Exocomets and minor bodies

Studies across the spectrum

Isabel Rebollido Vázquez

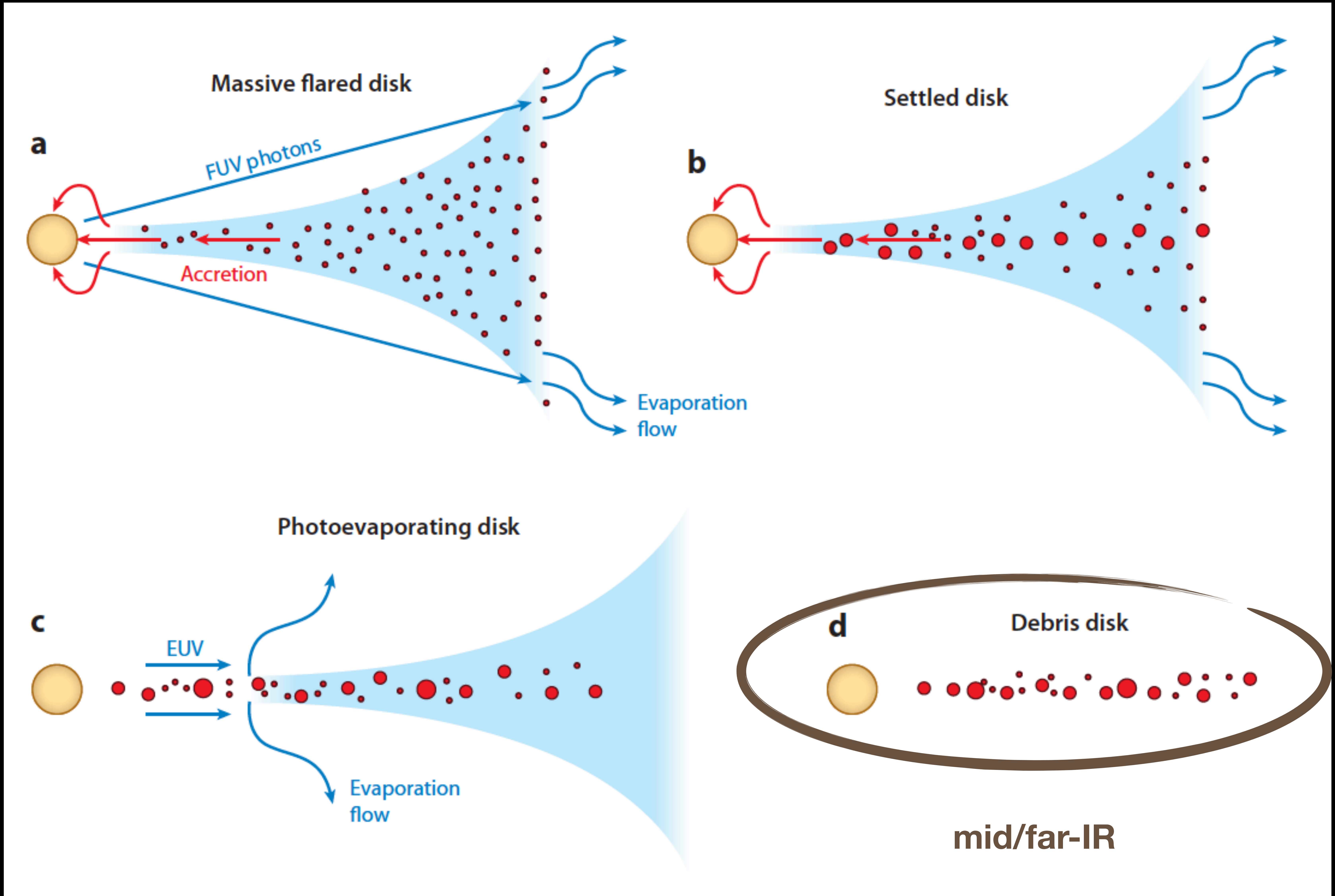
ExoPAG meeting
Jan. 7th 2023

Introduction

Artist impression of planetary system

NASA/JPL

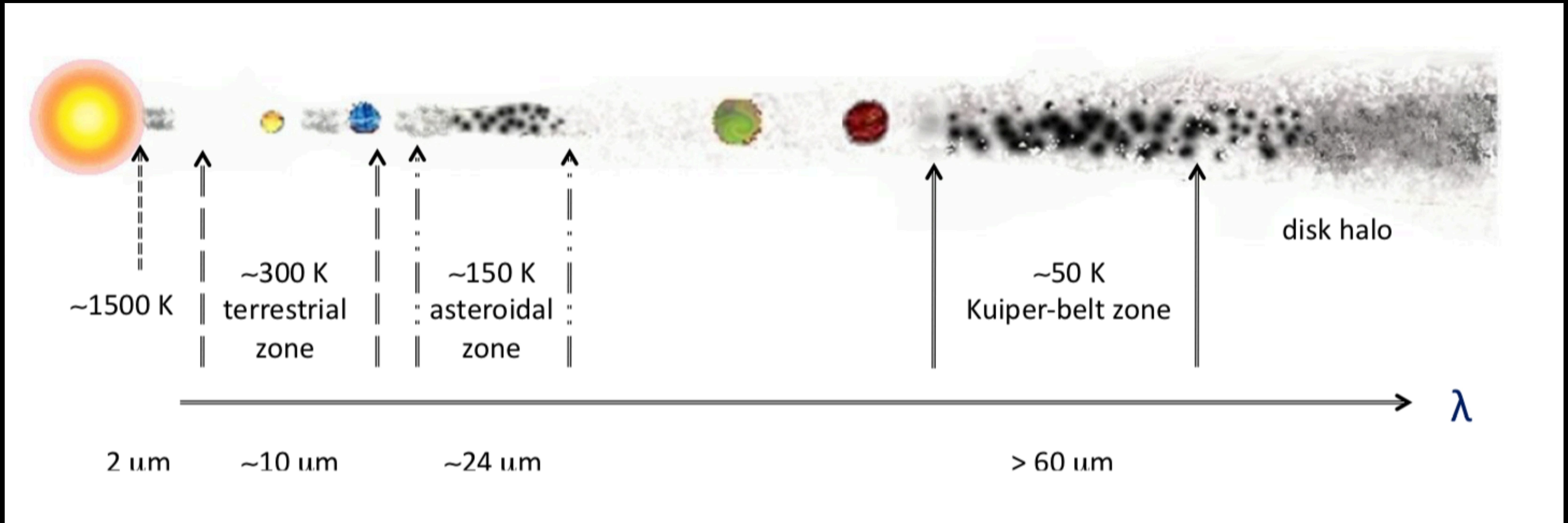
Debris disks



Planet formation process

Williams&Cieza,11

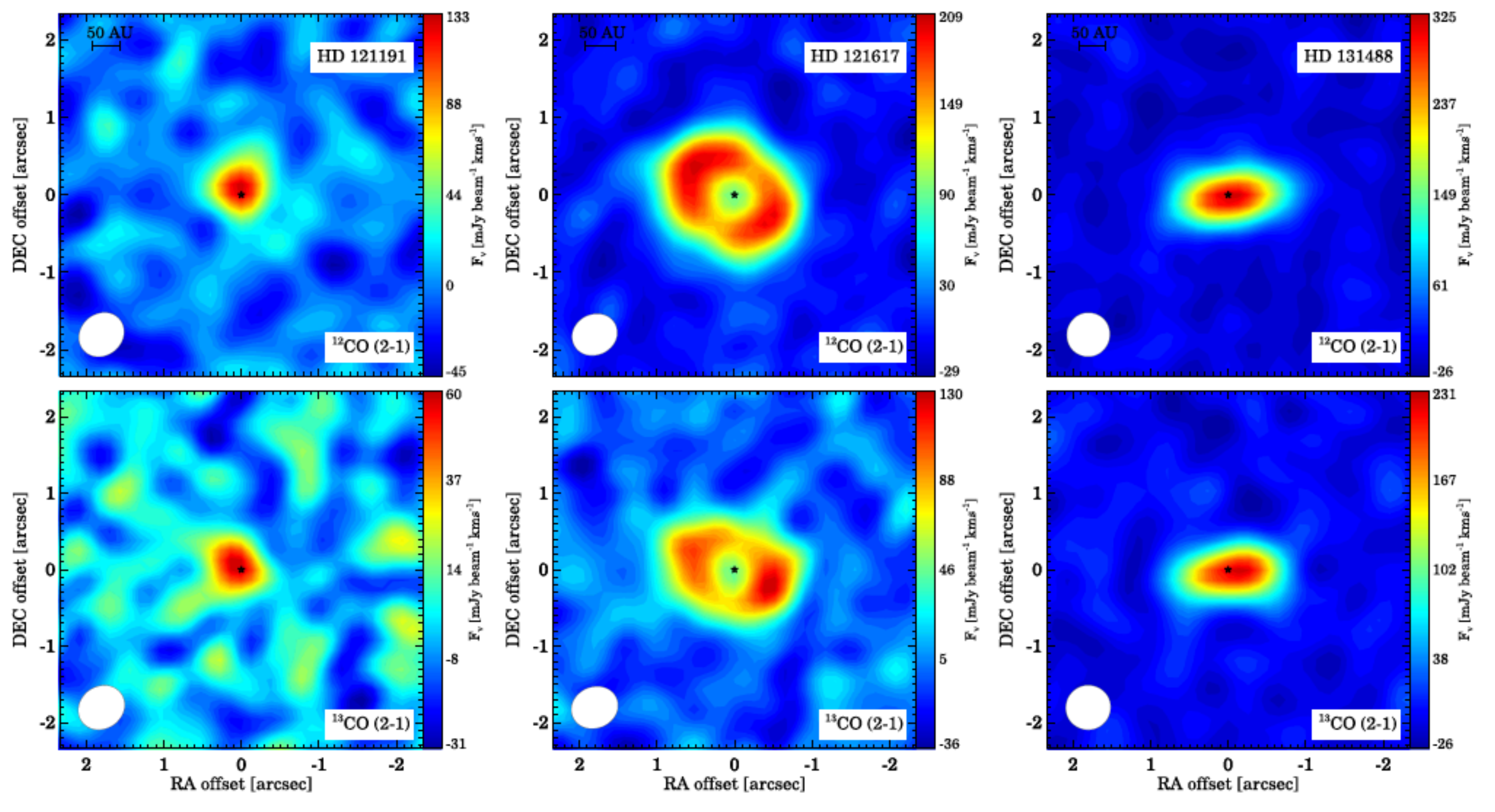
Debris disks



Configuration of planetary systems

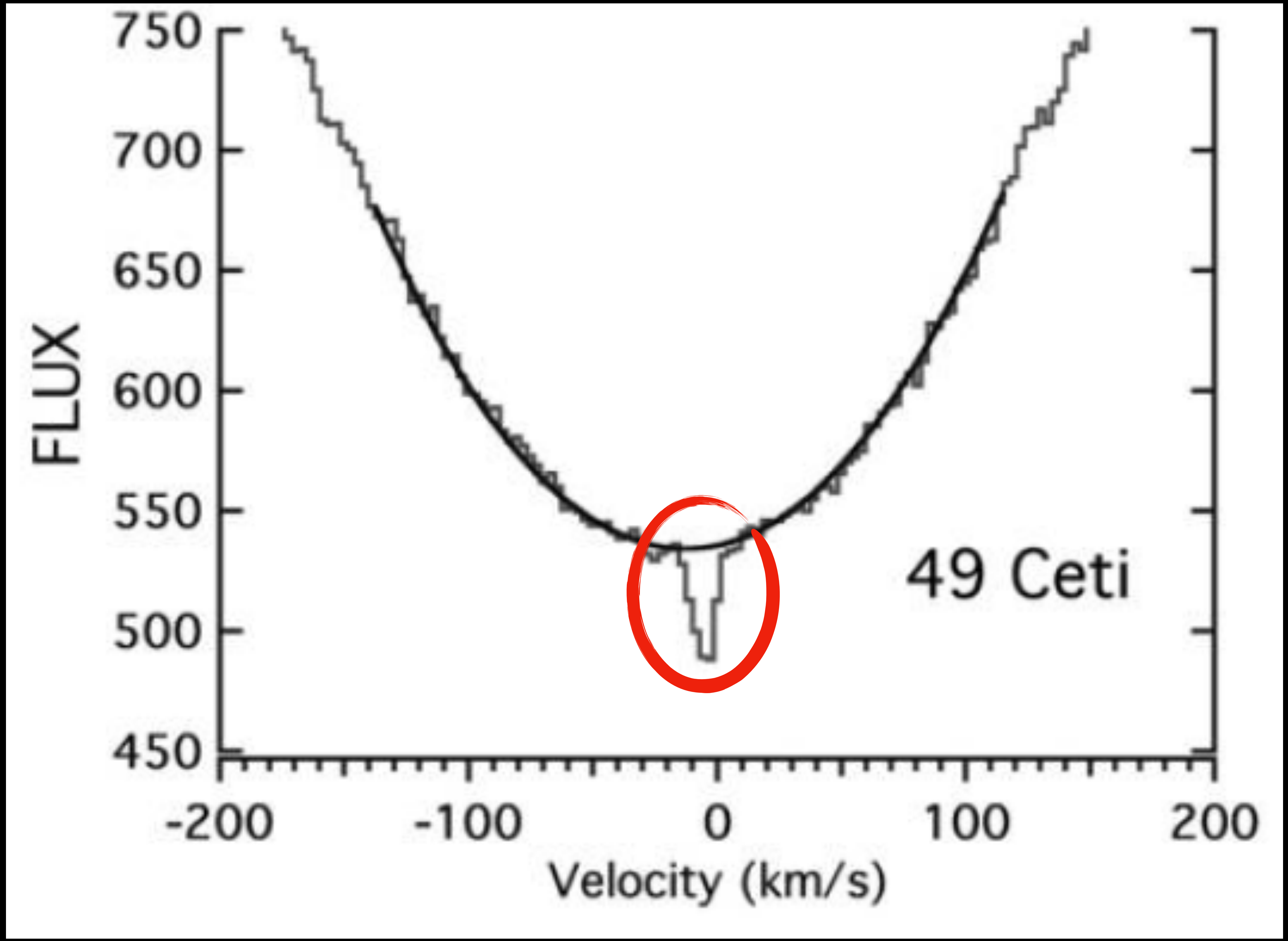
