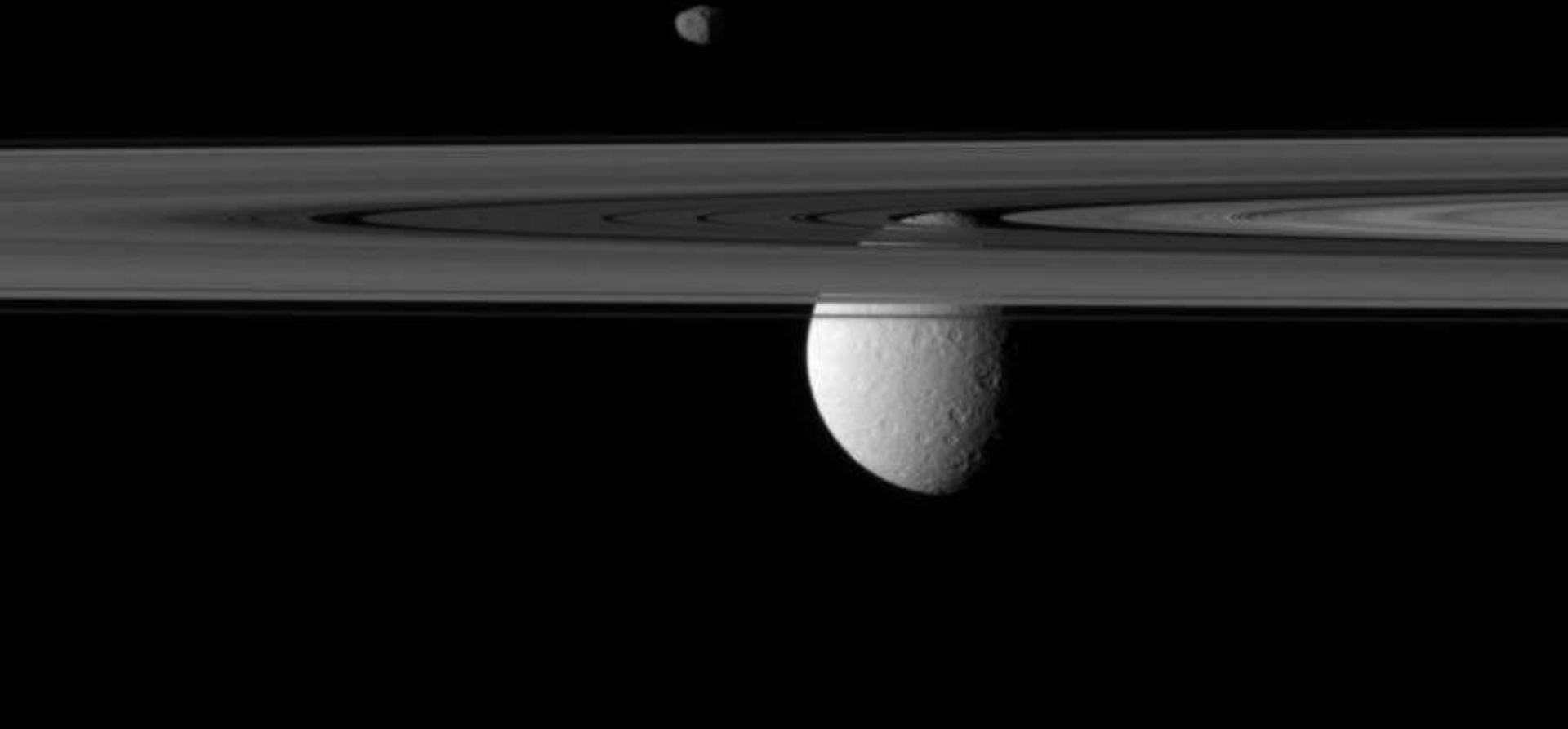
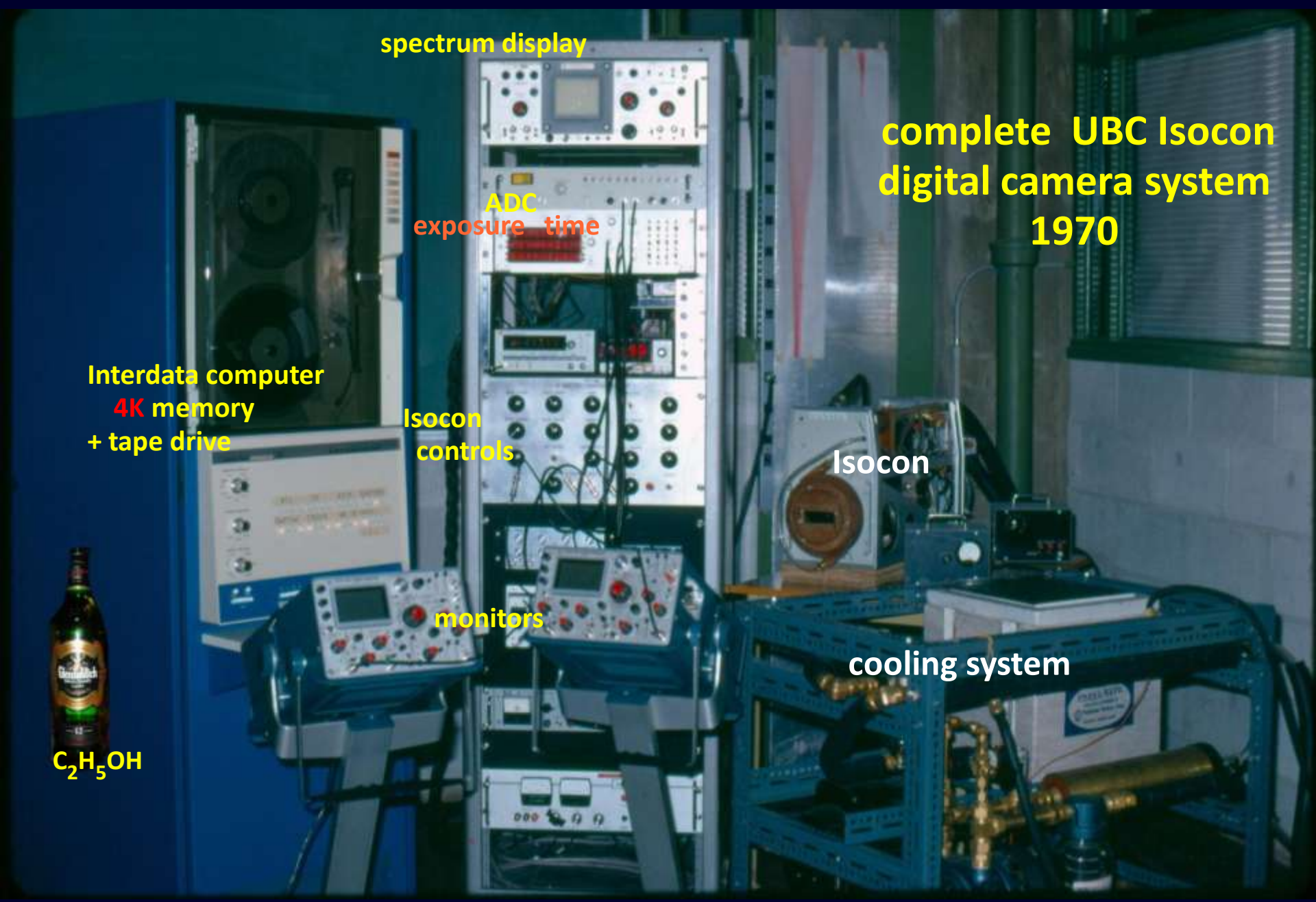
From large velocities to tiny accelerations

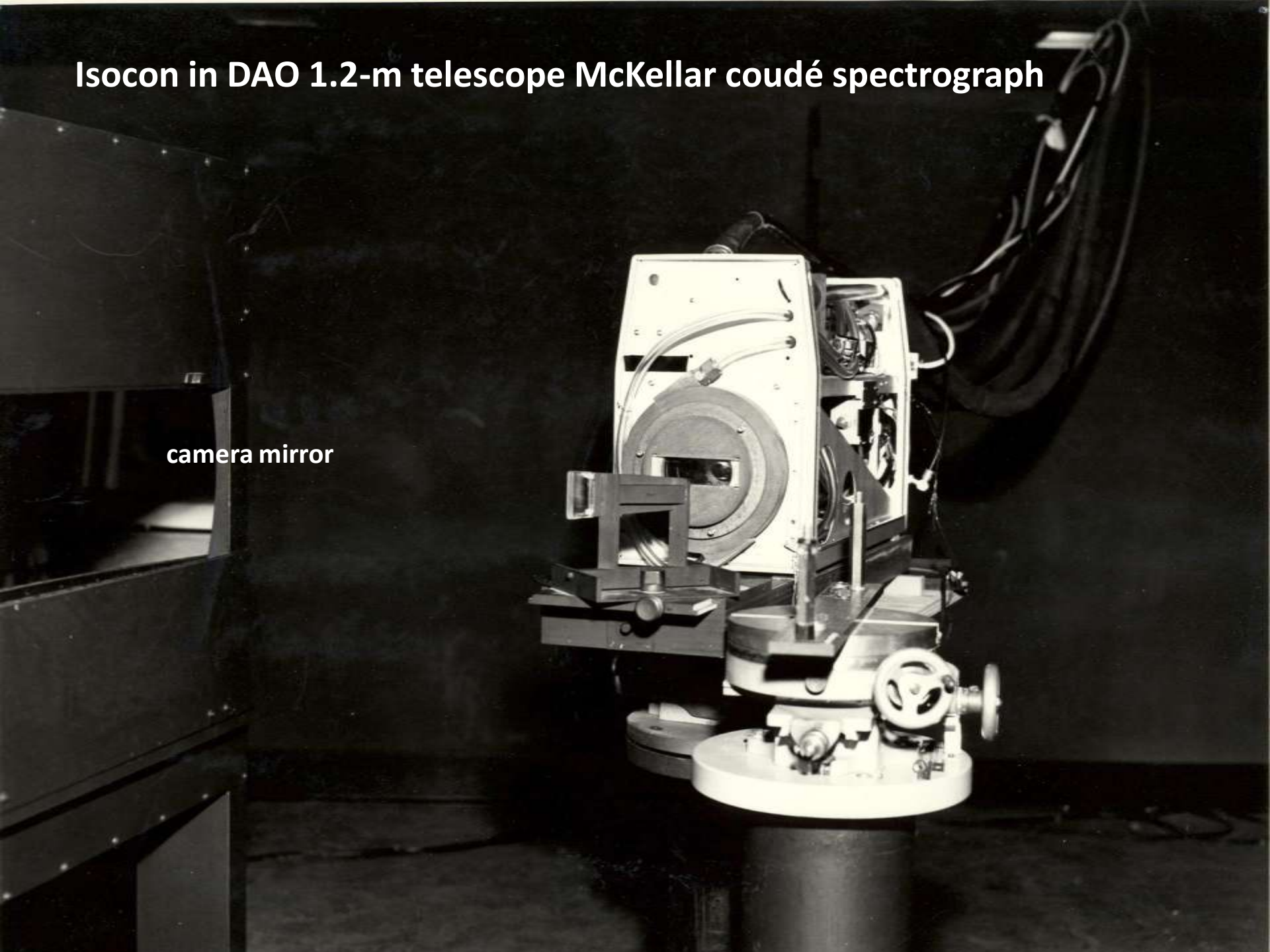
- the successful Doppler detection of exo-planets

