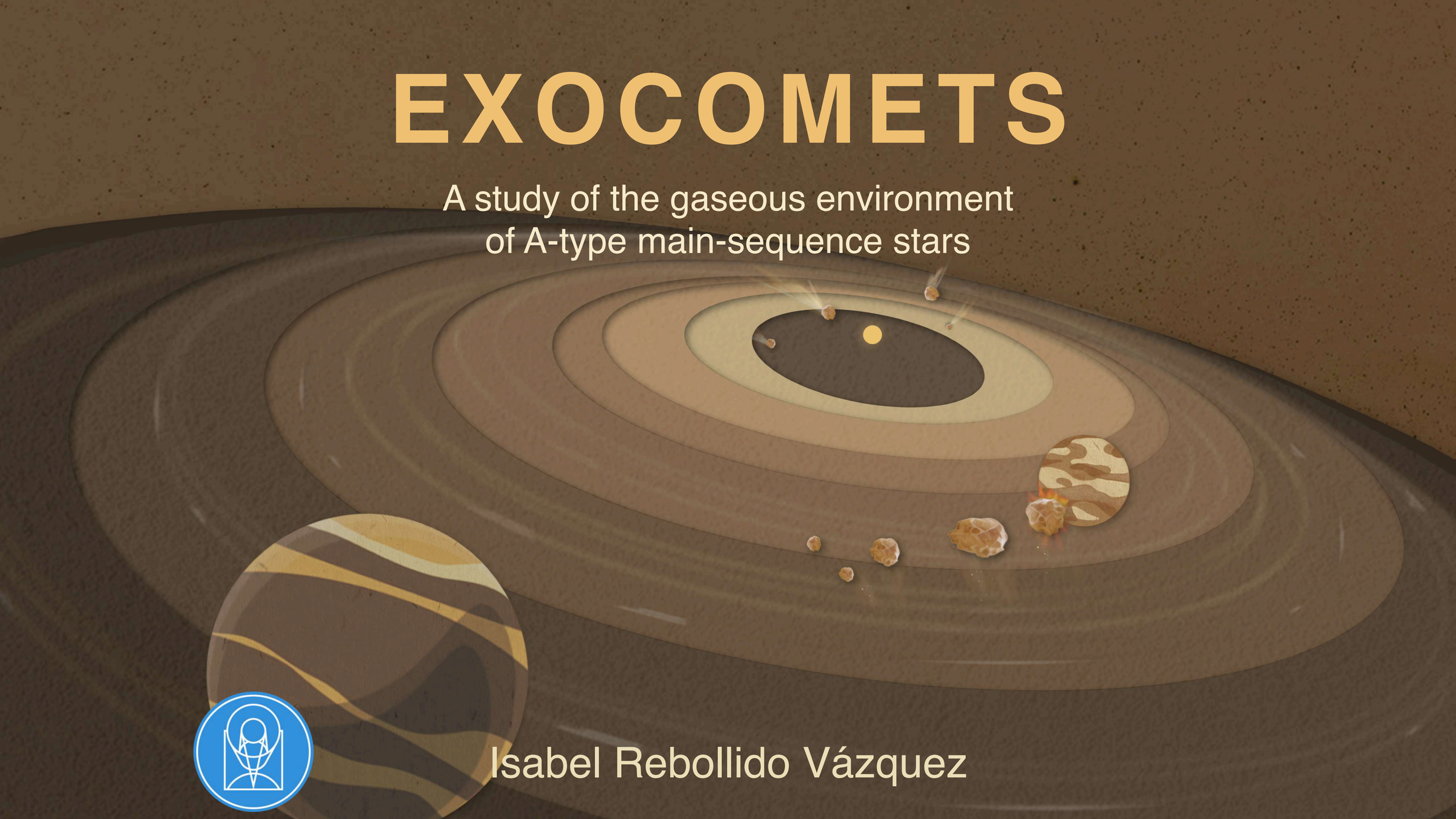
EXOCOMETS

A study of the gaseous environment
of A-type main-sequence stars



Isabel Rebollido Vázquez

Introduction

Artist impression of planetary system

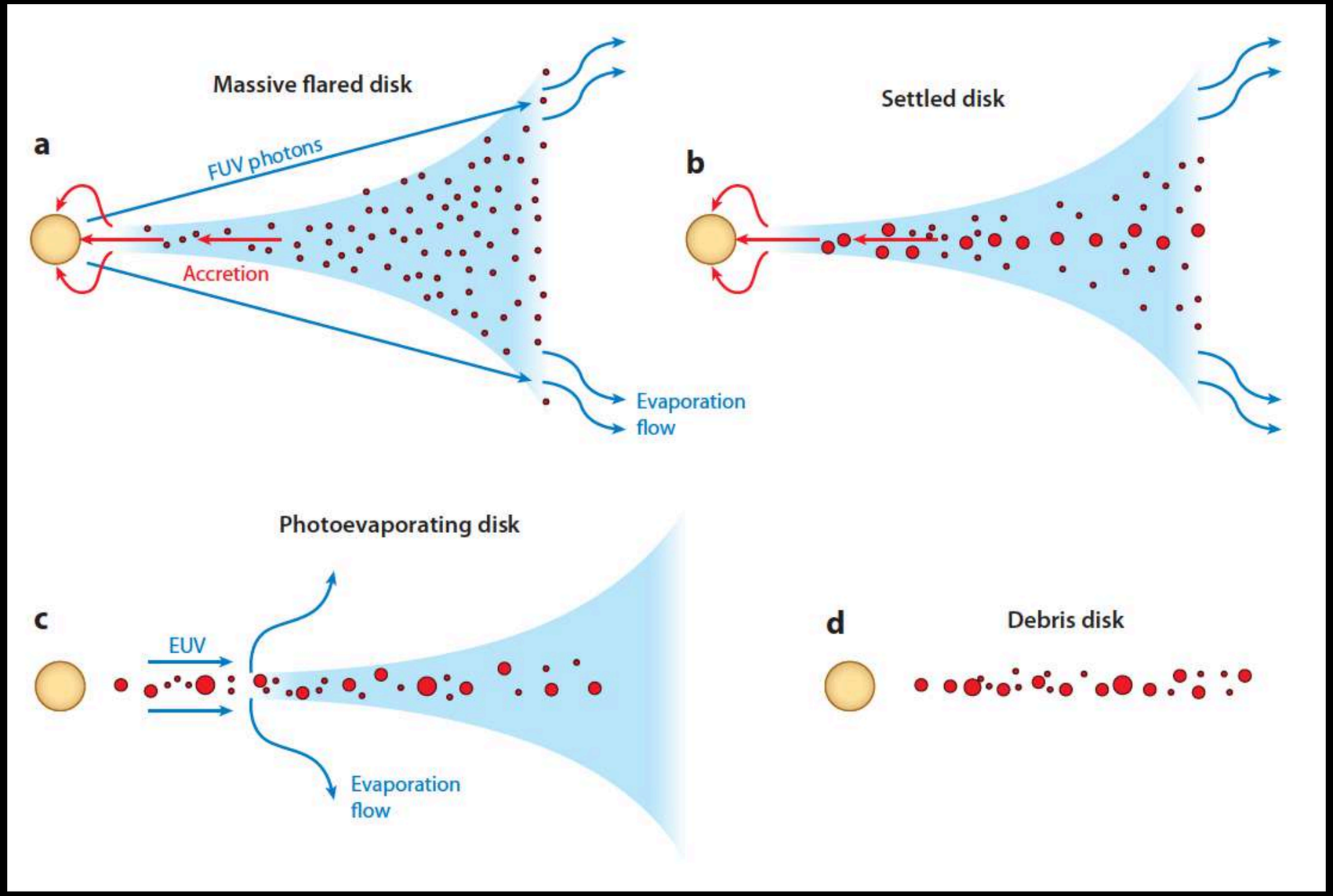
NASA/JPL

Introduction

Artist impression of planetary system

NASA/JPL

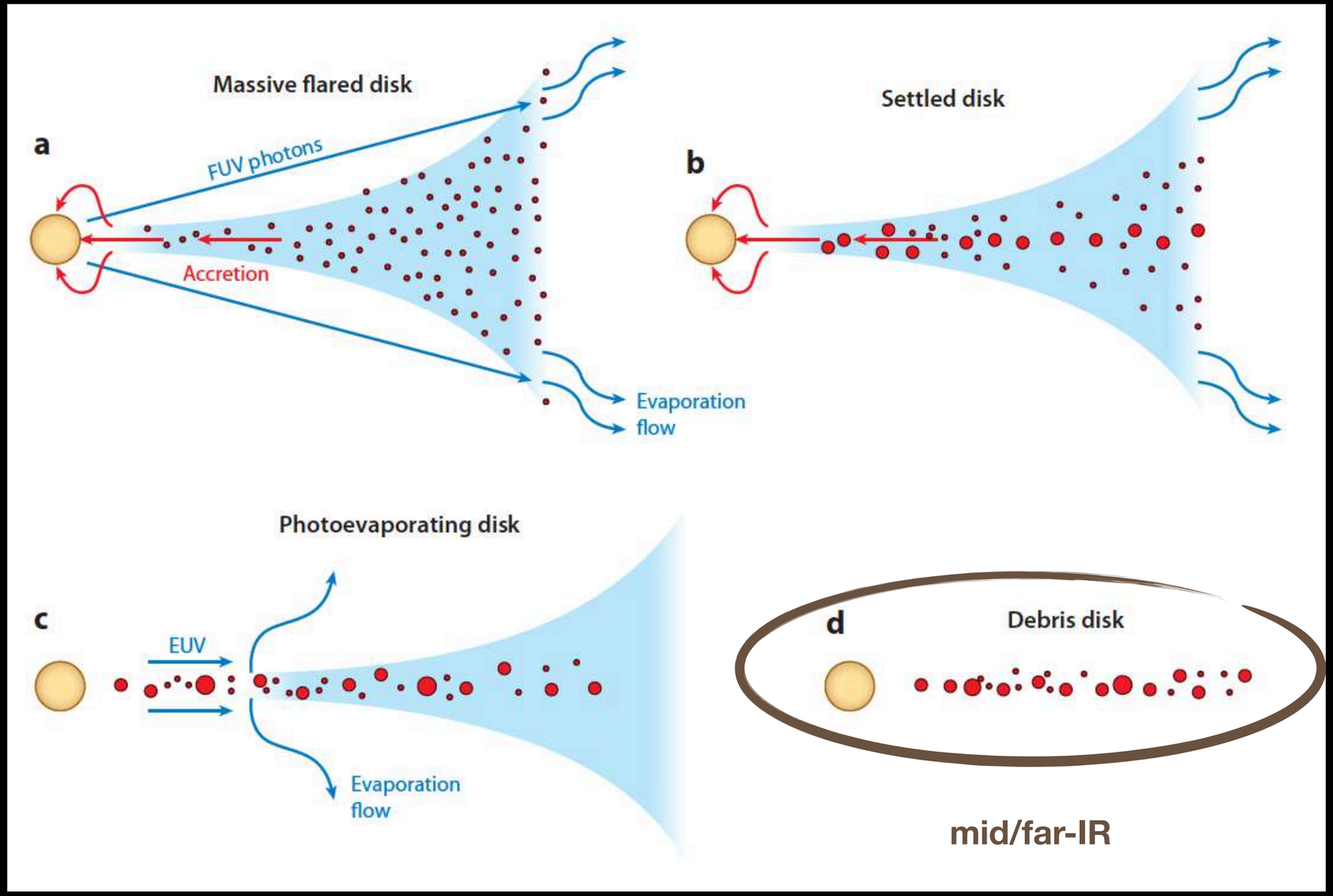
Introduction



Planet formation process

Williams&Cieza,11

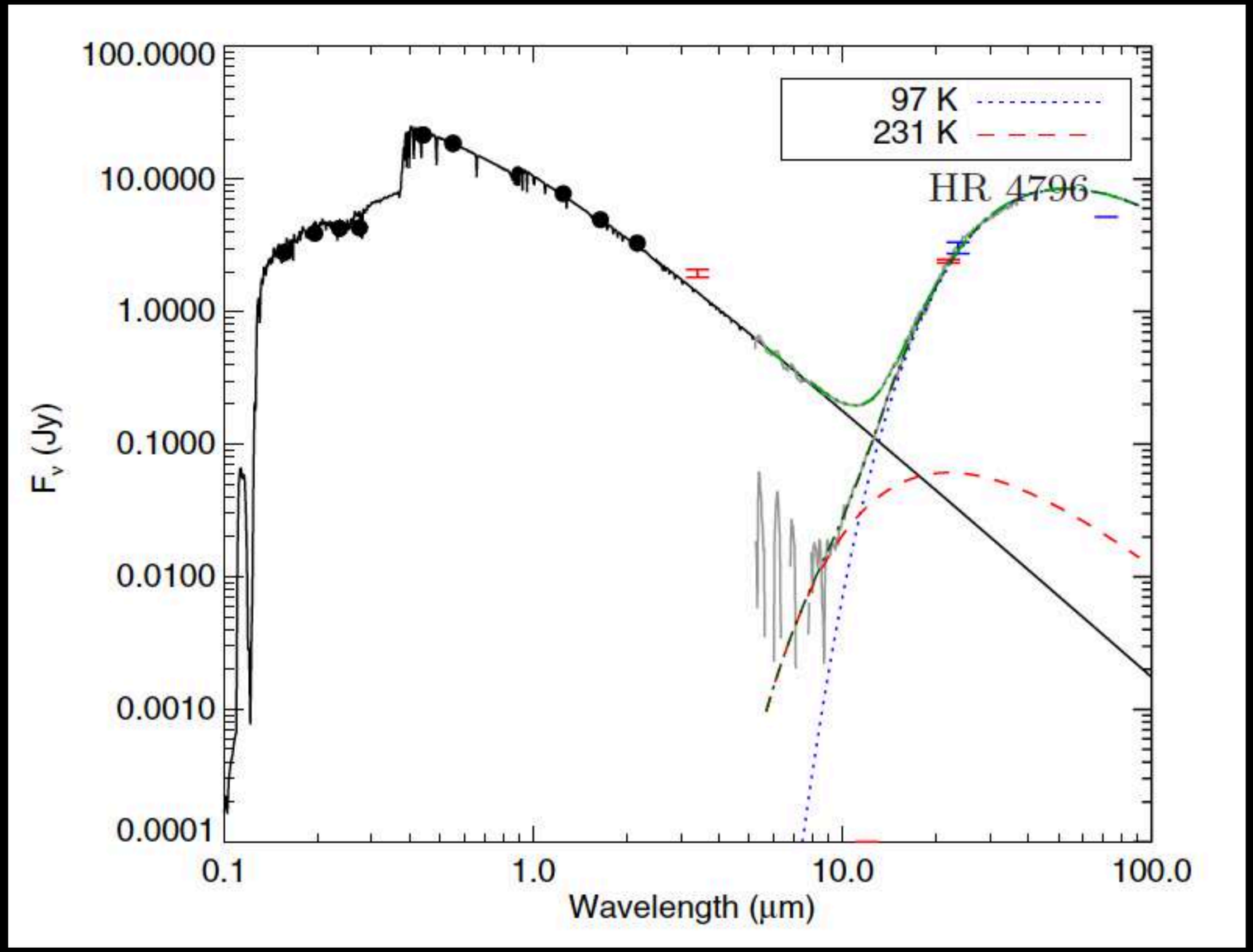
Introduction



Planet formation process

Williams&Cieza,11

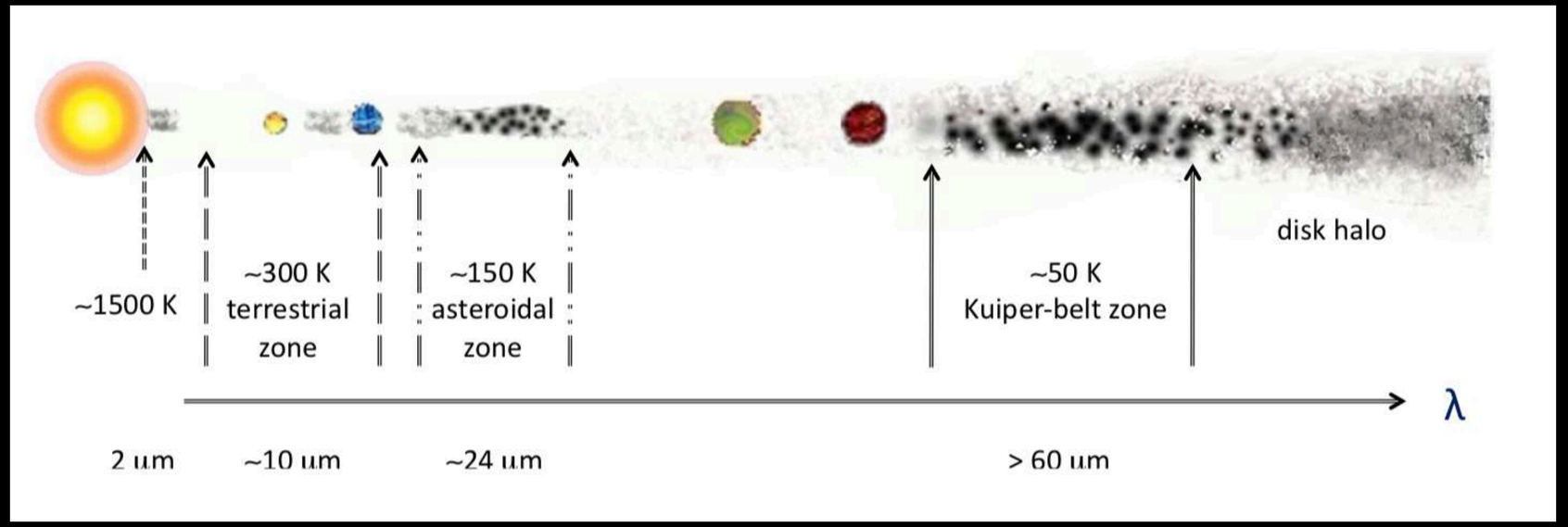
Introduction



Spectral Energy Distribution

Chen+14

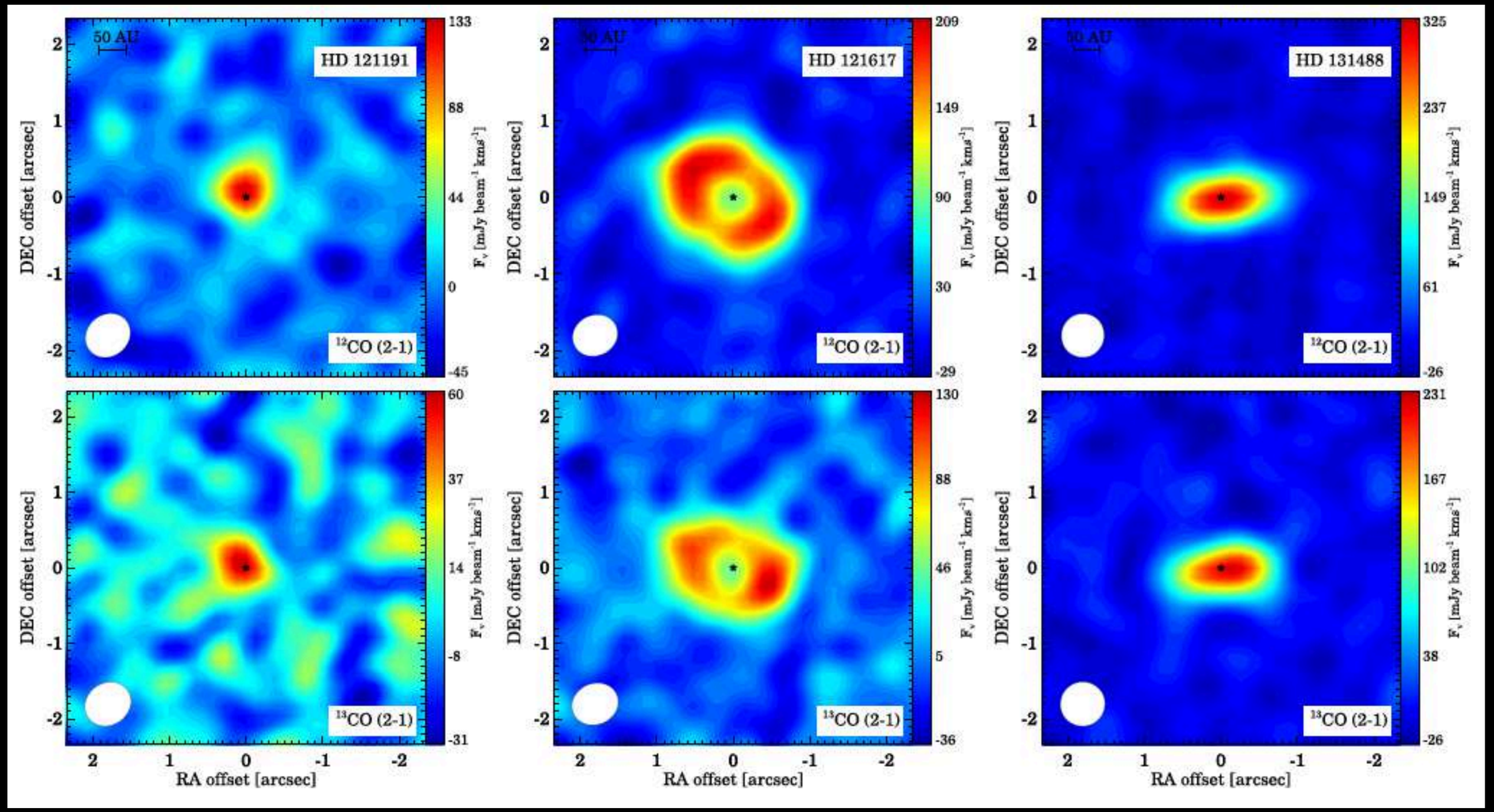
Introduction



Configuration of planetary systems

Matthews+14

Introduction



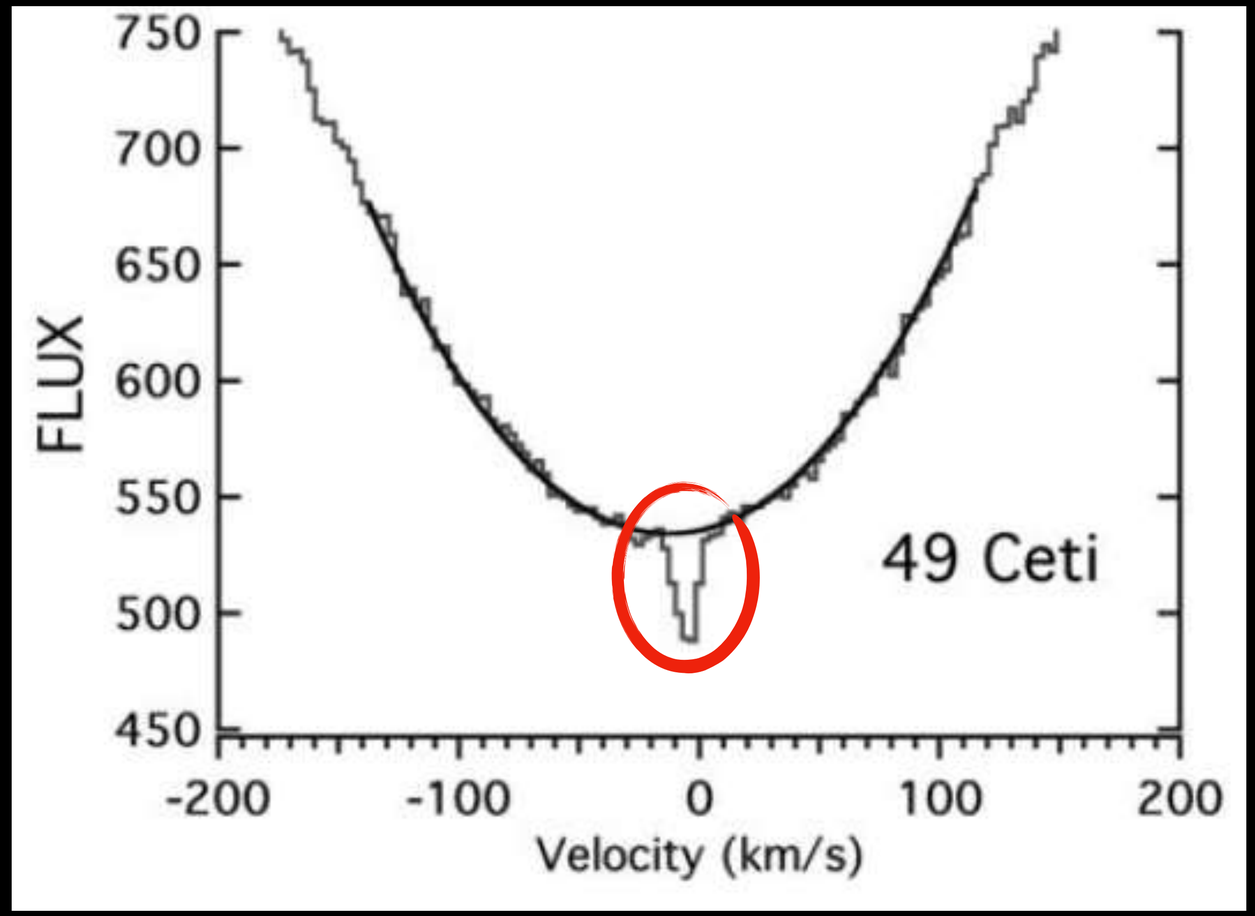
Emission CO lines

Outskirts of the system

~10 K

Moor+17

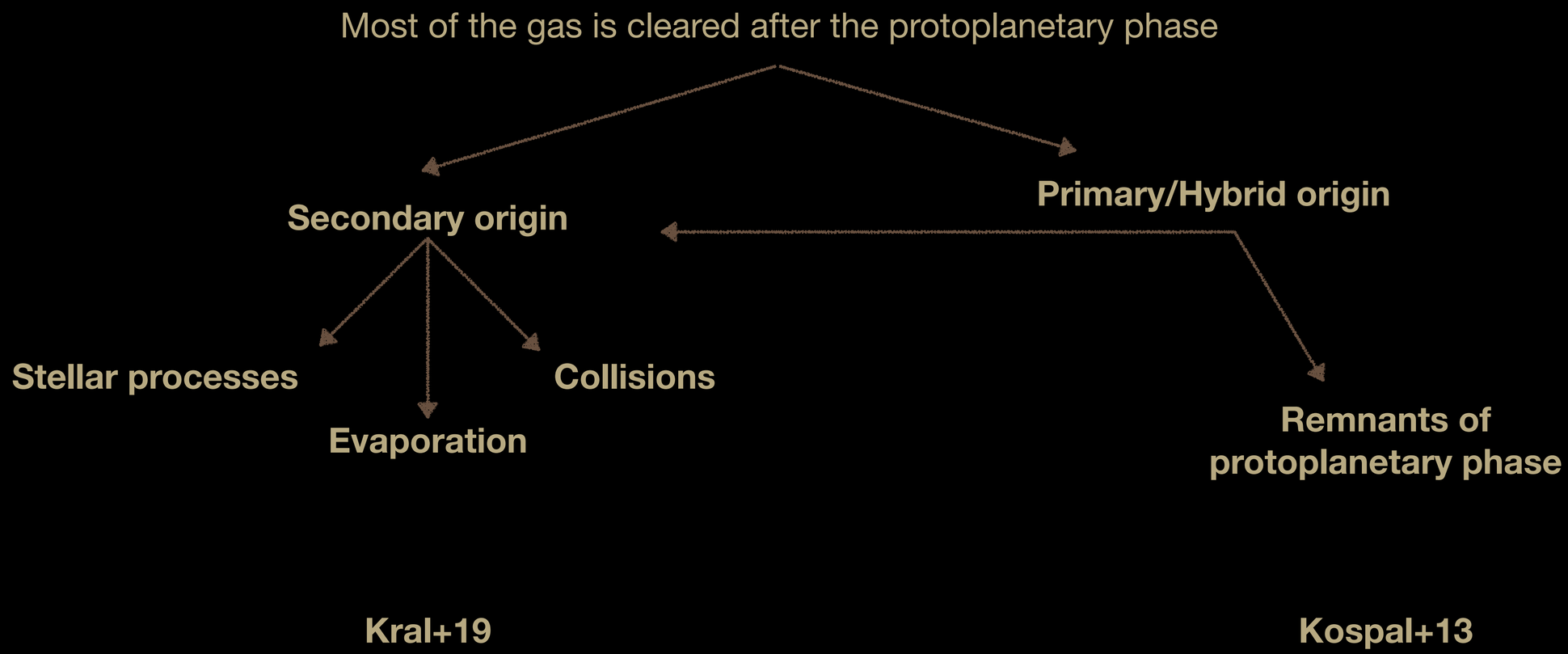
Introduction



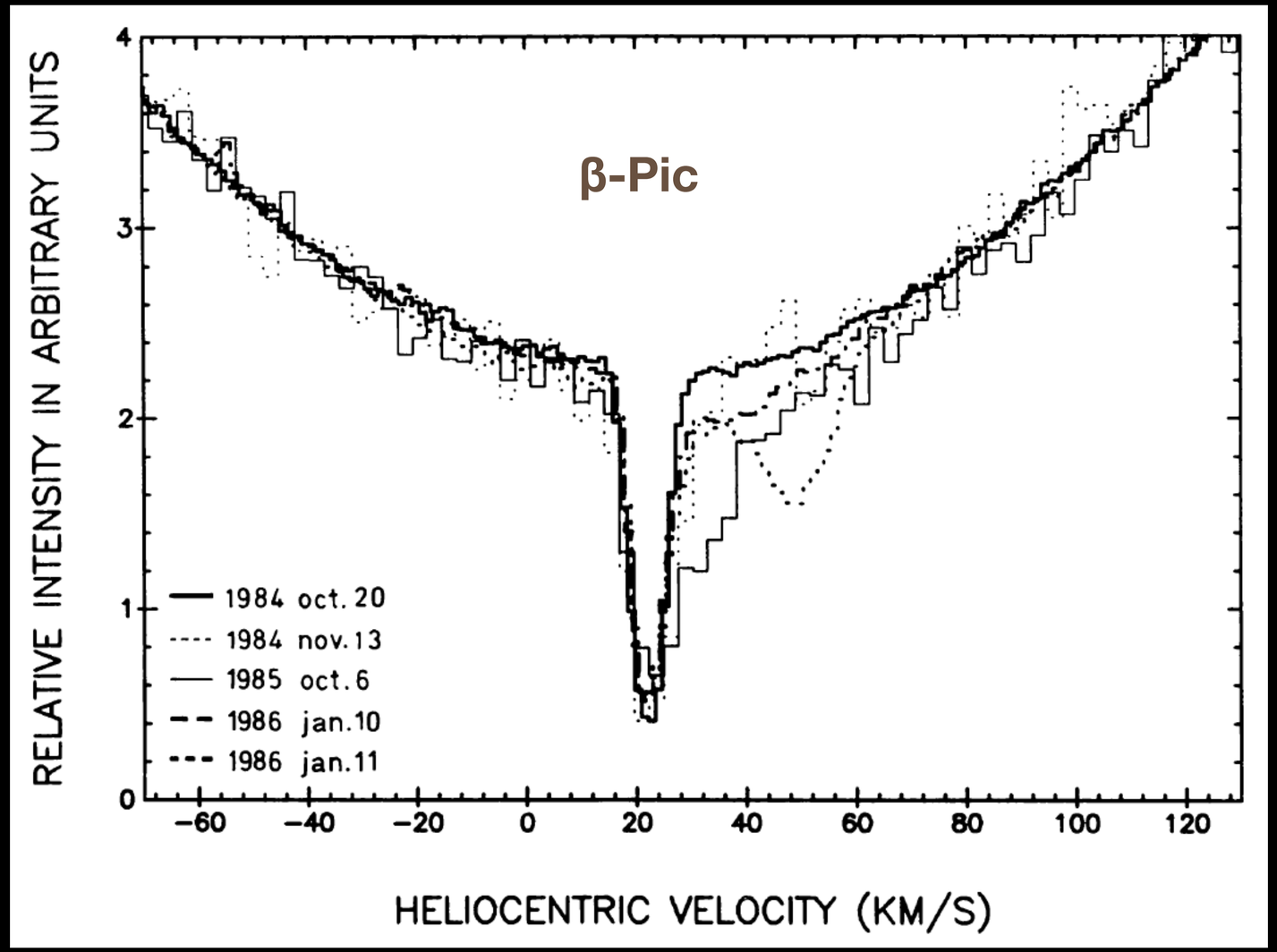
Montgomery&Welsh12

Absorption CaIIK (3933.66 Å)
Inner regions
~1000-2000 K

Introduction



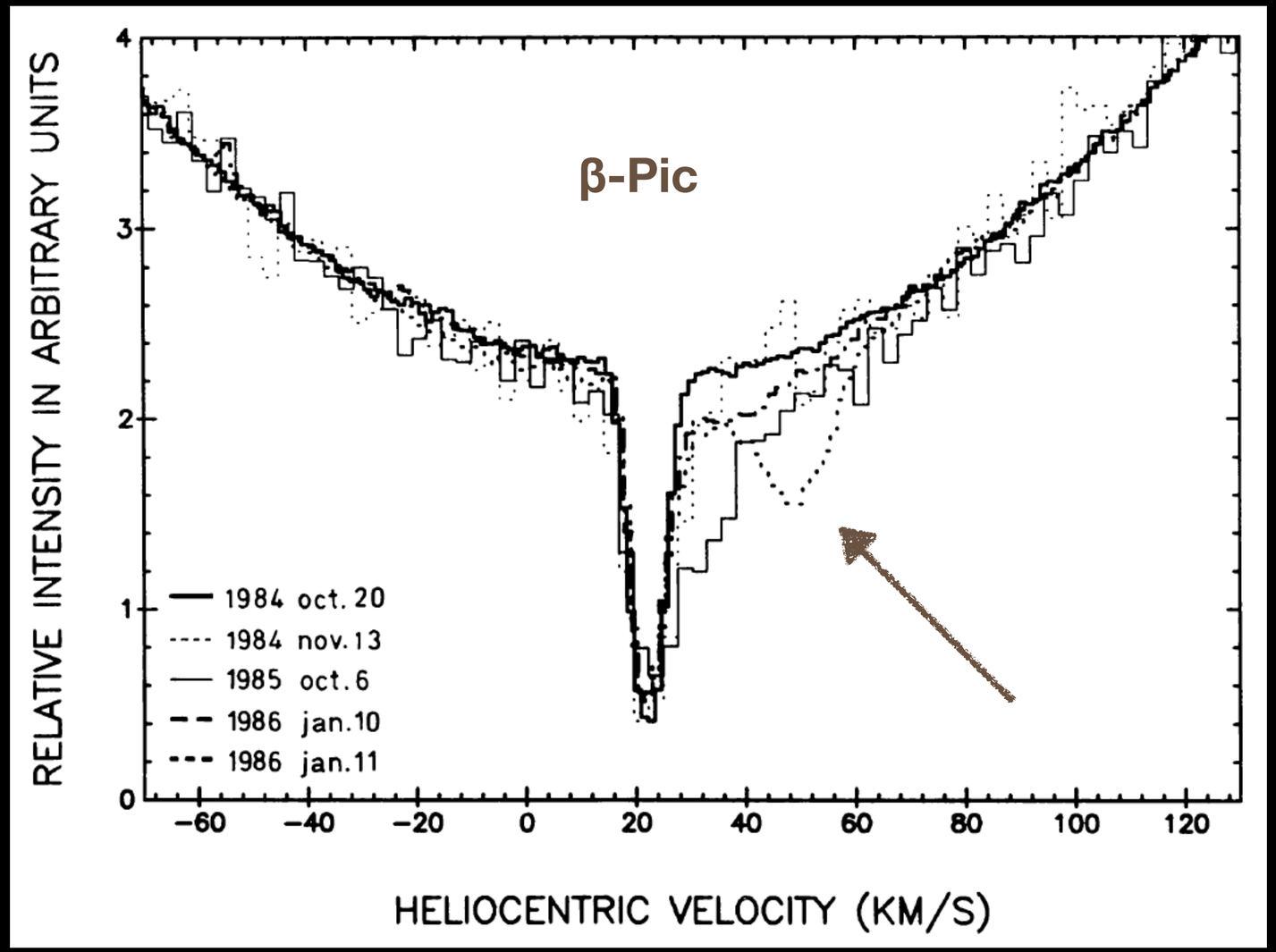
Introduction



CaIIK (3933.66 Å)

Ferlet+87

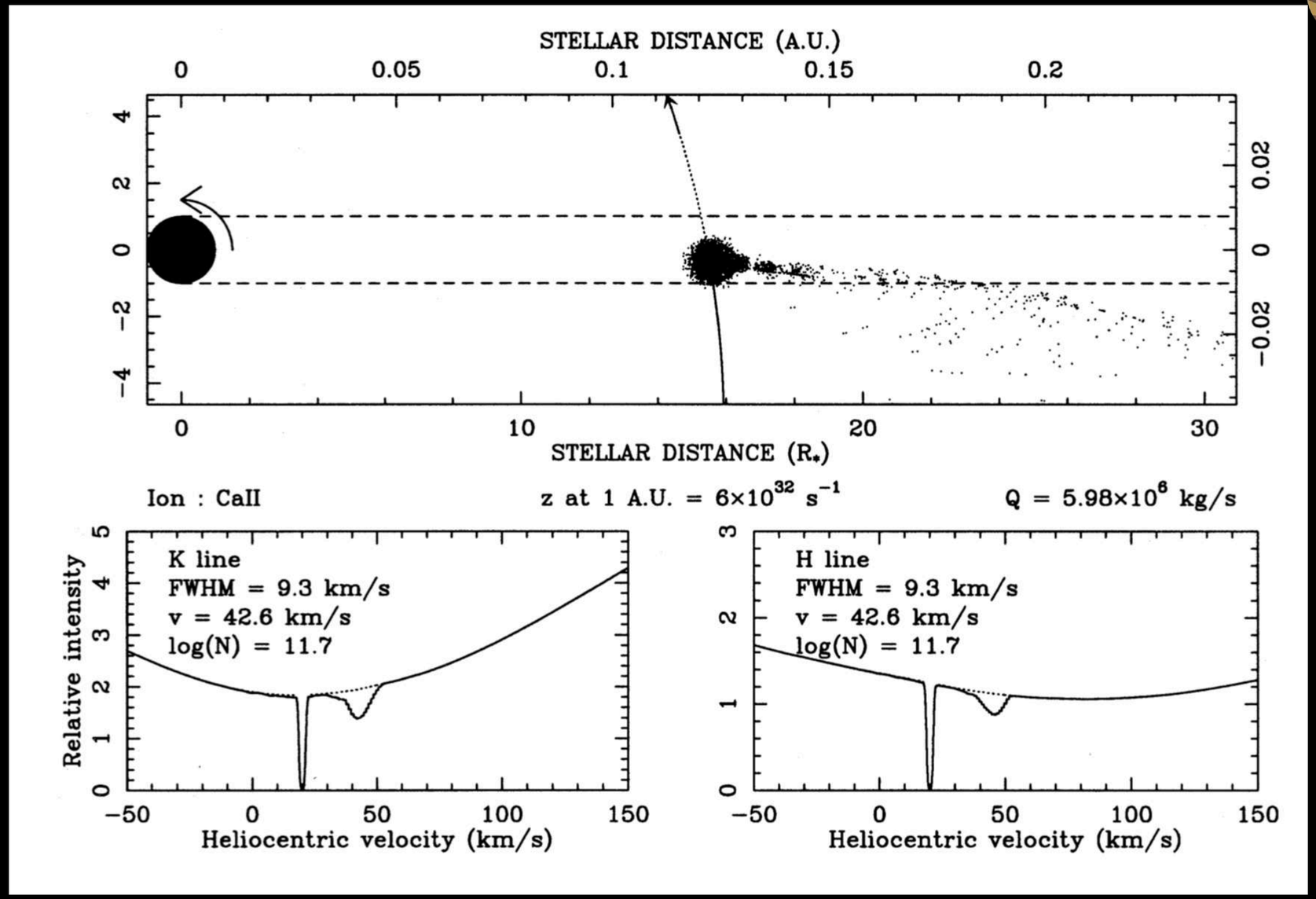
Introduction



CaIIK (3933.66 Å)

Ferlet+87

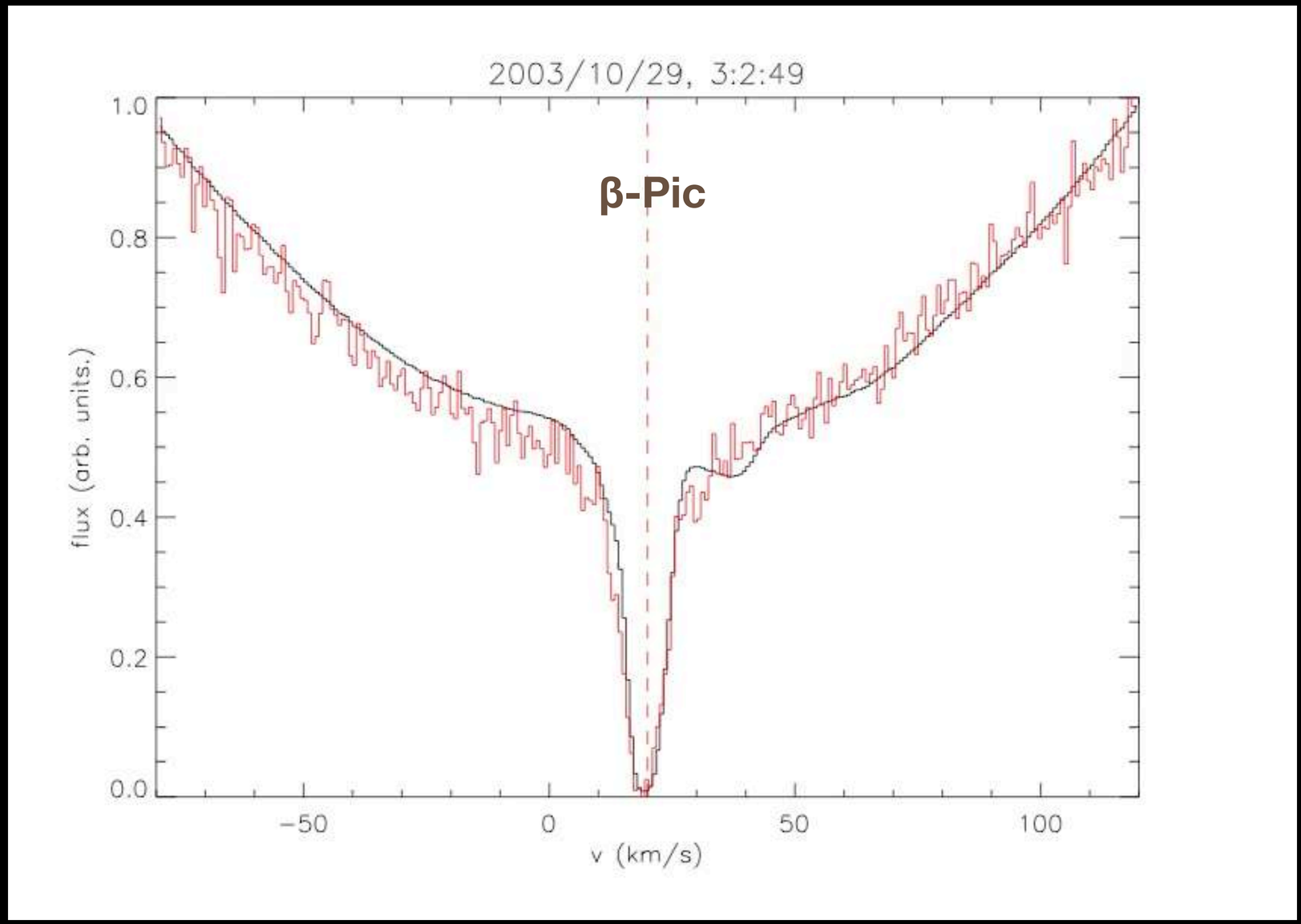
Introduction



Exocometary absorption in CaII

Beust+98

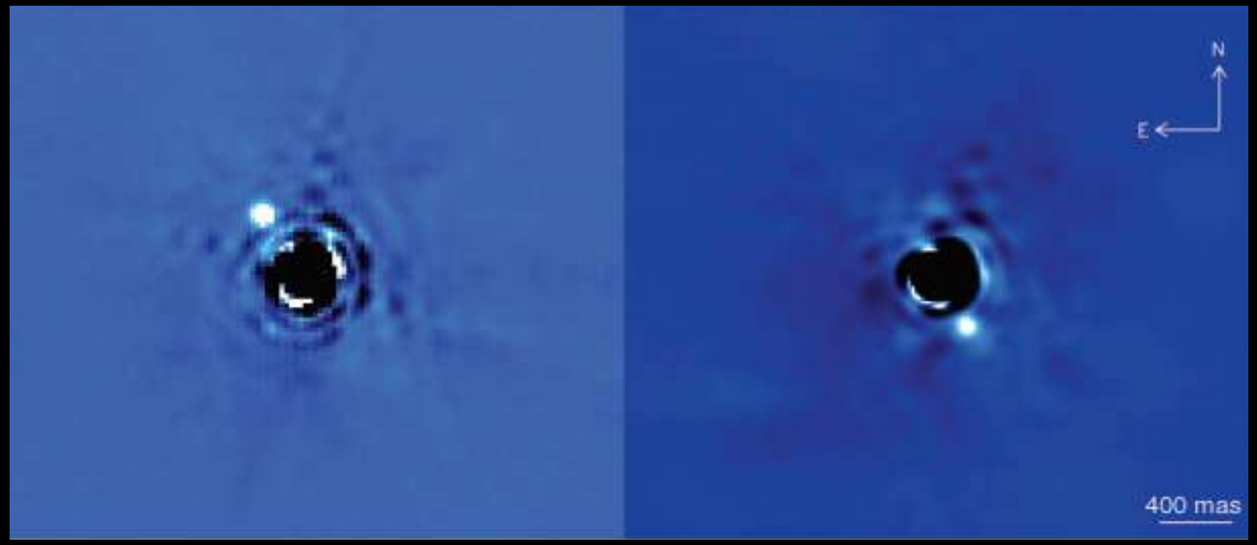
Introduction



CaIIK (3933.66 Å)