Matthews+14

Gas in Planetary Systems



Emission CO lines
Outskirts of the system
~10 K

Moor+17



Montgomery&Welsh12

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

Most of the gas is cleared after the protoplanetary phase

Primary origin

Remnants of protoplanetary phase

Kospal+13

Gas in Planetary Systems

Most of the gas is cleared after the protoplanetary phase

Primary origin

Remnants of protoplanetary phase

Secondary origin

Stellar processes

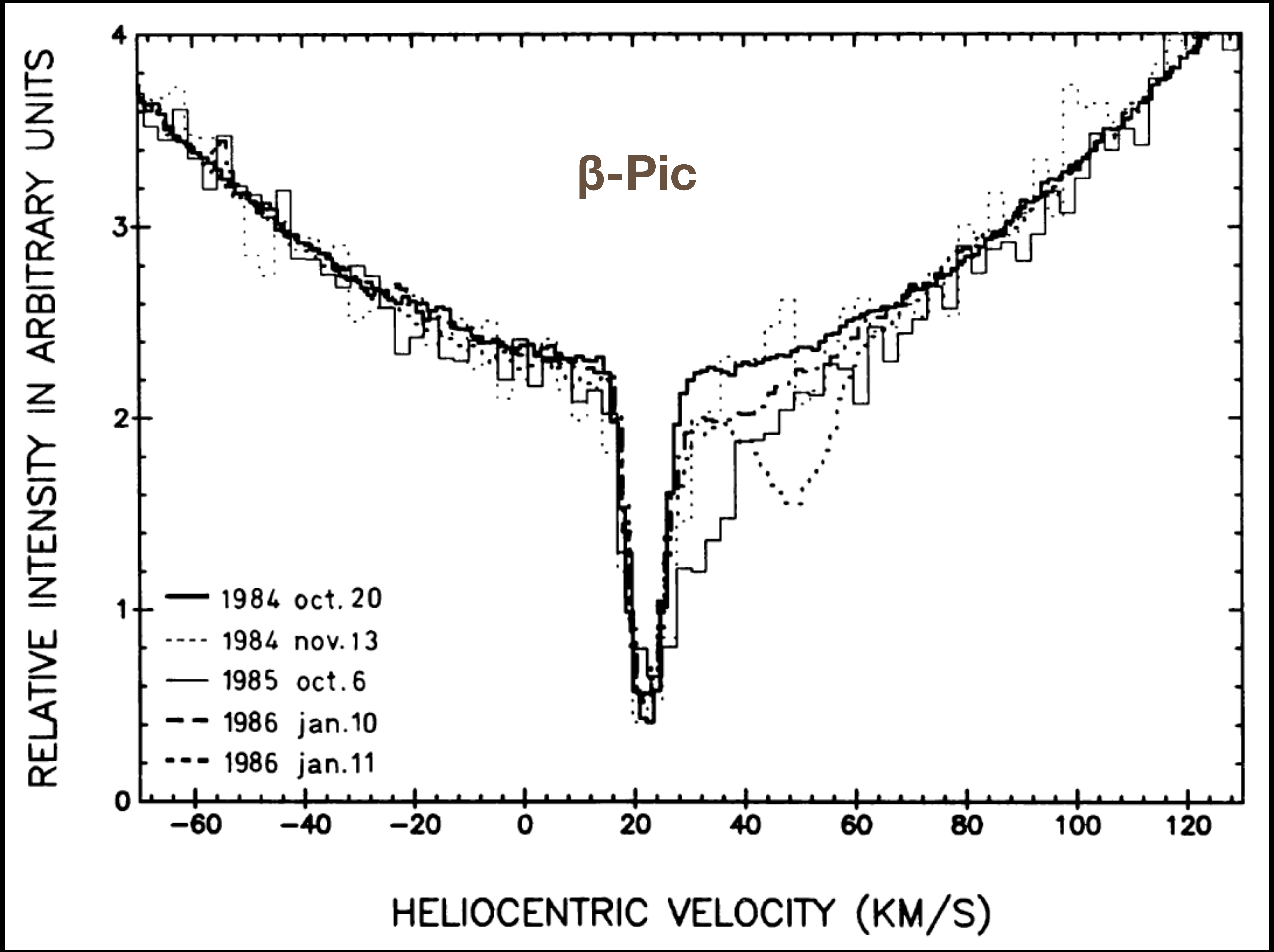
Evaporation

Collisions

Kospal+13

Kral+17,19

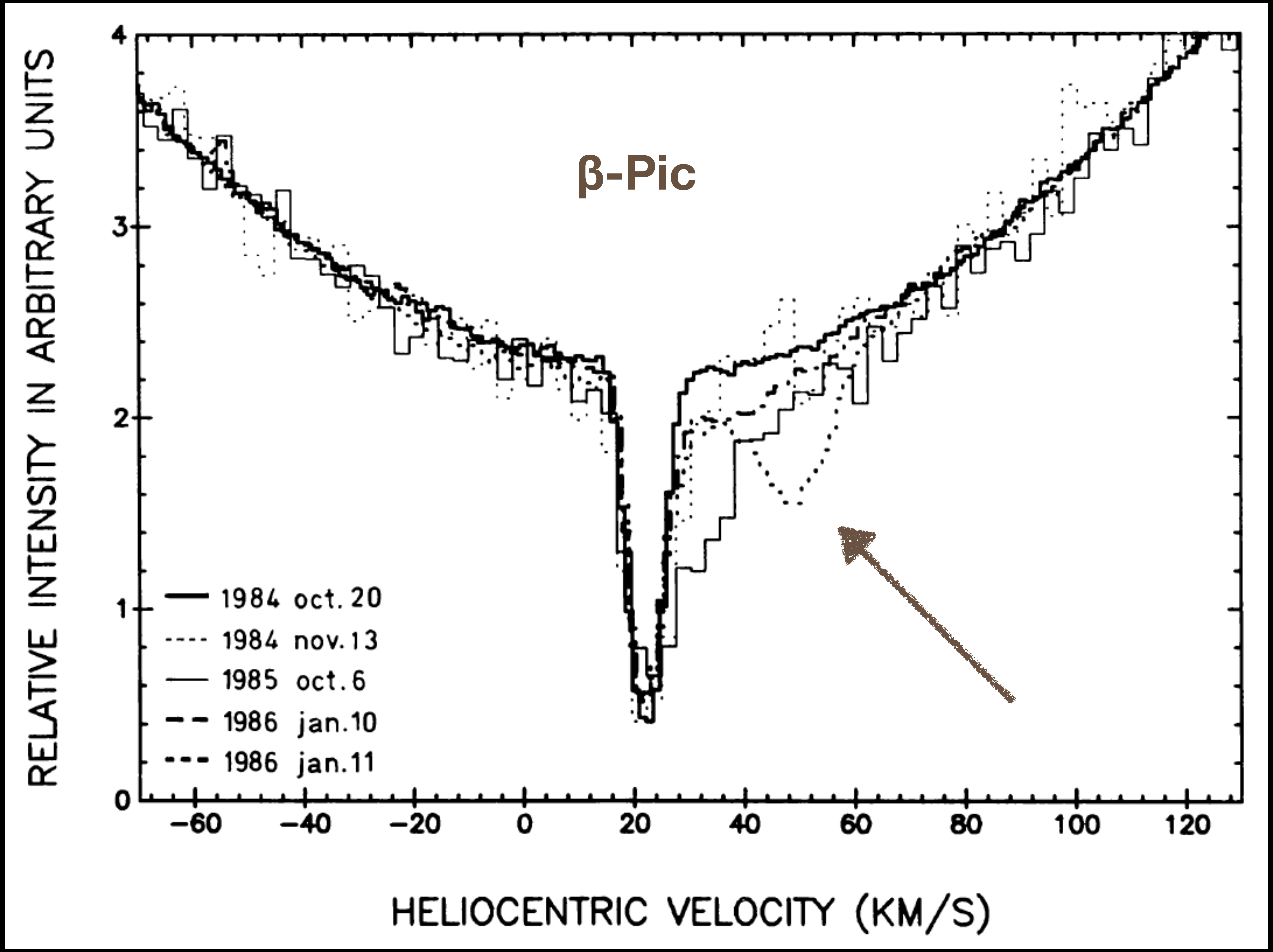
Exocomets



CaIIK (3933.66 Å)

Ferlet+87

Exocomets



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Ferlet+87

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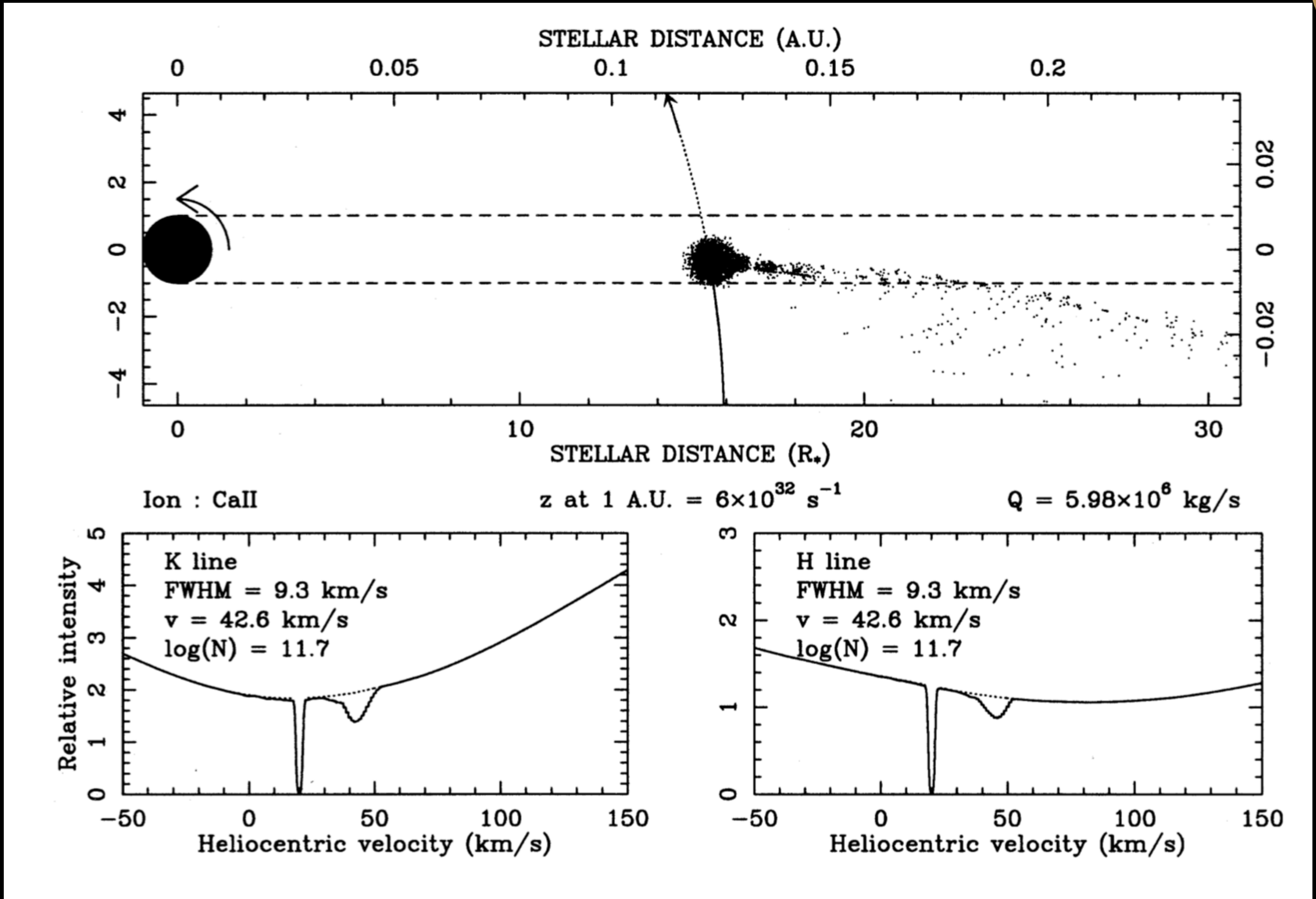
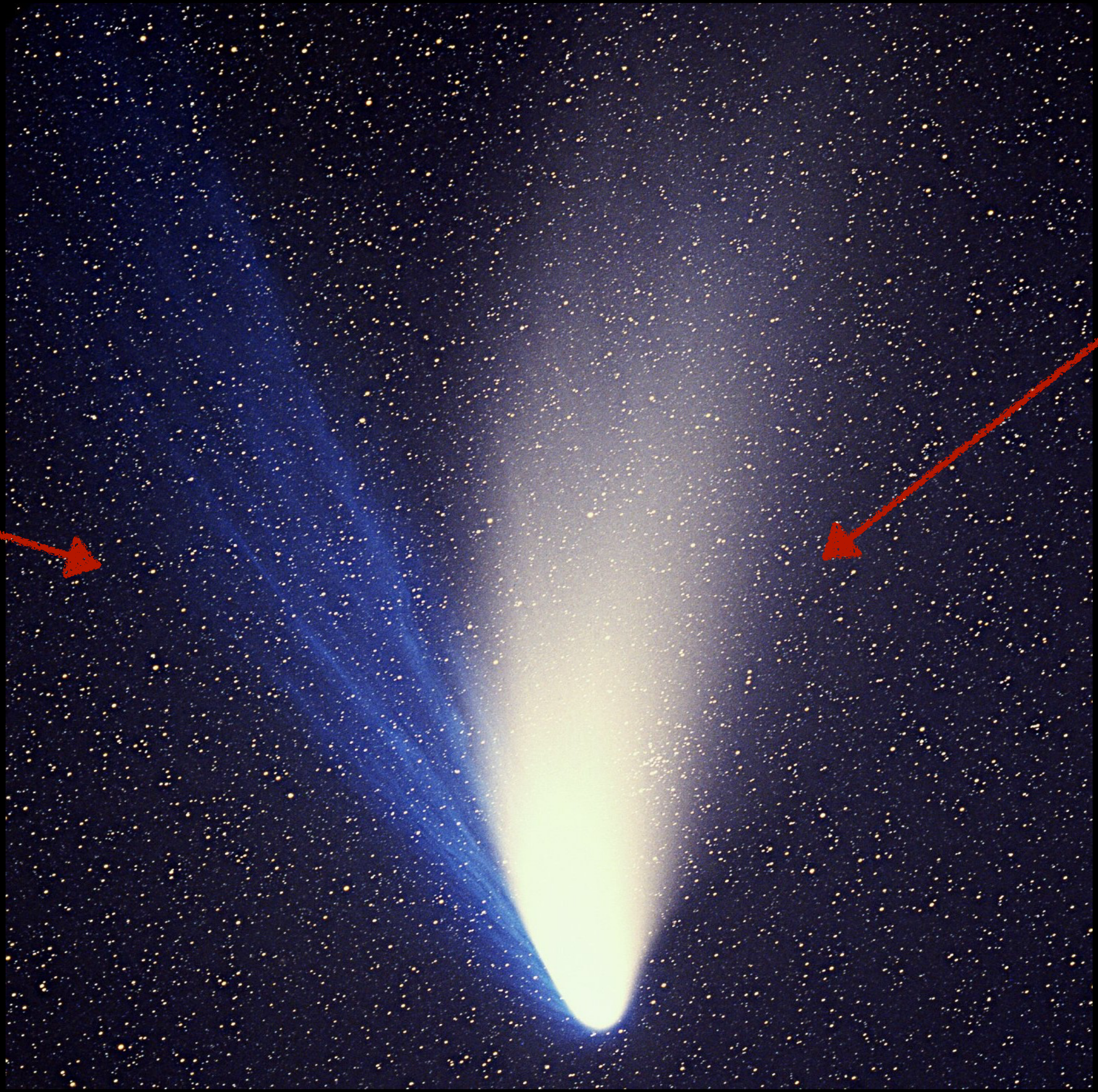


