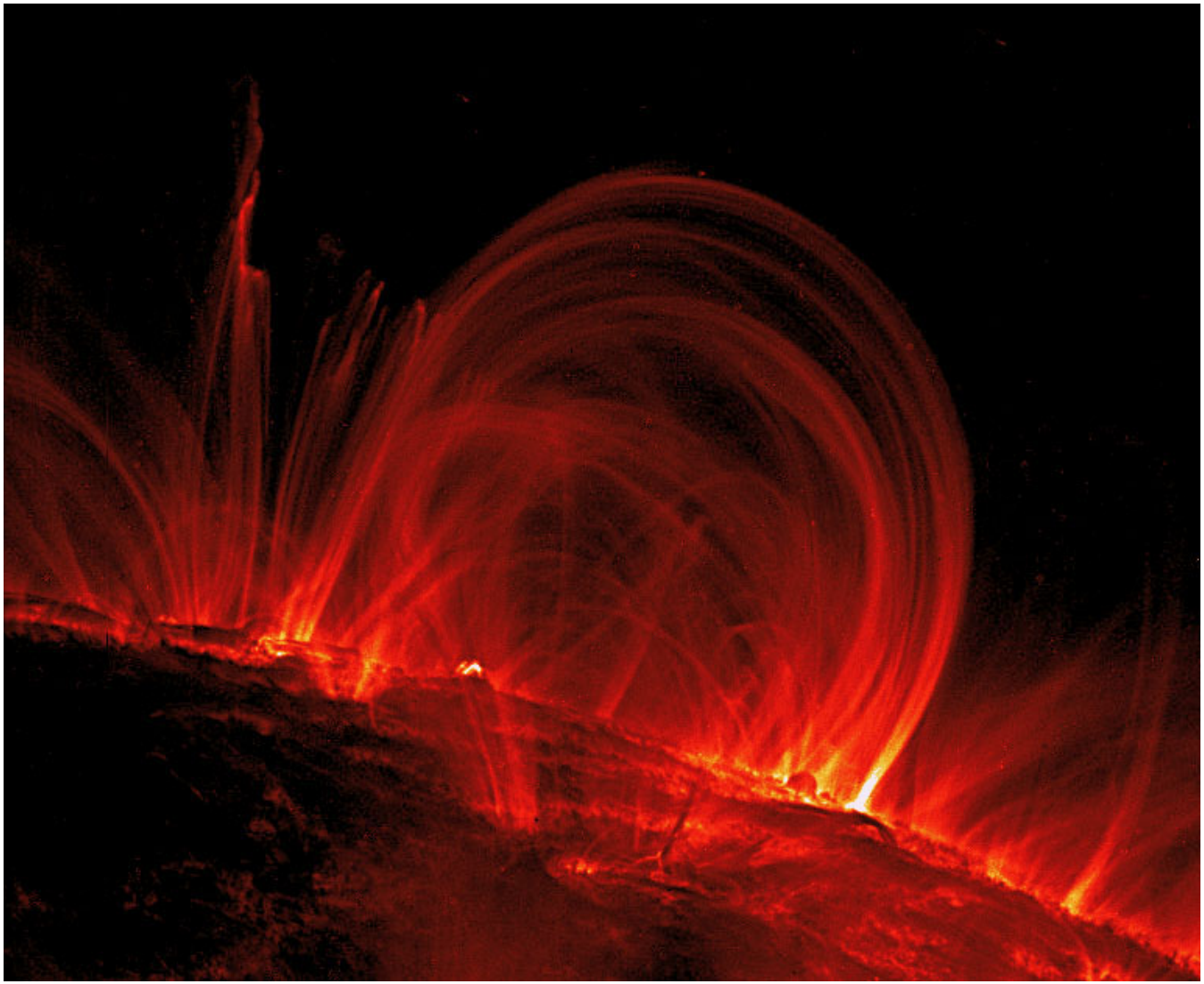


How this changes the picture

a link to a new element of the physics: the Zeeman effect and magnetic fields

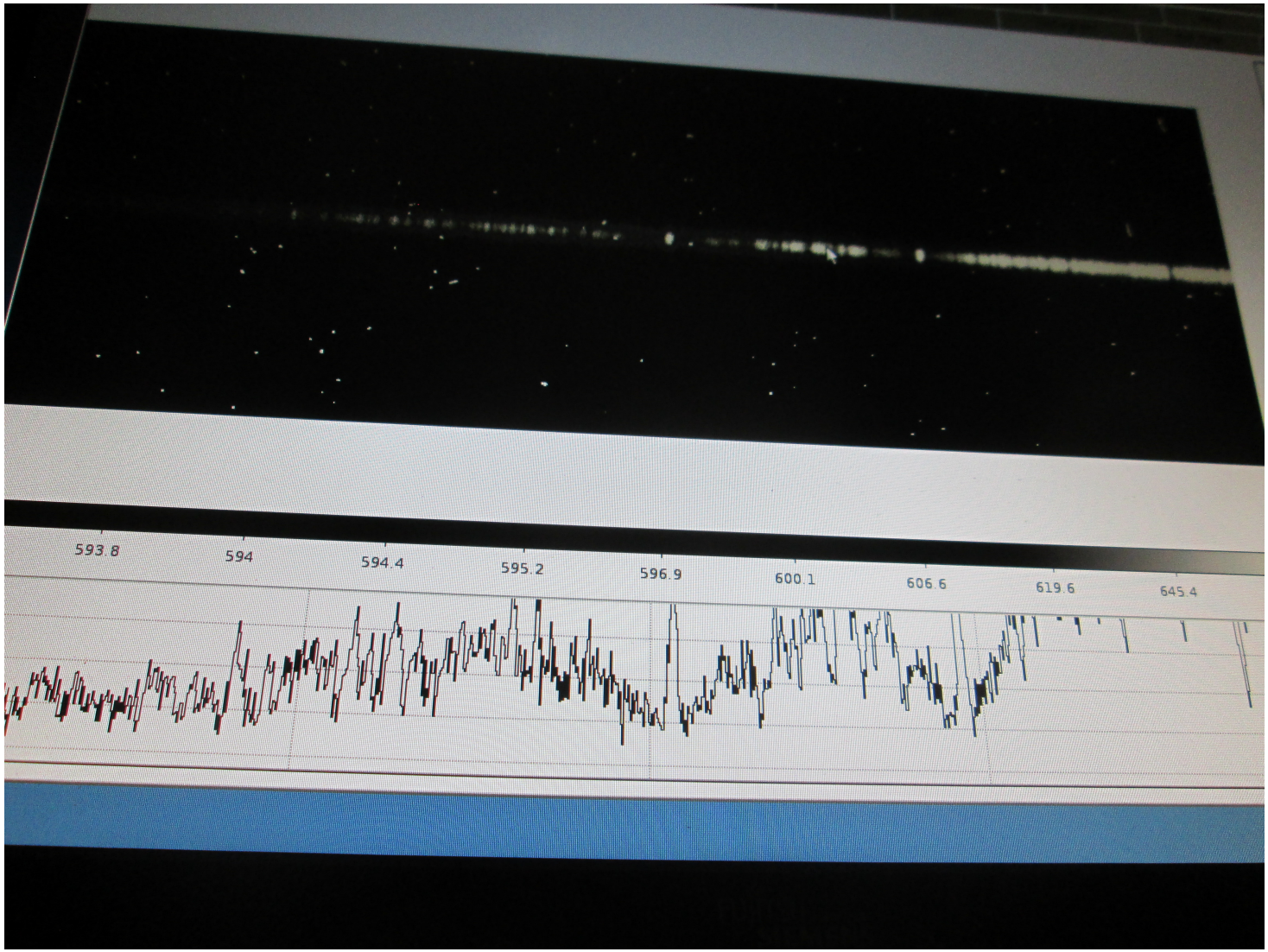


and the direct evidence: the Sun - corona and chromosphere



and the direct evidence of mass loss: the Sun - the solar wind

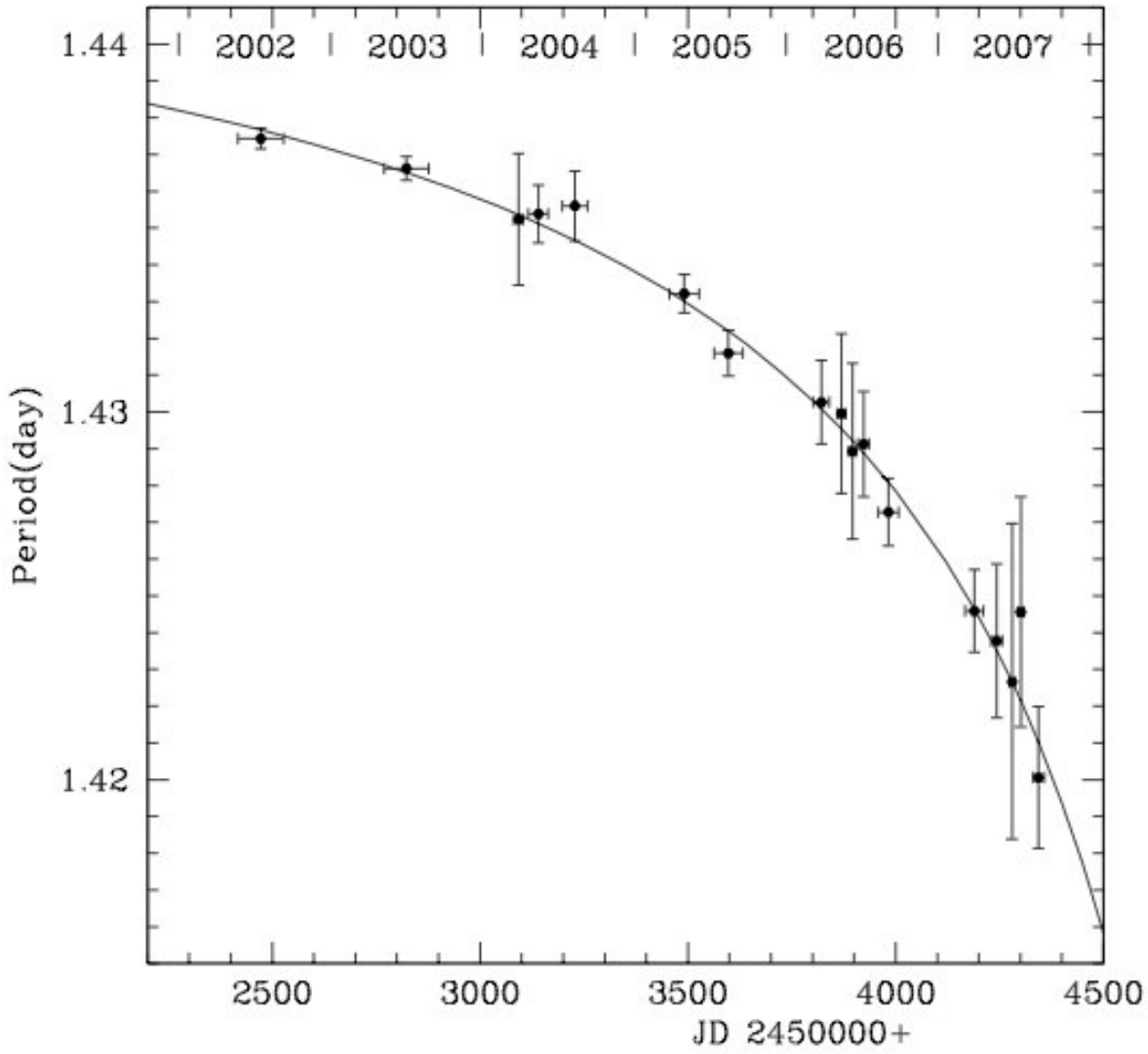
