Circumstellar material around main-sequence stars: looking for exocoments and related phenomena

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EXCELENCIA MARÍA DE MAEZTU

The connection exocomets and UXORs

«Many years ago I supposed that the redshifted absorption components which we observed in the Na I D lines in spectra of UXORs have a similar origin as those In β Pic. Later, however, we have shown –together with Antonella Natta- that such a spectroscopic activity can be also explained in the framework of magnetospheric accretion. This explanation dominates at present time.

The intensive accretion process masks the spectroscopic signatures of grazing exocomets. Only in the late phases of PMS evolution, in stars with debris discs, the comet like activity can be observed. So you can show in your talk the very important component of CS activity which exists in young stars as a sequence of planet formation processes, which cannot be observed in the spectra of younger stars due to the intensive disc accretion.»

Vladimir P. Grinin

See e.g. Grinin, Kozlova, Natta et al. (2001)

The connection exocomets and UXORs

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Research

Article submitted to journal

The transiting dust clumps in the evolved disk of the Sun-like UXor RZ Psc

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A final aspect to discuss regarding the origin of the clumps, and their relation to the IR excess, is the transient absorption features. These are seen towards UXors, but also seen towards some main-sequence A stars (e.g. [80–82]), so are not exclusive to stars that host gas-rich disks. For A-type stars these features are generally interpreted as sun-grazing "exocomets", and the same may apply to UXors and RZ Psc.

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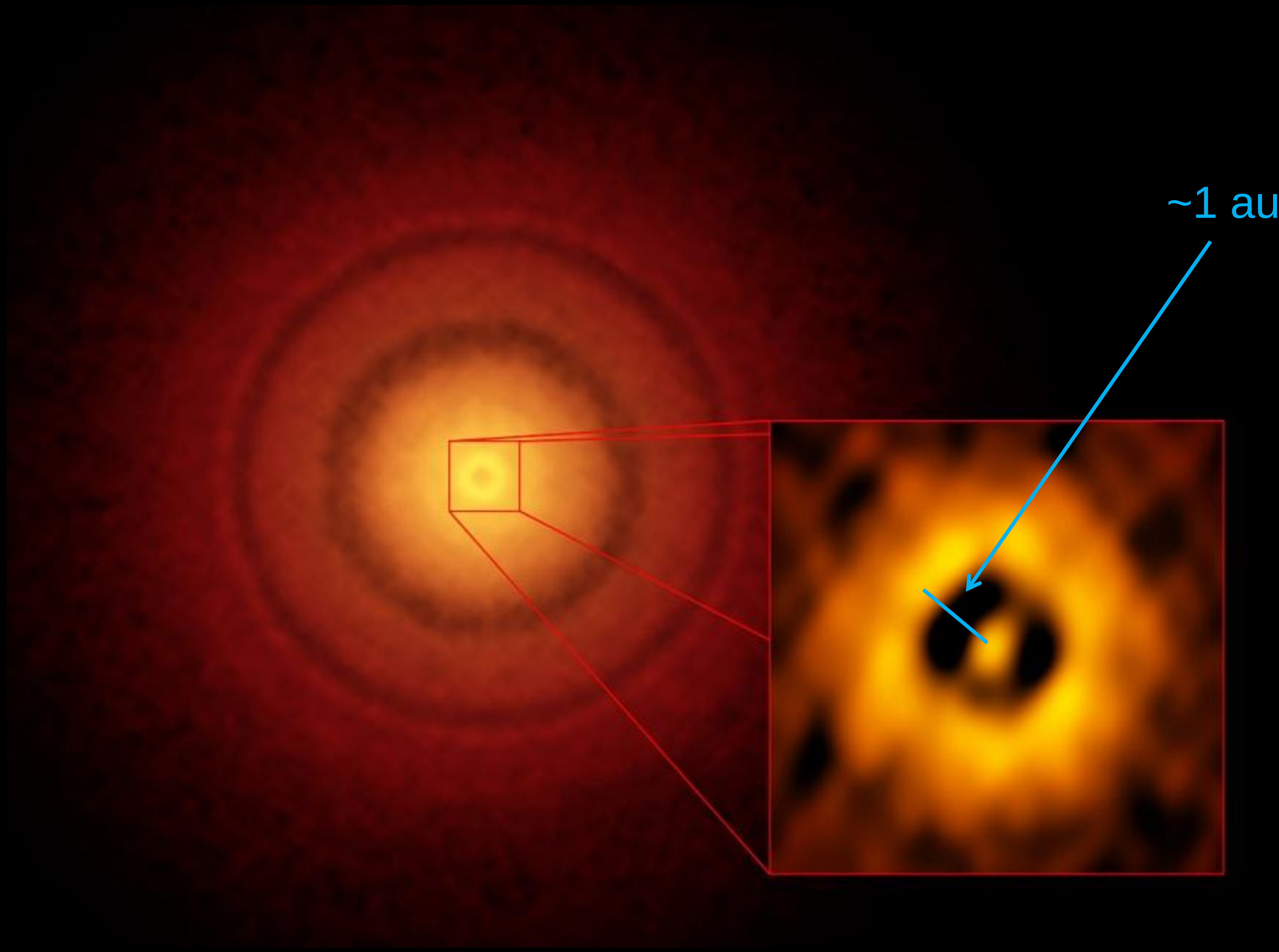
Introduction

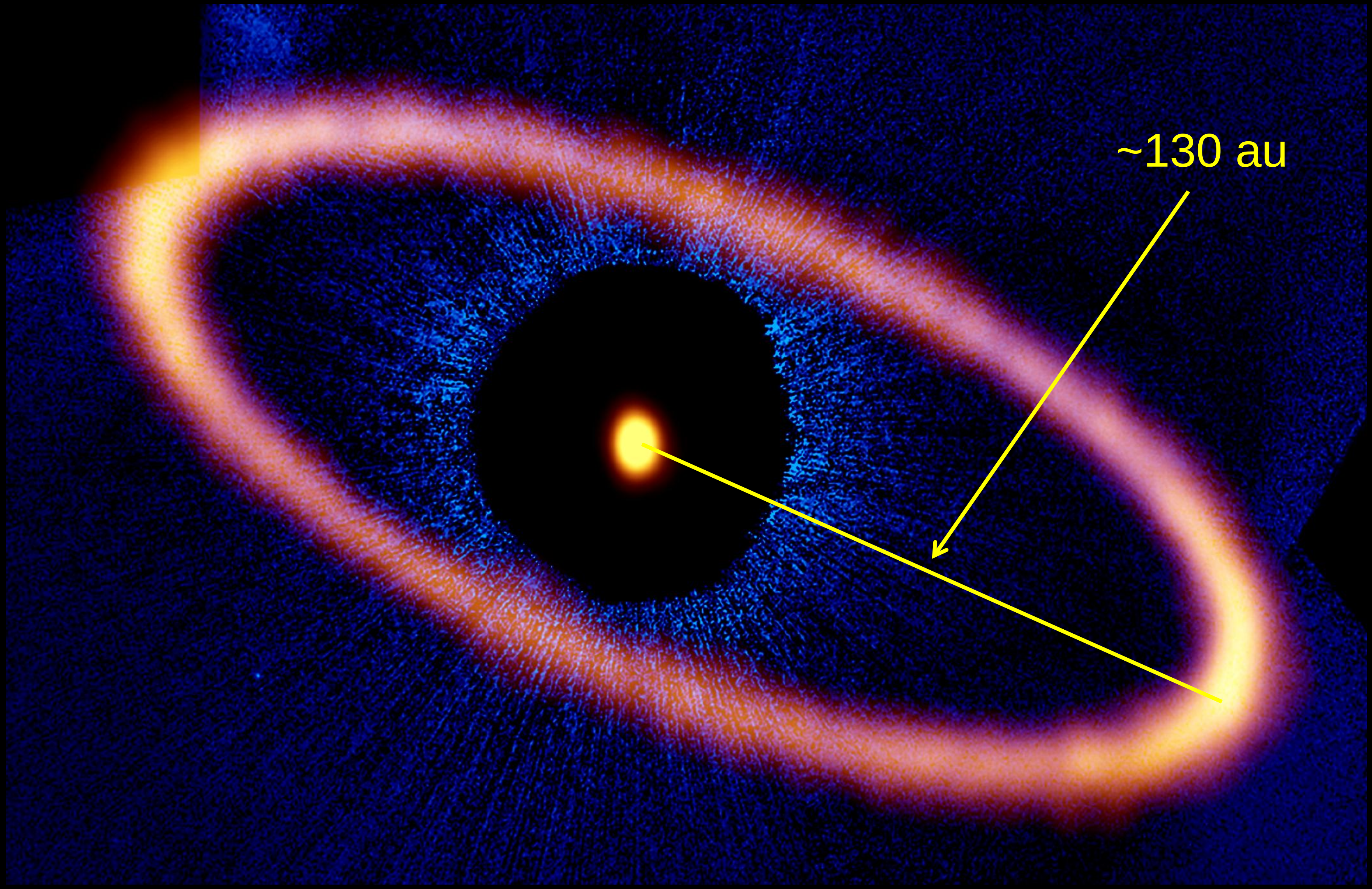
Protoplanetary discs: dense circumstellar discs made of gas and dust surrounding young -age a few Myr's- stars



ALMA image of the protoplanerary disc around TW Hydrae (10 Myr old, 60.1 pc)
S. Andrews (Harvard-Smithsonian CfA), ALMA (ESO/NAOJ/NRAO)

Introduction

Debris discs: circumstellar disc made –mostly!- of dust and debris, surrounding more mature stars. The gas from the protoplanetary disc is depleted and the dust is replenished by the collisions of planetesimals.



Composite image of the Fomalhaut (440 Myr, 7.7 pc) star system. ALMA (ESO/NAOJ/NRAO), M. MacGregor; NASA/ESA HST, P. Kalas; B. Saxton (NRAO/AUI/NSF).

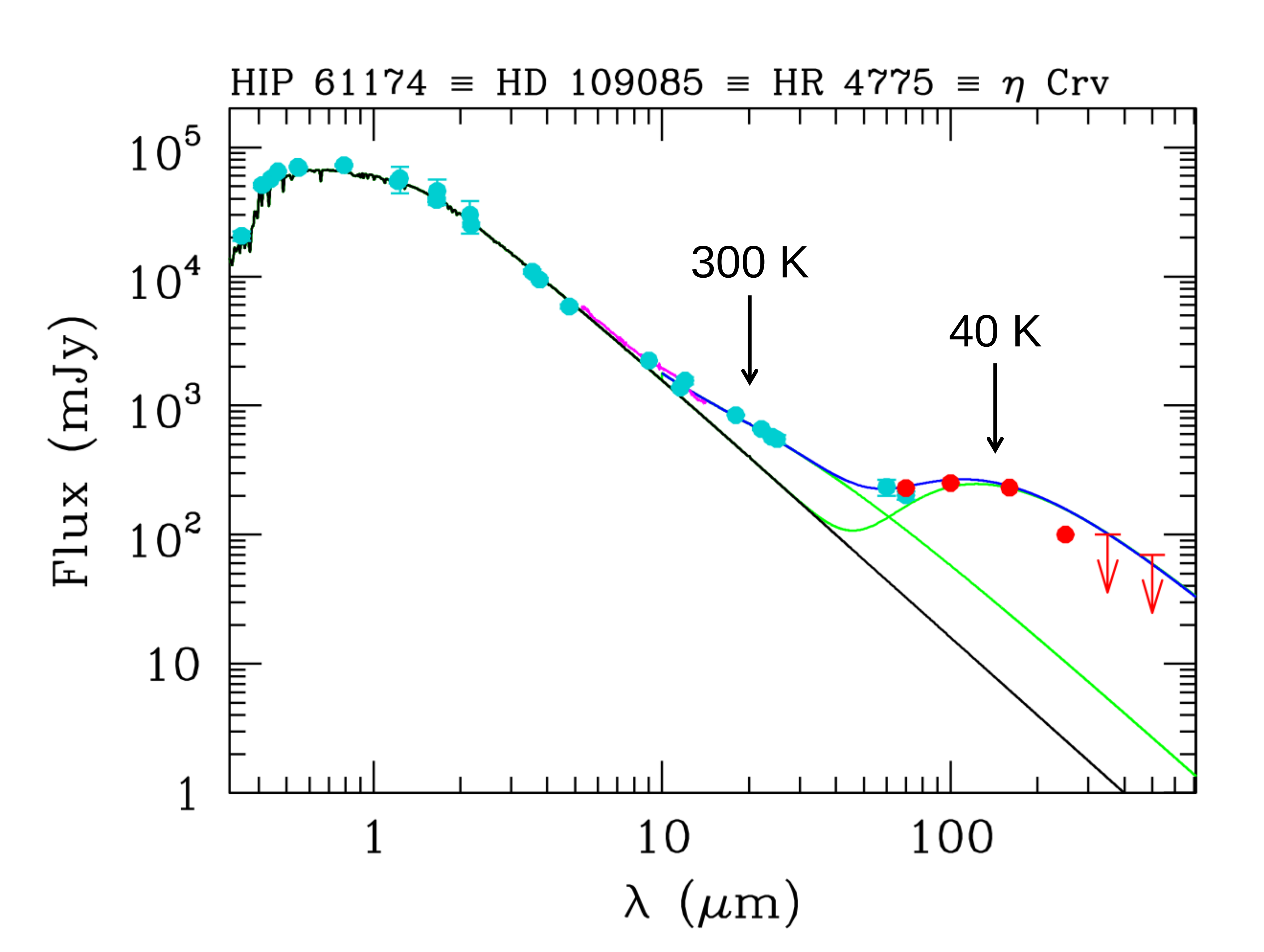
Introduction

Exoplanets are routinely detected, but we have little information about small bodies, which are important to understand the formation and architecture of planetary systems (e.g. Armitage, 2010).

Artist impression of a debris disc (NASA/JPL)

Introduction

We have indirect evidence of the presence of small bodies by, e.g. nIR photometry probing dust.

