Helium-3 in Planetary Nebulae

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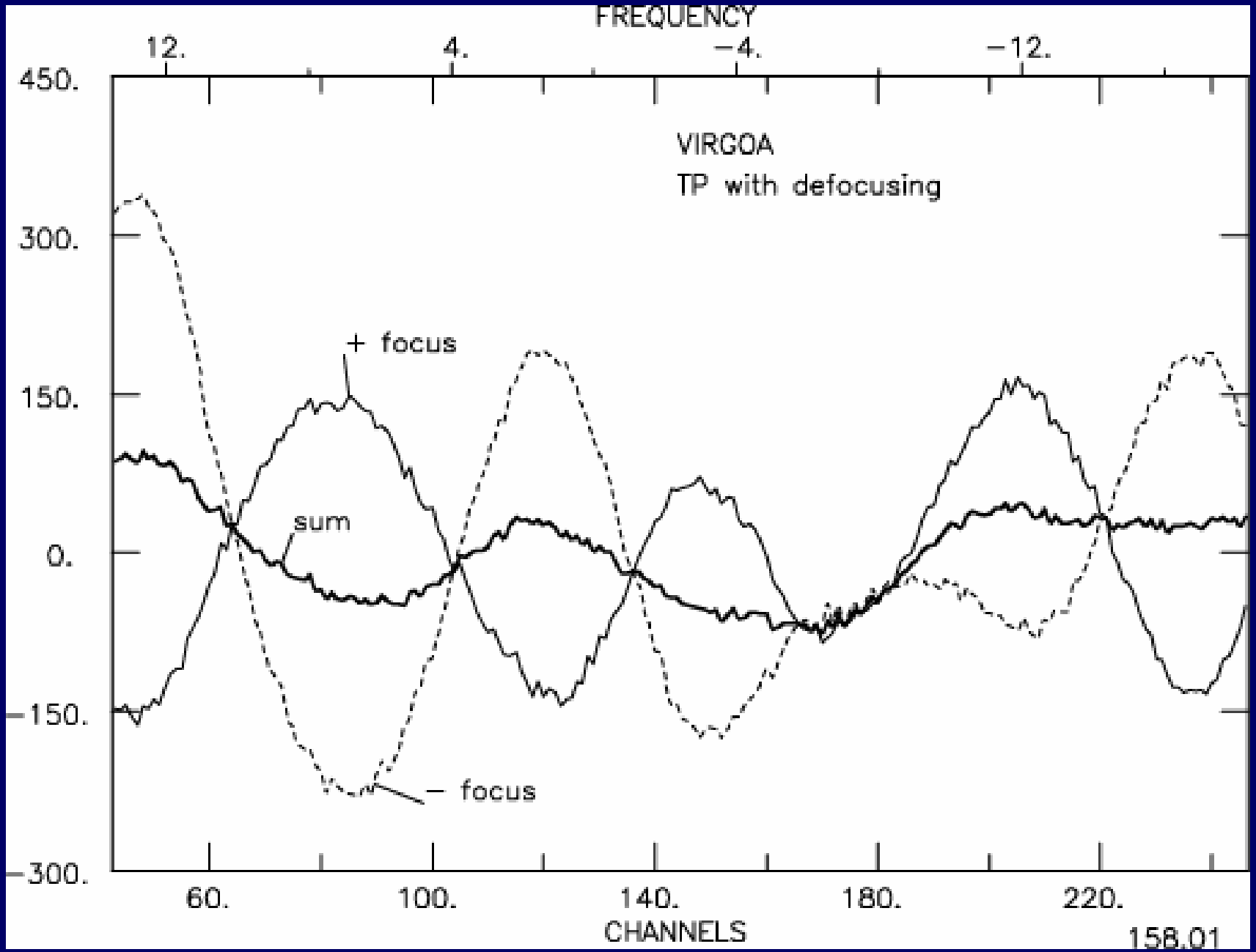
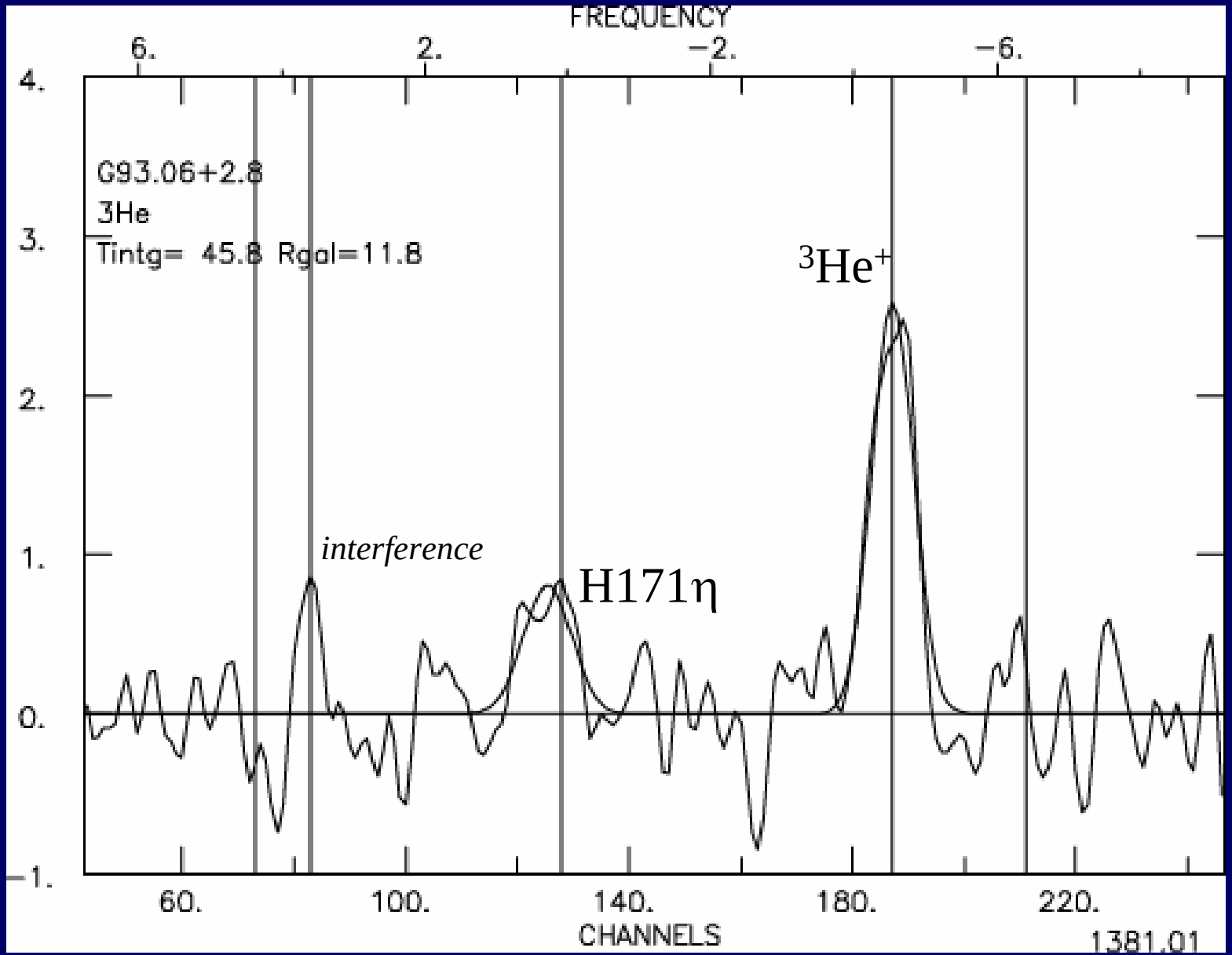
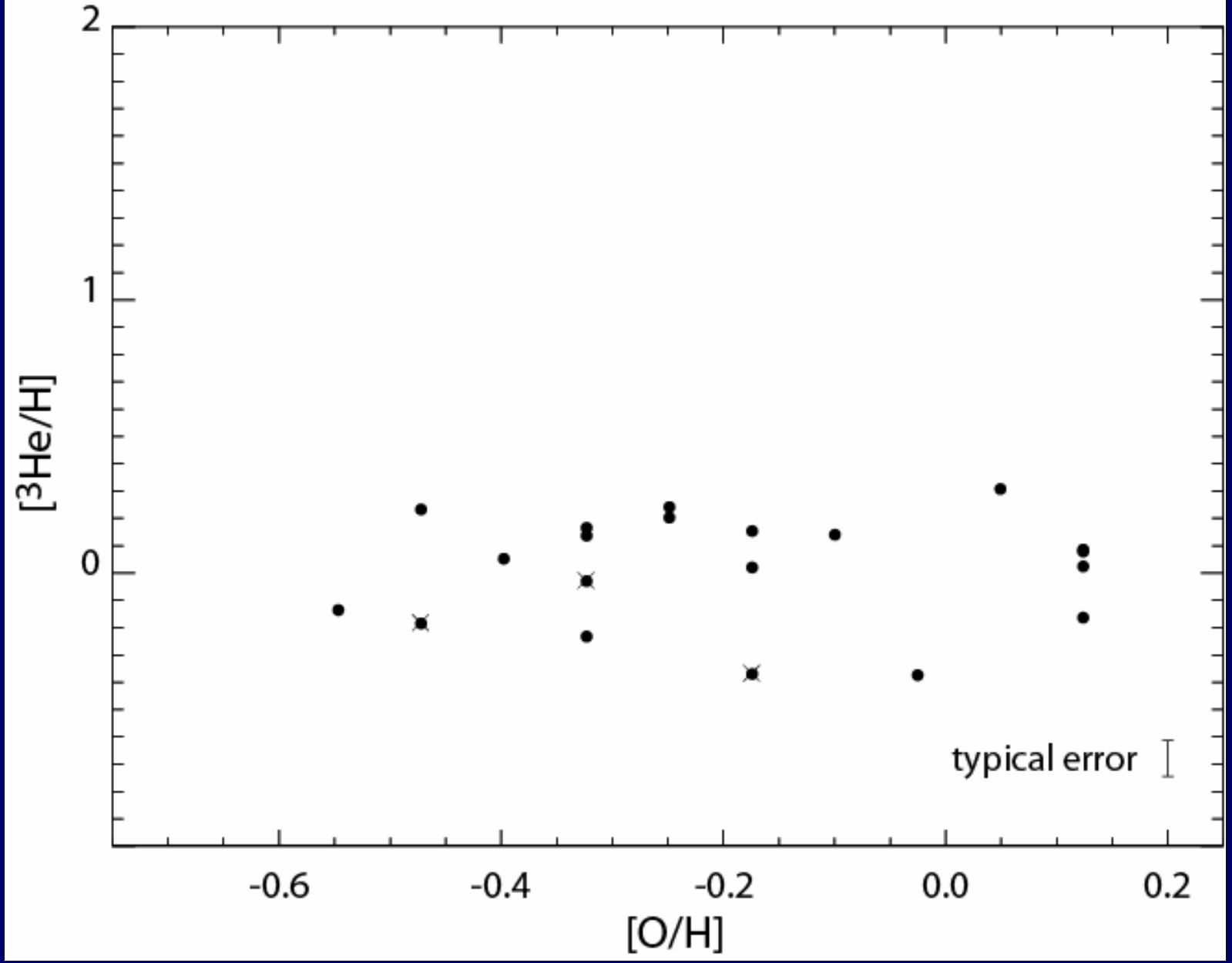
Observe 3He using the hyperfine (spin-flip) line of $^{3}He^{+}$

