Spectra disentangling applied to the Hyades binary θ^2 Tau

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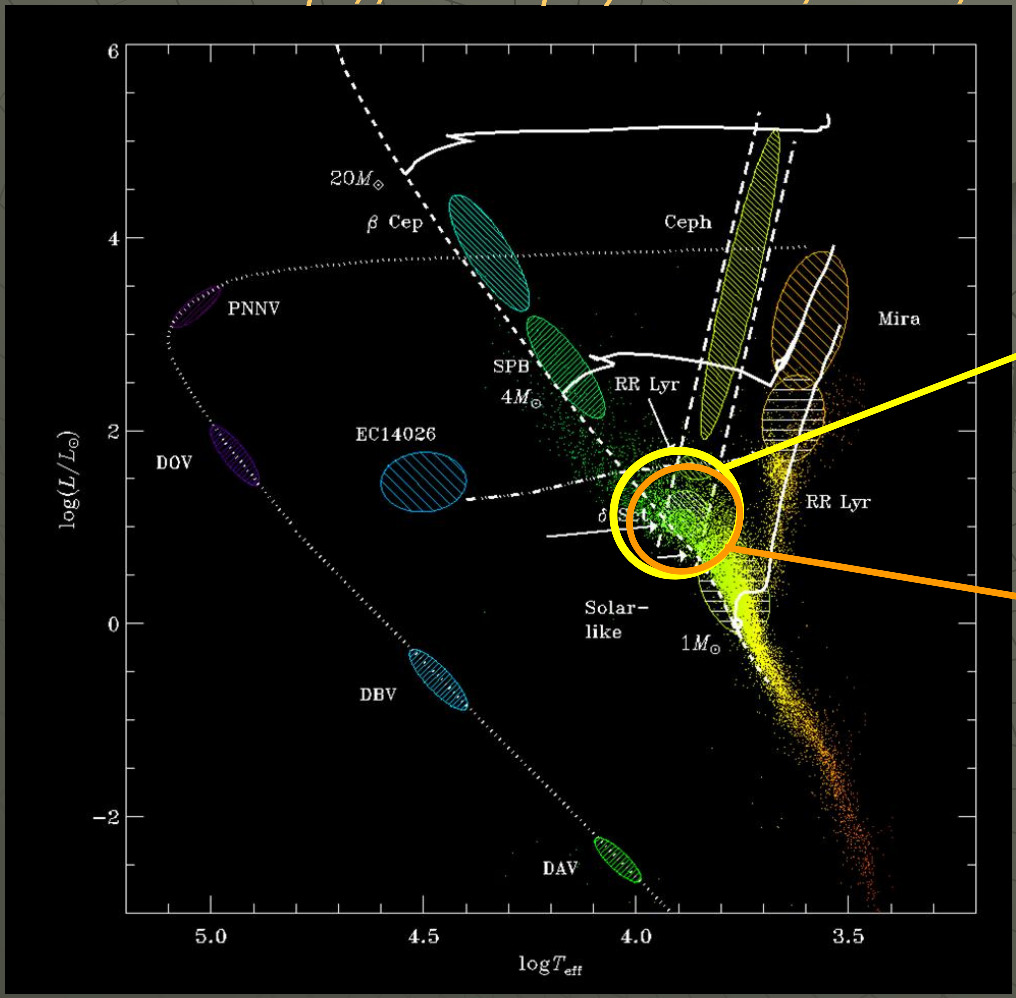
Special region of the HR diagram

