Workshop "Astrophysique de Laboratoire"

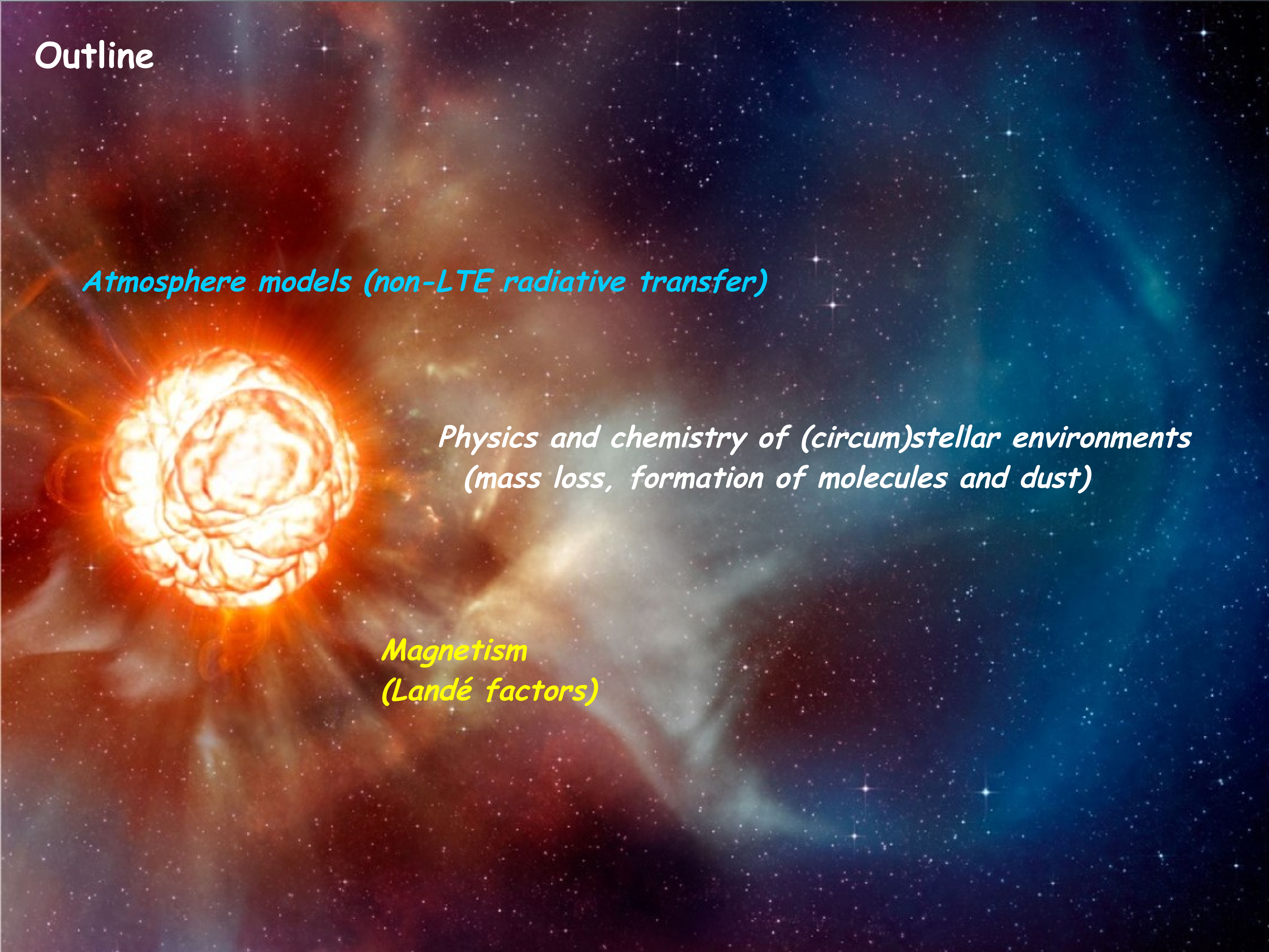
Atmosphères, couronnes et enveloppes circumstellaires

Fabrice Martins

Laboratoire Univers et Particules de Montpellier

Input de J. Hillier, L. Dessart, D. Talbi

Outline



Atmosphere models (non-LTE radiative transfer)

Physics and chemistry of (circum)stellar environments (mass loss, formation of molecules and dust)

Magnetism (Landé factors)

Atmosphere model

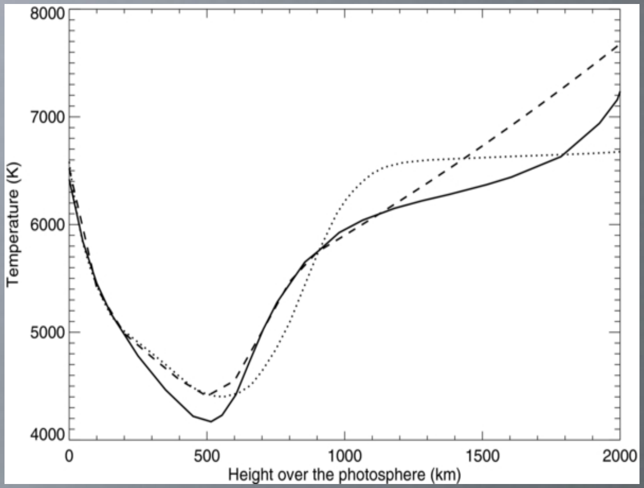
Atmosphere models predict:

1. the hydrodynamical (density, velocity) and temperature structure

2. the ionization and excitation for as many elements as possible

3. the properties of the radiation field (intensity, wavelength dependence)

1



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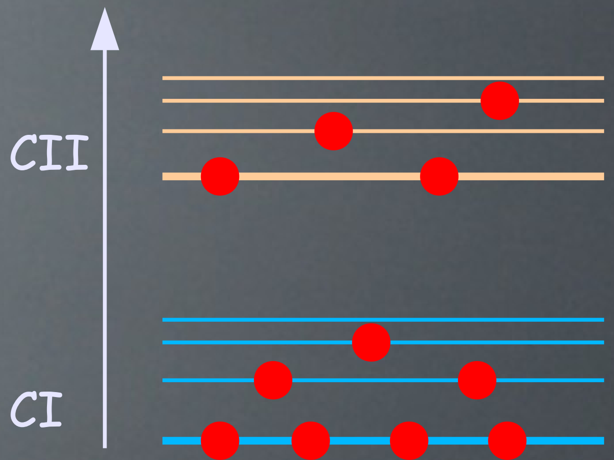

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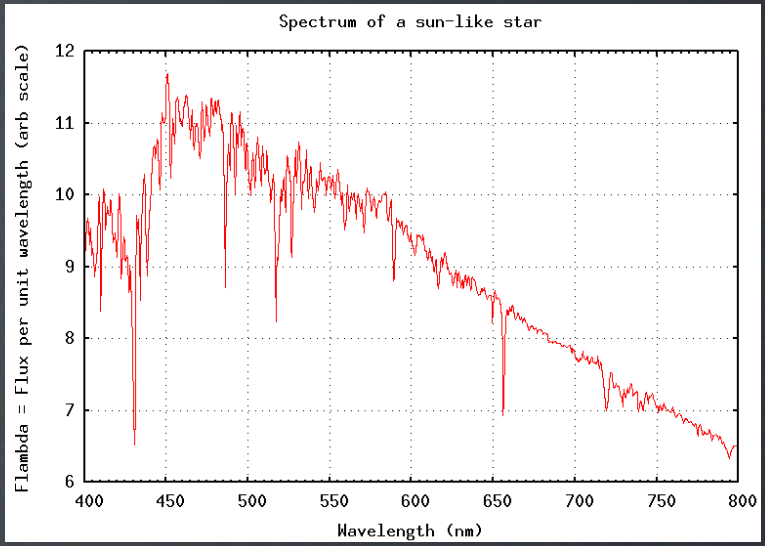