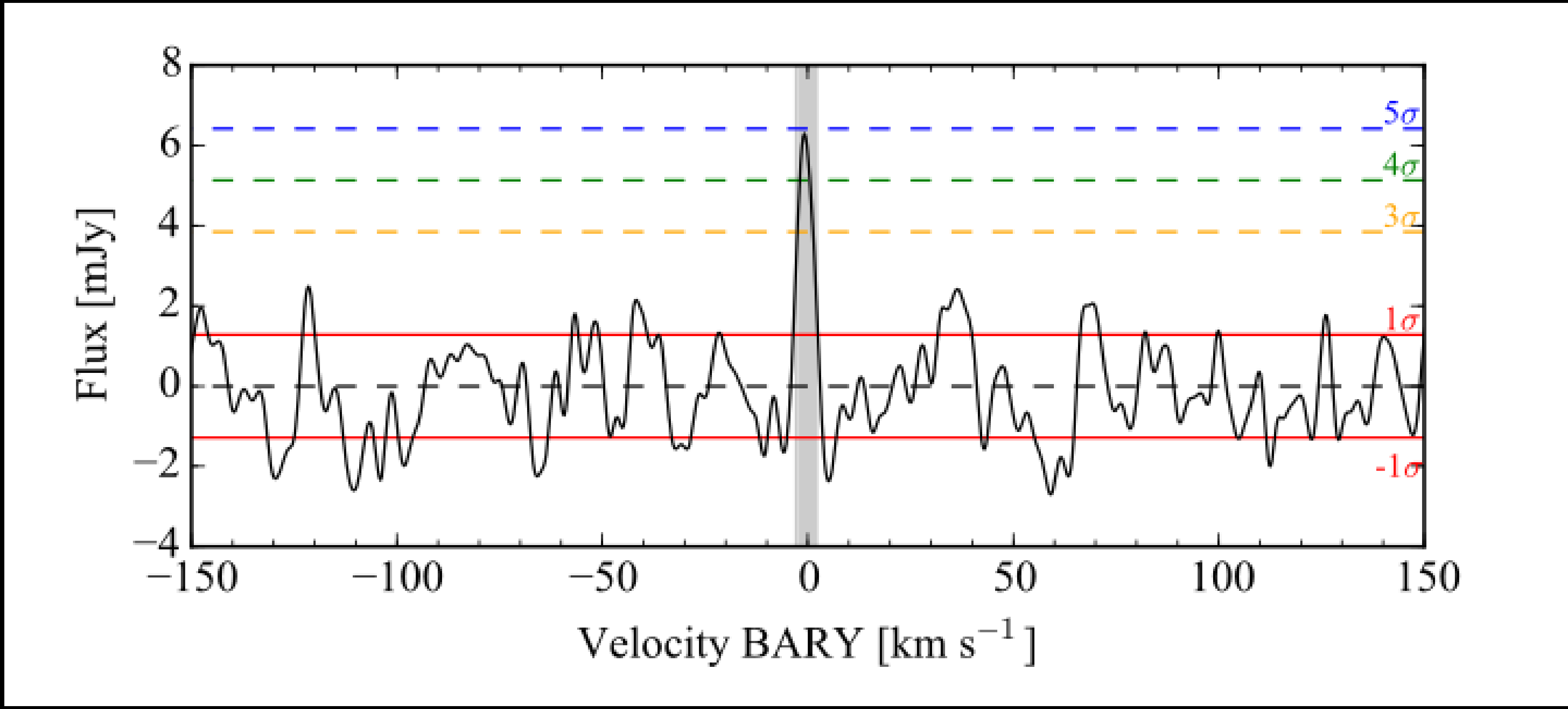


DUNES project: Eiroa et al. (2013), Montesinos et al. (2016)

Introduction

But we also find gas in main-sequence stars linked to debris discs.

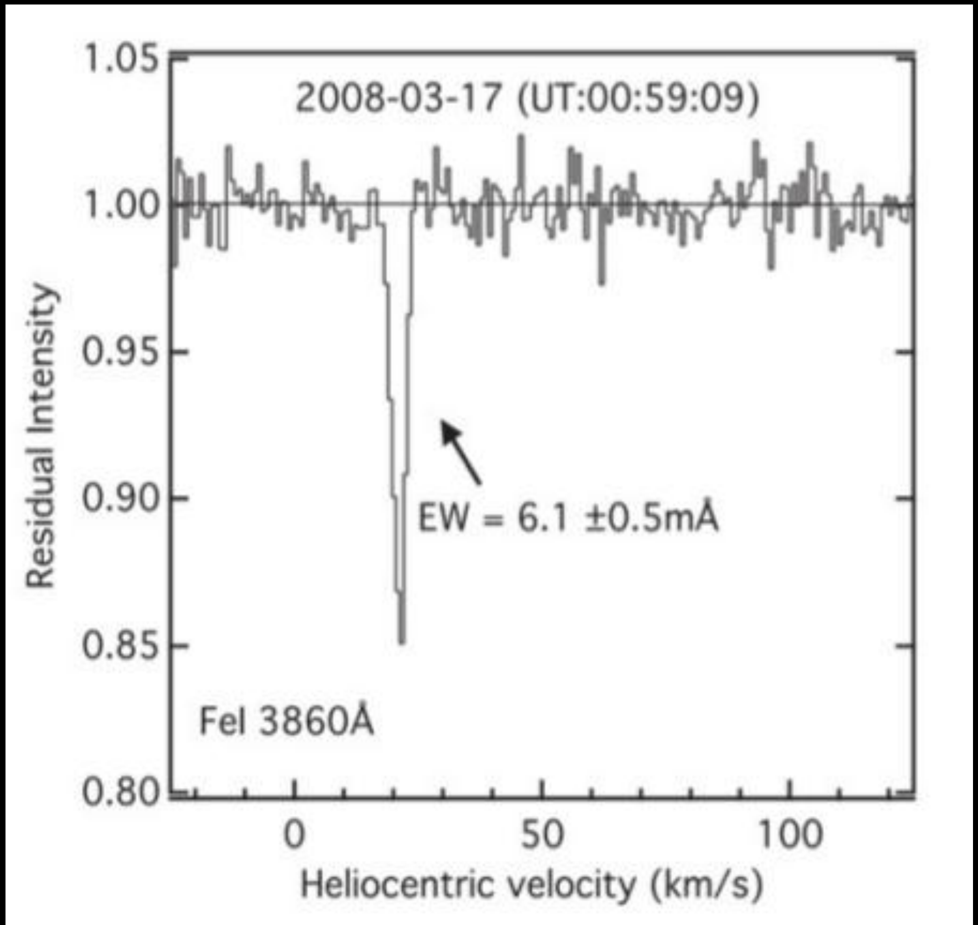
Molecular lines, in emission (cold gas ~50 K) :

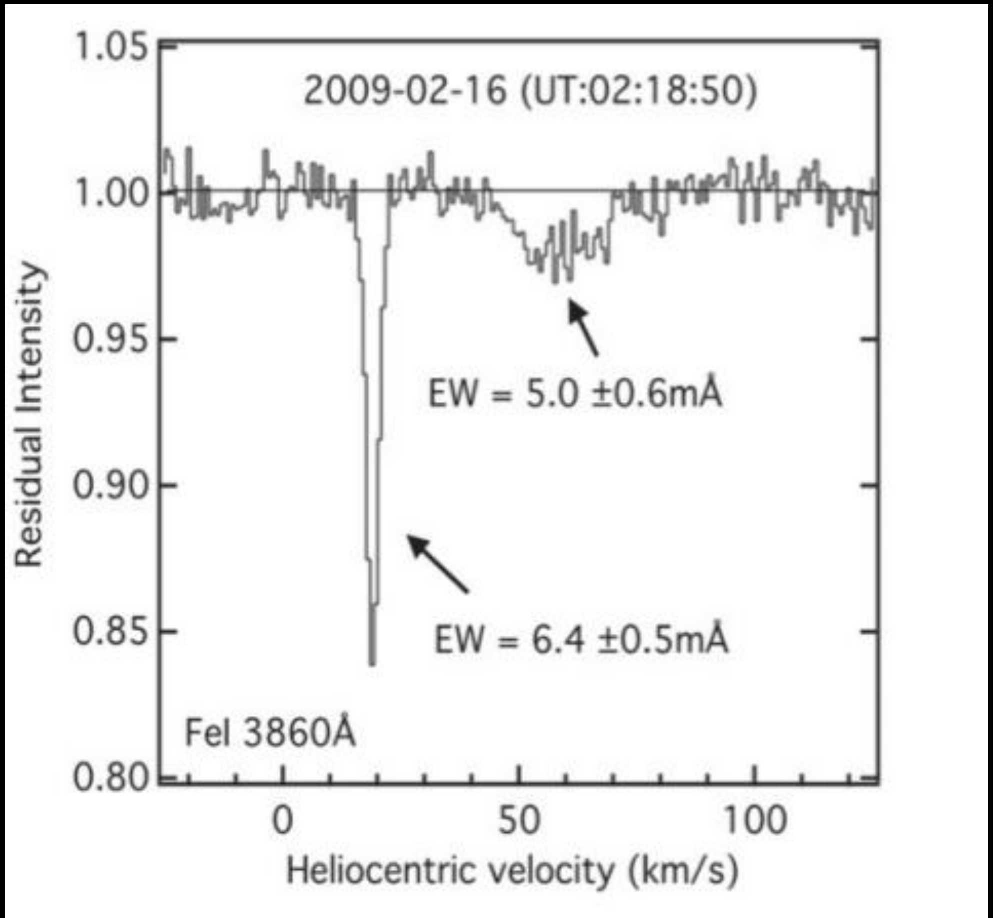


5σ detection of ^{12}CO (2-1) in the debris disc around HD 181327 (Marino et al. 2016)

Introduction

Metallic lines (from refractory elements Mg, Ca, Fe), in absorption (warm/hot gas ~1000-2000 K) :





Fe I circumstellar lines in β Pic (Welsh & Montgomery, 2016)

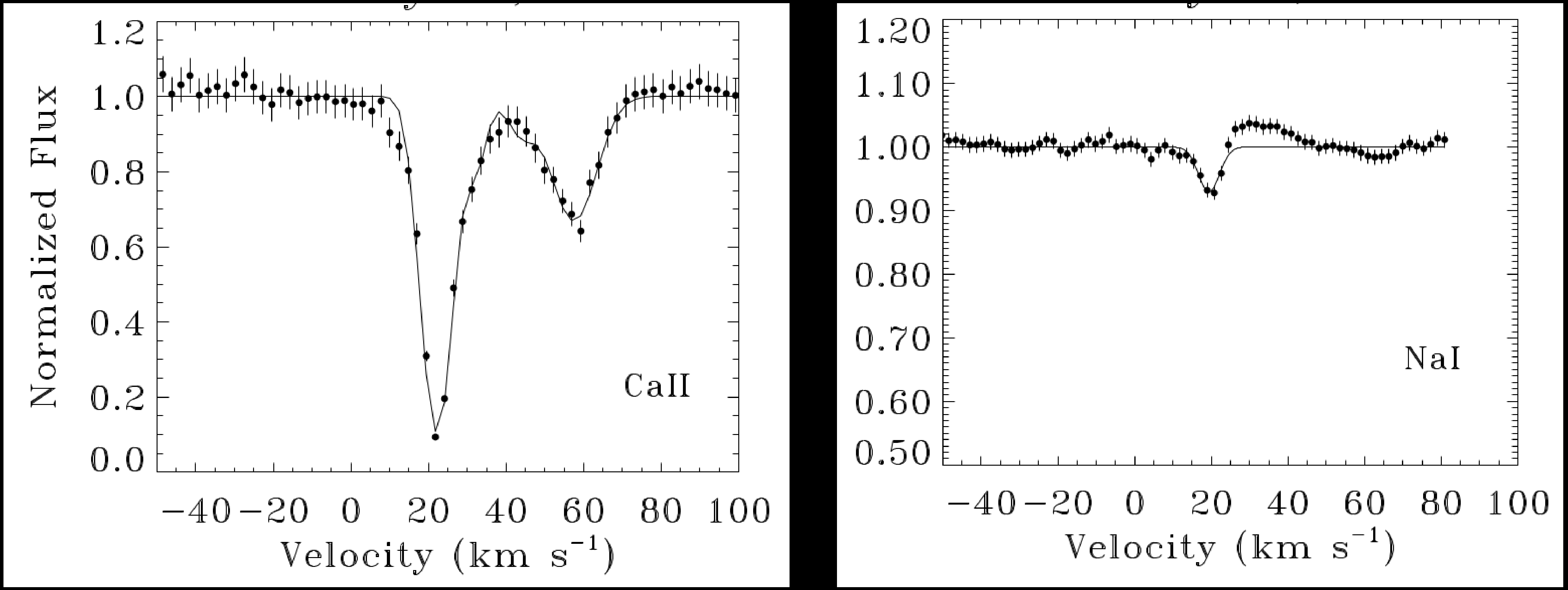
Origin of gas:

Primary: remnant from protoplanetary disc (e.g. Kóspál et al. 2013), or

Secondary: evaporation of icy bodies, colliding comets or planetesimals, grain-grain collisions (e.g. Matthews et al. 2014).

Introduction

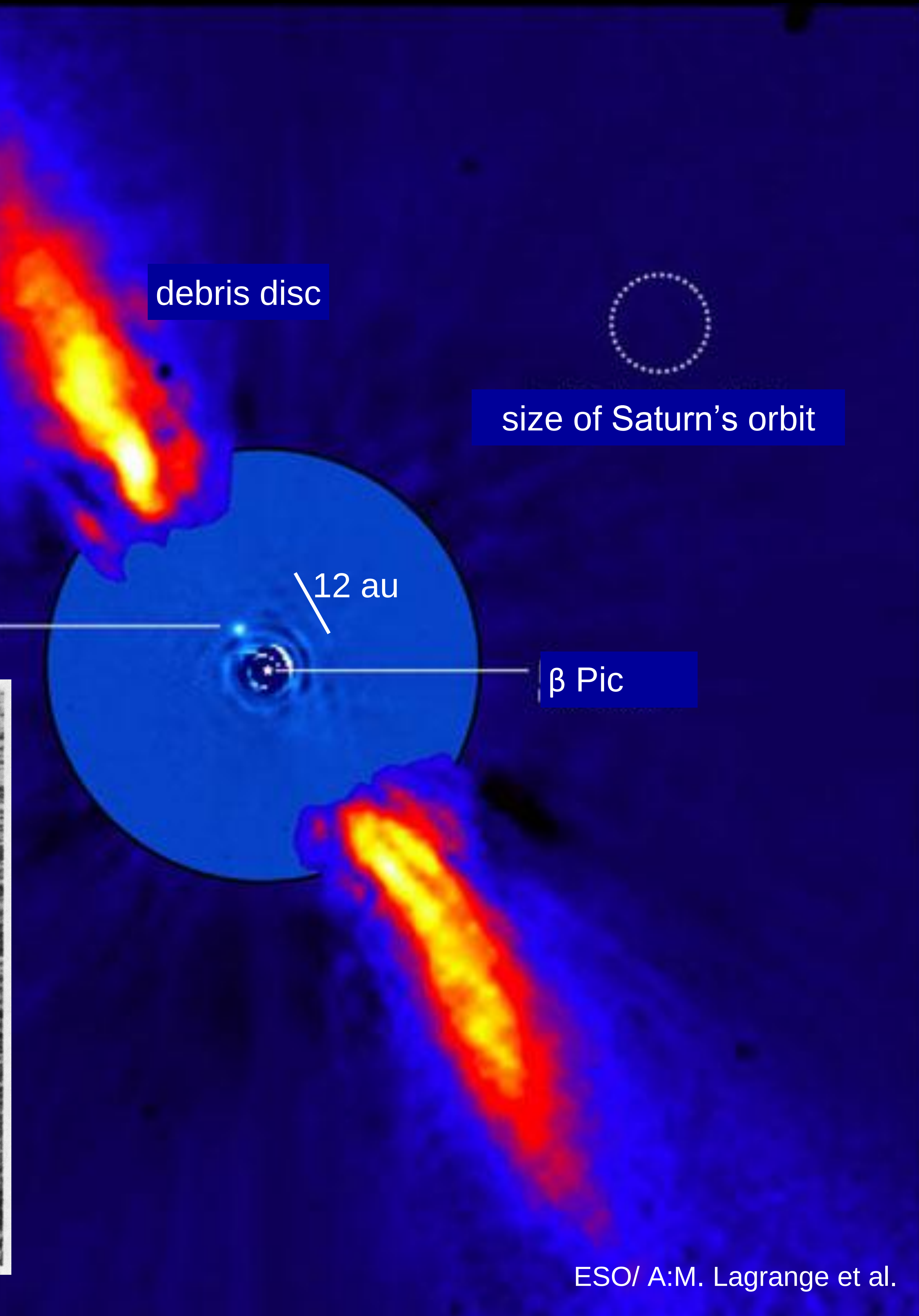
The most conspicuous CS features –and easy to observe in A or B type stars, difficult in later types- are the narrow features superimposed on the Ca II H and K and Na I D photospheric lines



