

# Helium-3 in Planetary Nebulae

Rood, Bania (BU), Balser (NRAO),  
Goss (NRAO), Quireza (ON, Brazil),  
Wilson (MPIfR)

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

Analog of the 21 cm line of H

$$\nu = 8665.65 \text{ MHz}$$

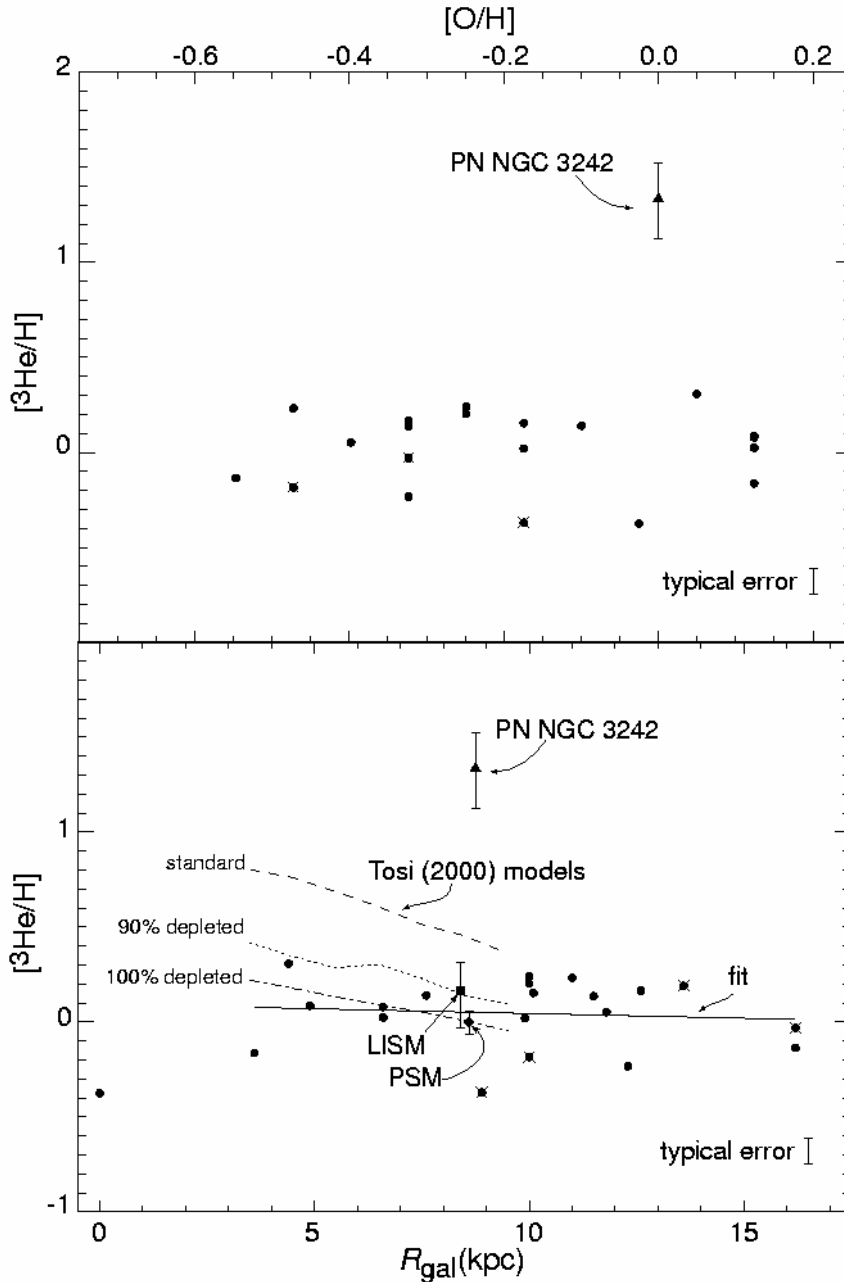
$$\lambda = 3.36 \text{ cm}$$

# Bania, Rood, & Balser 2002

$$\eta_{10} = 5.4^{+2.2}_{-1.2}$$
$$\Omega_B = 0.04$$

# Spergel et al. 2003, WMAP

$$\eta_{10} = 6.5^{+0.4}_{-0.3}$$
$$\Omega_B = 0.047 \pm 0.006$$



One is not enough!