Non LTE radiative transfer

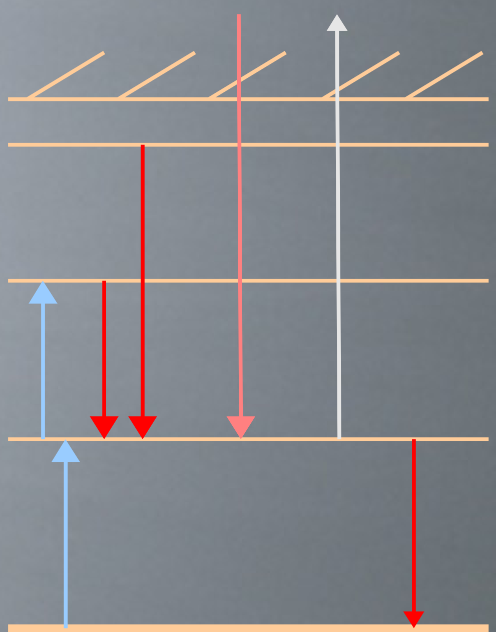
Non Local Thermodynamic Equilibrium: mandatory for hot massive stars
important for specific lines of most stars

$$\frac{\partial n_i}{\partial t} + \nabla (n_i . \vec{v}) = \sum_{j \neq i} n_j (C_{ji} + R_{ji}) - n_i \sum_{j \neq i} (C_{ij} + R_{ij})$$

All processes can be due to collisions with other particles, or can be radiative processes

Non-LTE radiative transfer codes exist (MULTI, SYNSPEC, CMF_FLUX...)

level i

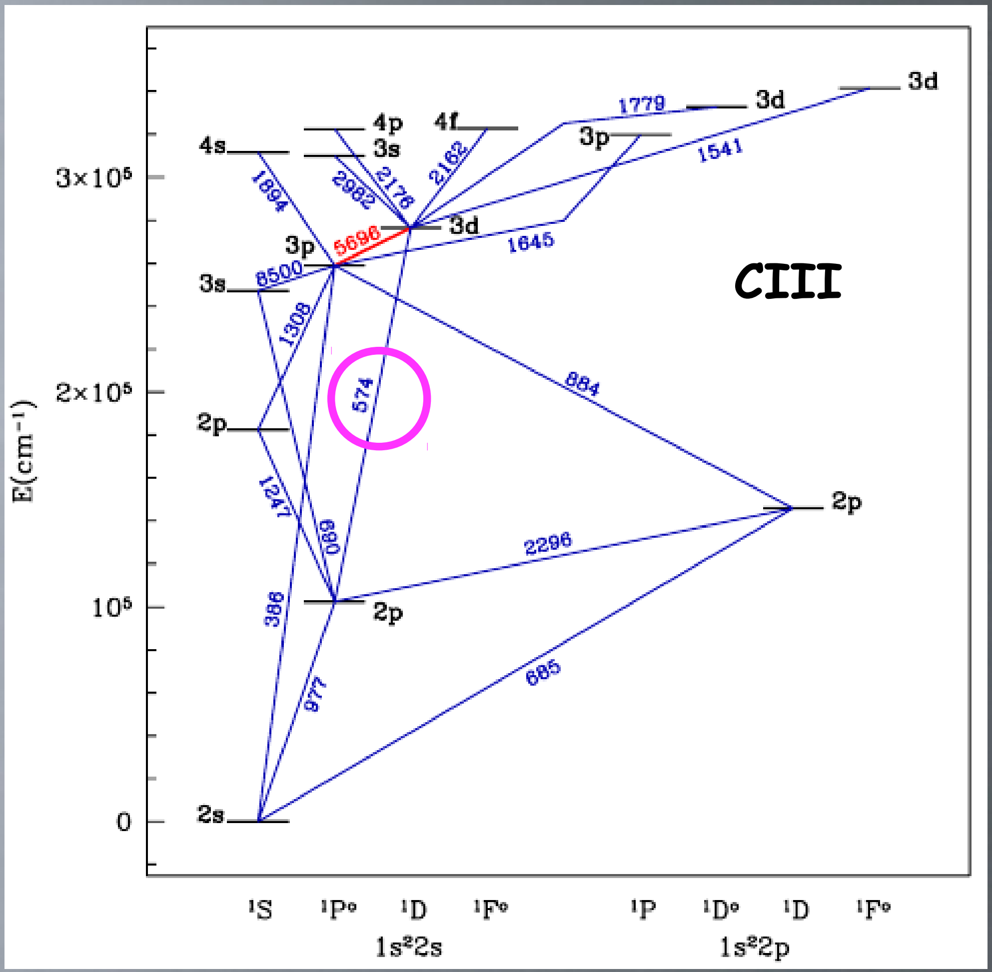


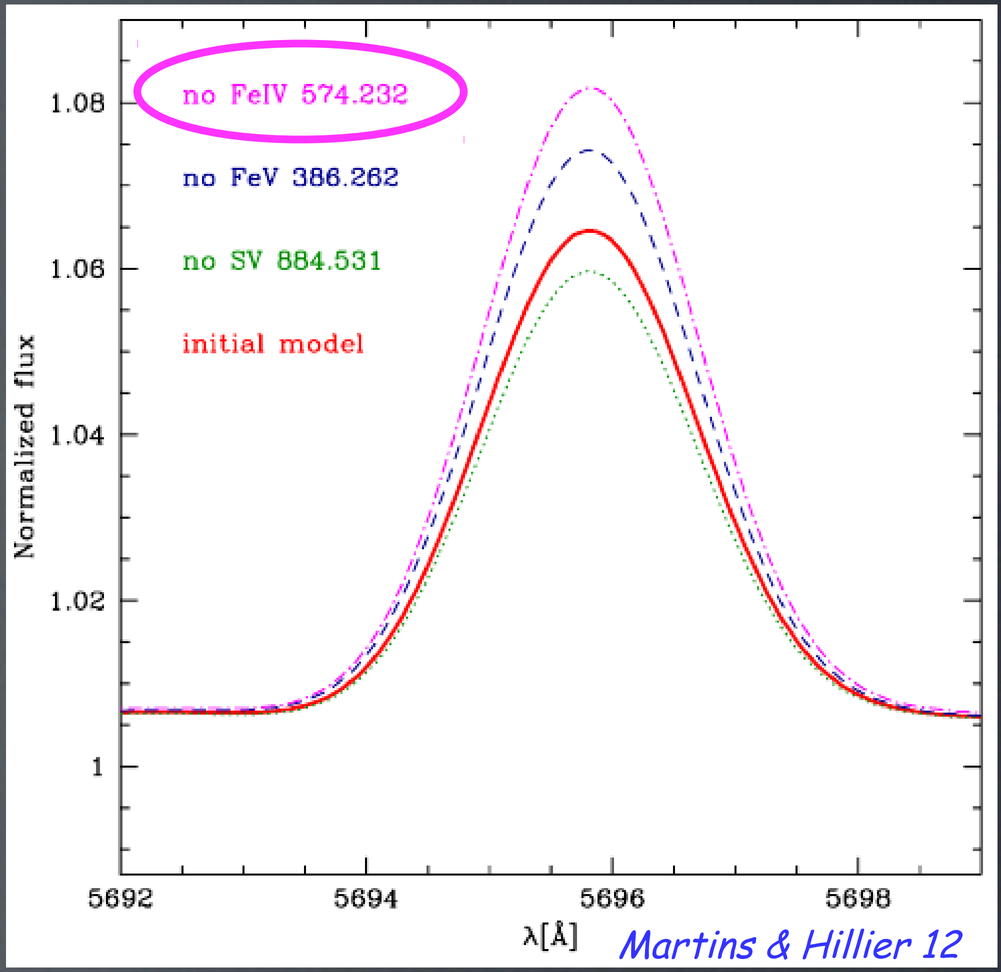
Excitation to/from level i
De-excitation to/from level i
Ionization from level i
Recombination to level i