Analog of the 21 cm line of H

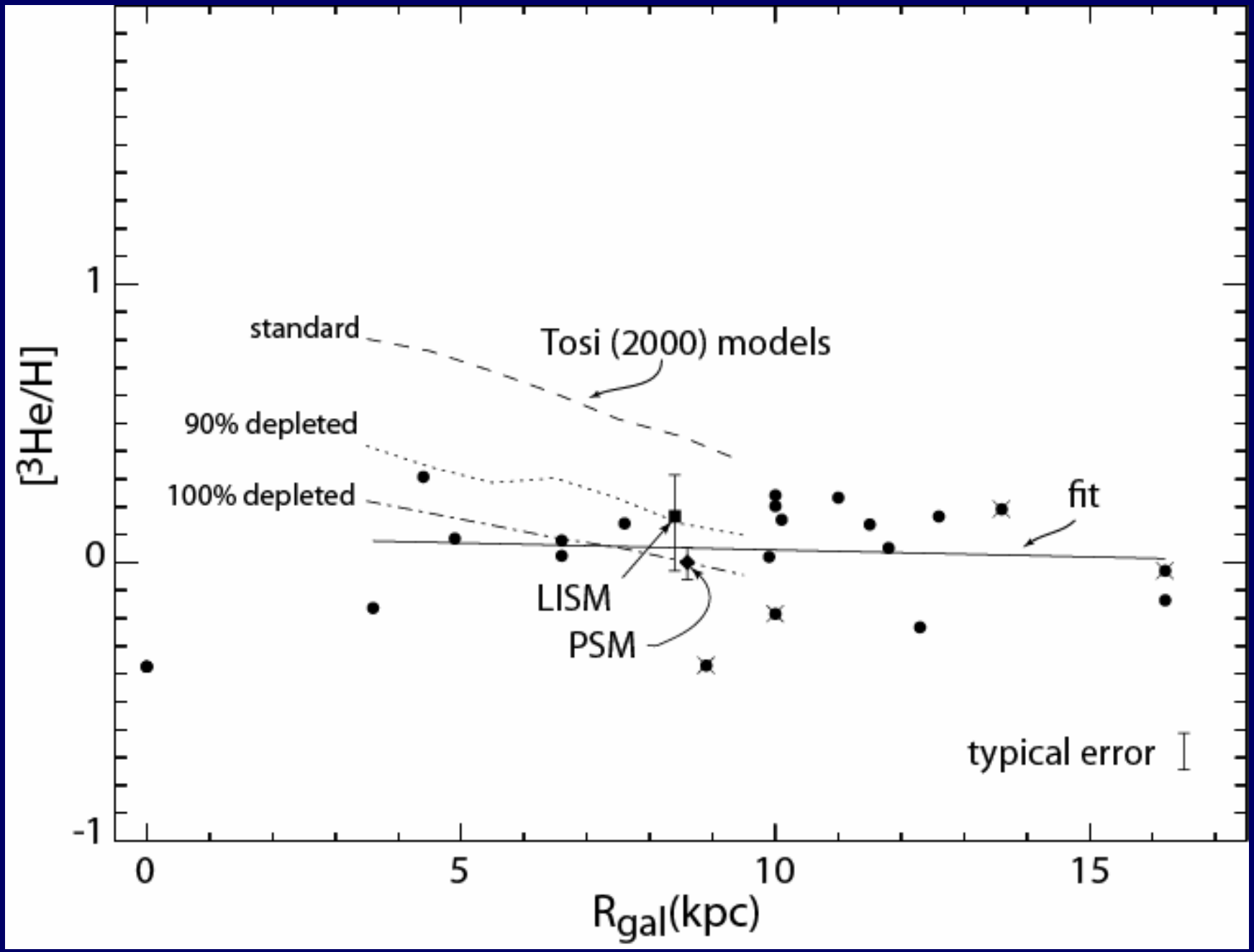
$\nu = 8665.65$ MHz $\lambda = 3.36$ cm

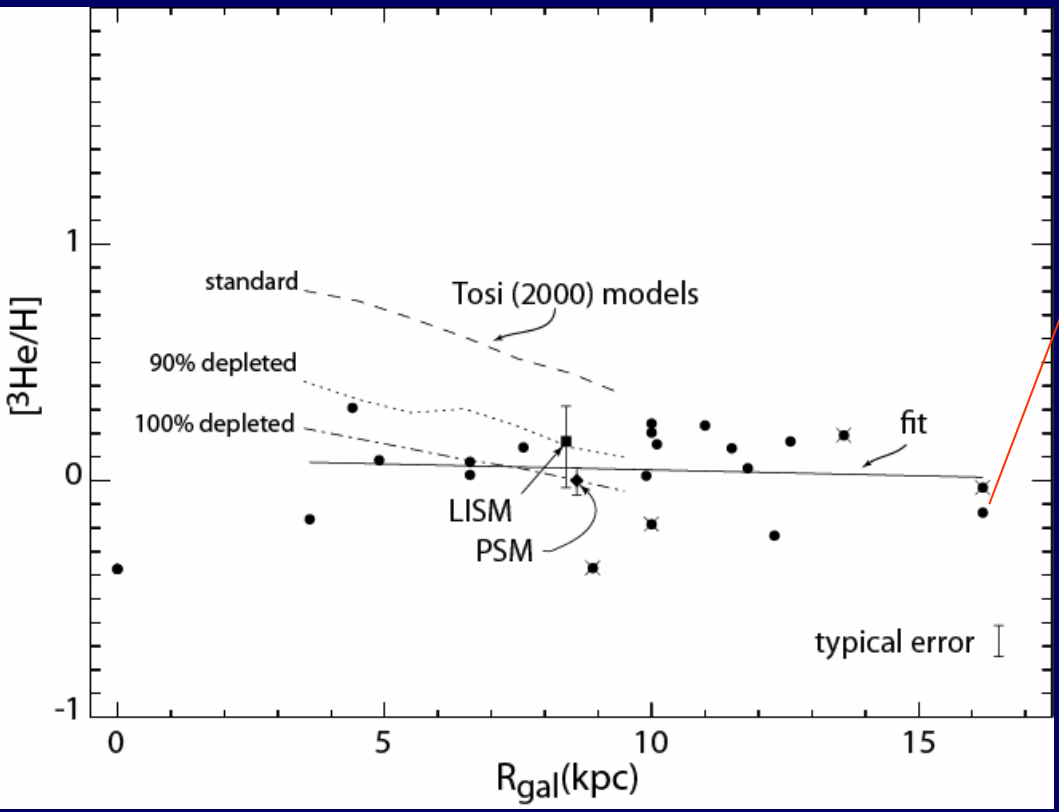

FREQUENCY
12.
4.
−4.
−12.
450.
300.
150.
0.
−150.
−300.
VIRGOA
TP with defocusing
+ focus
sum
− focus
60.
100.
140.
180.
220.
CHANNELS
158.01


FREQUENCY
6.
2.
−2.
−6.
4.
3.
2.
1.
0.
−1.
G93.06+2.8
3He
Tintg= 45.8 Rgal=11.8
$^3He^+$
interference
H171η
60.
100.
140.
180.
220.
CHANNELS
1381.01



H II Regions


standard
Tosi (2000) models
90% depleted
100% depleted
fit
LISM
PSM
typical error
[3He/H]
Rgal(kpc)
1
0
-1
0
5
10
15



Bania, Rood, & Balser 2002

$\eta_{10} = 5.4^{+2.2}_{-1.2}$

$\Omega_B = 0.04$

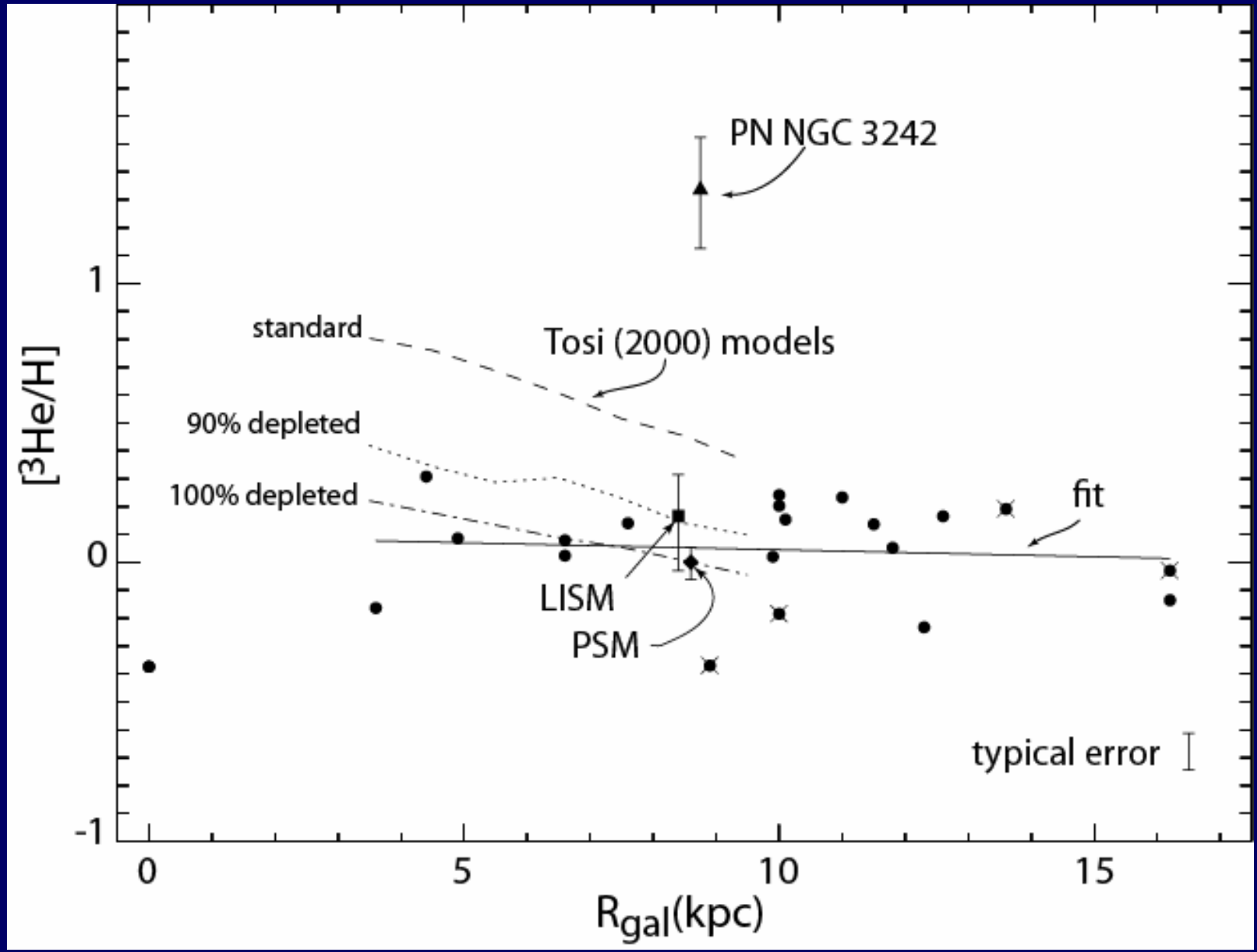
Spergel et al. 2003, WMAP

$\eta_{10} = 6.5^{+0.4}_{-0.3}$

$\Omega_B = 0.047 \pm 0.006$

For D highest observed value is a lower limit for cosmological D

For ^{3}He lowest observed ^{3}He/H is an upper limit for cosmological ^{3}He


PN NGC 3242
standard
Tosi (2000) models
90% depleted
100% depleted
fit
LISM
PSM
typical error
[3He/H]
Rgal(kpc)
1
0
-1
0
5
10
15

One is not enough!