Credit: Pablo Riviere-Marichalar

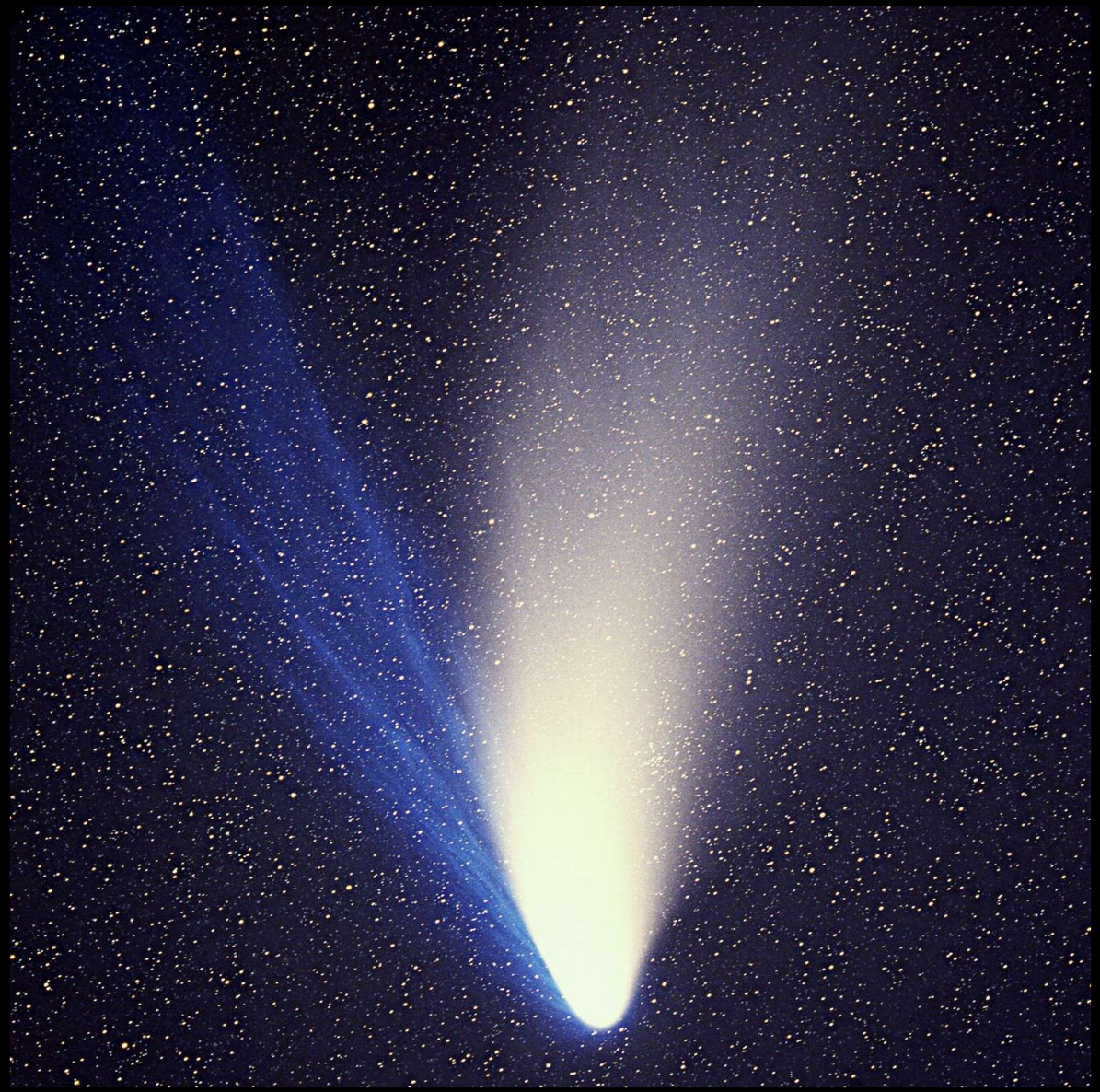
Introduction



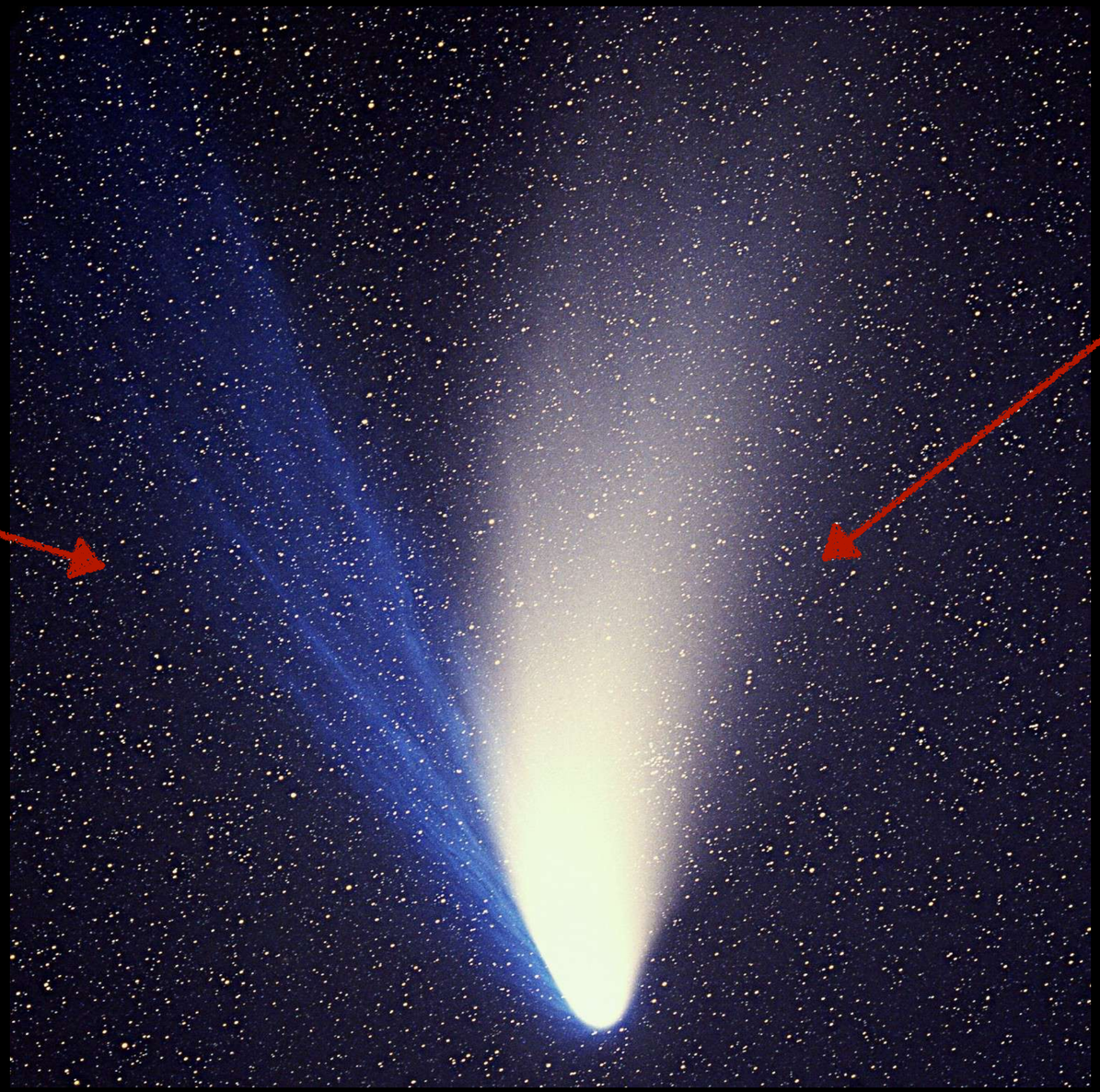
VLT/NACO imaging

Lagrange+08

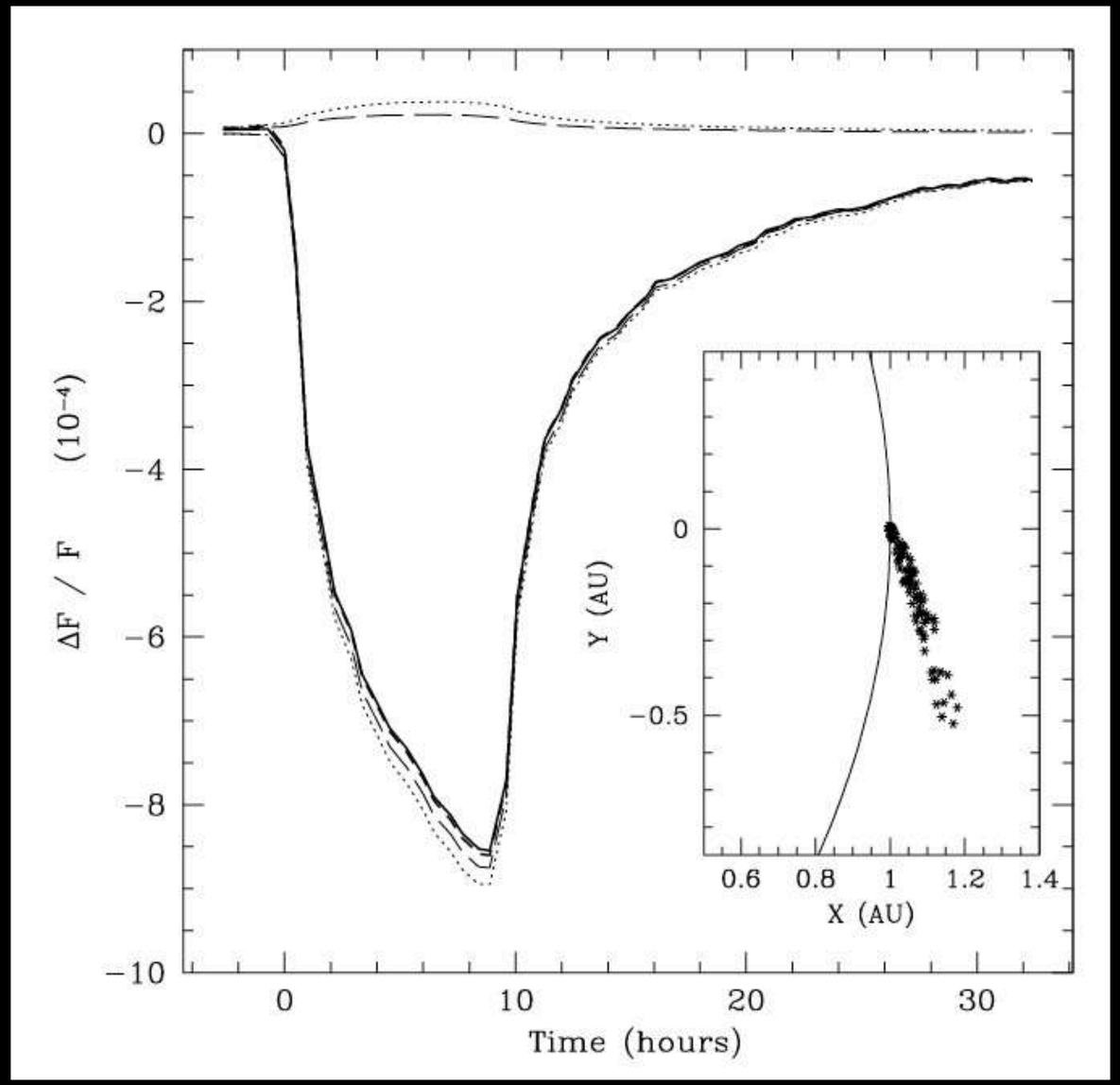
Introduction



Introduction



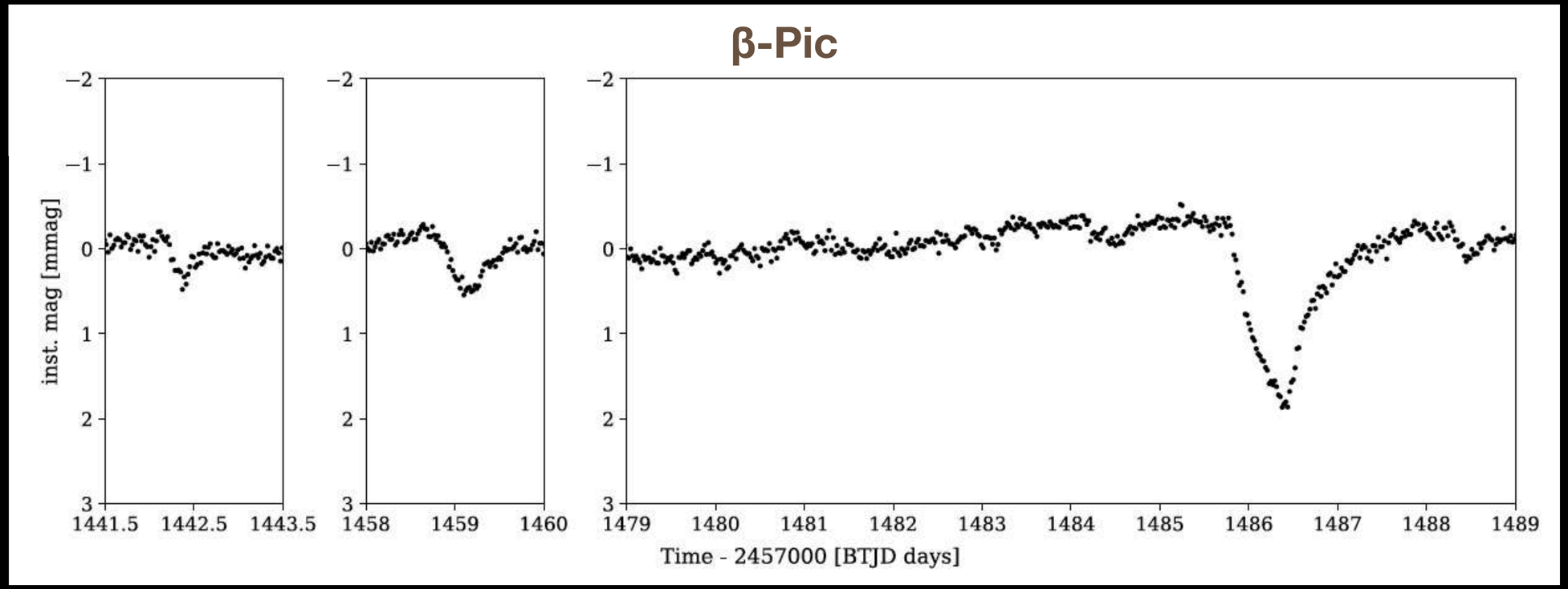
Introduction



Photometric model

Lecavelier+98

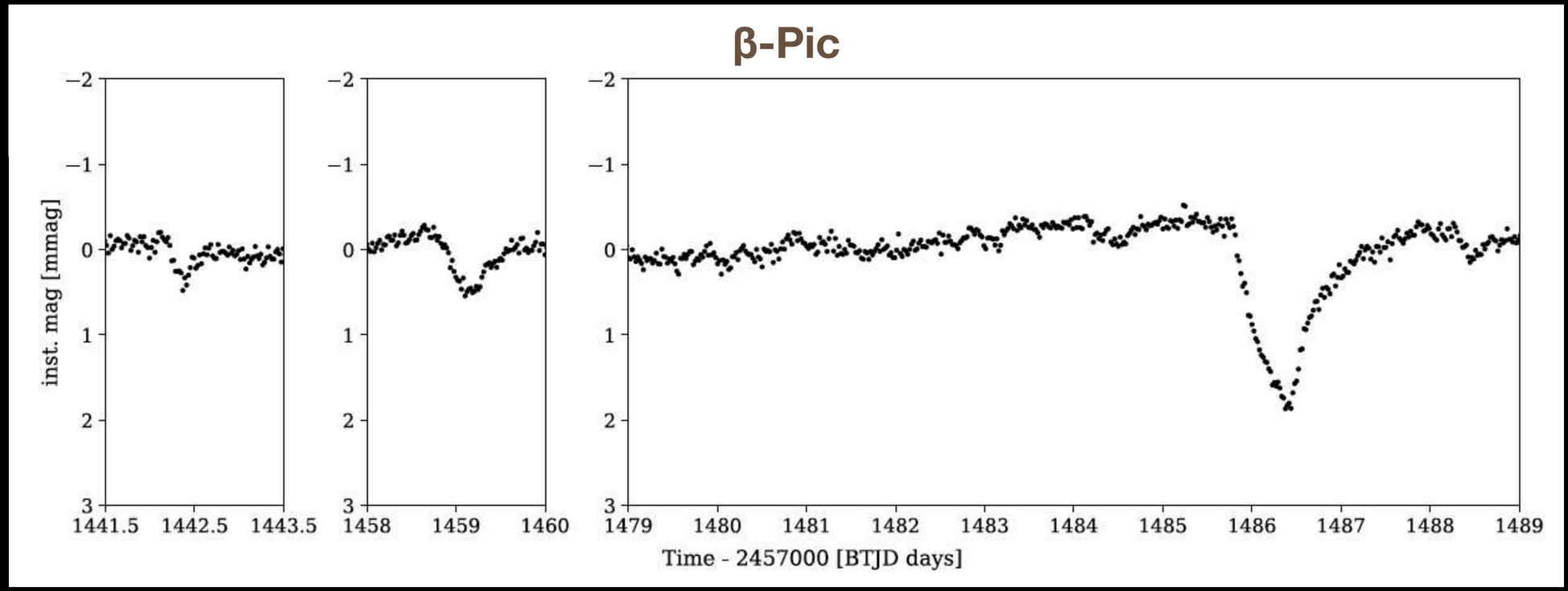
Introduction



Light curve
TESS data

Zieba+19

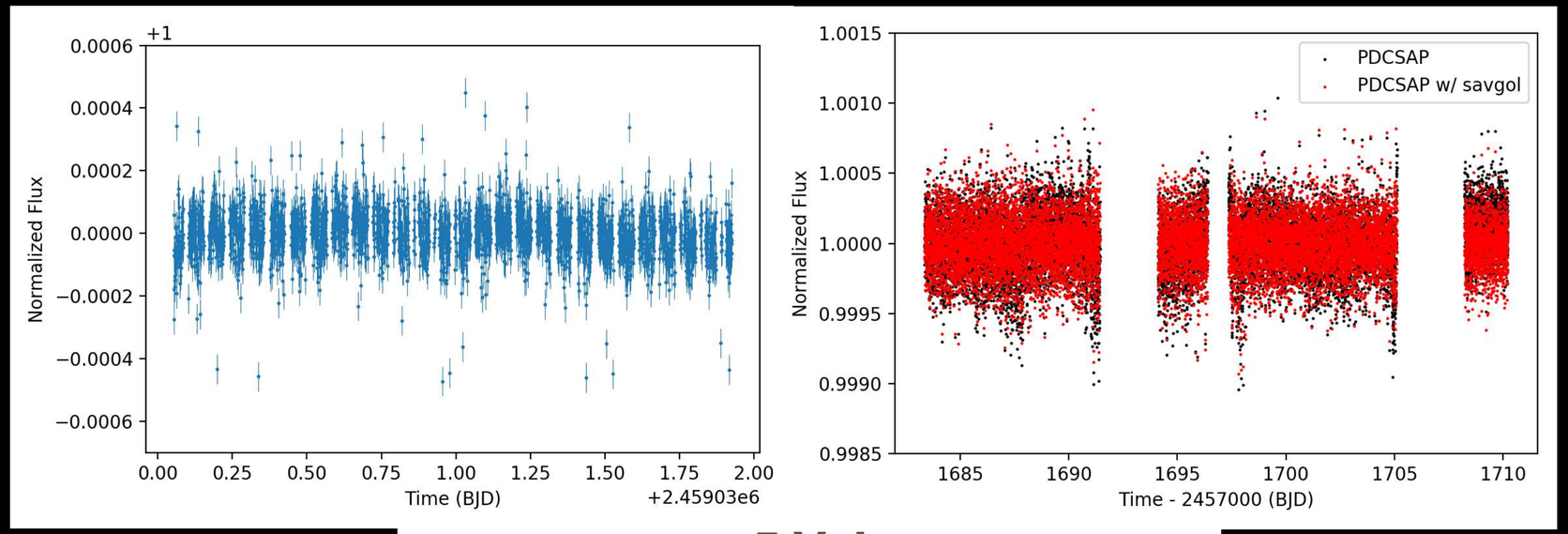
Introduction



Light curve
TESS data

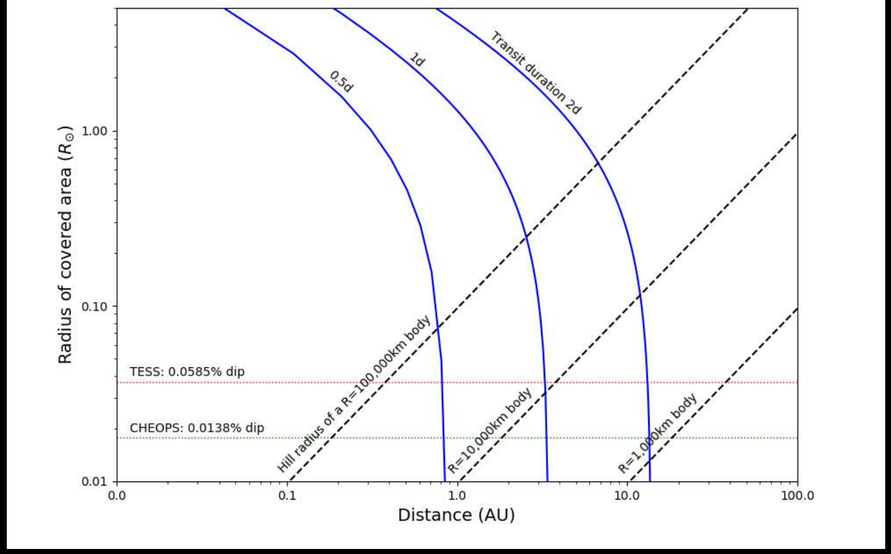
Zieba+19

Introduction



CHEOPS &
TESS data

5 Vul



Rebollido+in prep.

Introduction

~30 stars are known to host exocomet-like features

Table 1
Stars with Observations Showing Spectral or Photometric Variability Conclusively Attributed to Exocomet Activity

Name	Sp. Type	References
49 Cet (HD 9672)	A1V	(1)
β Pic (HD 39060)	A6V	(2), (3)
HD 172555	A7V	(4)
KIC 3542116 (Photometric detection)	F2V	(5)

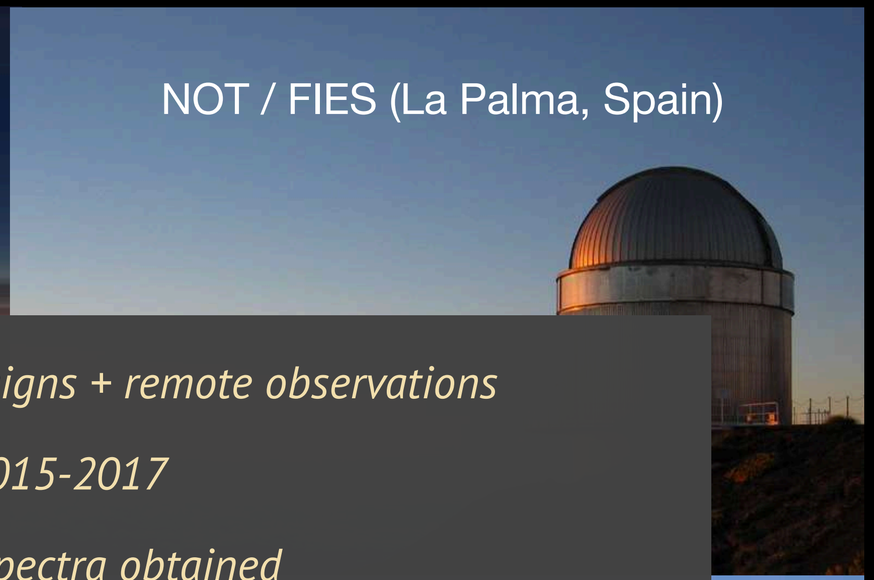
References. (1) Montgomery & Welsh (2012), (2) Ferlet et al. (1987), (3) Kiefer et al. (2014b), (4) Kiefer et al. (2014a), (5) (Rappaport et al. 2018). Spectral types were taken from the references.

