Age calibration using wide binaries containing white dwarfs

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OUTLINE

- **Introduction**
  - Motivation
  - Stellar activity
  - Rotation period
- **Age determination for low-mass stars**
  - White dwarfs in wide binaries
  - Method
  - Results
- **Gaia**
- **Summary**

Introduction

Motivation

- **Age is the most difficult stellar parameter to determine**

  the most theoretical grounded method is stellar isochrones
  but can not be applied to most stars, low-mass stars (MS)

  → proxy indicators of age are necessary:
  stellar activity, rotational period...

- **The derivation of the ages of old low-mass stars has many implications:**

  - calibration of the decrease of high-energy emissions of low-mass GKM stars with age (**Ribas et al. 2005, Silvestri et al. 2005**)

  - better knowledge of planetary atmospheres: understanding the past and current evolution of its host star is essential

  - Age-rotation relation: there are activity-P_{rot} relations, but the link with age is problematic (**Guinan et al. 1995, 1996, Mamajek & Hillenbrand 2008**)

Introduction

Stellar Activity

- Dynamo mechanism is a magnetic field generator
  → Convective envelope + rotation

- Manifest itself as : sunspots
  flares
  active regions, etc…

- There are different **activity indicators:**

Chromospheric activity: **Ca II H & K lines,** **Hα** and other Balmer lines

Coronal activity: **X-ray emission**

Introduction

Rotational period α Age

- **Gyrochronology;** relate rotation period to age

  Activity ⟷ P_{rot} ⟷ Age

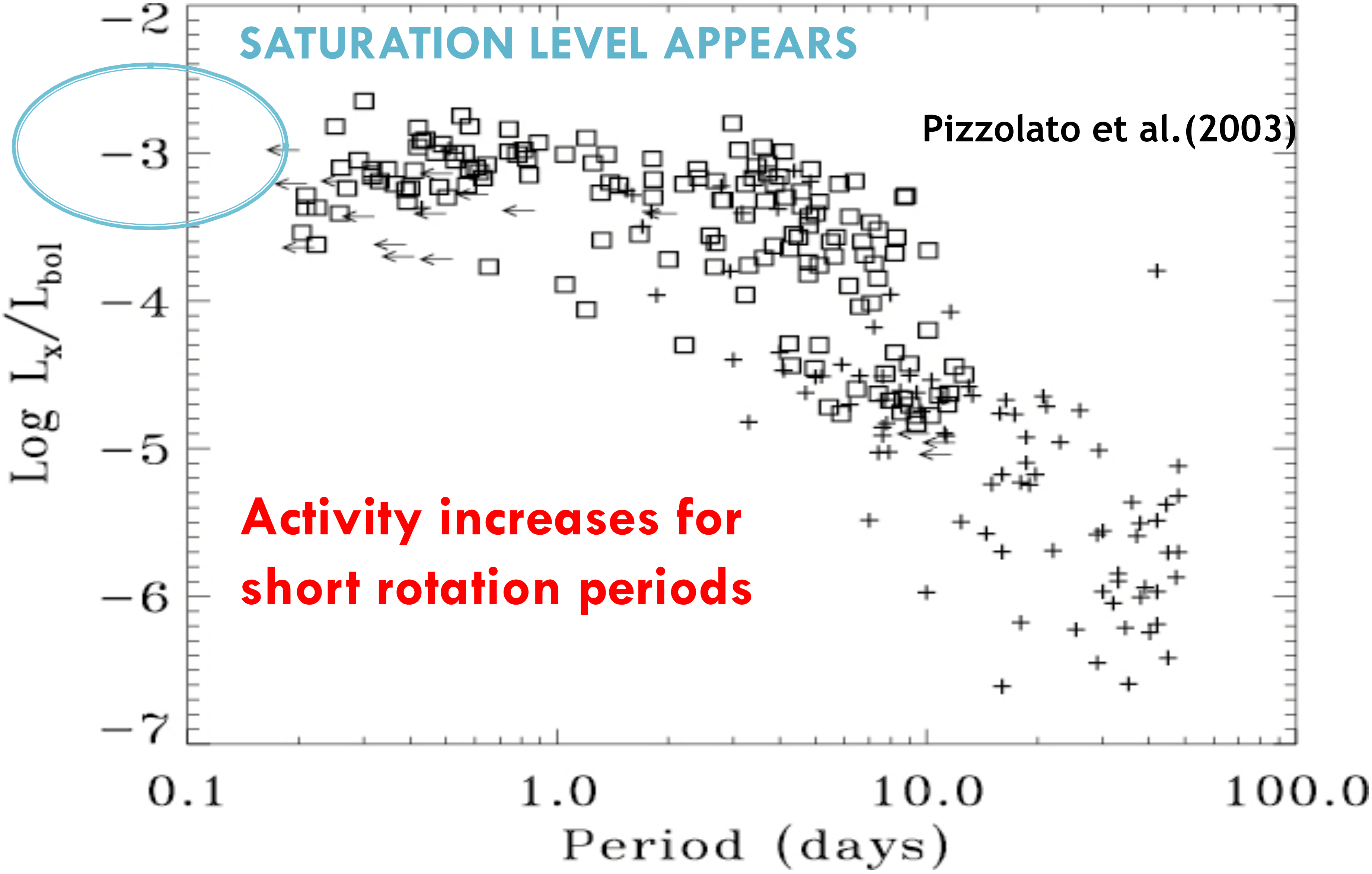
- **Rotation period** only depends on **mass** and **age**

  Barnes (2007) proposed a relationship in this way:

$$P_{rot}(M,t)$$

- **Pizzolato et al.(2003), Guinan & Ribas (2002), Mamajek & Hillebrandt (2008)**