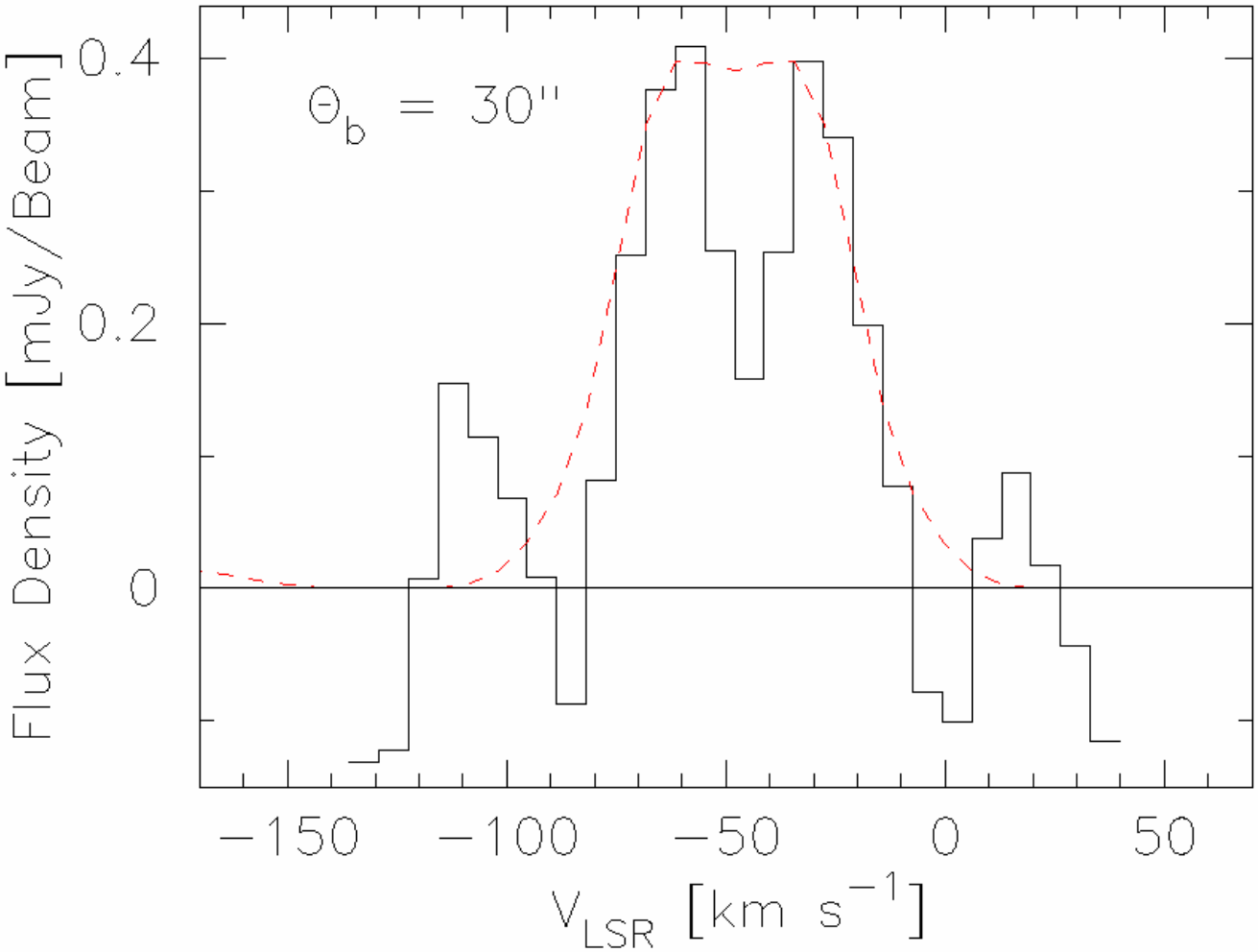
Except in cosmology

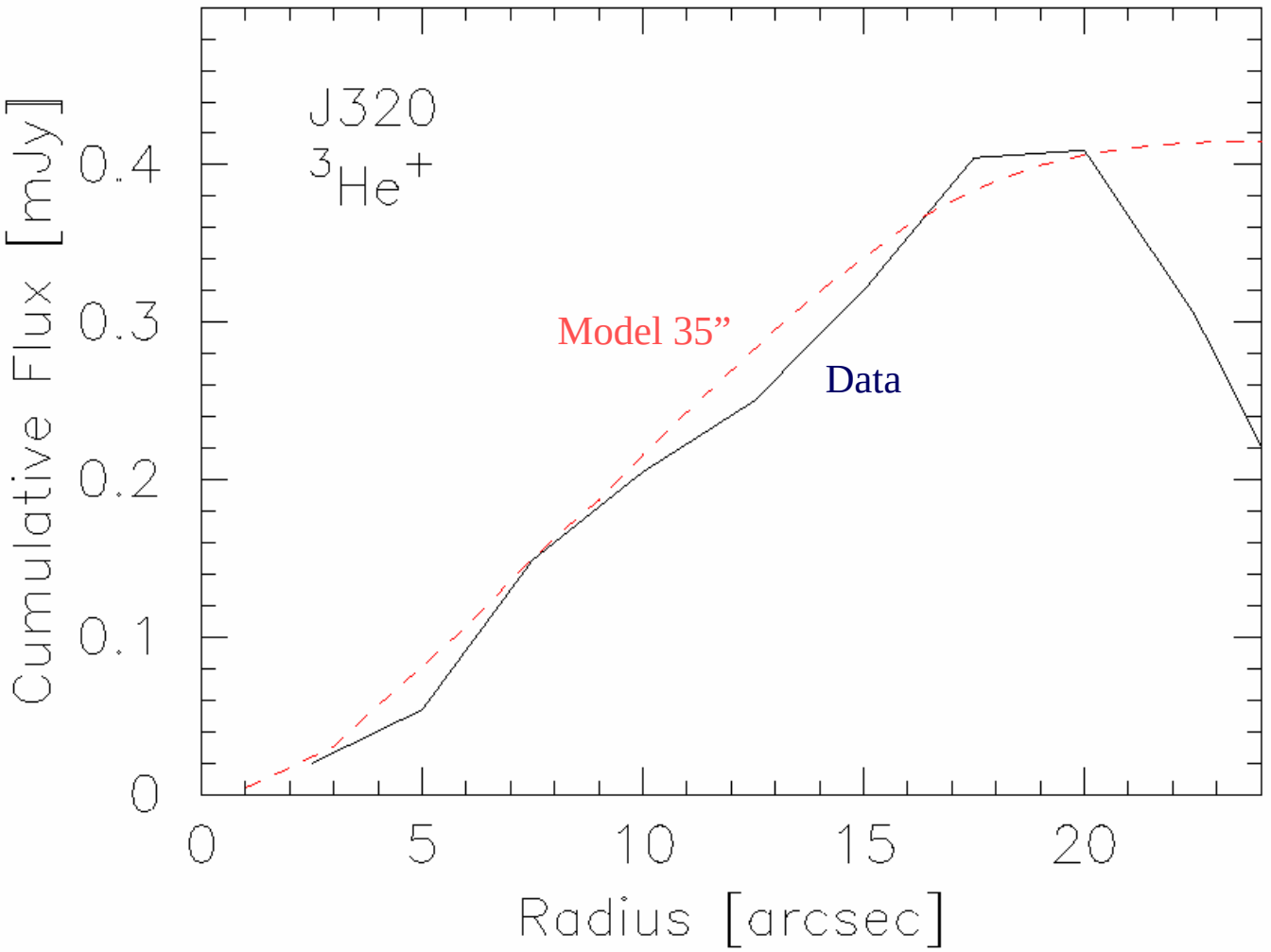
The PN sample:

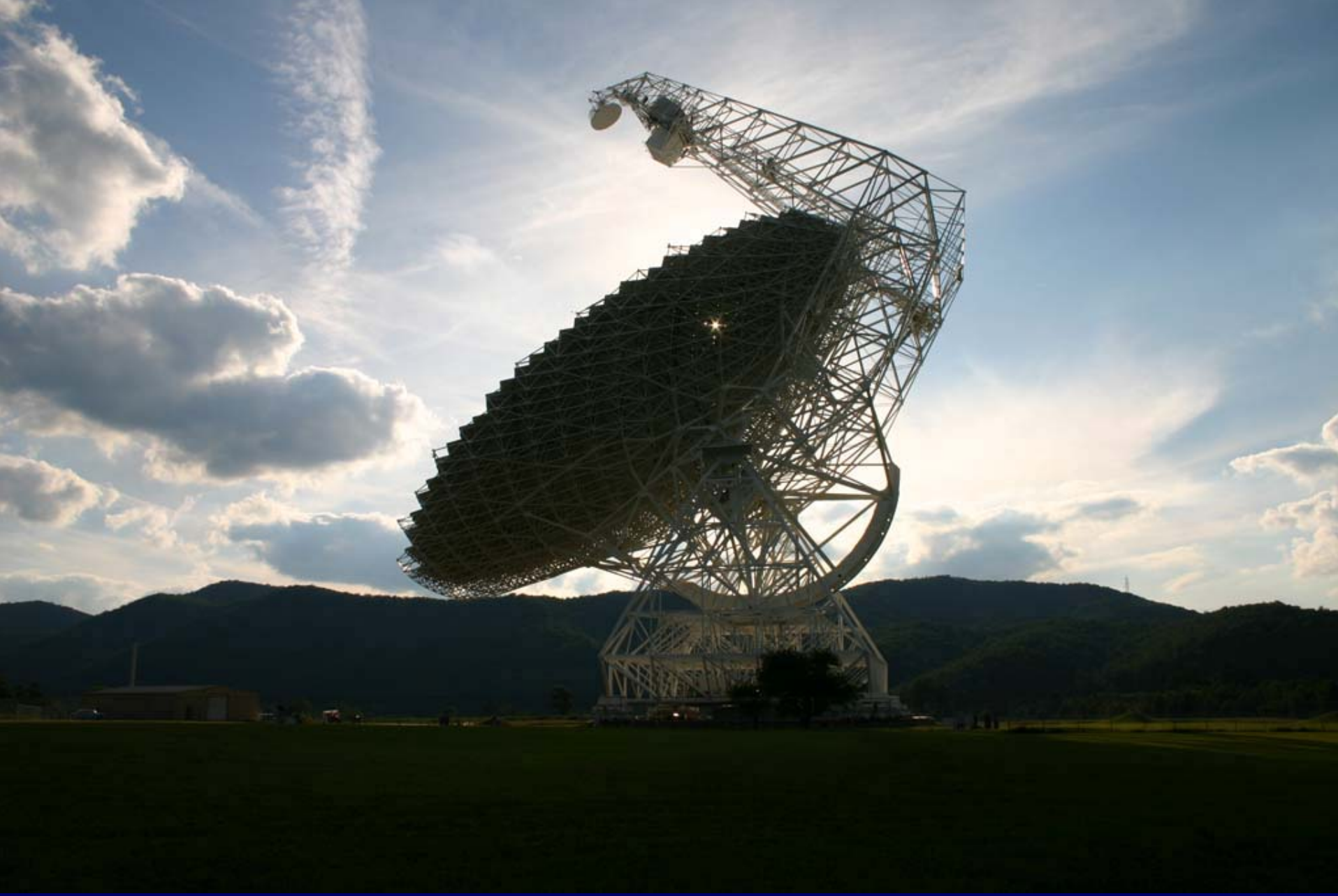
Why should I read a slide to you?