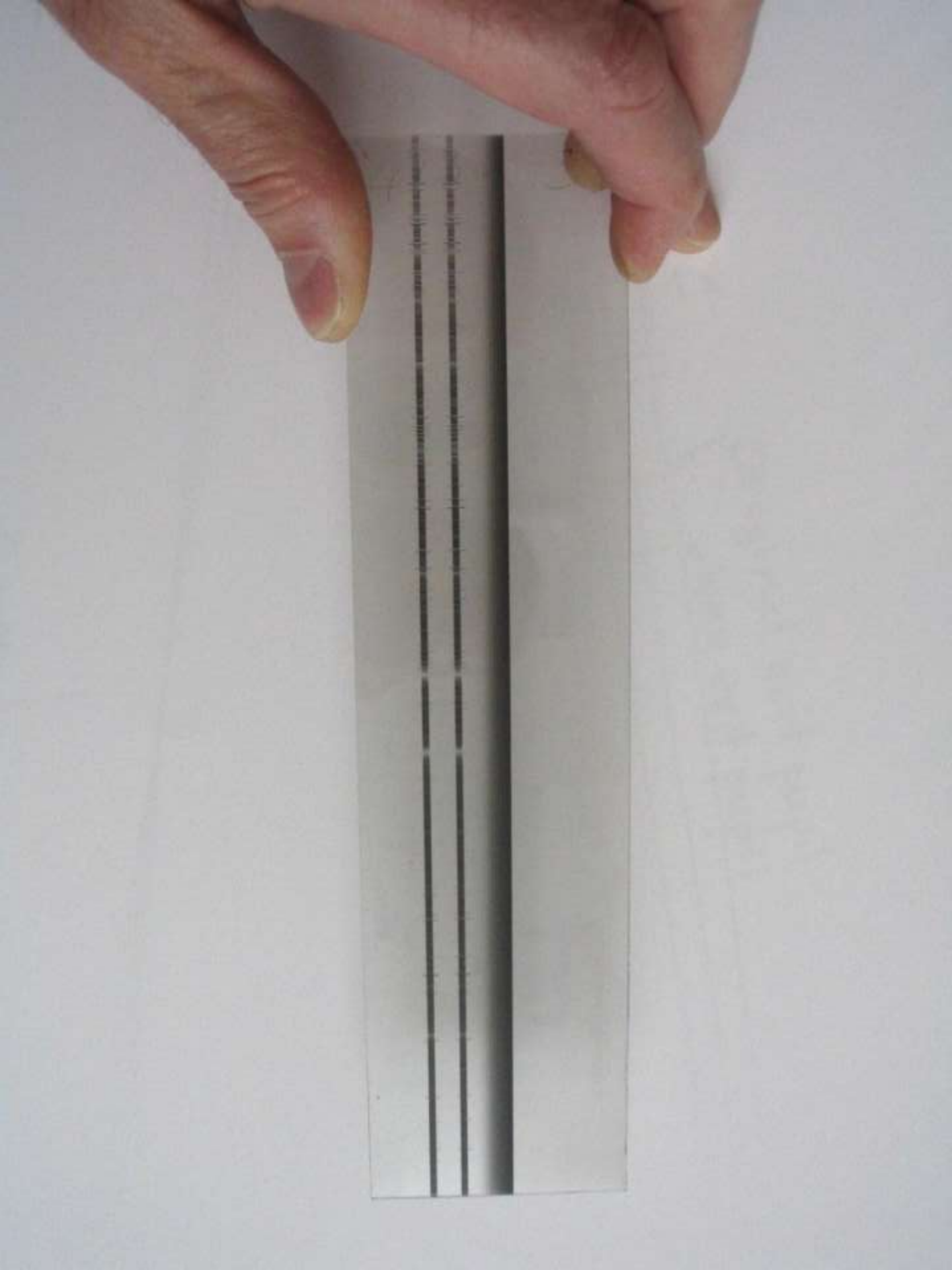
gordon walker

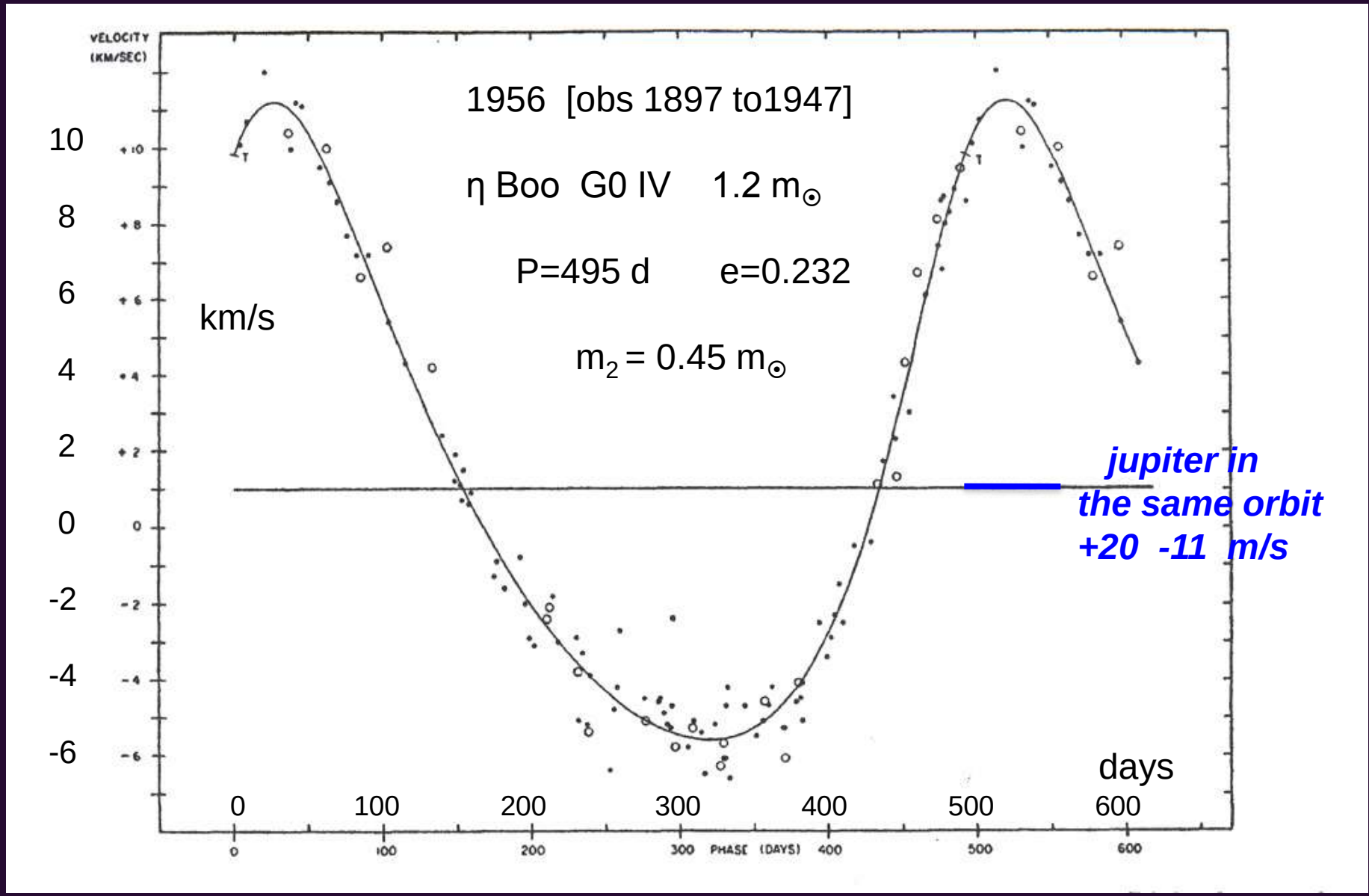


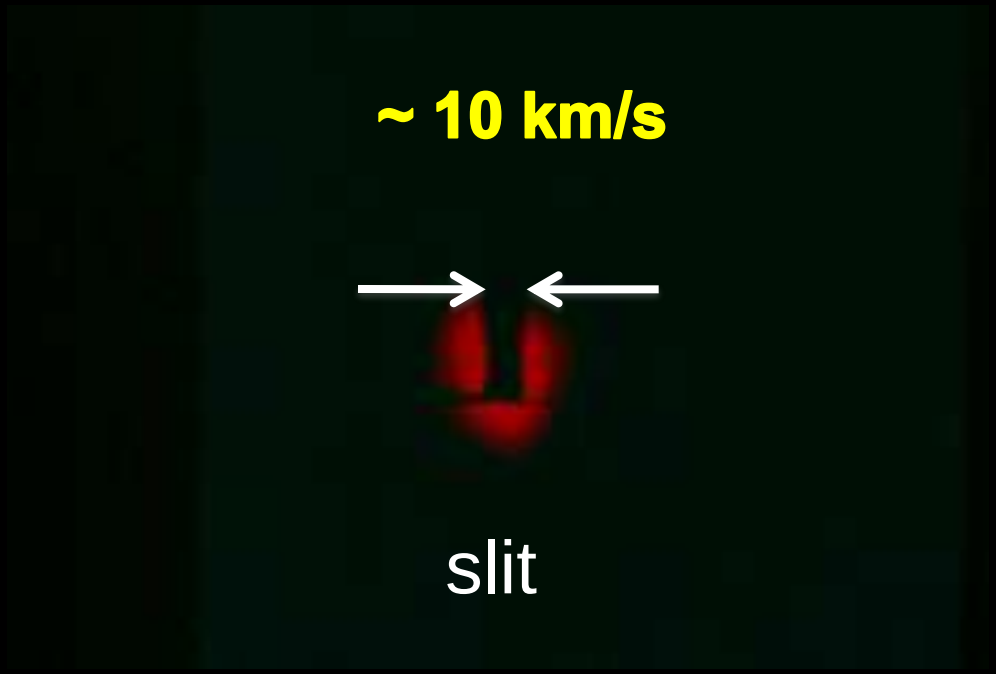

spectrum display
ADC
exposure time
complete UBC Isocon
digital camera system
1970
Interdata computer
4K memory
+ tape drive
Isocon
controls
Isocon
monitors
cooling system
C_2H_5OH

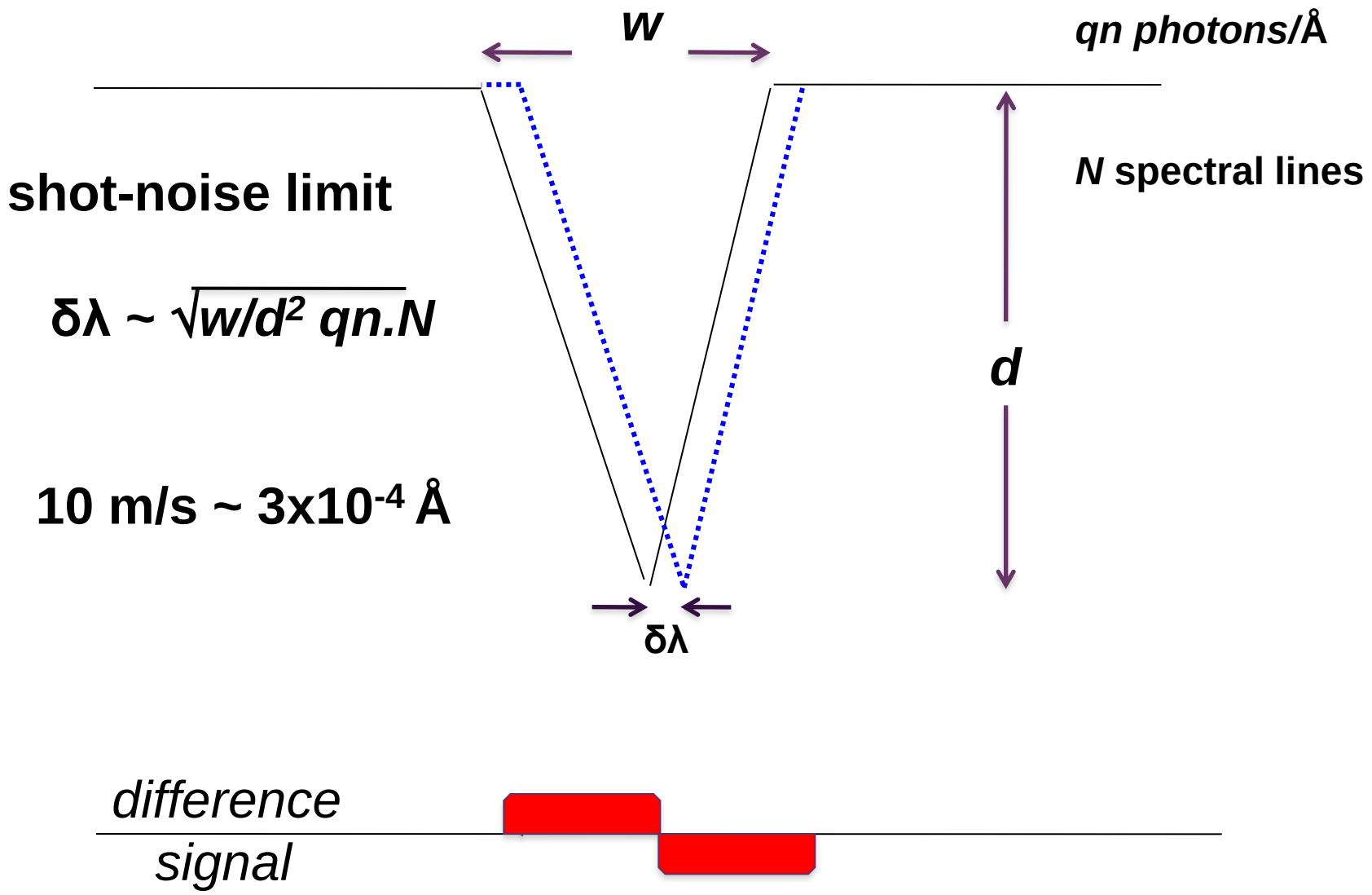
Isocon in DAO 1.2-m telescope McKellar coudé spectrograph