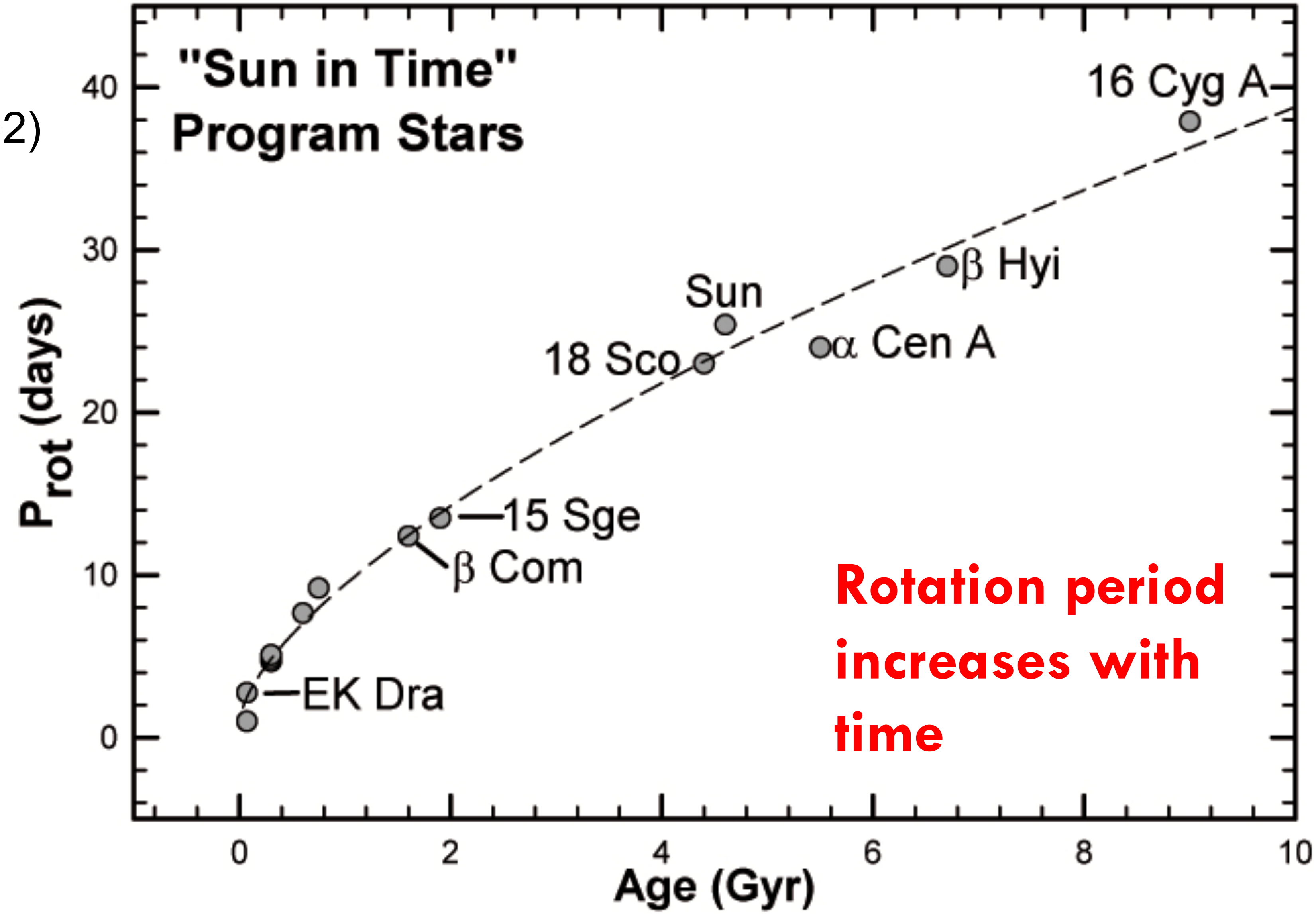
Introduction



Introduction

Rotational period α Age

Guinan & Ribas (2002)



Rotation period increases with time

Introduction

L_x vs Age relation

Preliminar activity vs age relation:

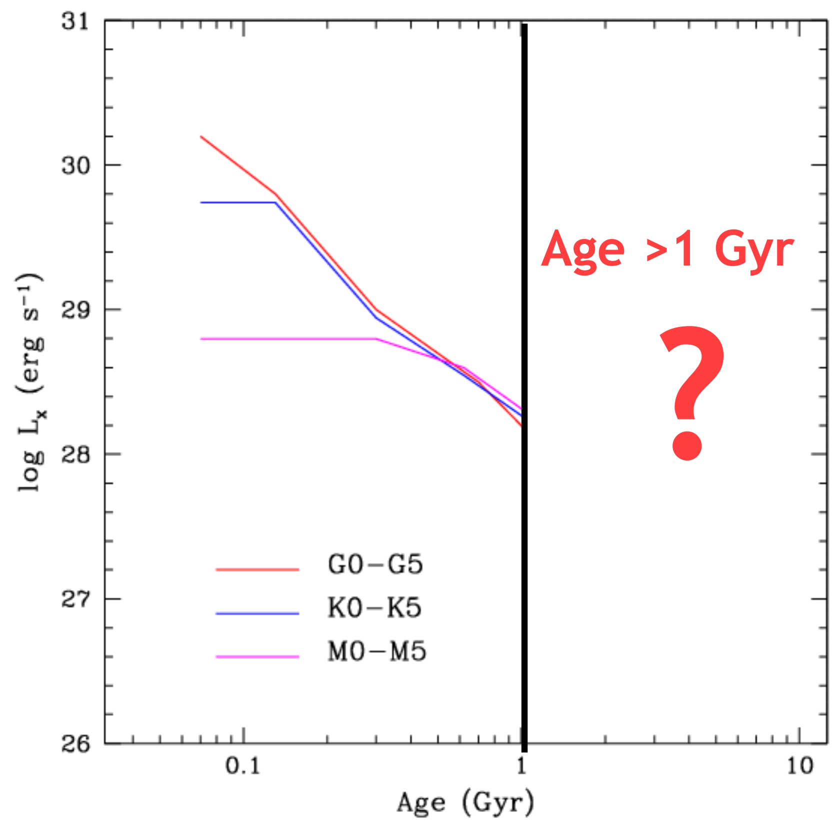
- Ribas et al. (2005)

Age < 1 Gyr: based in open clusters (IC2391, NGC2547, Pleyades, Uma, Hyades… Sun in Time + extension to K and M stars)

Age > 1 Gyr: lack of open clusters

→ alternative method needed

Wide binaries containing WDs: use the WD member to calibrate the age of the system