... and not just the Sun



evolution - a fact of life

groups and evolution

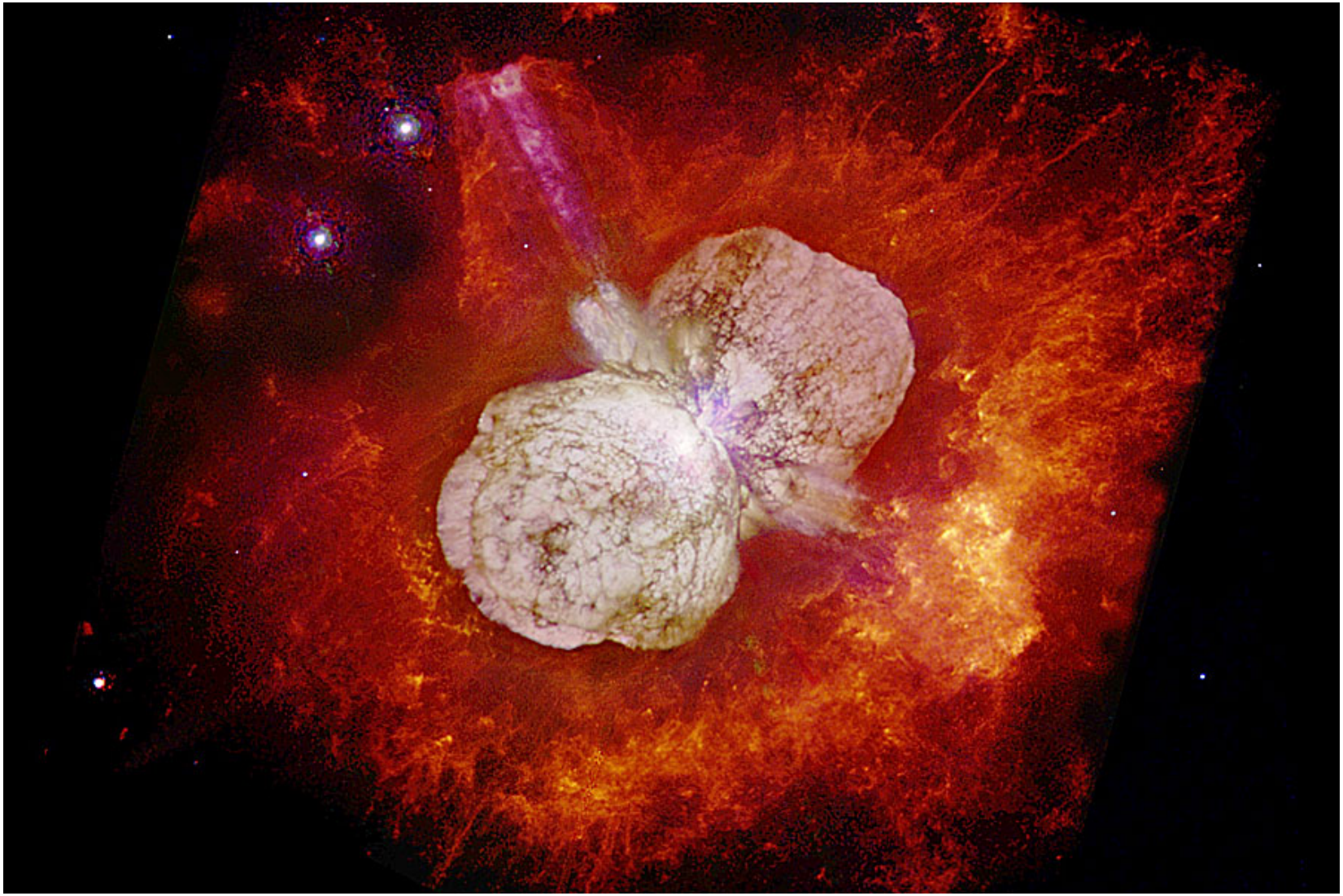
extreme cases - binary merger: V1309 Sco



extreme cases - episodic mass loss: V838 Mon and light echos

extreme events: the Red Square, approaching the end

η Car and the limit of mass loss (supernova impostors



the big picture (ex: NGC 7635): feedback and the eternal cycle

e alla fine, un commento di un eloquente newyorkese

When I heard the learn'd astronomer,
When the proofs, the figures, were ranged in columns before me,
When I was shown the charts and diagrams, to add, divide,
and measure them,
When I sitting heard the astronomer where he lectured with
much applause in the lecture-room,
How soon unaccountable I became tired and sick,
Till rising and gliding out I wander'd off by myself,
In the mystical moist night-air, and from time to time,
Look'd up in perfect silence at the stars.

Walt Whitman, *When I Heard the Learned Astronomer*

... they're waiting for your deep contemplation

dedica

a nostro modello Mauro

e a tutti voi,
il futuro