Need for:
collisional cross-sections (*w/ H but also others, in WC*), energy levels (*especially close to ionization limit*), photoionisation cross-sections (*Co and Ni for SN*), oscillator strength (*no LS coupling*), accurate wavelength, charge exchange reaction rates broadening parameters (*Stark, van der Waals for WD*)

experimental + numerical studies

Non-LTE effects on CIII lines of OB stars

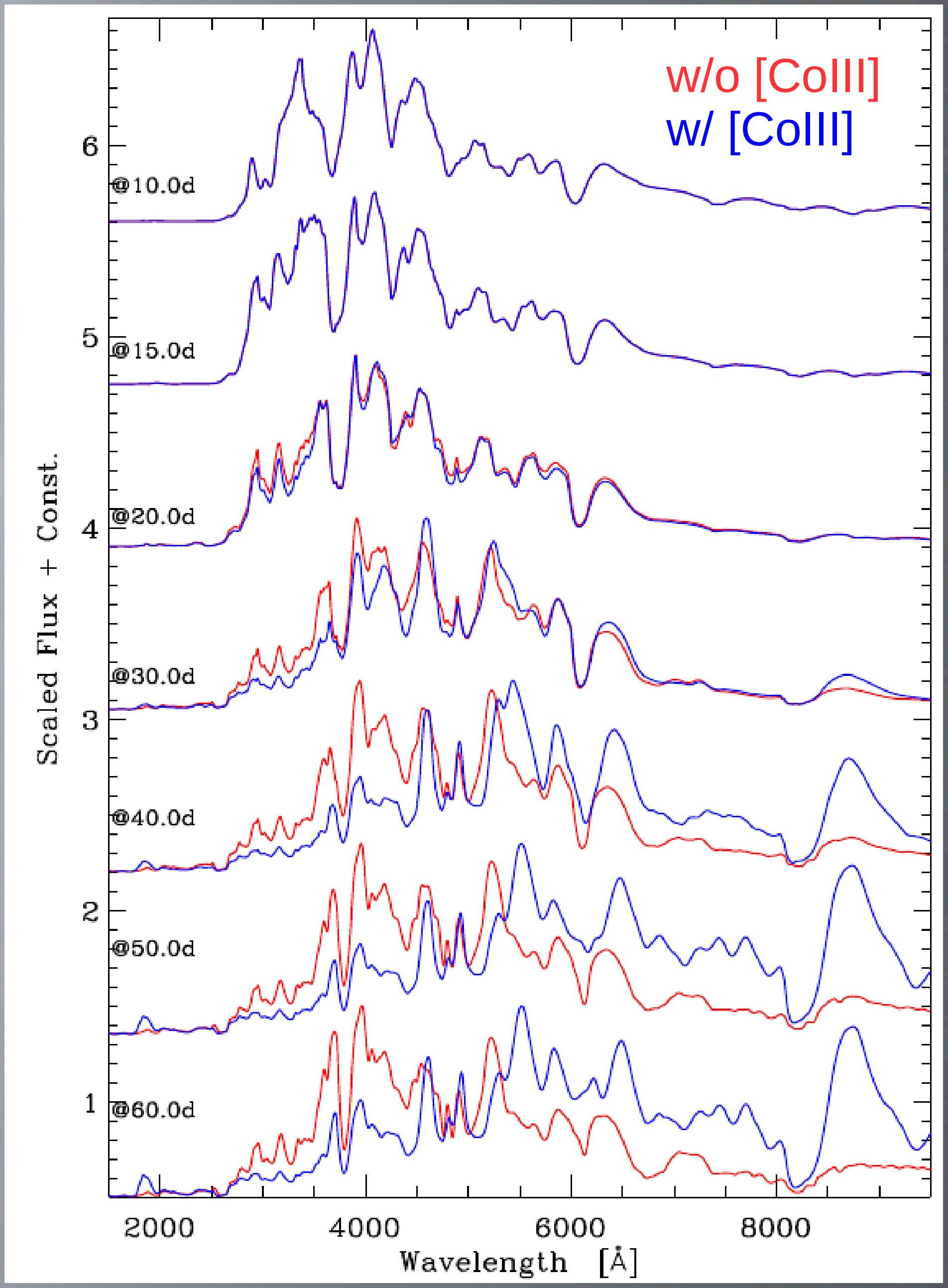


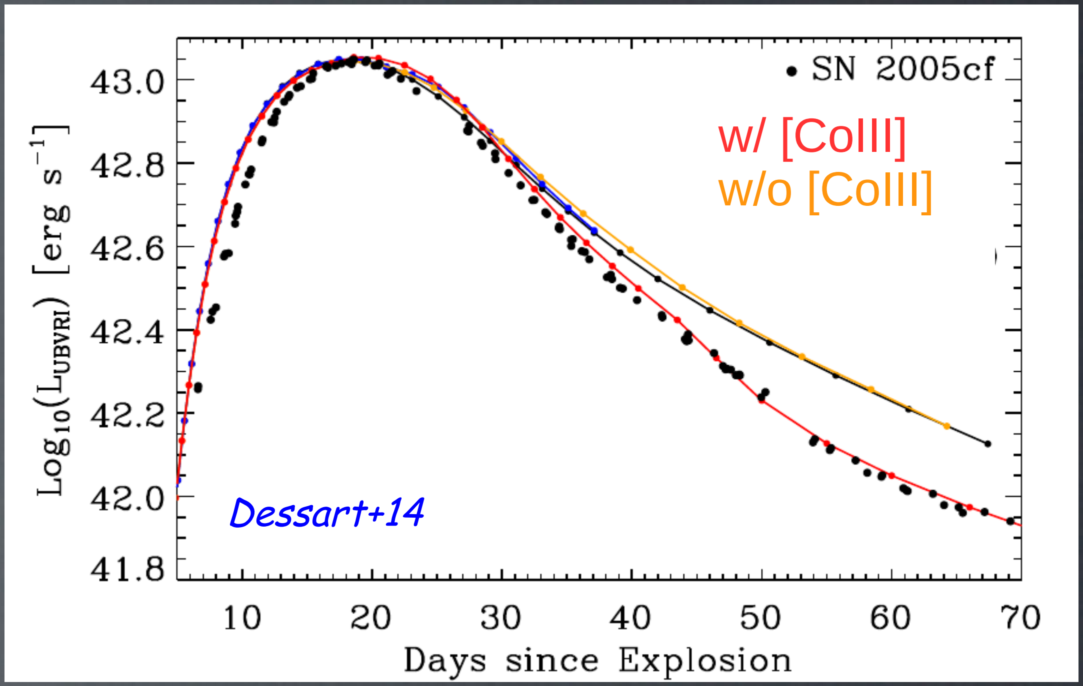


Uncertain wavelength / oscillator strength of metal lines impact on the intensity of CIII lines (Martins & Hillier 2012)