Exocometary absorption in CaII

Beust+98

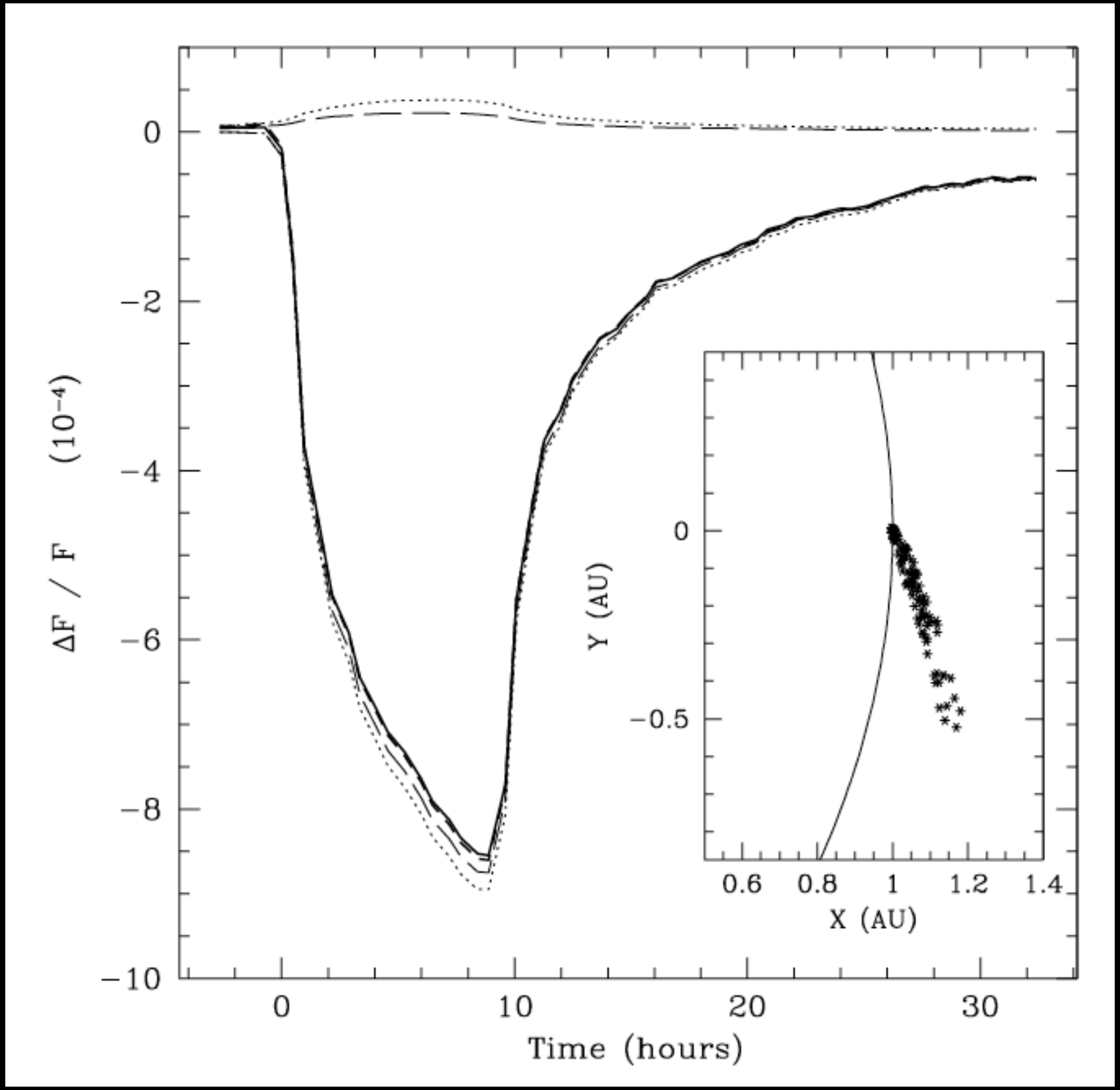
Exocomets



Gaseous tail

Dust tail

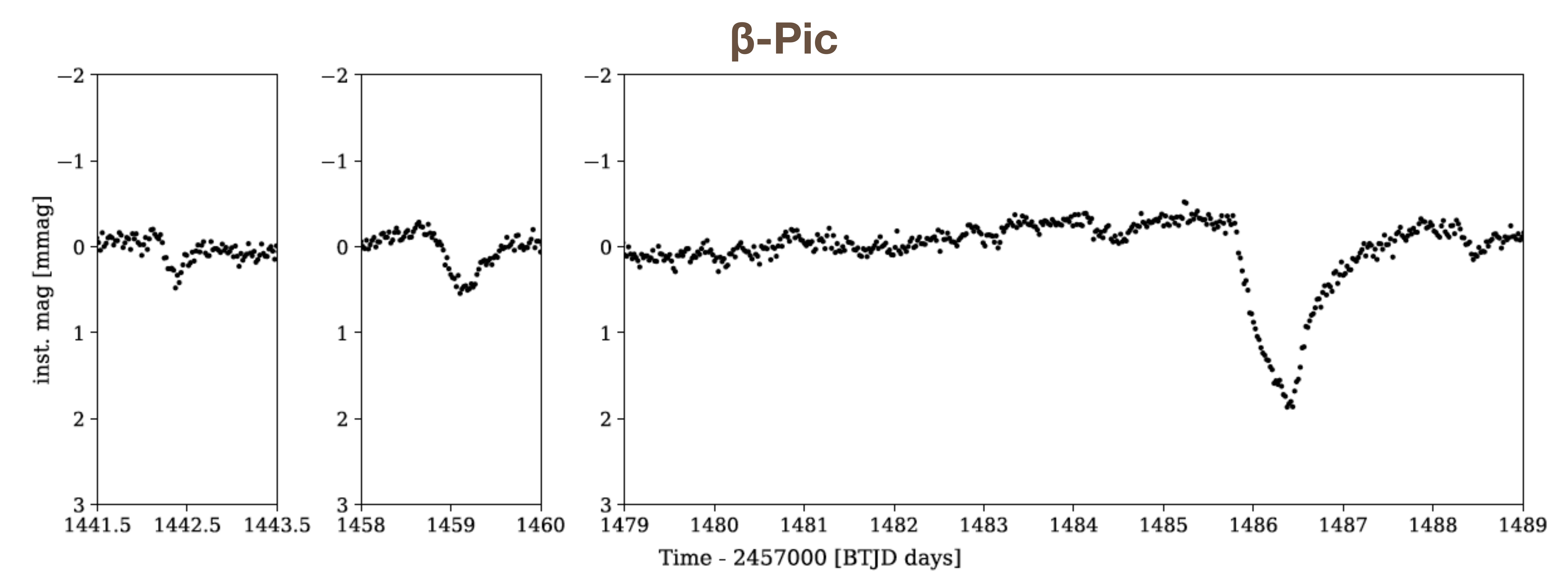
Exocomets



Photometric model

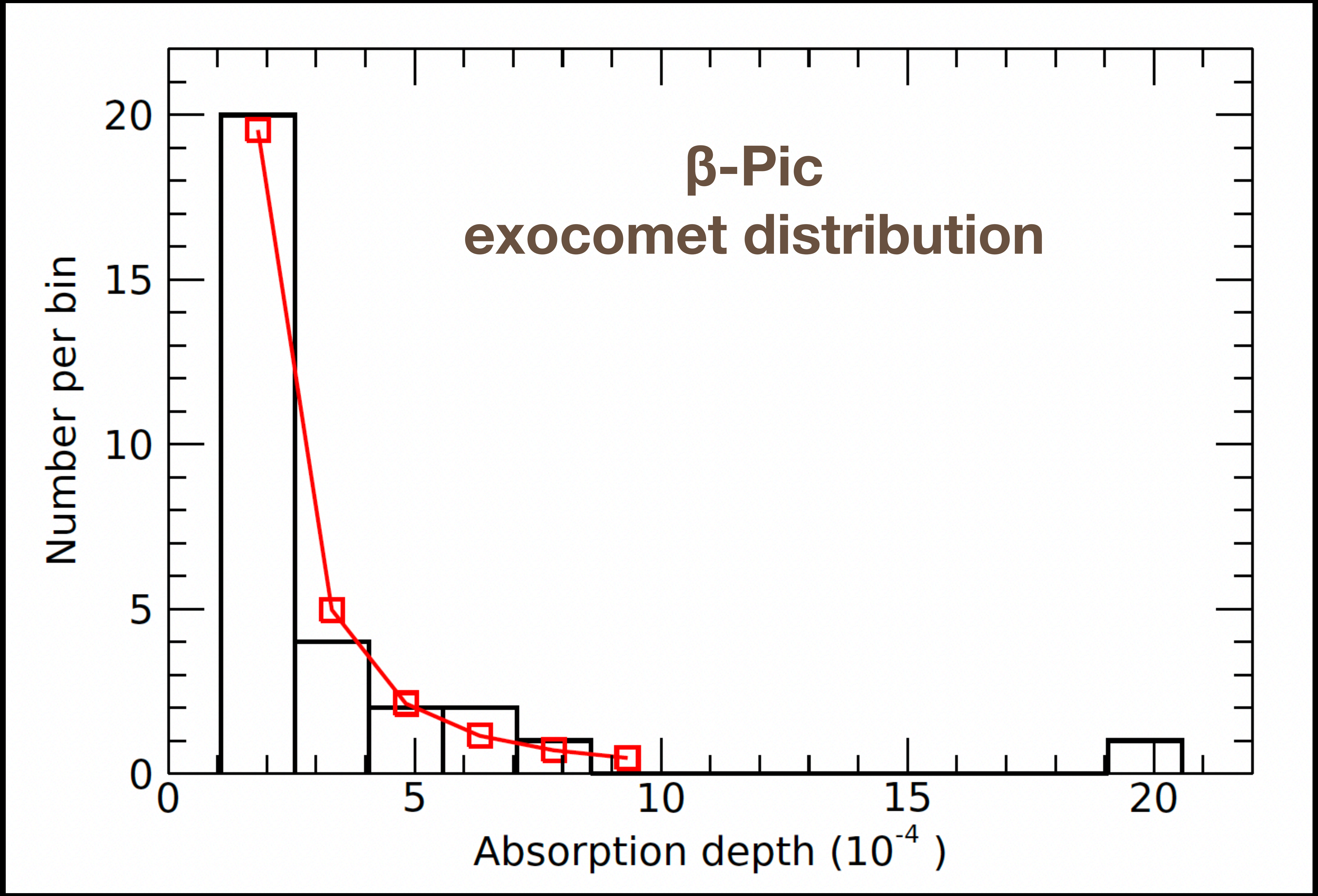
Lecavelier+98

Exocomets



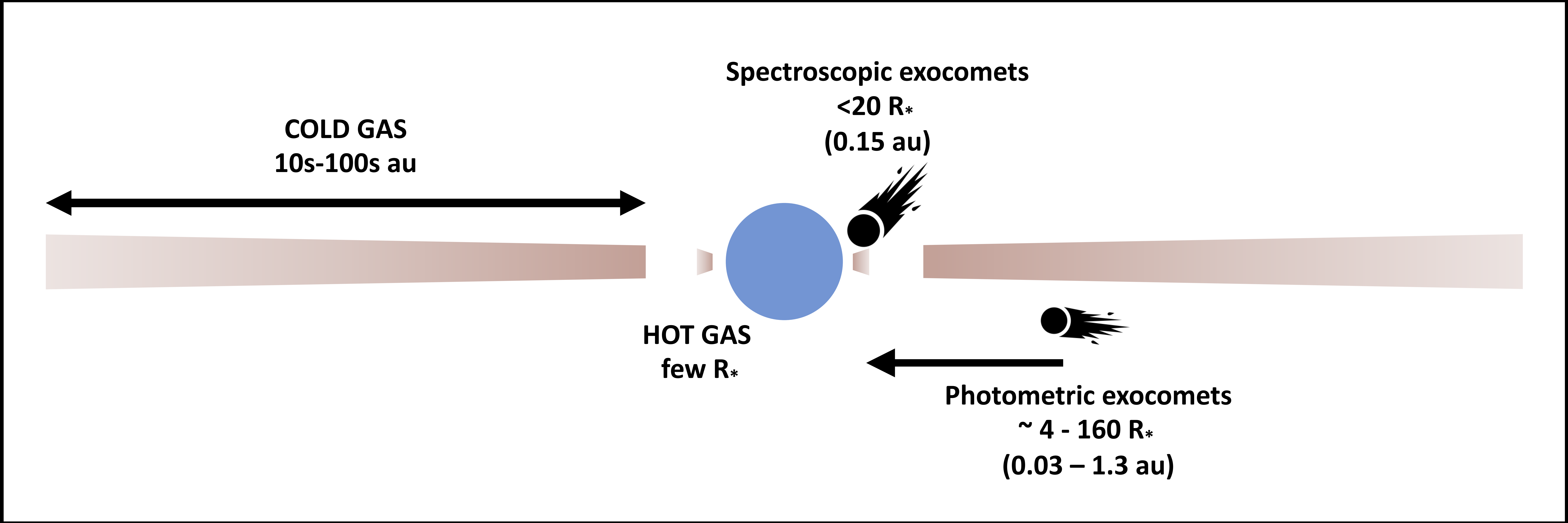
Light curve
TESS data

Zieba+19



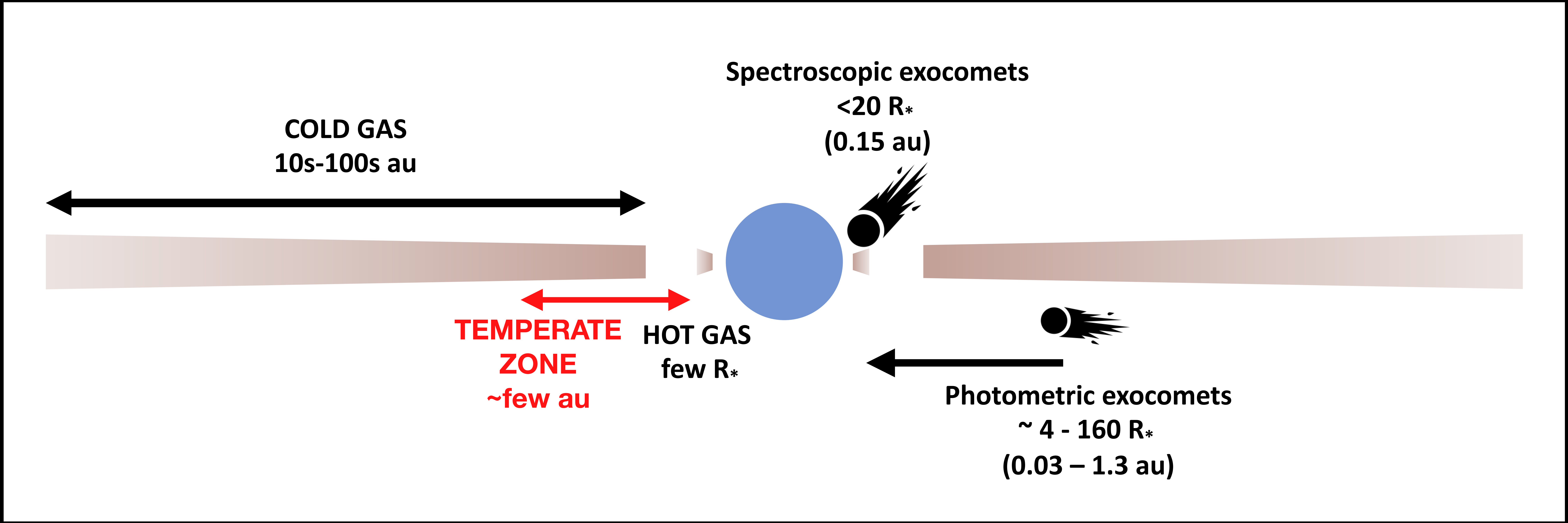
Lecavelier+22