Source: *http://astro.phys.au.dk/KASC/*



A2-F2/V-III

δ Scuti pulsating stars

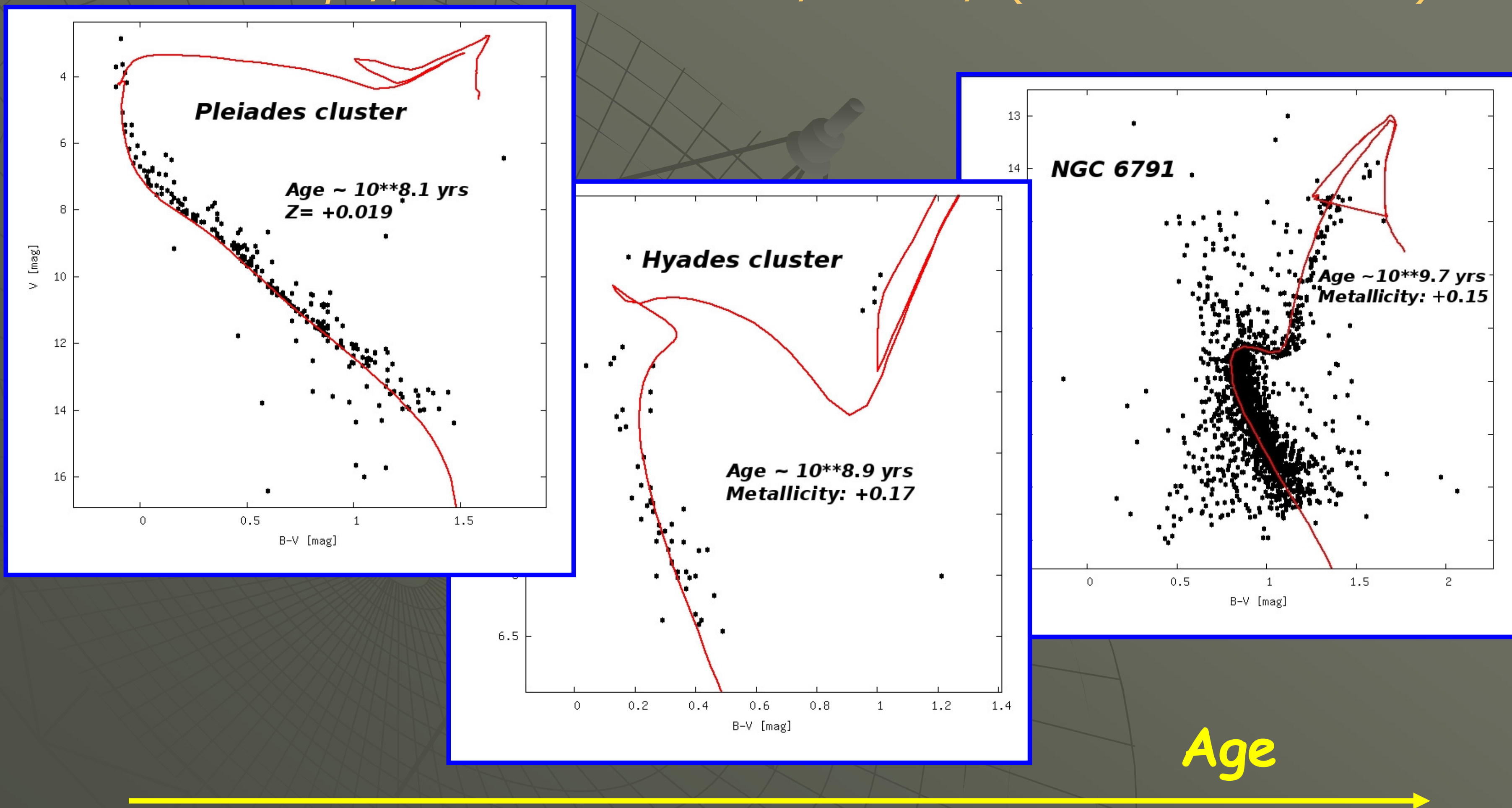
Variations ~ few hours (p-modes)
Amplitudes ~ 0.001- 0.3 mag
Rapid rotation (v.sin i ~ 100 km/s)
Standard chemical composition

Am/Fm stars

No or rare variation
Slow rotation (v.sin i < 100 km/s)
Often binaries
Metal-rich (non-solar)

CM diagrams of open clusters

Source: *http://www.univie.ac.at/webda/* (WEBDA database)



Binary & multiple stars

Sources of fundamental stellar parameters

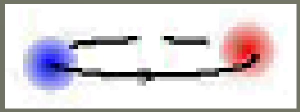
Constraints for stellar formation & evolution