Similar effects for some key HeI lines (Najarro et al. 2006) - *see review by Hillier 2011*

SNIa and [CoIII] lines





Effect of forbidden CoIII lines on spectral evolution and light curve of SNIa

⇒ *Lines act as a major coolant which affects ionization equilibrium and thus spectral appearance + photometry*

Need for atomic data for Co (see Dessart+16)

… and for heavier elements for coalescence of NS (and gravitational wave progenitors)

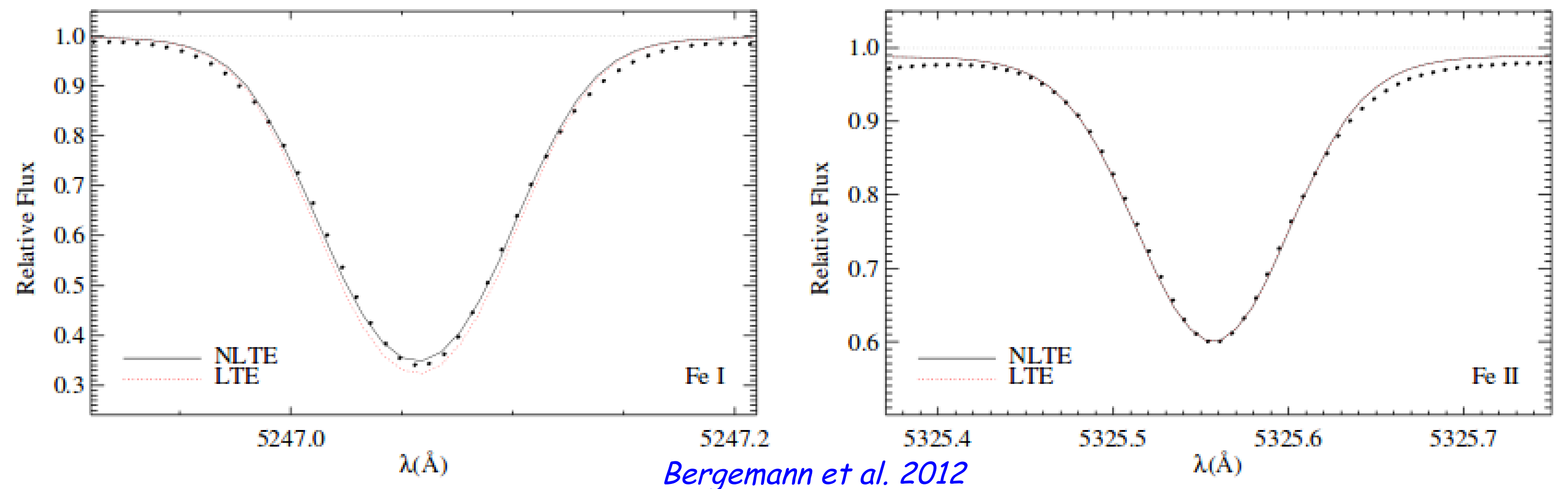
Non-LTE effects on Fe lines of FGKM stars

FeI and FeII lines are subject to non-LTE effects
Effects stronger in FeI

Athay & Lites 1972, Thévenin & Idiart 1999, Gehren et al. 2001, Mashonkina et al. 2011, Bergemann et al. 2012, Merle et al. 2012

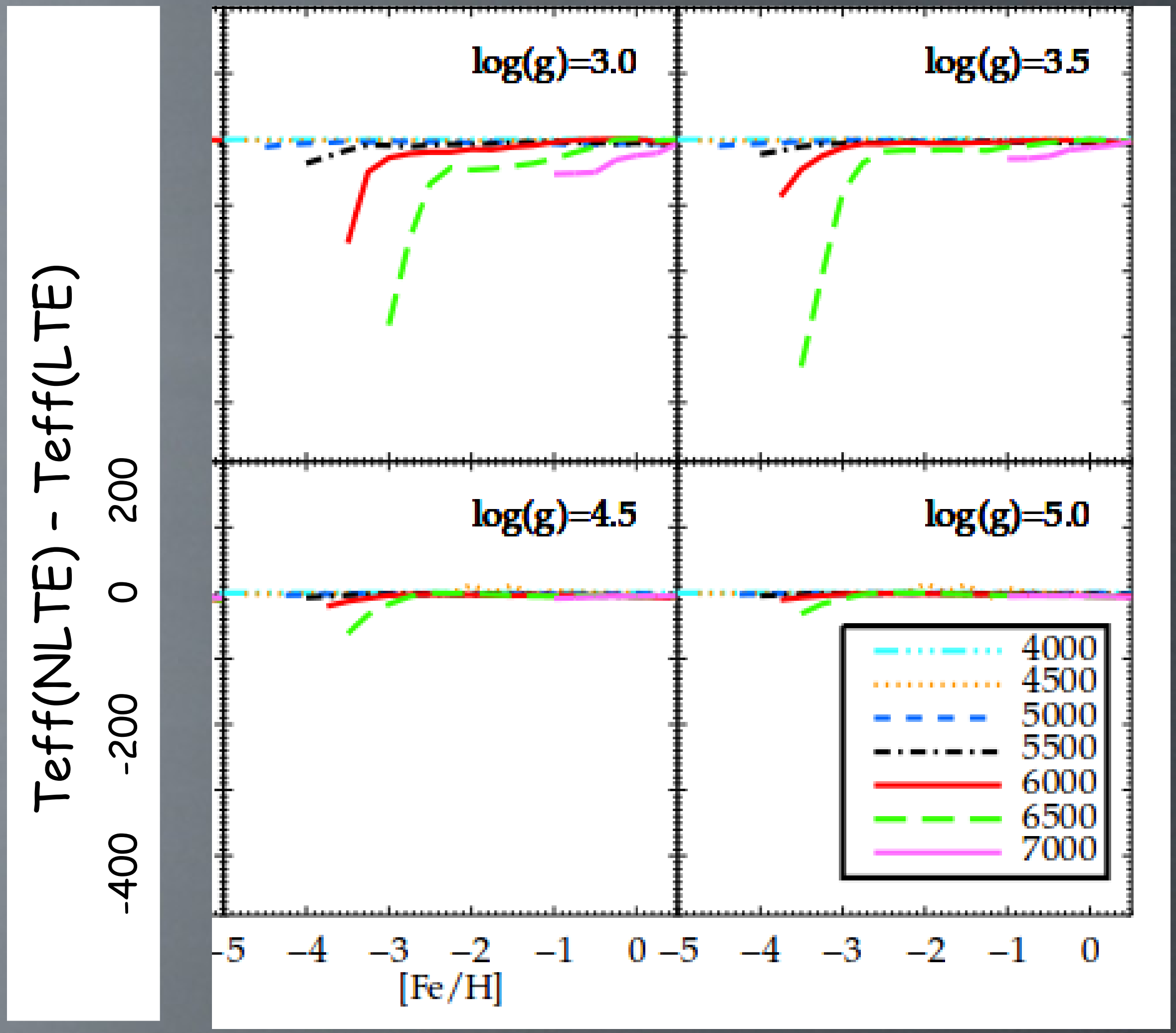
Main effect on FeI lines:
stronger UV flux in non-LTE
more ionization from low excitation FeI levels