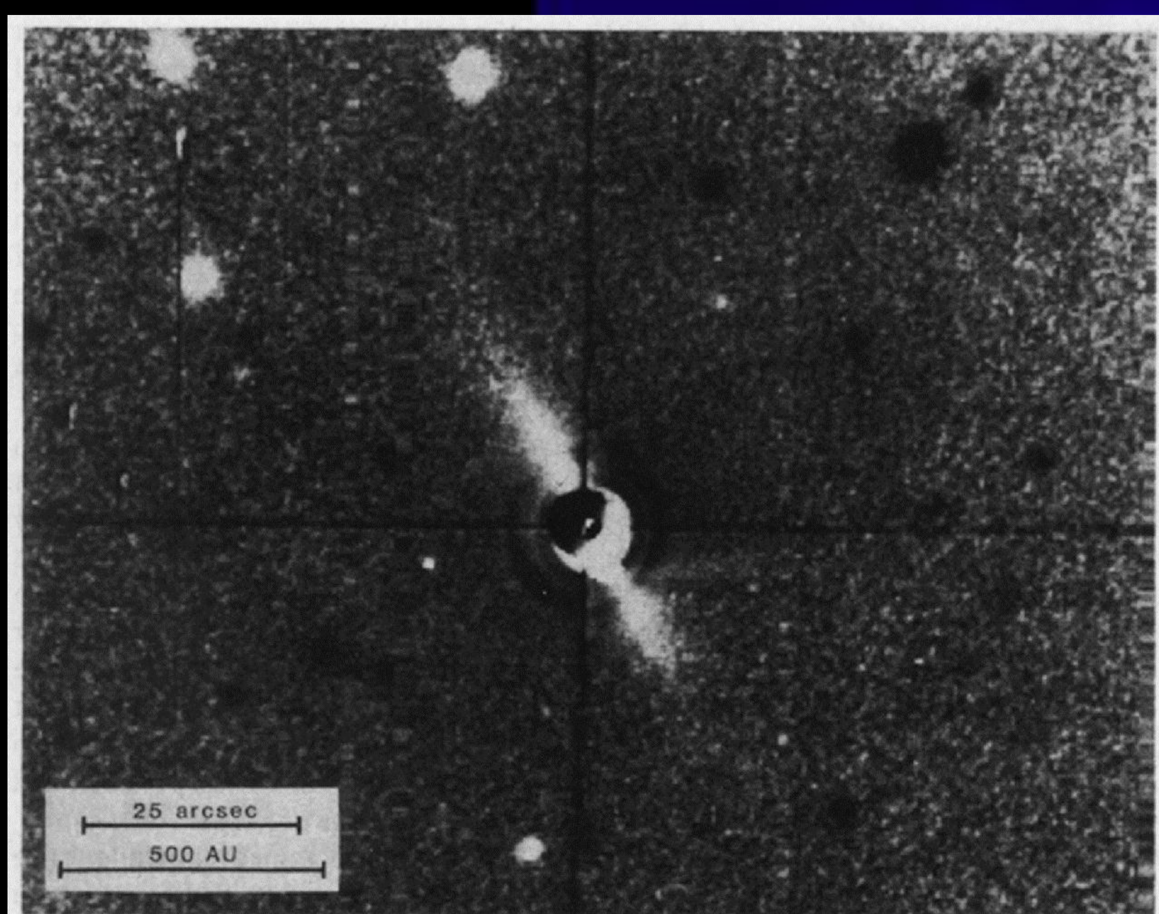
β Pic: Residual intensities after subtracting the photospheric profiles (Welsh et al., 1997)

β Pic

Sp. Type A6 V
d = 19.4 pc
T_{eff} = 8050 K
log g = 4.15
L= 8.7 $L_{\odot}$
Age ~23 Myr

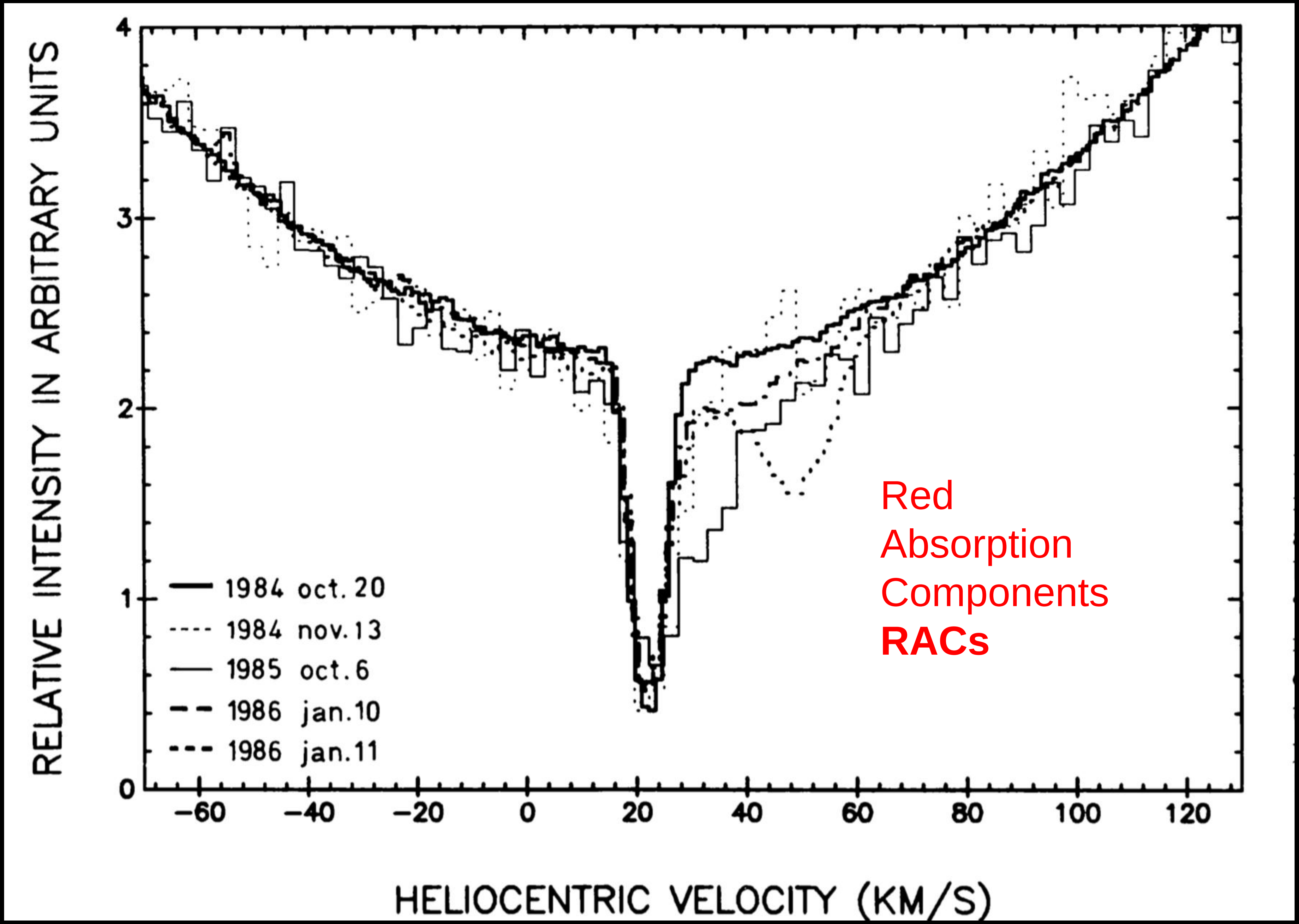


ESO/ A:M. Lagrange et al.



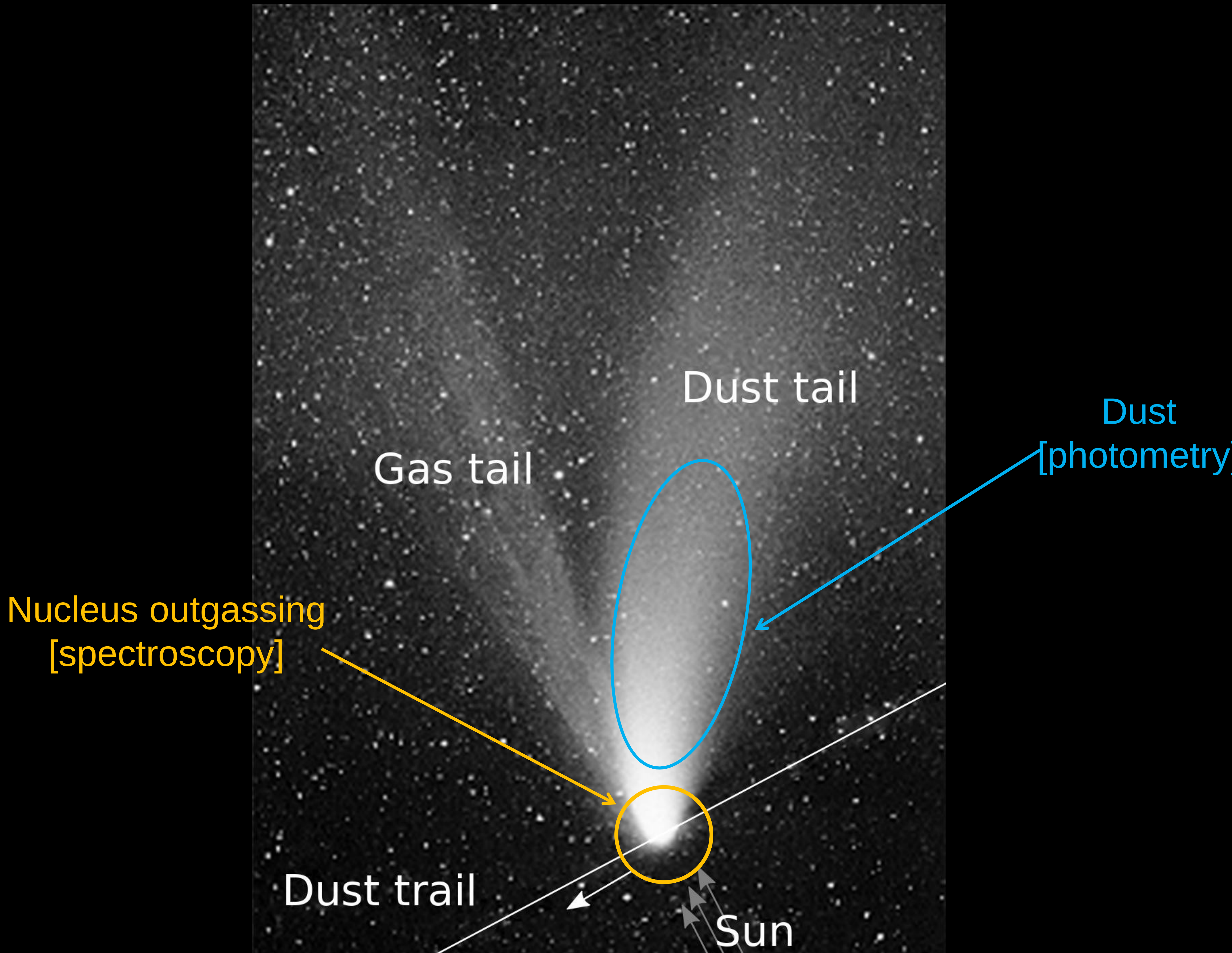
Smith & Terrile, (1984).

Introduction



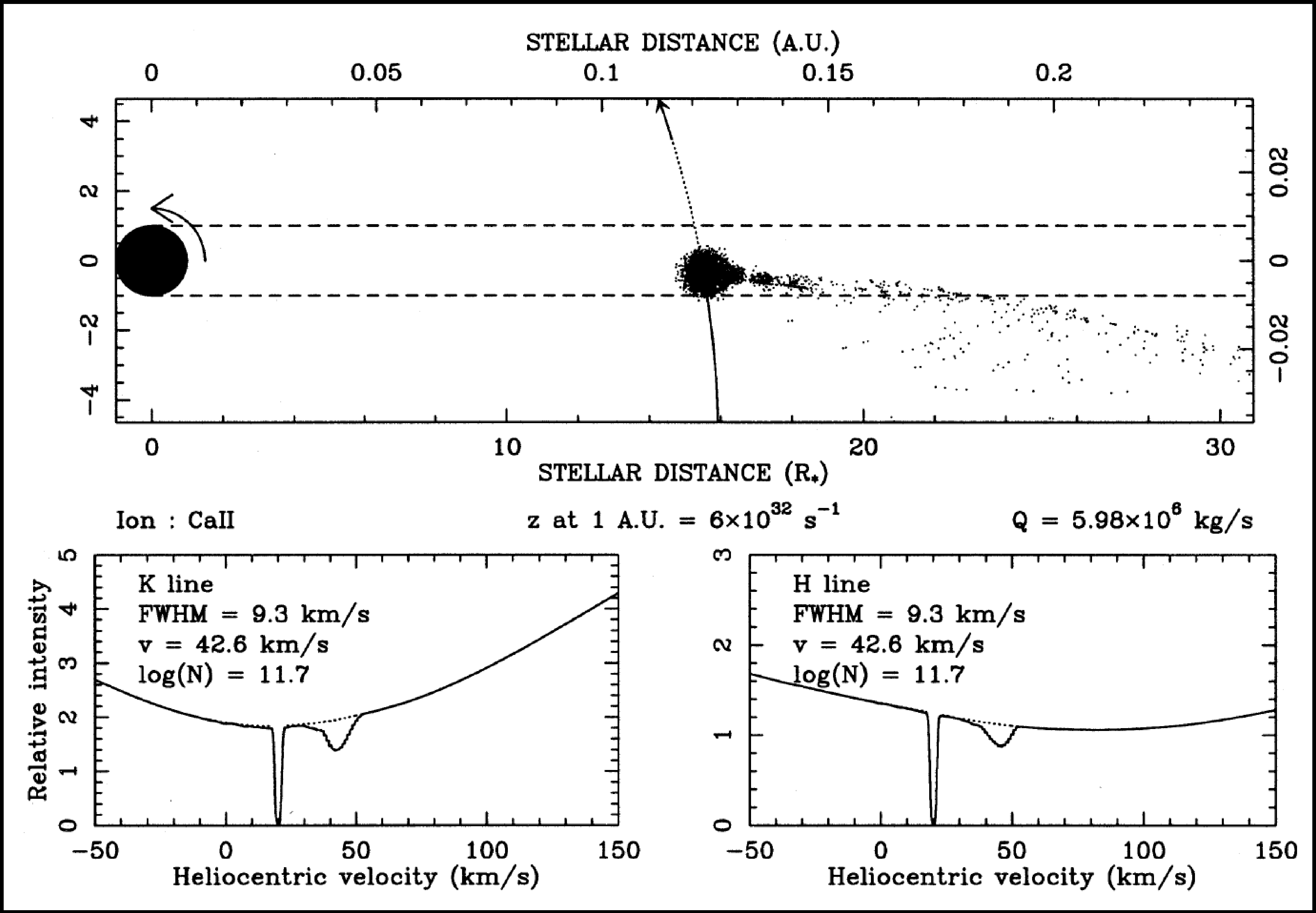
Ca II K profile in β Pic (Ferlet et al.,1987)