Same origin (age, composition) & same distance

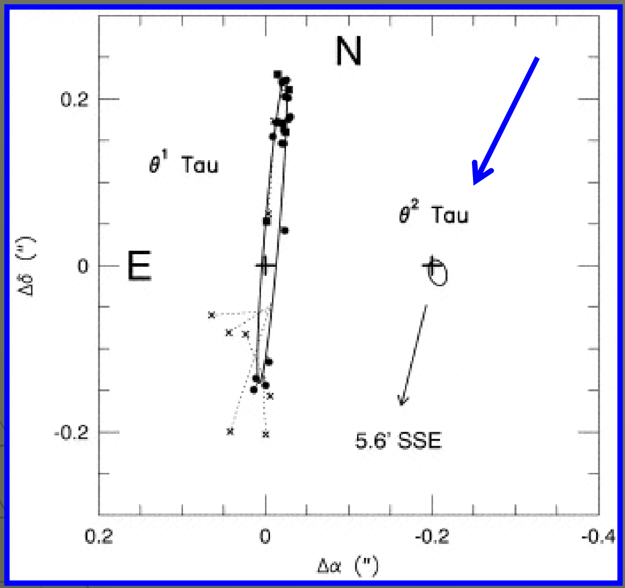
Verification of theories & models

θ^2 Tau AB, a cluster binary

HD 28319 = HIP 20894 = 78 Tau

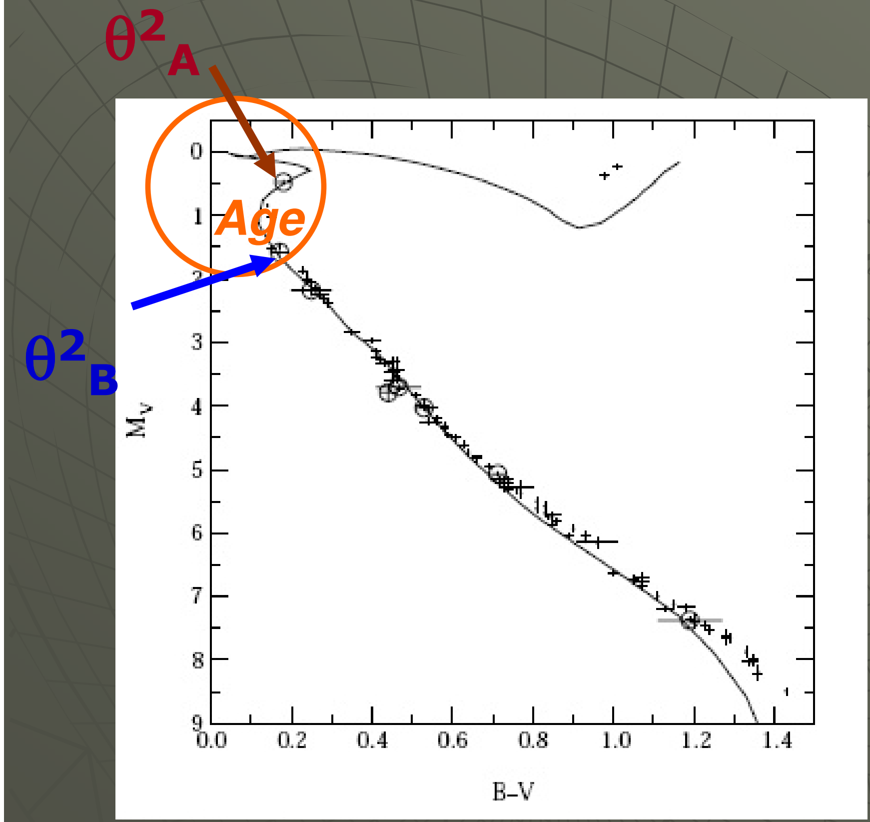
A  B

- AB = assoc. θ^1 Tau (= 77 Tau) resolved by Mark III & NPOI (Armstrong et al. 2006)
  P_{orb} ~ 140.7 days
  e ~ 0.7
  (VB-SB1→SB2) (Torres G. et al. '97 = TSL97)



- ∈ Hyades (d = 45 pc; Y = 0.26; [Fe/H]=+0.14; age = ~625 Myr) (Perryman et al. '98; Grenon 2000)

θ^2 Tau AB, cluster binary



- Located at "turnoff" ⇨ constrains age and convective core overshooting (Sp, θ^2_A=A7 III)
- Located in lower Cepheid instability strip (θ^2_A = multiper. δ Sct pulsator)

Lebreton et al. (2001) [Y = 0.26; Z = 0.024; age = 650 Myr]

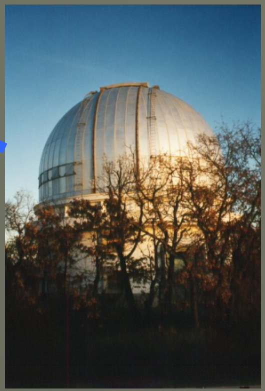
The difficulty

- Rapidly rotating components ⇨ broad & shallow spectral lines ⇨ severe blending of composite spectra ➡ Problem of the correct mass ratio !!

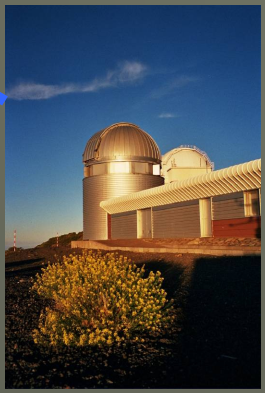
Source	$q = M_B/M_A$
KRL92	0.85 ±0.05
PSL93/P91	0.73 ± 0.05
TPM95	0.77± 0.06
TSL97	0.873± 0.048
LA99	0.82 ±0.05

The data sets

- 70 medium S/N spectra from Oak Ridge Obs., Harvard (Mass.) (Courtesy of G. Torres)
- 44 high S/N spectra with ELODIE, Obs. de Haute-Provence (France)