Exocomets



Rebollido+submitted

Exocomets



Rebollido+submitted

The search for gas

~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.

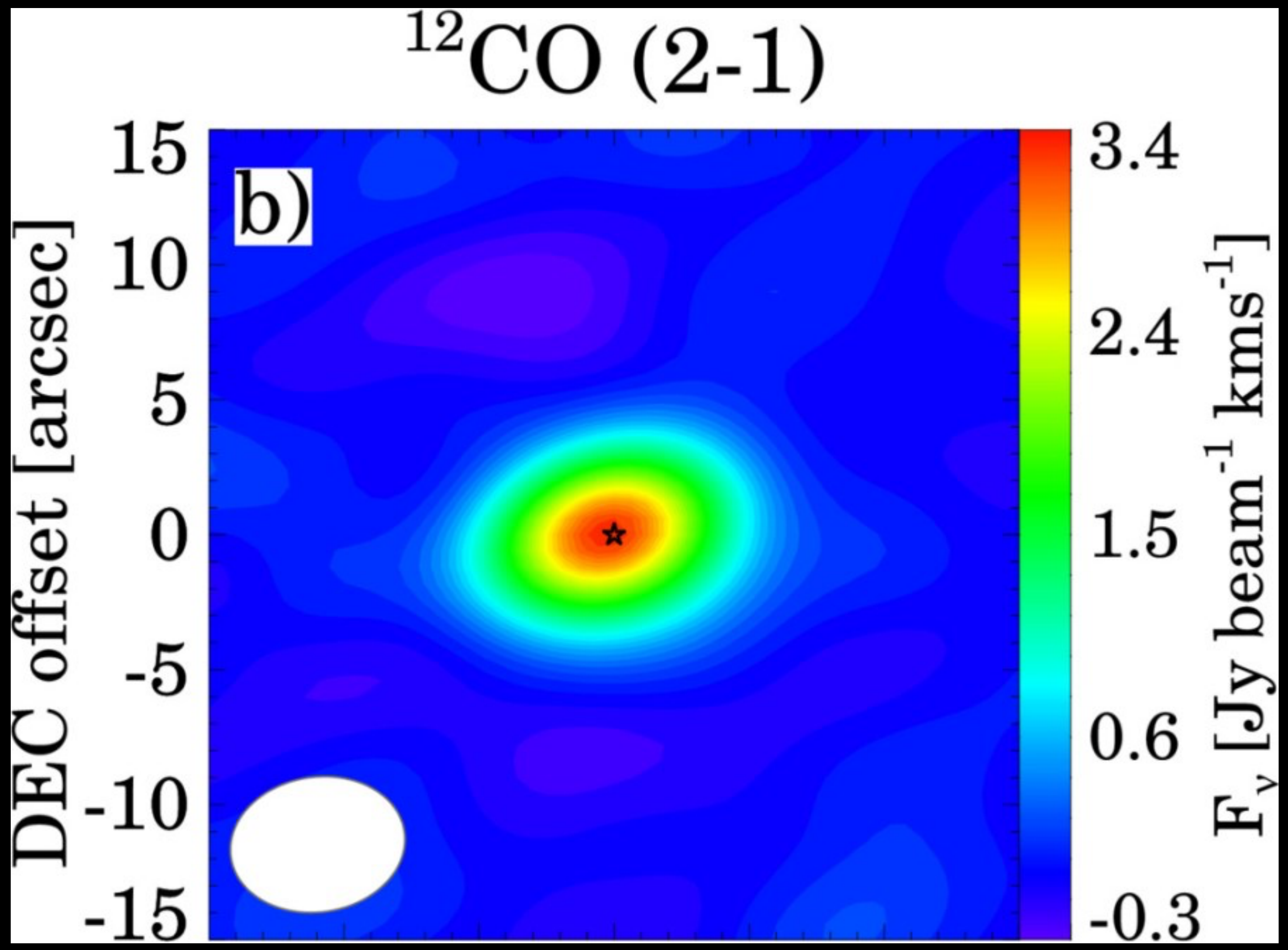
Table 2
Stars Which Show Variability in One of the Ca II H or K Lines or Weak Photometric Signatures that are Suggestive of Exocomet Activity

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)