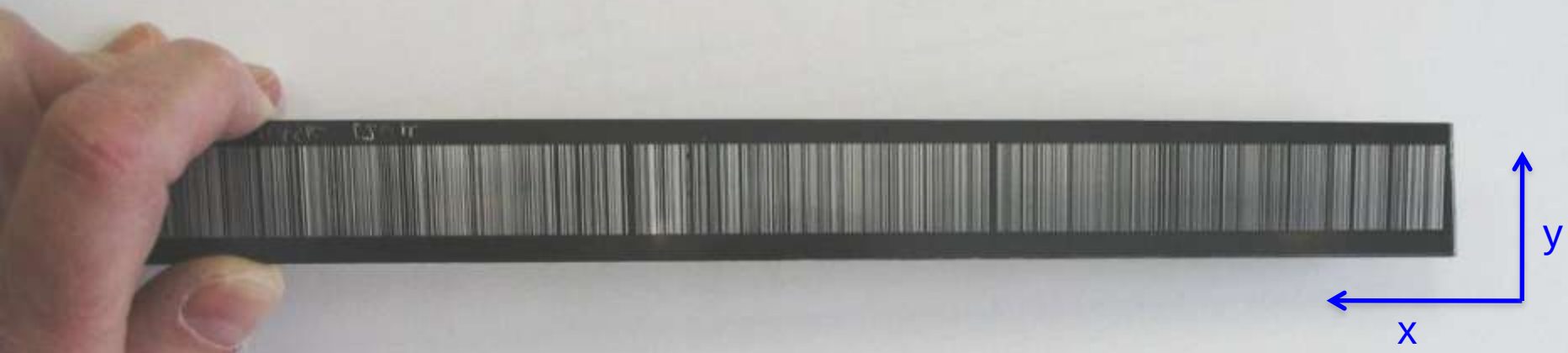



VELOCITY
(KM/SEC)
1956 [obs 1897 to1947]
η Boo G0 IV 1.2 m⊙
P=495 d e=0.232
m2 = 0.45 m⊙
km/s
10
8
6
4
2
0
-2
-4
-6
0
100
200
300
400
500
600
days
PHASE (DAYS)
jupiter in
the same orbit
+20 -11 m/s


~ 10 km/s
slit

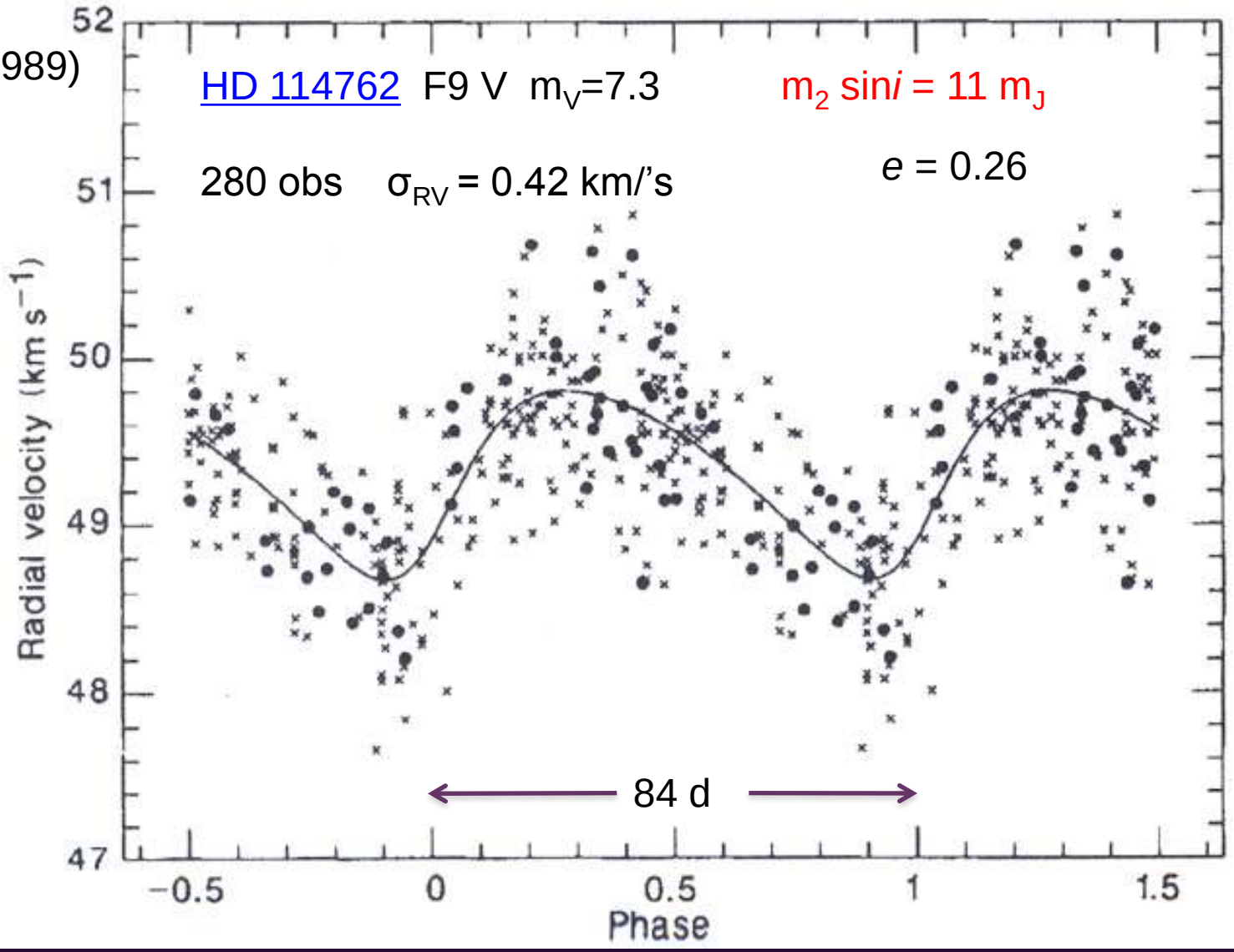

w
qn photons/Å
N spectral lines
d
δλ
shot-noise limit
δλ ~ √w/d² qn.N
10 m/s ~ 3x10-4 Å
difference
signal

RV scanner mask



Latham, Stefanik, Mazeh, Mayor, Burki -- CfA speedometer & CORAVEL

(1989)



ALGOL

John Glaspey & Greg Fahlman 1973

Si diode
Vidicon
output

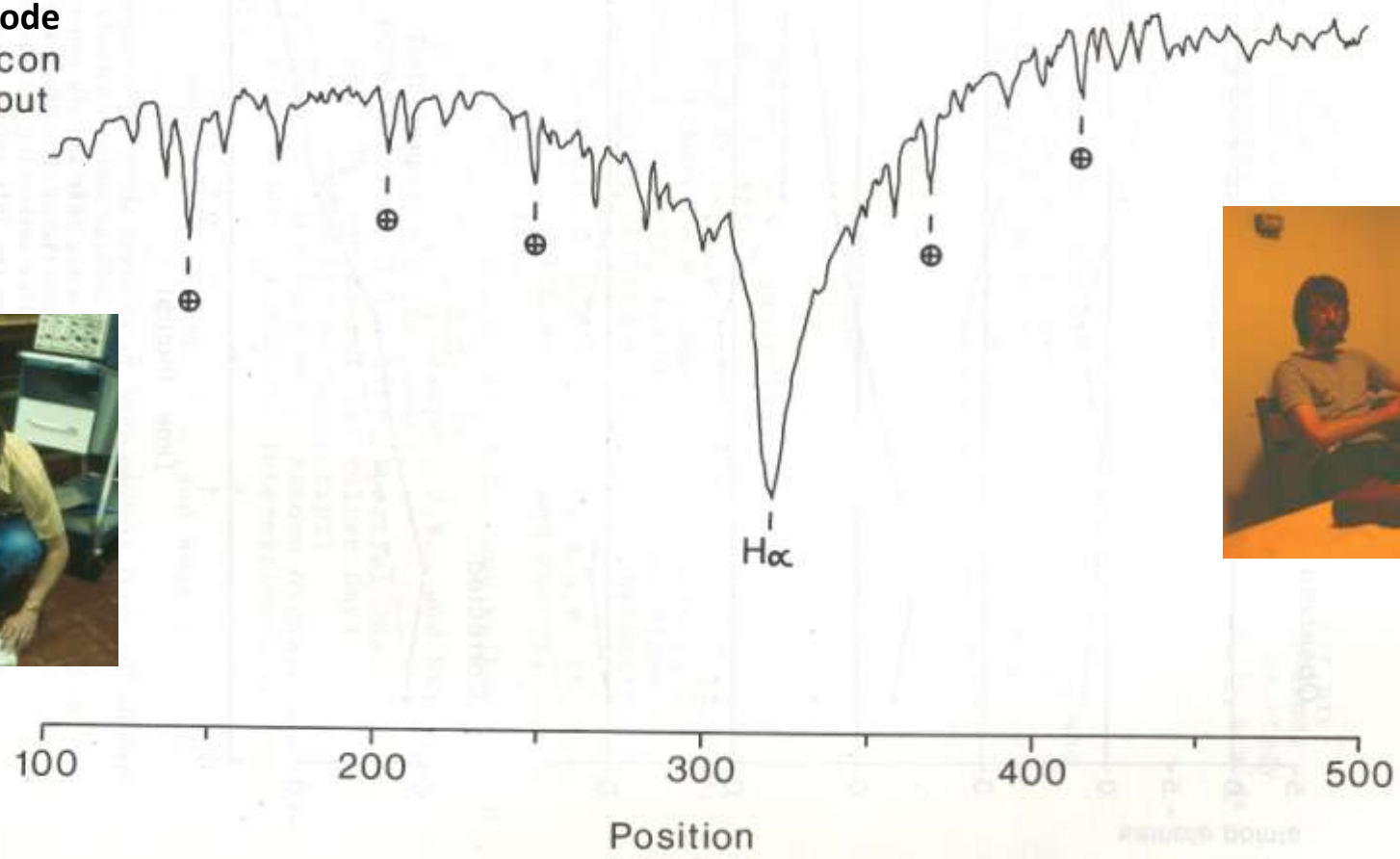


Fig. 9. Algol, Sept. 2, 1972. The five telluric features indicated were used in lieu of fiducial markers in order to determine the jitter in the Silicon Vidicon scanning raster.

ALGOL

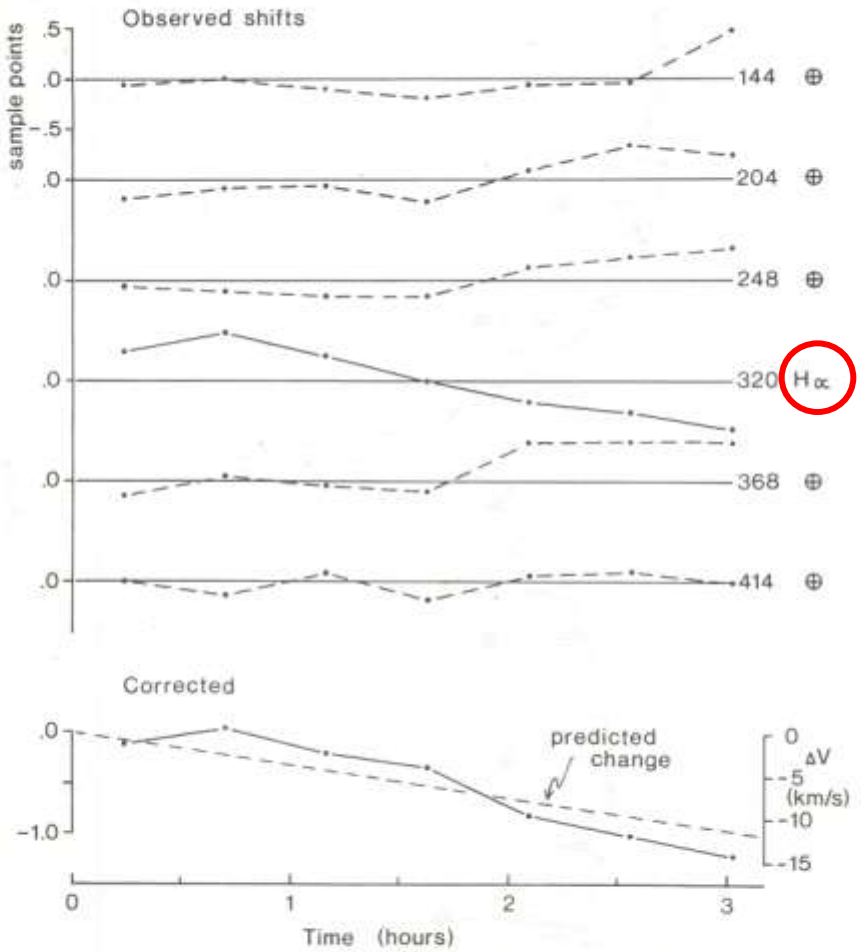
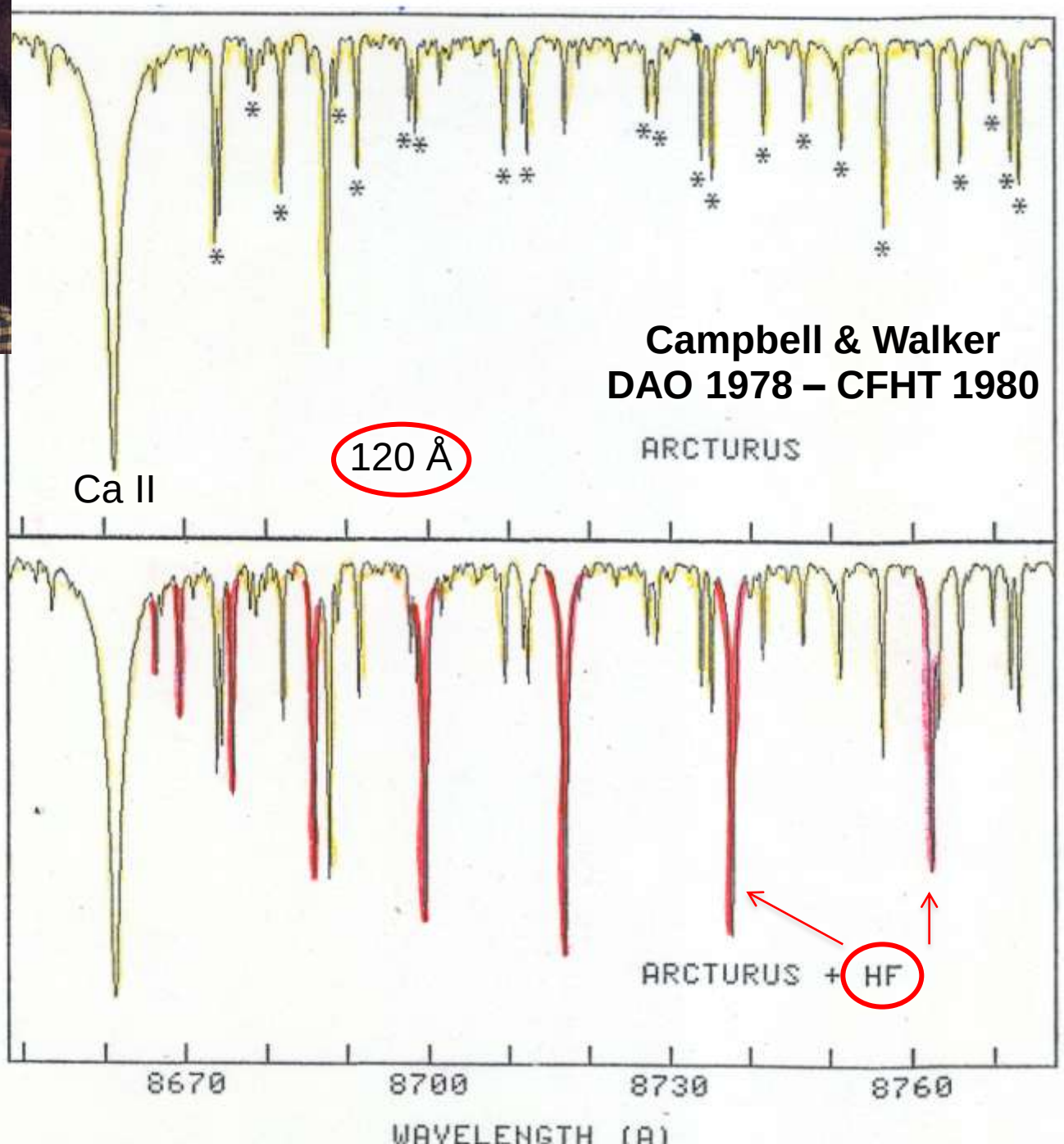