Except in cosmology

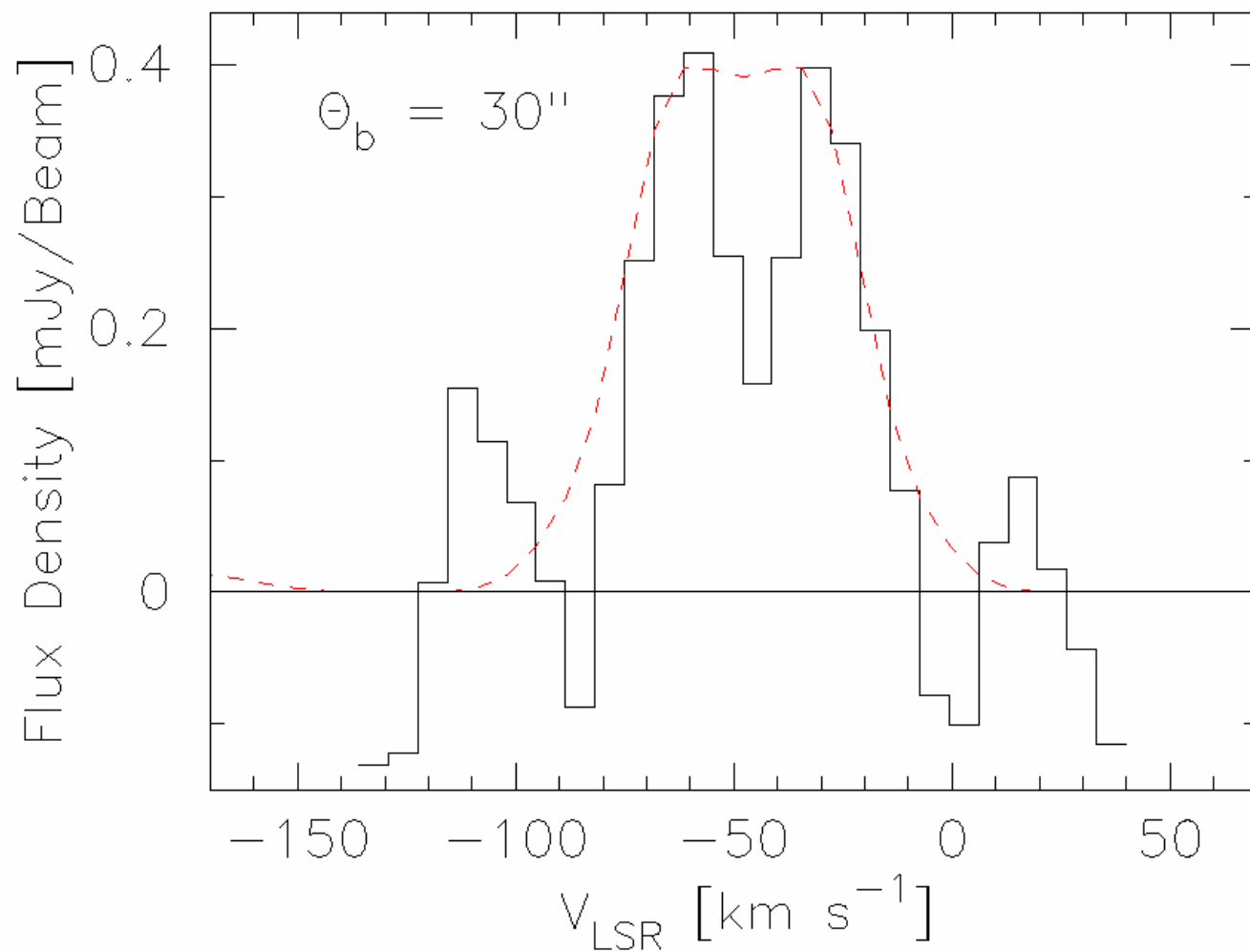
The PN sample:

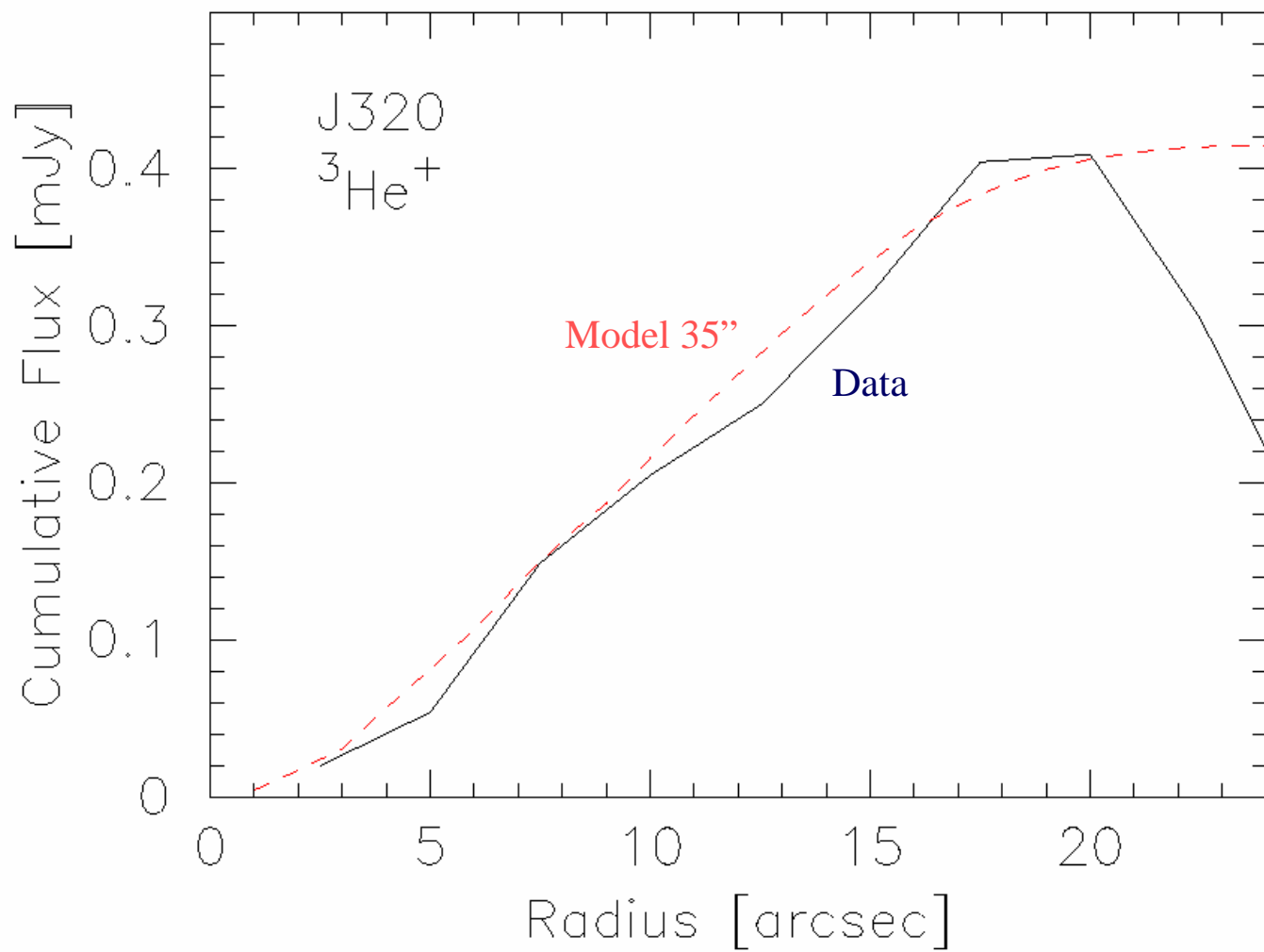
*Why should I read a slide to you?*



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

J320  $^3\text{He}^+$

















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

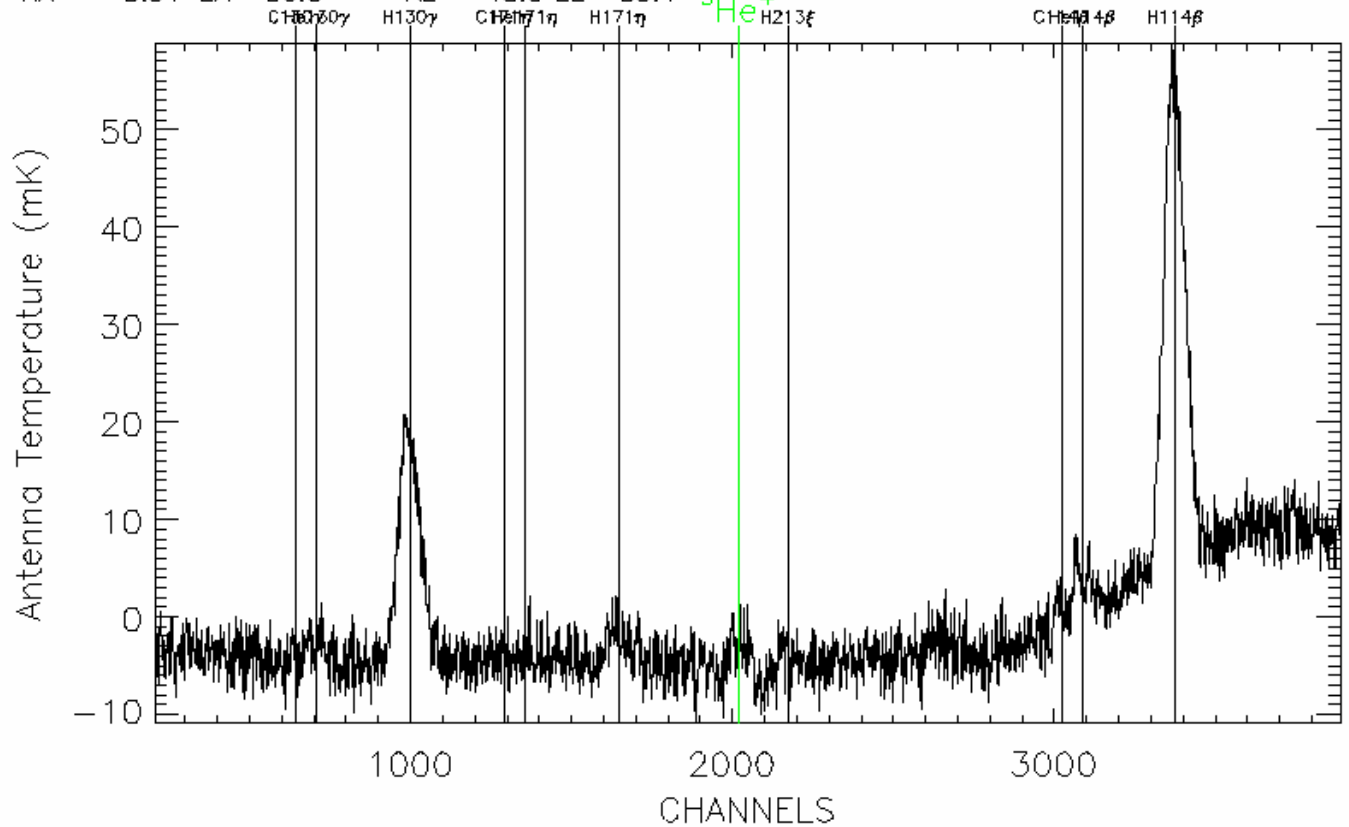