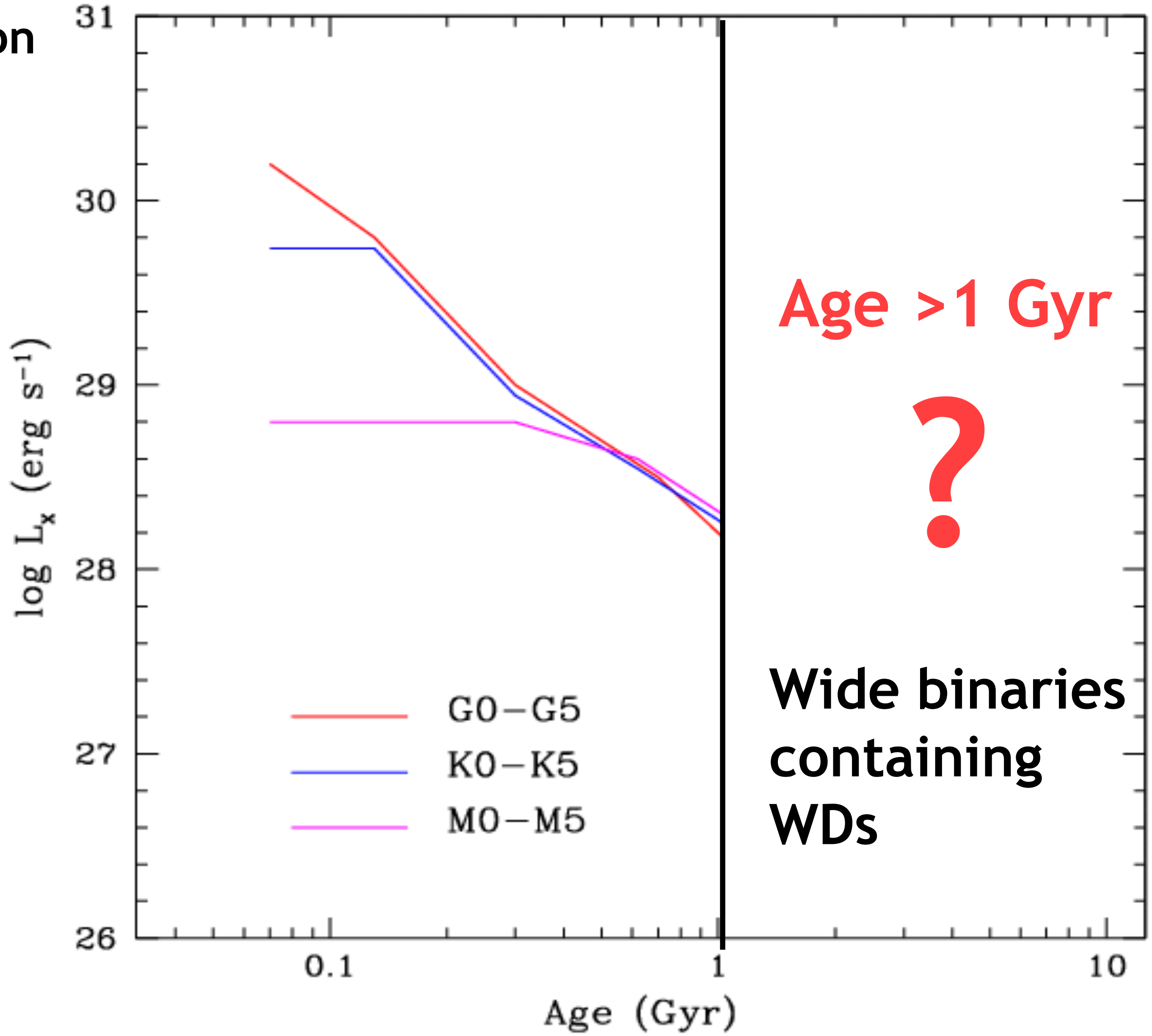
Ribas (2005) Sun in Time + extension to K-M

Introduction

L_x vs Age relation

Ribas et al. (2005)

Sun in Time + extension to K-M stars



es

Ages of low-mass stars

White dwarfs

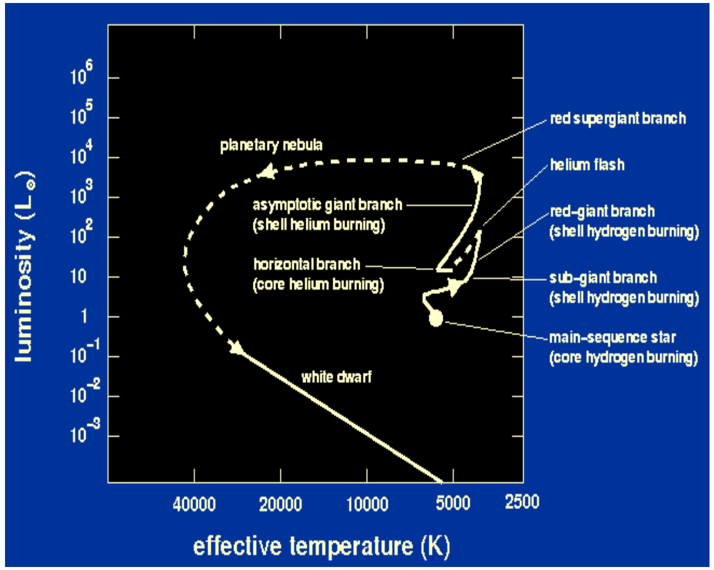
evolutionary end-product of most stars when finishing their main sequence lifetime ($M<8-12\ M_{\odot}$)

The study of the white dwarf population is of great importance for different reasons:

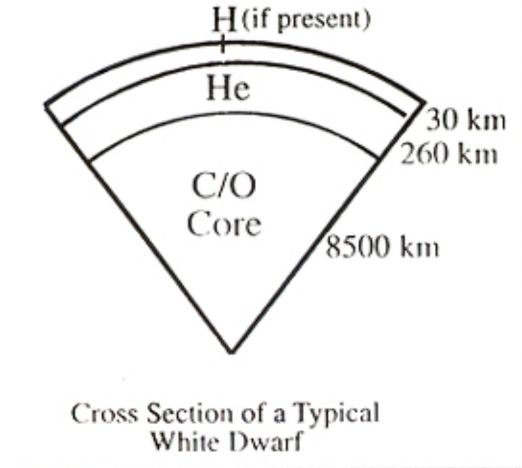
- long-lived stars: information about the age and star formation rate of the Galaxy

- cooling process relatively well-understood, **they can be used as age calibrators**

