ExoComets & Debris Disks: How typical is the Beta Pic System ??

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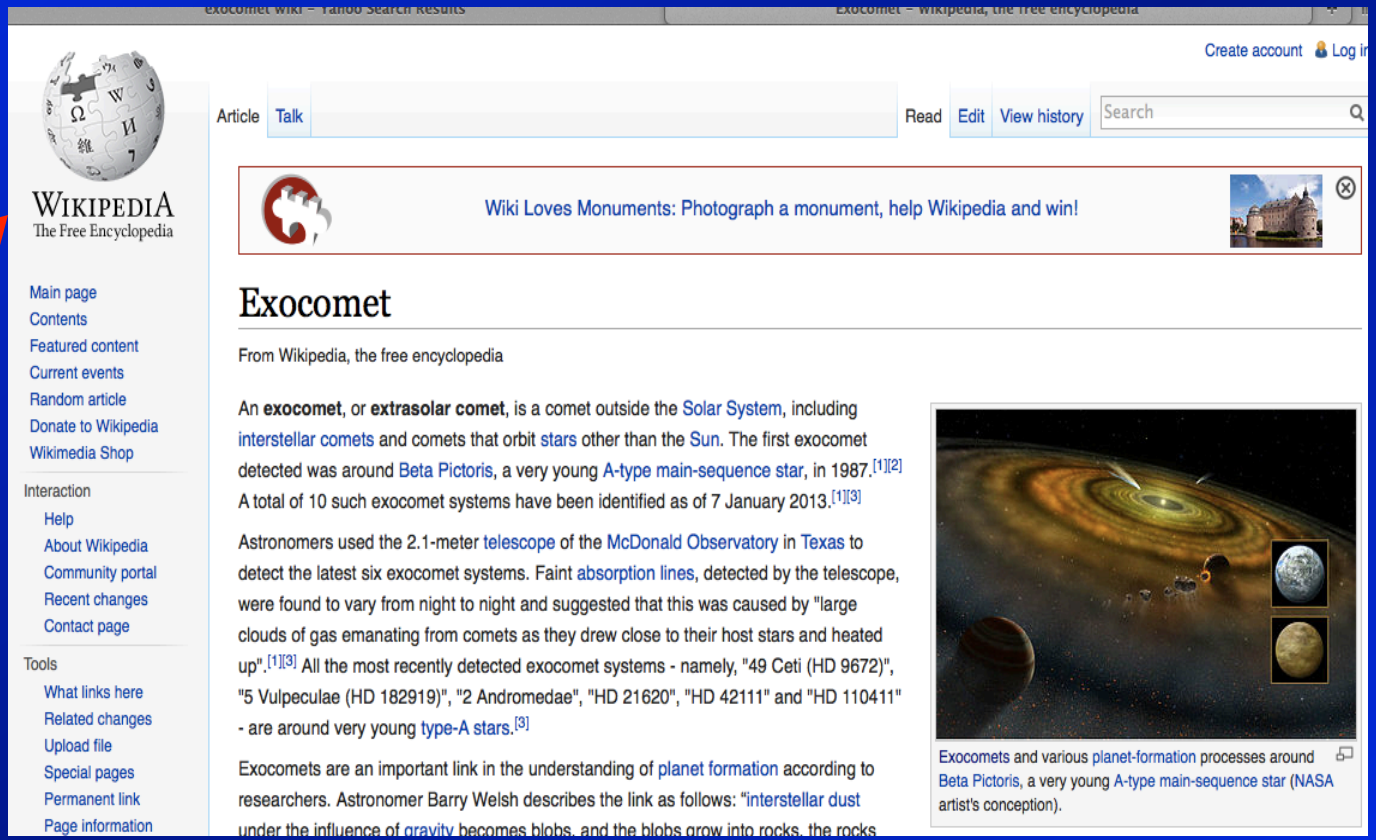
EXOCOMET HOST STARS EXHIBIT FEB ACTIVITY



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Exocomet

From Wikipedia, the free encyclopedia

An **exocomet**, or **extrasolar comet**, is a comet outside the Solar System, including interstellar comets and comets that orbit stars other than the Sun. The first exocomet detected was around Beta Pictoris, a very young A-type main-sequence star, in 1987.[1][2] A total of 10 such exocomet systems have been identified as of 7 January 2013.[1][3]

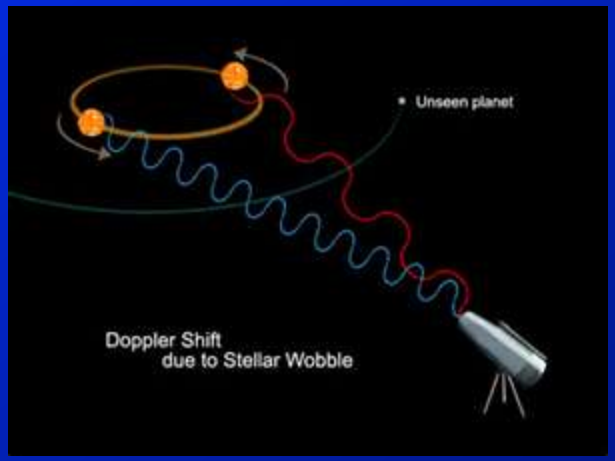
Astronomers used the 2.1-meter telescope of the McDonald Observatory in Texas to detect the latest six exocomet systems. Faint absorption lines, detected by the telescope, were found to vary from night to night and suggested that this was caused by "large clouds of gas emanating from comets as they drew close to their host stars and heated up".[1][3] All the most recently detected exocomet systems - namely, "49 Ceti (HD 9672)", "5 Vulpeculae (HD 182919)", "2 Andromedae", "HD 21620", "HD 42111" and "HD 110411" - are around very young type-A stars.[3]

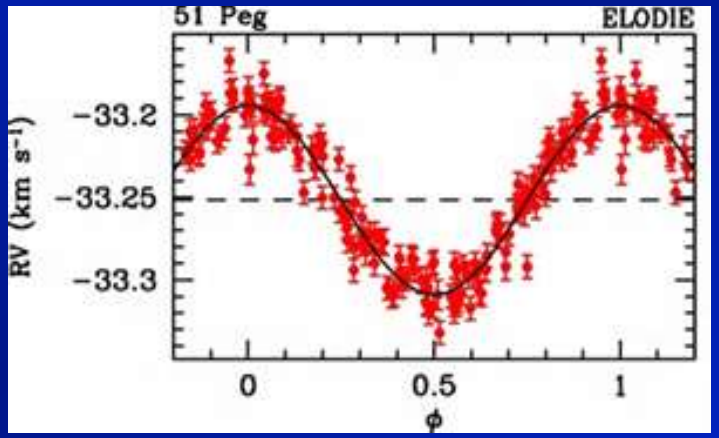
Exocomets are an important link in the understanding of planet formation according to researchers. Astronomer Barry Welsh describes the link as follows: "interstellar dust under the influence of gravity becomes blobs, and the blobs grow into rocks, the rocks

Exocomets and various planet-formation processes around Beta Pictoris, a very young A-type main-sequence star (NASA artist's conception).

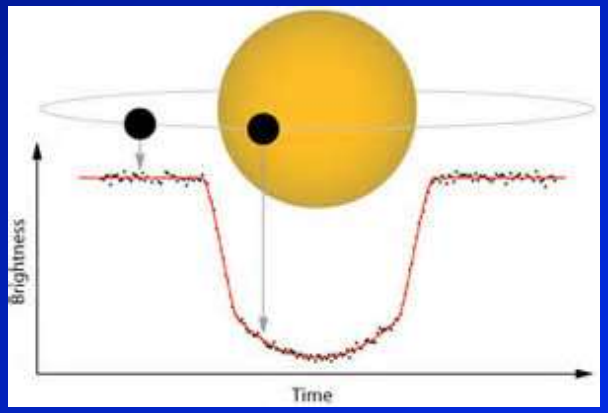
Scientific Importance

The great majority of exoplanets have been detected towards late-type (F, G, K, M) stars either by radial velocity variations





or periodic transit techniques



The Exoplanet – Exocomet Connection?