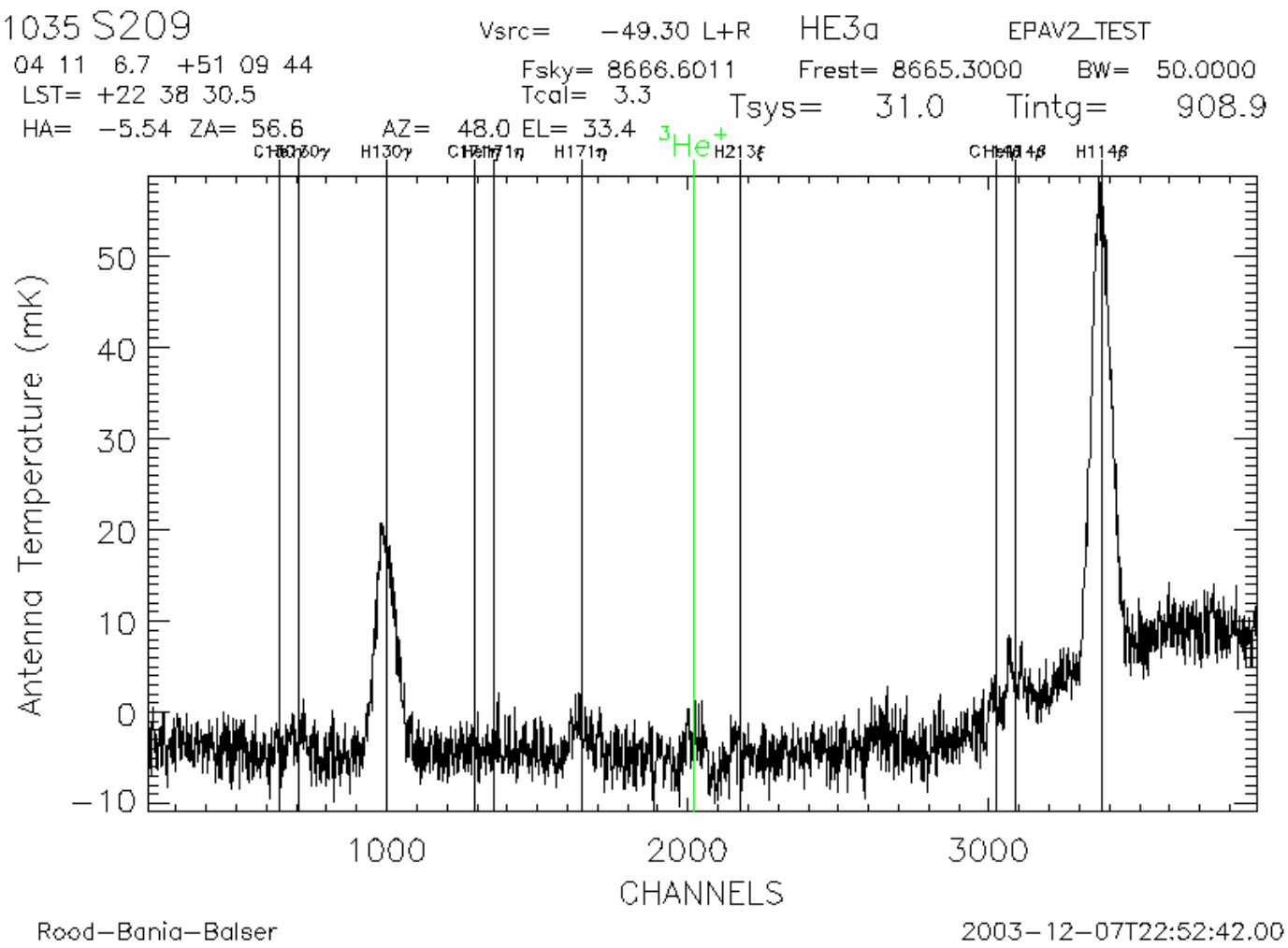
PNe He3 at the VLA: Balser, Goss, Bania, Rood (2005)