How to detect exocomets



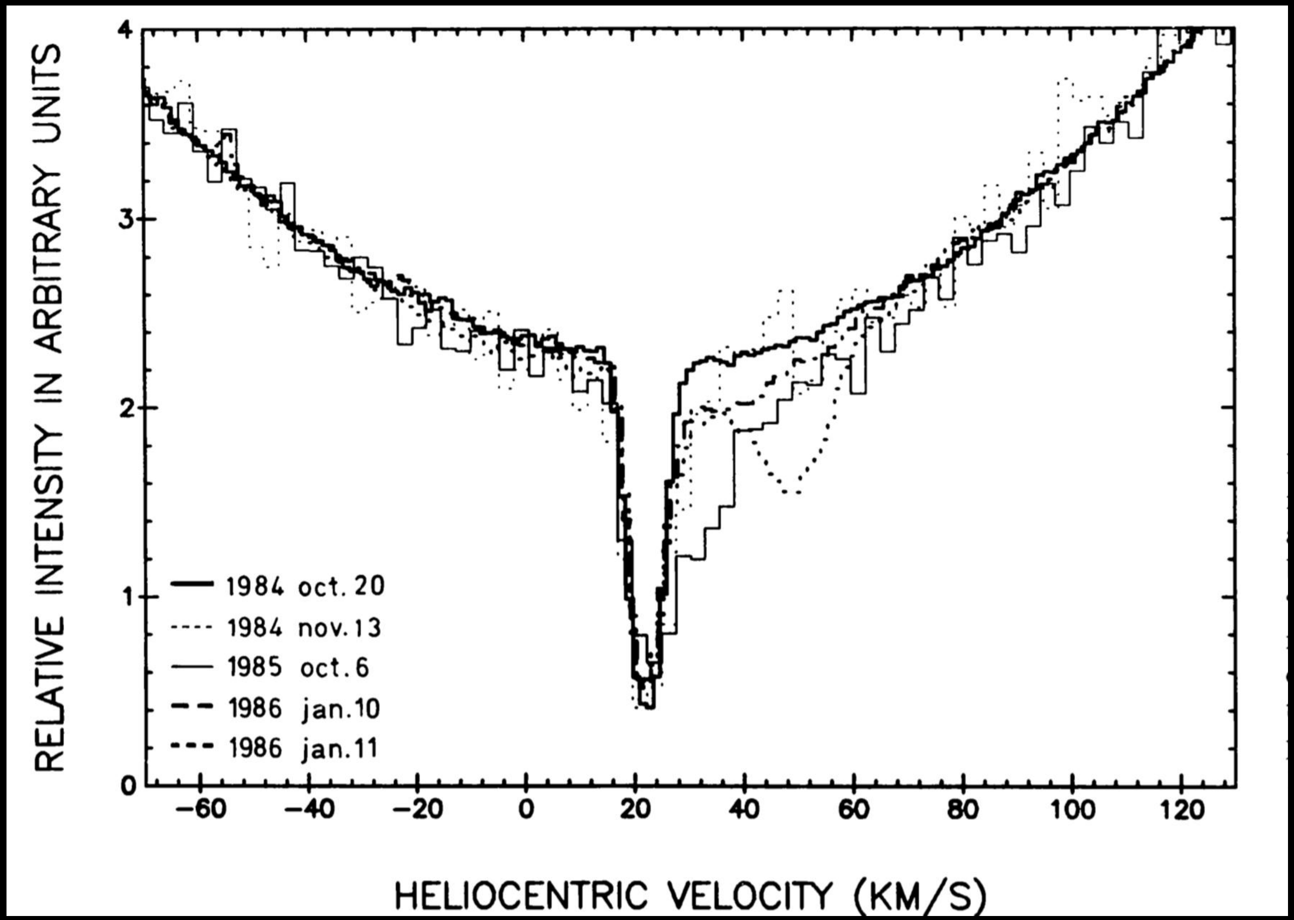
How to detect exocomets

The falling evaporating body (FEB) scenario (Beust et al., 1998)

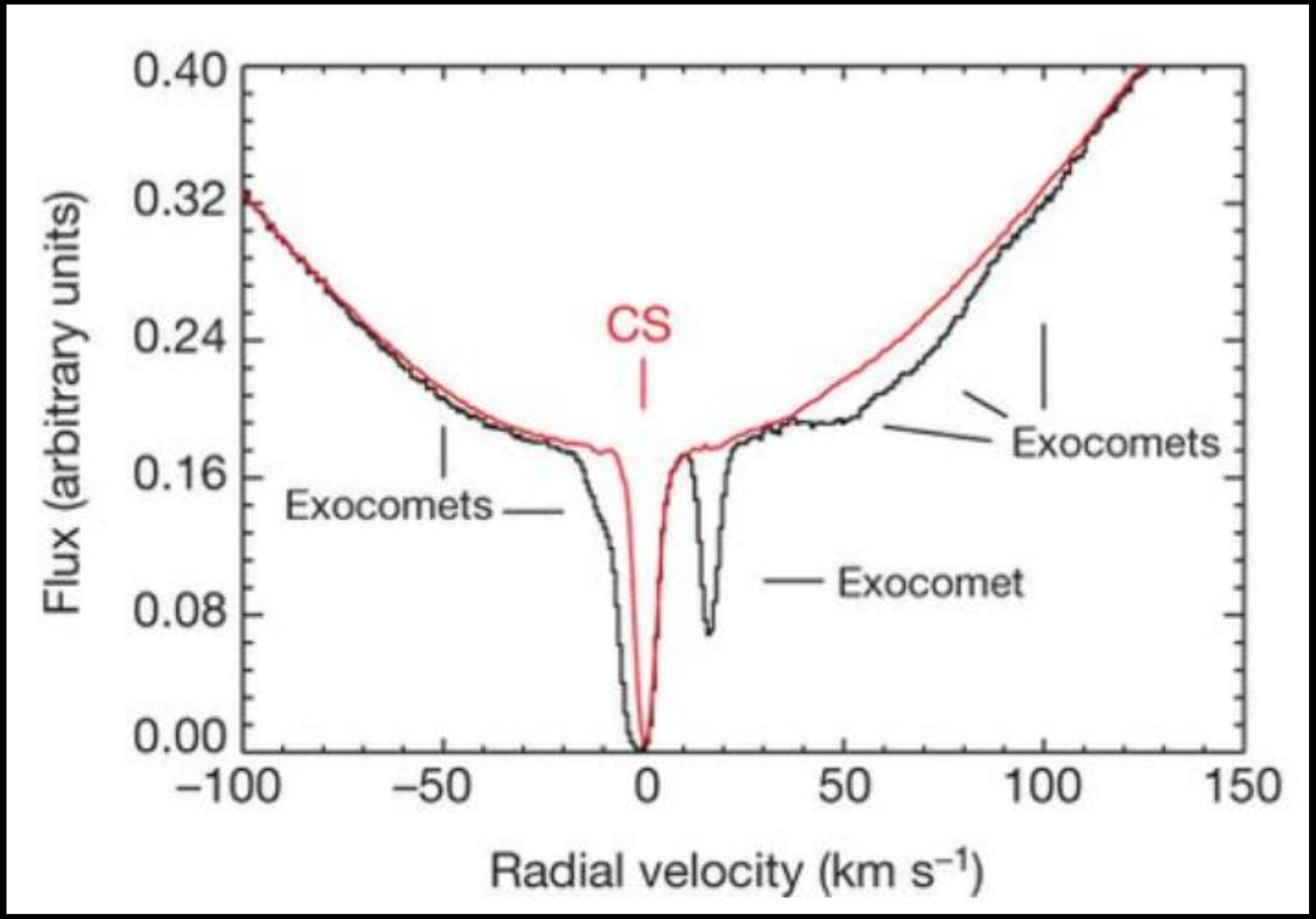


Red Absorption Components (RACs) ≡ Falling Evaporating Bodies (FEBs)

β Pic Ca II K profile

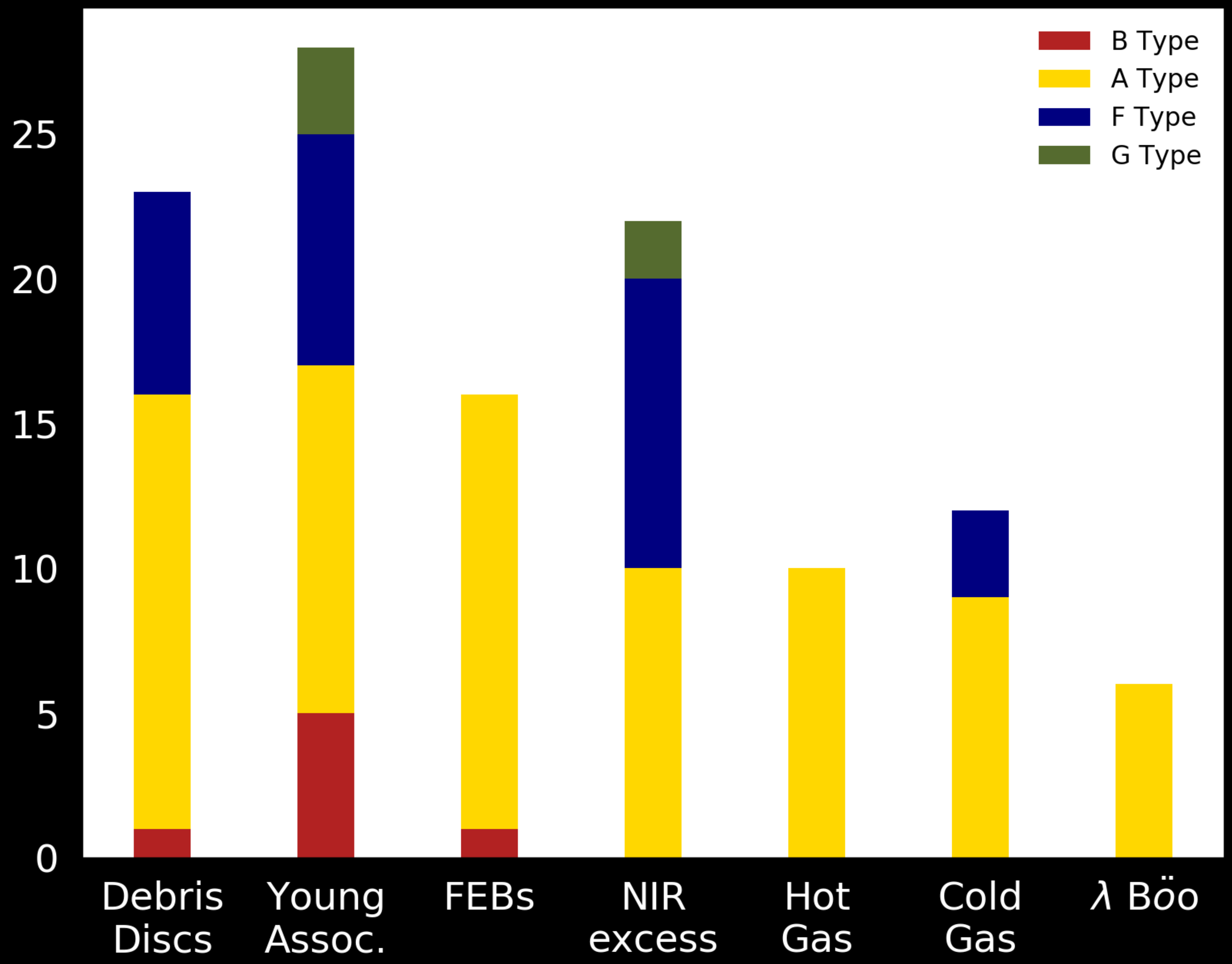


First report of exocomets: β Pic (Ferlet et al., 1987)



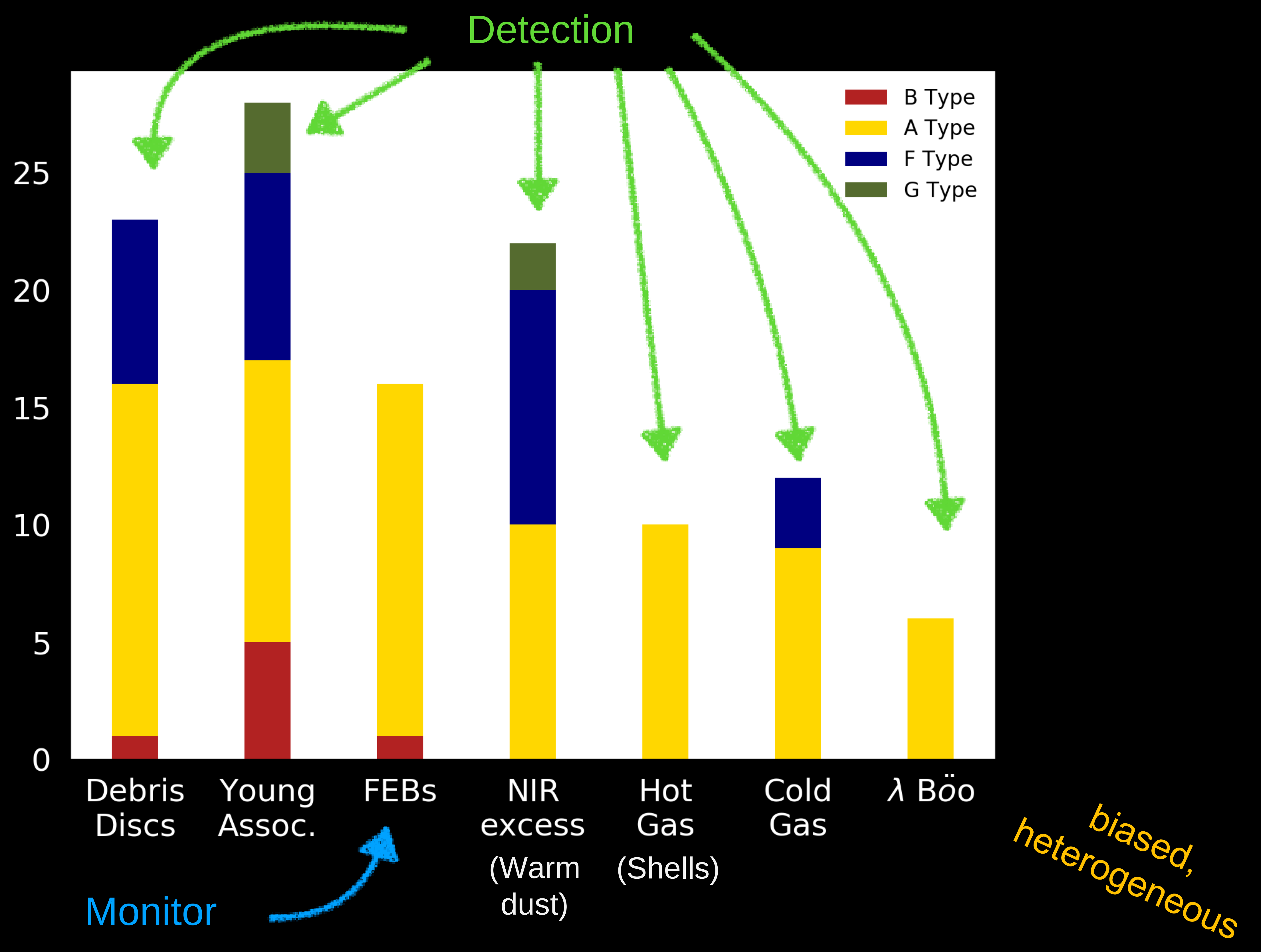
Two families of exocomets in β Pic (Kiefer et al., 2014)