Most exoplanet host stars are generally old (> 500 Myr) so we are viewing planetary systems that are well established and quite evolved

By observingA-type stars with debris disks (such as Beta Pic), we are are able to view the formative early (< 30 Myr) years of evolving exoplanet systems

However, detecting exoplanets around nearby A-type stars is technically quite difficult and extremely time consuming…….Standard Radial Velocity variations or Exoplanet Transit Detection Techniques don't work well

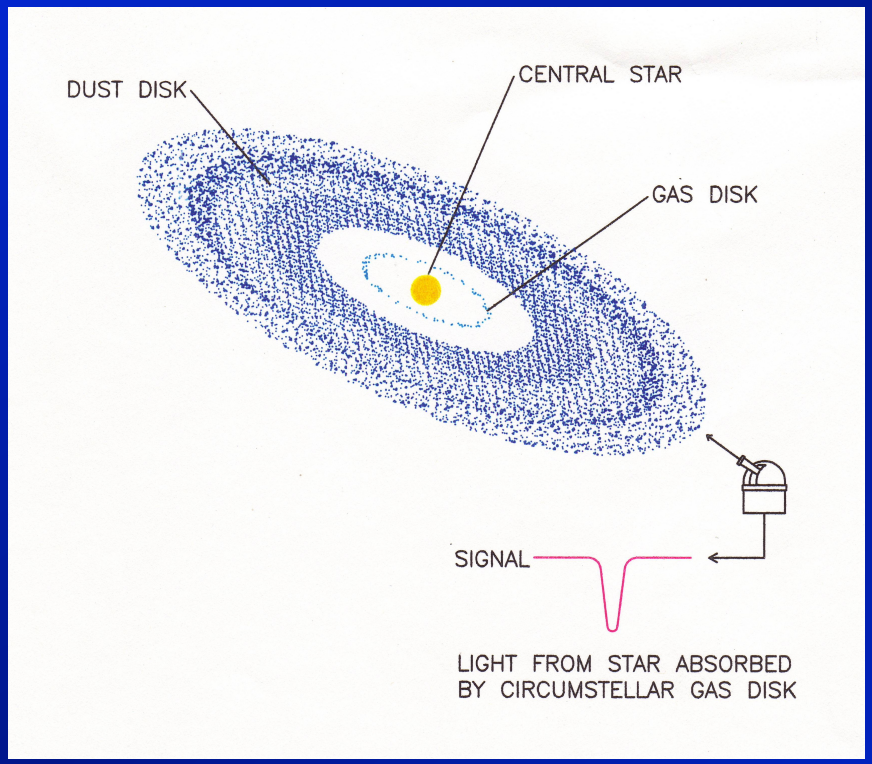
But the presence of exocomet activity might act as an indicator of which A-type stars probably also possess exoplanets.

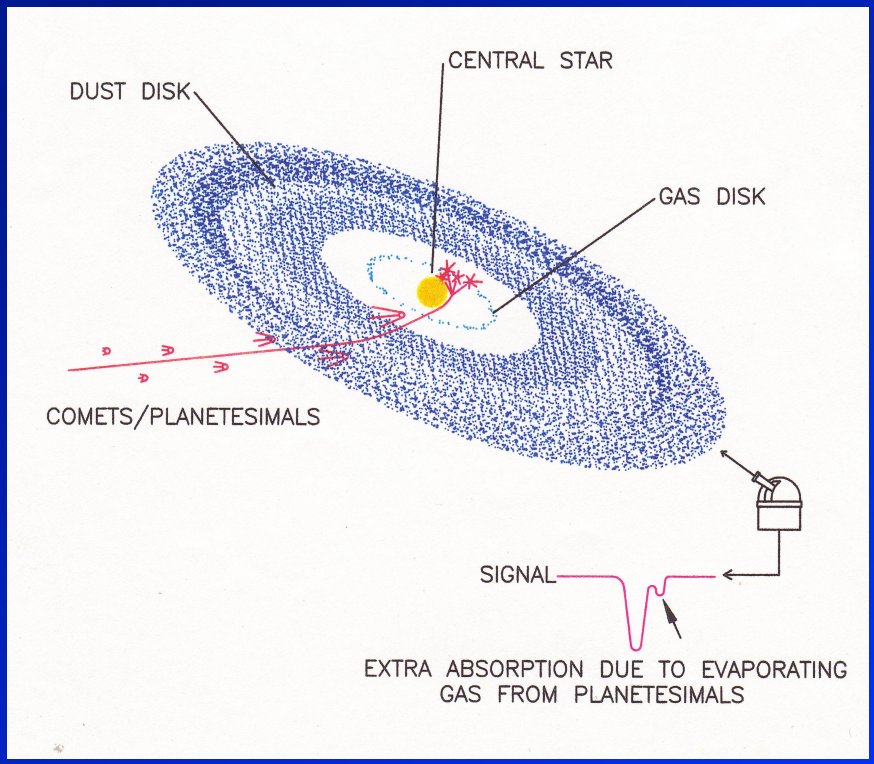
Herschel results require the presence of comet reservoirs (like the Oort cloud) to explain the dusty debris disks detected around old stars with low-mass exoplanets ***(Wyatt et al 2012, Lestrade et al 2012)***

Possible Exoplanet Connection

A "trigger" mechanism is required to bring numerous comet-like bodies out of a Keplerian rotating debris disk onto star-grazing orbits

Gravitational perturbations by at least one planet could provide such a dynamical mechanism *(Beust & Mordelli 2000)* or by self stirring collisions





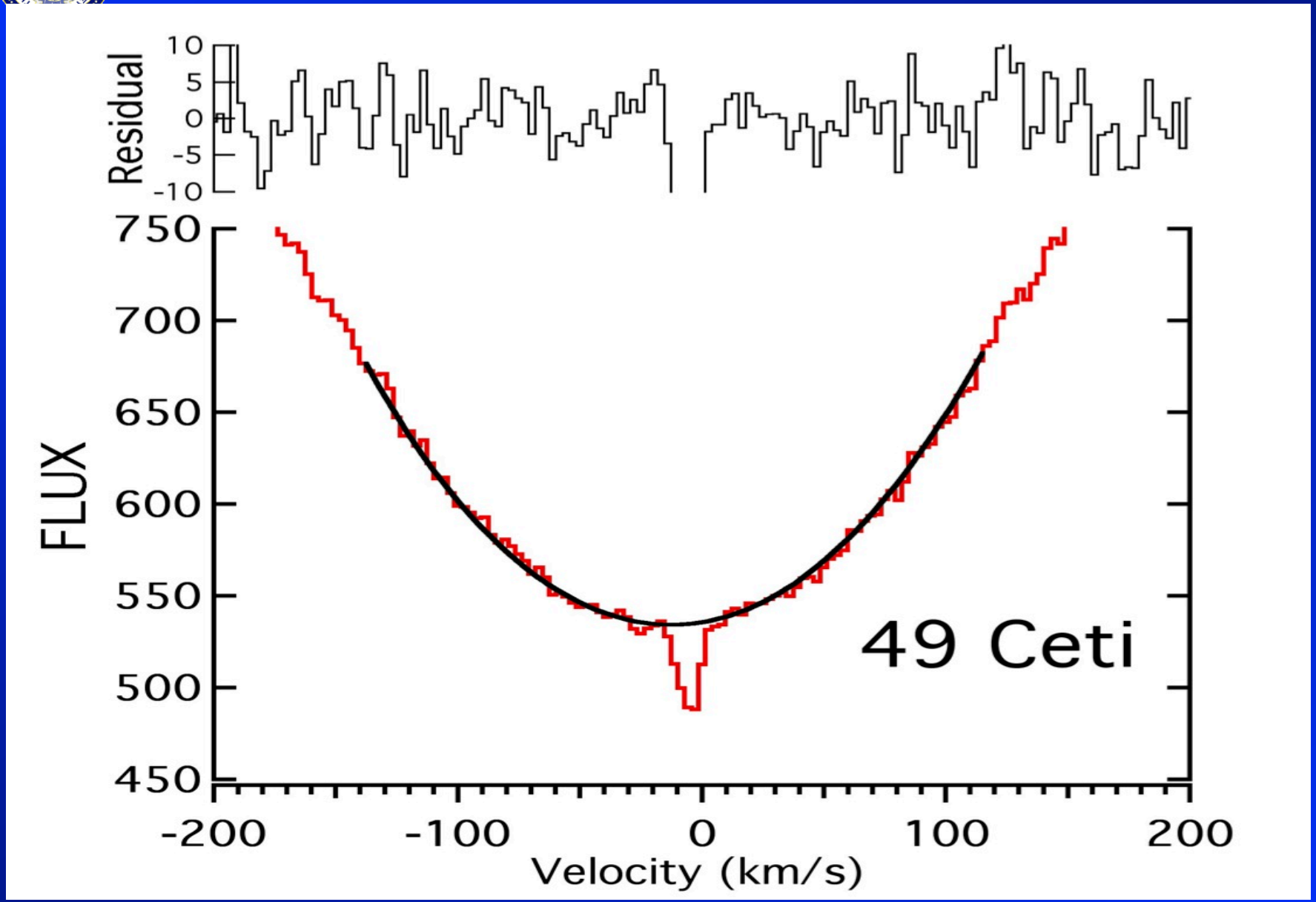
Target Selection & Observational Strategy

Until 2012 only 3 A-type stars with exocomet FEB activity as revealed by nightly changes in CaII K-line absorption were known.