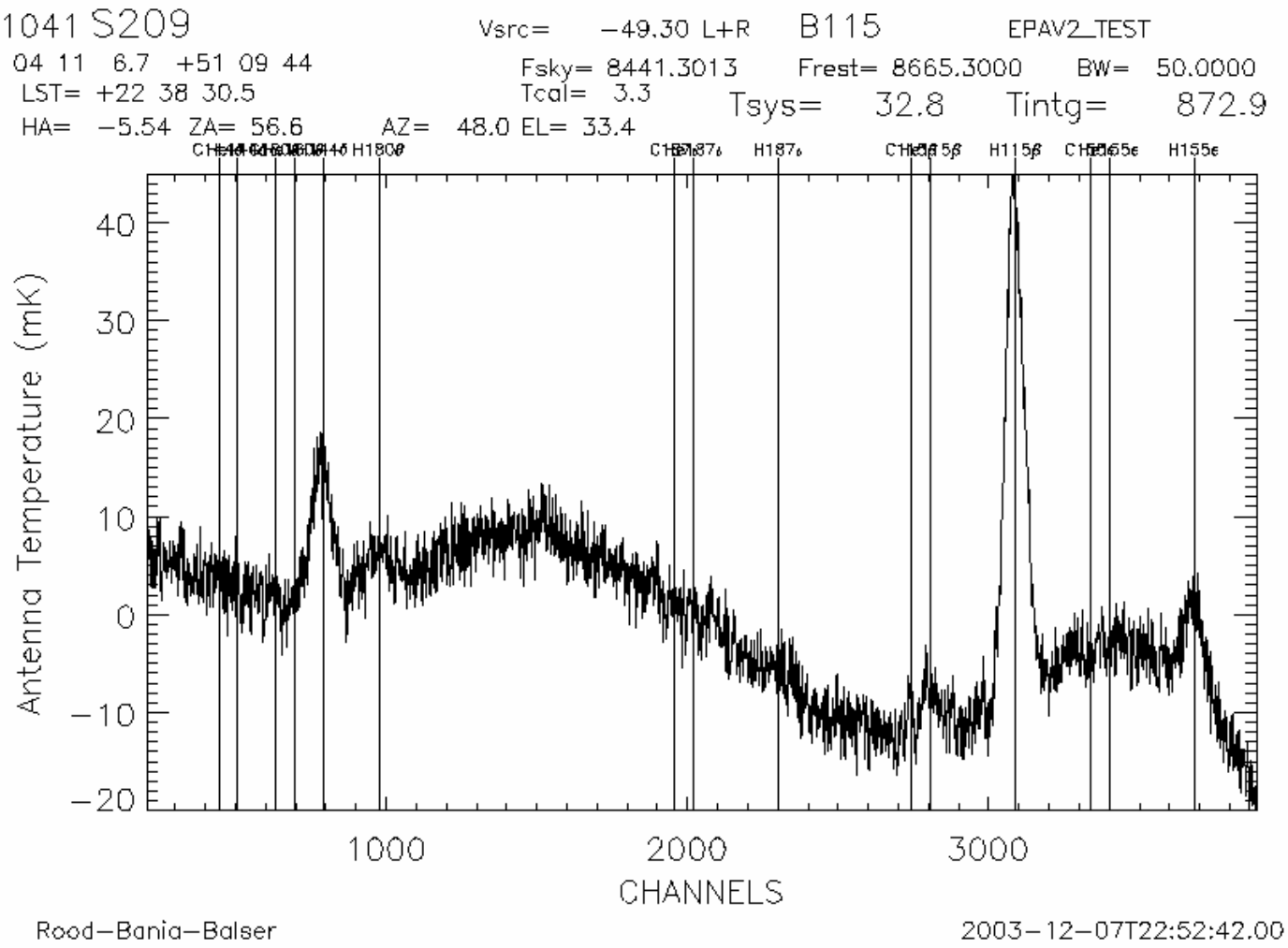
J320 $^3He^+$

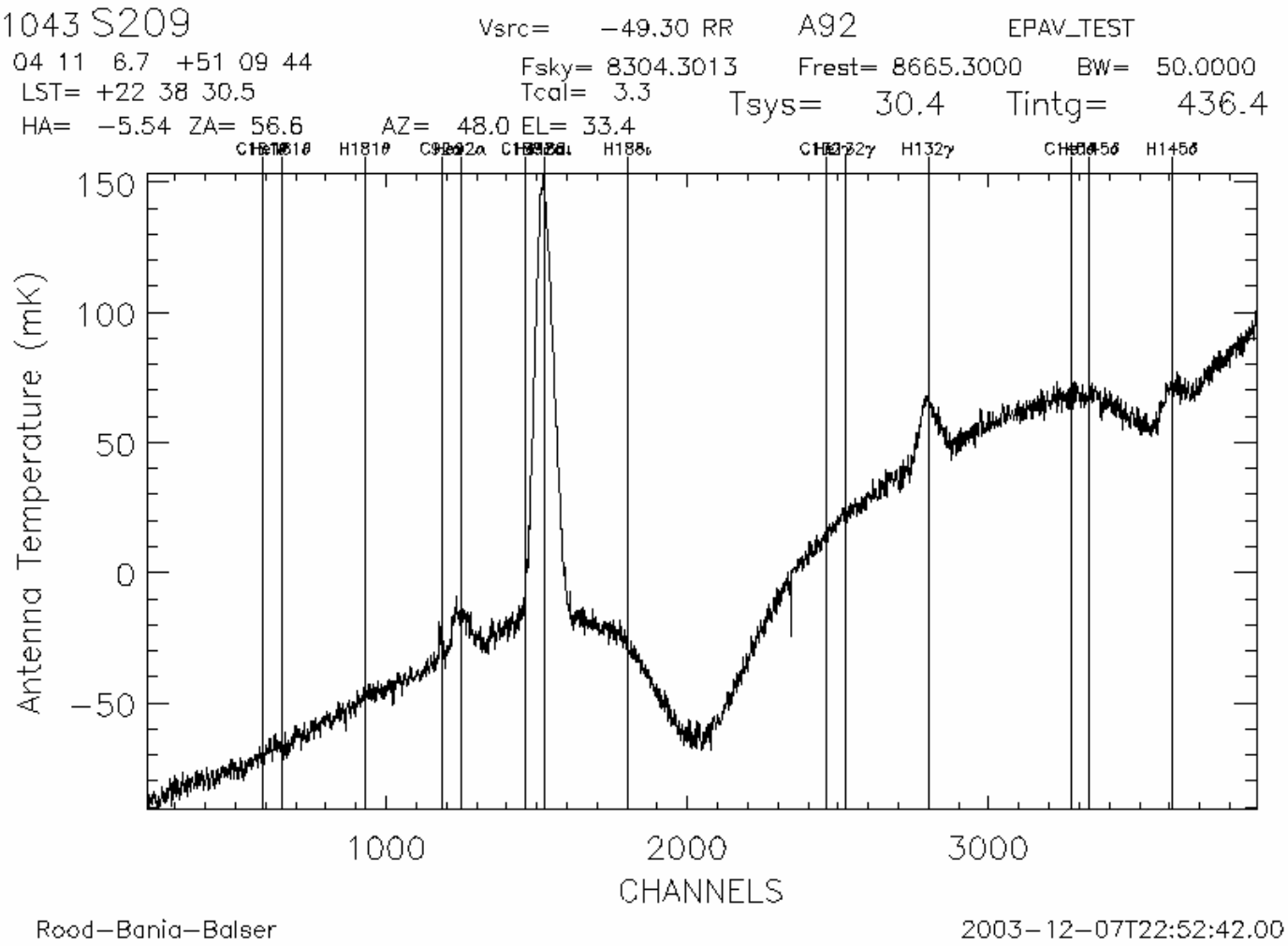

Flux Density [mJy/Beam]
0.4
0.2
0
Θ_b = 30"
−150
−100
−50
0
50
V_{LSR} [km s^{-1}]


J320
$^3He^+$
Model 35”
Data
Cumulative Flux [mJy]
0
0.1
0.2
0.3
0.4
0
5
10
15
20
Radius [arcsec]

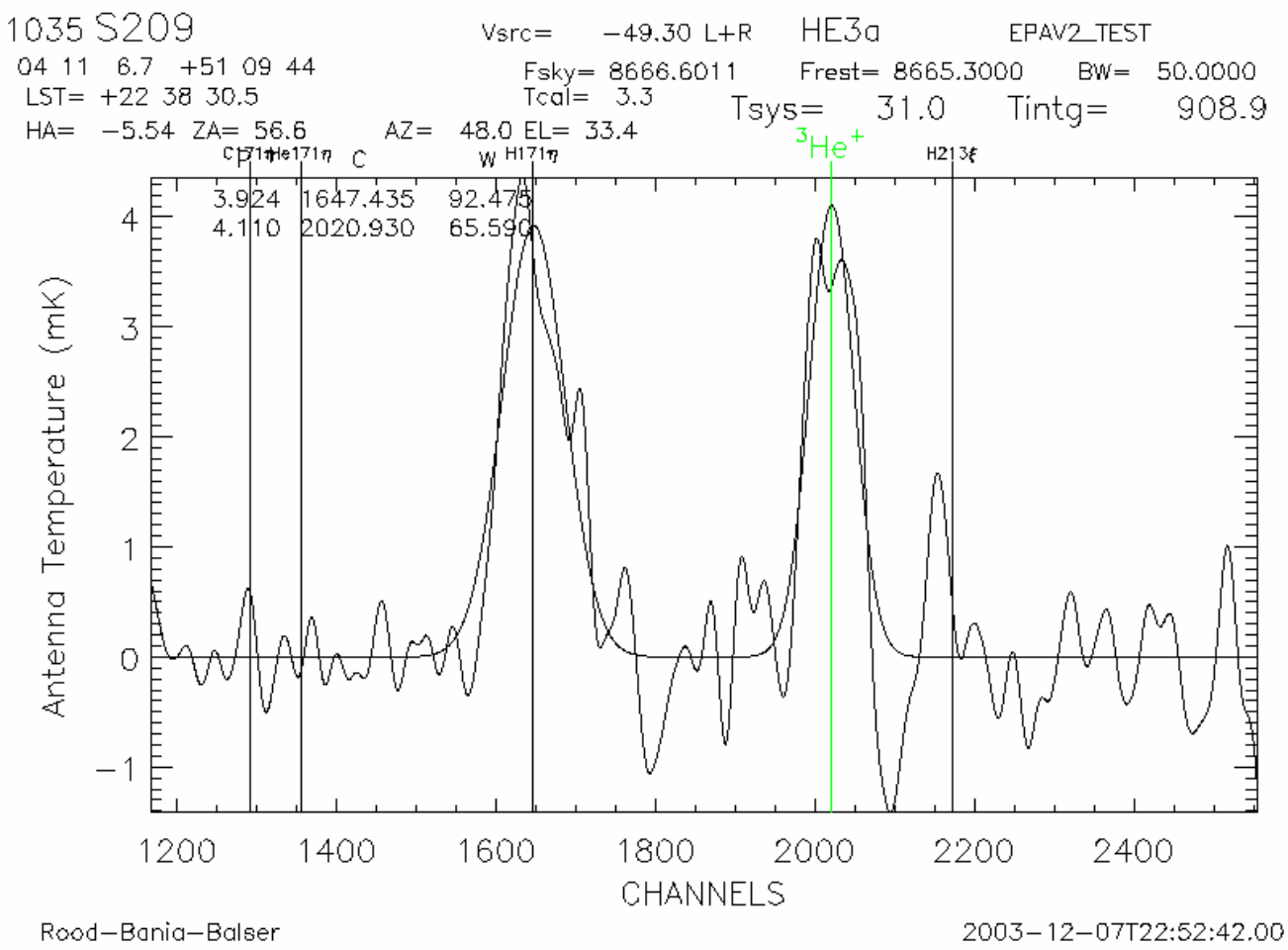



1035 S209
Vsrc= −49.30 L+R
HE3a
EPAV2_TEST
04 11 6.7 +51 09 44
Fsky= 8666.6011
Frest= 8665.3000
BW= 50.0000
LST= +22 38 30.5
Tcal= 3.3
Tsys= 31.0
Tintg= 908.9
HA= −5.54 ZA= 56.6
AZ= 48.0 EL= 33.4
H130γ
H171η
H171η
3He+
H213ξ
H114β
50
40
30
20
10
0
−10
Antenna Temperature (mK)
1000
2000
3000
CHANNELS
Rood−Bania−Balser
2003−12−07T22:52:42.00

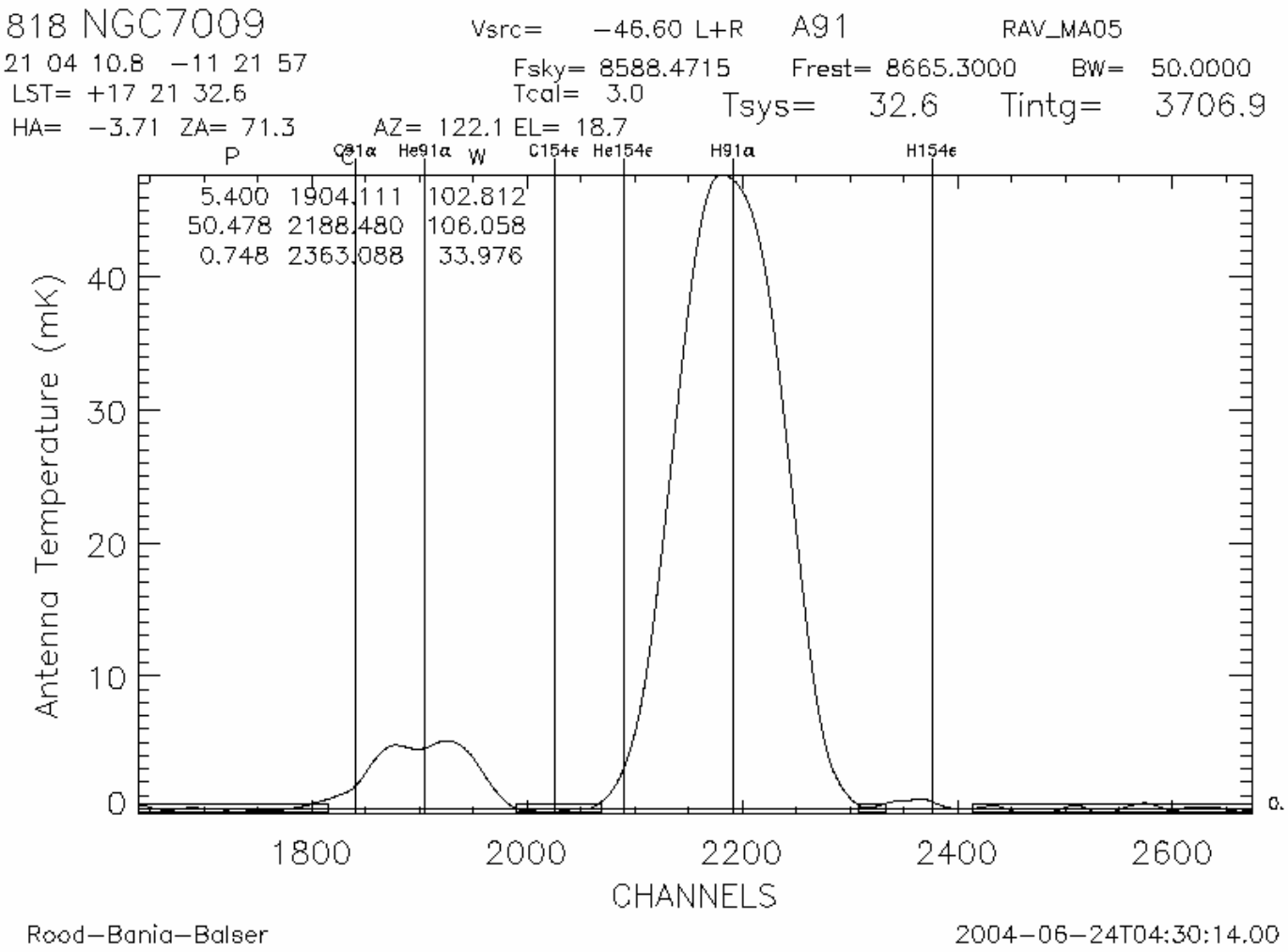

1041 S209
04 11 6.7 +51 09 44
LST= +22 38 30.5
HA= −5.54 ZA= 56.6 AZ= 48.0 EL= 33.4
Vsrc= −49.30 L+R
Fsky= 8441.3013
Tcal= 3.3
B115
EPAV2_TEST
Frest= 8665.3000
BW= 50.0000
Tsys= 32.8
Tintg= 872.9
H187δ
H187ε
H115β
H155ε
Antenna Temperature (mK)
40
30
20
10
0
−10
−20
1000
2000
3000
CHANNELS
Rood−Bania−Balser
2003−12−07T22:52:42.00