Total WD Age = $t_{cool} + t_{prog}$

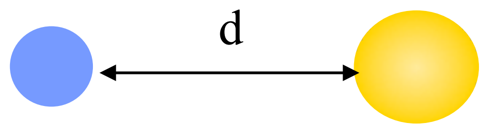


White dwarf structure



Ages of low-mass stars

Wide binaries



- common proper motion
- same metallicity, [Fe/H]
- wide separation, d~100-1000 AU

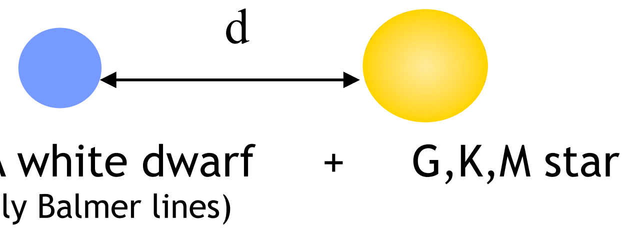
White dwarfs in wide binaries have been studied for years:
Wegner (1973): survey of southern hemisphere wide binaries with WDs
Oswalt (1981): spectroscopic study of wide binaries containing WDs
Oswalt et al. (1988, 1994): Catalogs of WDs in wide binaries

- if the companion is an low-mass star → use the white dwarf member to estimate the age of the old low-mass star **(Silvestri et al. 2005)**

From the study of the WD member we infer the total age of the companion

Ages of low-mass stars

Targets selection



-Chaname & Gould (2004): revision of the NLTT Catalogue
Census: 82 WD + GKM stars (27 DA, 19 DC…)

-Silvestri et al. (2005): 139 M dwarfs in wide binaries, chromospheric activity-age calibration

Spectroscopic observations

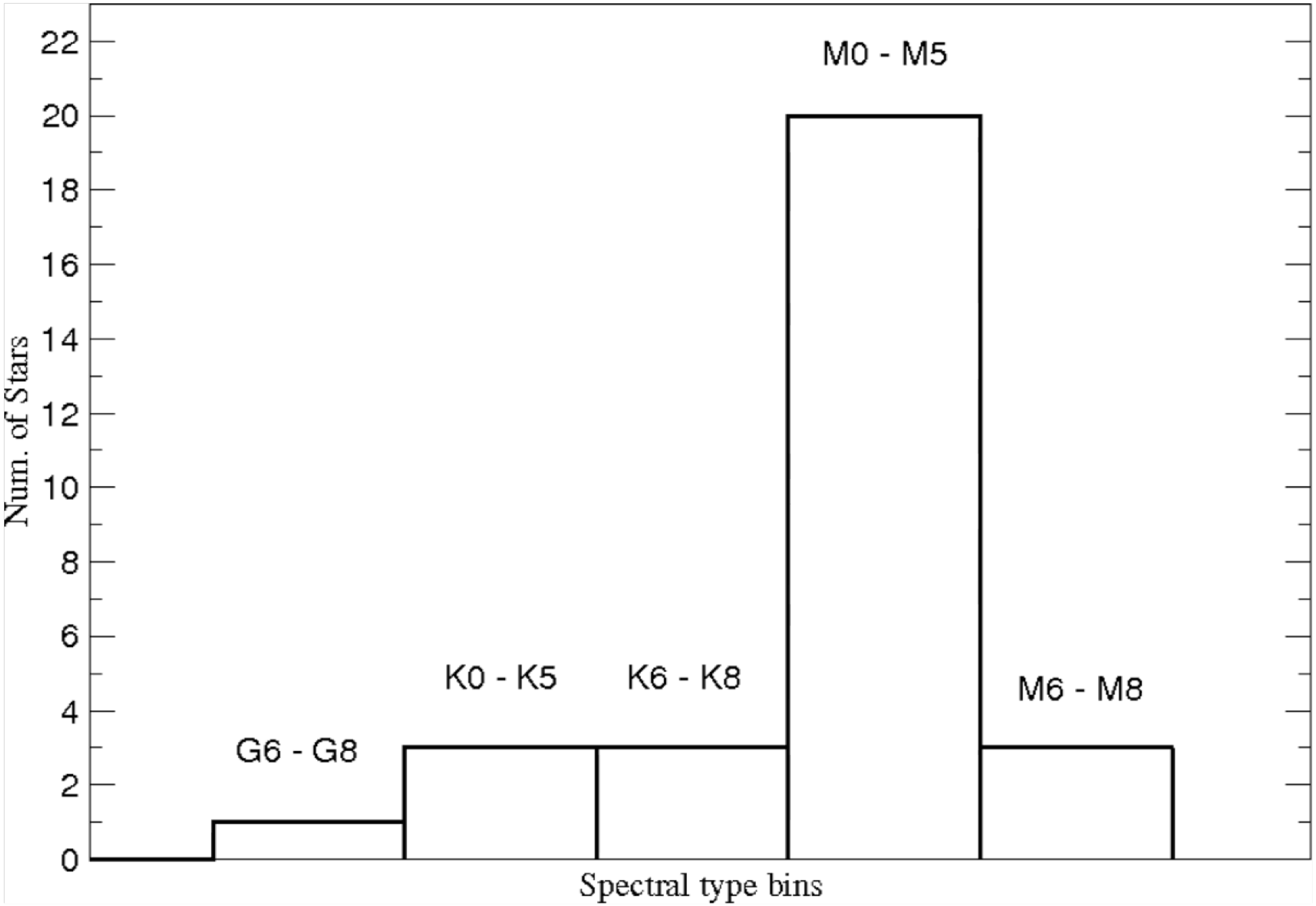
27 DA WD + GKM star

- WDs: 3.5m CAHA + TWIN, WHT + ISIS in la Palma
  R~1000 and S/N>100

- GKM stars: TNG + SARG in la Palma
  Stella in Tenerife
  XMM Newton, Chandra (X-ray)
  R~40000 and S/N>100

Ages of low-mass stars

Census G, K and M stars



Ages of low-mass stars

Method

- **DA WD**

Fit of synthetic models to Balmer lines

D. Koester's models

→ T_{eff}, $\log g$

Cooling sequences →

Salaris et al. (2000)

M_f → t_{cool}

M_f → **Semi-empirical IFMR**

Català́n et al. (2008)

M_i

[Fe/H]