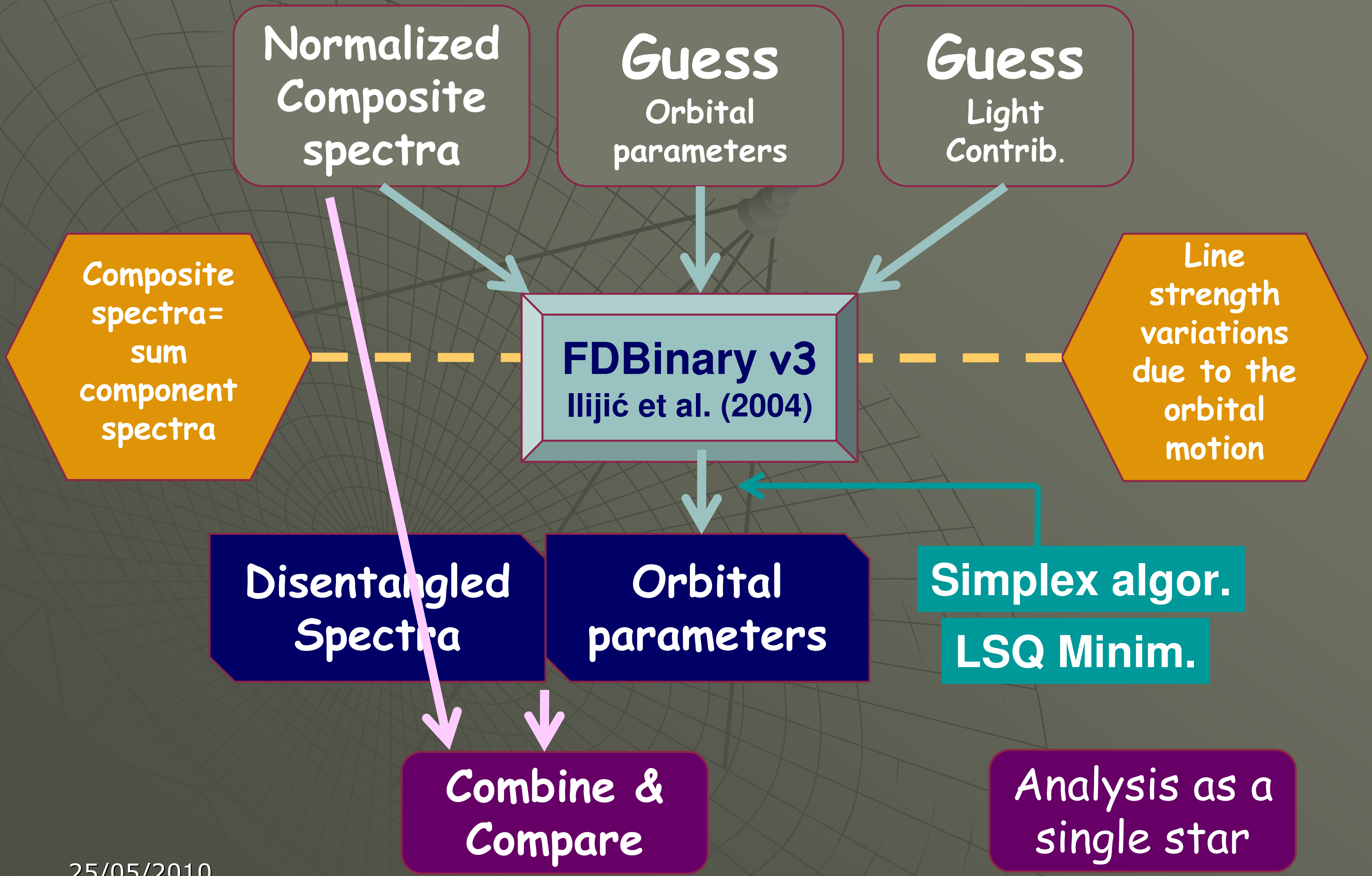


- 13 high S/N spectra with HERMES, Obs. Roque de los Muchachos (La Palma)



⇨ 127 échelle spectra homogeneously distributed in V_{rad} & phase (T=20 yr)