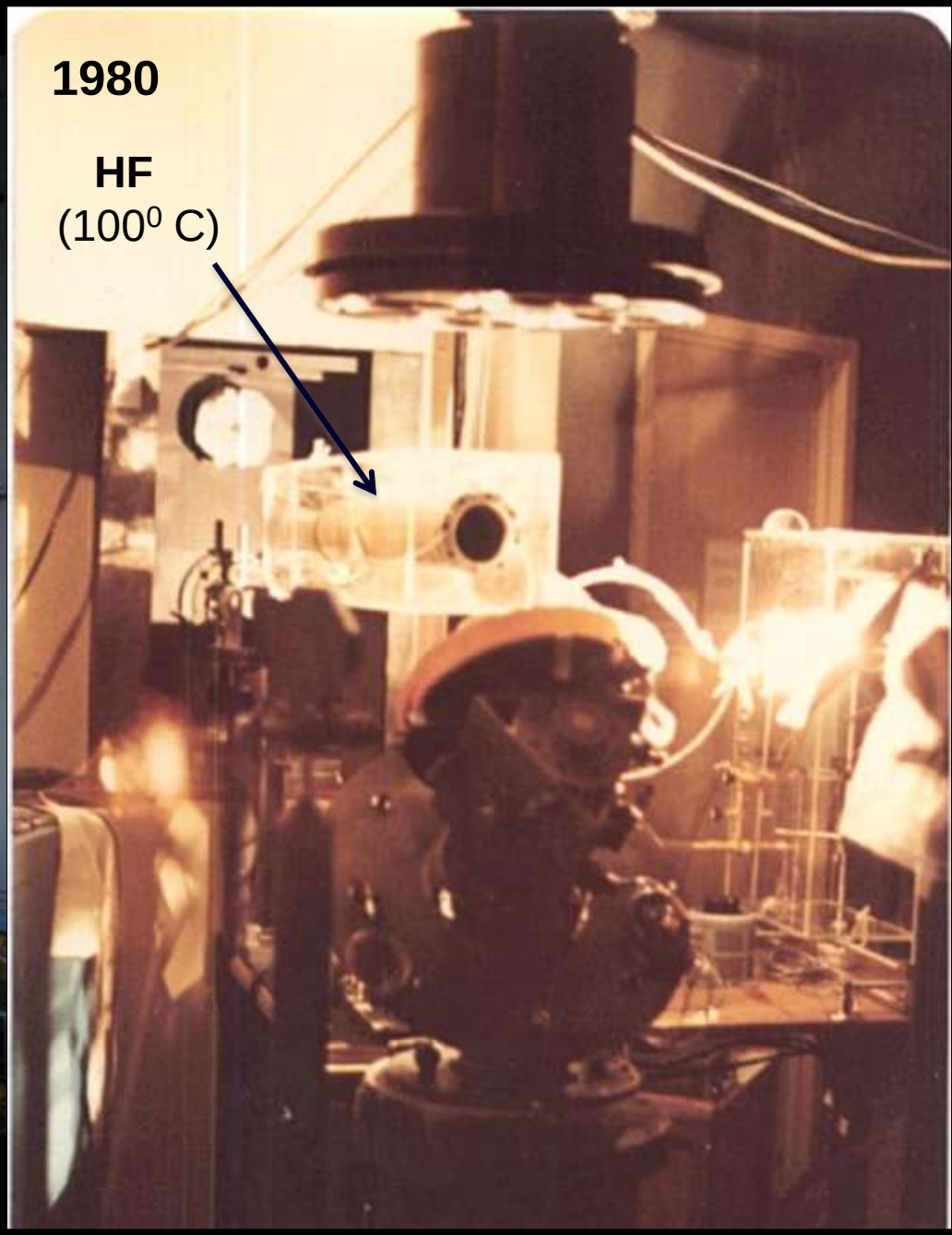
Fig. 10. The upper tracings show the observed shifts as a function of time for the Hα and the five telluric lines noted on Fig. 9. The shift scale is given at the top left and the central position of each feature is listed on the right. The lower tracin shows the positional change of Hα after correcting for the scanning raster variation. The scale on the left refers to the shift in sample points, and the corresponding change in radial velocity is indicated on the right. The dashed line is the change in the radial velocity of Algol A as predicted by the orbital elements of Hill et al (1971).

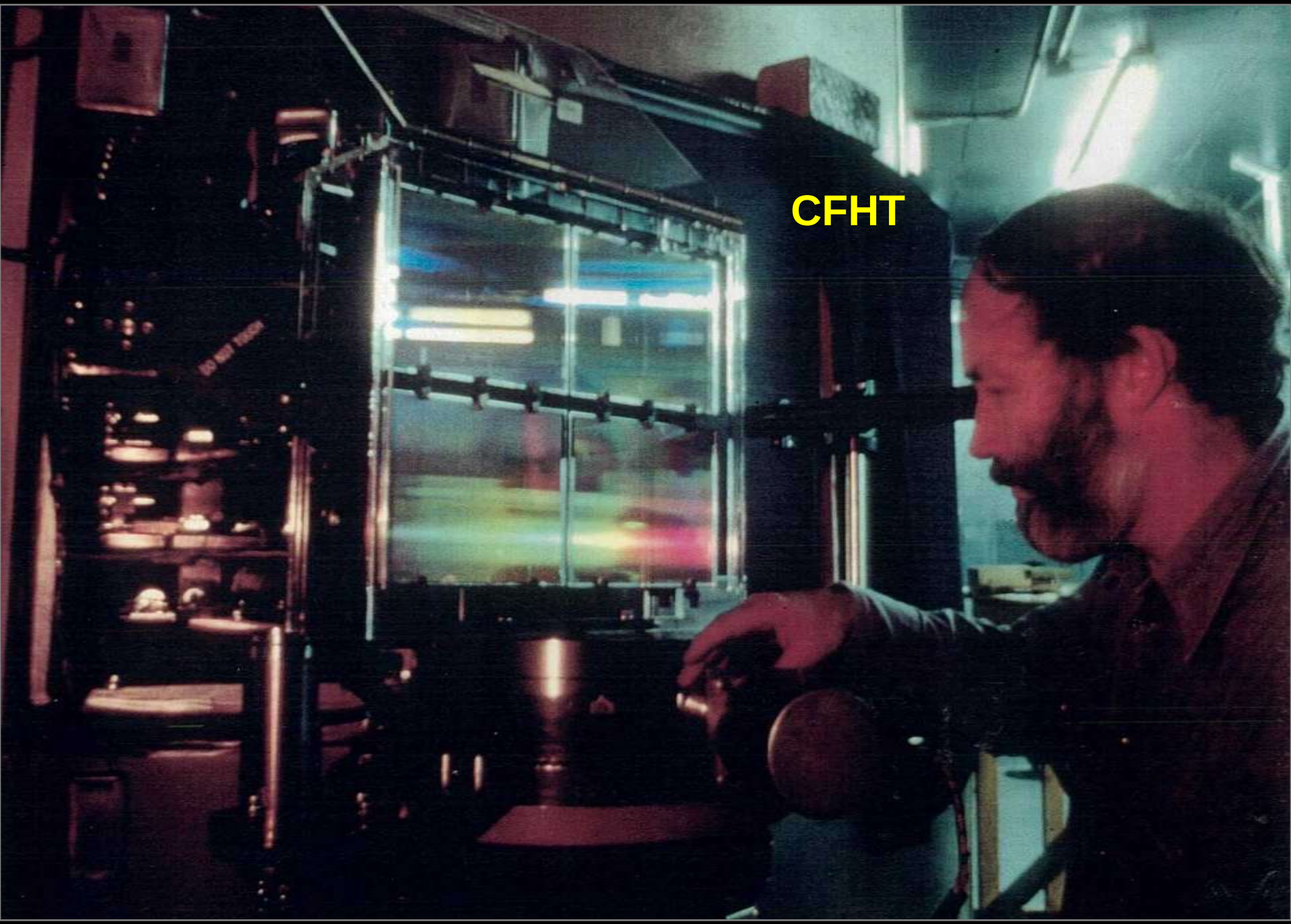

Reticon self-scanned Silicon diode arrays
256
1024
1872 15 x 750 µm


Campbell & Walker
DAO 1978 – CFHT 1980
ARCTURUS
120 Å
Ca II
ARCTURUS + HF
8670
8700
8730
8760
WAVELENGTH (A)