Stellar tracks

Domínguez et al. (1999)

t_{prog}

$t_{cool} + t_{prog}$ = *Age*

Total age of the wide binary, i.e., total age of the GKM star

Ages of low-mass stars

Method

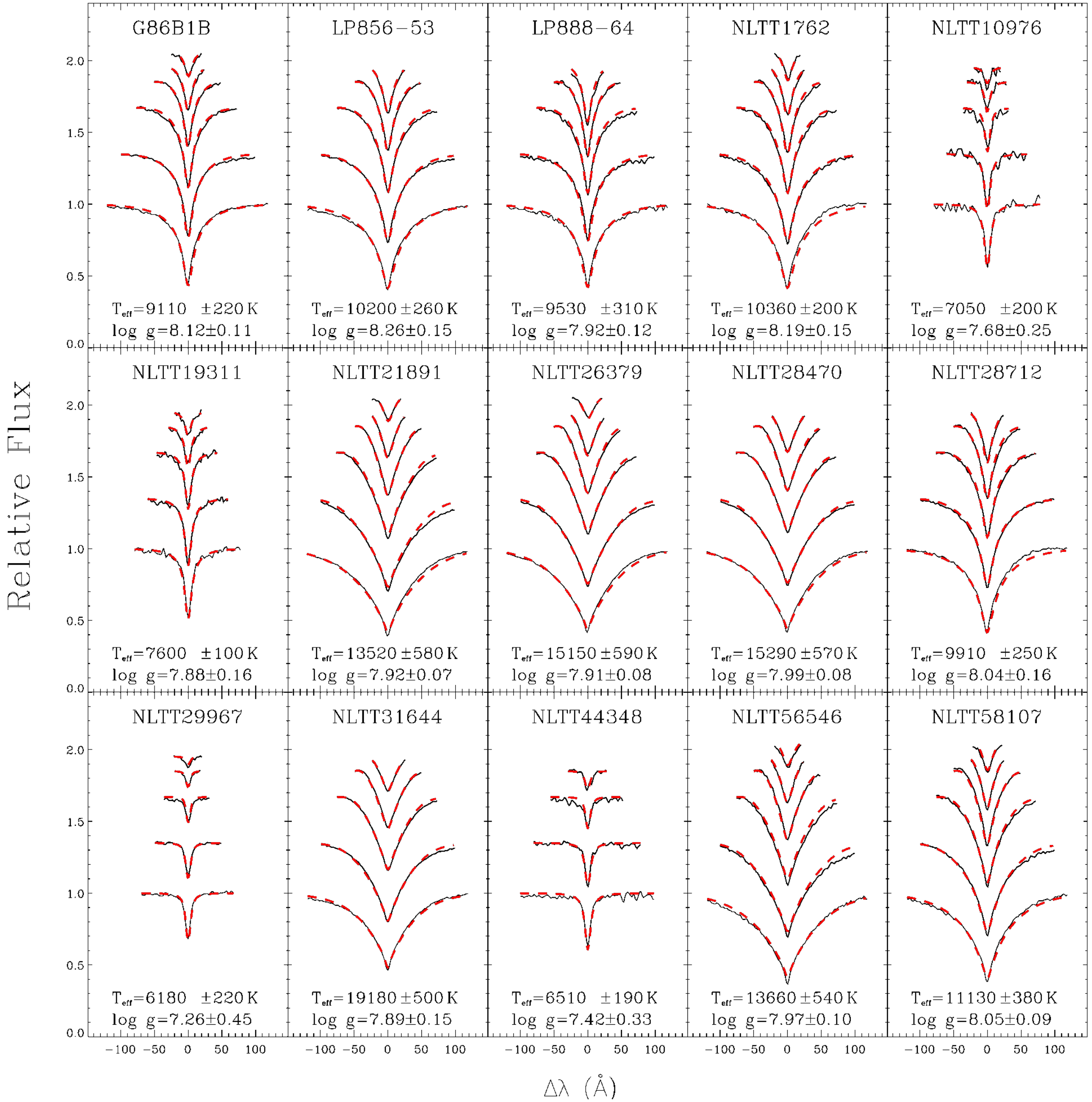
- **DA WD**

Fit of synthetic models to Balmer lines

Atmospheric Parameters

T_{eff}

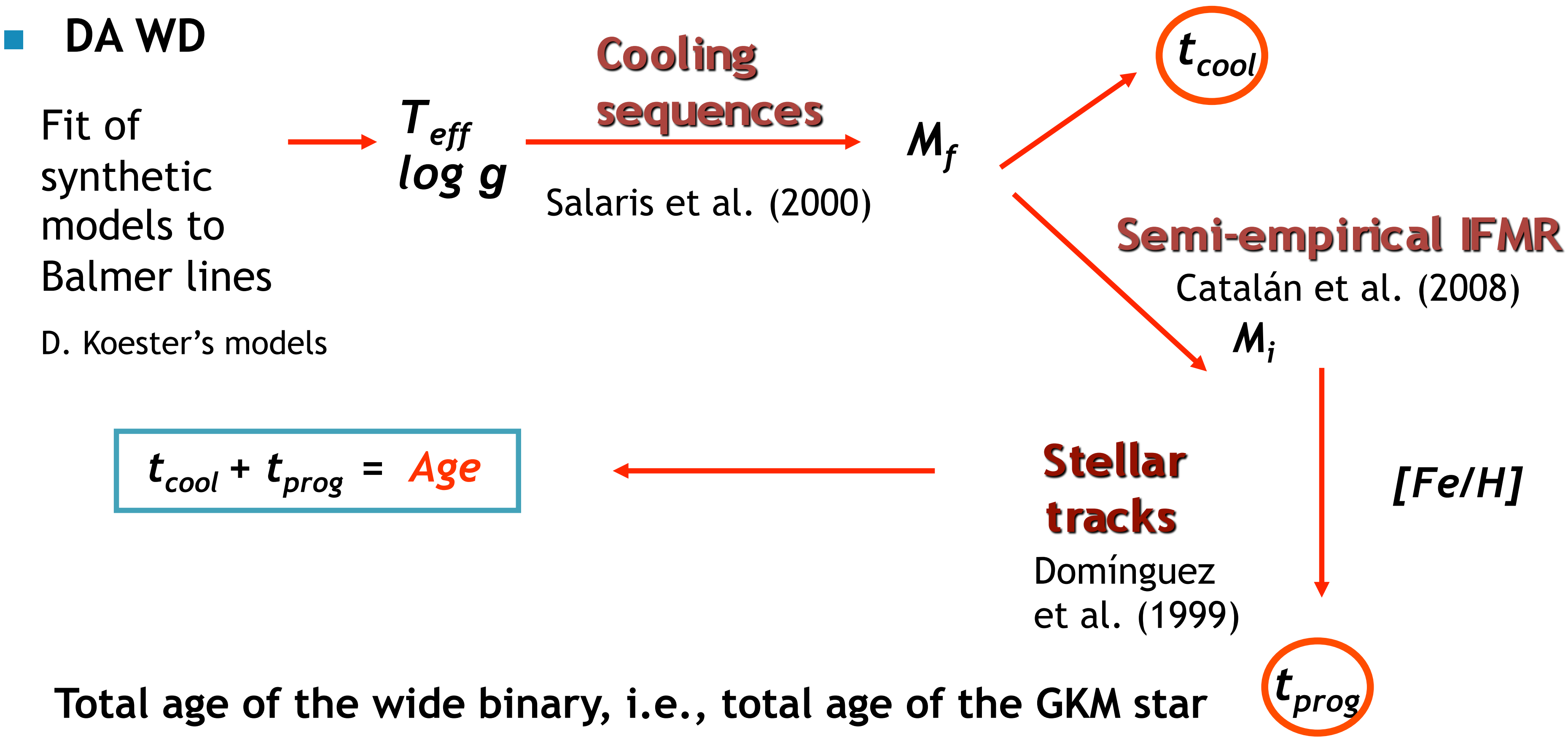
log g



Garcés, Catalán & Ribas 2011, A&A, 531, 7

Ages of low-mass stars

Method



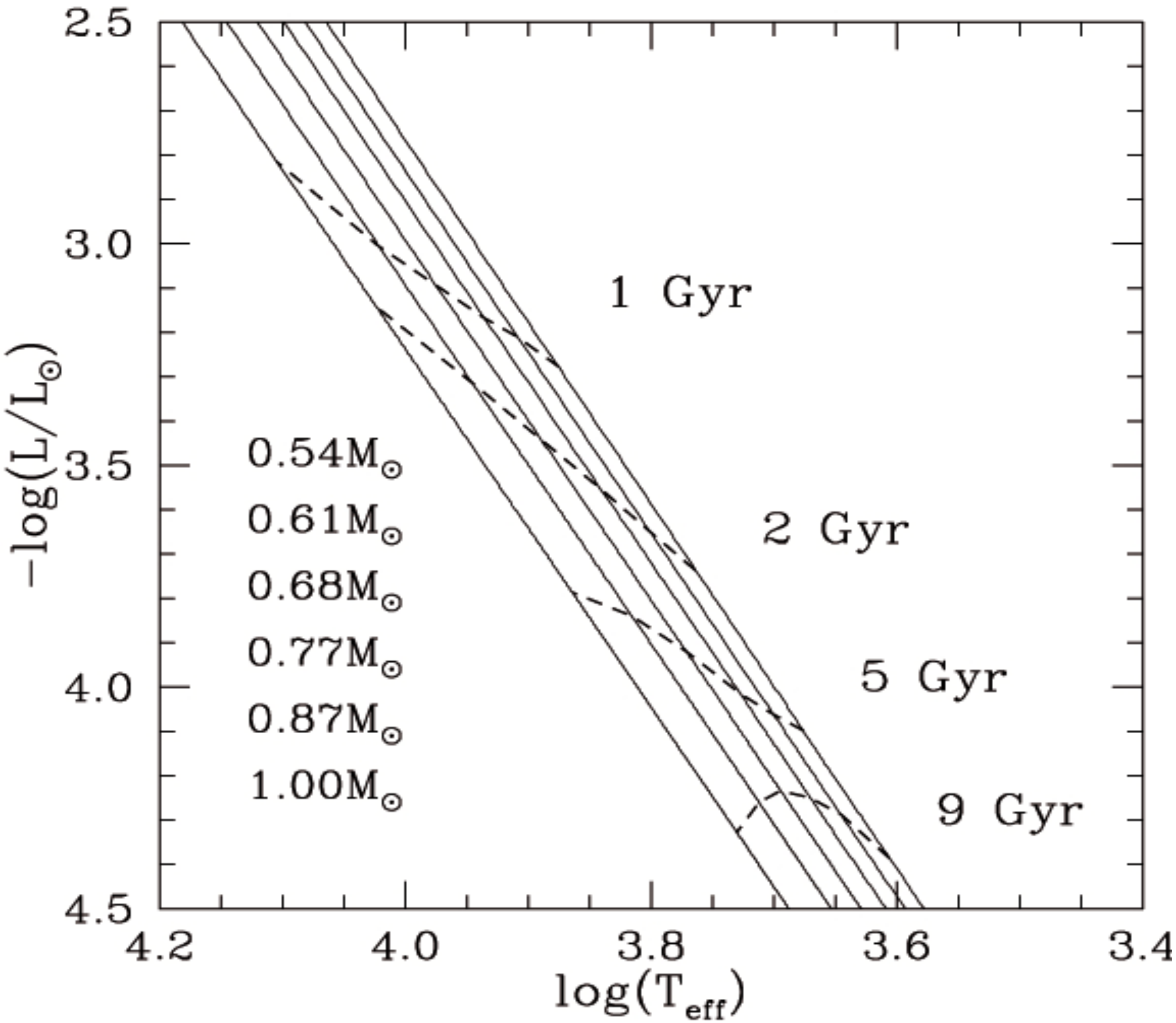
Ages of low-mass stars

Method

- **DA WD**