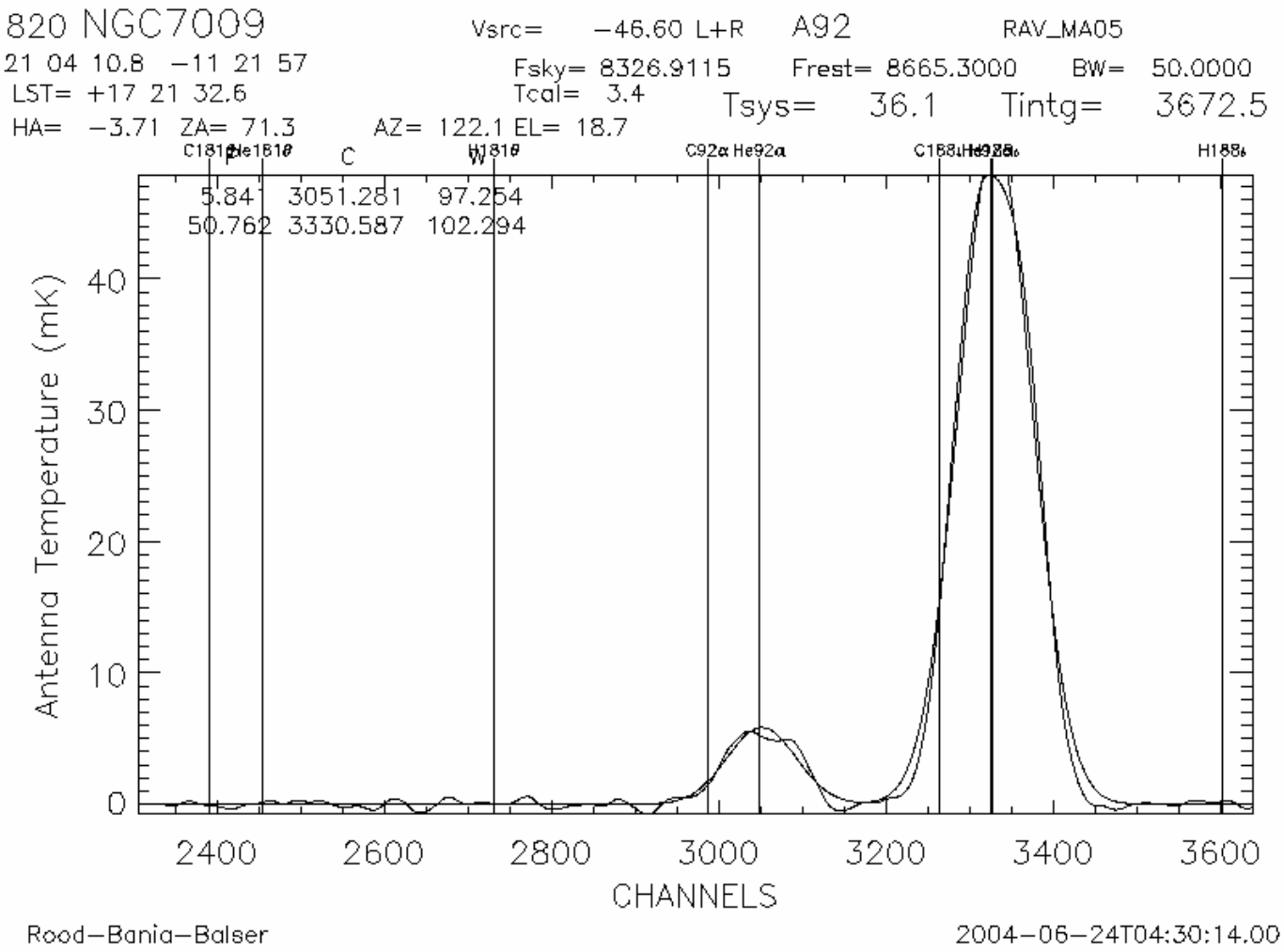


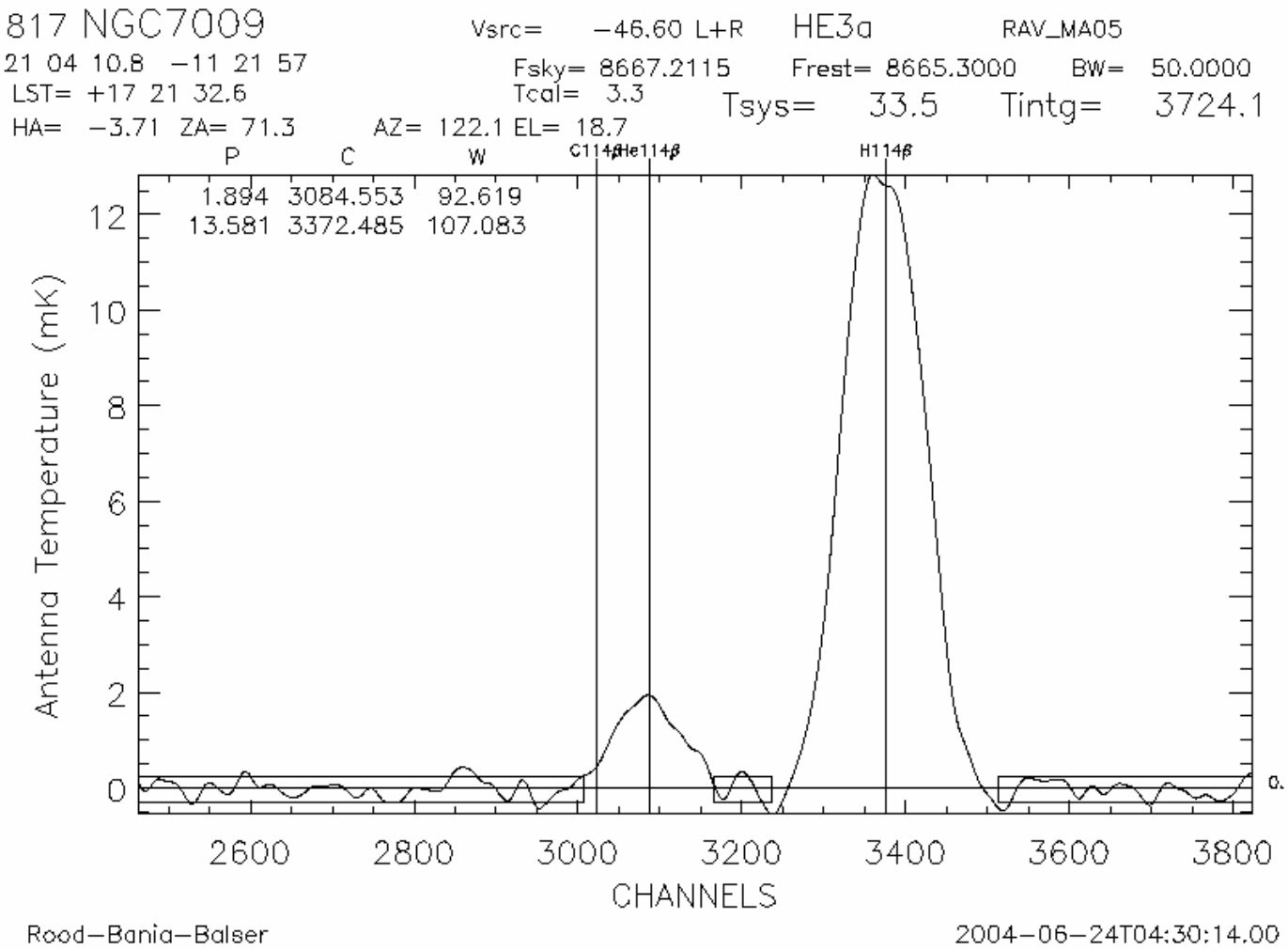
Some days it’s chicken; some days it’s feathers