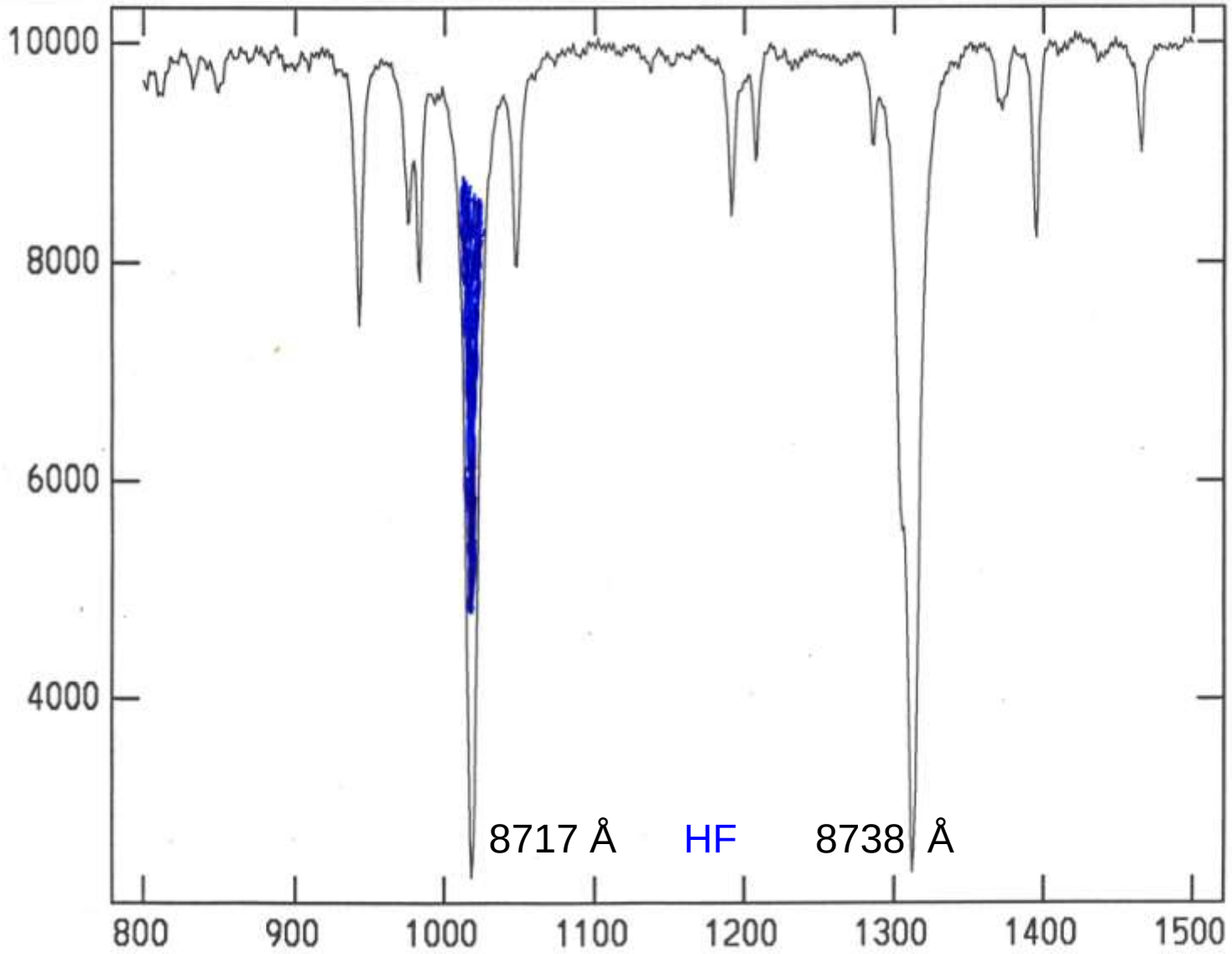
R~50,000


CFHT 3.6-m

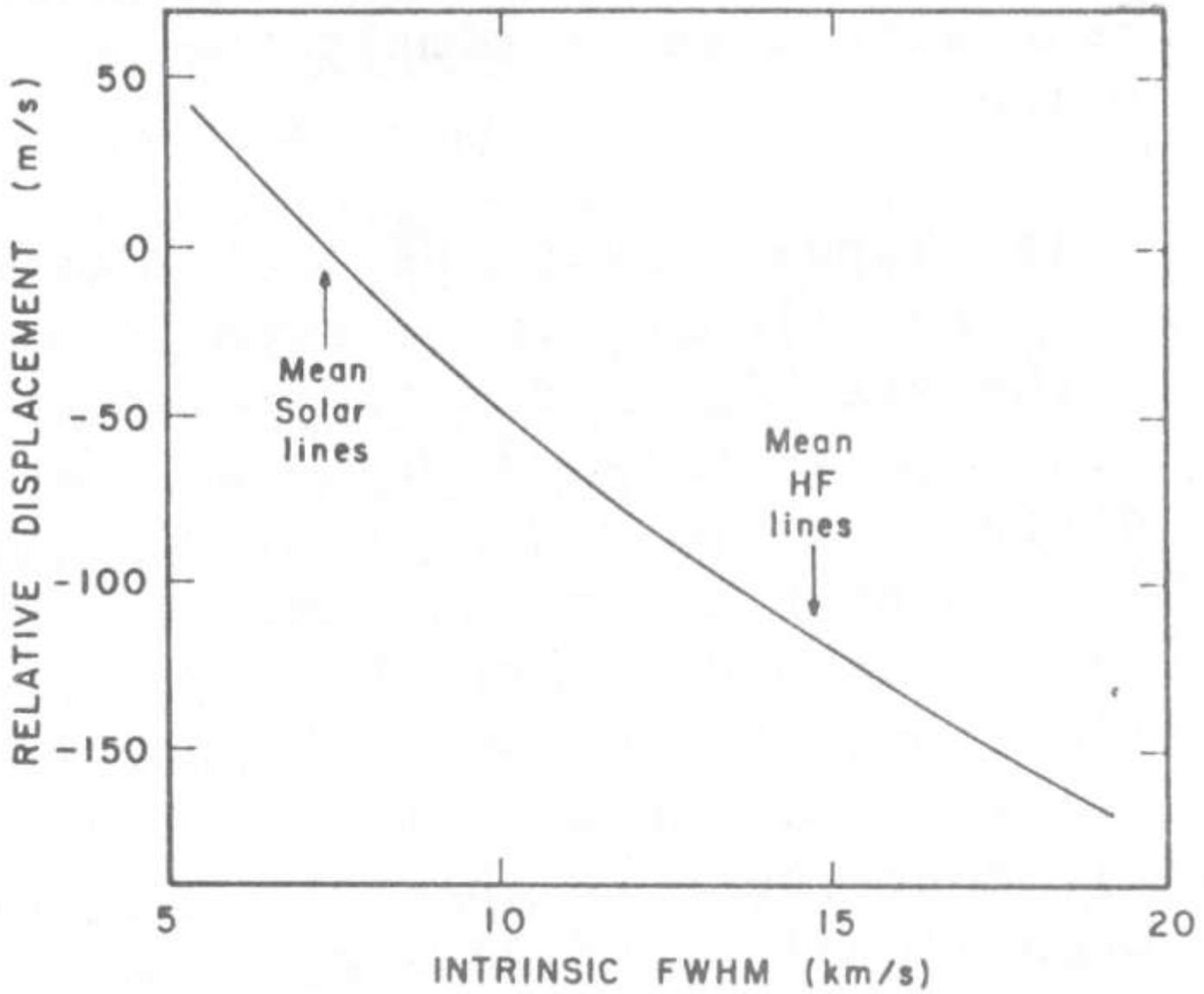

1980
HF
(100^0 C)

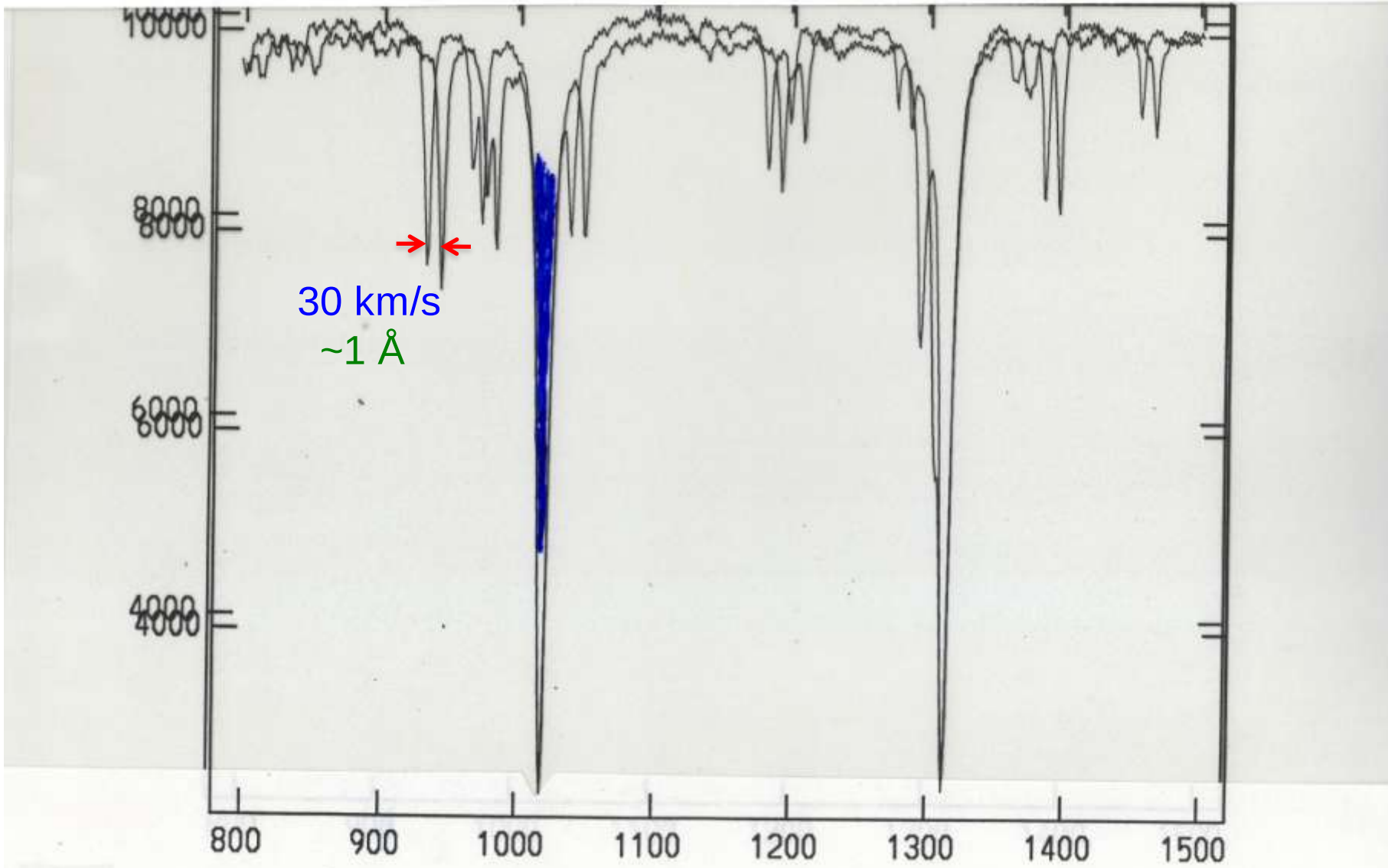

CFHT

impact of instrumental profile asymmetry ?



relative displacement of lines convolved with
a 610 m/s asymmetric instrumental profile




8000
6000
4000
30 km/s
~1 Å
800
900
1000
1100
1200
1300
1400
1500

1988
A SEARCH FOR SUBSTELLAR COMPANIONS TO SOLAR-TYPE STARS
Campbell, Walker & Yang
12 late-type stars – 8 (4x2) nights per year [later only 6]
external error 13 m/s
flagged potential planetary companions to:
γ Cep - single line SB + superimposed 2.7 y 25 m/s amplitude
ε Eri
1989
YELLOW GIANTS – A NEW CLASS OF RADIAL VELOCITY VARIABLE ?
Walker, Campbell, Yang & Irwin

1992
Alex Wolszczan & Dale Frail – terrestrial companions to B1257 +12

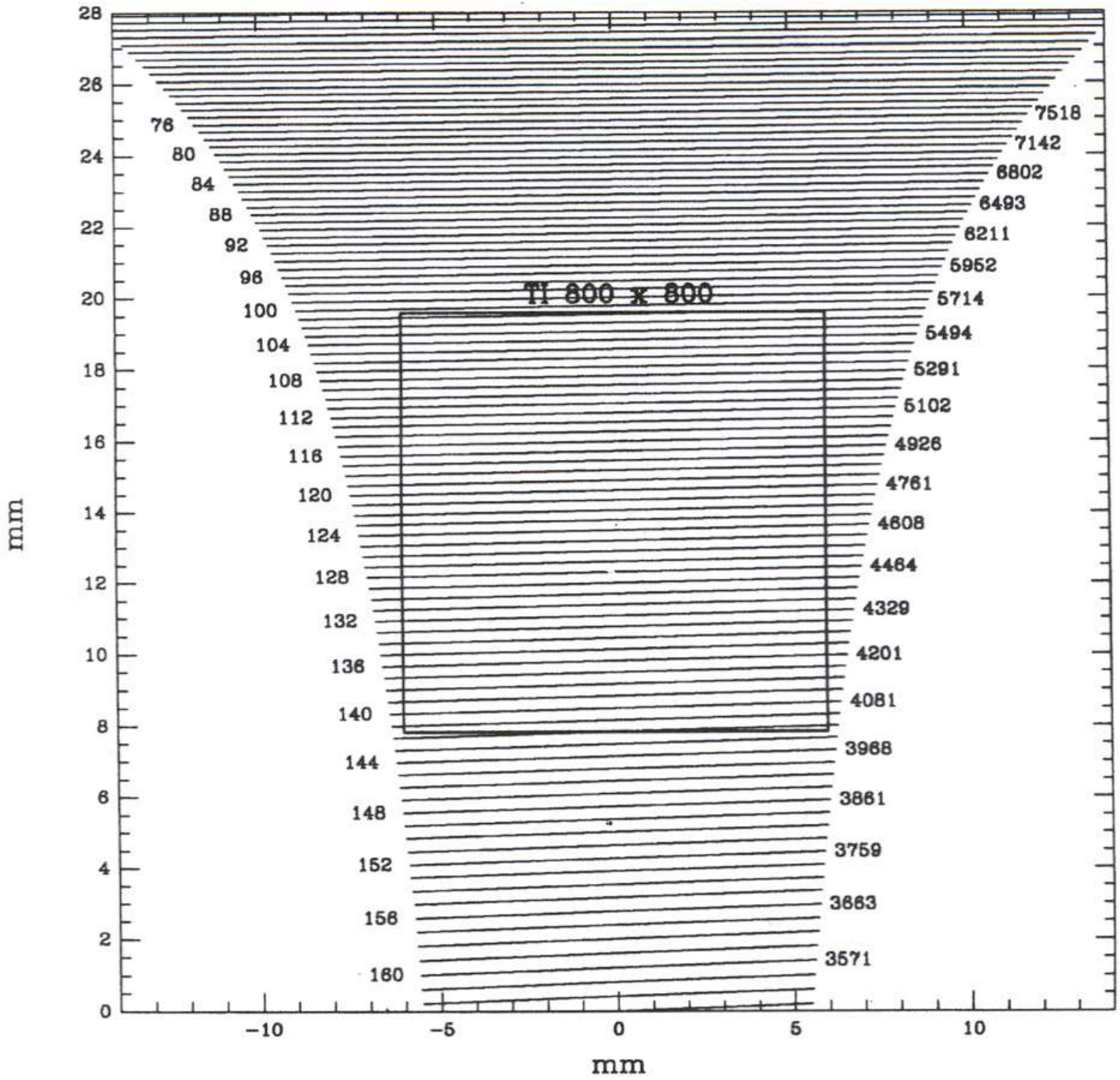
1995
Ana Larson – β Gem 590 d planetary period [also Cochran & Hatzes]