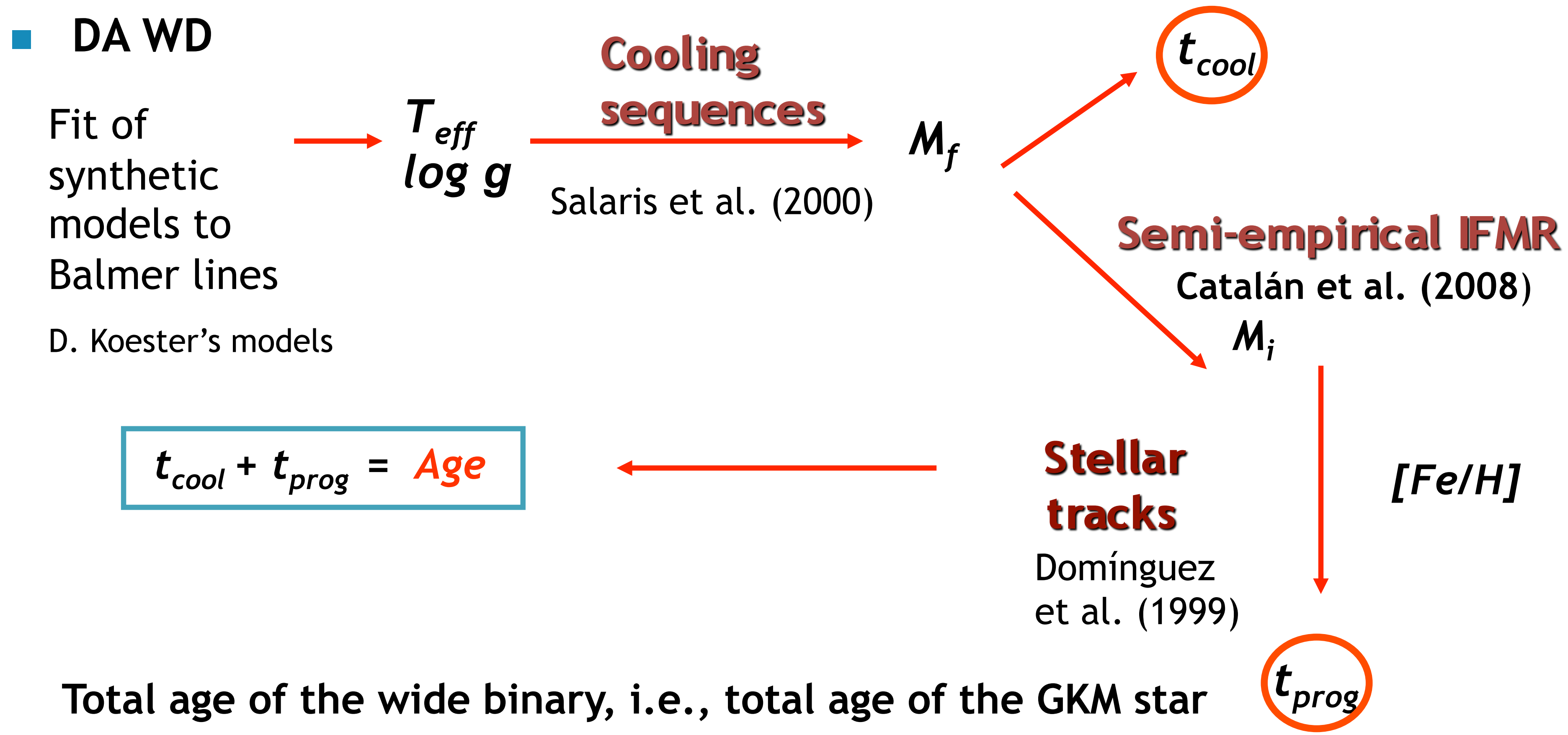
  We use cooling sequences of Salaris et al. (2000) to obtain the cooling time

  t_{cool}



Ages of low-mass stars

Method



Ages of low-mass stars

Results

Ages obtained > 1 Gyr → we are able to cover the L_x-age calibration in this domain

Considering:

- dependency on the models (cooling sequences, stellar tracks)
- initial-final mass relation adopted (intrinsic dispersion)

The ages are derived with an error of 20-30% aprox.

WD	T_{eff} (K)	M_{wd} ($M_\odot$)	t_{cool} (Gyr)	M_i ($M_\odot$)	t_{prog} (Gyr)	Age (Gyr)
NLTT28470	15290 ± 450	0.61 ± 0.03	0.18 ± 0.02	1.86 ± 0.38	1.49 ± 0.40	1.67 0.40
NLTT28712	9910 ± 250	0.63 ± 0.07	0.62 ± 0.09	2.05 ± 0.74	1.15 ± 0.50	1.77± 0.50
NLTT56546	13660 ± 540	0.59 ± 0.04	0.82 ± 0.10	1.72 ± 0.45	1.93 ± 0.60	2.17± 0.60
NLTT21891	13520 ± 580	0.57 ± 0.03	0.23 ± 0.03	0.18 ± 0.02	3.40 ± 1.00	3.60± 1.00
NLTT13110	6630 ± 220	0.59 ± 0.08	1.61 ± 0.35	0.30 ± 0.12	2.30 ± 1.10	3.90± 1.10
LP347-4	12760 ± 230	0.56 ± 0.02	0.27 ± 0.03	2.27± 0.02	4.30 ± 1.00	4.50± 1.00