The survey: Sample

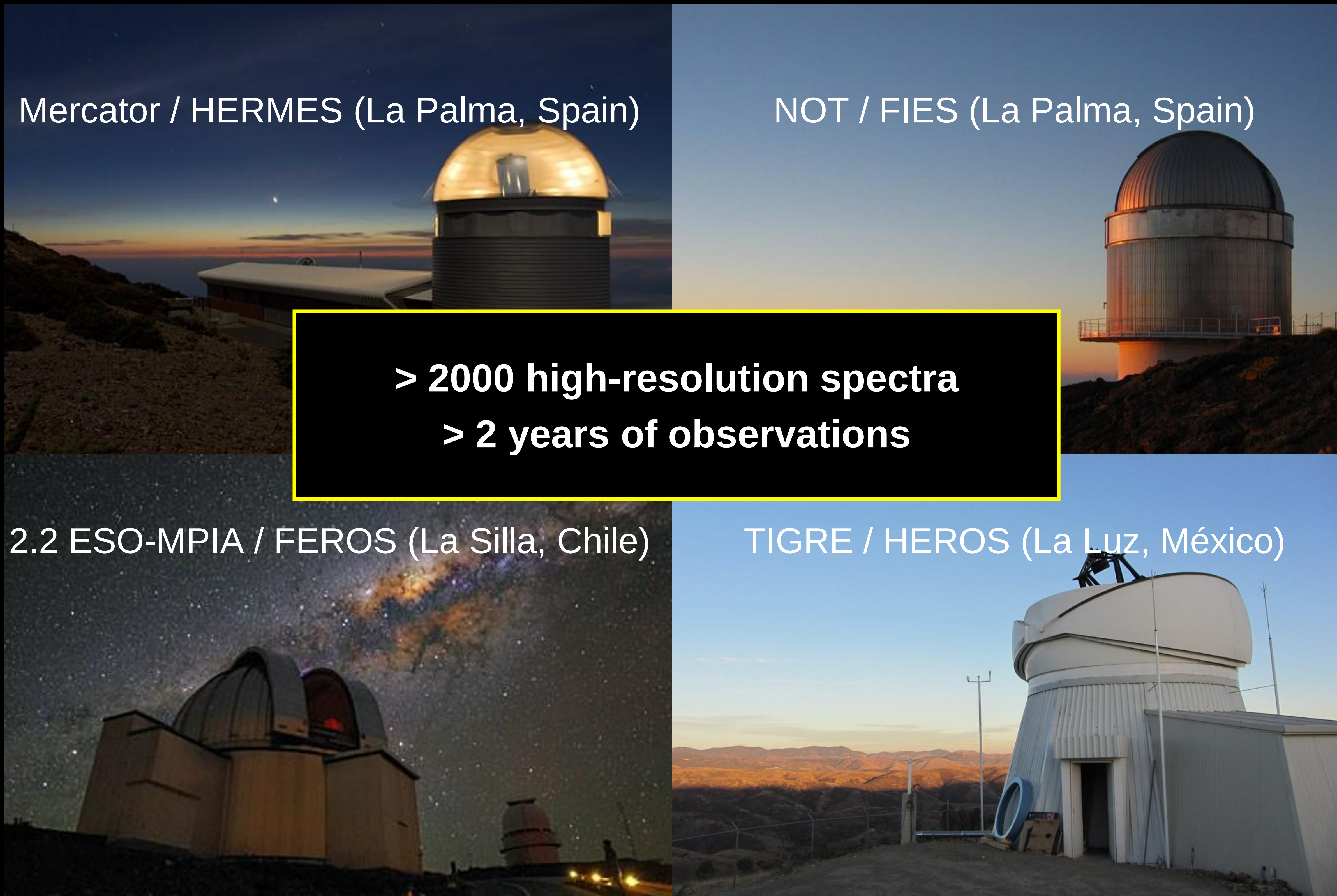


117 objects selected and observed (β Pic is not in the sample)

The survey: Sample



The survey: Observations

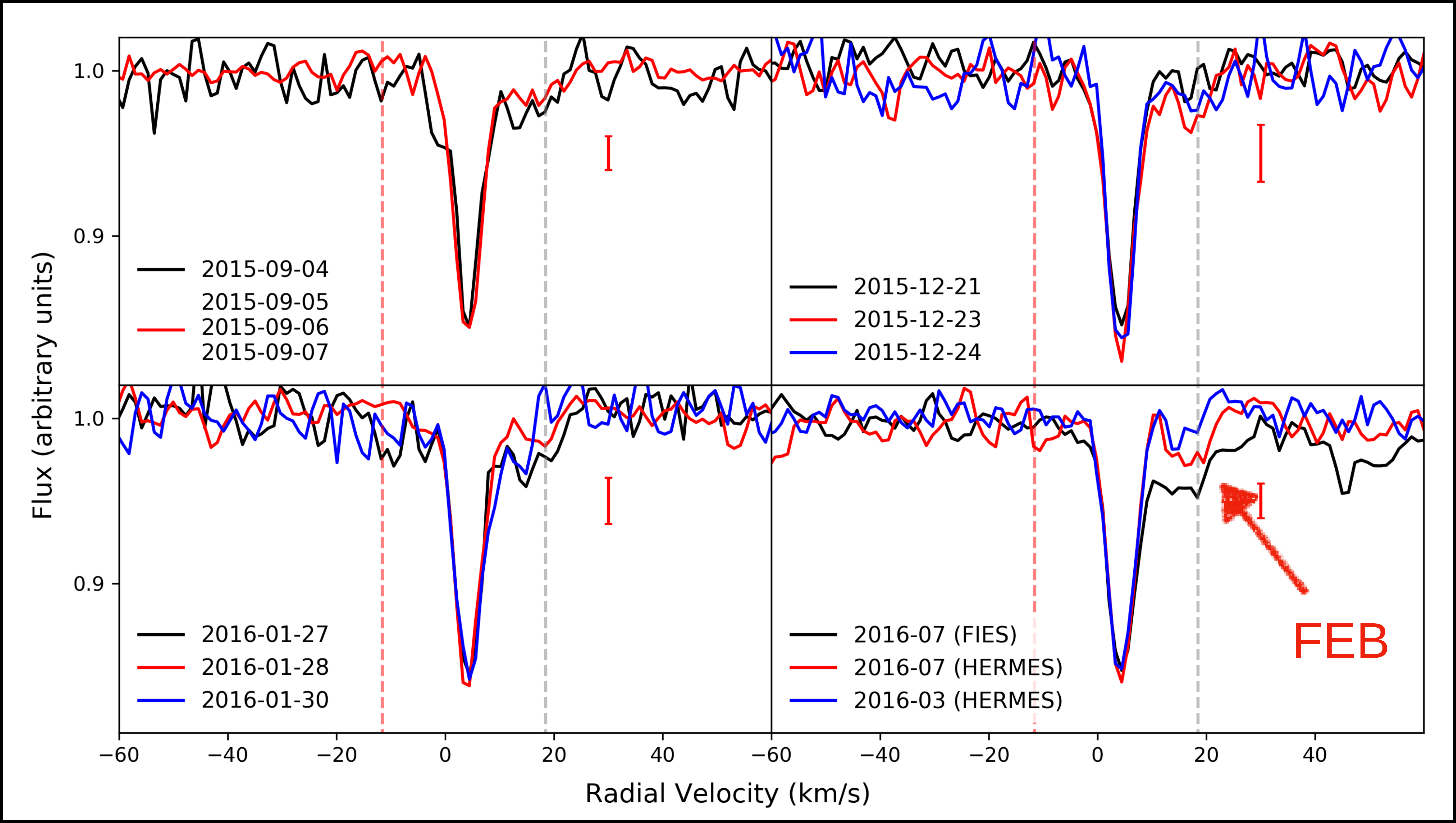


> 2000 high-resolution spectra

> 2 years of observations

The survey: Observations

Time series for variability detection

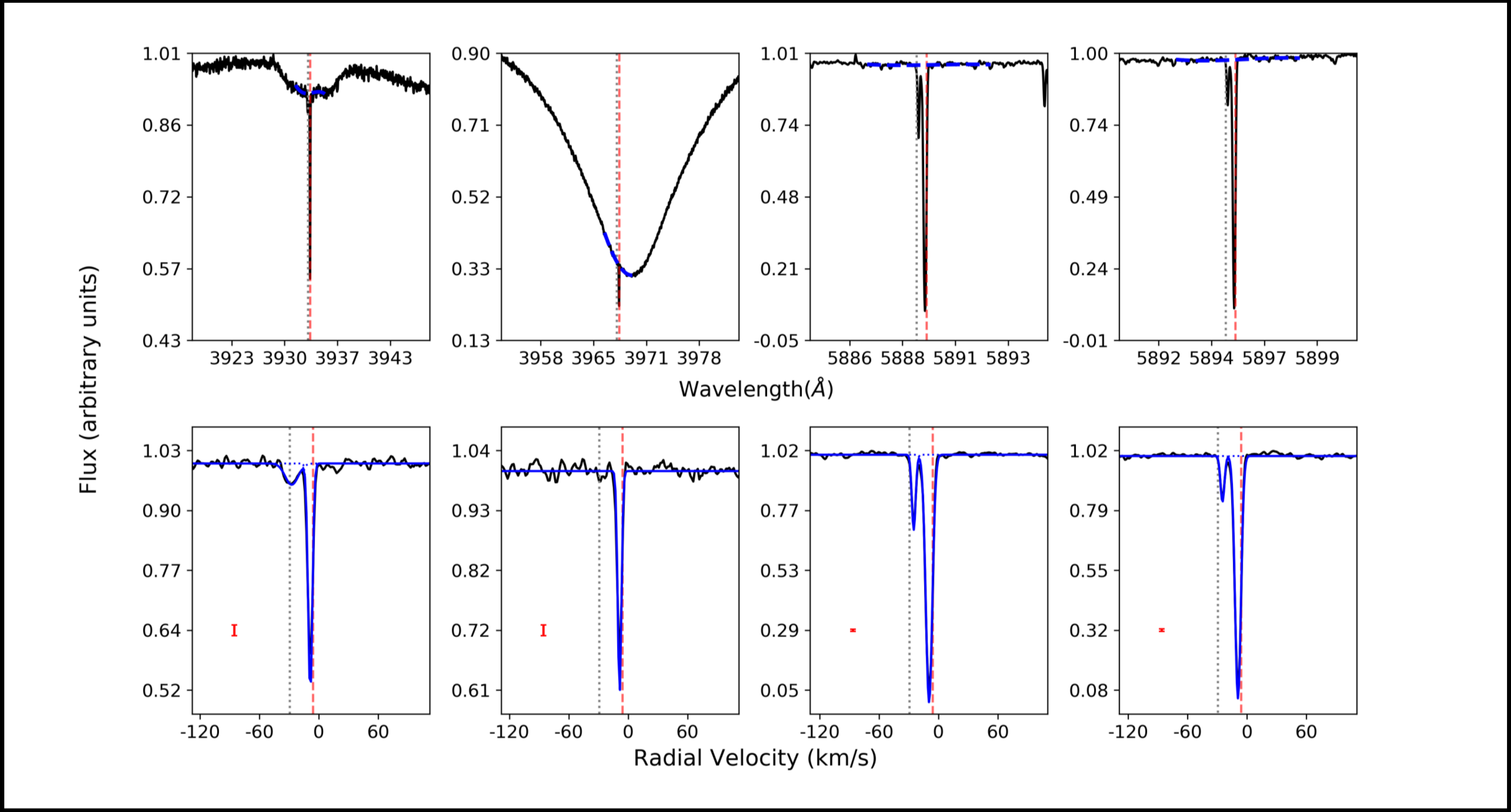


HD 21620:Rebollido et al. (2019, submitted)

The survey: Observations

Detection of narrow stable absorptions

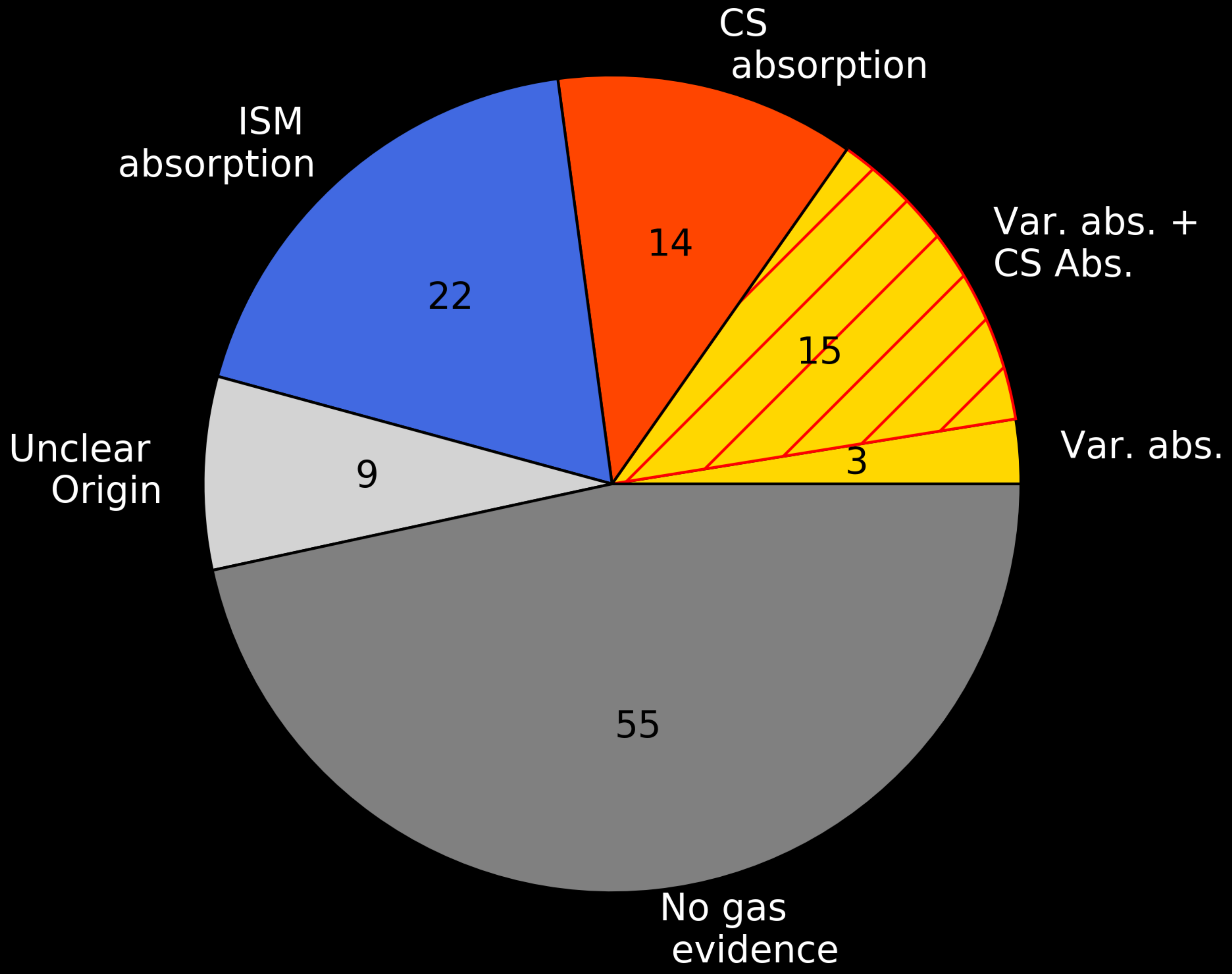
Ca II K&H **Na I D**



HD 145631: Rebollido et al. (2019, submitted)