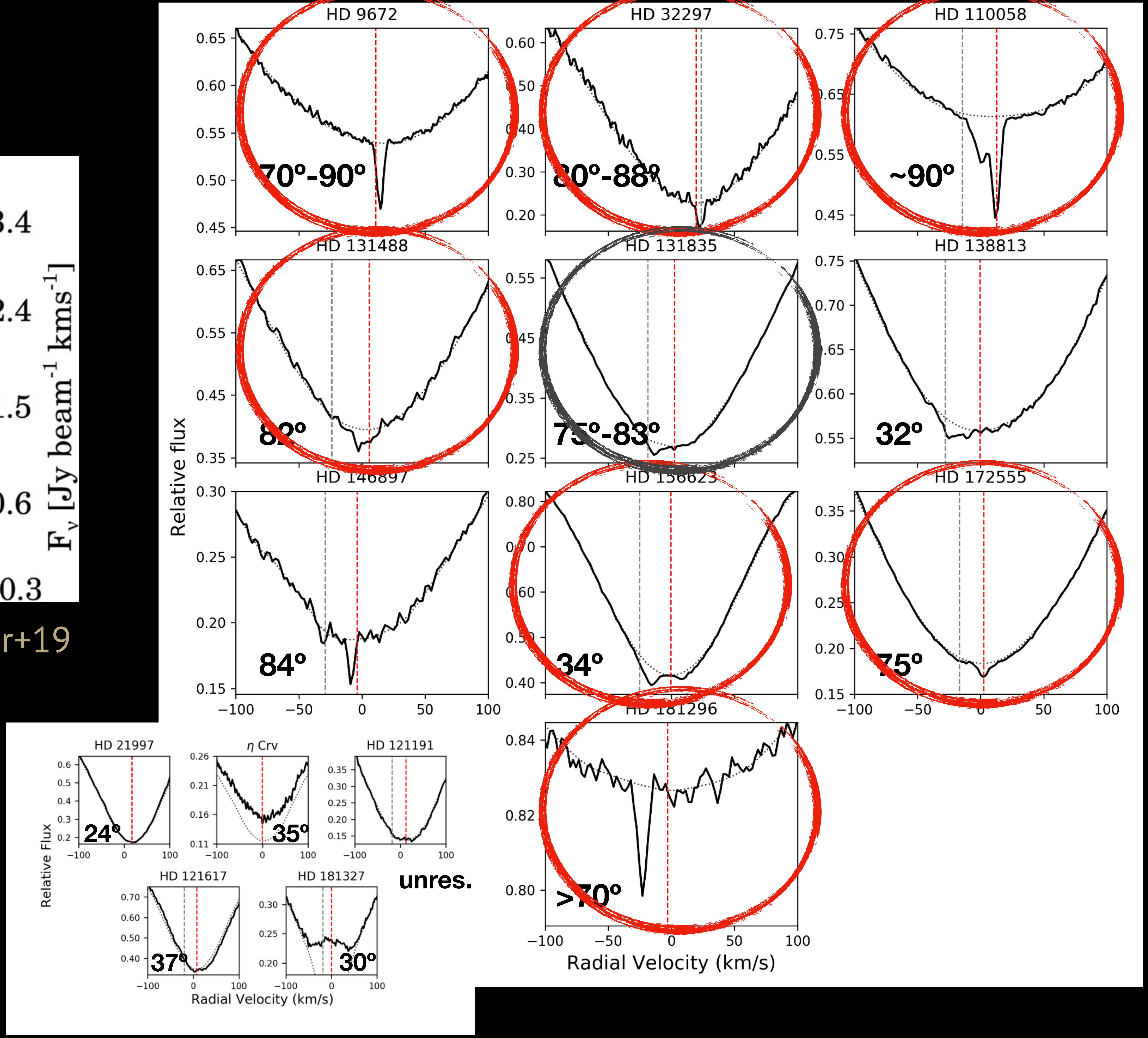
Strom+20, (Rebollido+20)

The search for gas

Hot and cold gas



Moor+19



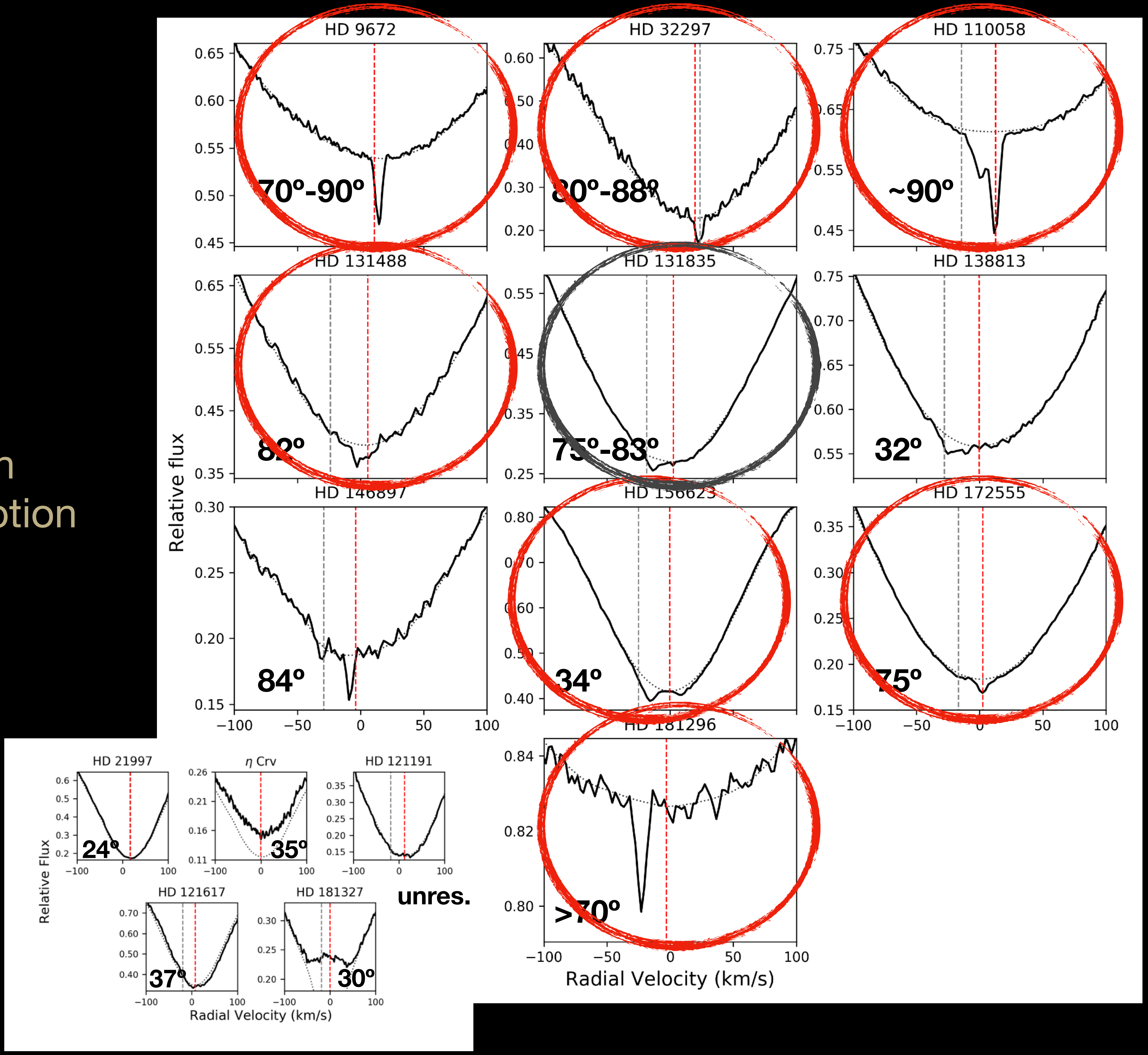
Rebollido+18

The search for gas

Hot and cold gas

All the sources have
cold gas detections

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



+ β Pic
Fomalhaut

Rebollido+18

The search for gas

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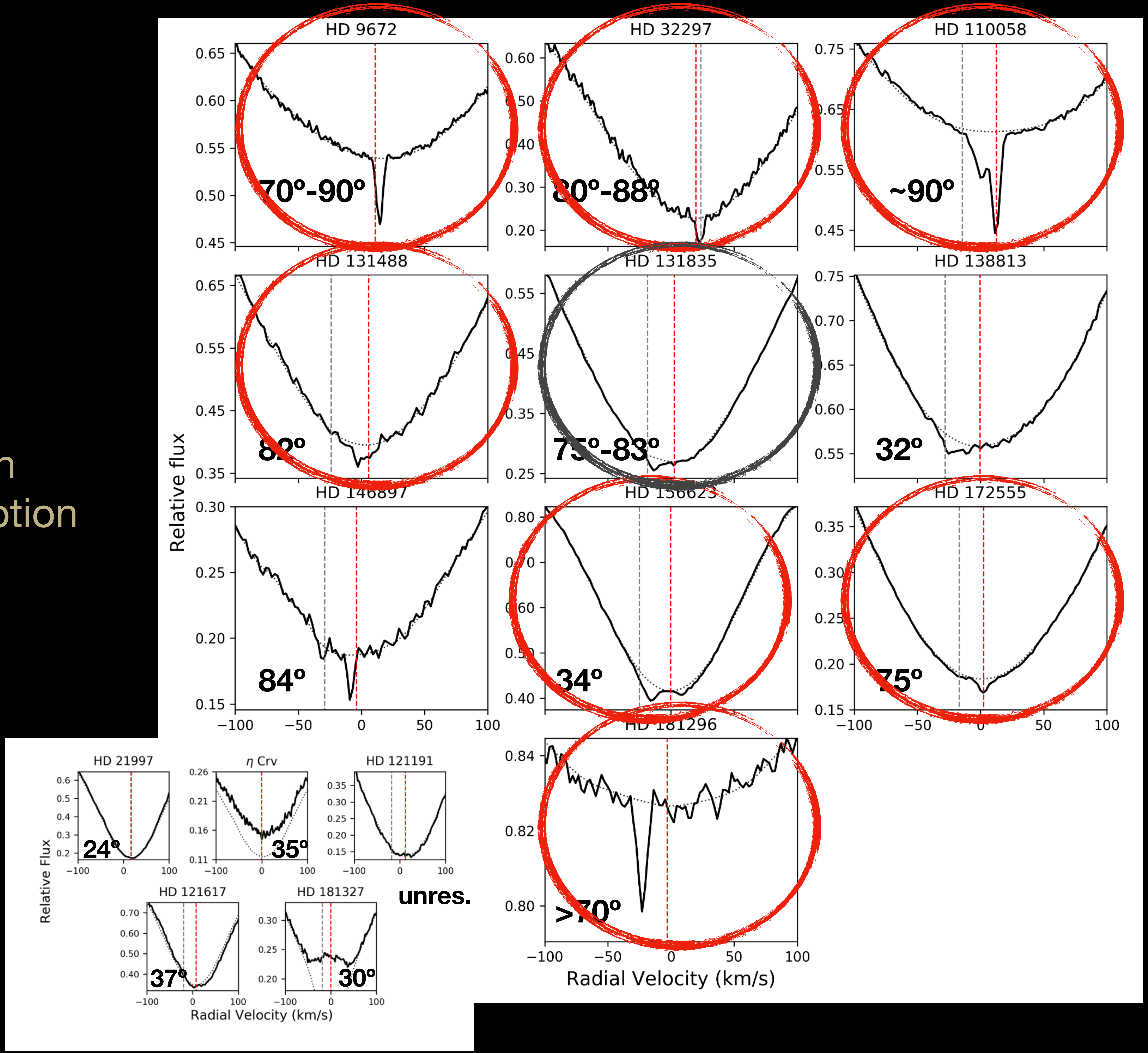
8/9 Edge-on show absorption
7/8 Face-on do not show absorption