Table 2
Stars Which Show Variability in One of the Ca II H or K Lines or Weak Photometric Signatures that are Suggestive of Exocomet Activity

Name	Sp. Type	Reference
HD 256 (HR 10)[a]	A2IV/V	(1), (12), (15), (20), (28)
HD 21620	A0V	(3)
HD 32297	A0V	(4)
HD 37306 (HR 1919)	A1V	(29)
HD 42111	A3V	(5), (12)
HD 50241	A7IV	(5), (11)
HD 56537 (λ Gem)	A3V	(6)
HD 58647	B9IV	(6)
HD 64145 (ϕ Gem)	A3V	(6)
HD 80007 (HR 3685)	A2IV	(11), (15)
HD 85905	A2V	(7), (15)
HD 98058 (ϕ Leo)	A5V	(30)
HD 108767 (δ Crv)	A0IV	(6)
HD 109573 (HR 4796)	A0V	(6), (16)
HD 110411 (ρ Vir)	A0V	(3)
HD 138629 (HR 5774)	A5V	(8)
HD 132200 (κ Cen)	B2IV	(19)
HD 145964	B9V	(3)
HD 148283 (HR 6123)	A5V	(5), (13)
HD 156623 (HIP 84881)	A0V	(19)
HD 182919 (5 Vul)	A0V	(2)
HD 183324 (c Aql)	A0IV	(10), (16)
HD 217782 (2 And)	A3V	(2), (5), (14)
HD 24966	A0V	(21)
HD 38056	B9.5V	(21)
HD 79469 (θ Hya)	B9.5V	(21)
HD 225200	A1V	(21)
KIC 11084727 (Phot.)	F2V	(22)
KIC 8462852 (Phot.)	F3V	(23), (24), (25), (26), (27)