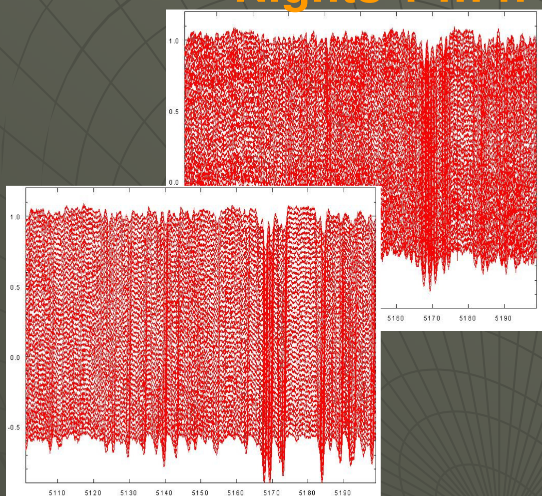
Spectral Disentangling



Spectral Disentangling

Composite spectra

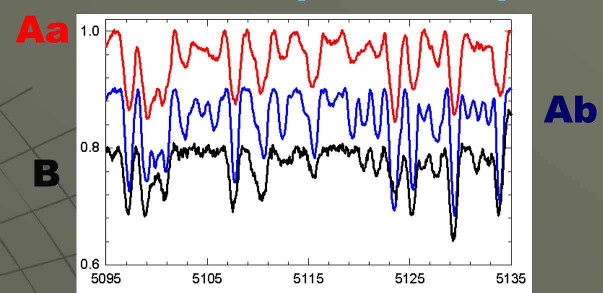
Nights 1 … n



KOREL

Results

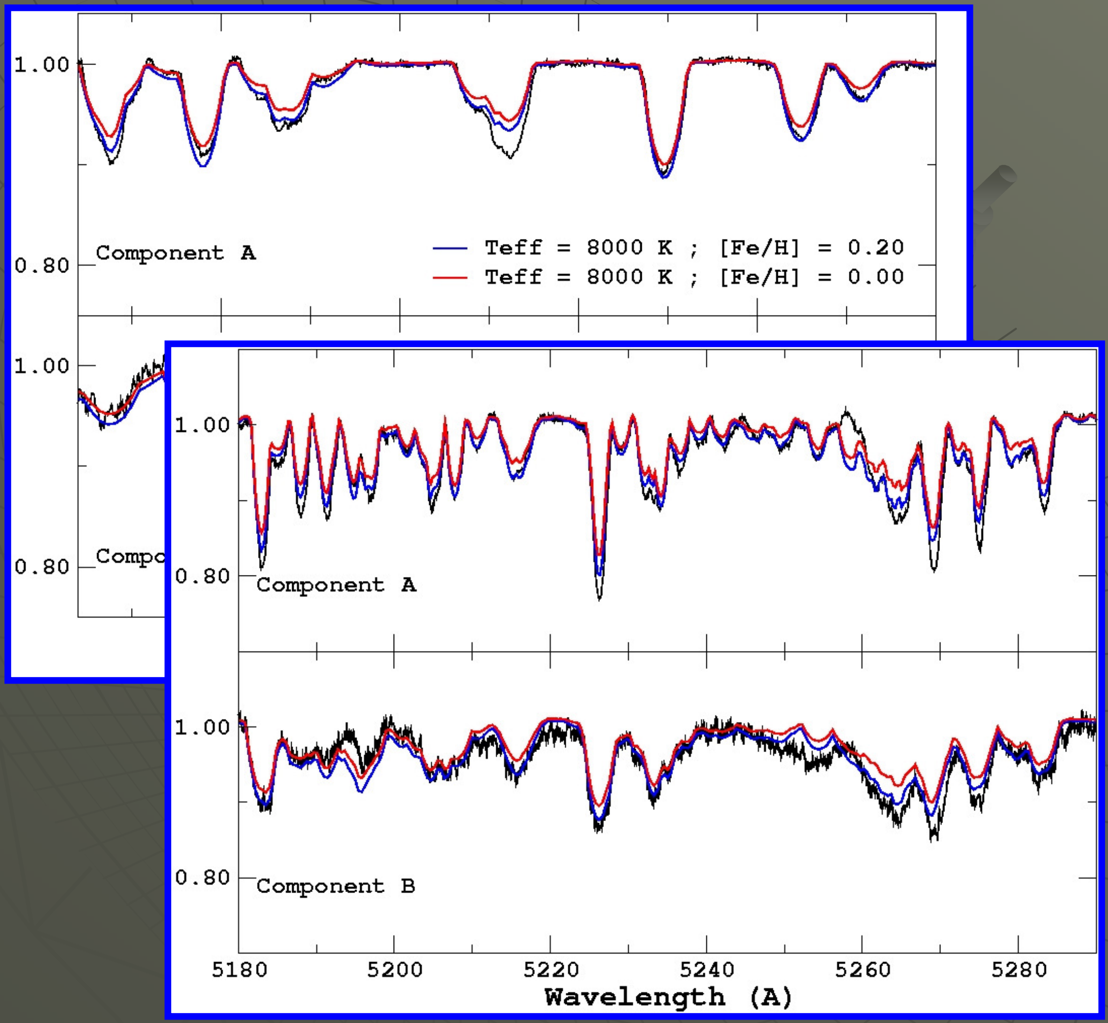
… Component spectra



http://sail.zpf.fer.hr/fdbinary/

http://www.asu.cas.cz/~had/korel.html

Component spectra & metallicity



Confront with model spectra (Y, Z, $\log T_{eff}$, $\log g$):