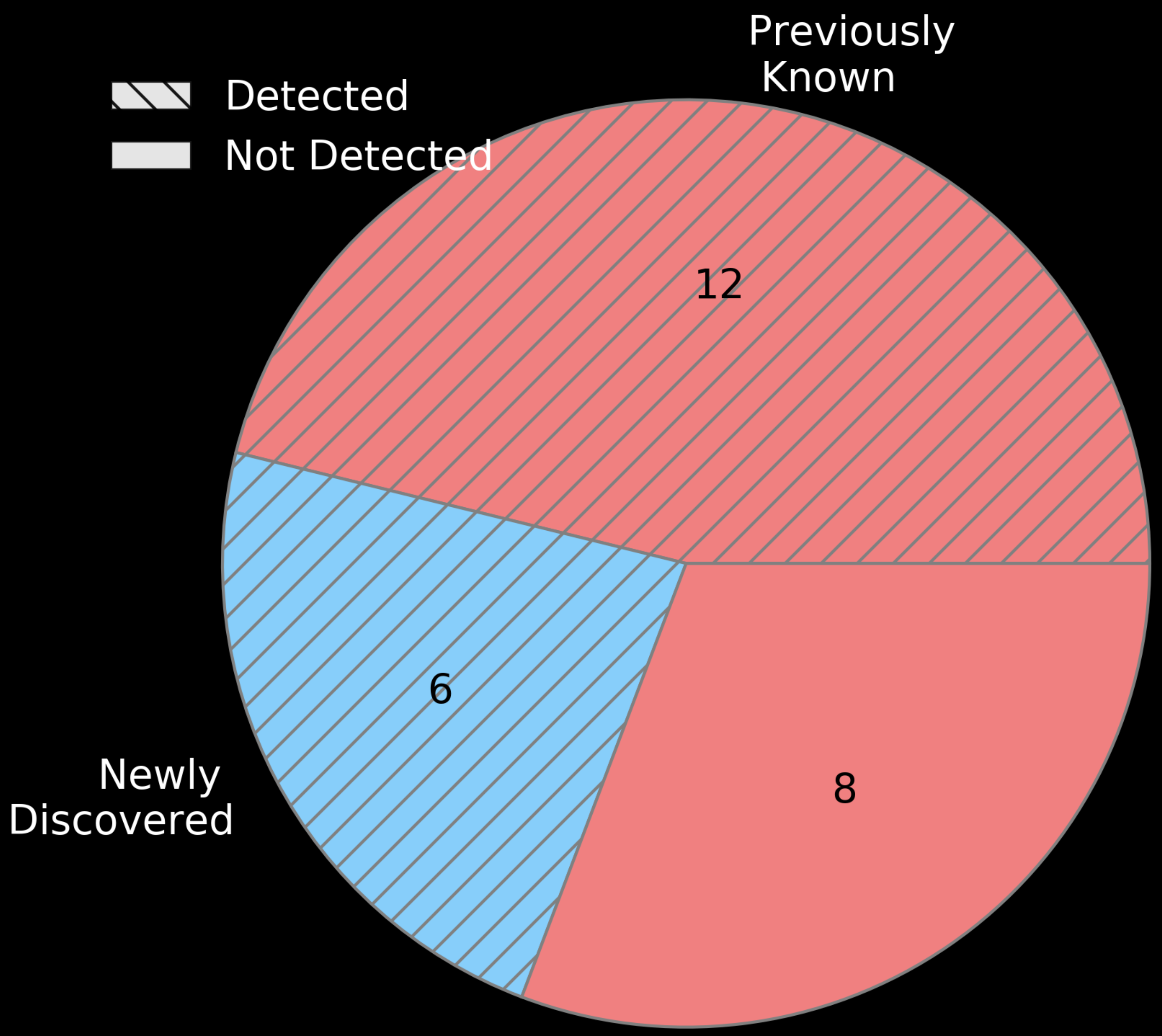
The survey: Results

Gas detection



The survey: Results

FEB host stars



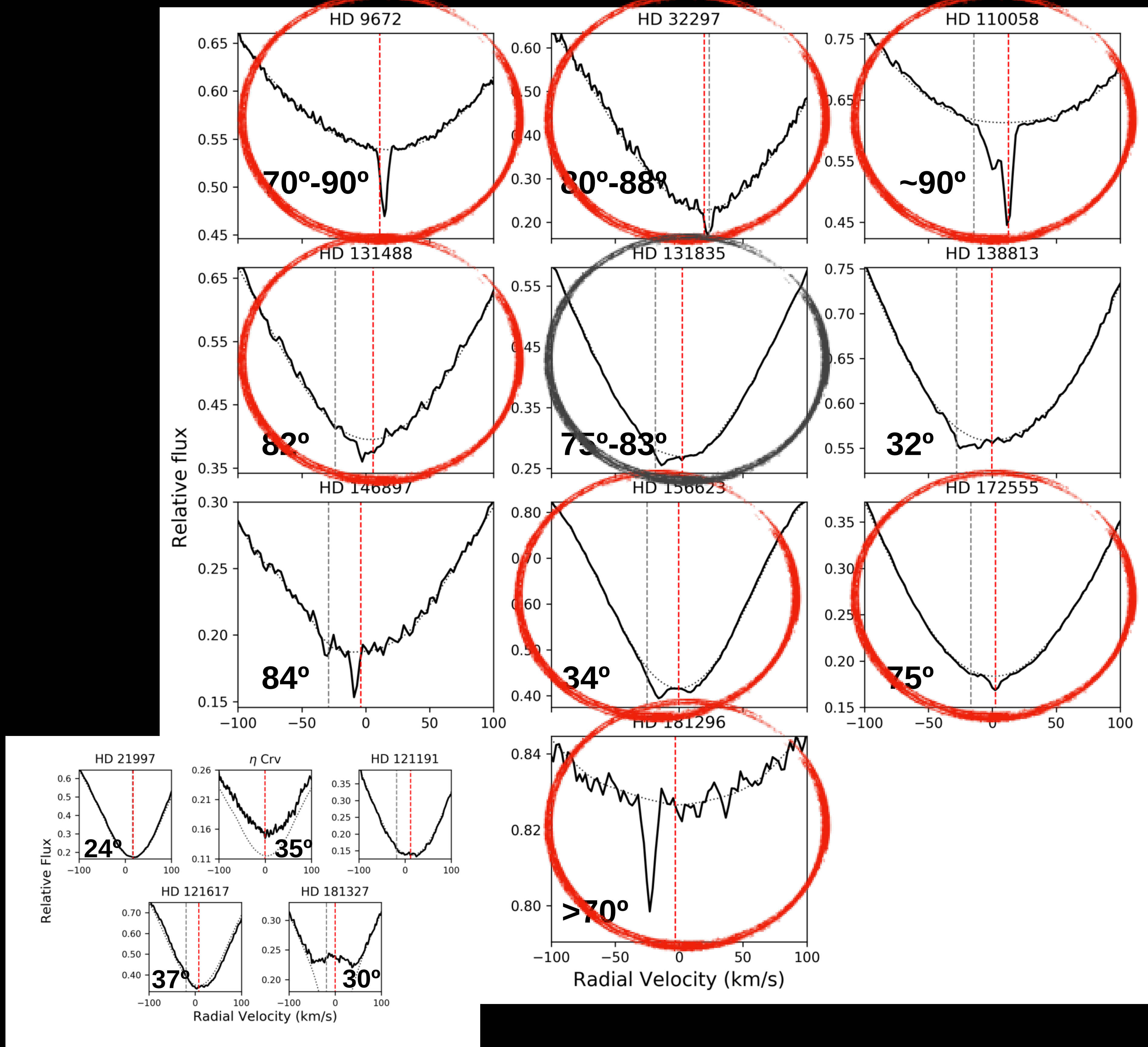
The survey: Results

Previous results + our survey (Rebollido et al. 2019, and PhD):

26 stars, all of them A-type, but HD 109085, F2 V (Welsh & Montgomery, 2019) show variability in circumstellar features interpreted as FEBs (…exocomets?)

Results: Co-existence of hot and cold gas

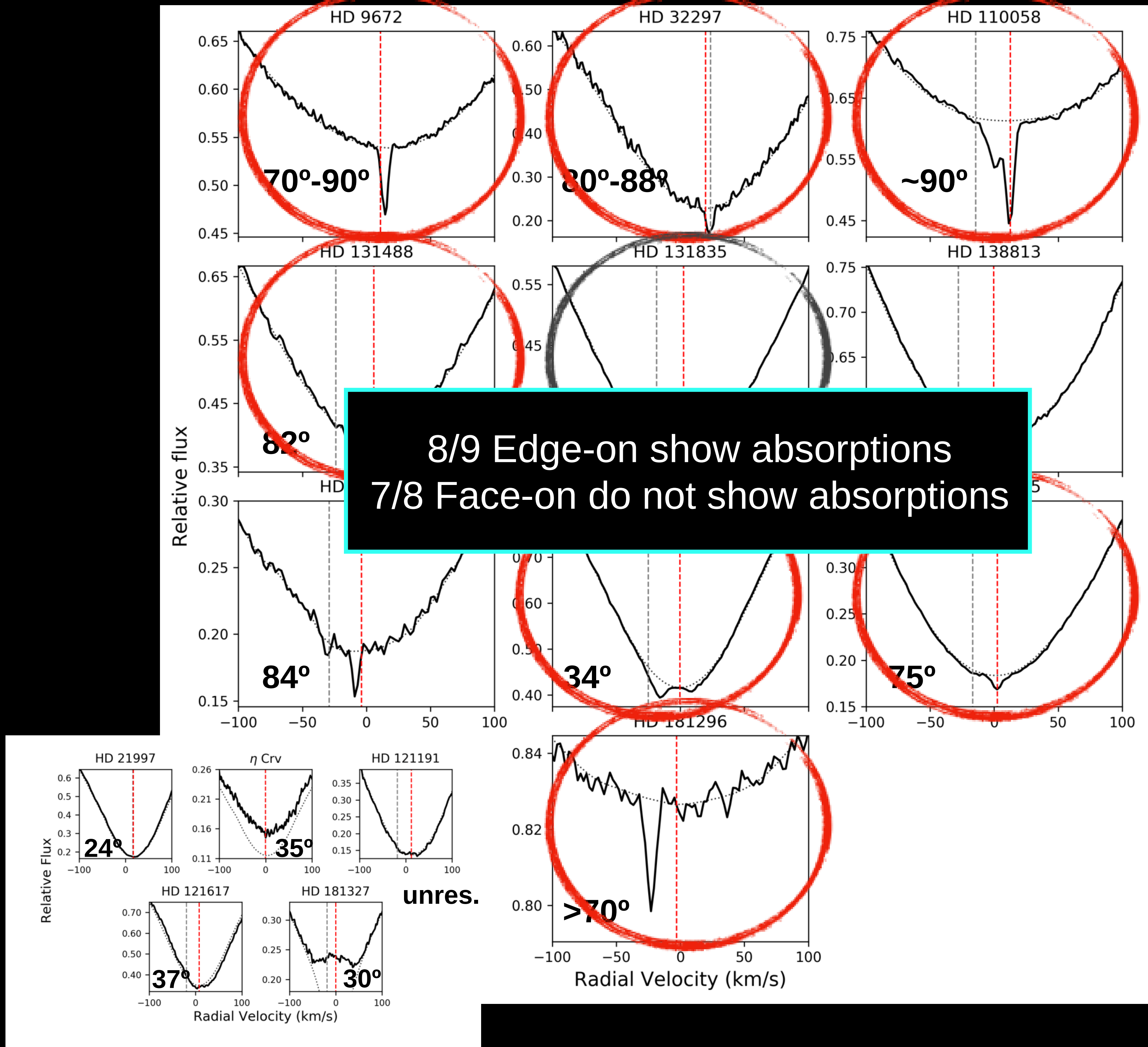
Cold gas bearing debris discs



Rebollido et al. (2018)

Results: Co-existence of hot and cold gas

Cold gas bearing debris discs



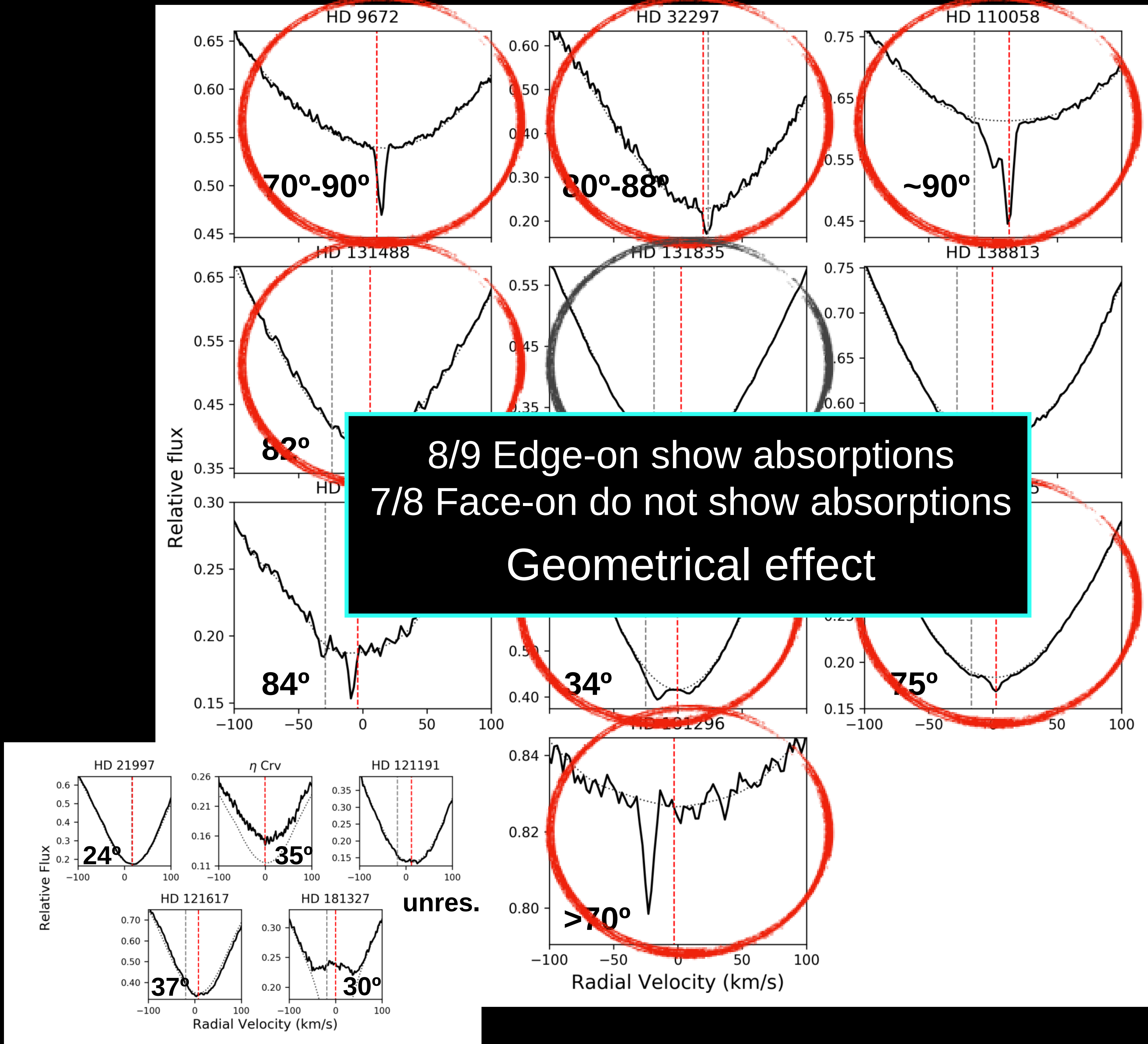
8/9 Edge-on show absorptions
7/8 Face-on do not show absorptions