Strom+20

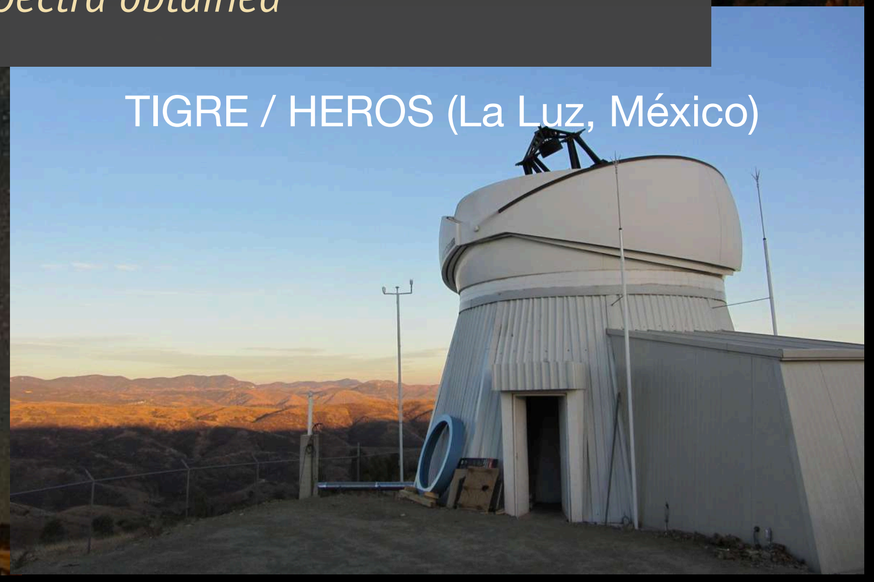
Spectroscopic Survey



14 observing campaigns + remote observations

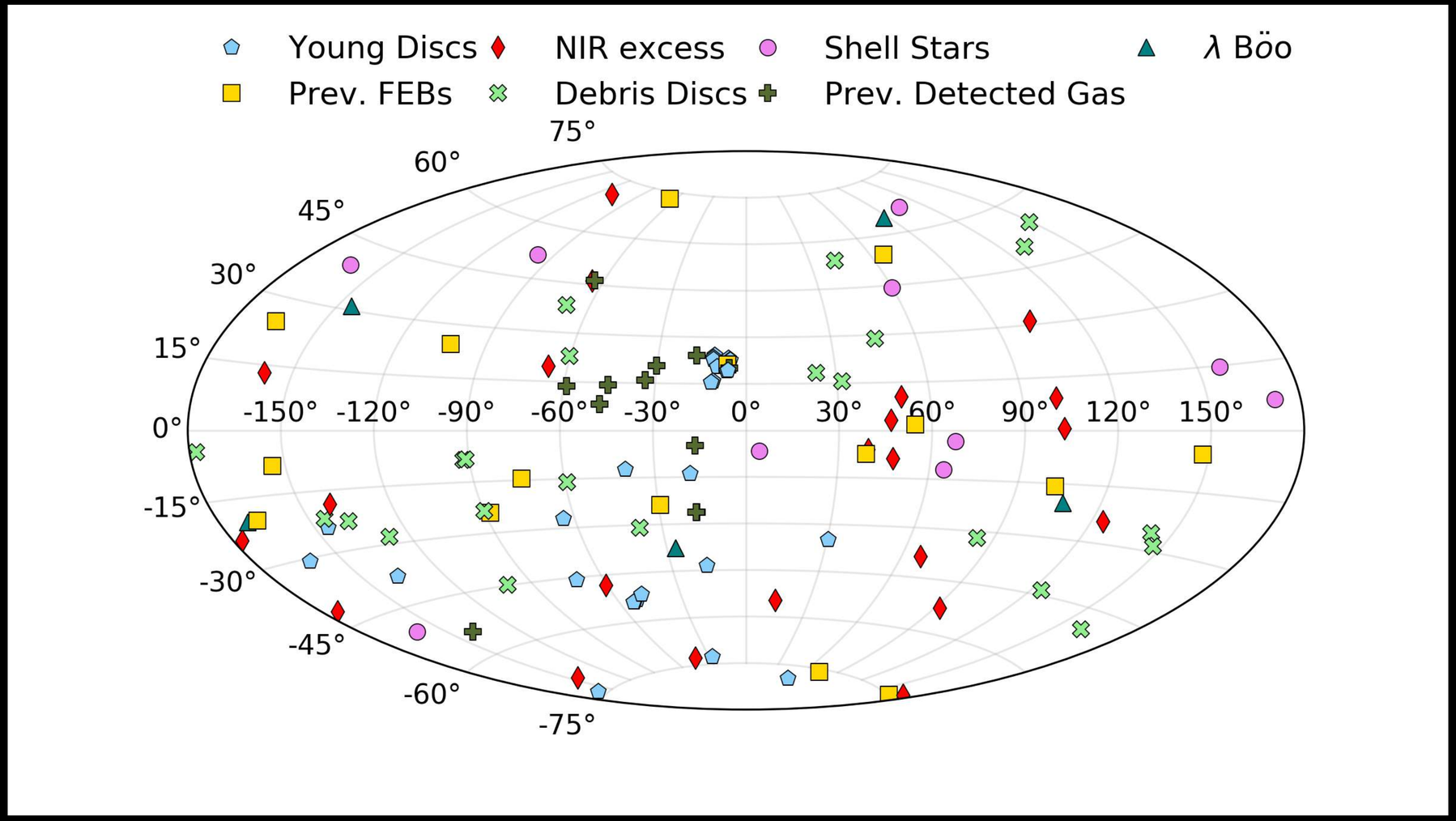
2015-2017

~2000 spectra obtained



Spectroscopic Survey

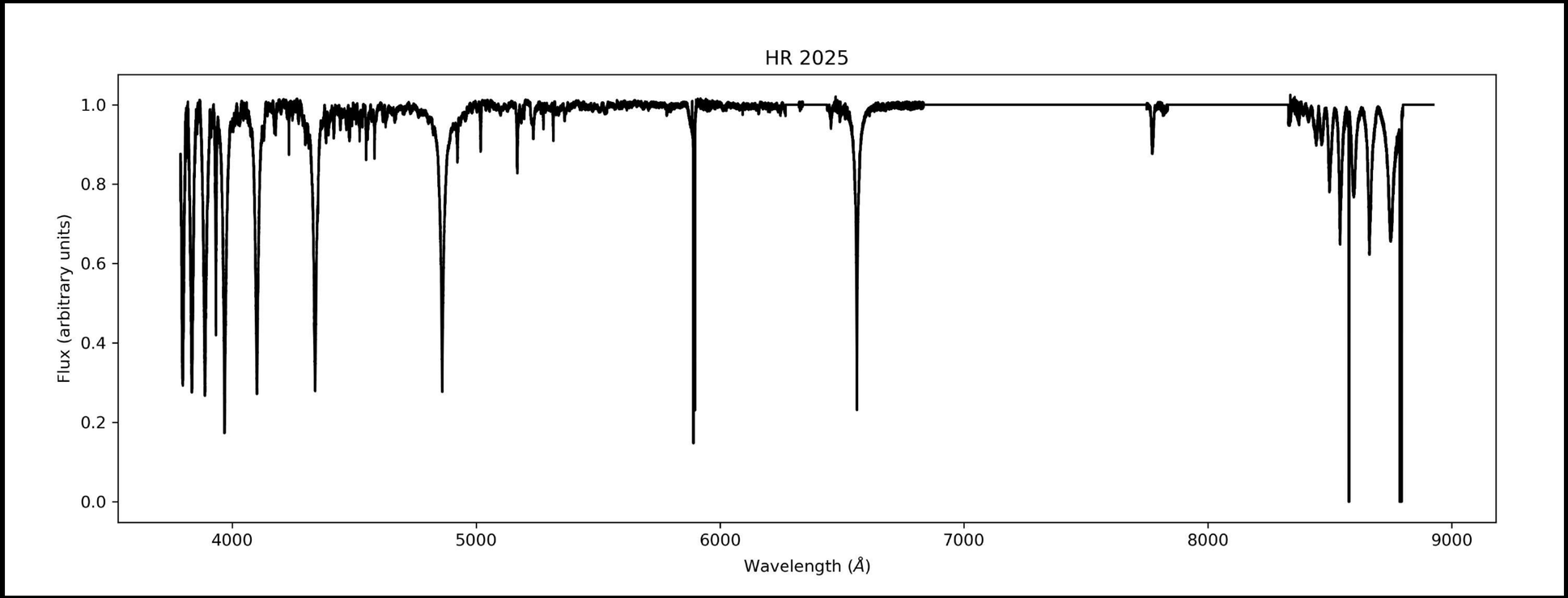
Sample



Rebollido+20

Spectroscopic Survey

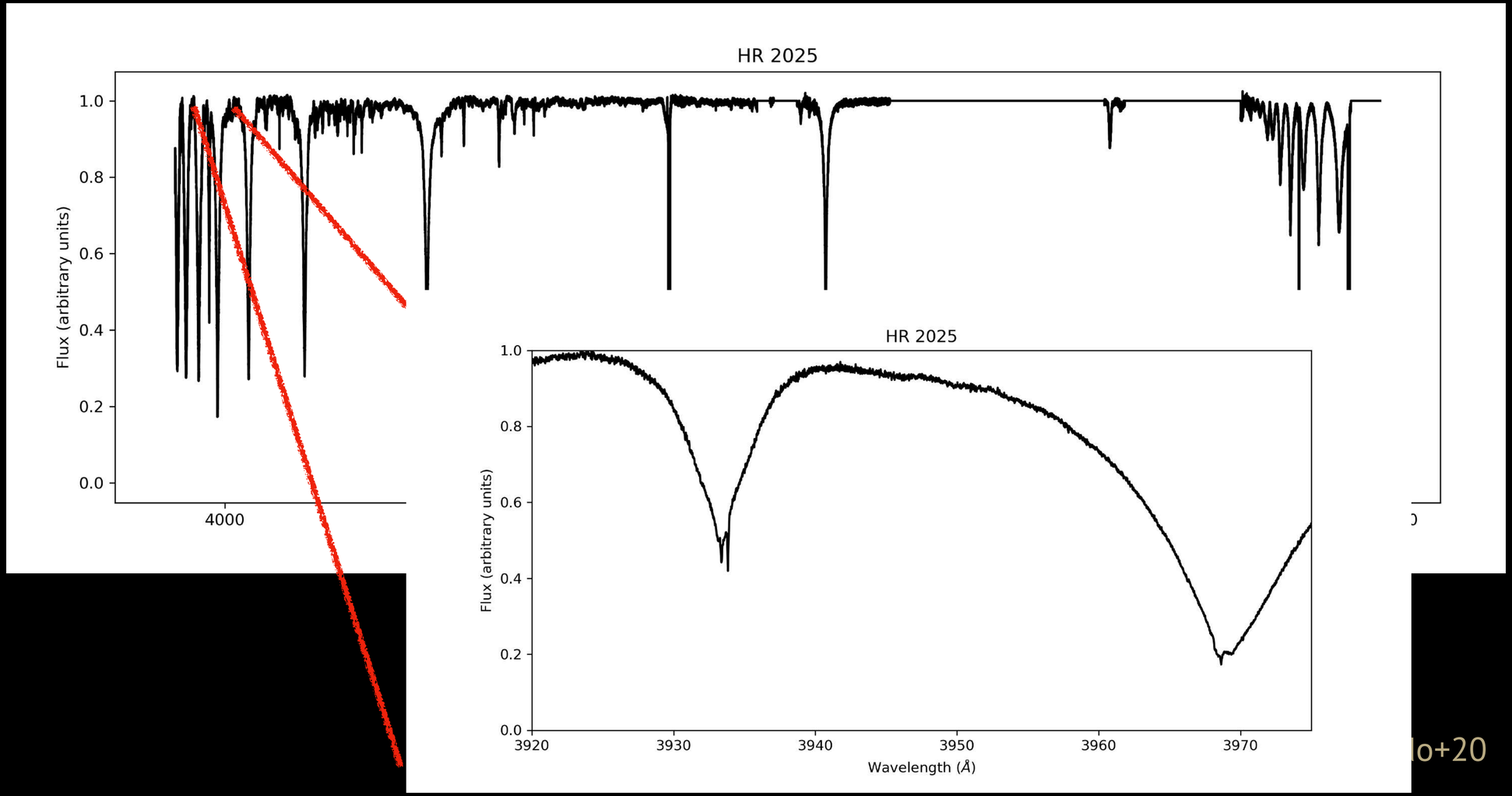
Data



Rebollido+20

Spectroscopic Survey

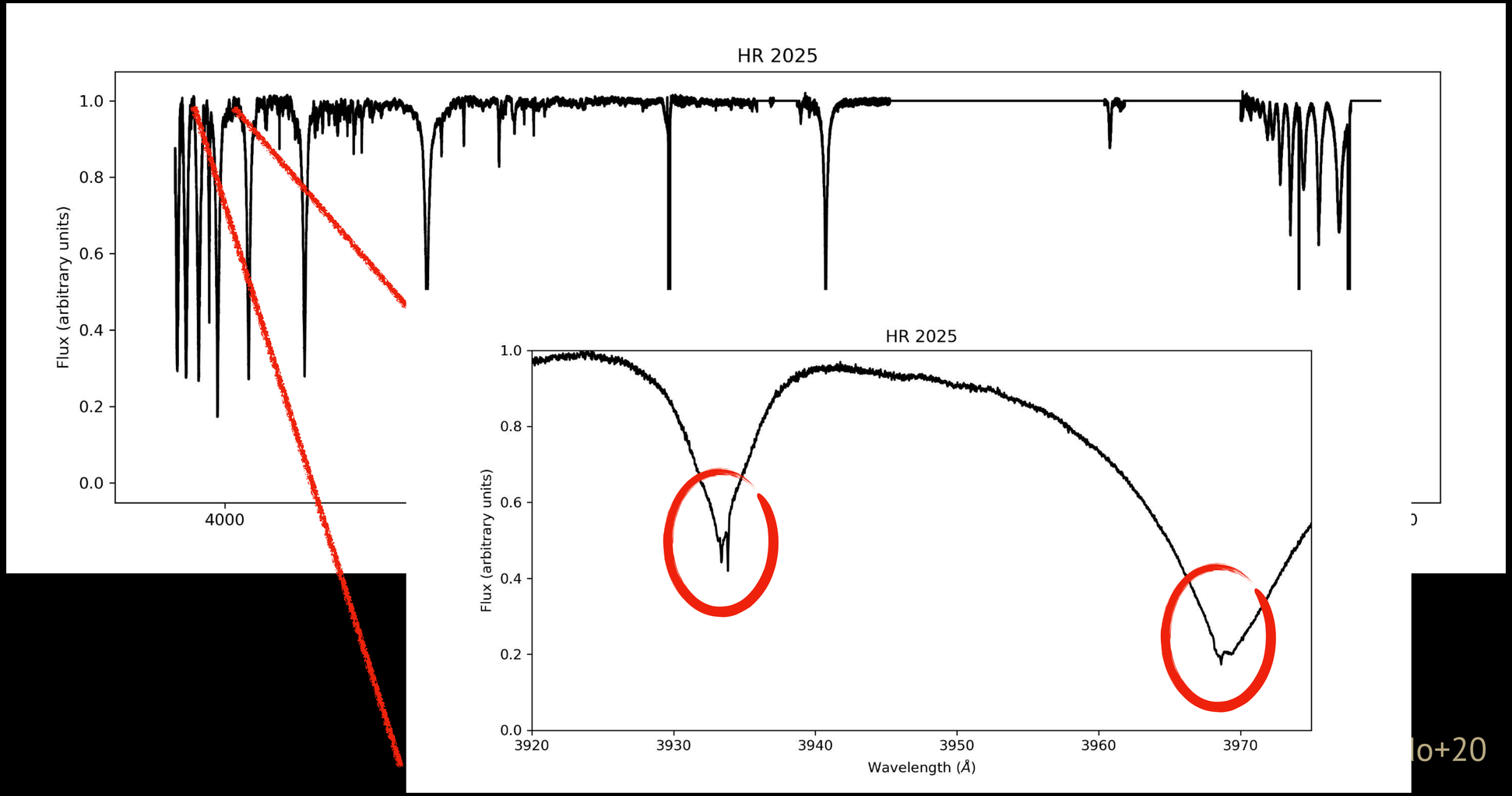
Data



lo+20

Spectroscopic Survey

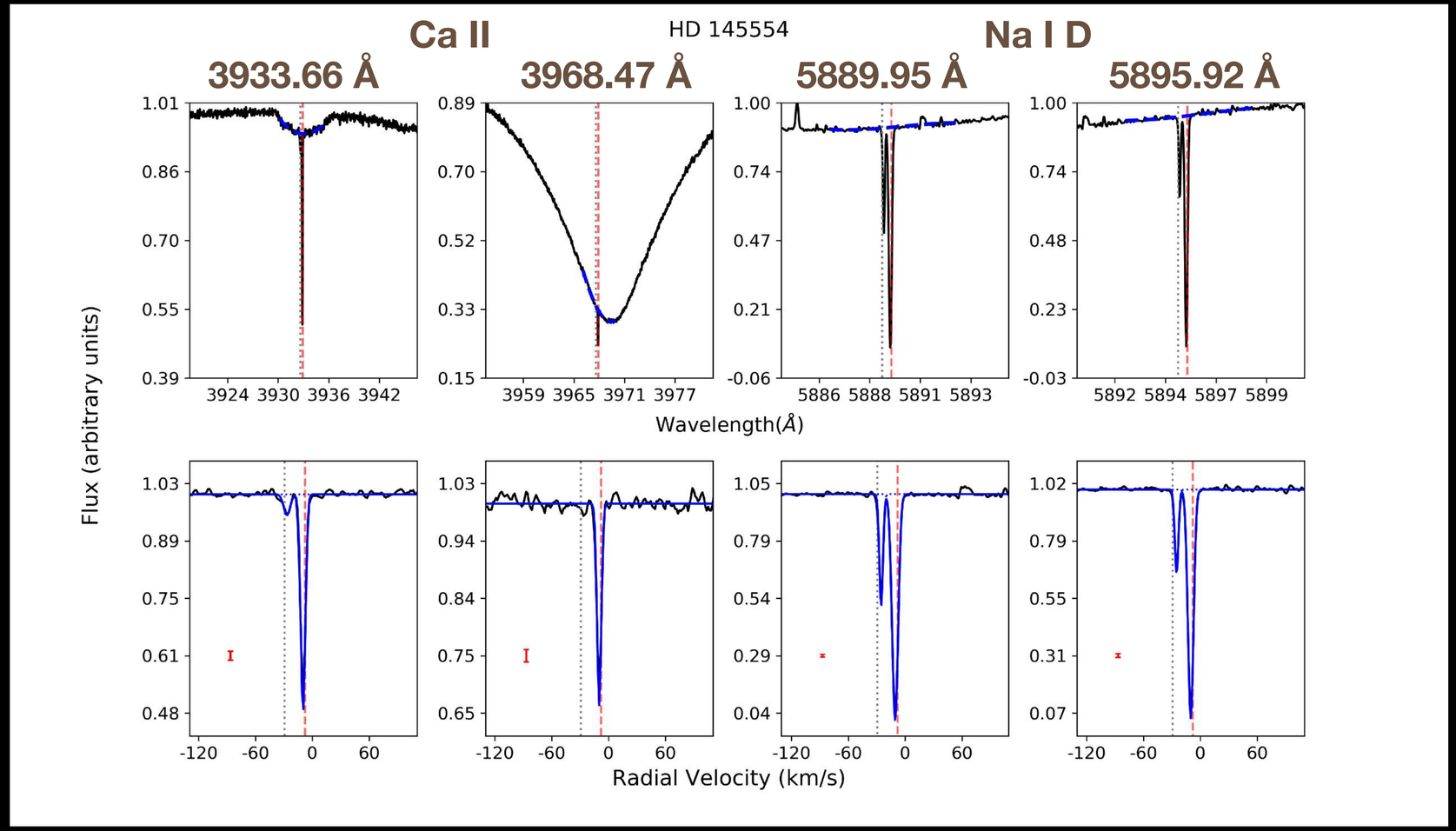
Data



lo+20

Spectroscopic Survey

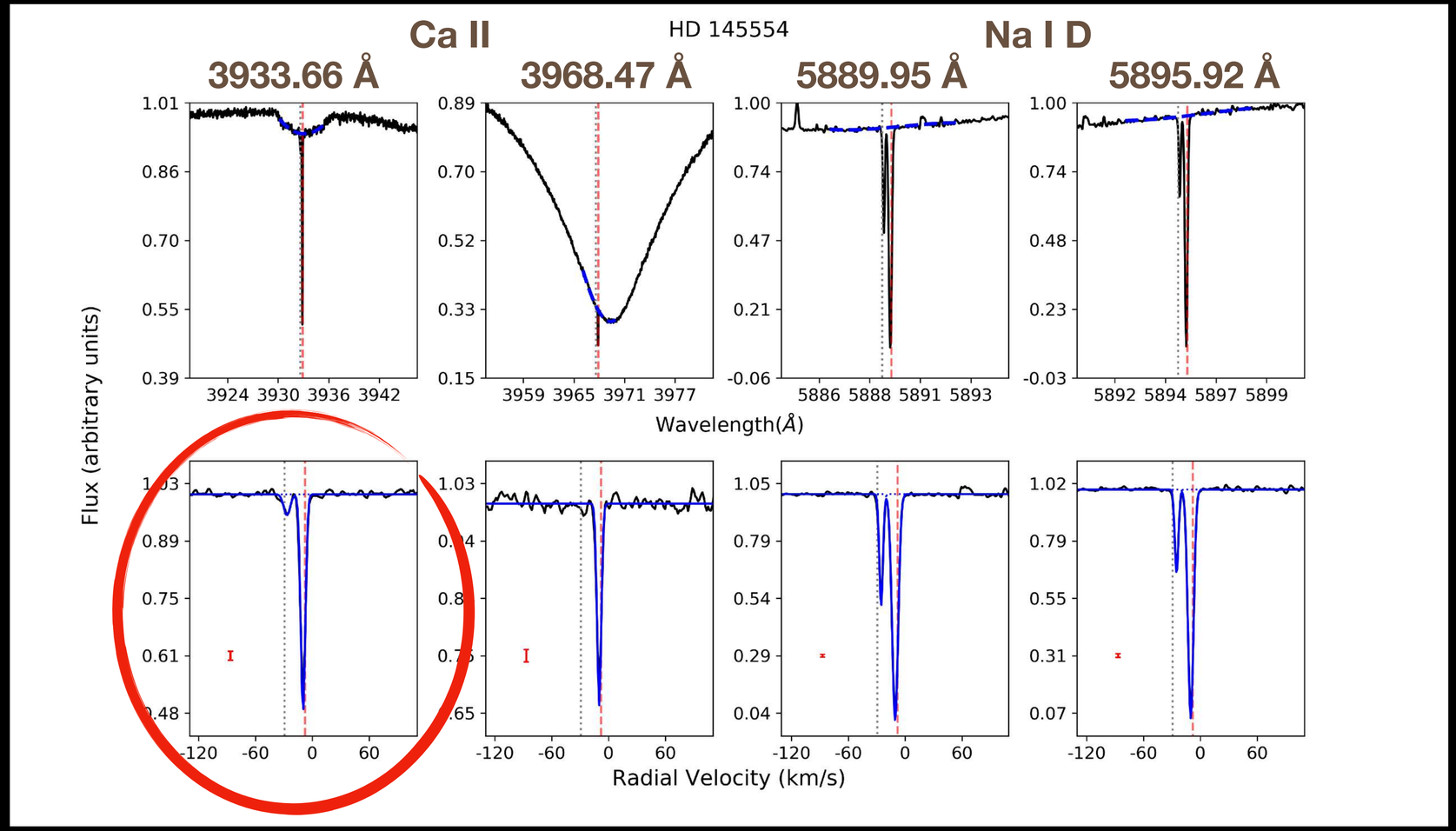
Narrow non-photospheric absorptions



Rebollido+20

Spectroscopic Survey

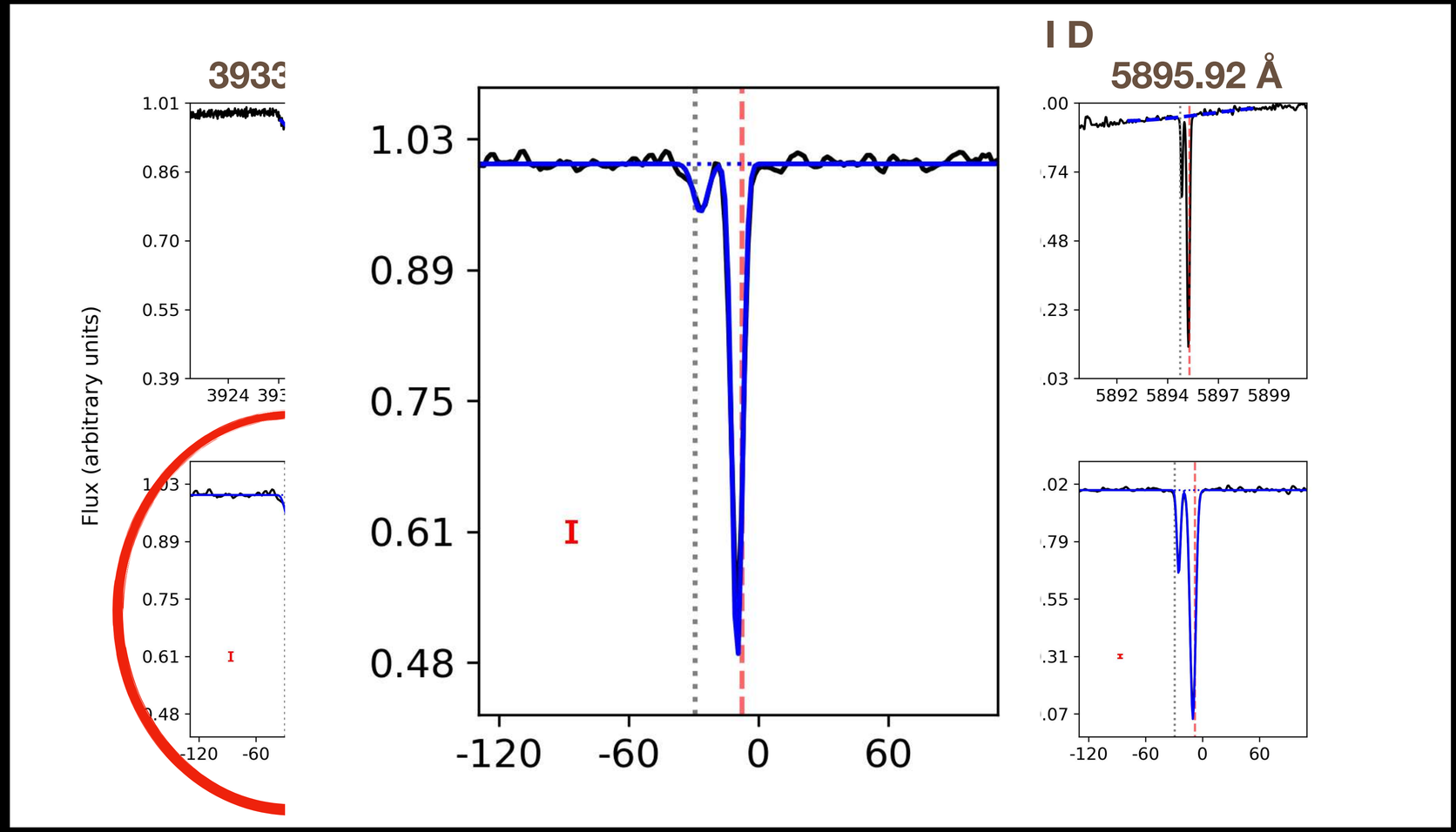
Narrow non-photospheric absorptions



Rebollido+20

Spectroscopic Survey

Narrow non-photospheric absorptions

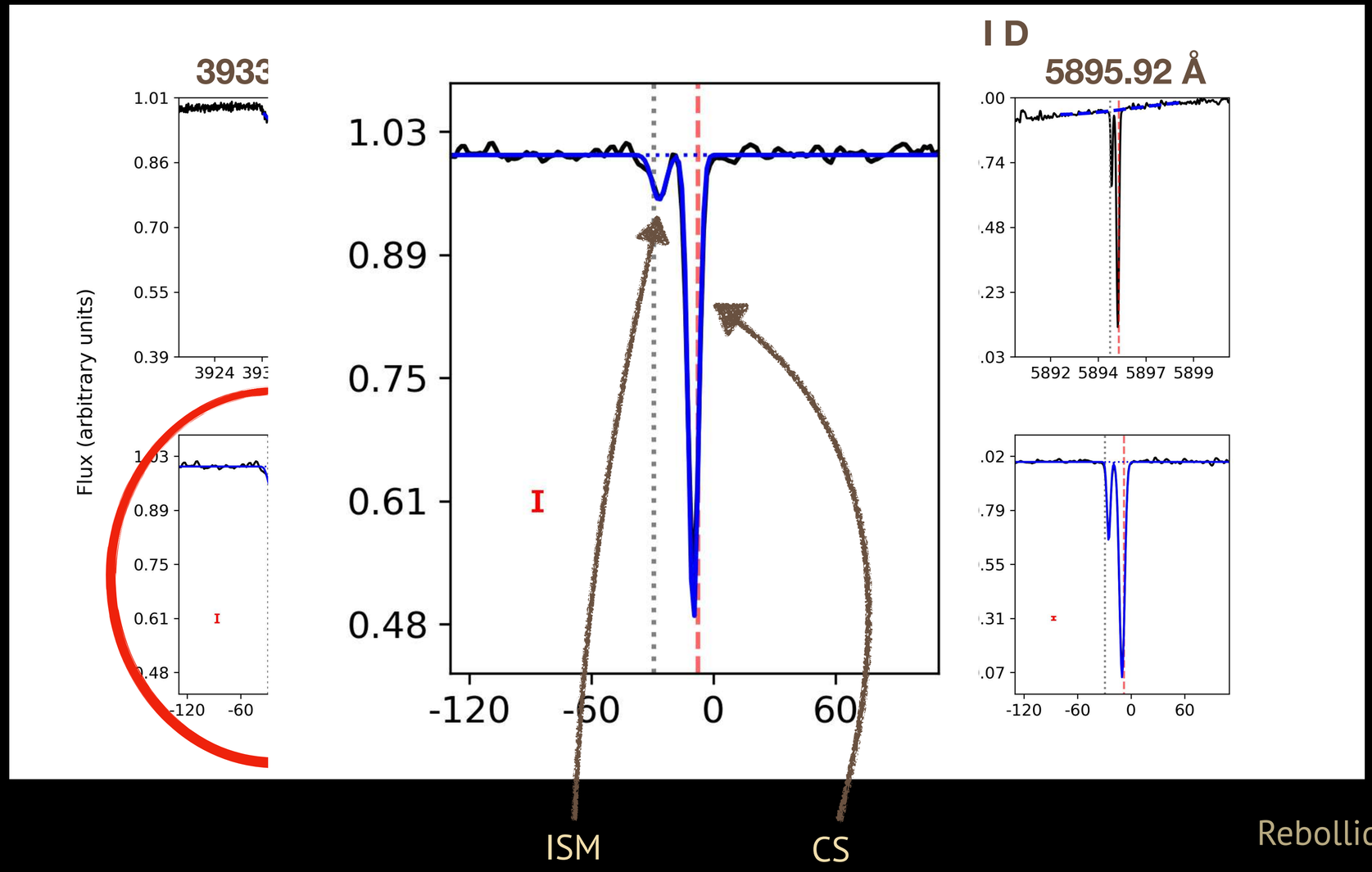


ISM CS

Rebollido+20

Spectroscopic Survey

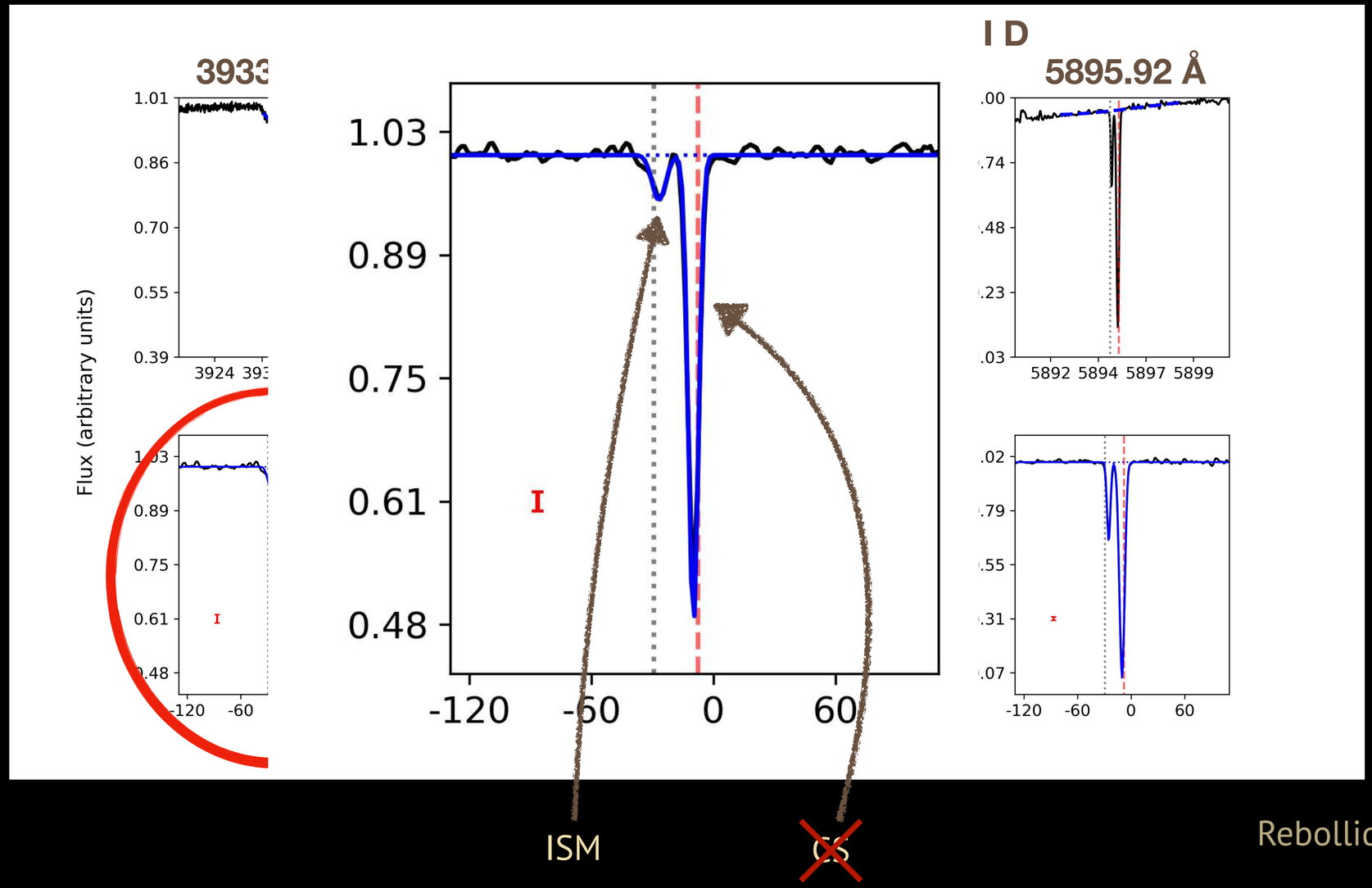