⇒ FeI levels globally less populated and thus lines weaker



Bergemann et al. 2012

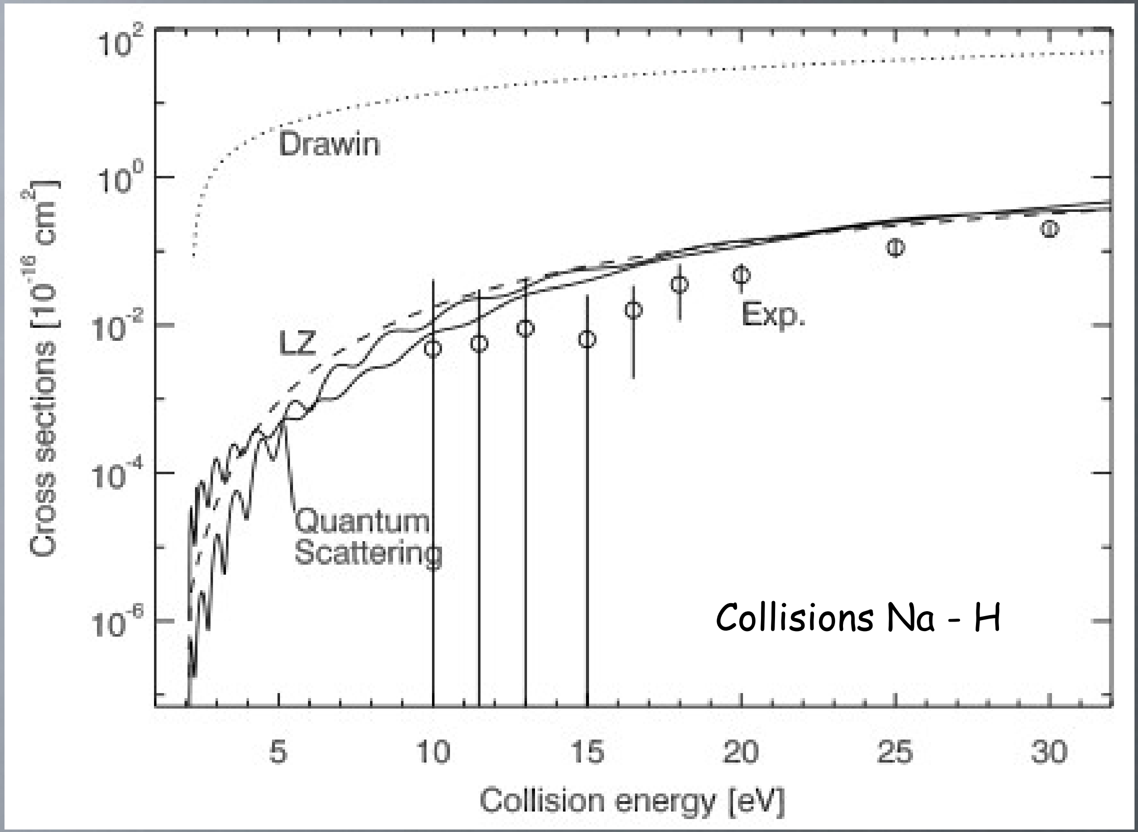
Non-LTE effects on Fe lines of FGKM stars



Lind et al. 2012

Non-LTE effects: collisions with H

Major uncertainty = inelastic collisions with H



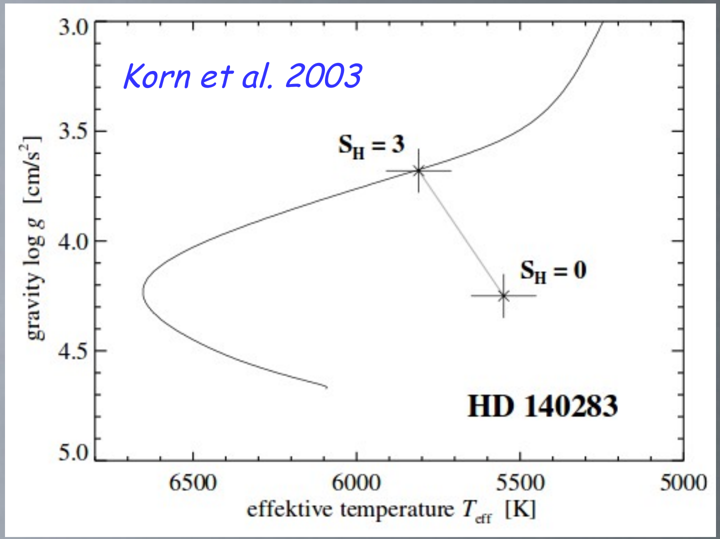
- Collisional cross section approximated by analytical formula (Drawin 1968)
- Known to overestimate real cross section
- Scaled by ad-hoc factor (S_H) in non LTE calculations

Need for experimental values

Barklem et al. 2002

Non-LTE effects: collisions with H

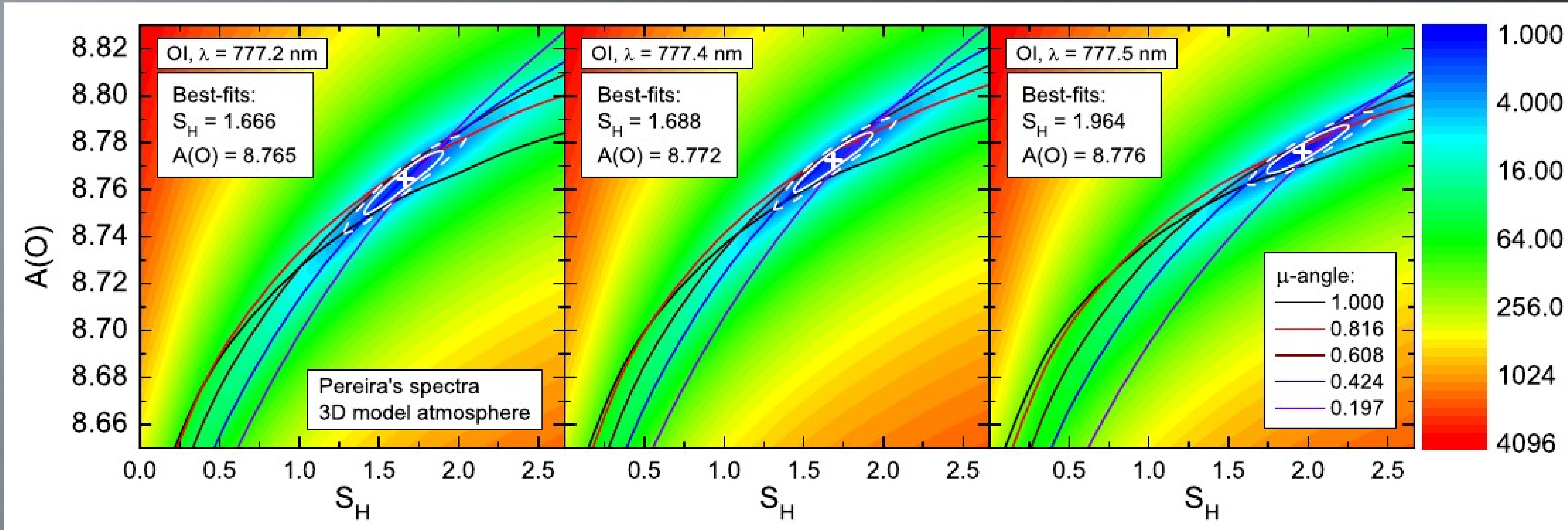
Major uncertainty = inelastic collisions with H