We selected nearby (d < 100pc) A-type stars with similar properties to Beta Pictoris with ages (< 50Myr), known IR excess(i.e. dust/gas disk), high stellar rotational velocity (> 120 km/s) in order to view an edge-on disk

We recorded high resolution (R > 60,000), high S/N absorption spectra of each target star recorded once per night for > 4 nights

We look for statistically significant changes in the CaII K-line absorption characteristics


Residual
10
5
0
-5
-10
750
700
650
600
550
500
450
FLUX
-200
-100
0
100
200
Velocity (km/s)
49 Ceti

Known Exocomet Systems

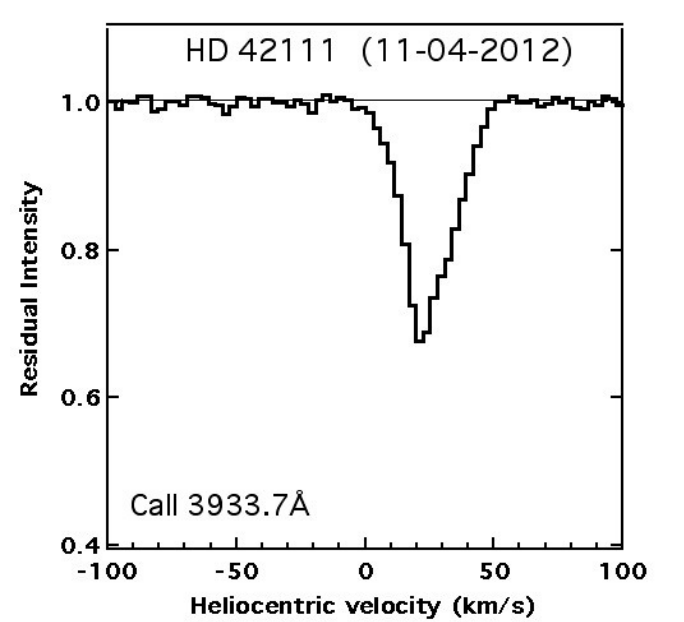
HD 256	(HR 10)	Lagrange-Henri et al 1990
HD 9672	(49 Ceti)	Montgomery & Welsh 2012
HD 21620		Welsh & Montgomery 2013
HD 39060	(Beta Pic)	Ferlet et al 1987
HD 42111		Welsh & Montgomery 2013
HD 85905		Welsh et al 1998
HD 110411		Welsh & Montgomery 2013
HD 145964		Welsh & Montgomery 2013
HD 182919	(5 Vul)	Montgomery & Welsh 2012
HD 217782	(2 And)	Cheng et al 1997
HD 172555		Kiefer et al (2014)

Two new systems

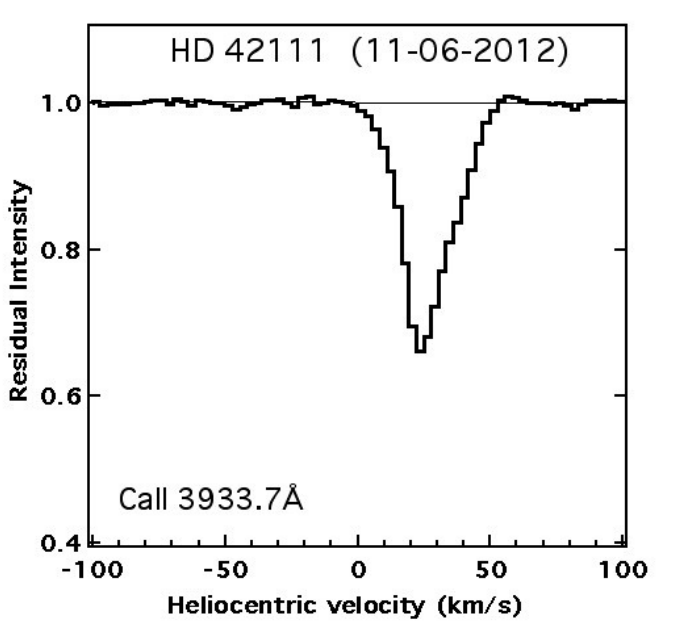
HD 56537	(l Gem)
HD 108767	(HR 4757A)

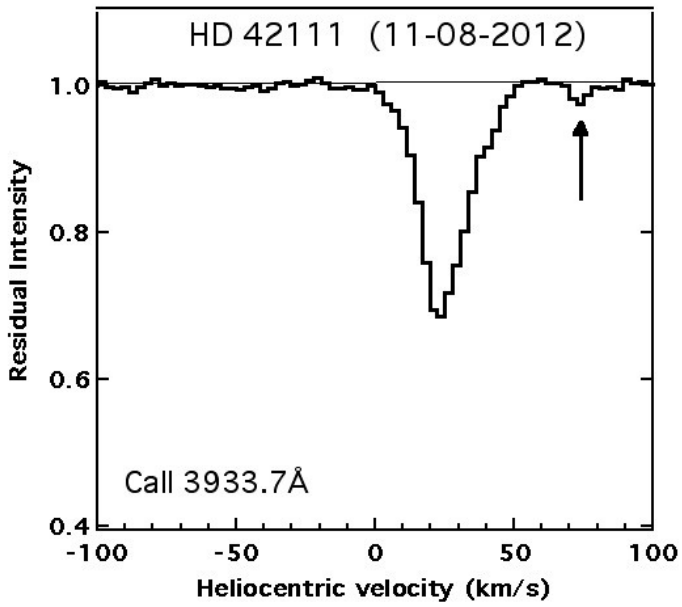
Systems identified solely on the basis of FEB-like variable absorption activity observed in the CaII K-line profile