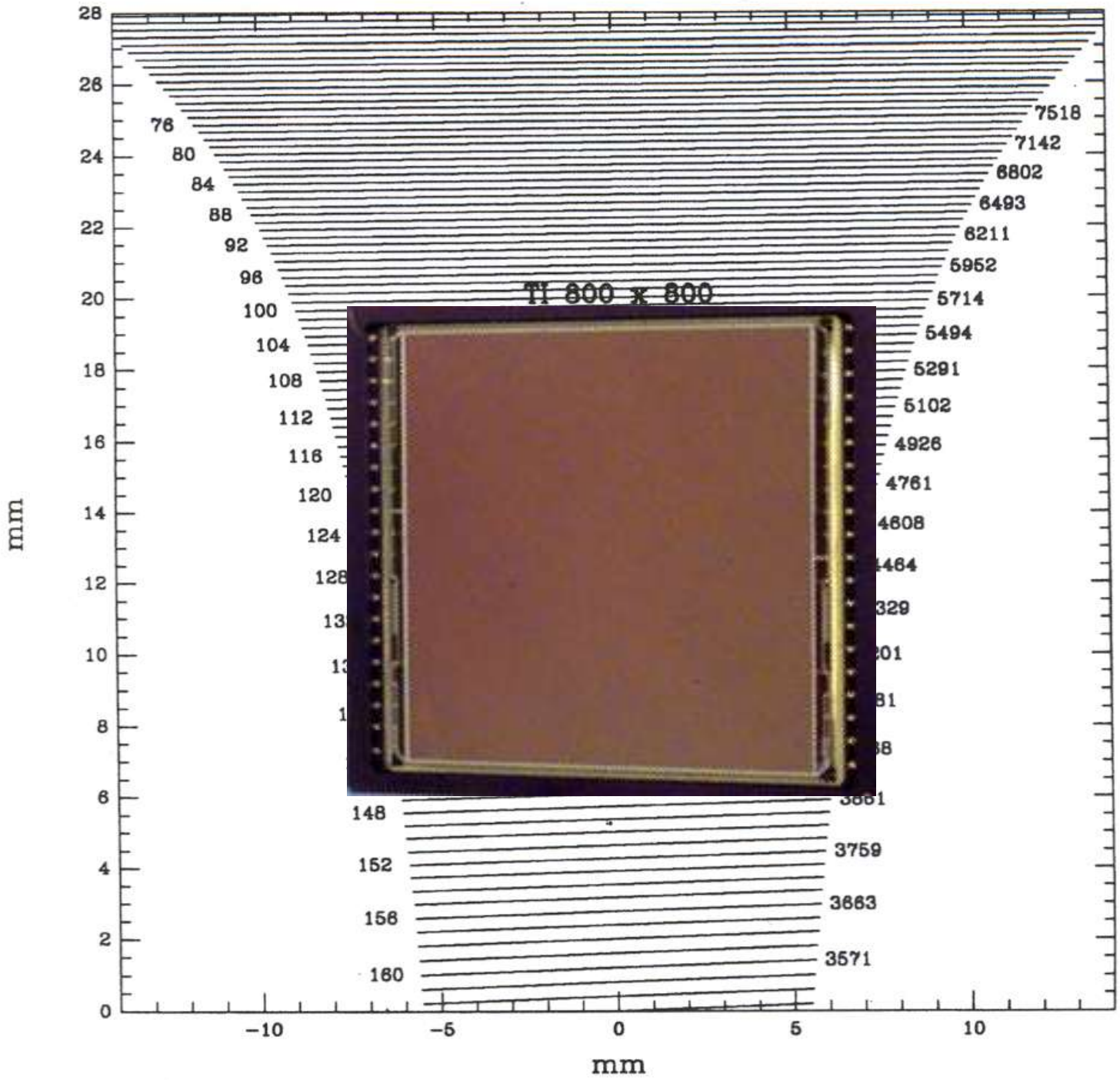
1995
A SEARCH FOR JUPITER MASS COMPANIONS TO NEARBY STARS
21 stars 1980 – 92

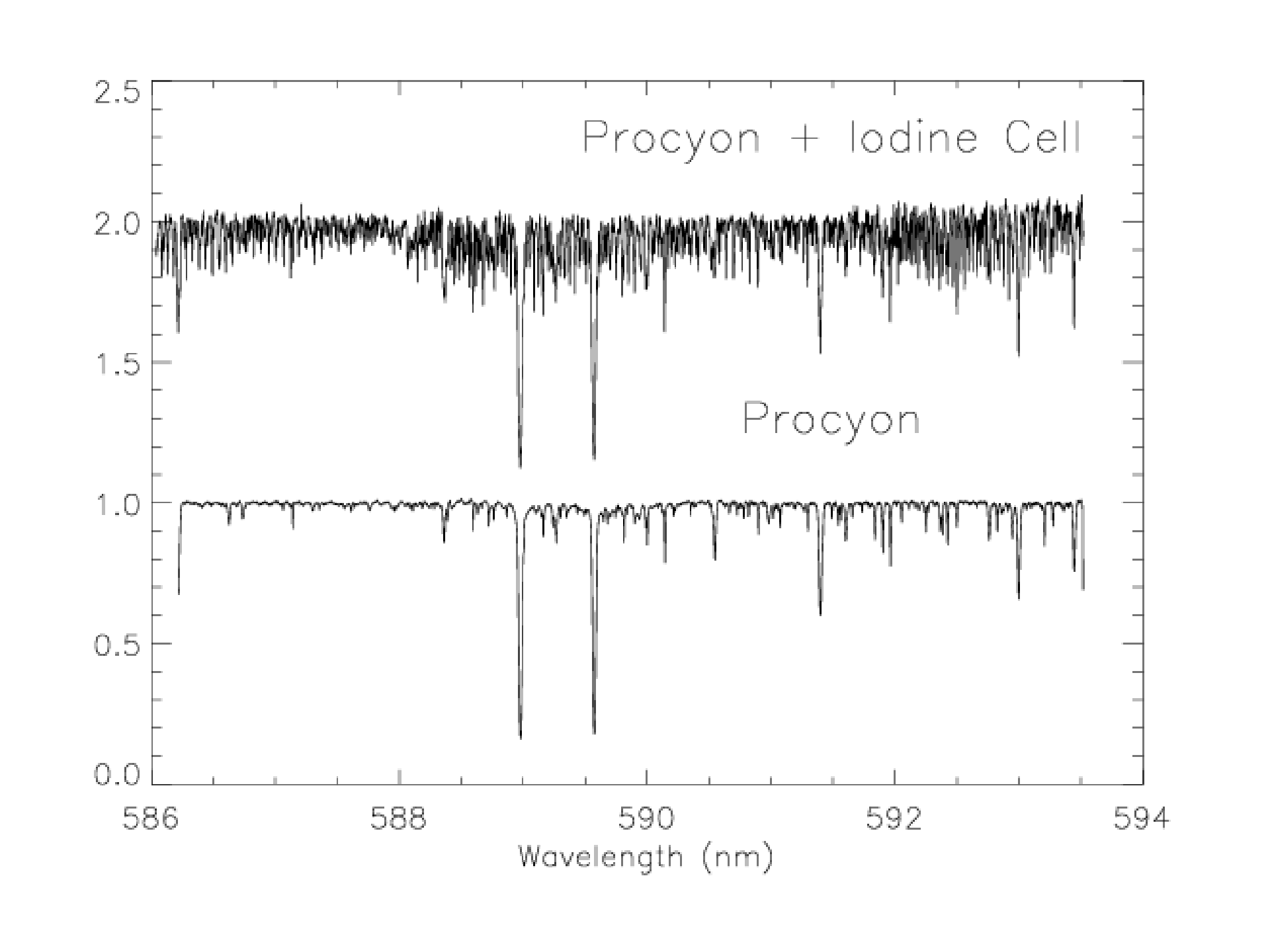

Marcy & Butler
5019 to 5872 Å = 853 Å
1987
50⁰ C
I2

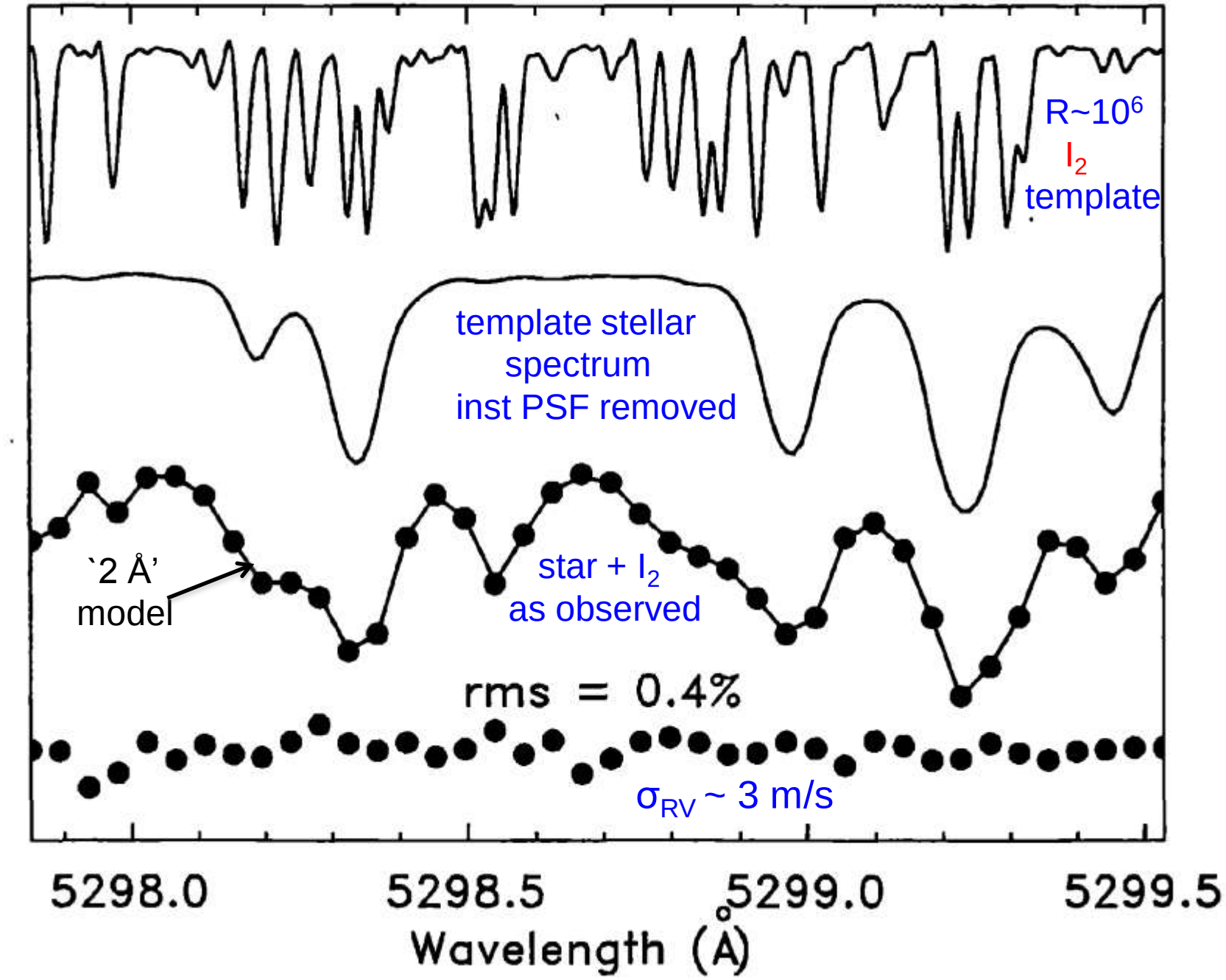
Shane
3-m

Hamilton échelle (Vogt) R = 62,000


TI 800 x 800
mm
mm
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
−10
−5
0
5
10
76
80
84
88
92
96
100
104
108
112
116
120
124
128
132
136
140
144
148
152
156
160
7518
7142
6802
6493
6211
5952
5714
5494
5291
5102
4926
4761
4608
4464
4329
4201
4081
3968
3861
3759
3663
3571


TI 800 x 800
mm
mm
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
−10
−5
0
5
10
76
80
84
88
92
96
100
104
108
112
116
120
124
148
152
156
160
7518
7142
6802
6493
6211
5952
5714
5494
5291
5102
4926
4761
3759
3663
3571