Different values of S_H imply different initial masses/ages and different surface abundances (including for the Sun)

See also Ezzeddine+16

Steffen+16

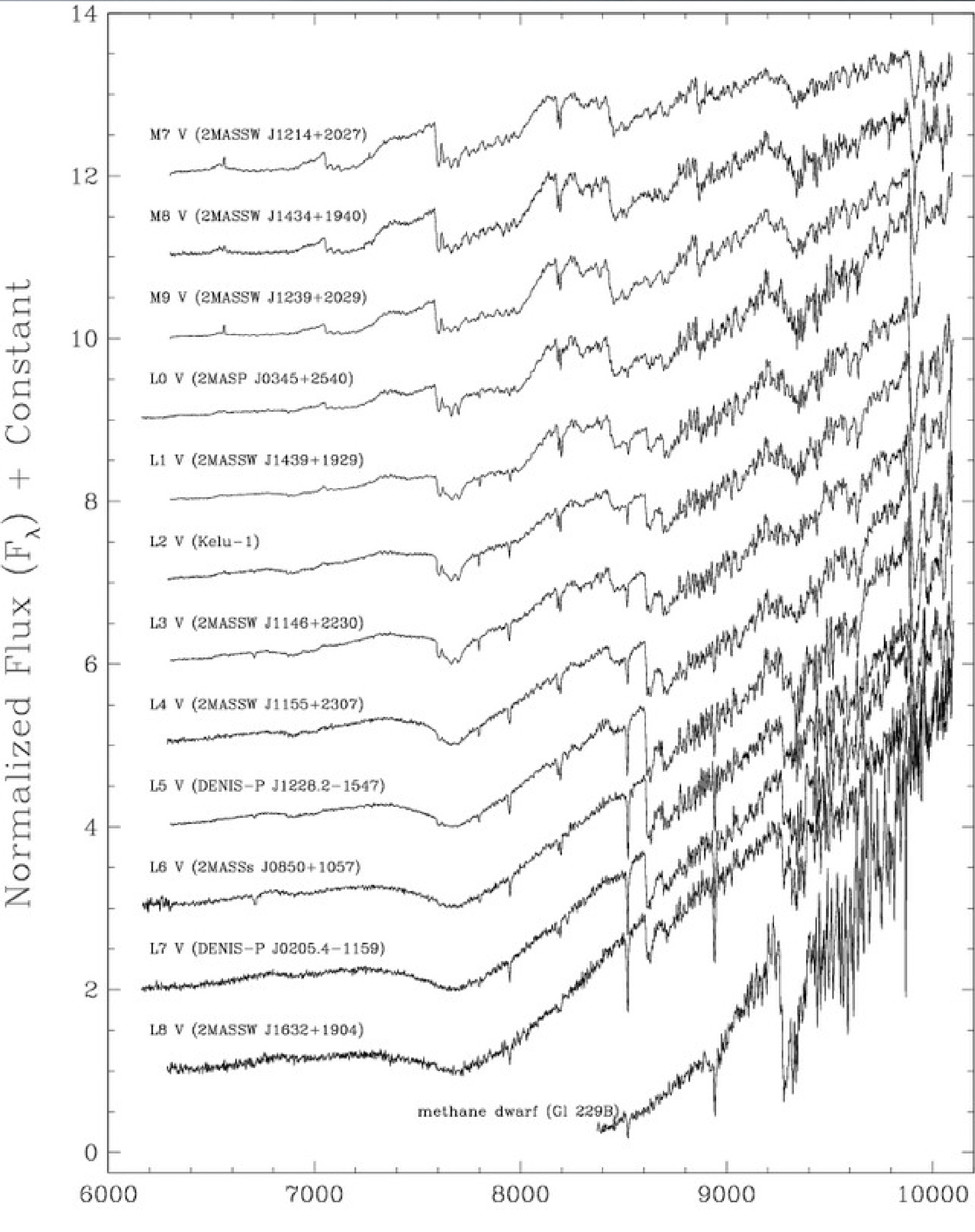


Molecular lines
very cool stars + IR

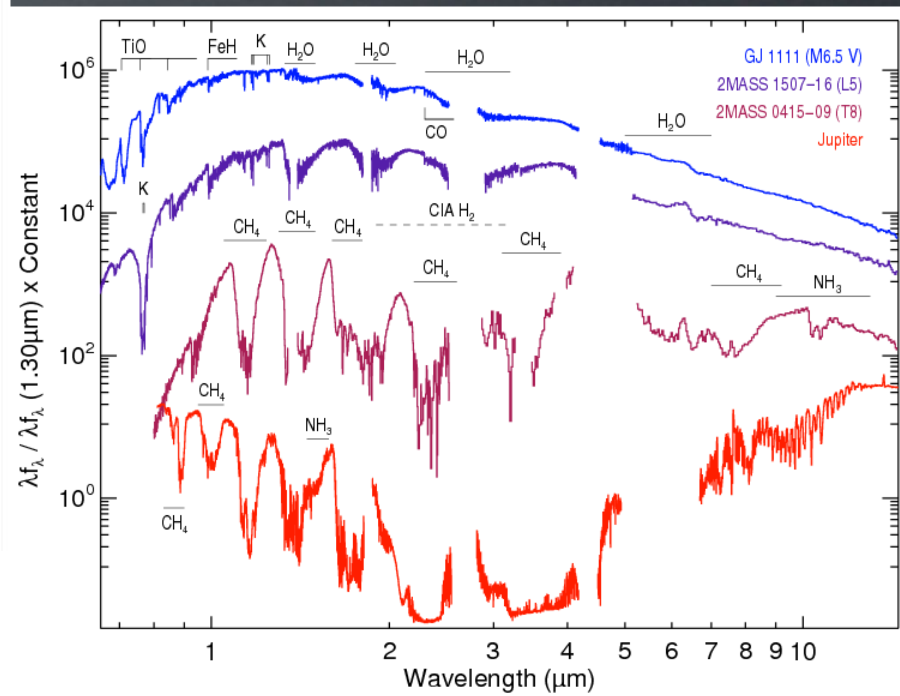
Need for line lists, especially in the red/IR for MLT dwarfs

Molecular Line list calculation
Project ExoMol (Tennyson & Yurchenko 16)