+ β Pic
Fomalhaut

Rebollido et al. (2018)

Results: Co-existence of hot and cold gas

Cold gas bearing debris discs



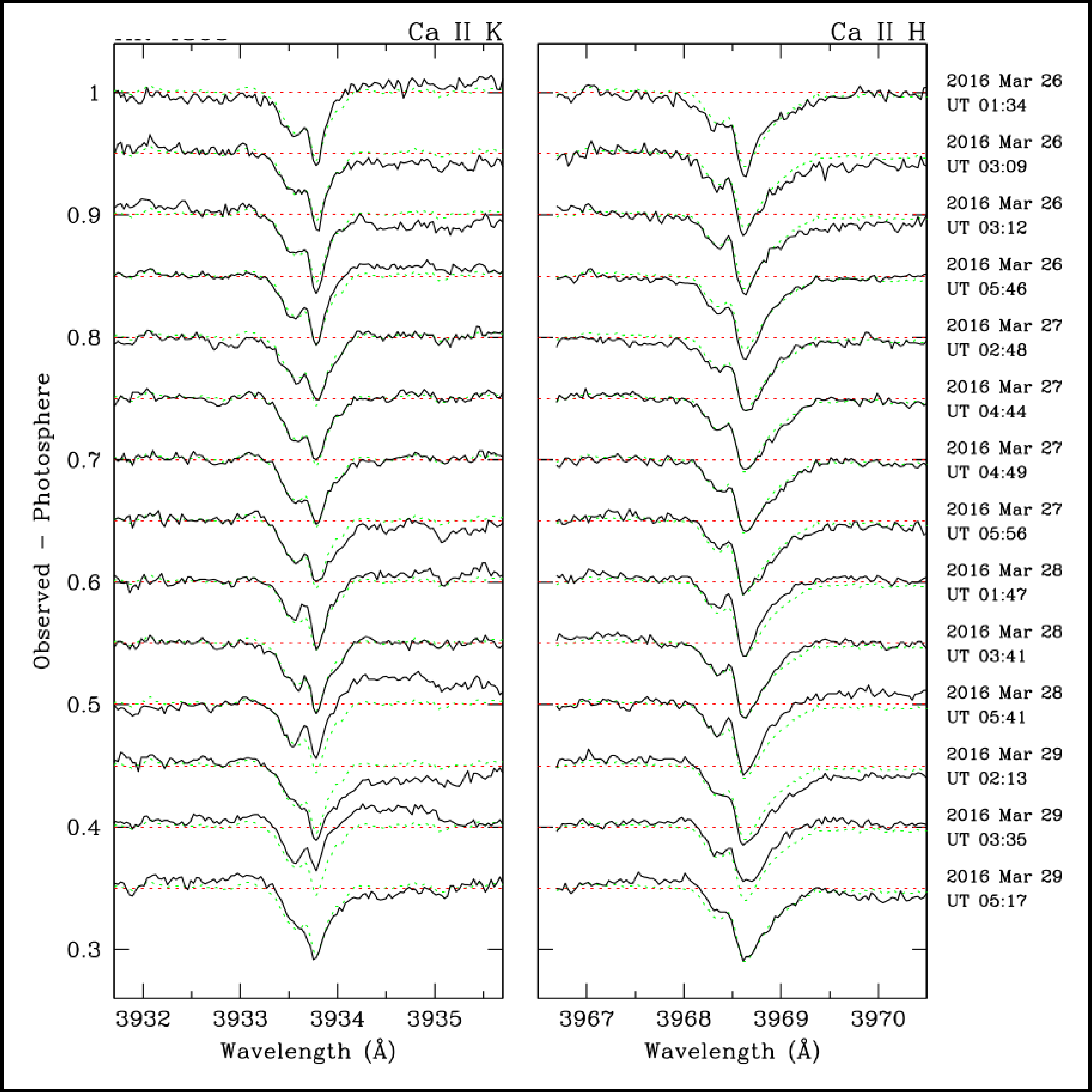
8/9 Edge-on show absorptions
7/8 Face-on do not show absorptions

Geometrical effect

\+ β Pic
Fomalhaut

Rebollido et al. (2018)

Results: Φ Leo



ϕ Leo

Sp. Type A7 IV
d = 56.5 pc
T_{eff} = 7500 K
log g = 3.75
L= 45 $L_{\odot}$
Age ~500 - 900 Myr

Only second to β Pic in variability, but much older : 500 - 900 Myr.

Lack of a massive debris disc

CS disc detected in Ti II

Variability: …exocomets?

Eiroa et al. (2016)

Results: HR 10

WARNING: The variability in the narrow absorptions which is attributed to FEBs or exocometary events might have another origin…

Results: HR 10

HR 10 (before our work)

Single object

Spectral type: A2 V/IV

$V = 6.23$

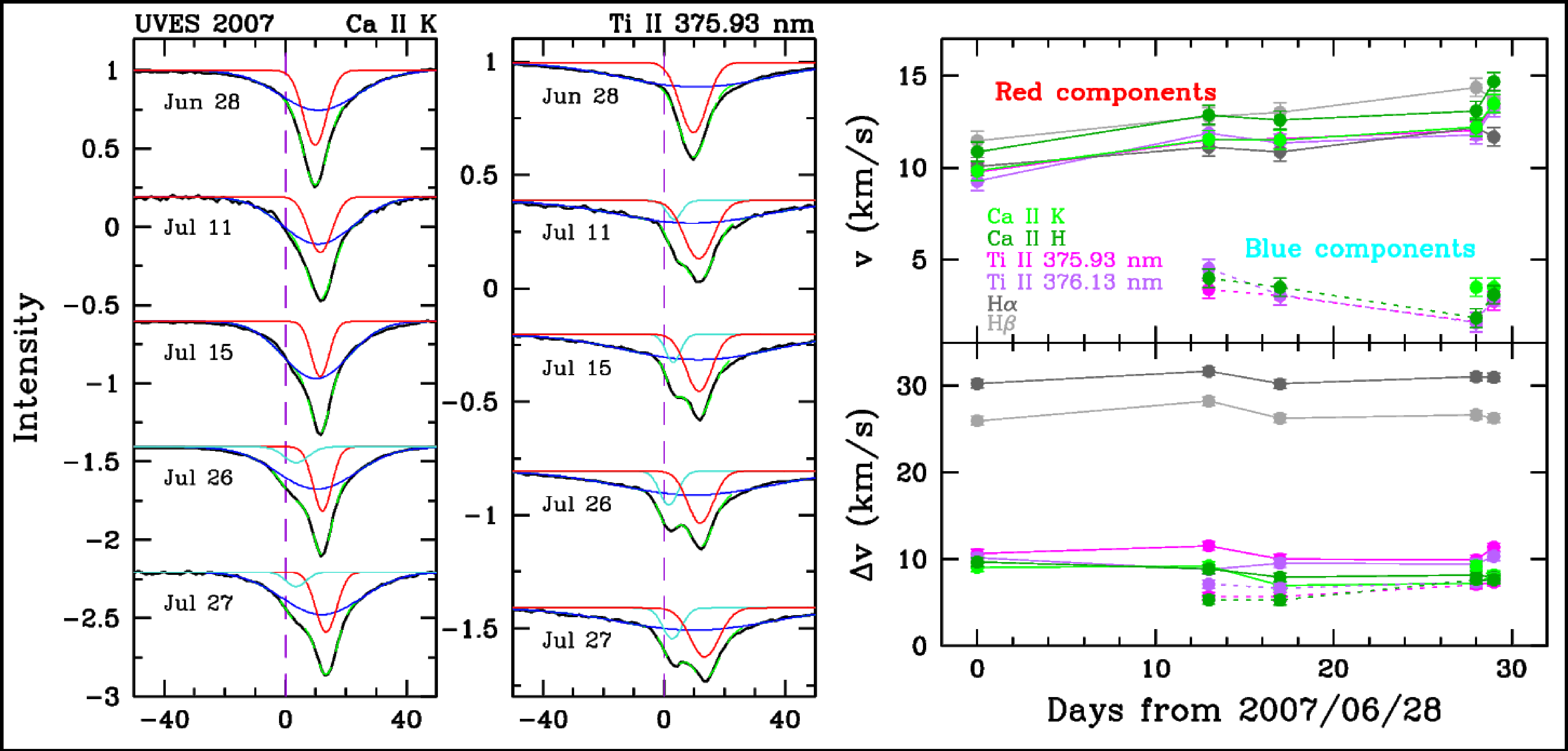
$v \sin i \sim 290$ km/s

$T_{eff} \sim 8500 - 9500$ K

Variability in the CS components attributed to FEBs

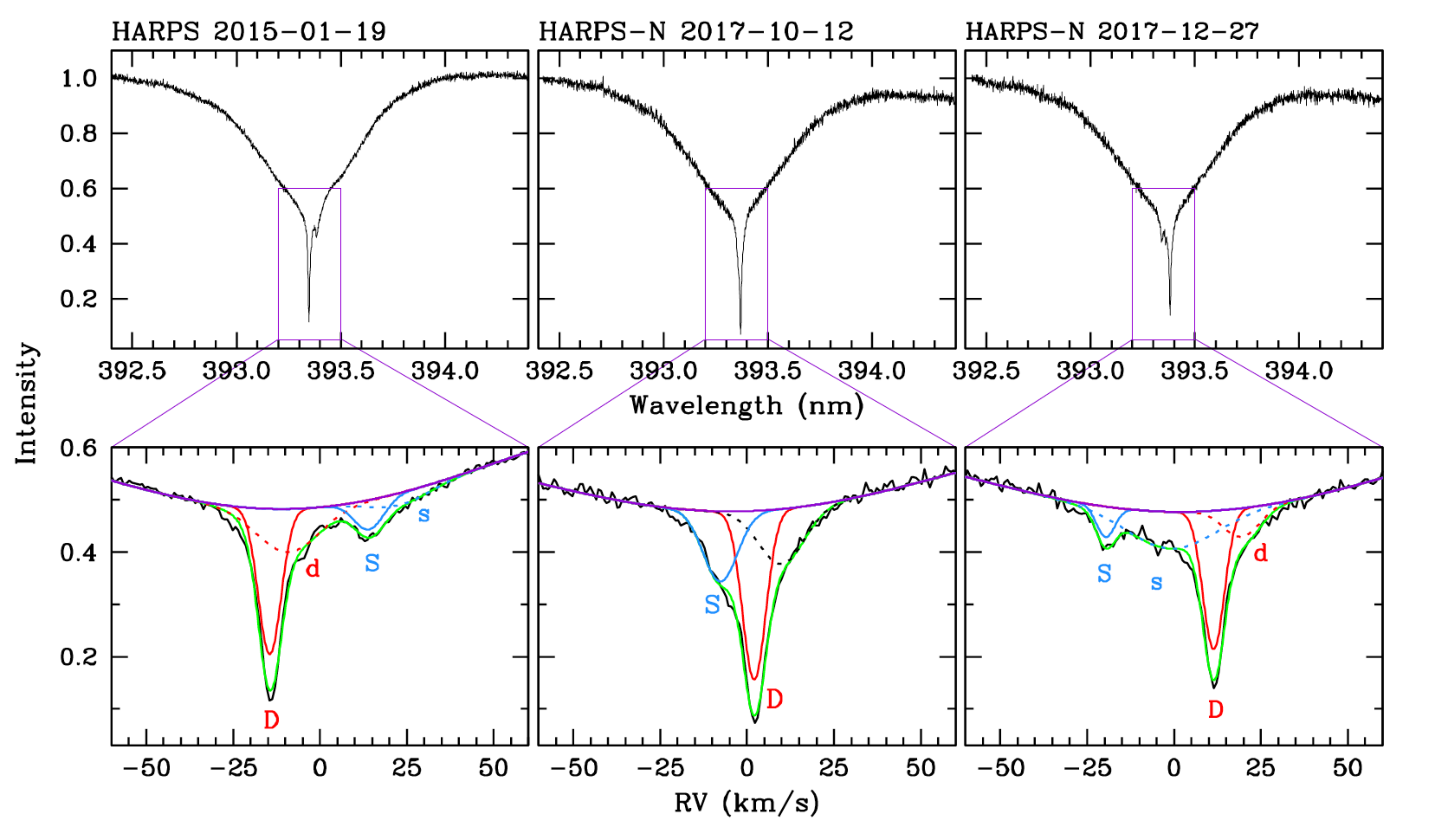
Results: HR 10

Looking at data spanning short times intervals the behaviour of the narrow absorption components resembled that of exocometary events…



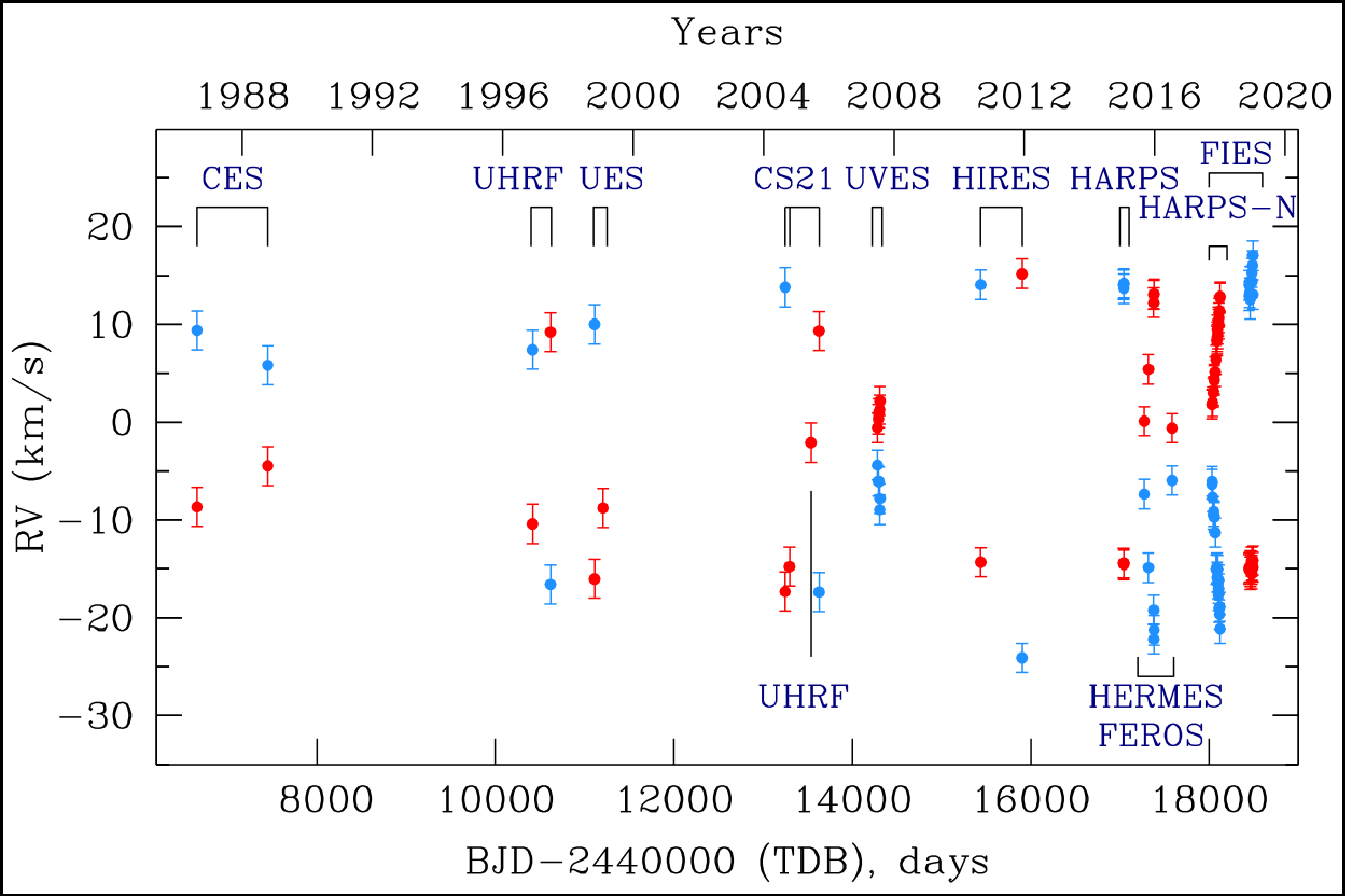
Results: HR 10

…however, when a longer time interval of observations is analysed the interpretation of the variability as FEBs is not the correct one…