Narrow non-photospheric absorptions



Rebollido+20

Spectroscopic Survey

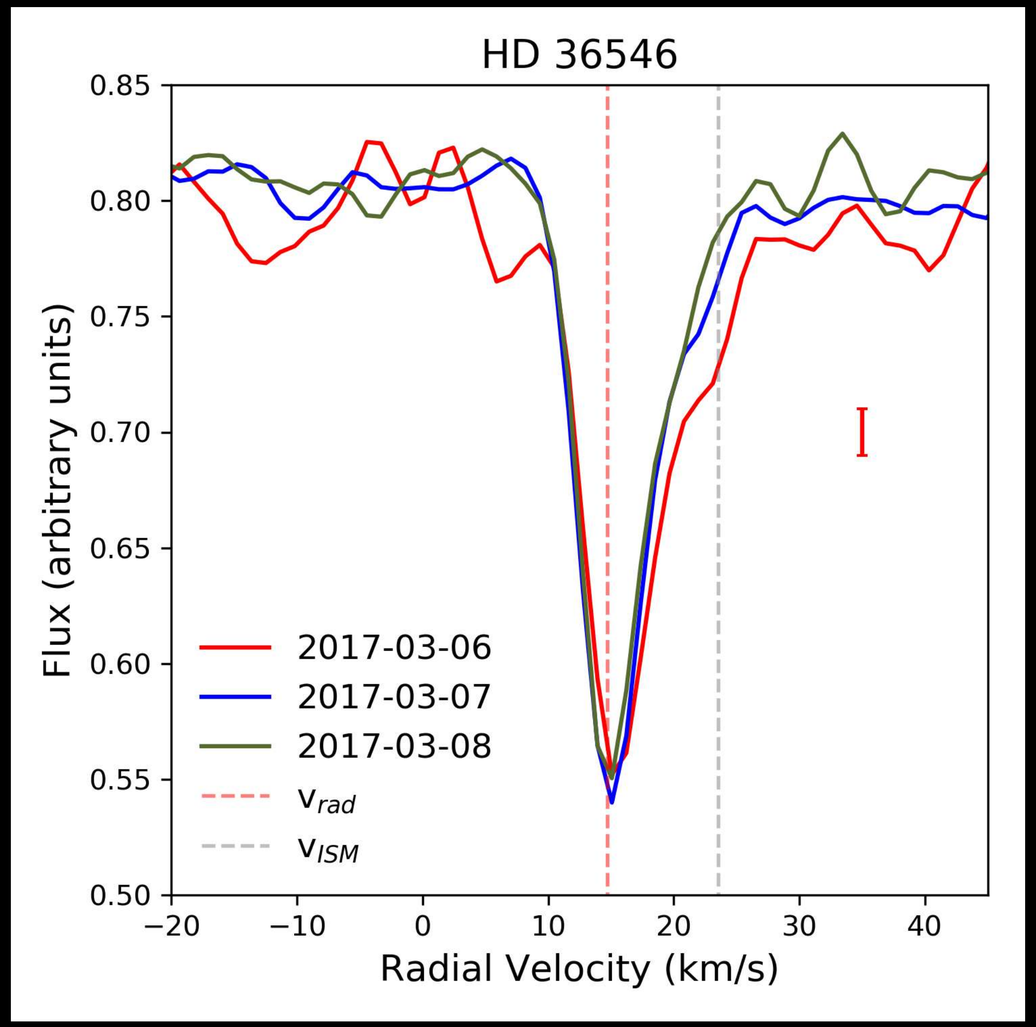
Narrow non-photospheric absorptions



Rebollido+20

Spectroscopic Survey

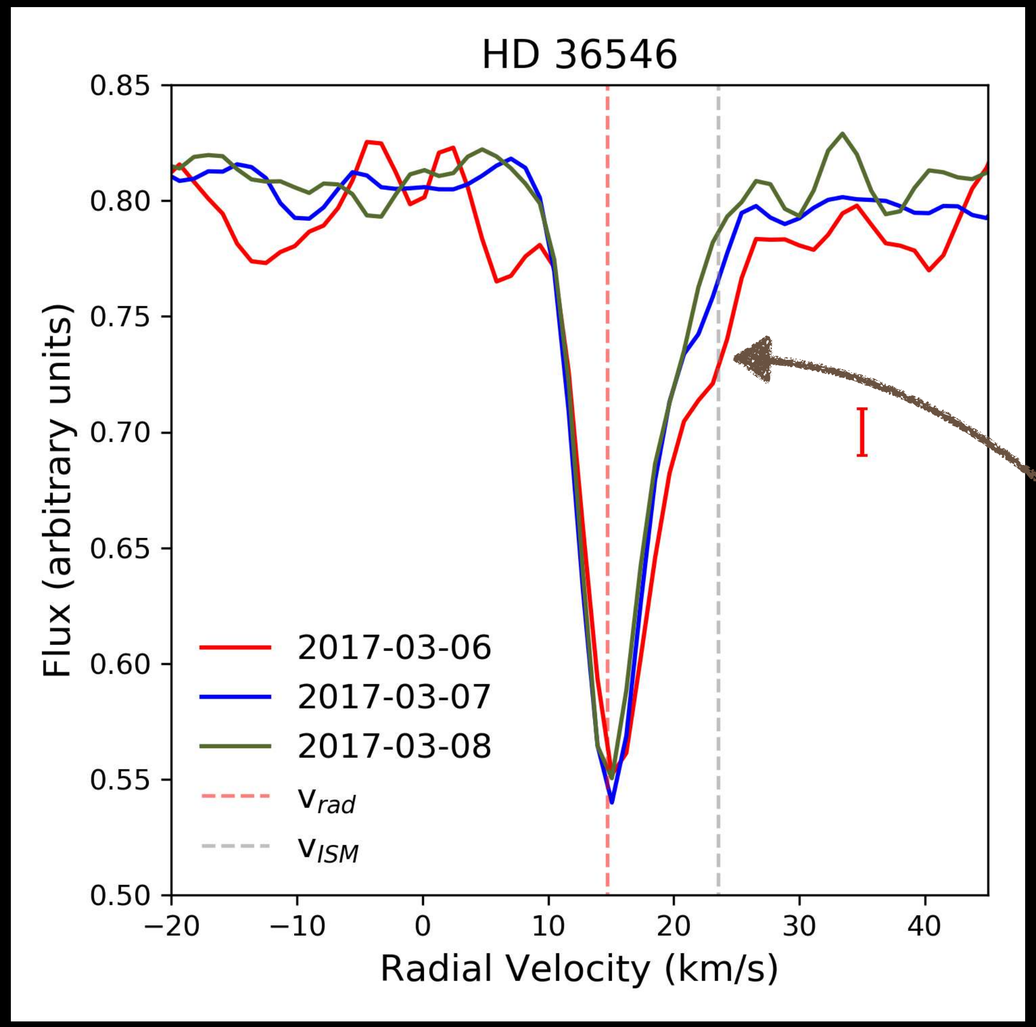
Variable non-photospheric features



Rebollido+20

Spectroscopic Survey

Variable non-photospheric features

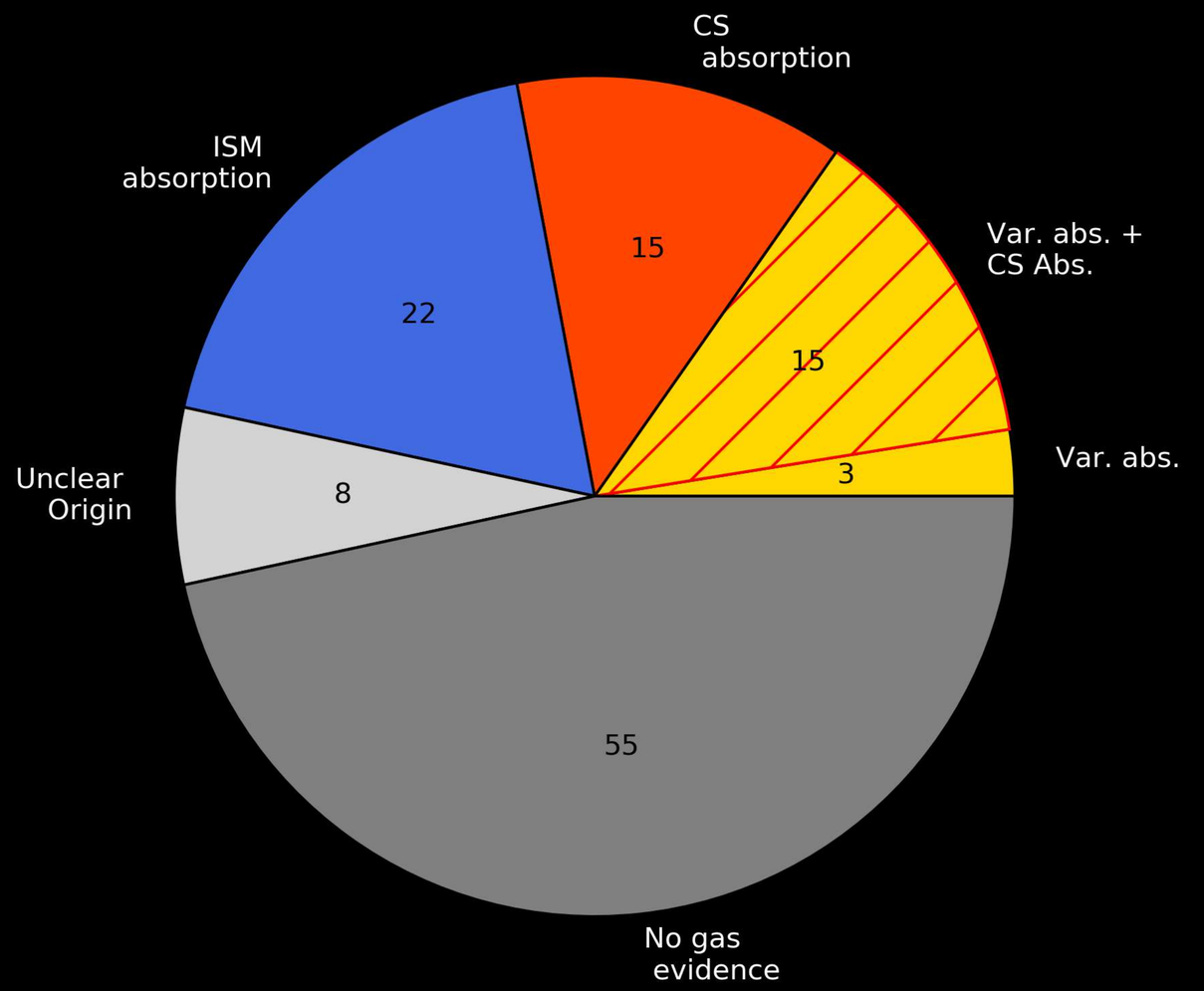


Rebollido+20

Spectroscopic Survey

Detection rates

Non-photospheric absorption
Detections

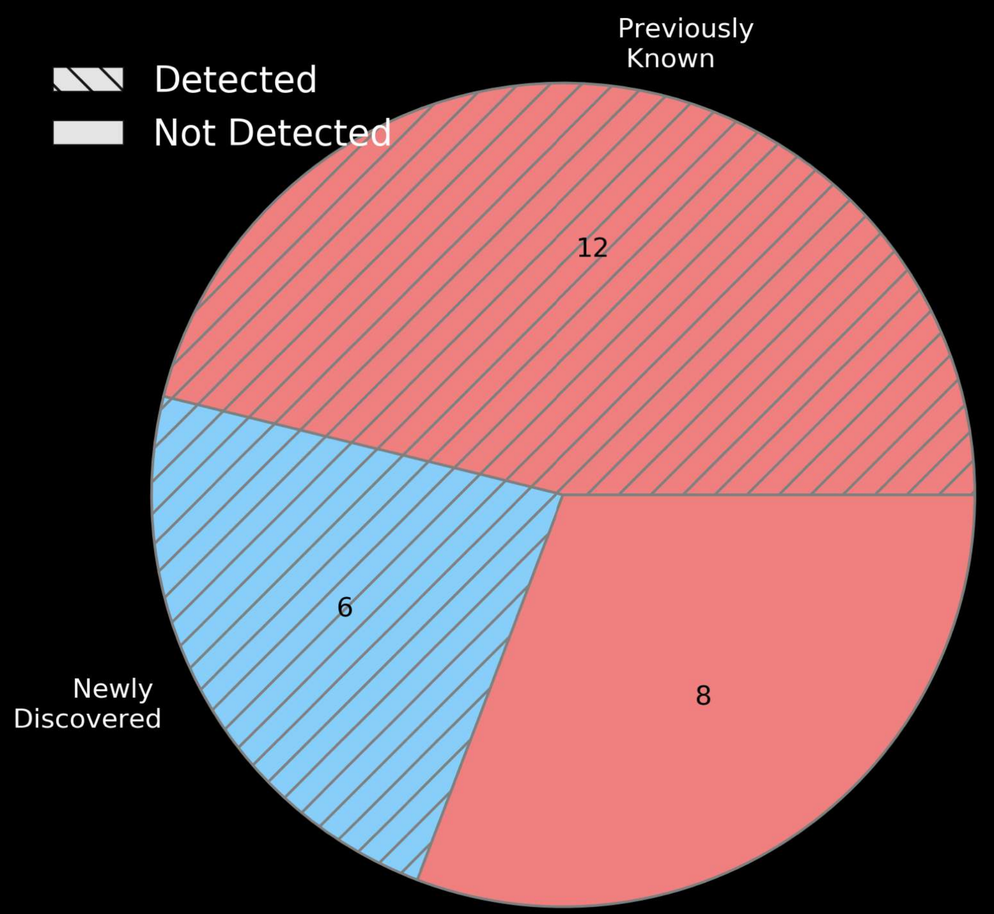


Rebollido+20

Spectroscopic Survey

Detection rates

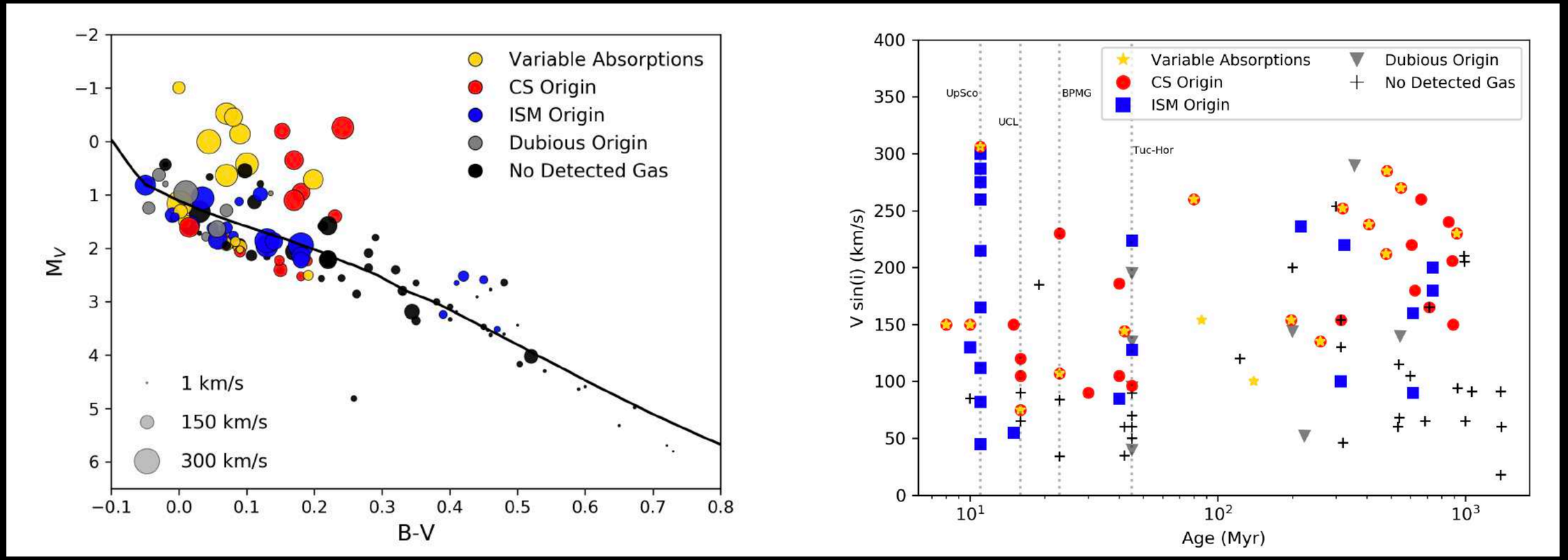
Variability
Detections



Rebollido+20

Spectroscopic Survey

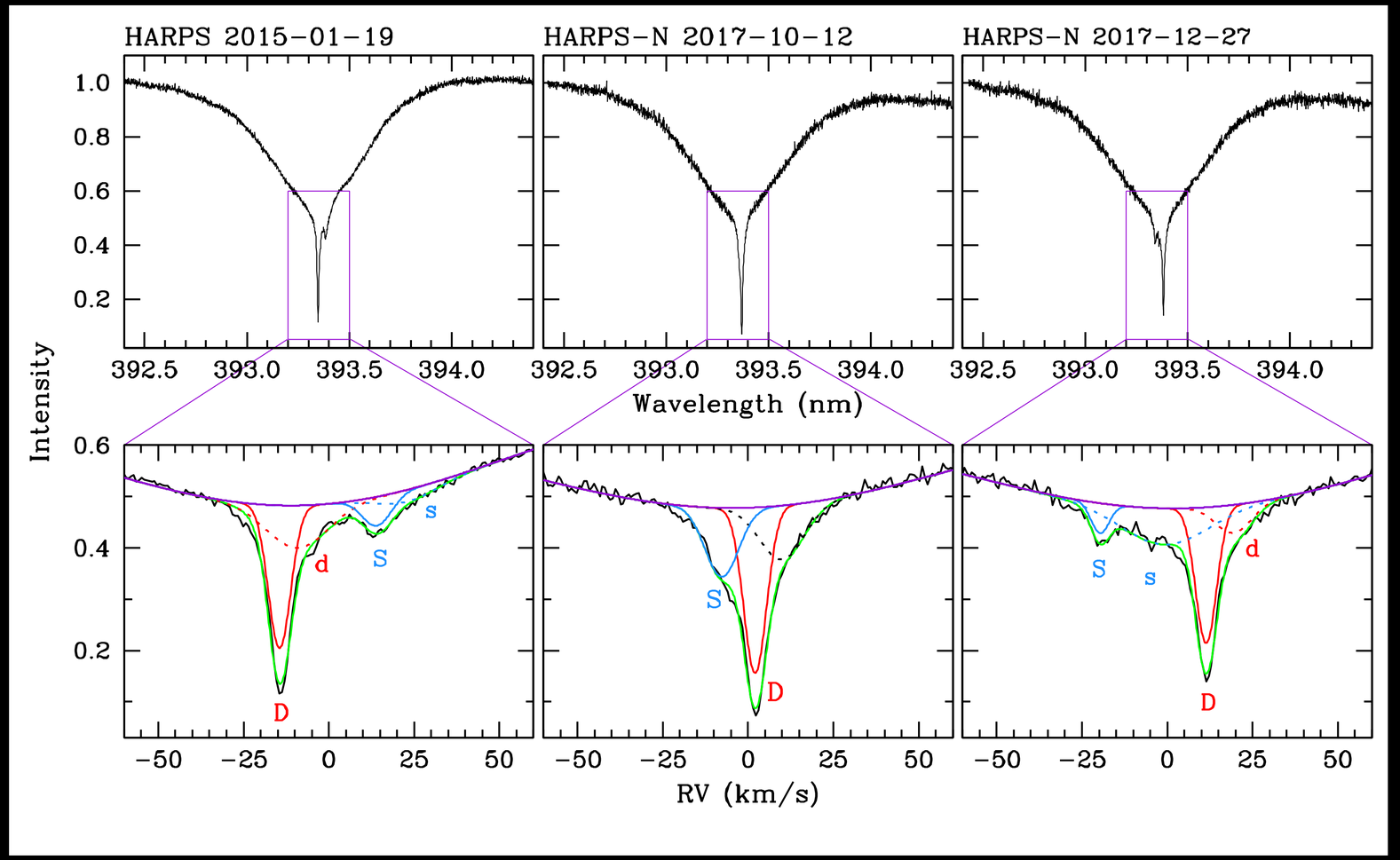
Global results



Rebollido+20

Spectroscopic Survey

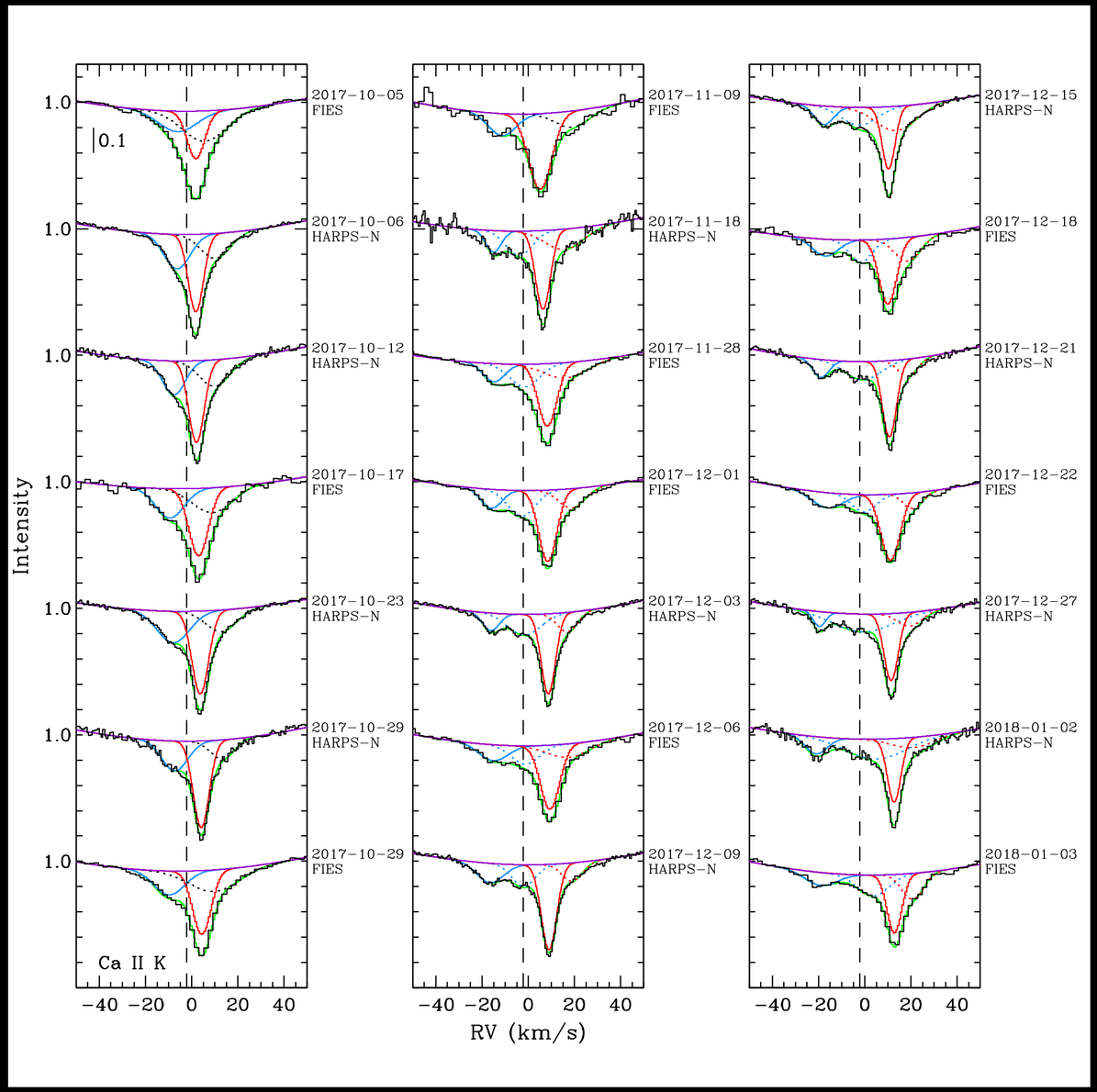
False positives: HR 10



Montesinos+19

Spectroscopic Survey

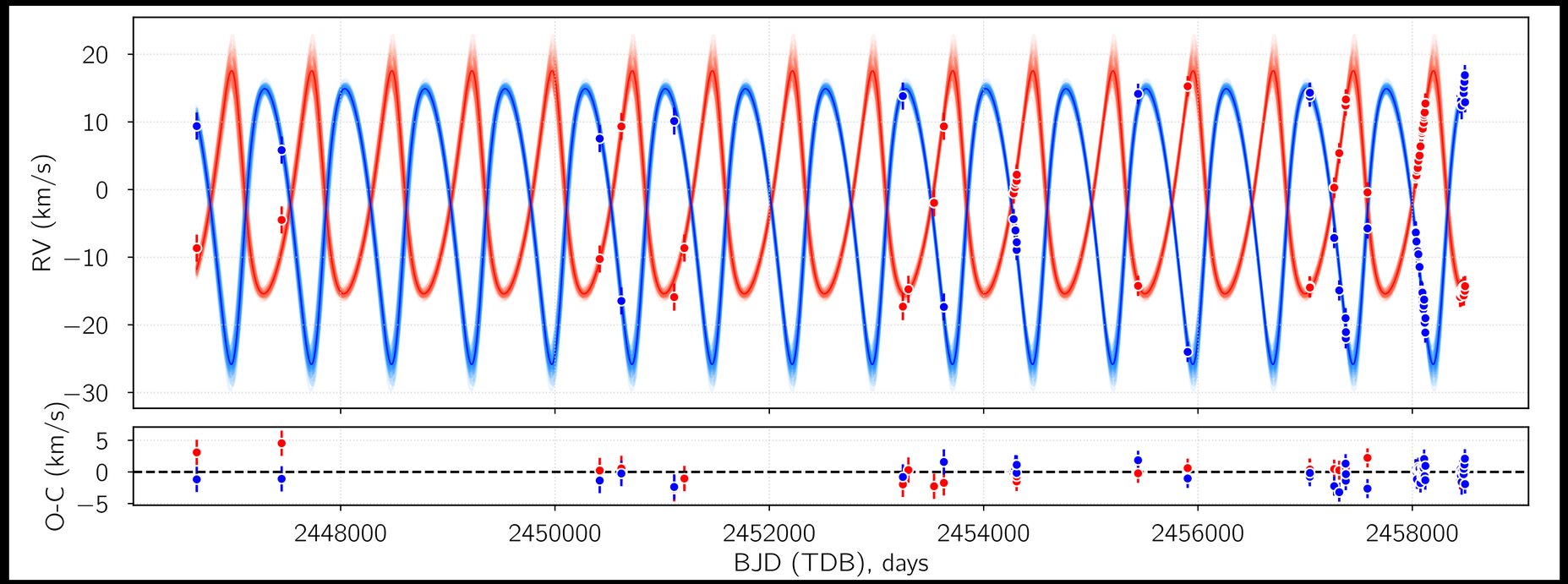