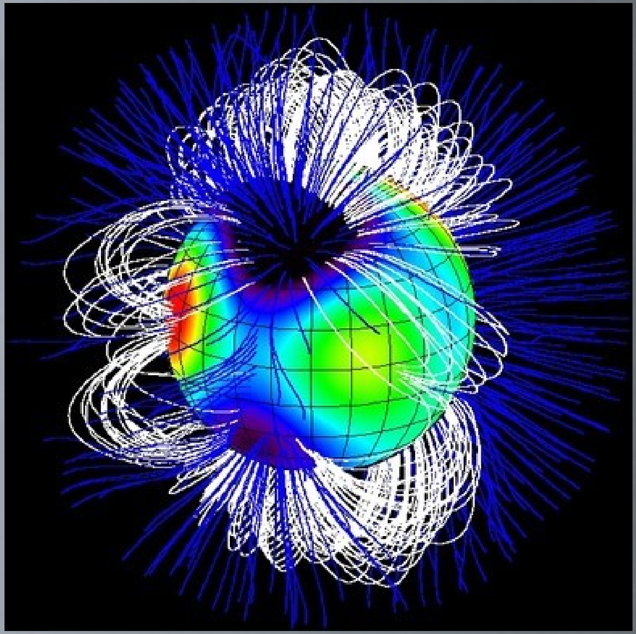
See talk B. Plez



Kirkpatrick+99



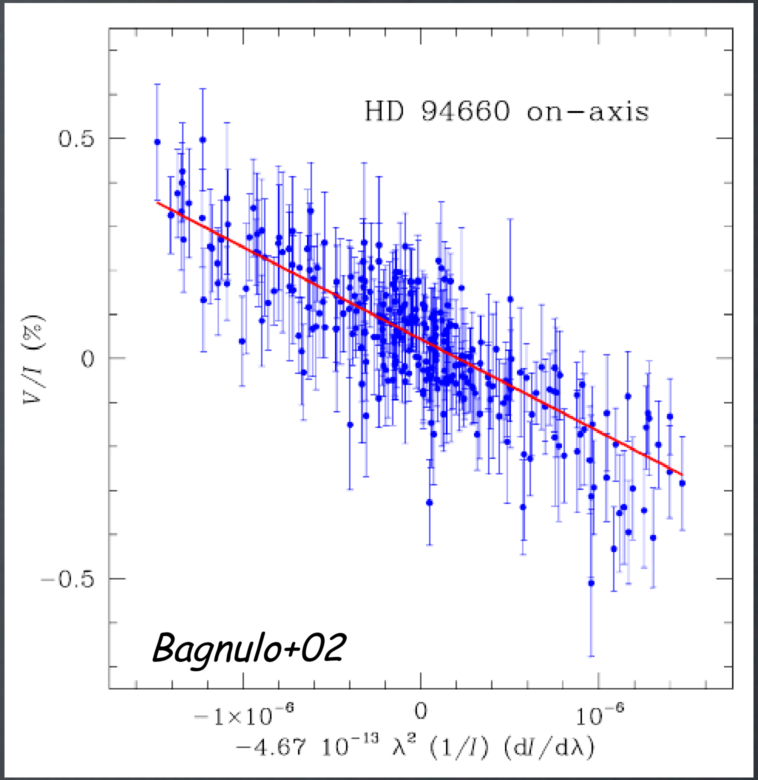
Determination of surface magnetic fields through spectropolarimetry



$$\frac{V}{I} = -4.67\ 10^{-13}\ g_{eff}\ \frac{\lambda^2}{I}\ \frac{dI}{d\lambda}\ Bz$$

Landé factor

LSD technique uses many lines/Landé factors

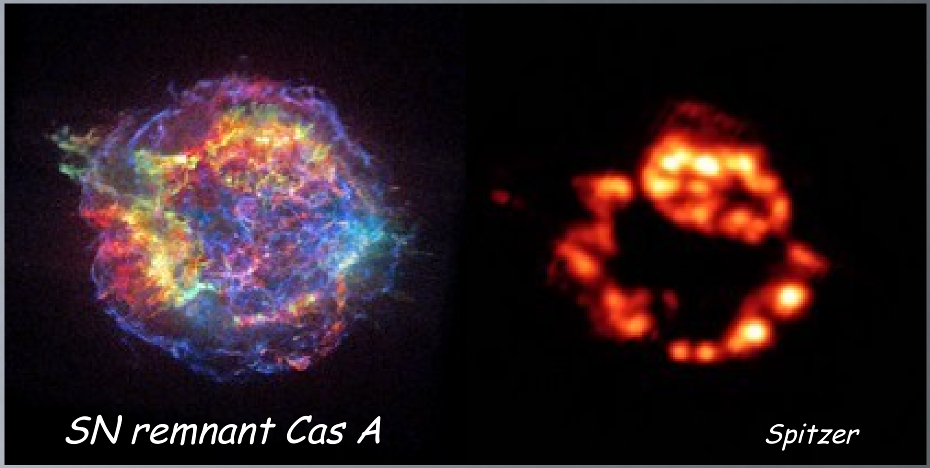


Usually about 80% of optical lines have Landé factors

Fraction much lower for IR + molecular lines

See talk J. Morin

Dust in stars



AGB stars and CC supernovae are thought to be the main dust producers in the Universe
(Todini & Ferrara 01, Valiante+09, Cherchenef f 14)

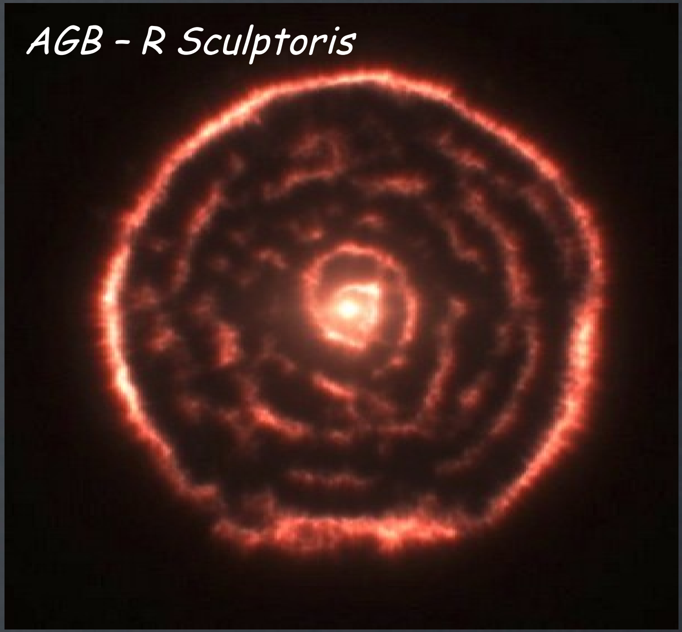
Dust in galaxies: effects on SEDs (and determination of photo-z, SF history...)
Formation of "first" dust – impact on popIII stars

Two main categories of dust:

- carbonaceous (amorphous carbon, graphite,)
- silicate and metal oxide (Mg_2SiO_4, Al_2O_3...)