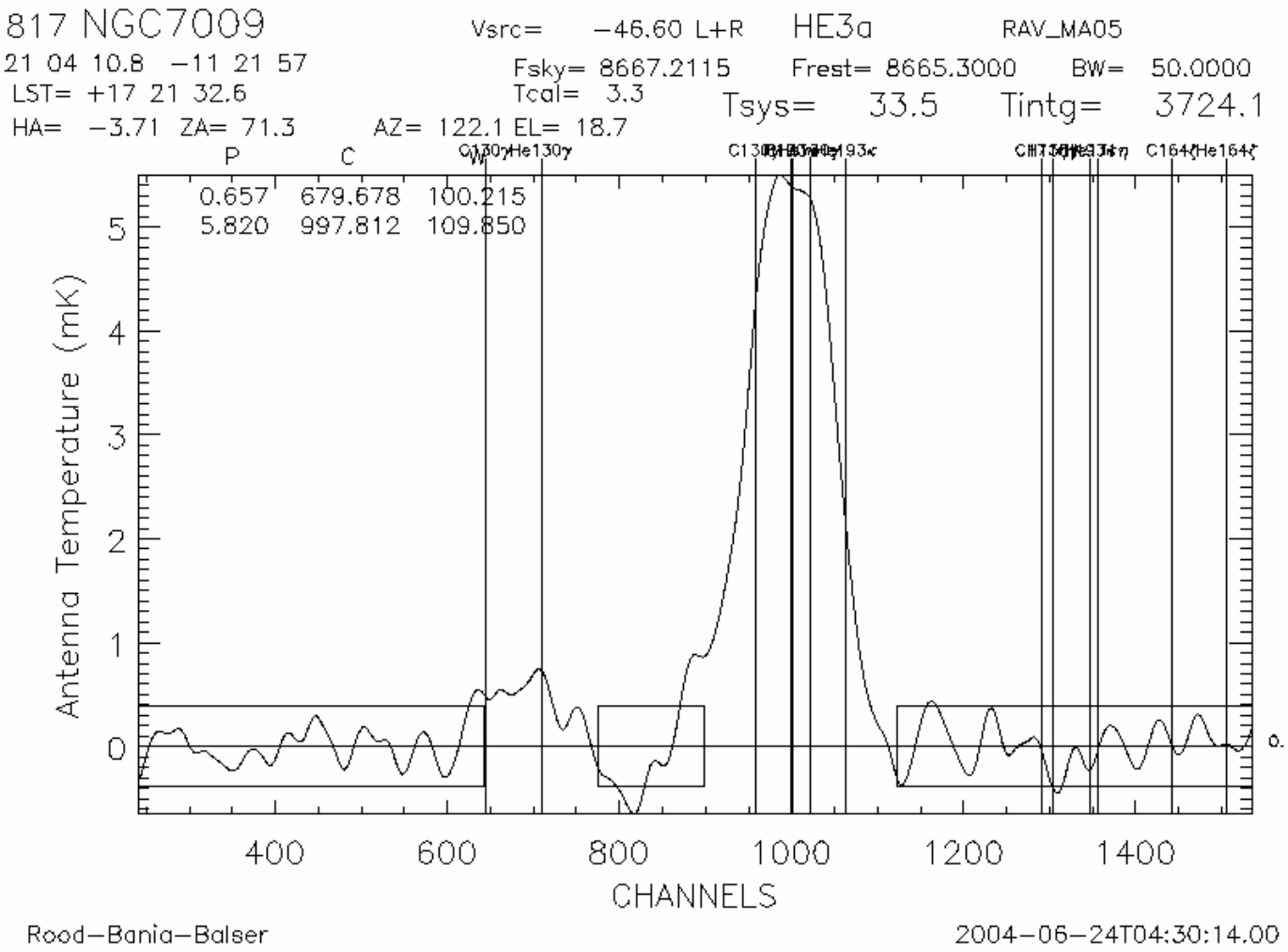


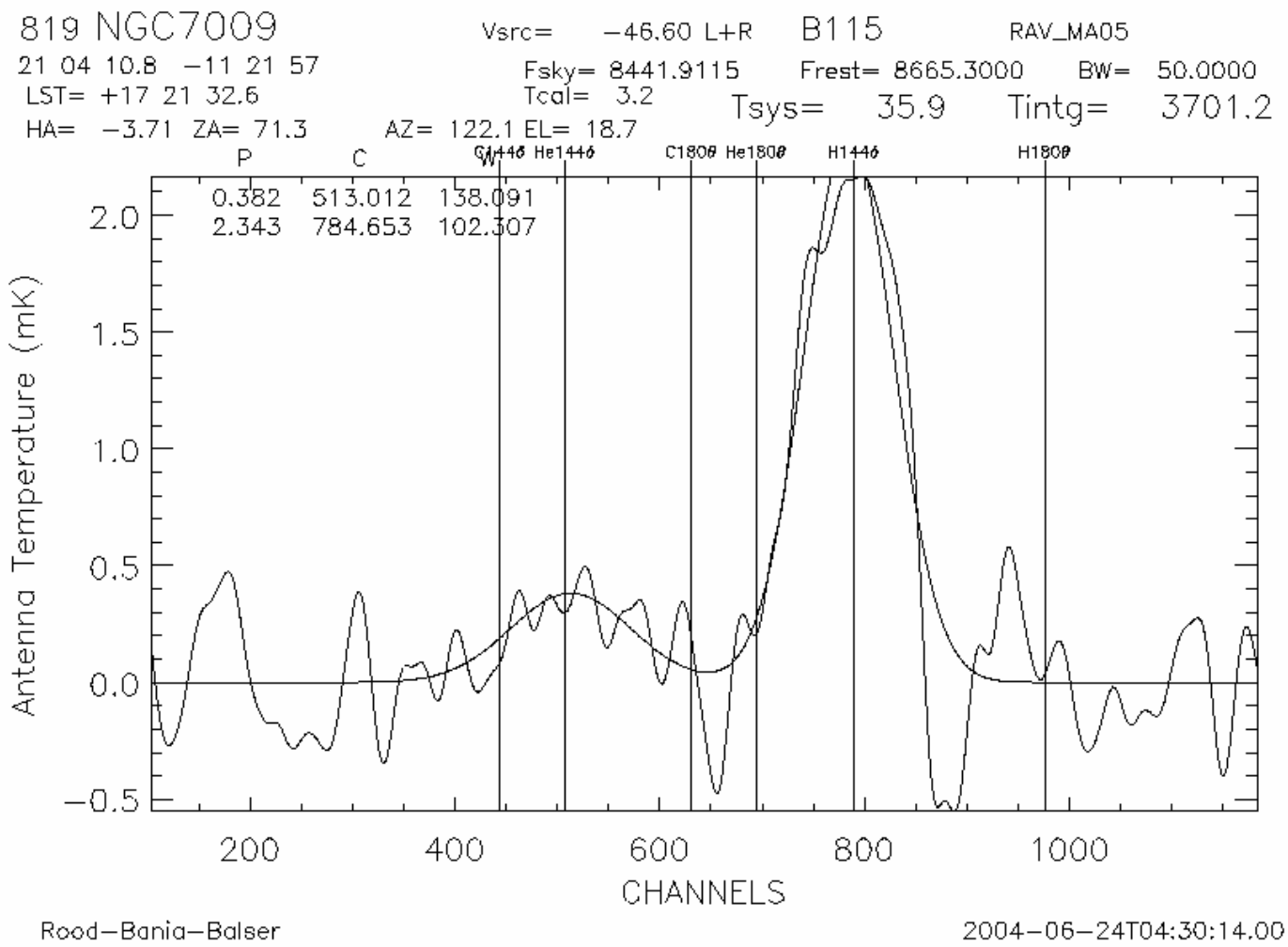
He3 in S209 in only 7.5hr!


818 NGC7009
21 04 10.8 −11 21 57
LST= +17 21 32.6
HA= −3.71 ZA= 71.3
Vsrc= −46.60 L+R
AZ= 122.1 EL= 18.7
A91
RAV_MA05
Fsky= 8588.4715
Frest= 8665.3000
BW= 50.0000
Tcal= 3.0
Tsys= 32.6
Tintg= 3706.9
P
C
C91α
He91α
W
C154α
He154α
H91α
H154α
5.400 1904.111 102.812
50.478 2188.480 106.058
0.748 2363.088 33.976
Antenna Temperature (mK)
0
10
20
30
40
1800
2000
2200
2400
2600
CHANNELS
Rood−Bania−Balser
2004−06−24T04:30:14.00

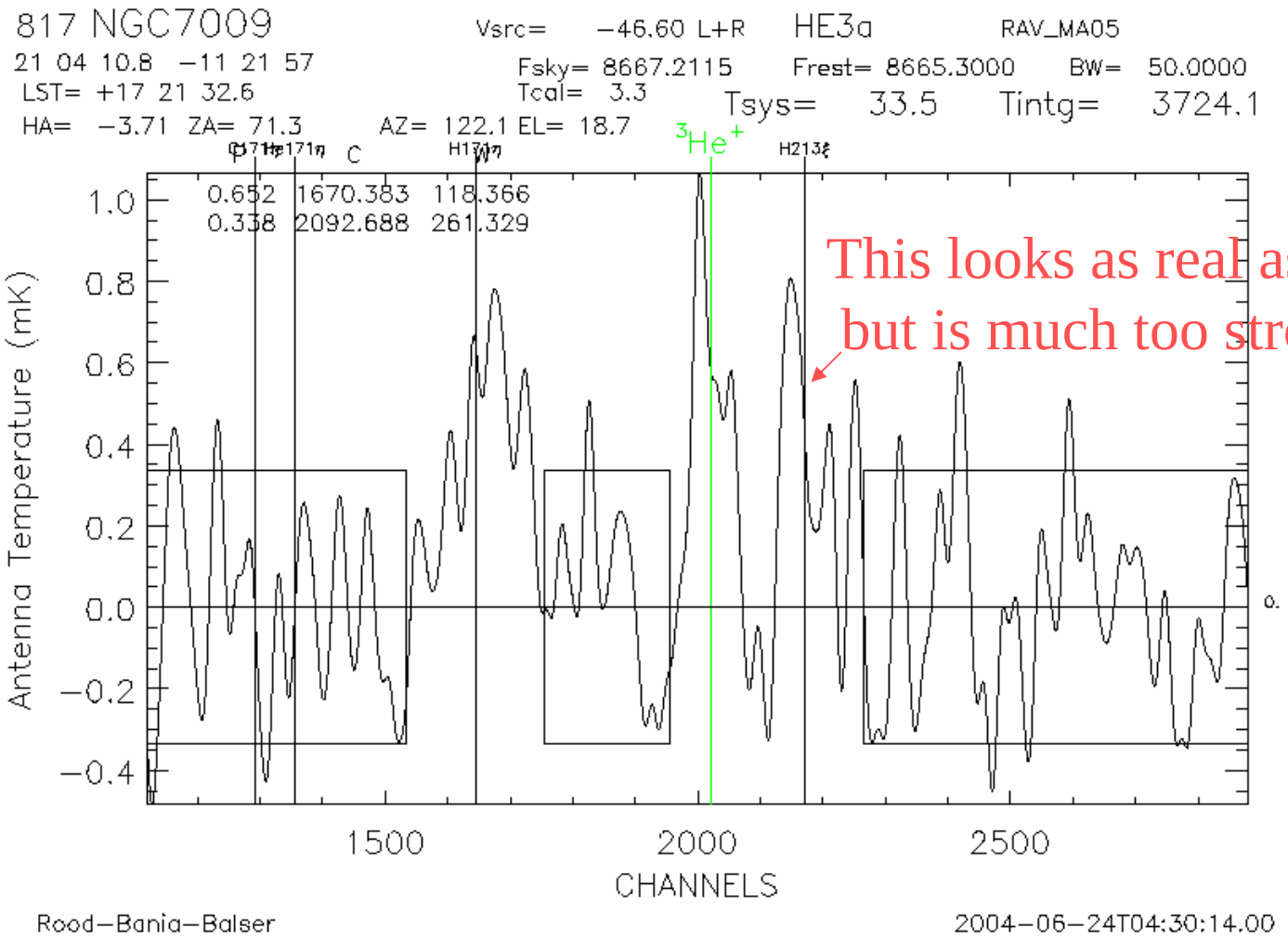

820 NGC7009
Vsrc= −46.60 L+R A92 RAV_MA05
21 04 10.8 −11 21 57
Fsky= 8326.9115 Frest= 8665.3000 BW= 50.0000
LST= +17 21 32.6
Tcal= 3.4
Tsys= 36.1 Tintg= 3672.5
HA= −3.71 ZA= 71.3 AZ= 122.1 EL= 18.7
C
W
C92α He92α
H188δ
5.84 3051.281 97.254
50.762 3330.587 102.294
Antenna Temperature (mK)
0
10
20
30
40
2400
2600
2800
3000
3200
3400
3600
CHANNELS
Rood−Bania−Balser
2004−06−24T04:30:14.00