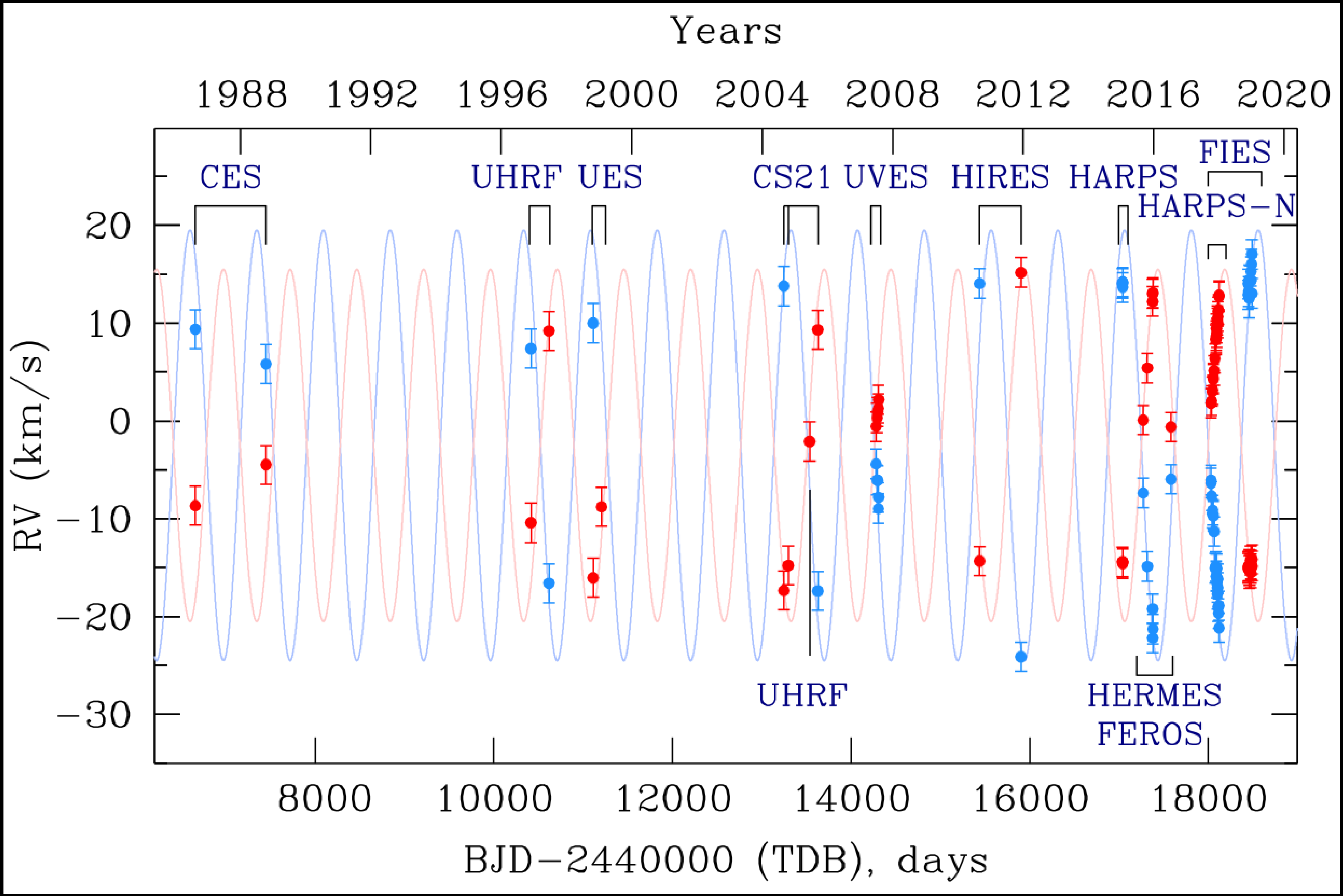
Montesinos et al. (2019)

Results: HR 10



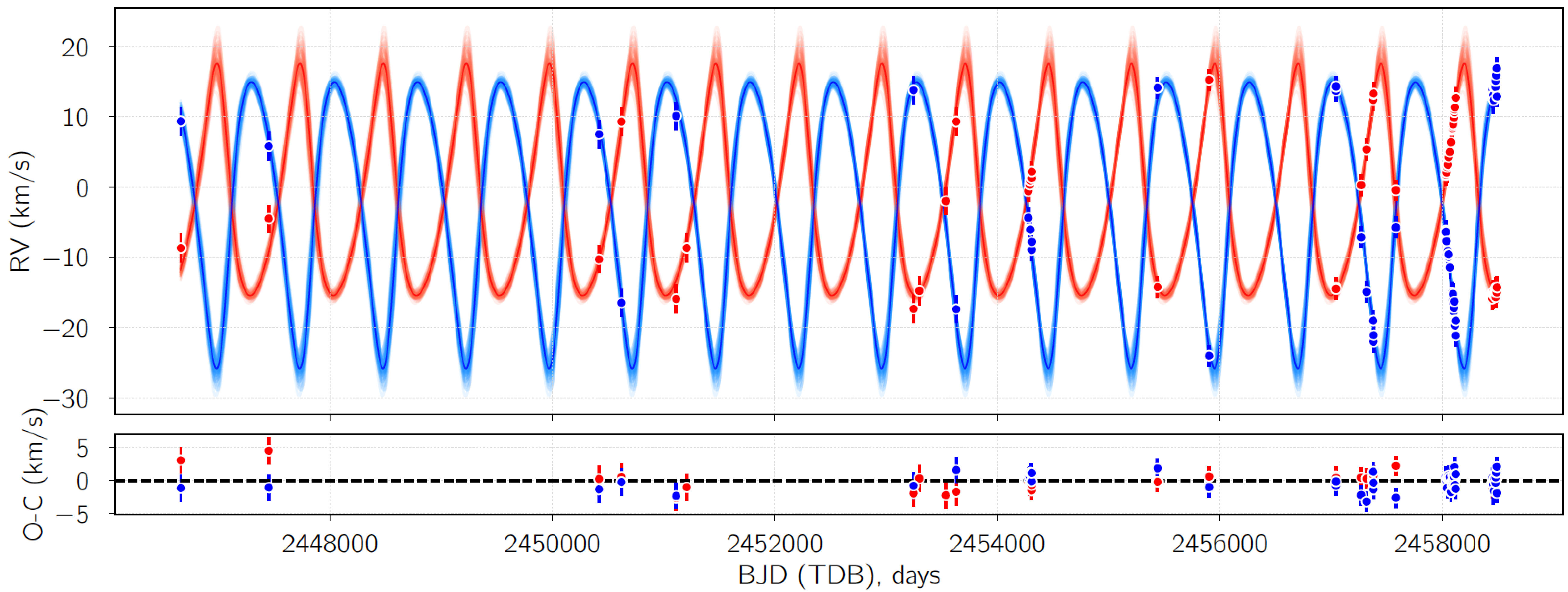
Montesinos et al. (2019)

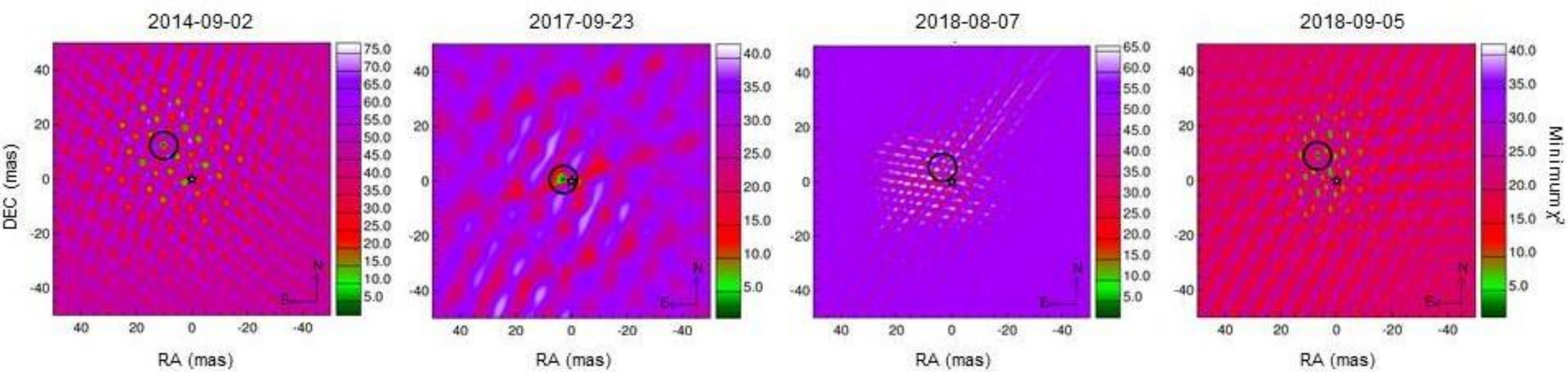
Results: HR 10



Montesinos et al. (2019)

Results: HR 10





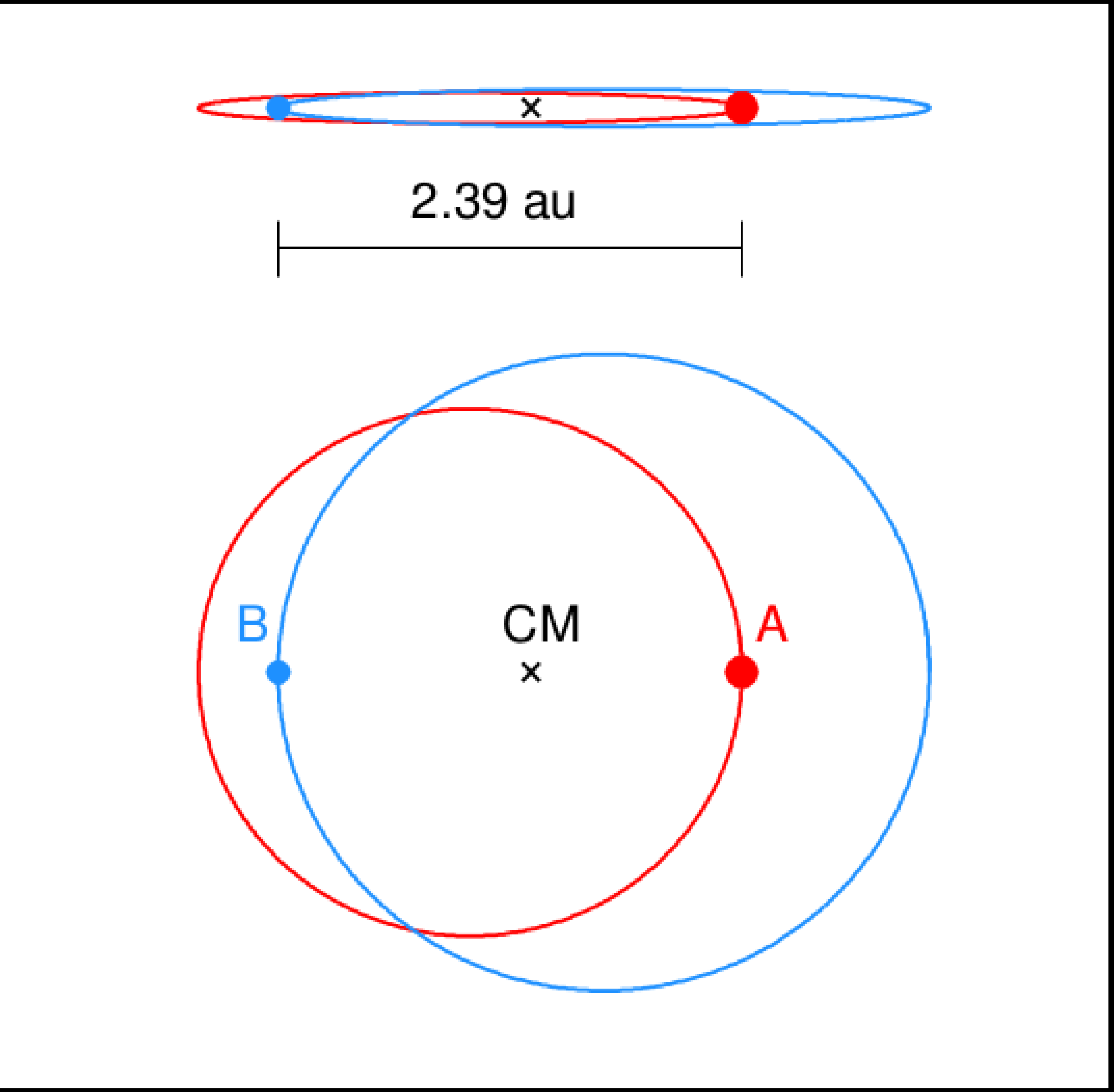
Montesinos et al. (2019)

Results: HR 10

Main-sequence binary **with individual envelopes around each component**. The circumstellar absorptions trace the orbit of each star.

Message: collect observations over long time spans to rule out the possibility of misinterpreting the origin of the variability.

P_{orb} =750 days



Take home messages

- 6 new stars with variability (FEBs)
- Previous works + our survey: 26 objects shows FEBs
- 18 stars with detected variability (FEBs)
- 60 stars with narrow absorptions detected, likely ~32 have a circumstellar origin (Rebollido et al., 2019, and PhD Thesis)

- Φ Leo: Discovery of large variations in timescales of hours (Eiroa et al., 2016)

- Hot-cold gas relation: Inclination angle favours the detection of close-in gas (Rebollido et al., 2018)

- HR 10: variability not due to exocomets (Montesinos et al. 2019)