- [Fe/H]= 0.00
- [Fe/H]=+0.20

Atmospheric parameters

	From synthetic spectra	Ref.star HD2628	TSL97
$V_{rot}(A)$ [Km/s]	68.4 ± 1.5	66	70[a]
$V_{rot}(B)$ [Km/s]	113 ± 6	130	110 ± 4
$T_{eff}(A)$ [K]	7800 ± 170	7308 ± 311	8250[a]
$T_{eff}(B)$ [K]	7800 ± 170	-	-
Log g_A	3.6 ± 0.1	-	4.0[a]
Log g_B	3.9 ± 0.1	-	4.5[a]
γ [Km/s]	39.3 ± 0.9	39.5	39.5 ± 0.2

The combined orbit

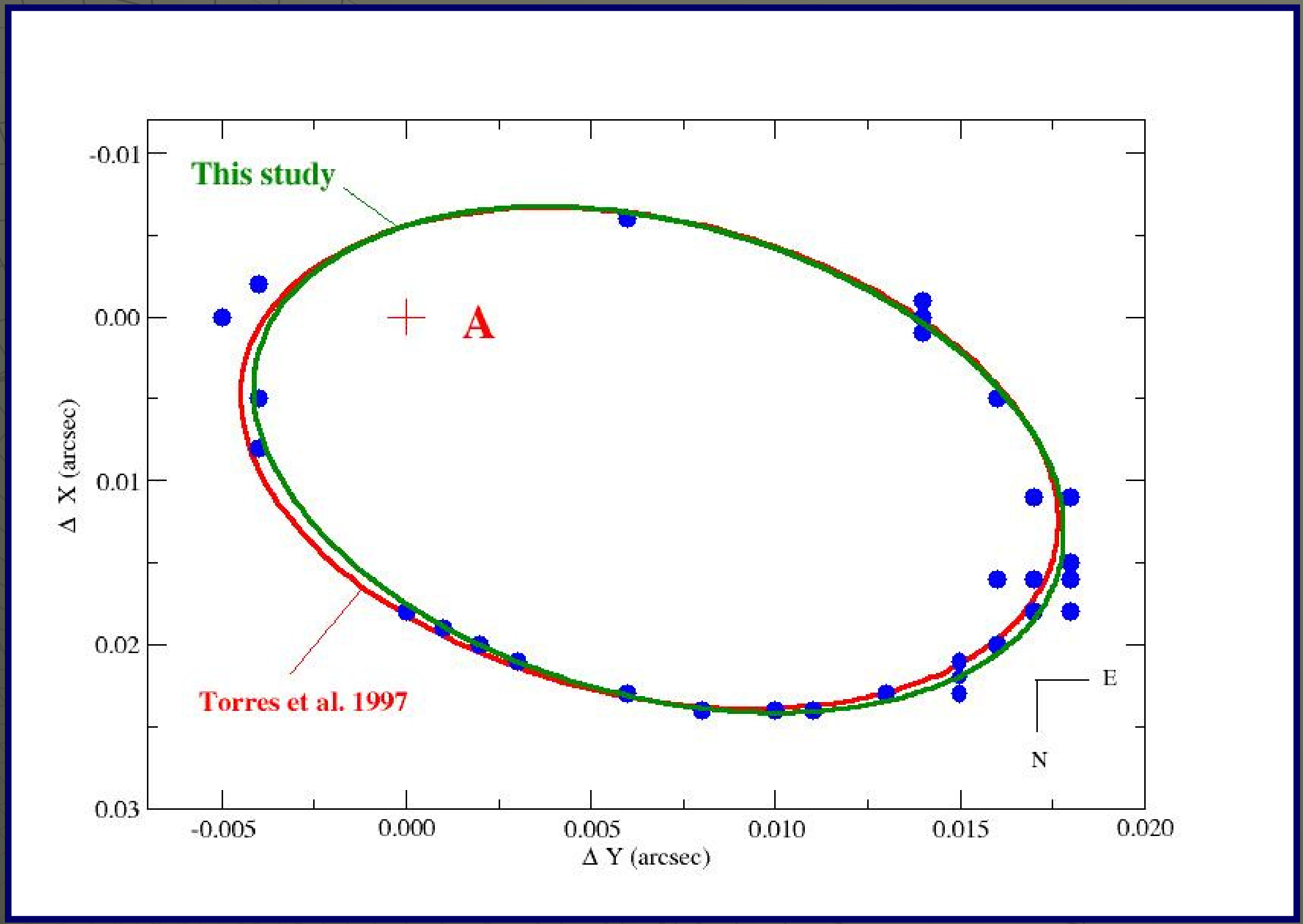
V_{radial} from FDBinary → Spectroscopy

+

Interferometric data from Armstrong et al. (2006) : 34 (t, θ, ρ) → Astrometry

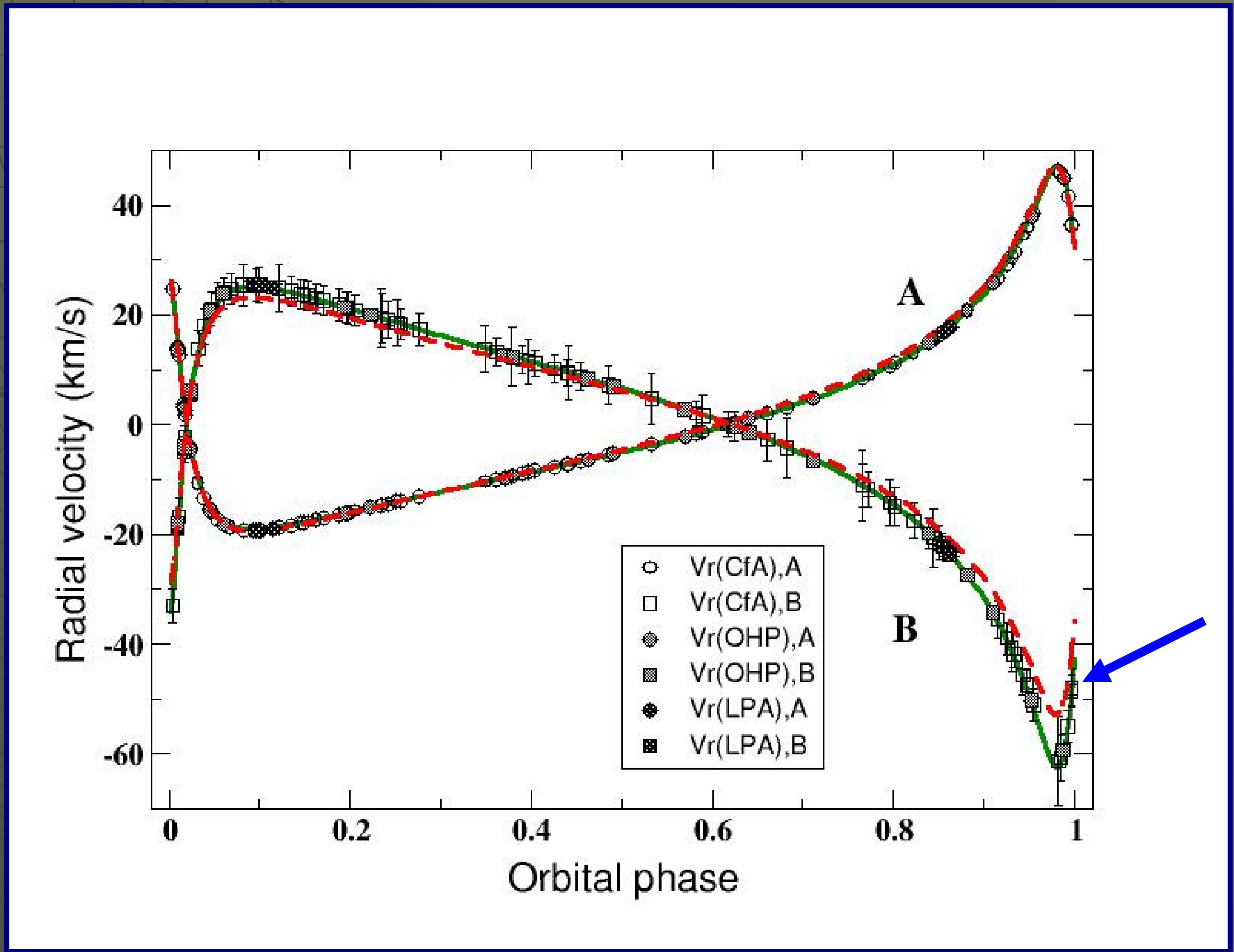
With VBSB2 (global exploration of 10-D parameter space followed by simultaneous LSQ minimisation) (Pourbaix '98)