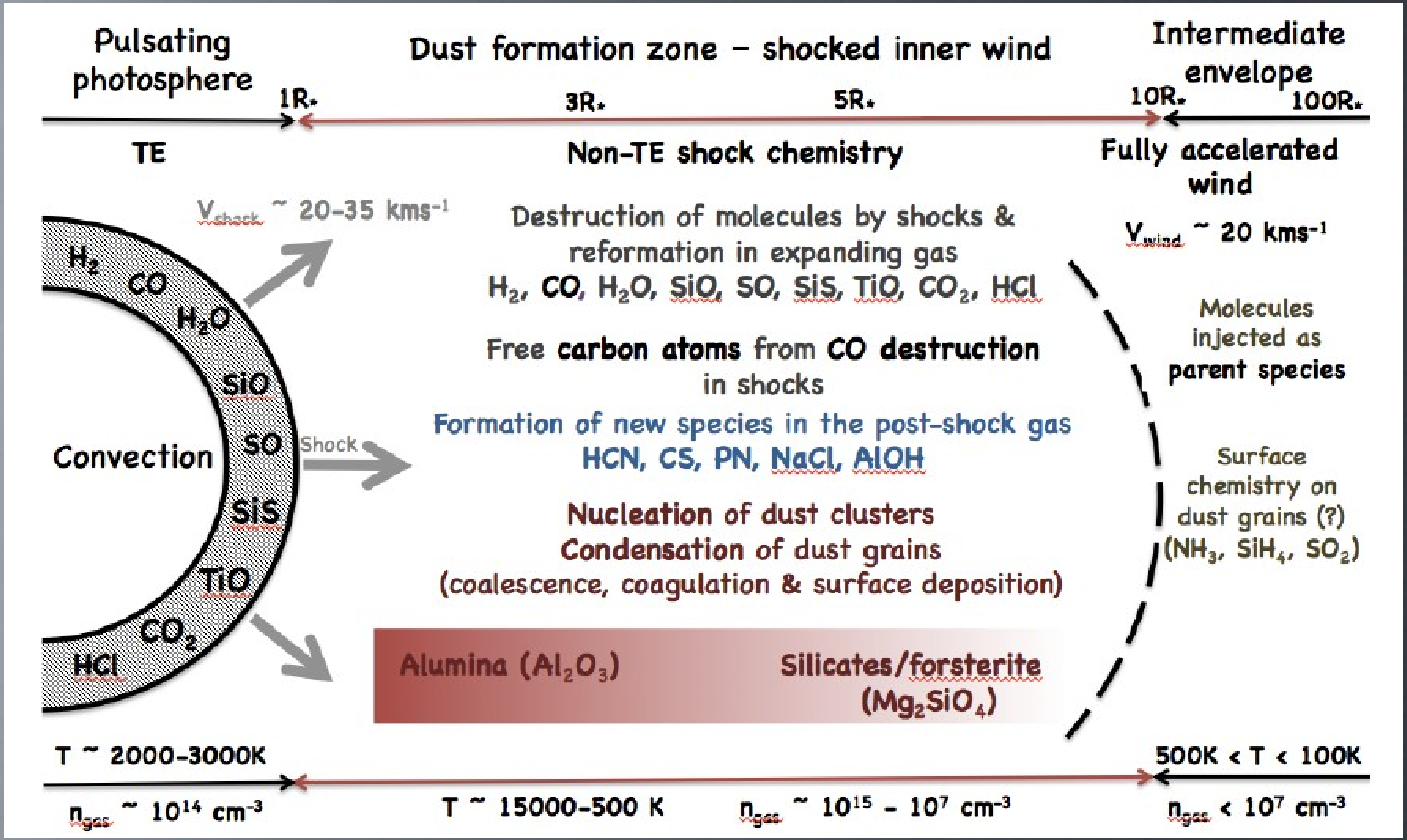
Formation process:
atom/molecule → "cluster" → dust
poorly constrained (especially in O-rich AGBs)

Need for: identification of clusters and types of dust (Herschel, ALMA...), reaction rates, coupling with stellar/envelope models, effect of shocks, chemical networks



See talk L. Biennier

Dust in stars

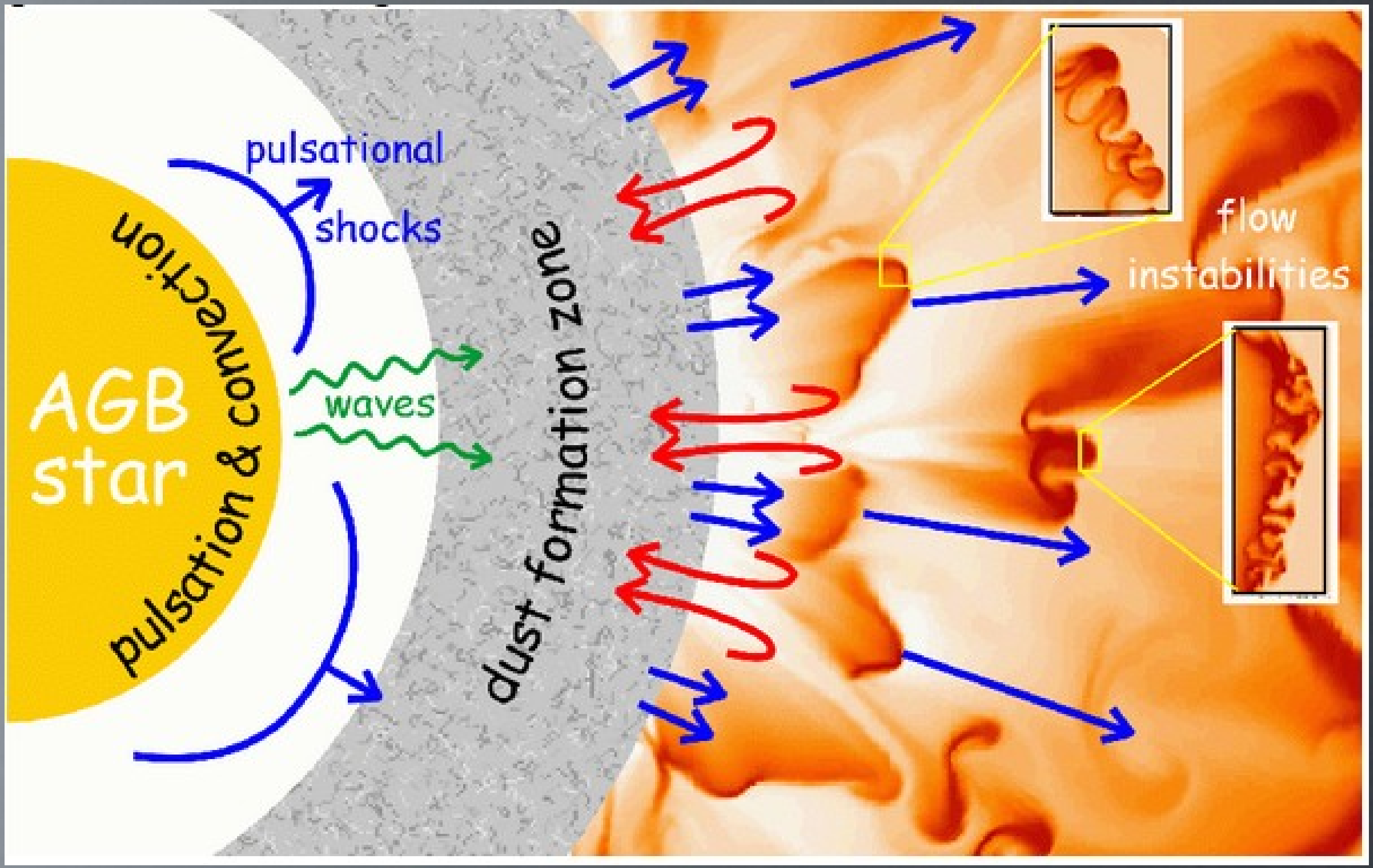


Gobrecht, Cherchenef et al. 2016

Formation of dust in O-rich AGB star IK Tau
Non equilibrium, chemical kinetic study

Crucial to understand mass loss

Dust in stars



Photospheric shocks/sound waves
Dust formation region
Radiative acceleration on dust

Interferometric observations constrain position of dust shells in AGB stars (*Wittkowski+07, Sacuto+13, Karovicova+13*)

For red supergiants, difficulties to accelerate through radiation pressure

Summary

Non-LTE radiative transfer for all types of stars:
- accurate wavelengths and energy levels (FeIV, V..., Co)
- broadening parameters
- data for collisions w/H

Cool stars:
- molecular lines basic data

Magnetism:
- Landé factors for molecular lines

Dust/envelopes:
- identification of species/clusters
- formation processes
- chemical models of stellar envelopes