GEOMETRICAL EFFECT



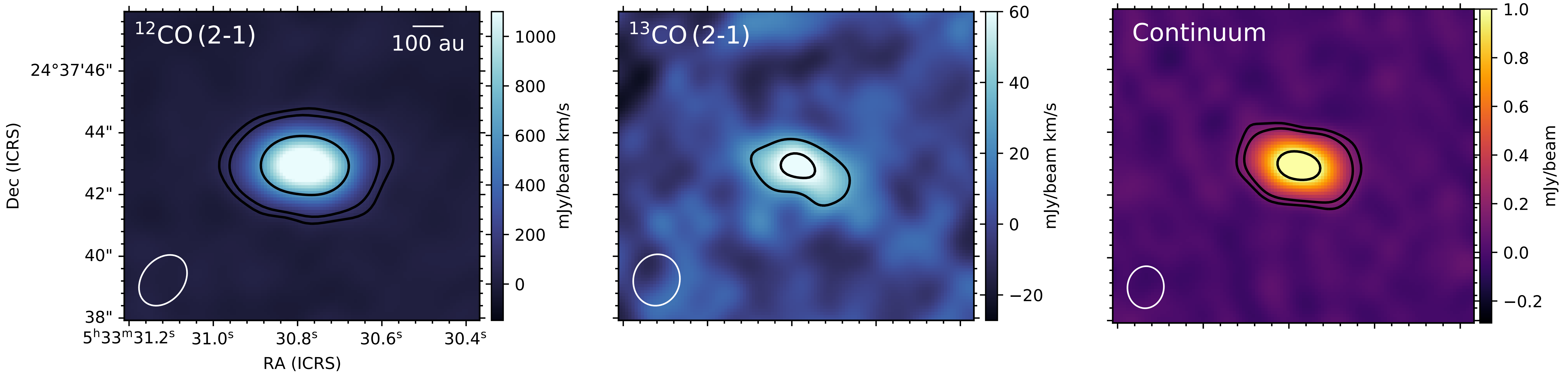
+ β Pic
Fomalhaut

Rebollido+18

The search for gas

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+22

The search for gas

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

The search for gas

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 search for gas

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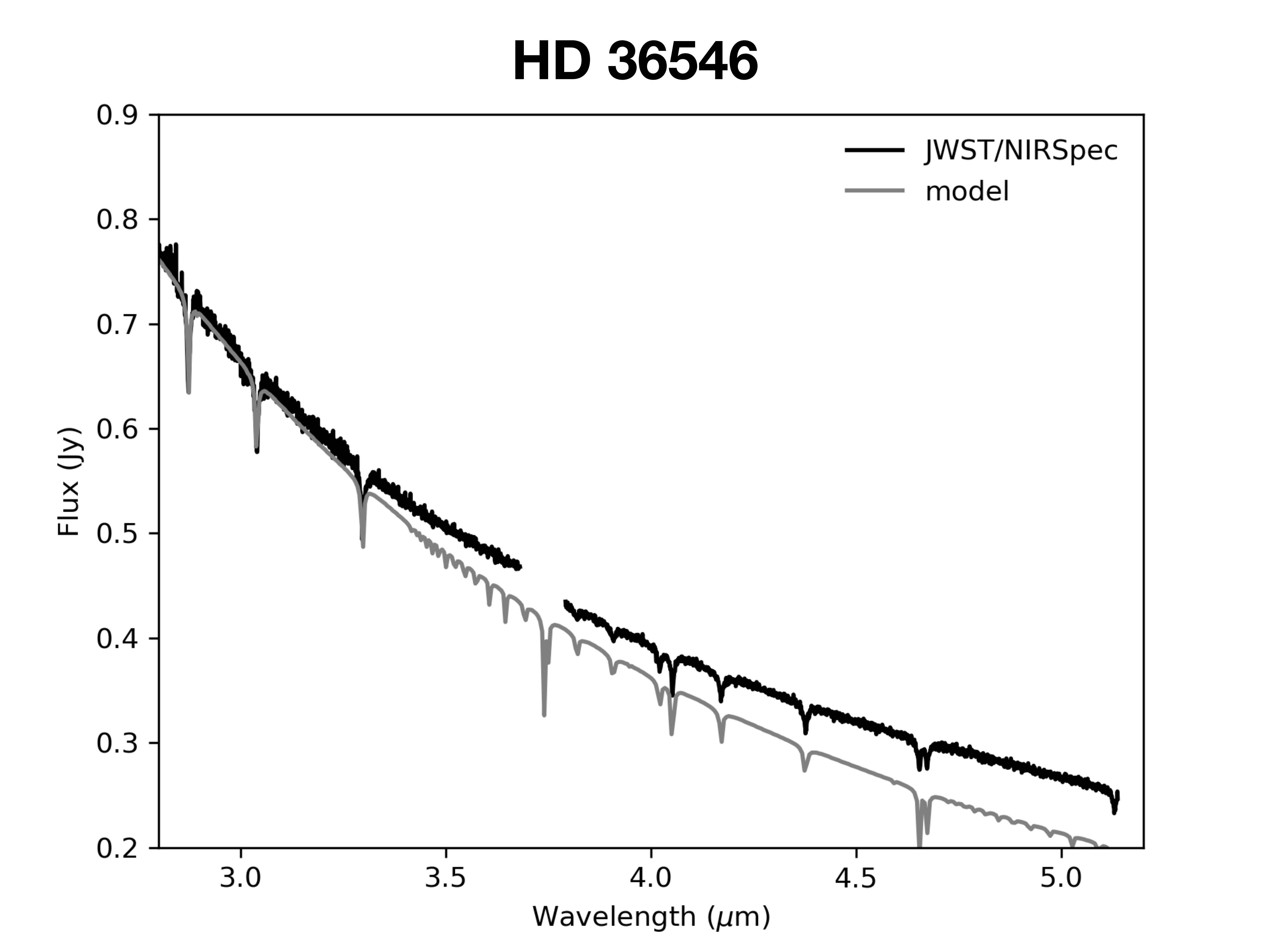
The search for gas

JWST Cycle 1

PRELIMINARY RESULTS

Ongoing improvement of the data reduction as in-flight calibrations become accessible



Rebollido+in prep.

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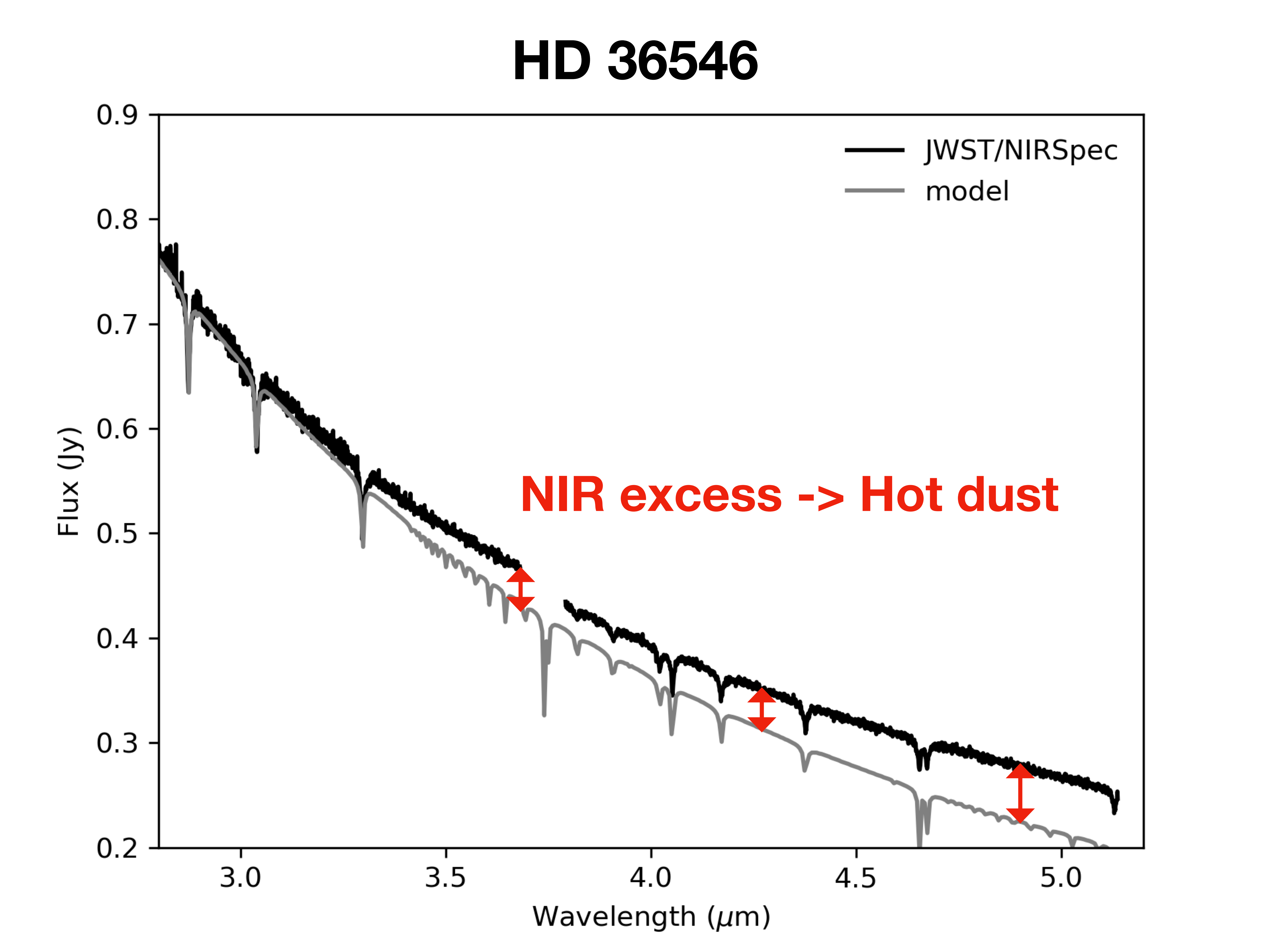

Rebollido+in prep.