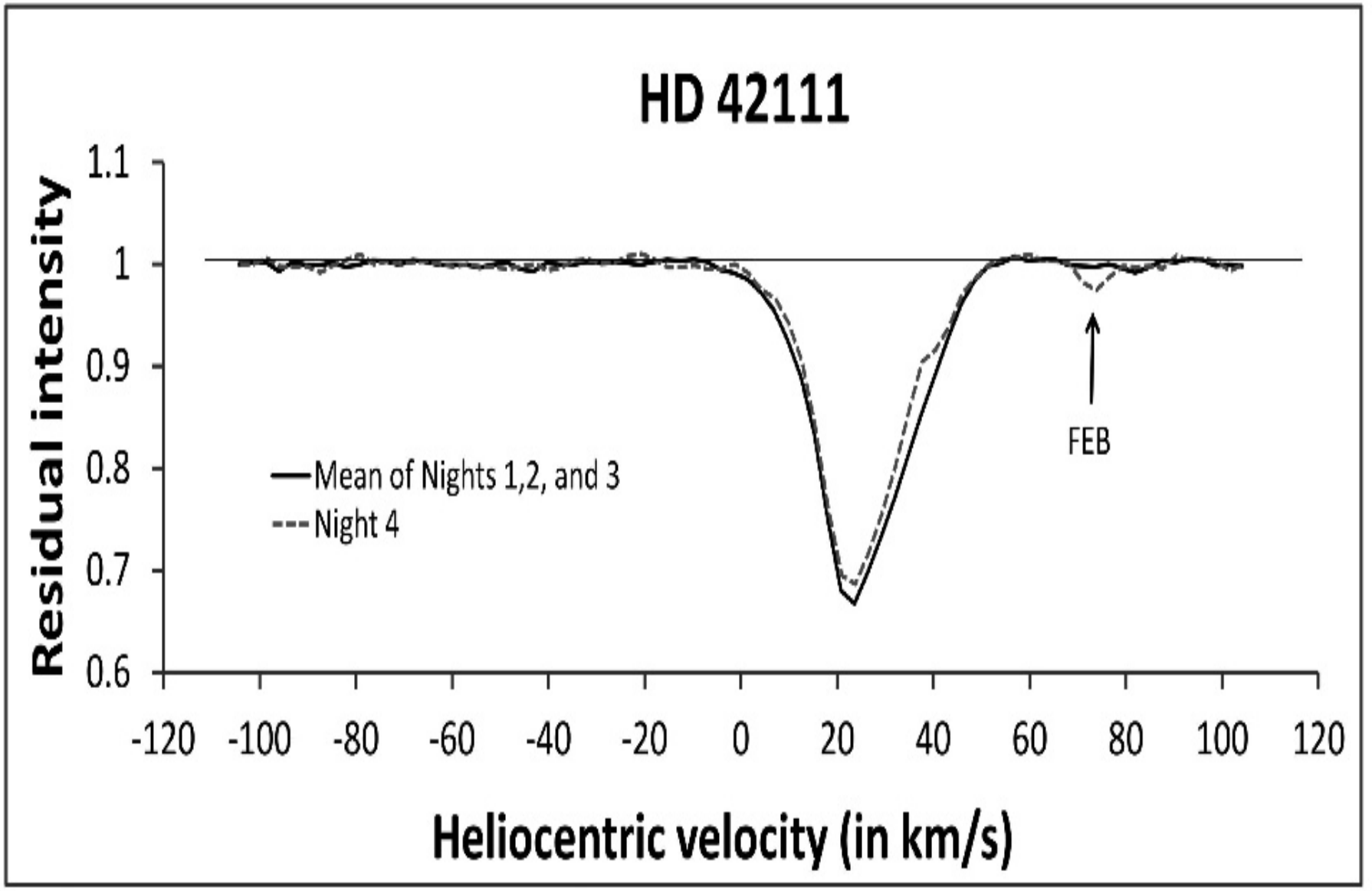
HD 42111



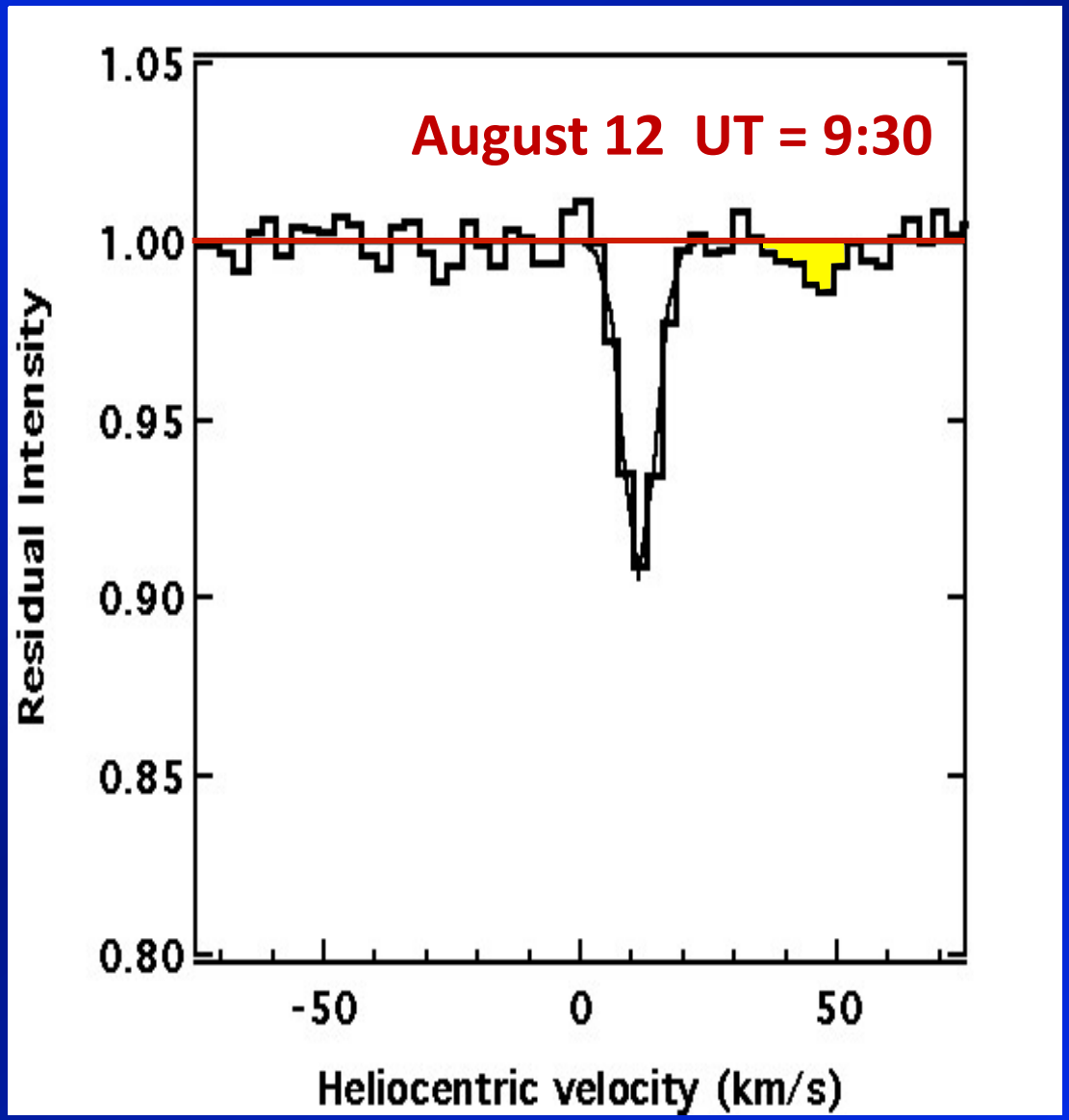
Sp: A3V
Age: 0.2 Myr
Dist: 200 pc
RV_*: +34 km/s



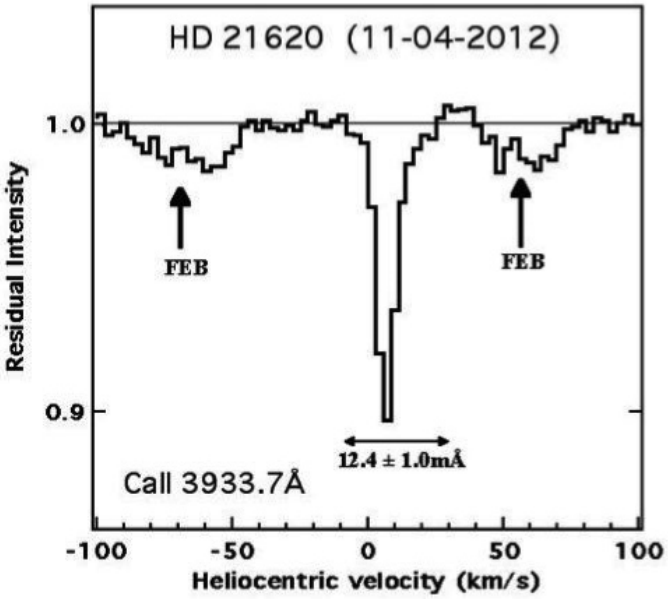


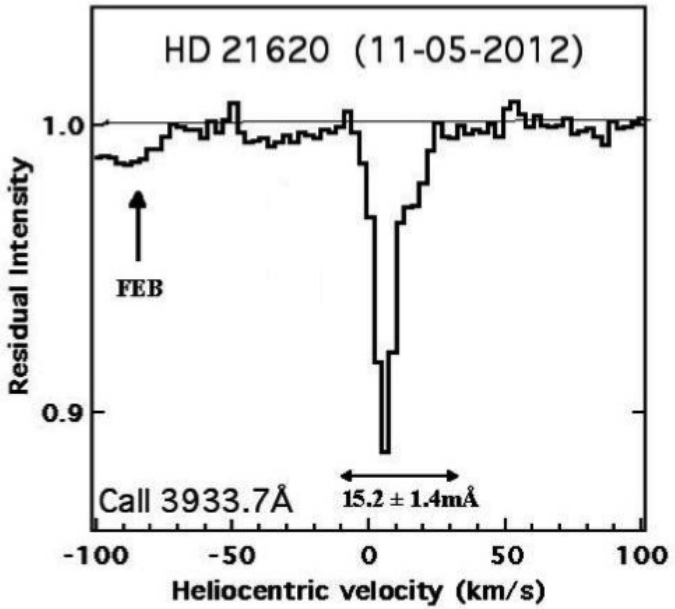

HD 42111
Residual intensity
1.1
1
0.9
0.8
0.7
0.6
Mean of Nights 1,2, and 3
Night 4
FEB
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
Heliocentric velocity (in km/s)