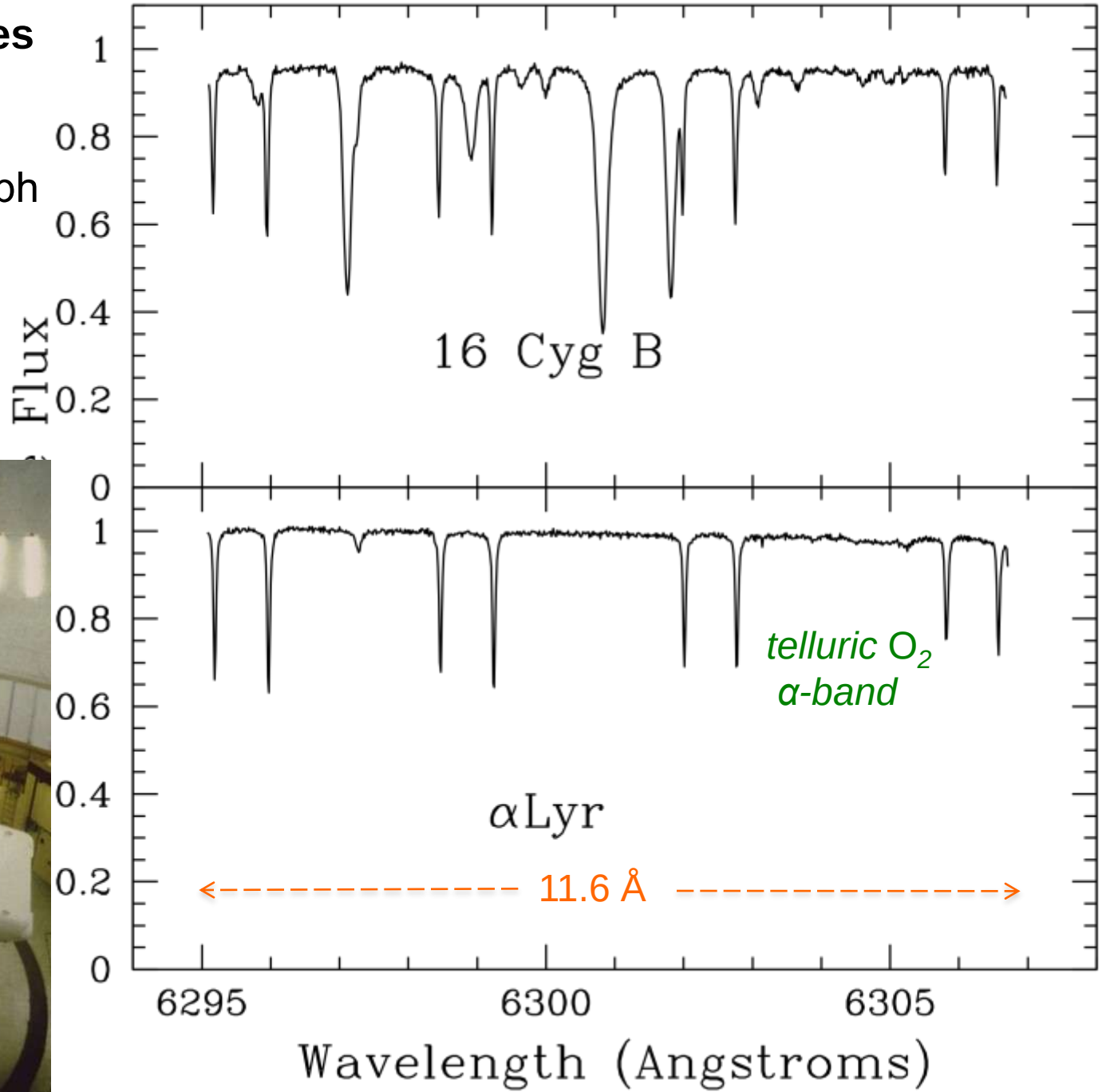

Procyon + Iodine Cell
Procyon
2.5
2.0
1.5
1.0
0.5
0.0
586
588
590
592
594
Wavelength (nm)

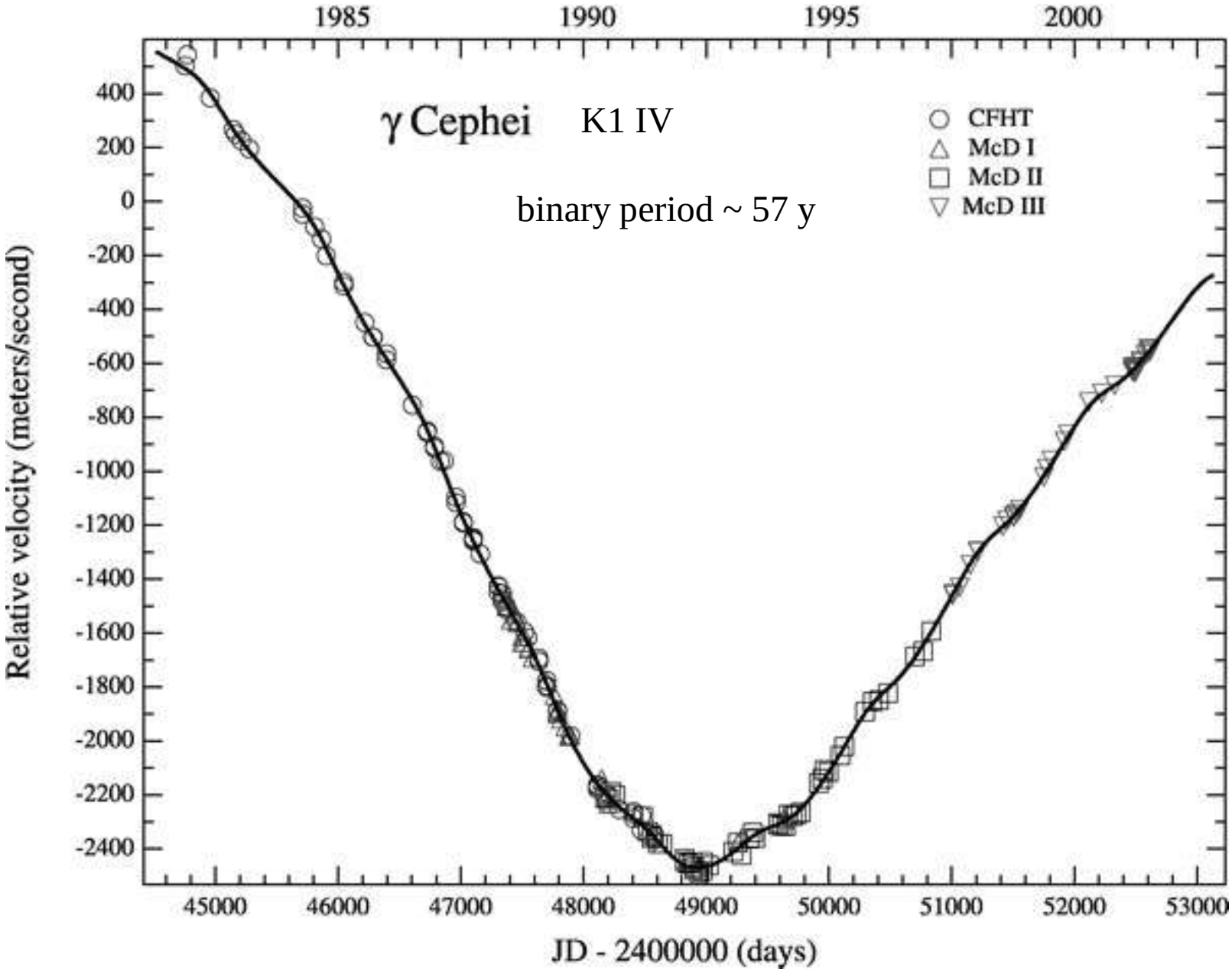

R~10^6
I2
template
template stellar
spectrum
inst PSF removed
`2 Å'
model
star + I2
as observed
rms = 0.4%
σRV ~ 3 m/s
5298.0
5298.5
5299.0
5299.5
Wavelength (Å)