False positives: HR 10



Montesinos+19

Spectroscopic Survey

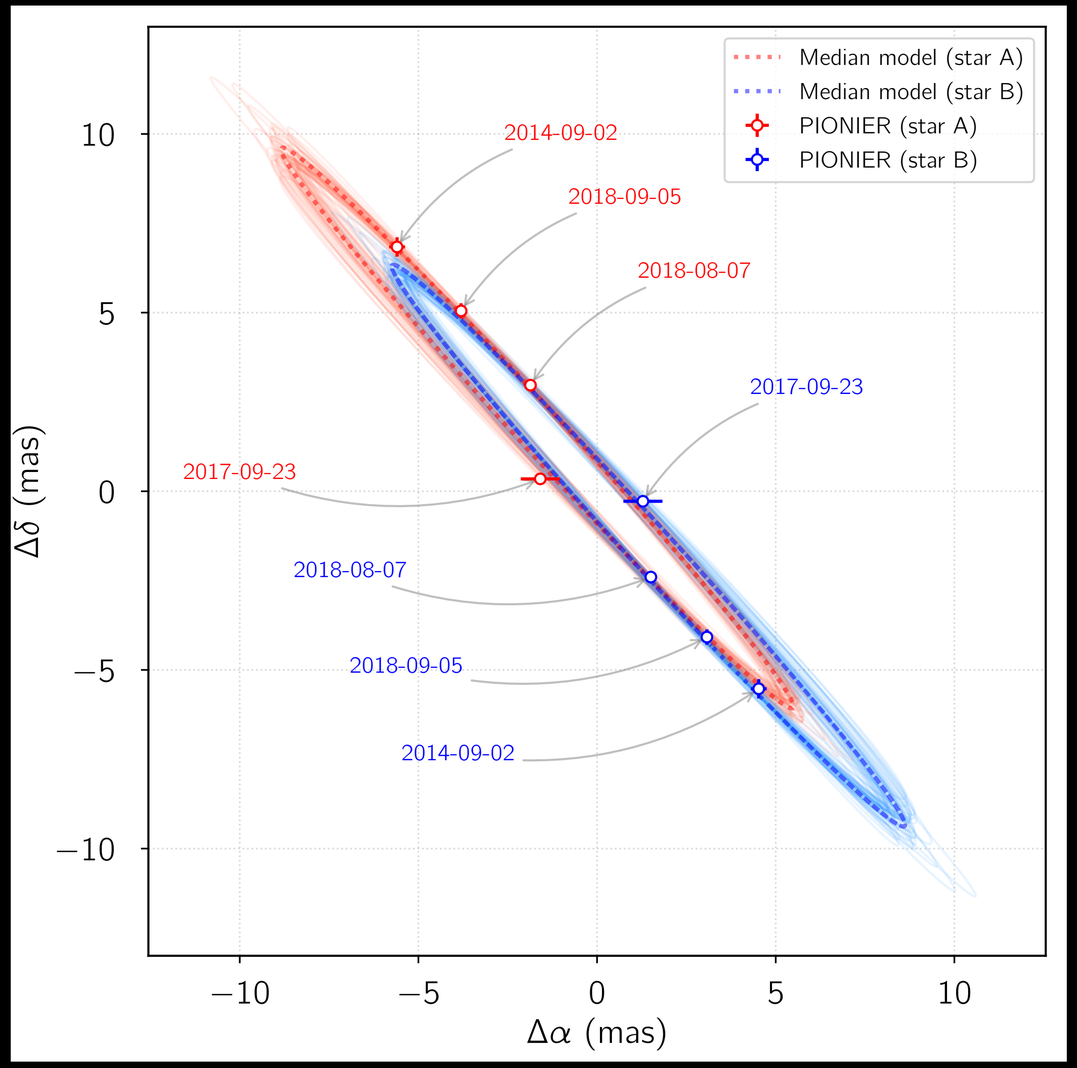
False positives: HR 10



Montesinos+19

Spectroscopic Survey

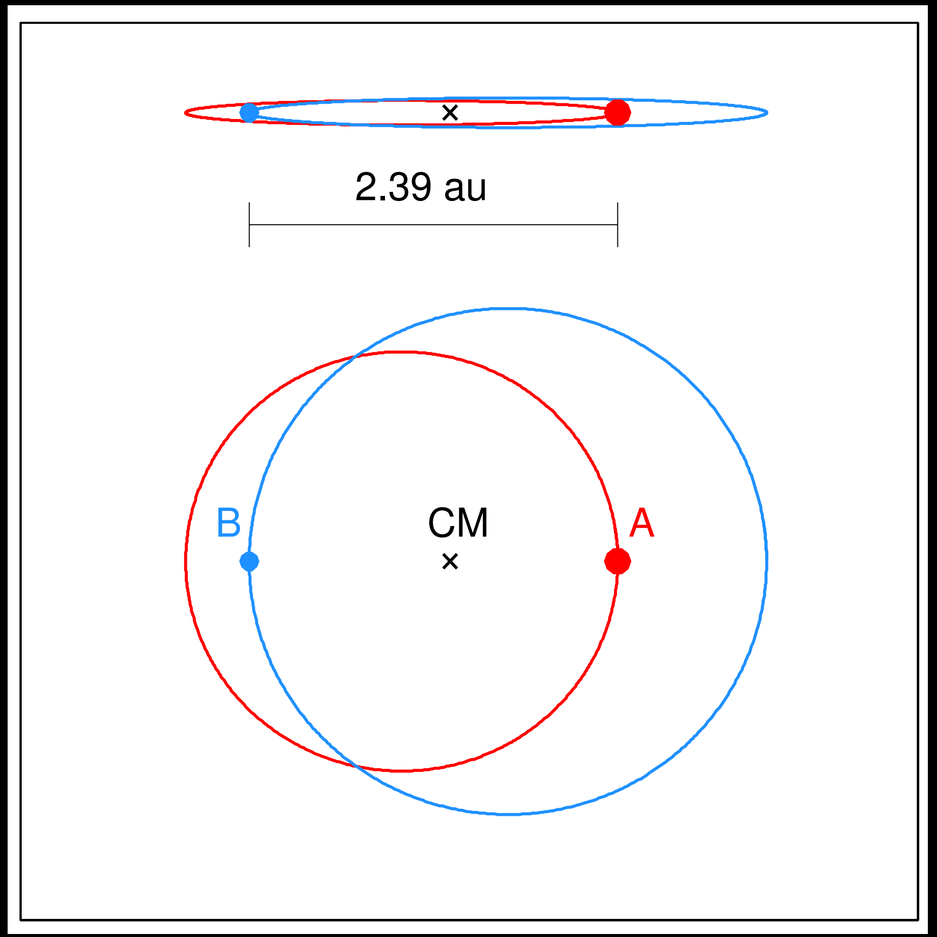
False positives: HR 10



Montesinos+19

Spectroscopic Survey

False positives: HR 10



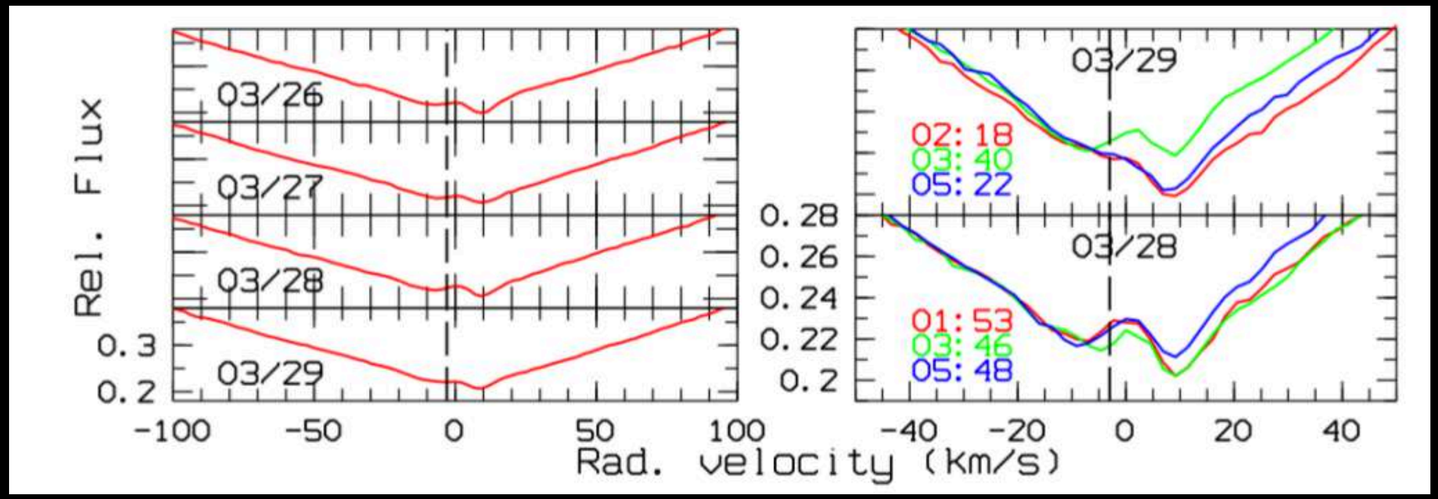
Parameters of the individual components

Parameter	Star A	Star B
$T_{\rm eff}$ [K]	9000 ± 100	8250 ± 100
$\log g_*$ [cgs]	3.8 ± 0.1	4.2 ± 0.1
$L/L_\odot$ [from tracks]	64.9 ± 10.0	12.6 ± 4.0
$L/L_\odot$ [from SED fit]	57.3 ± 2.0	13.7 ± 0.5
$M/M_\odot$ [from tracks]	2.5 ± 0.1	1.8 ± 0.1
$M/M_\odot$ [from eq. (4.2)]	1.94 ± 0.15	1.62 ± 0.13
$v \sin i$ [km/s]	294 ± 9	200 ± 20
Age [Myr]	530 ± 50	
$E(B-V)$	0.10	0.05

Montesinos+19

Spectroscopic Survey

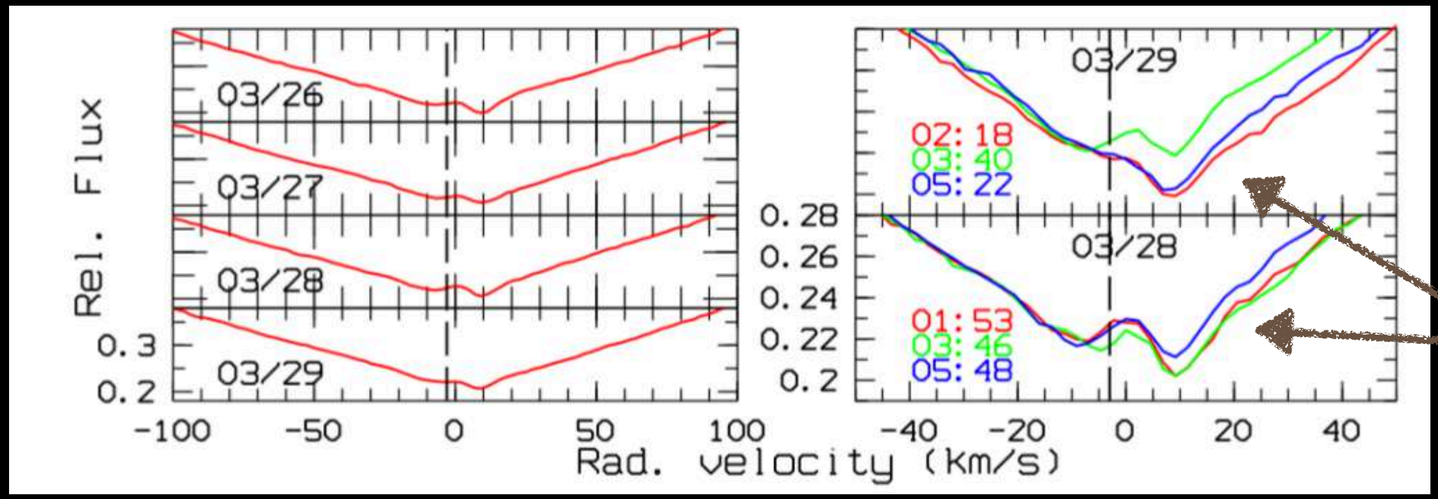
False positives: ϕ Leo



Eiroa+16

Spectroscopic Survey

False positives: ϕ Leo



Comets?