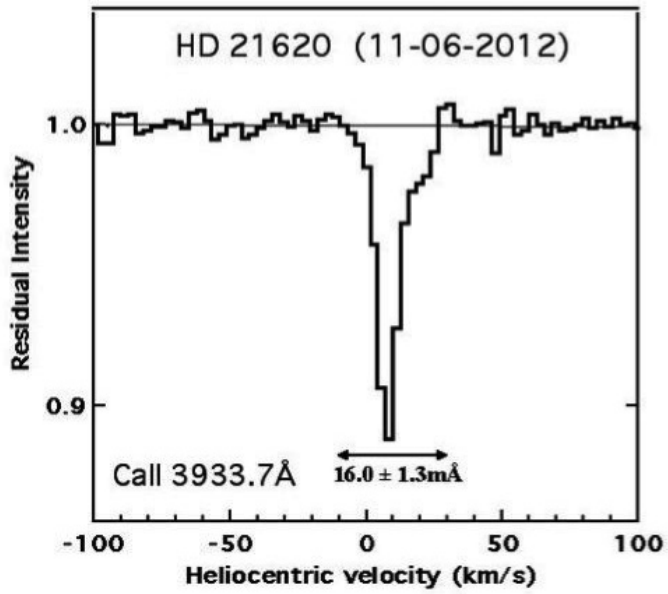
Hourly changes in the CaII absorption spectrum of 49 Ceti

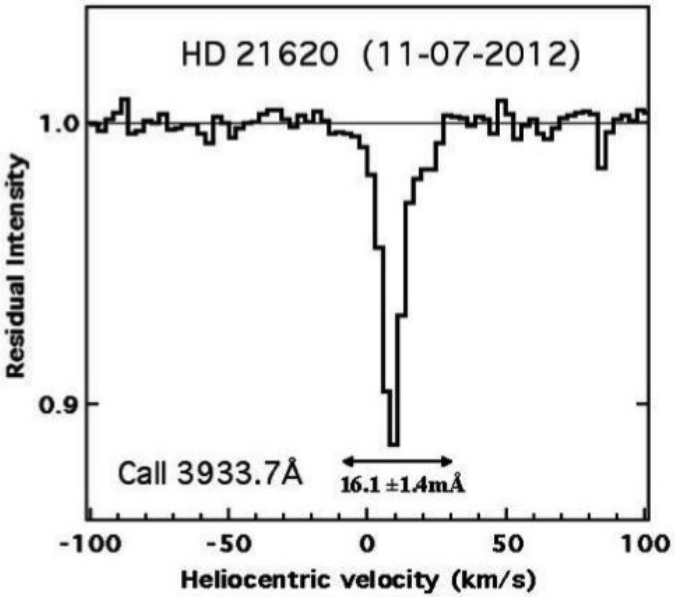


HD 21620

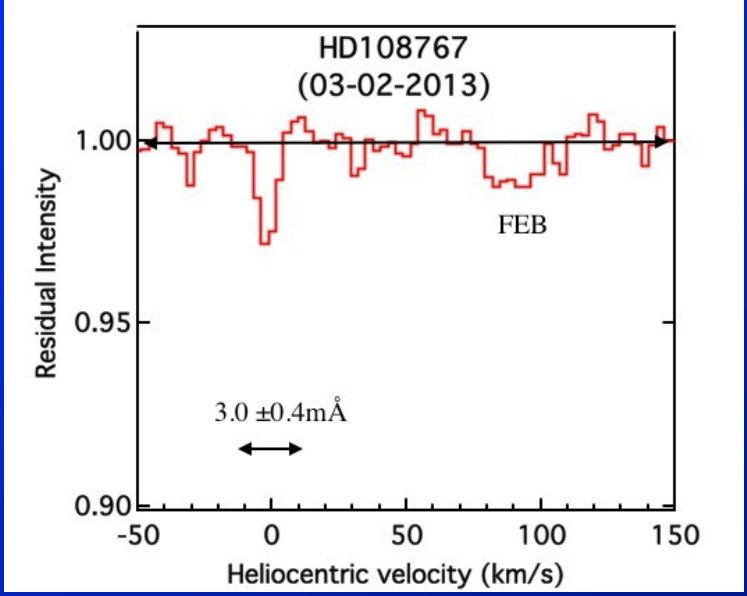

HD 21620 (11-04-2012)
Residual Intensity
1.0
0.9
FEB
FEB
12.4 ± 1.0mÅ
Call 3933.7Å
-100
-50
0
50
100
Heliocentric velocity (km/s)

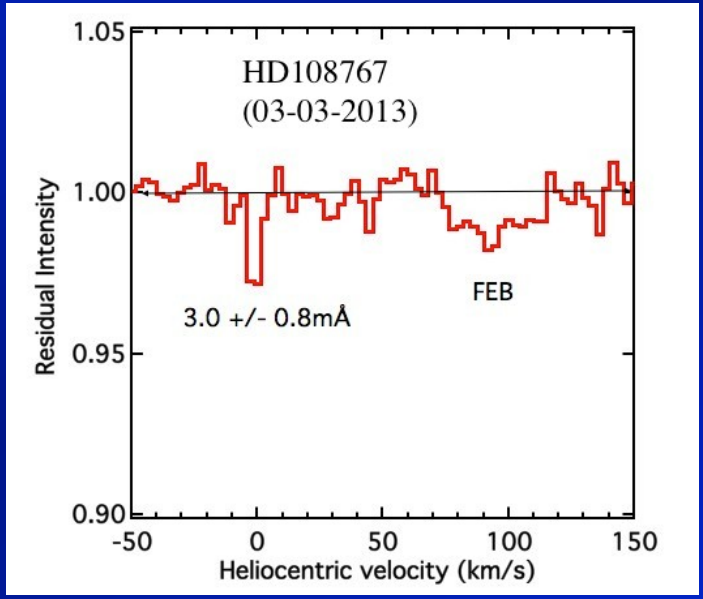

HD 21620 (11-05-2012)
Residual Intensity
1.0
0.9
FEB
15.2 ± 1.4mÅ
Call 3933.7Å
-100
-50
0
50
100
Heliocentric velocity (km/s)

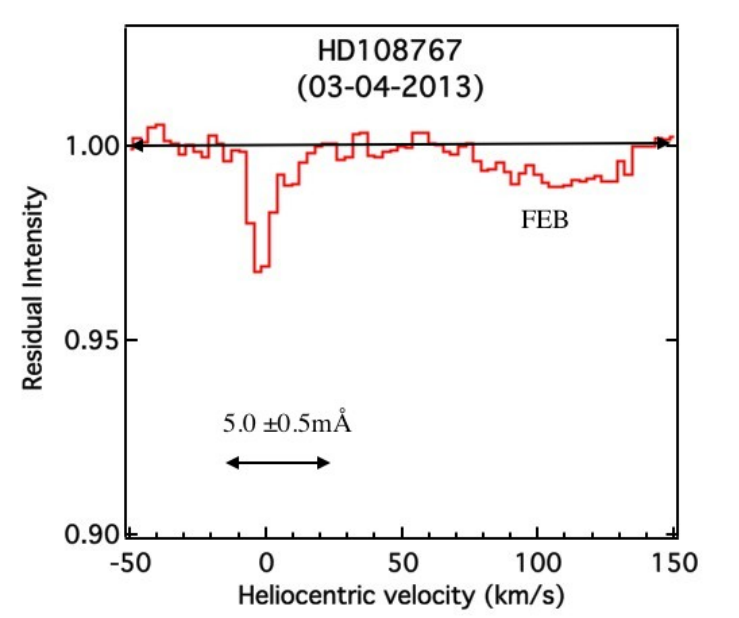

HD 21620 (11-06-2012)
Residual Intensity
1.0
0.9
16.0 ± 1.3mÅ
Call 3933.7Å
-100
-50
0
50
100
Heliocentric velocity (km/s)

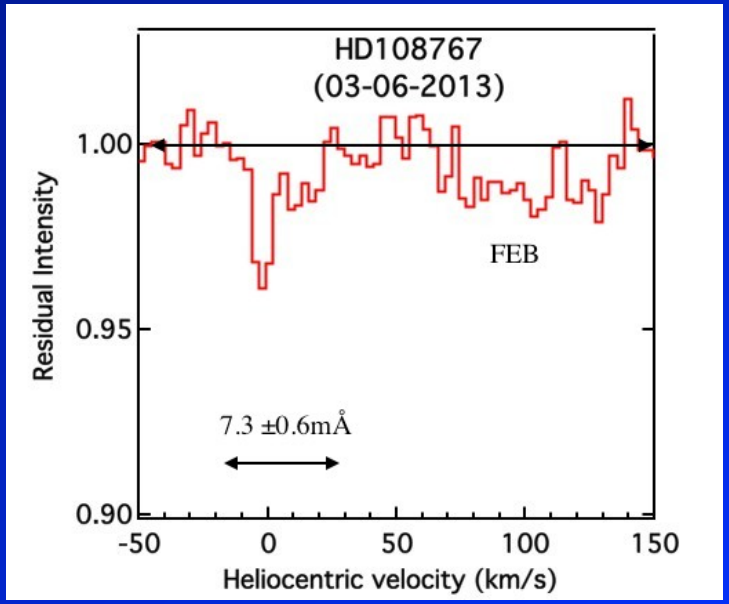

HD 21620 (11-07-2012)
Residual Intensity
1.0
0.9
16.1 ±1.4mÅ
Call 3933.7Å
-100
-50
0
50
100
Heliocentric velocity (km/s)