The astrometric part



$\sigma(O\text{-}C)_\theta = 1.2°$ & $\sigma(O\text{-}C)_\rho = 0.47$ mas

The spectroscopic part



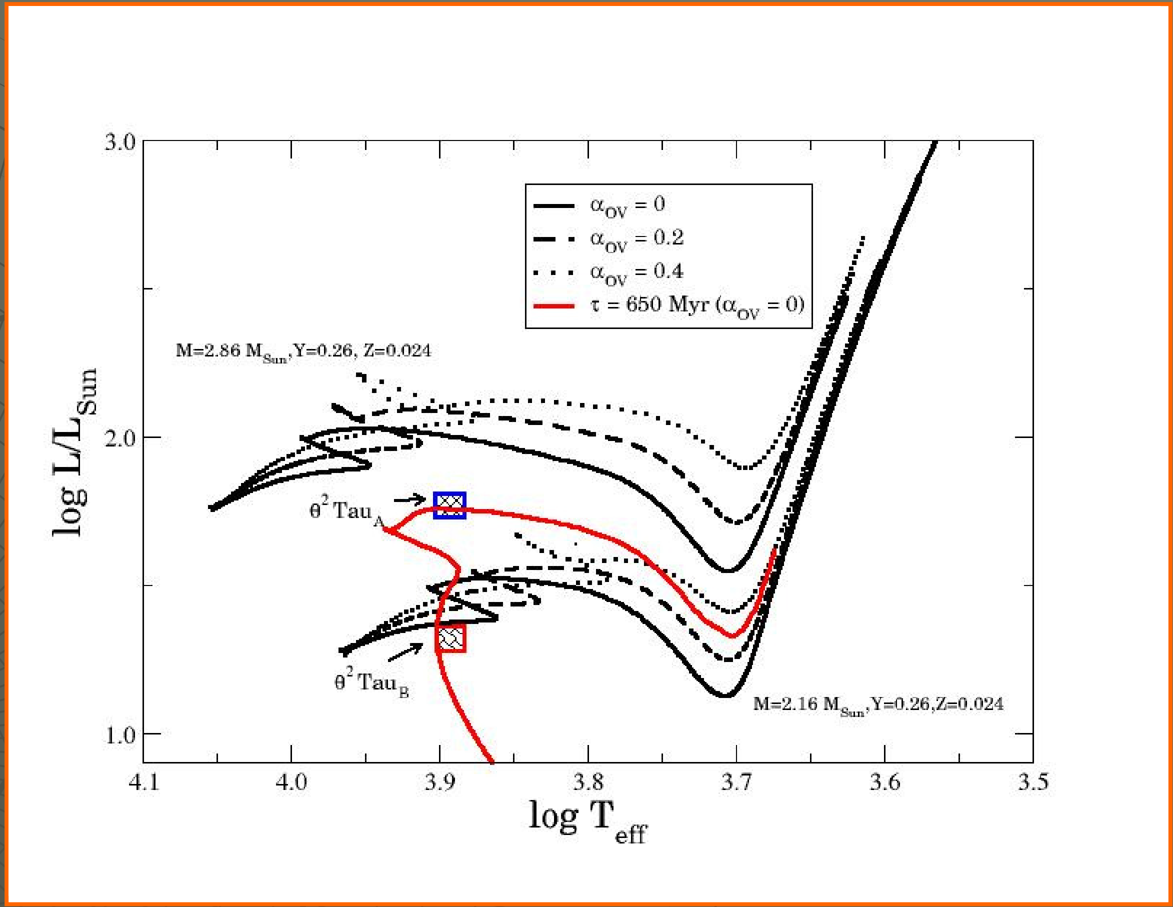
$\sigma(O-C)_{Vr,A} = 0.10$ & $\sigma(O-C)_{Vr,B} = 0.13$ km/s

The full orbital solution

	This work		Torres et al.'97
Period (days)	140.7302 ± 0.0002	✓	140.7282 ± 0.0009
Eccentricity	0.7360 ± 0.0003	✓	0.727 ± 0.005
Inclination	47.8 ± 0.1 °	✓	46.2 ± 1.0 °
Semi-major axis	18.91 ± 0.06 mas	✓	18.6 ± 0.2 mas
K_A (km/s)	32.95 ± 0.04	✓	33.18 ± 0.49
K_B (km/s)	43.68 ± 0.14		38 ± 2
$q \equiv M_B/M_A$	0.754 ± 0.001		0.87 ± 0.05
Parallax (mas)	20.90 ± 0.10	✓	21.22 ± 0.76
M_A ($M_\odot$)	2.86 ± 0.03		2.42 ± 0.30
M_B ($M_\odot$)	2.16 ± 0.02	✓	2.11 ± 0.17

Fundamental component properties

Comp.	A	B
Mass ($M_\odot$)	2.86 ± 0.03	2.16 ± 0.02
Mv (mag)	0.33 ± 0.03	1.44 ± 0.04



CESAM tracks with [Y = 0.26; Z = 0.024]

Conclusions

- Succesful disentangling of the component spectra with FDBinary. For the first time: an objective measurement of the radial velocity amplitude of θ^2Tau B and uncovering of its spectrum.

- Full orbital solution of high (formal) accuracy, i.e. reliable mass ratio, accurate parallax, component masses & luminosities (thanks to previous step).

- The component spectra of θ^2Tau show enhanced metallicity as expected for the Hyades cluster. TO DO: detailed chemical abundance analysis.

- The location of comp B corresponds to the Hyades main-sequence (H-core burning).

Conclusions (2)

- The location of the more evolved component *A* is currently not explained by suitable theoretical models.

- Accurate fundamental properties also very useful for a pulsation modelling (θ^2Tau *A* is a well-studied multiperiodic δ Scuti pulsator).

- TO DO: detailed chemical abundance analysis of both disentangled component spectra & confrontation with adapted theoretical models.

⇨ New insights for understanding the interaction(s) pulsation – rotation - binarity

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