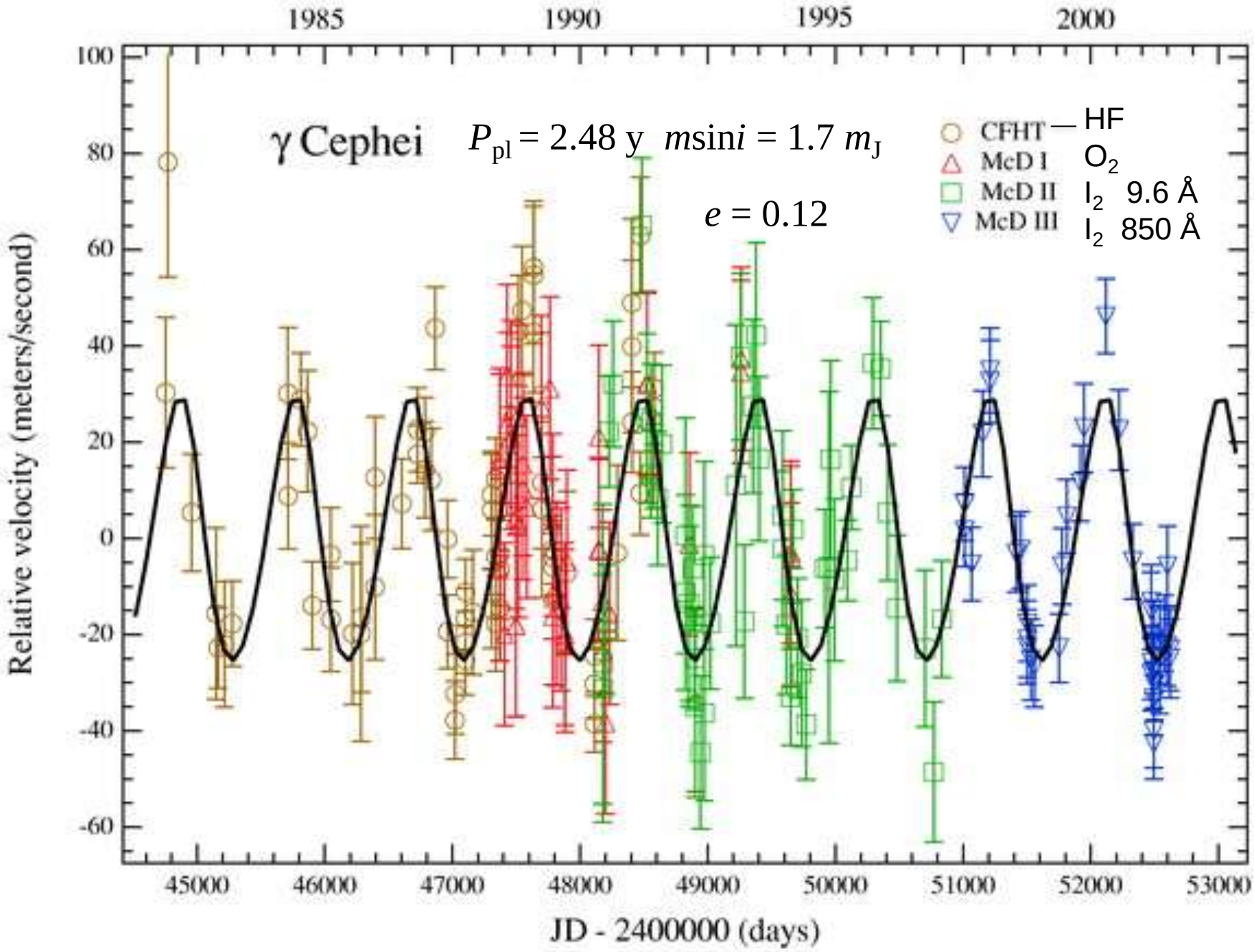
Cochran & Hatzes
MD I 1988

Tull coudé sp'graph
R~210,000
TI 800x800

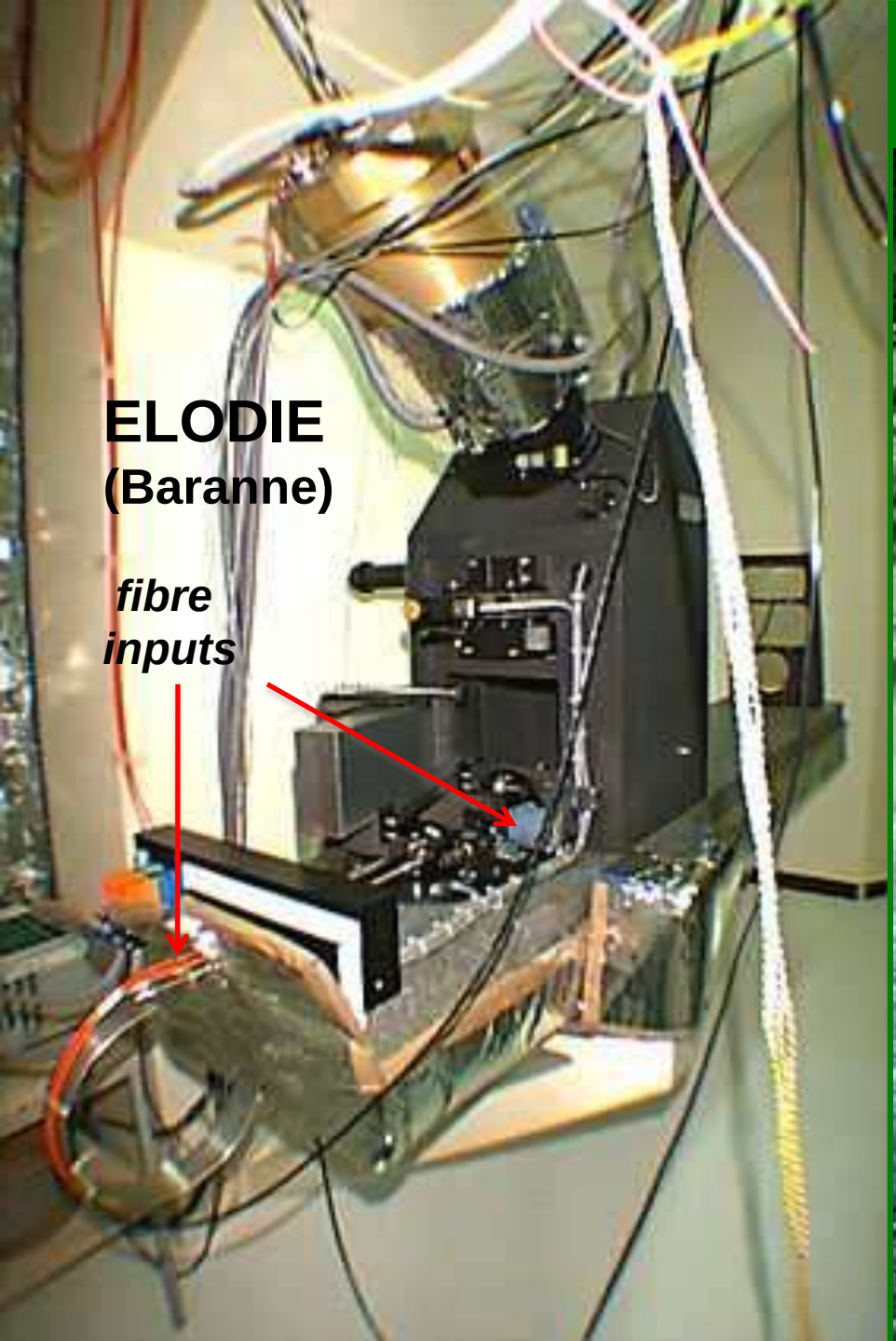
2.7-m Harlan Smith




γ Cephei K1 IV
binary period ~ 57 y
CFHT
McD I
McD II
McD III
1985
1990
1995
2000
Relative velocity (meters/second)
400
200
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-2000
-2200
-2400
45000
46000
47000
48000
49000
50000
51000
52000
53000
JD - 2400000 (days)


1985
1990
1995
2000
γ Cephei
P_{pl} = 2.48 y
$m\sin i$ = 1.7 m_J
e = 0.12
CFHT
McD I
McD II
McD III
HF
O_2
I_2 9.6 Å
I_2 850 Å
Relative velocity (meters/second)
JD - 2400000 (days)
100
80
60
40
20
0
-20
-40
-60
45000
46000
47000
48000
49000
50000
51000
52000
53000

Mayor & Queloz 1994



ELODIE

R = 42,000

67 orders

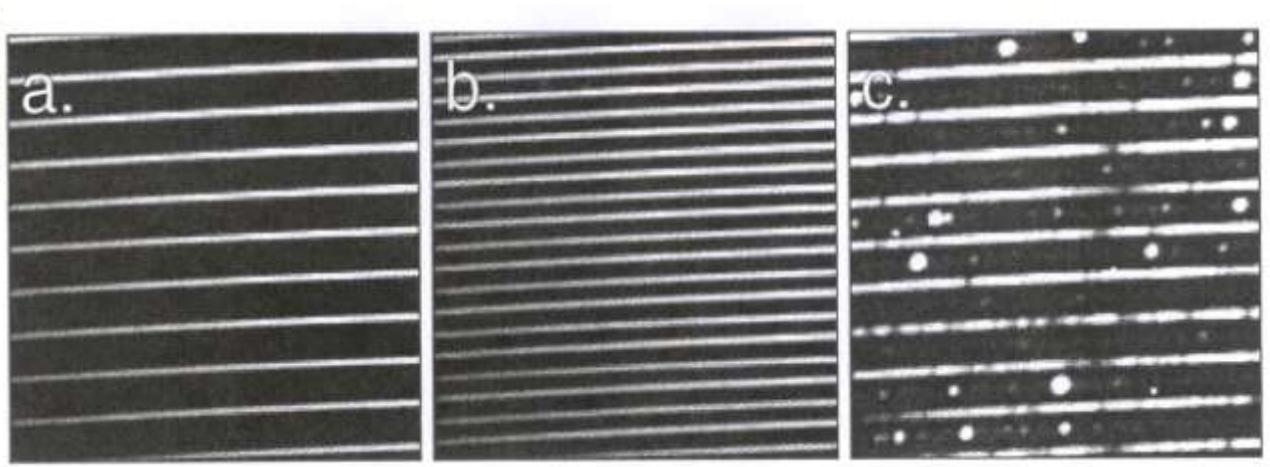
Tk 1024^2

3900 to 6800 Å

twin fibre feed
light scrambling

→ ***stable psf***

only



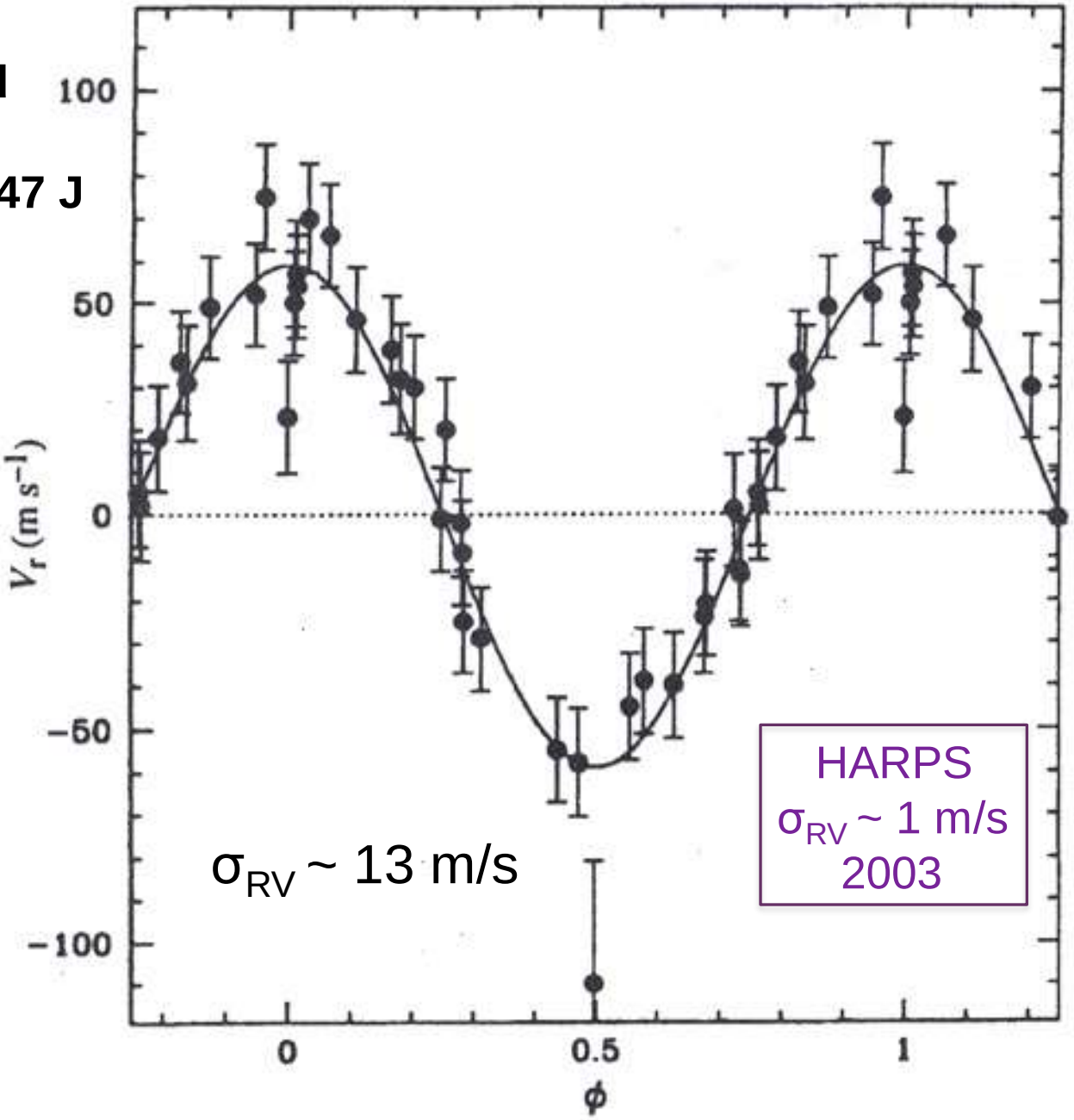
★

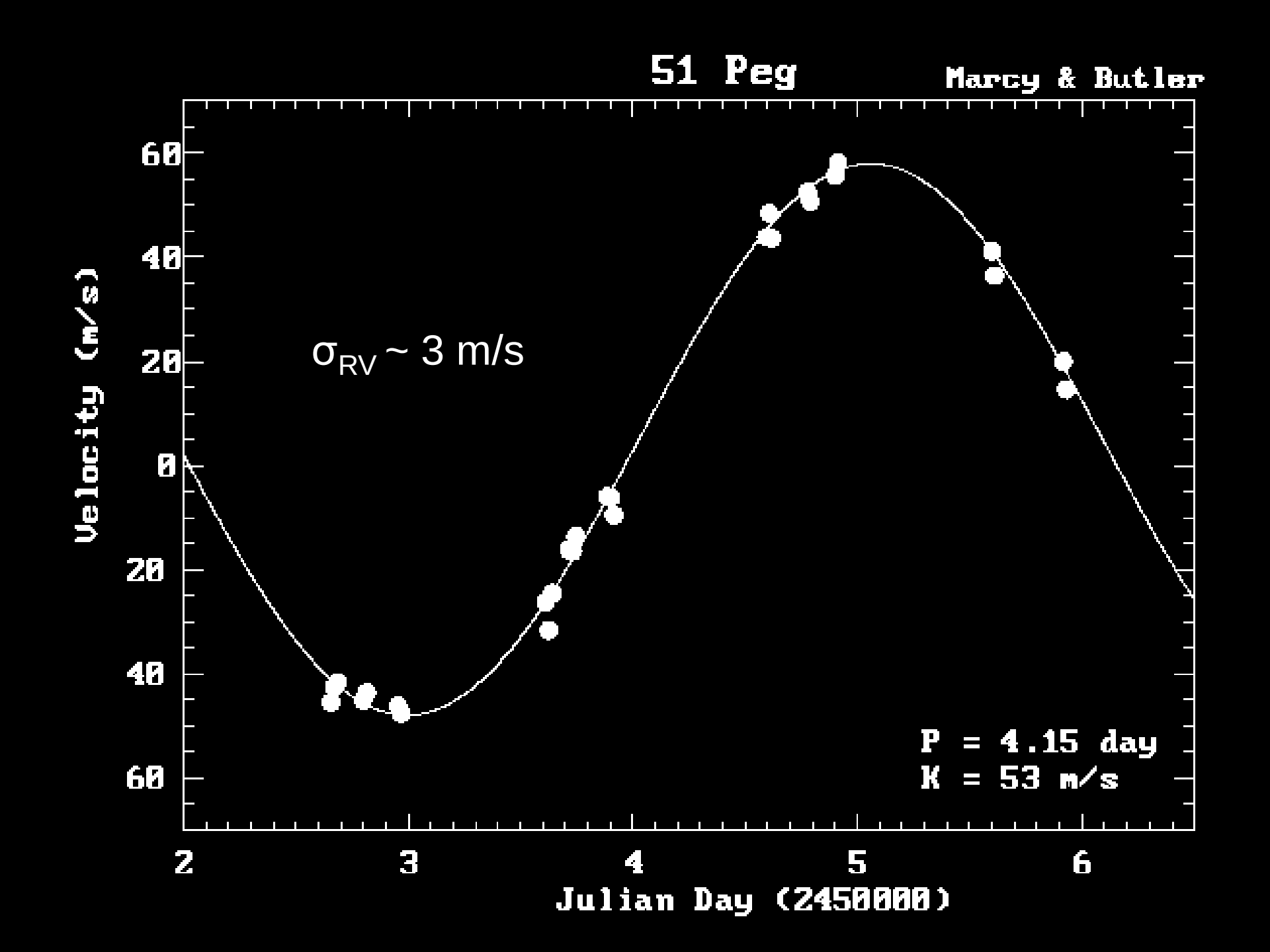
+ Th/Ar arc

51 Peg **Mayor & Queloz** **1995**

P **= 4.23 d**

m **sin*i*** **= 0.47 J**




51 Peg
Marcy & Butler
Velocity (m/s)
60
40
20
0
20
40
60
2
3
4
5
6
Julian Day (2450000)
σRV ~ 3 m/s
P = 4.15 day
K = 53 m/s

the future ?

space

4-m at L2 – Strehl ~ 0.5

spectrograph

R>250,000

λ 0.3 to 2 μm