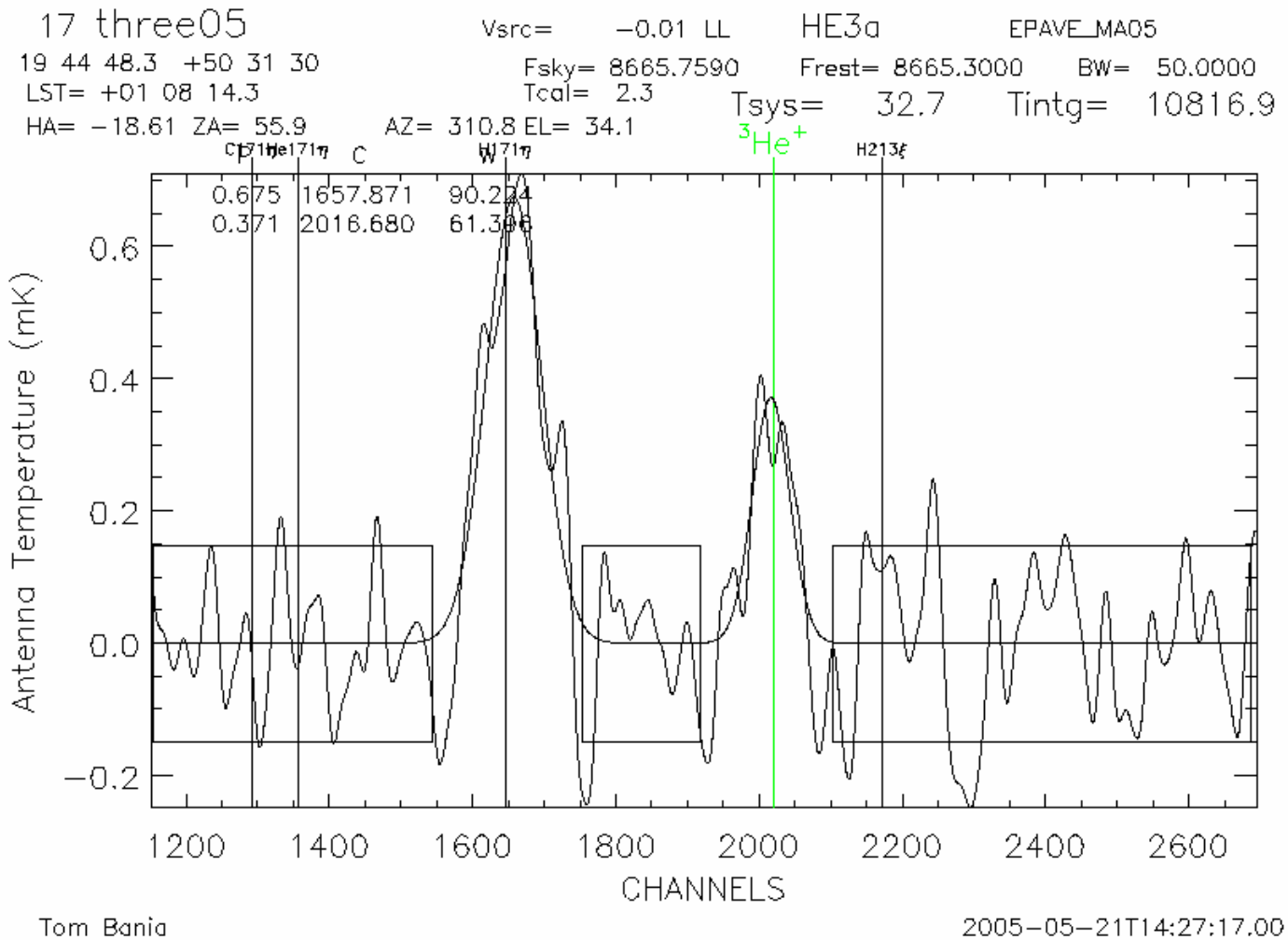

817 NGC7009
21 04 10.8 −11 21 57
LST= +17 21 32.6
HA= −3.71 ZA= 71.3 AZ= 122.1 EL= 18.7
Vsrc= −46.60 L+R
Fsky= 8667.2115
Tcal= 3.3
HE3a
RAV_MA05
Frest= 8665.3000
BW= 50.0000
Tsys= 33.5
Tintg= 3724.1
P C W
1.894 3084.553 92.619
13.581 3372.485 107.083
C114βHe114β
H114β
Antenna Temperature (mK)
CHANNELS
Rood−Bania−Balser
2004−06−24T04:30:14.00


817 NGC7009
21 04 10.8 −11 21 57
LST= +17 21 32.6
HA= −3.71 ZA= 71.3 AZ= 122.1 EL= 18.7
Vsrc= −46.60 L+R
Fsky= 8667.2115
Tcal= 3.3
HE3a
RAV_MA05
Frest= 8665.3000
BW= 50.0000
Tsys= 33.5
Tintg= 3724.1
P C
0.657 679.678 100.215
5.820 997.812 109.850
C130γHe130γ
C164ζHe164ζ
Antenna Temperature (mK)
CHANNELS
Rood−Bania−Balser
2004−06−24T04:30:14.00

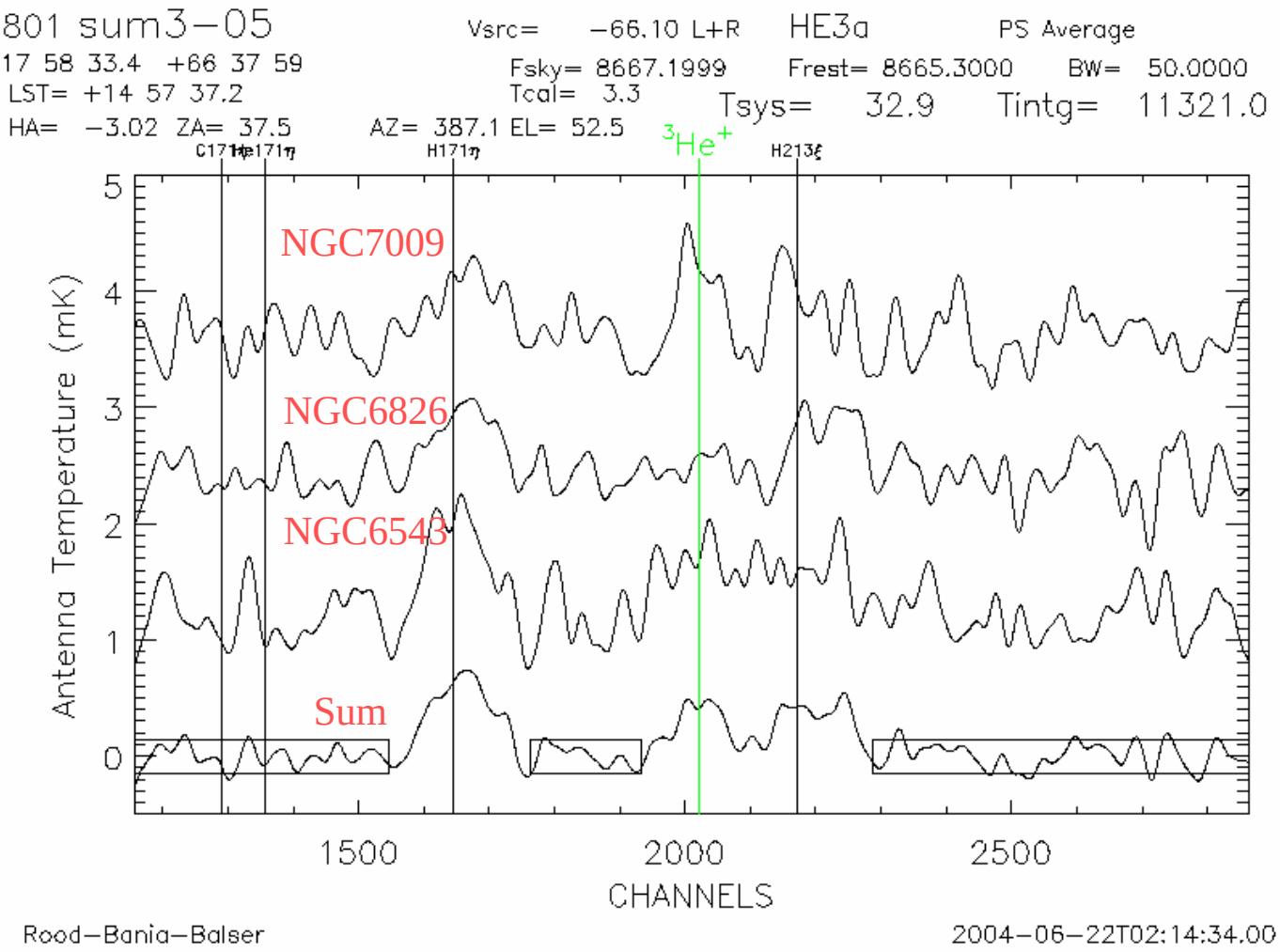


Conclude reliability level for NGC7009 ~ 0.5 mK


817 NGC7009
21 04 10.8 −11 21 57
LST= +17 21 32.6
HA= −3.71 ZA= 71.3 AZ= 122.1 EL= 18.7
Vsrc= −46.60 L+R HE3a RAV_MA05
Fsky= 8667.2115 Frest= 8665.3000 BW= 50.0000
Tcal= 3.3 Tsys= 33.5 Tintg= 3724.1
0.652 1670.383 118.366
0.338 2092.688 261.329
This looks as real as He3
but is much too strong
Antenna Temperature (mK)
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
1500
2000
2500
CHANNELS
Rood−Bania−Balser
2004−06−24T04:30:14.00



NGC7009 + NGC6543 + NGC6826


801 sum3−05
17 58 33.4 +66 37 59
LST= +14 57 37.2
HA= −3.02 ZA= 37.5
Vsrc= −66.10 L+R
HE3a
PS Average
Fsky= 8667.1999
Frest= 8665.3000
BW= 50.0000
Tcal= 3.3
Tsys= 32.9
Tintg= 11321.0
AZ= 387.1 EL= 52.5
H171η
3He+
H213ξ
NGC7009
NGC6826
NGC6543
Sum
Antenna Temperature (mK)
0
1
2
3
4
5
1500
2000
2500
CHANNELS
Rood−Bania−Balser
2004−06−22T02:14:34.00

GBT Conclusions

- Standing waves are not a problem
- There is still baseline structure (BS) probably resulting from the broadband feed, the polarizer, and or mismatches in the IF system.
  - BS varies with frequency sometimes almost invisible other times very problematic
  - BS amplitude is proportional to source continuum and moves with sky frequency
- At the mK level there are pseudo-lines
- In some AC bands there are short duration spikes in the ACF at seemingly random times, lags, and amplitudes

Helium-3 Conclusions

- We have found helium-3 in another PN, J320, using the VLA
- We probably have found helium-3 in NGC7009 using the GBT and may have a second detection in NGC6543
- Roughly 25% of PNe meet our selection criteria. To avoid conflict with Monica we should detect 3He in only 1/5
- The scheduling mode and proposal pressure on the GBT may not allow us to solidify these results in the near future.
- The EVLA (10 x more sensitive than the VLA) has great potential

A bonus: He^{++} or O^{++} RRL (a first?)