HD 108767 (Vrad = +14 km/s)

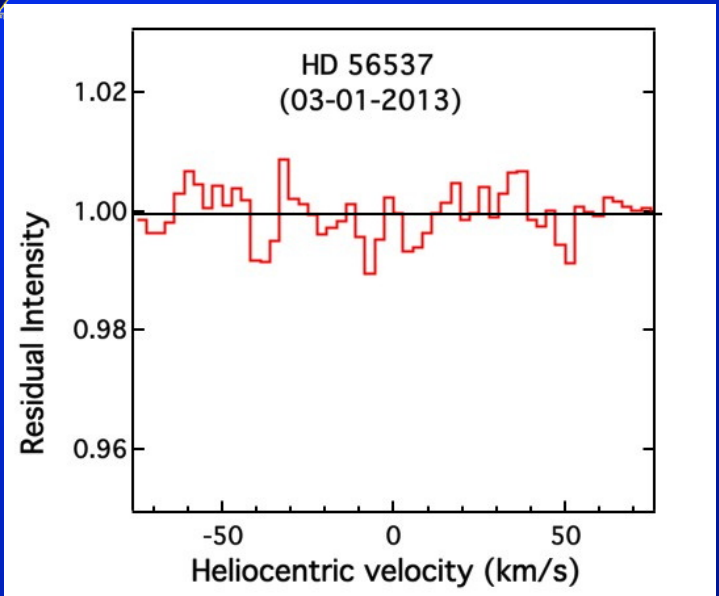


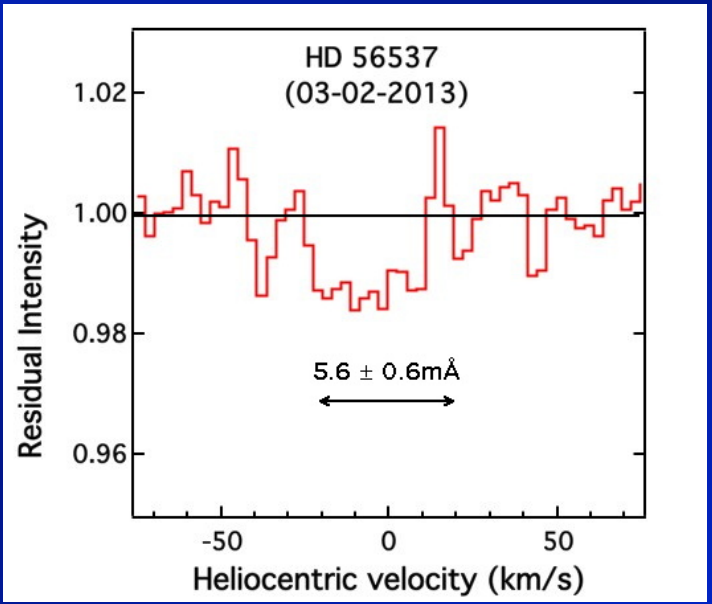


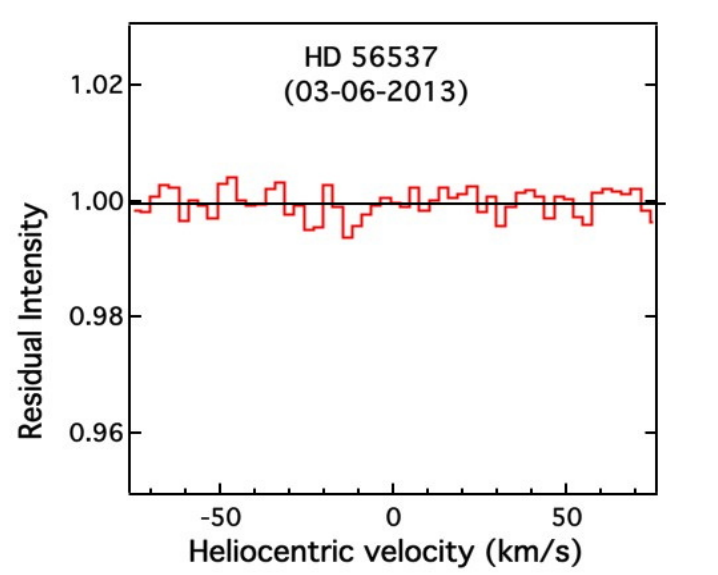


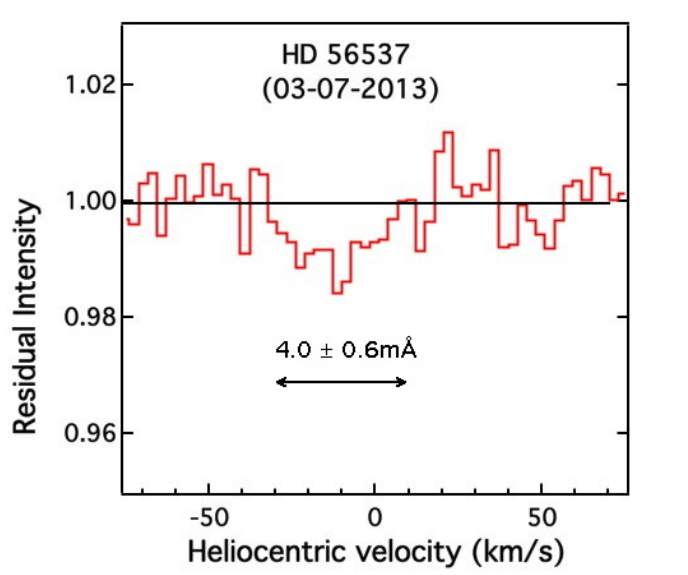


HD 56537 (Vrad = -7.4 km/s)









Absorption Properties of Beta Pic Exocomet Gas

1) Strong circumstellar CaII K-line absorption centered at the radial velocity of the star

2) Frequent and sporadic (hourly/daily) *mostly* red-shifted CaII K-line absorption events (FEBs) with velocities < +200 km/s

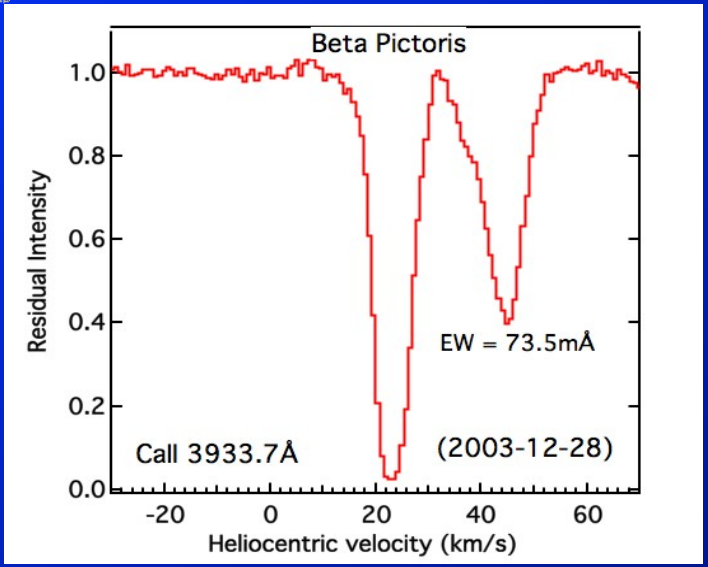
3) Weak circumstellar NaI D-lines such that: N(CaII) / N(NaI) > 50:1

4) Small velocity shift between circumstellar NaI and CaII line profiles due to "gas braking"