Summary

- ~ 30 stars with exocomets in spectroscopy and ~ 5 in photometry (Rebollido+20, Strøm+20)
- Cold and hot gas might be simultaneously present, but detection is dependent on the inclination of the disk. (Rebollido+18, Rebollido+21)
- JWST observations will allow the search for volatiles in the temperate zones of exocometary systems.
  - (JWST Cycle 1, PI. Rebollido, *Search for NIR gas in debris disks. Is there a water delivery mechanism?*)
  - **First source already showed NIR excesses compatible with hot dust!!**

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STScI

2023 Spring Symposium

Planetary Systems and the Origins of Life in the Era of JWST

16-19, May, 2023

Description

Building on the foundational work enabled by HST and Spitzer, one of JWST's main scientific drivers is the study of the origins of life, from planetary formation and exoplanetary systems to investigations of our own solar system. The data to be collected through ERS, GTO, and Cycle 1 GO programs over the coming months will revolutionize our current understanding of chemical compositions within the atmospheres of exoplanets, brown dwarfs, and the planets, moons, and minor bodies of the solar system. Studies of protoplanetary and debris disks will establish fundamental initial conditions and endpoints for forming these planetary systems. The power of JWST will expand through development of multi-wavelength synergies with other missions, particularly HST, enabling astrobiologists to develop more accurate simulations of biosignatures on other worlds.

Speakers

Richard Cartwright (SETI)
Elodie Choquet (Laboratoire d'Astrophysique de Marseille, Aix-Marseille University)
Katherine de Kleer (Caltech)
Jennifer Glass (Georgia Institute of Technology)
Brittany Miles (University of Arizona)
Karin Öberg (Harvard/CfA)
Noemí Pinilla-Alonso (Florida Space Institute, University of Central Florida)
Sukrit Ranjan (University of Arizona)
Geronimo Villanueva (NASA Goddard Space Flight Center)
Hannah Wakeford (University of Bristol)

Science Organizing Committee

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Isabel Rebollido, Chair (Space Telescope Science Institute)
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John Debes (Space Telescope Science Institute)
Dean Hines (Space Telescope Science Institute)
Bryan Holler (Space Telescope Science Institute)
Elena Manjavacas (Space Telescope Science Institute)
Jamila Pegues (Space Telescope Science Institute)
Amaya Moro-Martin (Space Telescope Science Institute)
Nikolay Nikolov (Space Telescope Science Institute)
Emily Rickman (ESA/Space Telescope Science Institute)
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Jocelyne DiRuggiero (Johns Hopkins University)
Jacob Lustig-Yaeger (Johns Hopkins University)

The search for gas

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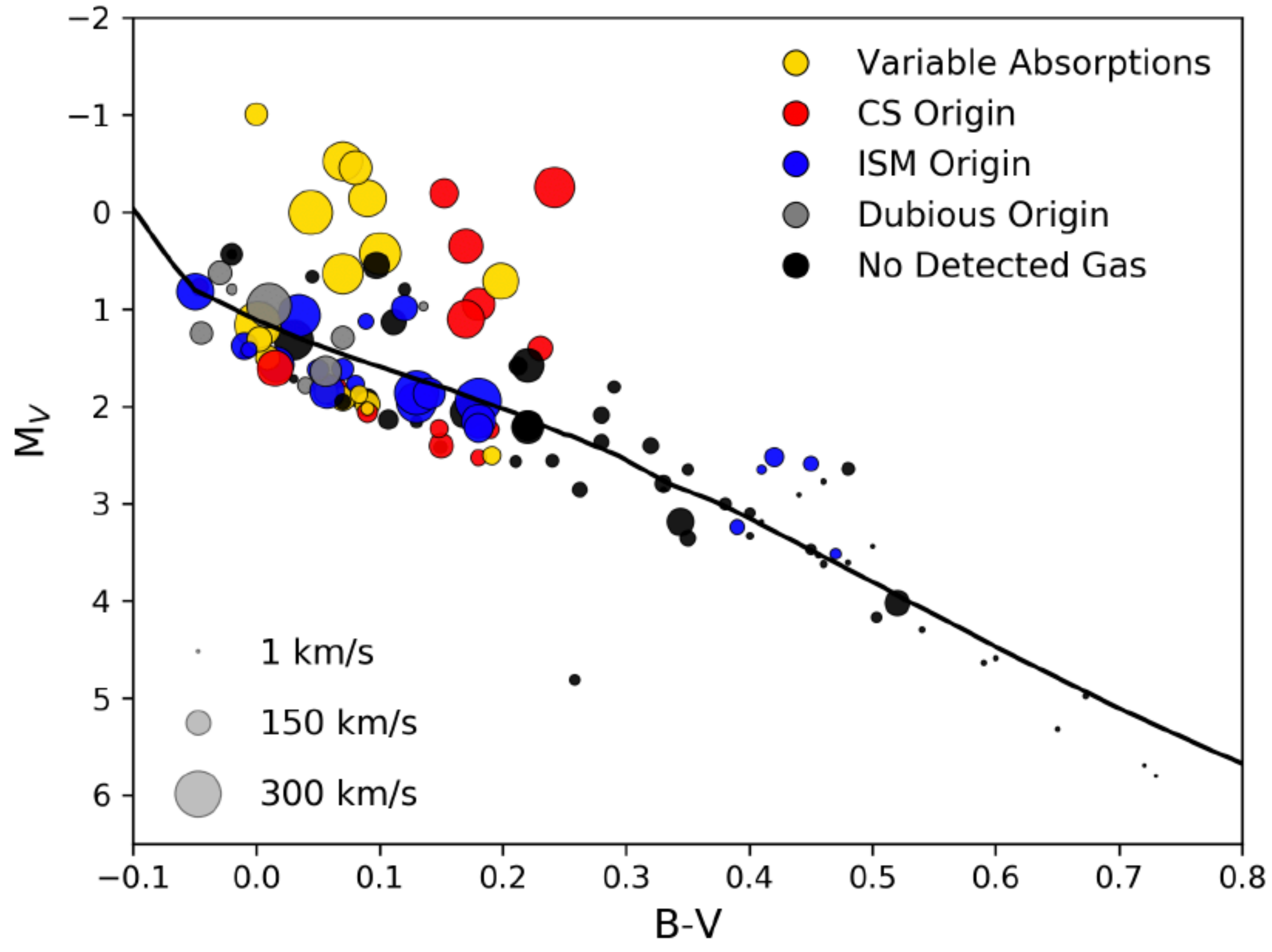

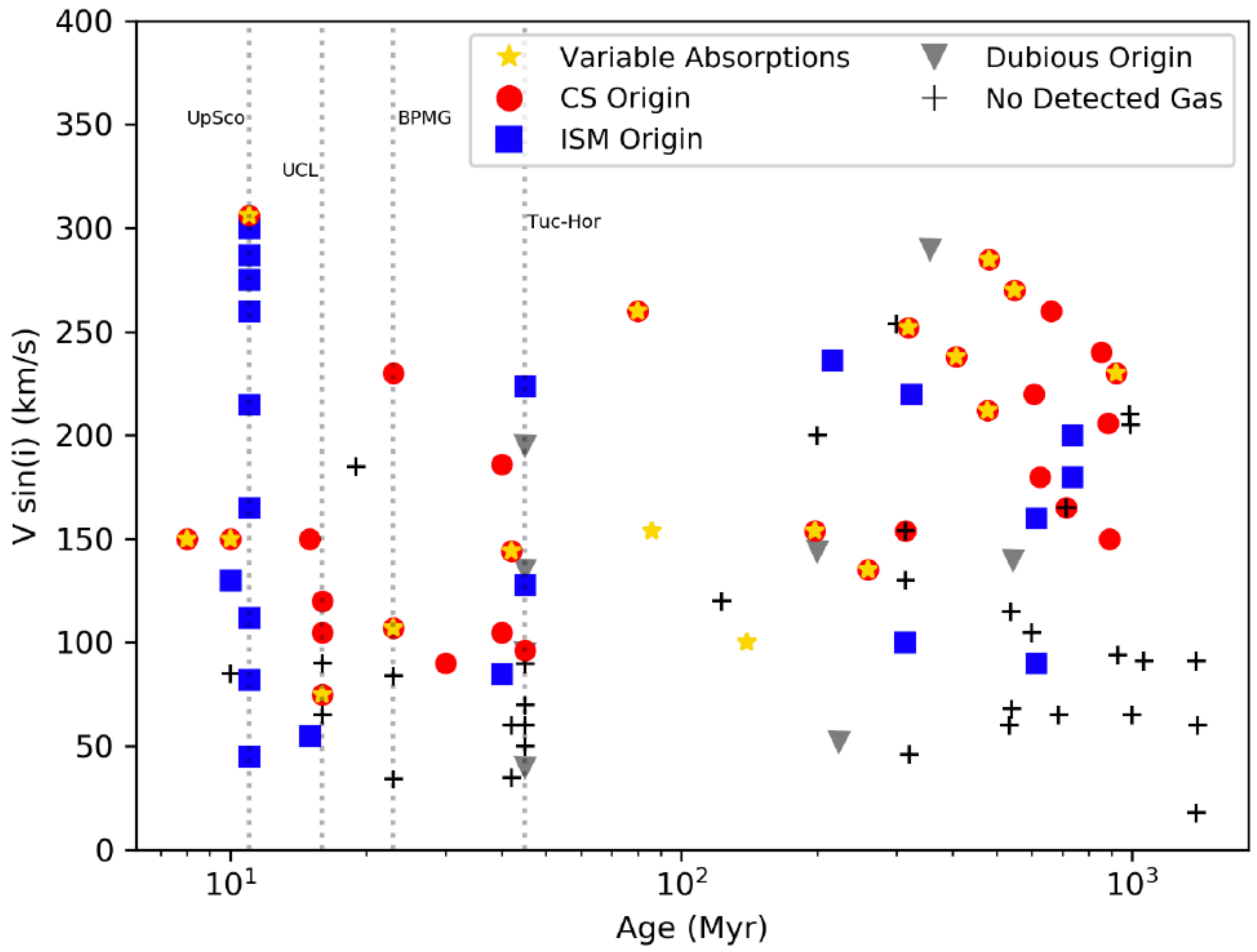

Rebollido+in prep.

Rebollido+20