Eiroa+16

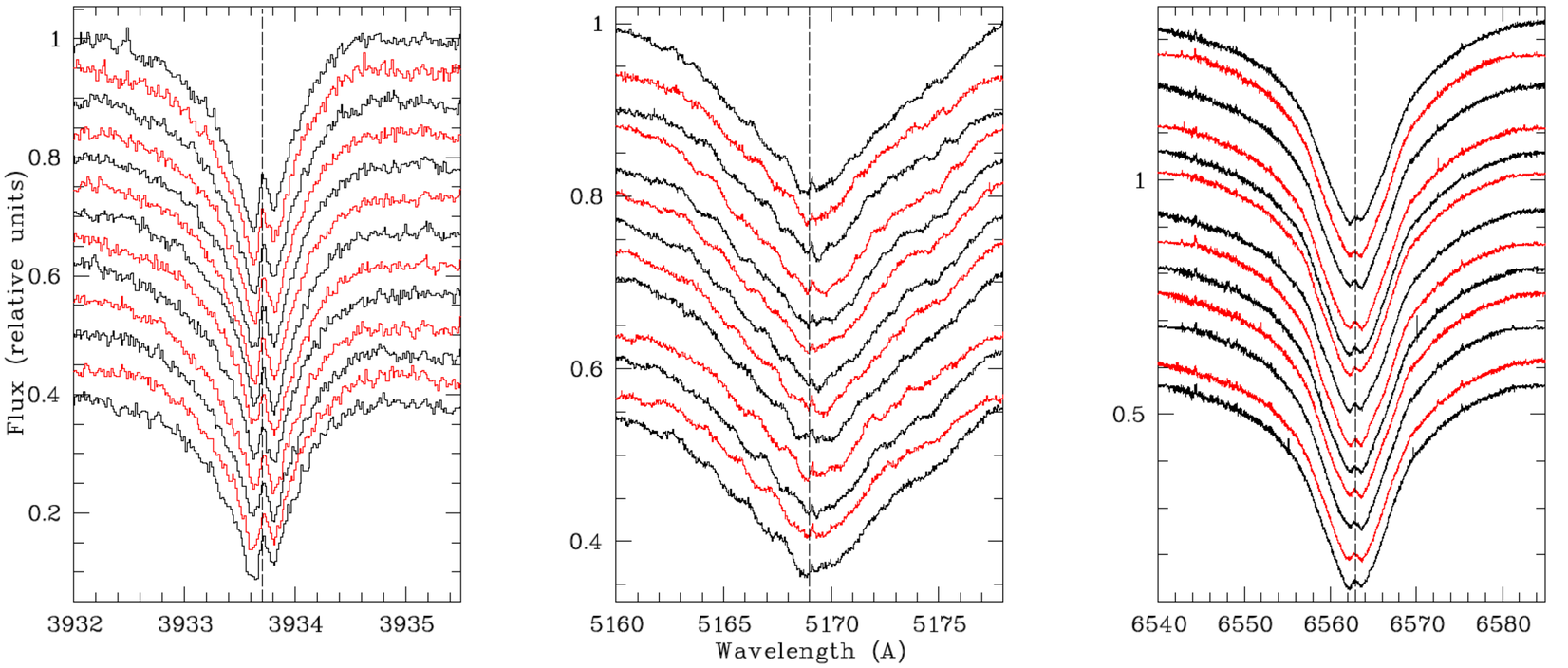
Spectroscopic Survey

False positives: ϕ Leo

Ca II K

Fe II

Hα



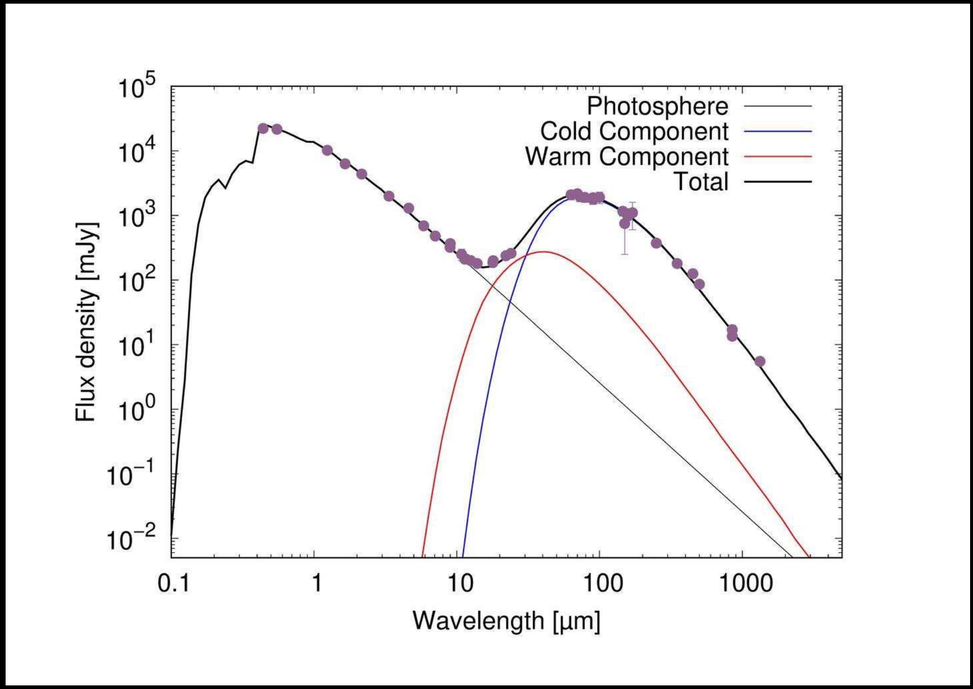
Stellar pulsations + circumstellar material

Eiroa+21

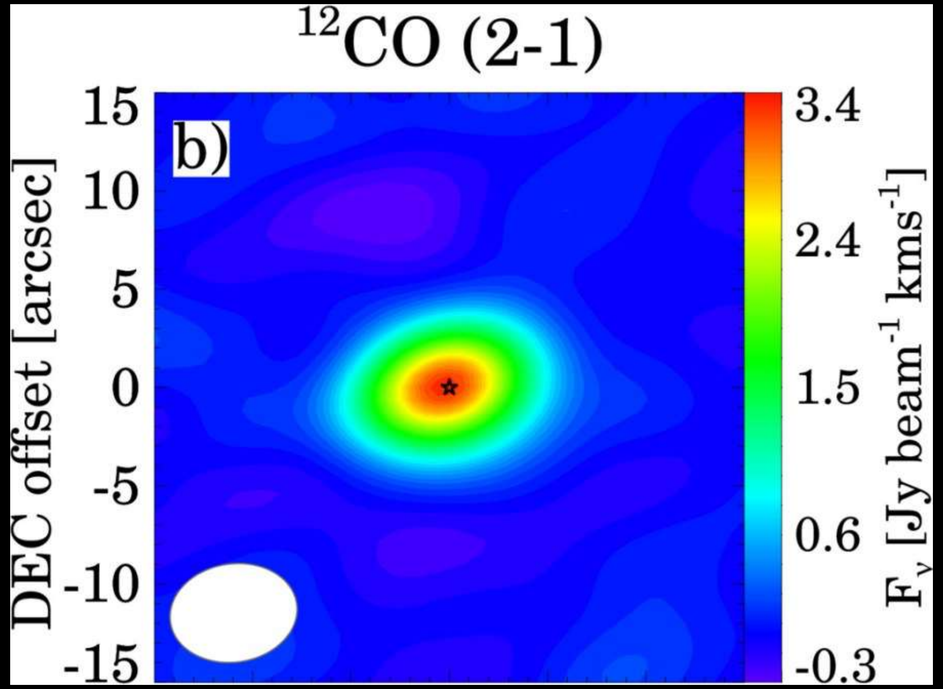
The gas in main-sequence stars

Hot and cold gas

49 Cet



Pawellek+19

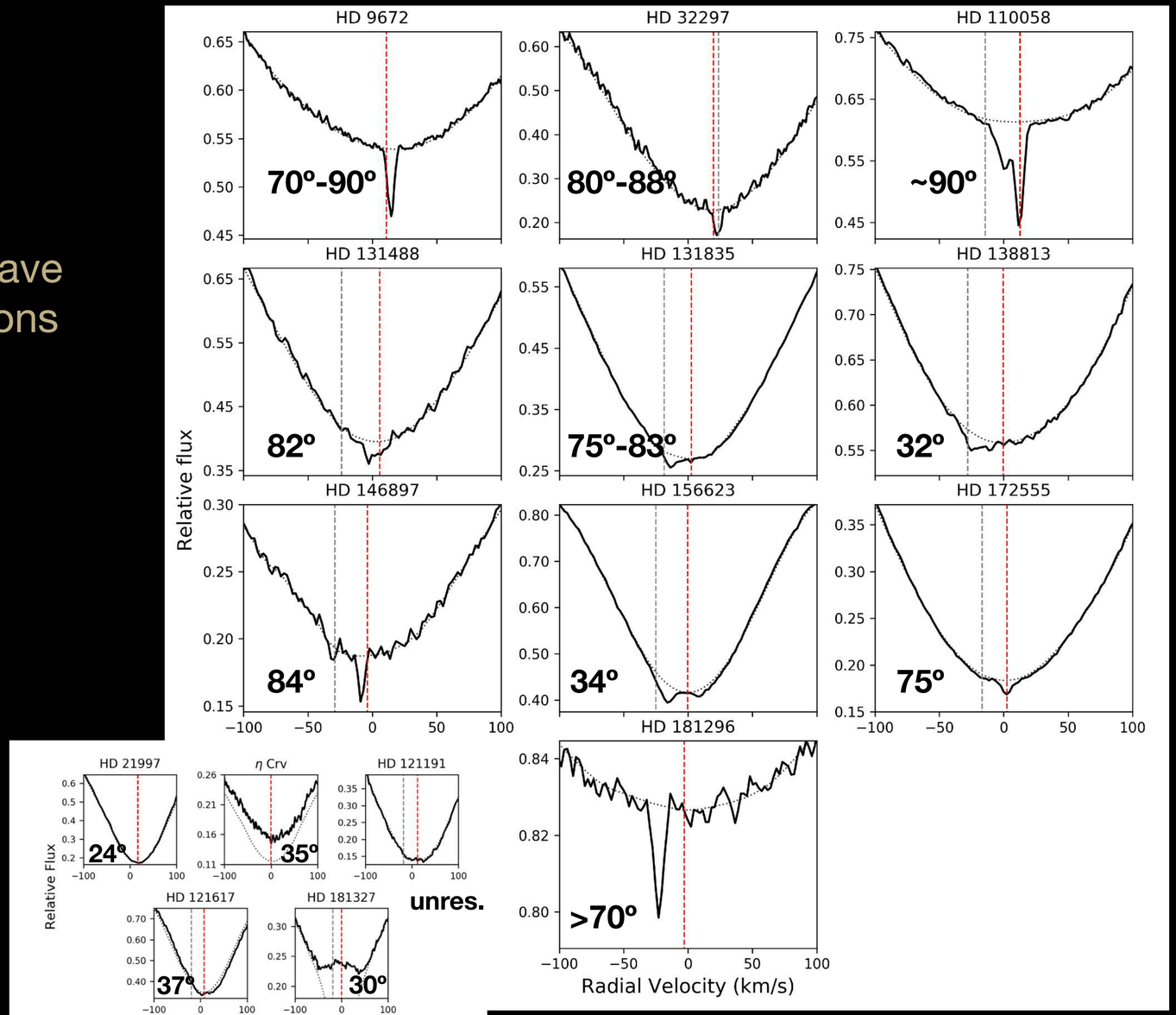


Moor+19

The gas in main-sequence stars

Hot and cold gas

All the sources have cold gas detections

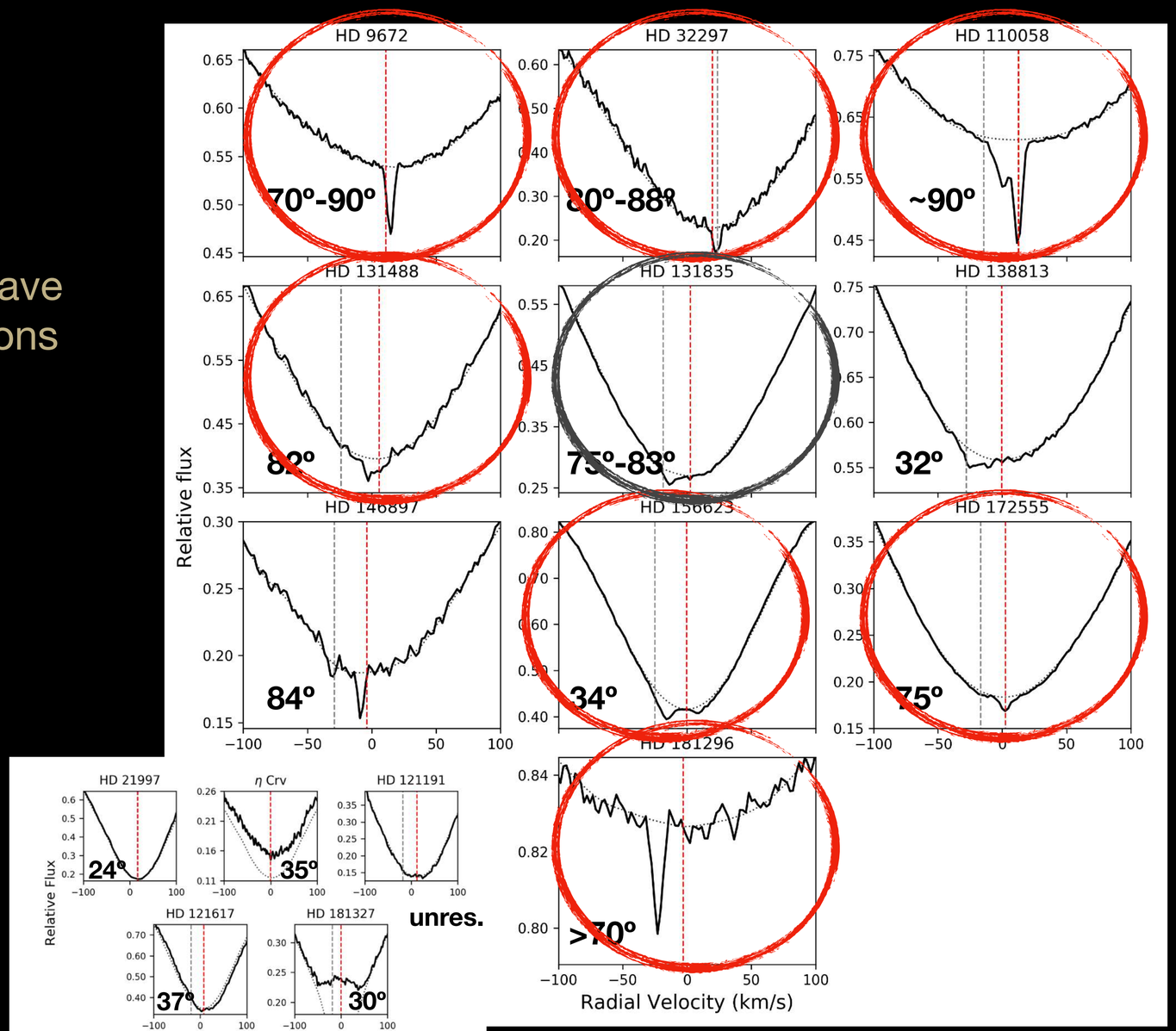


Rebollido+18

The gas in main-sequence stars

Hot and cold gas

All the sources have cold gas detections

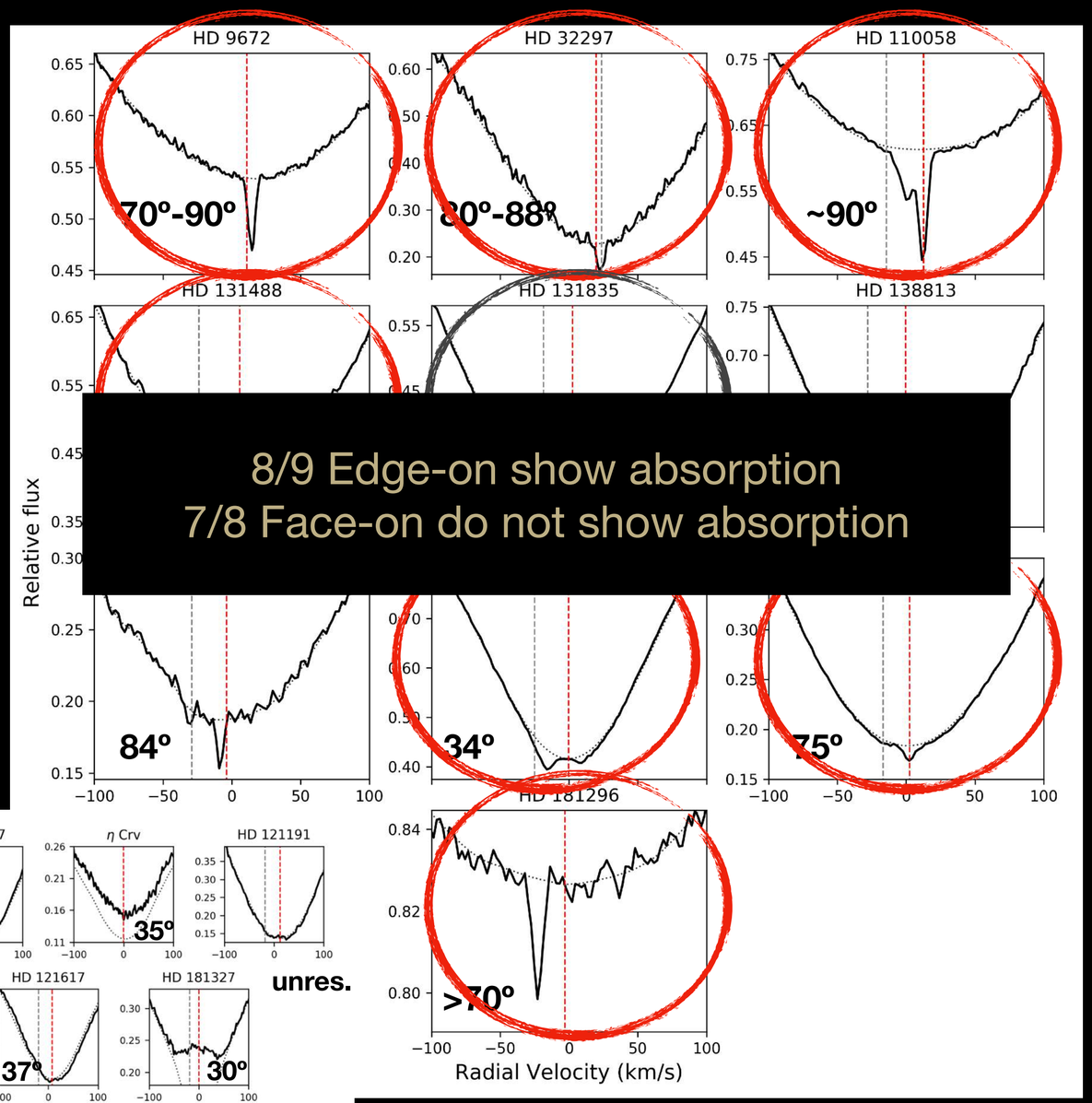


Rebollido+18

The gas in main-sequence stars

Hot and cold gas

All the sources have cold gas detections



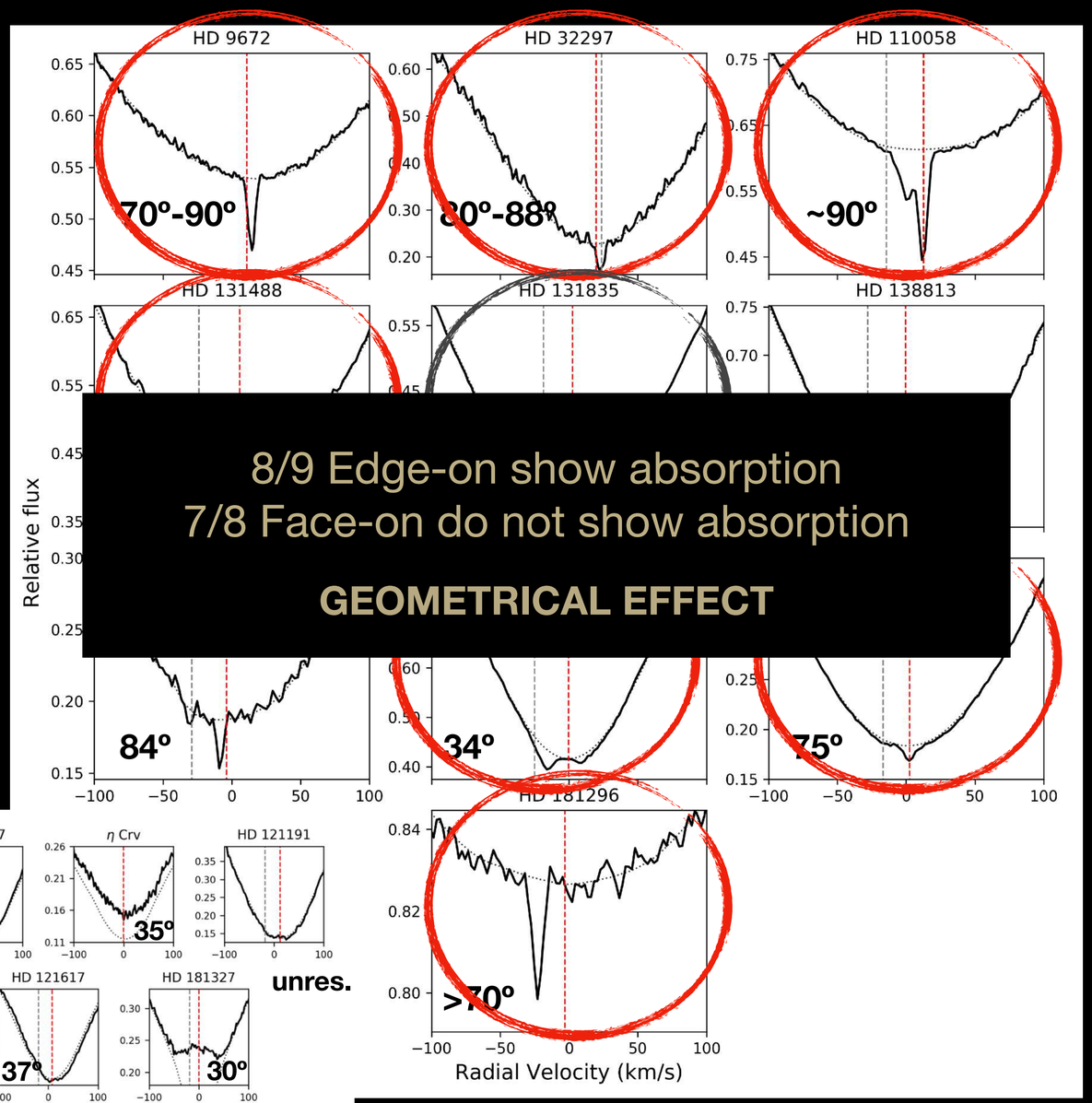
+ β Pic
Fomalhaut

Rebollido+18

The gas in main-sequence stars

Hot and cold gas

All the sources have cold gas detections



\+ β Pic
Fomalhaut

Rebollido+18

The gas in main-sequence stars

Hot and cold gas

Name	RA (J2000)	DEC (J2000)	Sp. type	Distance(*)	V	Age	L_{IR}/L_*	F_ν(1.3 mm)	^{12}CO (2-1)
	hh:mm:ss	dd:mm:ss		pc	(mag)	Myr		mJy	mJy km s^{-1}
HD 5267	00:54:35.23	+19:11:18.3	A1V	76.8 ± 4.4	5.79	200 (1)	$3.9\cdot10^{-5}$(1)	<0.11	<9.5
HD 36546	05:33:30.76	+24:37:43.72	B8V(†)	100.2 ± 0.4	6.95	3-10 (2)	$3.4\cdot10^{-3}$(2)	2.59±0.05	(2.67 ± 0.04)×10^3
HD 37306	05:37:08.77	-11:46:31.9	A2V	69.6 ± 0.2	6.09	38-48 (3)	$1.2\cdot10^{-4}$(1)	<0.11	<9.5
HD 110411	12:41:53.06	+10:14:08.3	A3V	38.9 ± 0.2	4.88	86 (1)	$6.4\cdot10^{-5}$(3)	0.29±0.06	<10.5
HD 145964	16:14:28.88	-21:06:27.5	B9V	113.0 ± 0.6	6.41	11 (1)	$1.5\cdot10^{-5}$(1)	<0.13	<13.5
HD 158352	17:28:49.66	+00:19:50.3	A8Vp	63.8 ± 0.3	5.41	890 (1)	$9.3\cdot10^{-5}$(4)	1.63±0.15	<14.0
HD 182919	19:26:13.25	+20:05:51.8	A0V	72.1 ± 0.2	5.59	198 (1)	$3.4\cdot10^{-5}$(1)	<0.08	<10.5
HD 183324	19:29:00.99	+01:57:01.6	A0IV	60.4 ± 0.2	5.79	140 (1)	$1.8\cdot10^{-5}$(5)	<0.13	<14.0