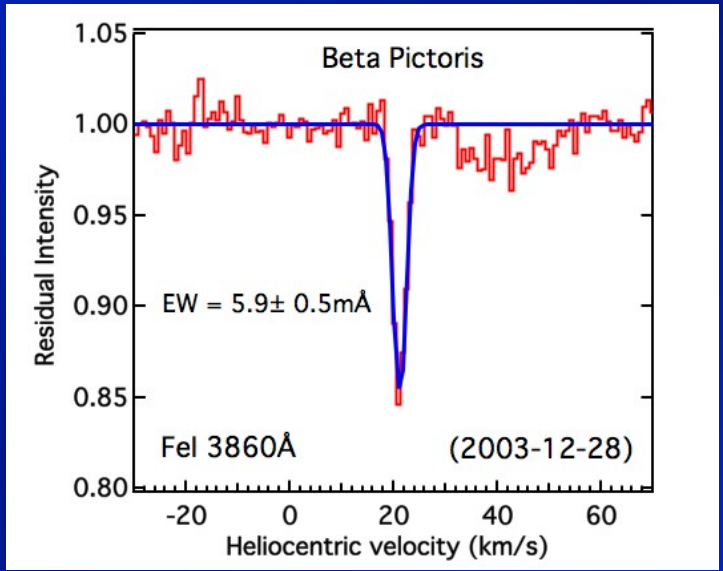
5) Unusually strong circumstellar FeI 3860Å absorption, with occasional FEB activity that velocity matches the CaII FEB activity

6) Circumstellar absorption due to the CaII IR Triplet at 8540Å

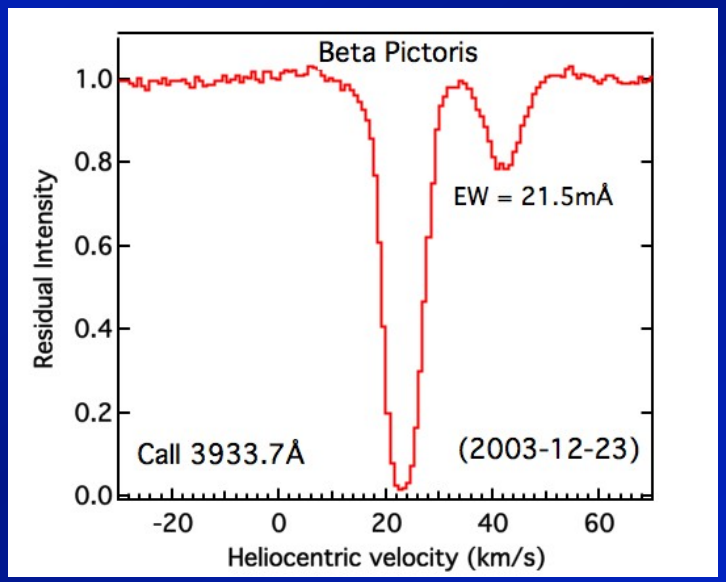
Observations of FeI 3860Å circumstellar absorption

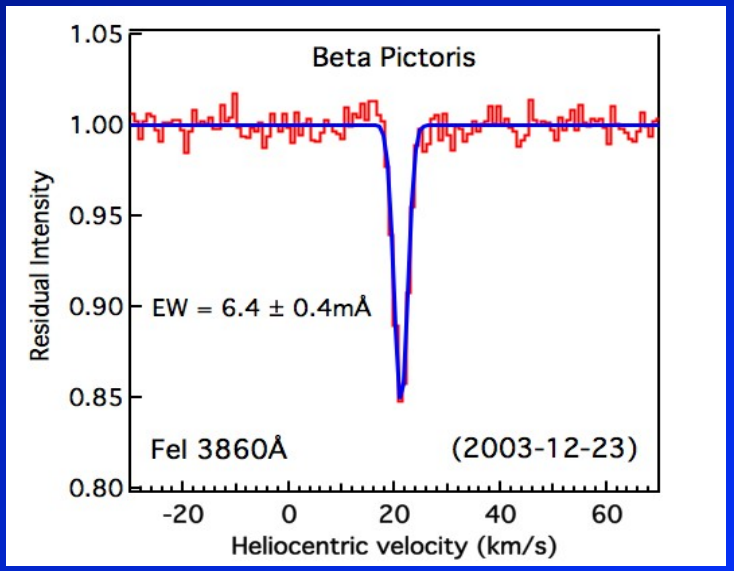


CaII K-line

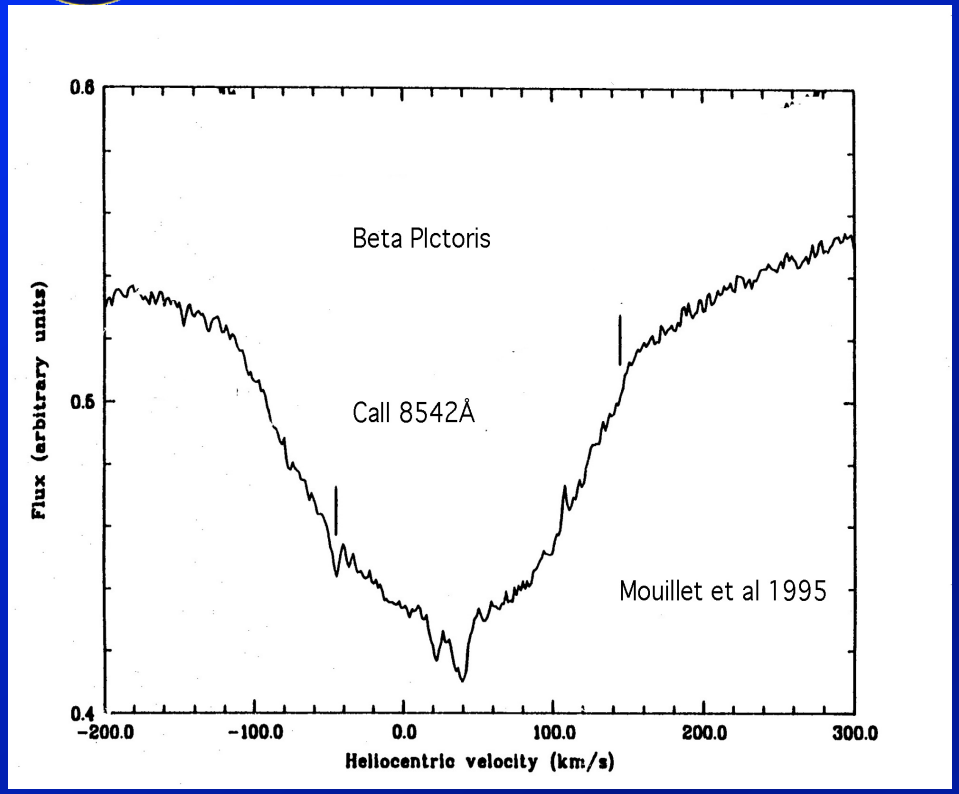


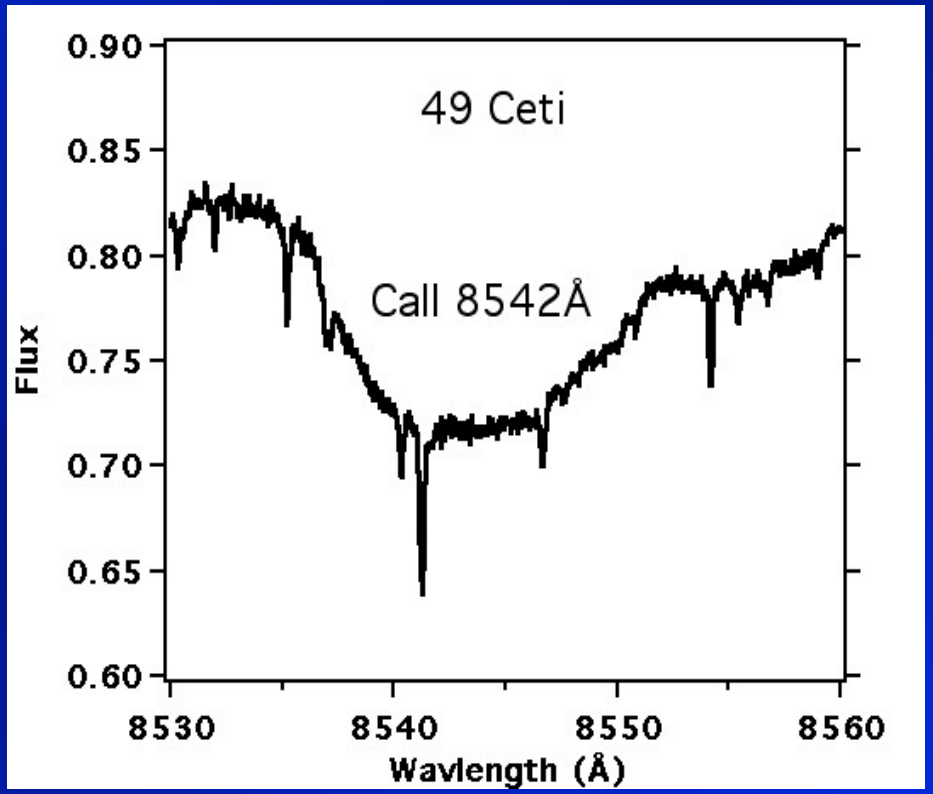
FeI 3860





Circumstellar CaII 8542Å line (9/2/2013)