Ages of low-mass stars

Results

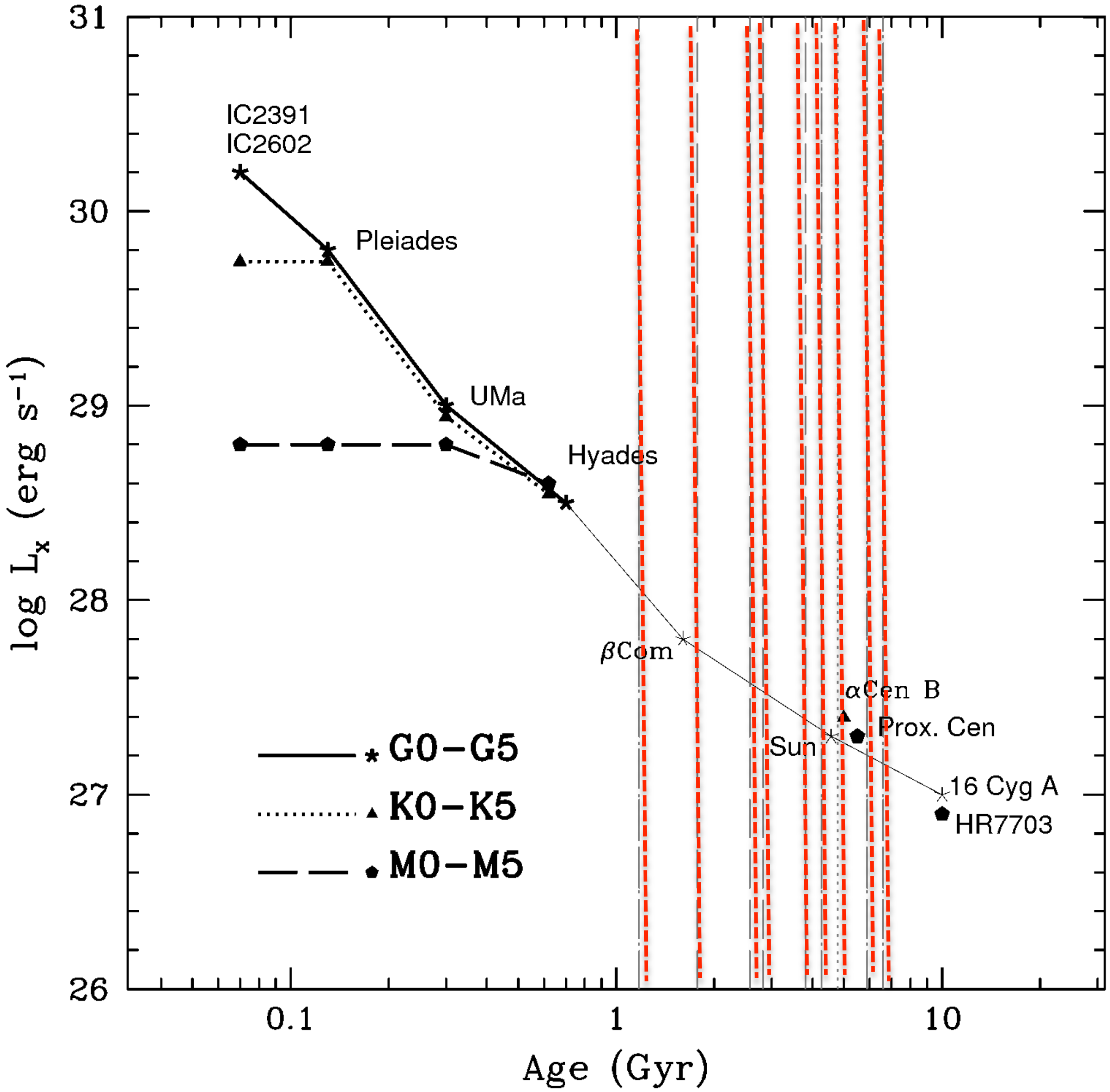
We have studied 27 wide binaries containing

DA WD + GKM star

ages obtained > 1 Gyr

we are able to cover the L_X-age calibration in this domain

Garcés, Catalán & Ribas 2011, A&A, 531, 7



Ages of low-mass stars

Future work

We are currently working in the analysis of the spectra of the **G, K and M stars:**

- Activity indicators: Hα, CaII H K and Mg lines (**Montes et al. 1995**)

  → link with L_x using flux-flux relations (**Cincunegui et al. 2007, Martinez-Arnaiz et al. 2011**)

- L_x from XMM Newton and Chandra observations

- Metallicities to improve the age determinations if possible

Garcés, Ribas & Catalán 2011, in preparation

White dwarfs in Gaia

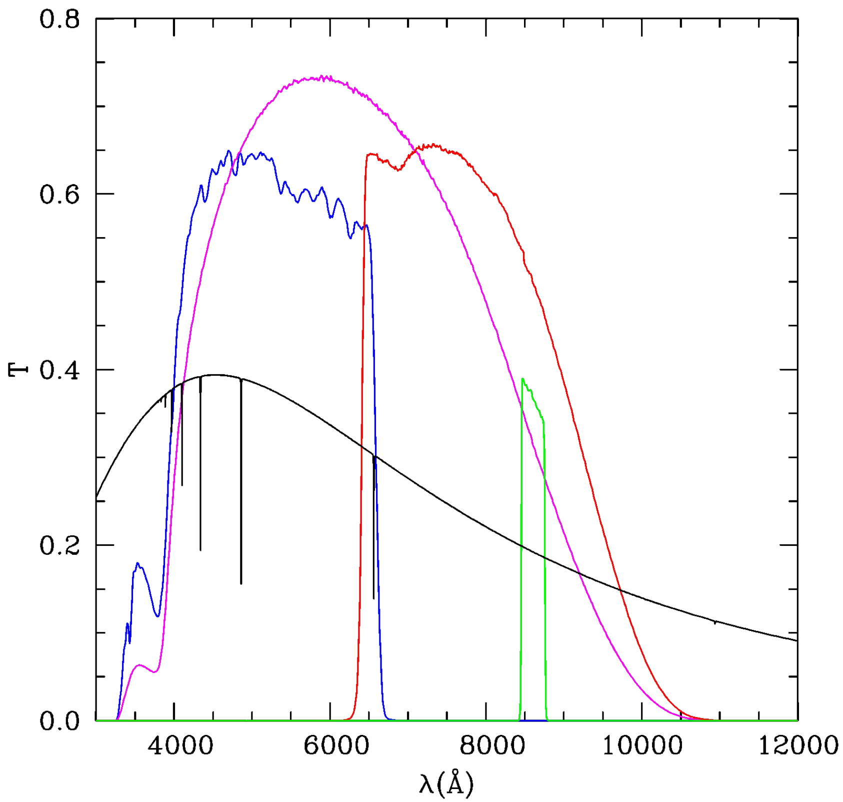
Gaia and the End States of Stellar Evolution, 11 - 14 April 2011, University of Leicester, UK

Torres et al. (1999, 2005), Monte-Carlo simulations:

about 400000 WDs down to V=20 detected by GAIA

According to **Holberg et al. (2008)**:
25% of WDs belong to binary systems,
6.5% to Sirius-like systems (WD + K-type or earlier companion)

→ **100000 binaries containing a WD**



GAIA filters G, G_{BP}, G_{RP}, G_{RVS} + 6000K WD spectrum (black line)

Summary

- Wide binaries with white dwarfs allow to infer the total age of relatively old GKM stars

- This method will allow to determine ages for low-mass stars up to an error **of 20-30% aprox.**

- improve the calibration of the decrease of high-energy emissions of low-mass GKM stars with age

- better knowledge of planetary atmospheres: understanding the past and current evolution of its host star is essential

- Age-rotation relation: there are activity-P_{rot} relations, but the link with age is still problematic