Rebollido+21

All the sources have hot gas detection in Rebollido+20

The gas in main-sequence stars

Hot and cold gas

Name	RA (J2000)	DEC (J2000)	Sp. type	Distance(*)	V	Age	L_{IR}/L_*	F_ν(1.3 mm)	^{12}CO (2-1)
	hh:mm:ss	dd:mm:ss		pc	(mag)	Myr		mJy	mJy km s^{-1}
HD 5267	00:54:35.23	+19:11:18.3	A1V	76.8 ± 4.4	5.79	200 (1)	$3.9\cdot10^{-5}$(1)	<0.11	<9.5
HD 36546	05:33:30.76	+24:37:43.72	B8V(†)	100.2 ± 0.4	6.95	3-10 (2)	$3.4\cdot10^{-3}$(2)	2.59±0.05	$(2.67 \pm 0.04)\times10^3$
HD 37306	05:37:08.77	-11:46:31.9	A2V	69.6 ± 0.2	6.09	38-48 (3)	$1.2\cdot10^{-4}$(1)	<0.11	<9.5
HD 110411	12:41:53.06	+10:14:08.3	A3V	38.9 ± 0.2	4.88	86 (1)	$6.4\cdot10^{-5}$(3)	0.29±0.06	<10.5
HD 145964	16:14:28.88	-21:06:27.5	B9V	113.0 ± 0.6	6.41	11 (1)	$1.5\cdot10^{-5}$(1)	<0.13	<13.5
HD 158352	17:28:49.66	+00:19:50.3	A8Vp	63.8 ± 0.3	5.41	890 (1)	$9.3\cdot10^{-5}$(4)	1.63±0.15	<14.0
HD 182919	19:26:13.25	+20:05:51.8	A0V	72.1 ± 0.2	5.59	198 (1)	$3.4\cdot10^{-5}$(1)	<0.08	<10.5
HD 183324	19:29:00.99	+01:57:01.6	A0IV	60.4 ± 0.2	5.79	140 (1)	$1.8\cdot10^{-5}$(5)	<0.13	<14.0

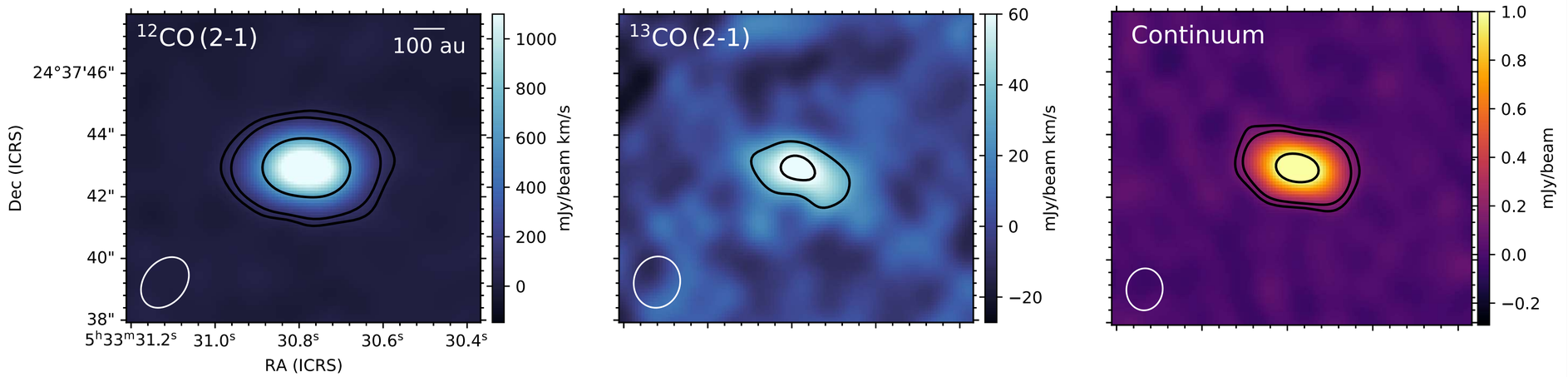
Rebollido+21

All the sources have hot gas detection in Rebollido+20

The gas in main-sequence stars

Hot and cold gas

HD 36546

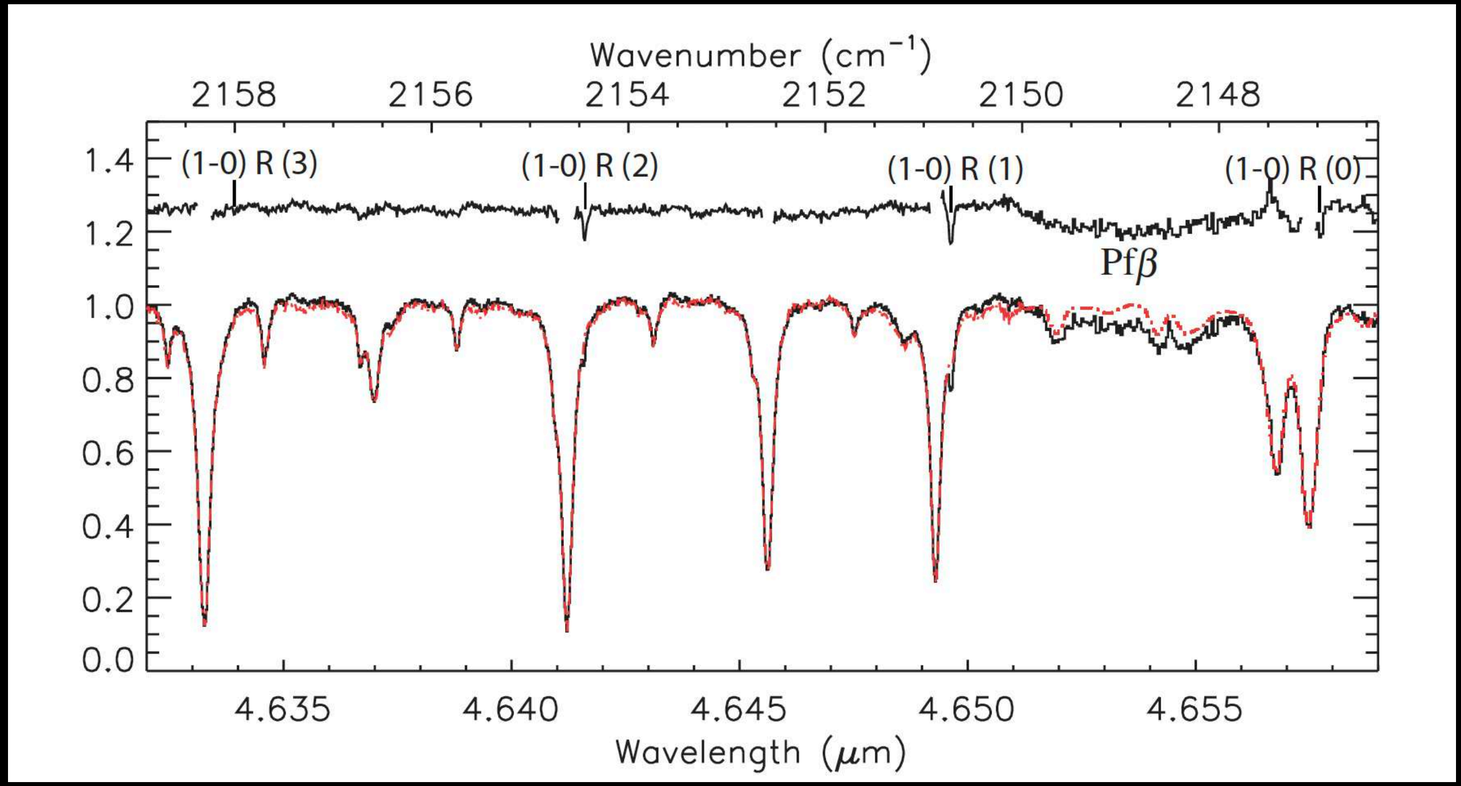


	Peak Intensity*	Flux*	a (au)	Incl. (deg)	M ($M_\oplus$)
Cont.	1.33 ± 0.03 mJy	2.59±0.05 mJy	187.7 ± 6.2	79.0 ± 1.5	$(9.0\pm1.0)\cdot10^{-2}$
^{12}CO	1.42 ± 0.02 Jy km s^{-1} beam^{-1}	2.67 ± 0.04 Jy km s^{-1}	216 ± 4	78.3 ± 1.2	$(3.2\pm1.2)\cdot10^{-3}$
^{13}CO	0.07 ± 0.01 Jy km s^{-1} beam^{-1}	0.15 ± 0.02 Jy km s^{-1}	259 ± 84	75.1 ± 6.2	

Rebollido+21

Molecular gas in the IR

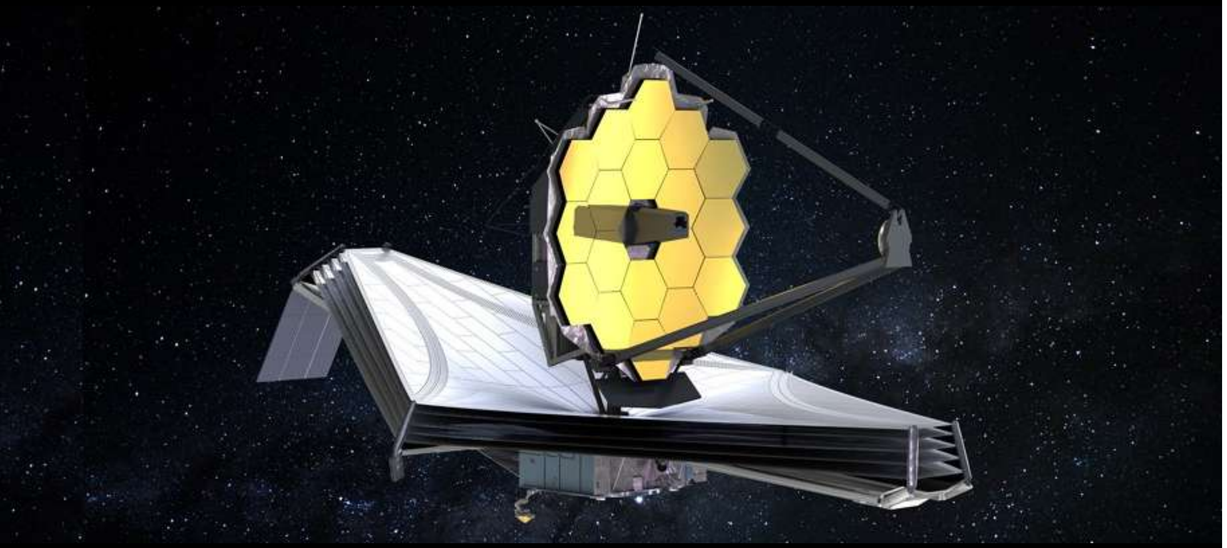
CO ro-vibrational lines

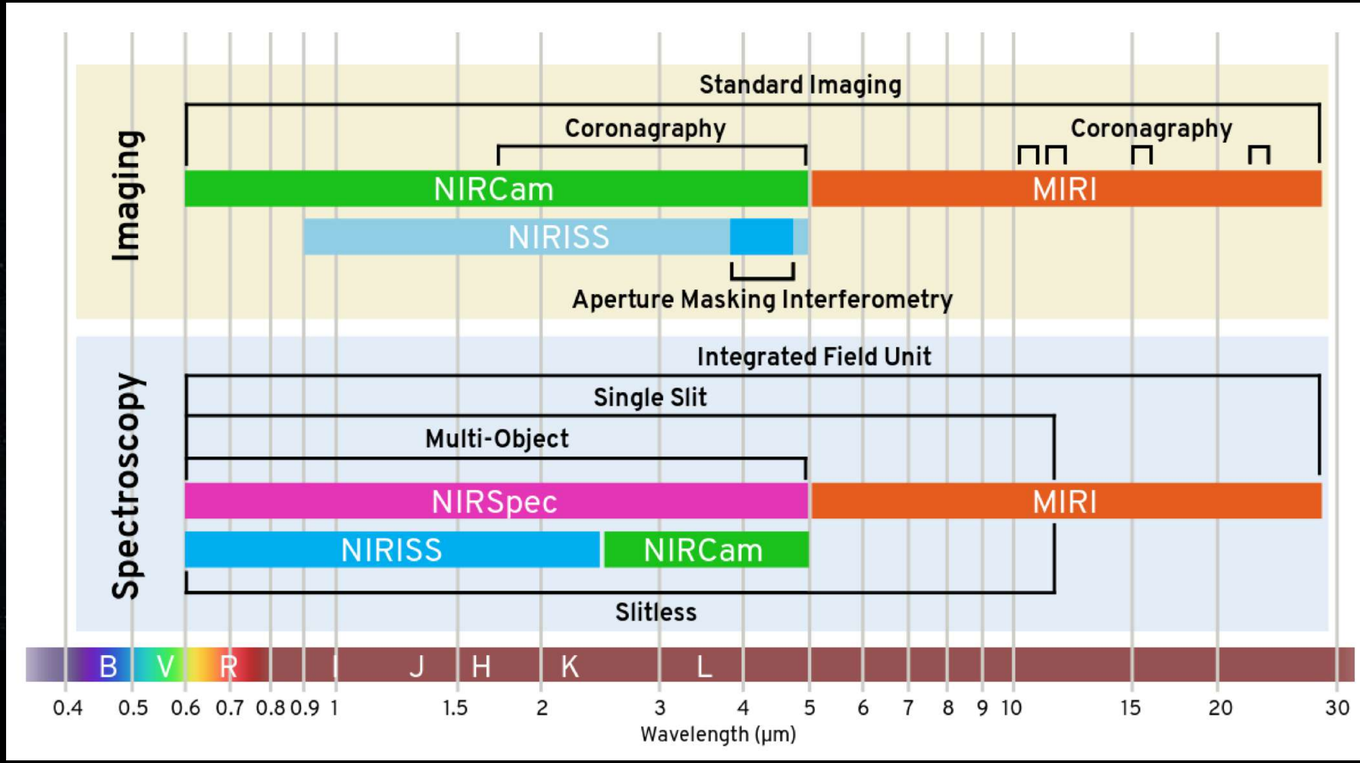


Troutman+11

The gas in main-sequence stars

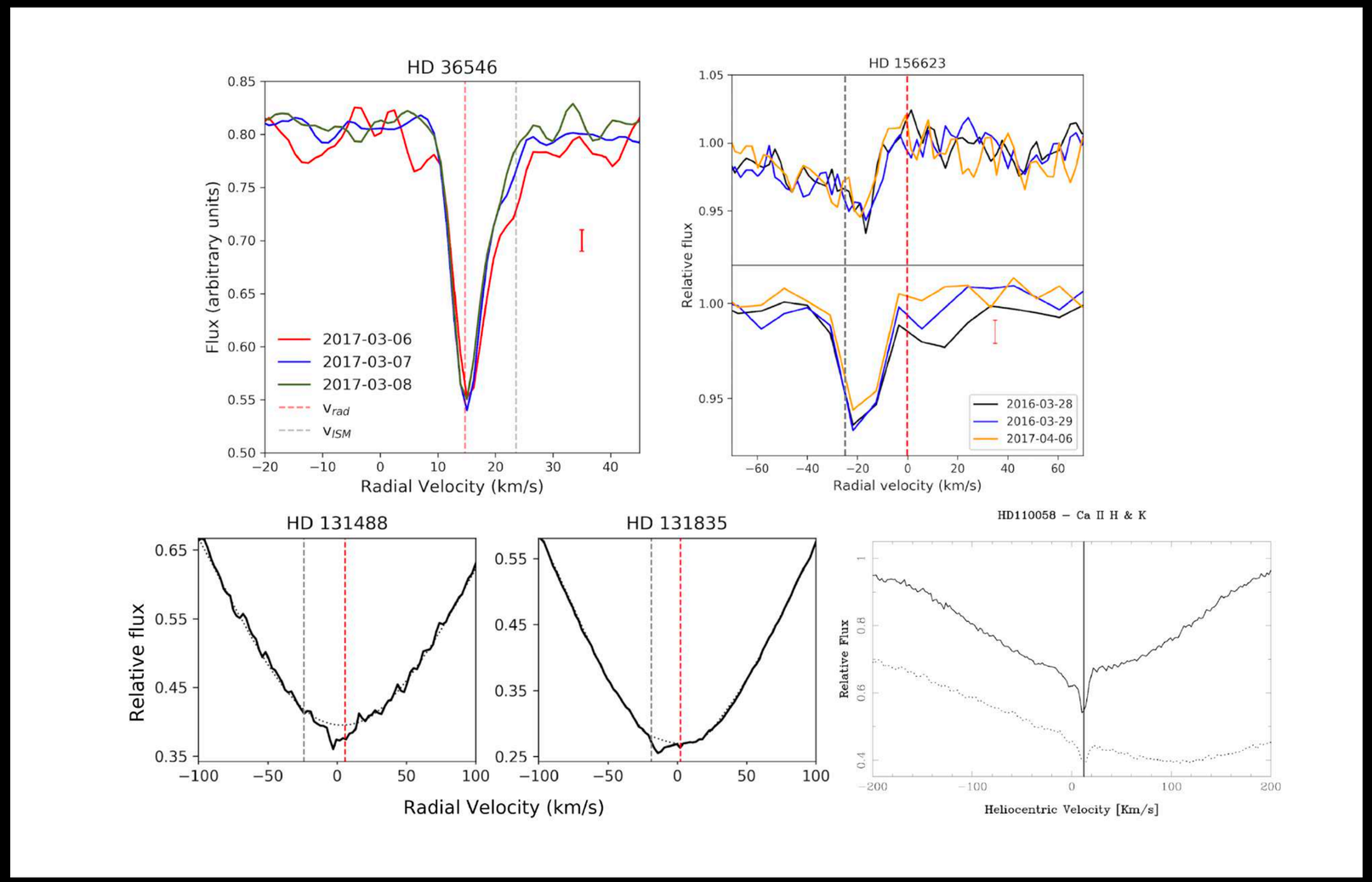
JWST Cycle 1





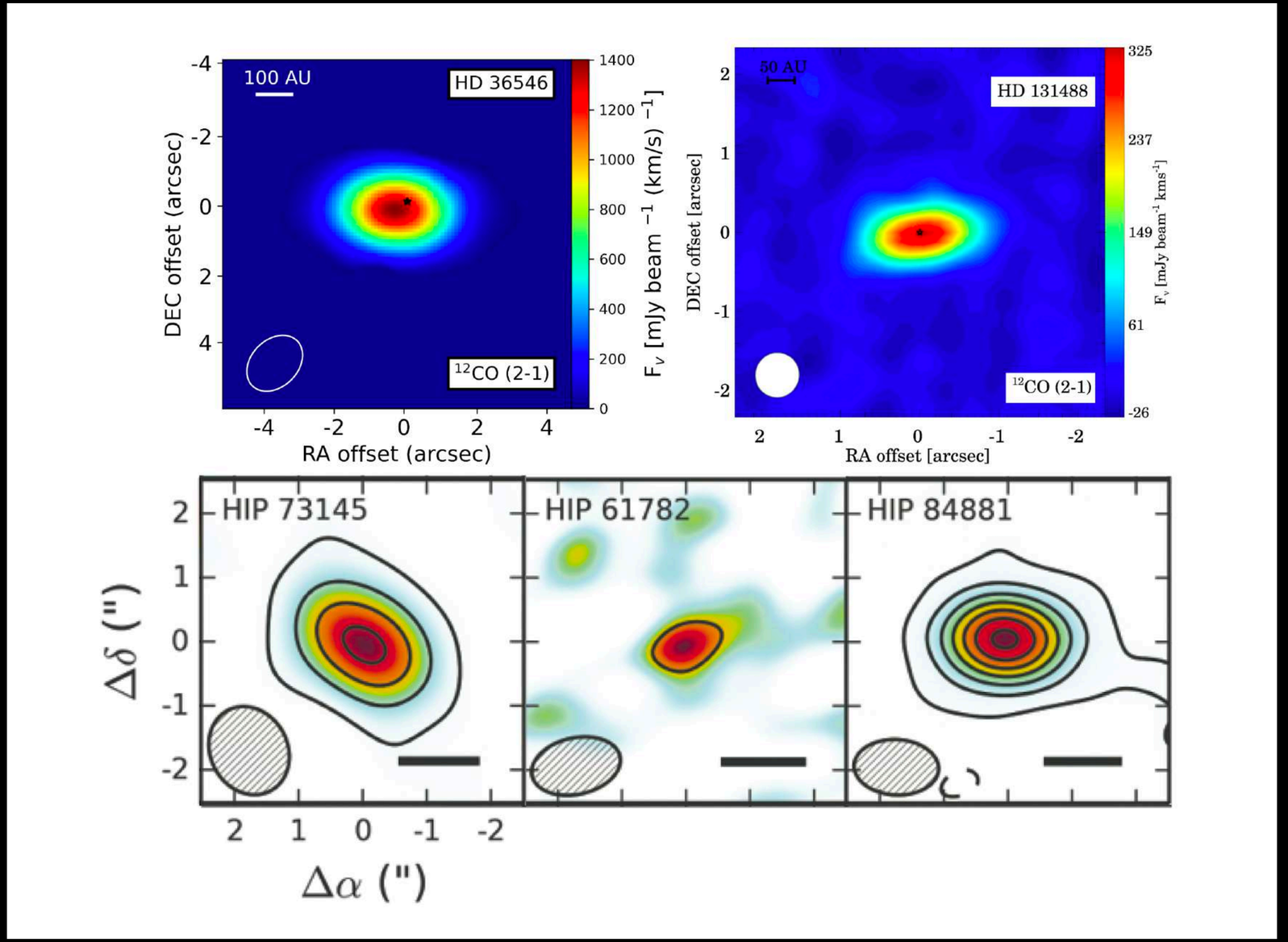
The gas in main-sequence stars

JWST Cycle 1



The gas in main-sequence stars

JWST Cycle 1



The gas in main-sequence stars

JWST Cycle 1

Star	SpT	Age (Myr)	Dist. (pc)	L_{IR}/L_* (10^{-3})	Disk incl. (deg)	K mag	CO detection	Optical gas detection
HD 36546	B8V	10	101.3	4.0		6.815	(1)*	(5)†
HD 110058	A0V	15	129.9	1.4		7.583	(2)	(6)
HD 131488	A1V	16	154.6	5.5		7.803	(3)	(7)
HD 131835	A2IV	16	133.6	3.0		7.524	(4)	(7)
HD 156623	A0V	16	111.7	7.8		7.010	(2)	(7)†

* Private communication; † Exocomet-like features

Star	Exposure Time (s)	Expected SNR (ETC calculation)	Min. col. density (cm^{-2})
HD 36546	97.78	565.97	$7.74 \cdot 10^{11}$
HD 110058	178.96	579.91	$1.16 \cdot 10^{12}$
HD 131488	211.44	577.34	$1.17 \cdot 10^{12}$
HD 131835	162.73	566.73	$1.20 \cdot 10^{12}$
HD 156623	114.02	571.74	$1.19 \cdot 10^{12}$

The gas in main-sequence stars

JWST Cycle 1

Search for NIR gas in debris disks. Is there a water delivery mechanism?

Show affiliations

Rebollido, Isabel ; Chen, Christine ; Debes, John Henry ; Lu, Cicero ; Moro-Martin, Amaya ; Perrin, Marshall ; Roberge, Aki

Publication: JWST Proposal. Cycle 1, ID. #2053

Pub Date: March 2021

Bibcode: 2021jwst.prop.2053R

NIRSpec (G395H/F290LP)

2.9 to 5.2 μm

Fixed slit (1.6x1.6 arcsec)

Mid-resolution

~6 hours

Summary

- ~ 30 stars with exocomets in spectroscopy and ~ 5 in photometry (Rebollido+20, Strøm+20)
- There are at least two cases of false positive exocomet detection (Montesinos+19, Eiroa+21)
- Cold and hot gas might be simultaneously present, but detection is dependent on the inclination of the disk. (Rebollido+20, Rebollido+21)
- Future JWST observations will allow the search for volatiles in exocometary systems.
  - (JWST Cycle 1, PI. Rebollido, *Search for NIR gas in debris disks. Is there a water delivery mechanism?*)

EXOCOMETS

A study of the gaseous environment
of A-type main-sequence stars