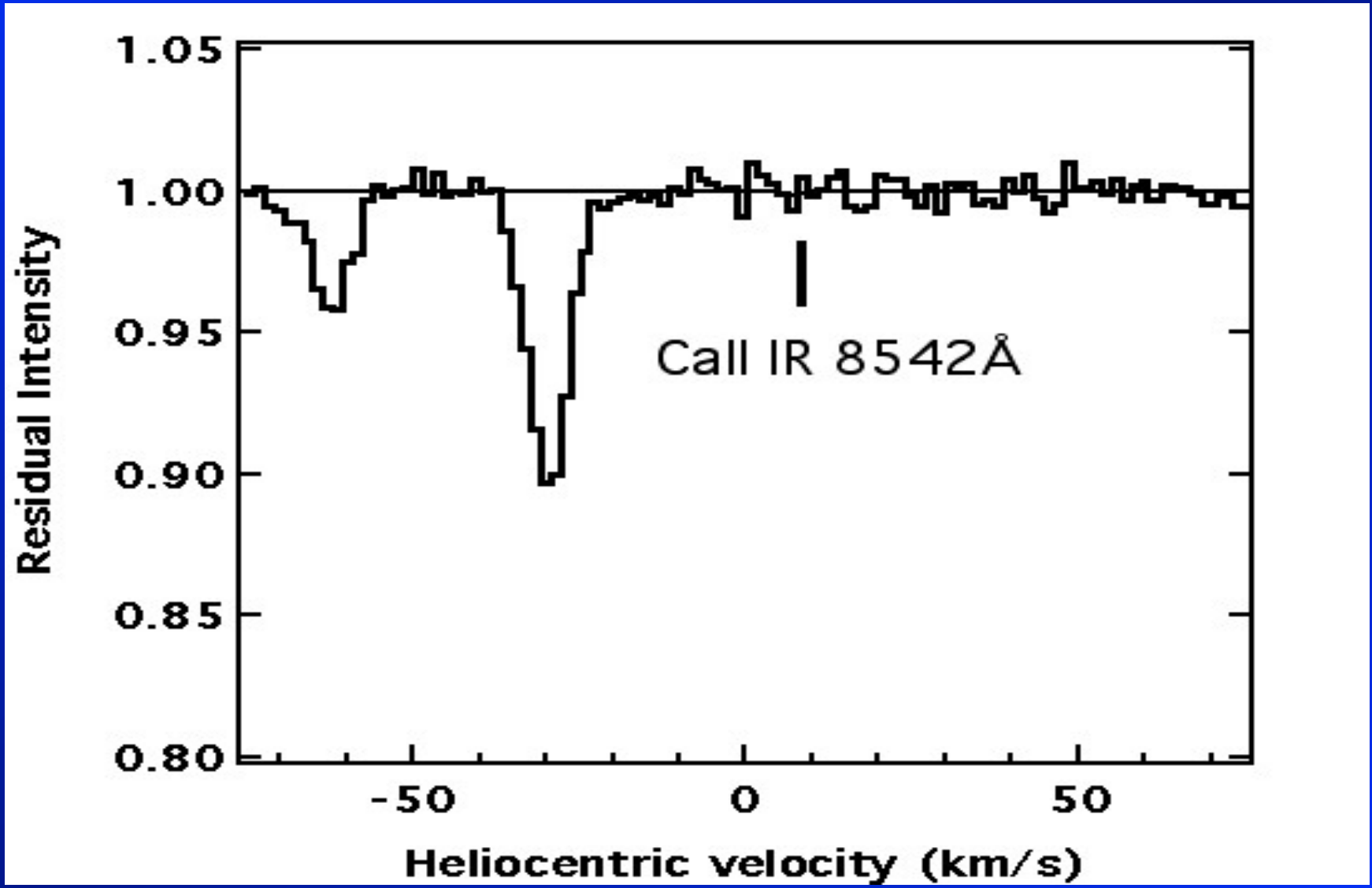




Beta Pic

49 Ceti

49 Ceti…..no CaII



Cicrumstellar FeI & CaII IR Absorption in other Exo-comet systems

TABLE 4

PHYSICAL PARAMETERS OF A-STARS OBSERVED NIGHTLY AT THE CaII K-LINE

Star HD#	Other name	Spectral type	$V \sin i$ (km s^{-1})	Age (Myr)	mid-IR excess?	Chemically peculiar?	λ Boo Star?	EW λ4481 (Å)
Stars not showing FEB activity								
HD 1404	σ And	A2V	130	450	Y	N	N	0.45
HD 6798		A3V	207	200	Y	N	N	0.51
HD 21688		A5III/IV	196	unknown	Y	N	N	0.52
HD 29488	92 Tau	A5Vn	154	625	N	N	N	0.64
HD 31295	7 Ori	A0V	108	100	Y	Y	N	0.22
HD 37507	d Ori	A4V	205	unknown	unknown	N	N	0.44
HD 38090	12 Lep	A2/A3V shell	207	unknown	unknown	N	N	0.47
HD 38545	131 Tau	A3V shell	191	13	N	N	N	0.42
HD 38678	ζ Lep	A2IV-Vn	245	170	Y	N	N	0.48
HD 39182		A2V shell	238	unknown	unknown	N	N	0.38
HD 80007	β Car	A2IV/V	145	260	N	unlisted	N	unlisted
HD 102647	β Leo	A3V	110	50	Y	N	N	0.57
HD 109573		A0Ve	152	8	Y	N	N	unlisted
HD 118232	24 CVn	A5V	159	3.1	Y	N	N	0.61
HD 141569		A0Ve	228	5.4	Y	unlisted	N	unlisted
HD 148283	25 Her	A5V	280	unknown	N	N	N	0.4
HD 158643	c Oph	A0Ve	228	0.7	Y	N	N	0.41
HD 165459		A2	unknown	5	Y	unlisted	N	unlisted
HD 183324	V1431 Aql	A0V	110	10	Y	Y	Y	0.16
HD 184006	ι Cyg	A5V	210	450	N	N	N	0.50
HD 223884	HR 9043	A5V	241	5.5	N	N	N	0.46
Stars exhibiting FEB activity								
HD 256	HR10	A2IV/V shell	241	1.8	N	N	N	0.31
HD 9672	49 Ceti	A1V	196	8.9	Y	N	N	0.64
HD 21620		A0Vn	217	80	Y	N	N	0.64
HD 39060	β Pic	A6V	122	12	Y	N	N	0.33
HD 42111		A3Vn shell	120	0.2	N	N	N	0.46
HD 85905		A2-A3III	264	unknown	N	unlisted	N	0.37
HD 110411	ρ Vir	A0V	154	100	Y	Y	Y	0.21
HD 145964		B9V	306	5	N	Y	weak	0.32
HD 182919	5 Vul	A0V	154	100	Y	N	N	0.44
HD 217782	2 And	A3Vn	212	unknown	N	N	weak	0.48

WHY ?

Why is FeI so strong in the Beta Pic gas disk??

Why is the CaII IR Triplet absorption in Beta Pic so strong??

Why are most exocomet events red-shifted in Beta Pic, while many blue-shifted FEB events are observed in the other A-star debris disks?

So…… in summary

To date only one A-type star with exocomet activity is known to possess an exoplanet (Beta Pic)

High spatial resolution IR imaging of the disks surrounding each of the "FEB" A-type stars might reveal 'warps" that could indicate the presence of an exoplanet…….look at 49 Ceti or HD 172555

The regular in-fall of cometary material onto the stellar surface might result in unusual stellar metalicities in all these systems

…the strength of circumstellar absorption and the frequency of FEB (exocomet) activity in the Beta Pic system are VERY much greater than that found in the other 12 exocomet systems

WHY?

So perhaps……..

Are we are witnessing some sort of associated stellar phenomenon around these other young A-stars that we don't understand ?

Could we mostly be detecting "blobs" of circumstellar gas that occasionally become detached from the gaseous debris disks and do NOT originate in evaporating exocomet gas ?

Or is Beta Pic totally UNTYPICAL and the remaining A-stars are the norm for young debris disk systems ?

However, the A-type stars all have quite similar physical properties to Beta Pic

so until there is a better explanation

If is quacks, waddles & has feathers…it is probably a (exocomet) duck!