LST= +22 38 30.5

Tcal= 3.3

Tsys= 31.0 Tintg= 908.9

HA= -5.54 ZA= 56.6

AZ= 48.0 EL= 33.4



Rood-Bania-Balser

2003-12-07T22:52:42.00

1041 S209

Vsrc= -49.30 L+R B115 EPAV2\_TEST

04 11 6.7 +51 09 44

Fsky= 8441.3013 Frest= 8665.3000 BW= 50.0000

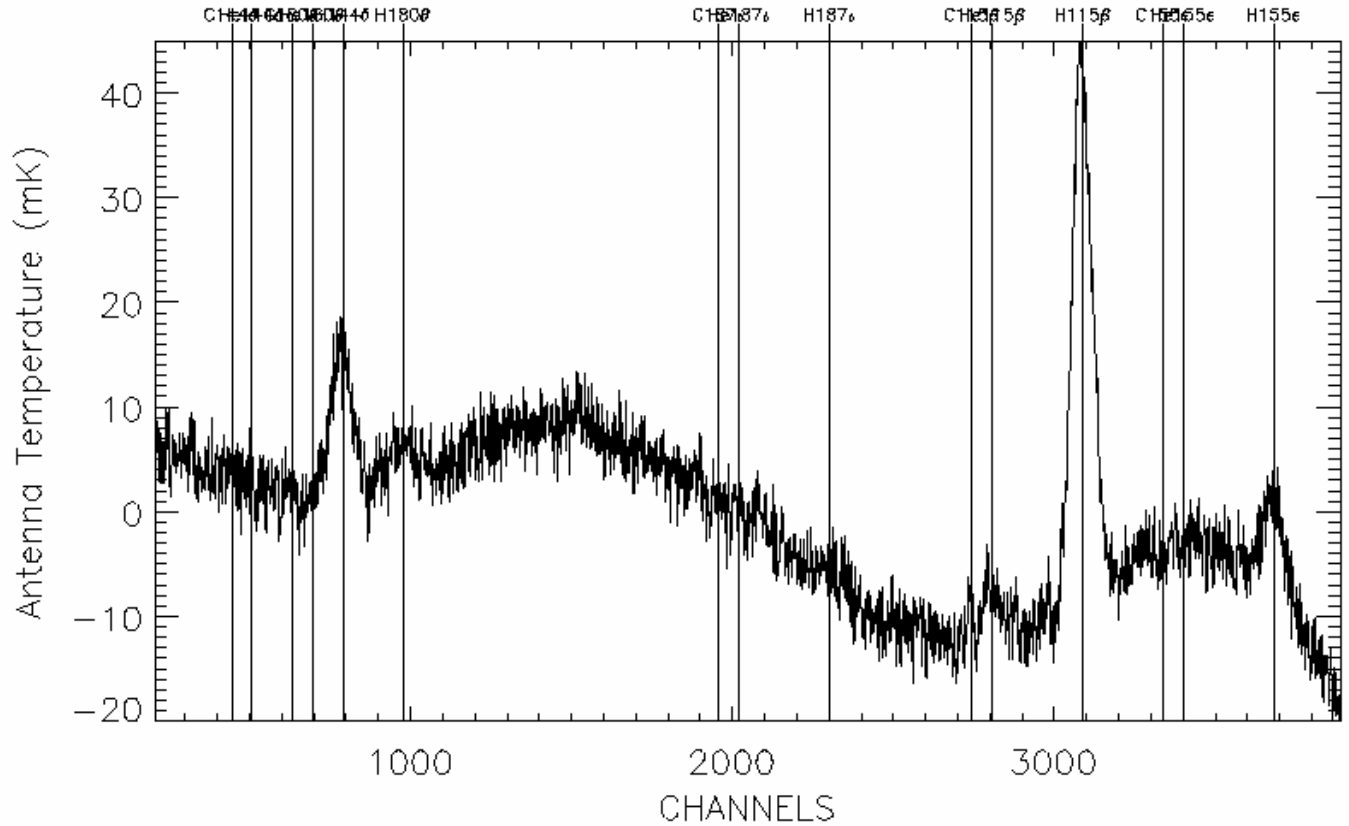
LST= +22 38 30.5

Tcal= 3.3

Tsys= 32.8 Tintg= 872.9

HA= -5.54 ZA= 56.6

AZ= 48.0 EL= 33.4



Rood-Bania-Balser

2003-12-07T22:52:42.00

1043 S209

Vsrc= -49.30 RR

A92

EPAV\_TEST

04 11 6.7 +51 09 44

Fsky= 8304.3013

Frest= 8665.3000

BW= 50.0000

LST= +22 38 30.5

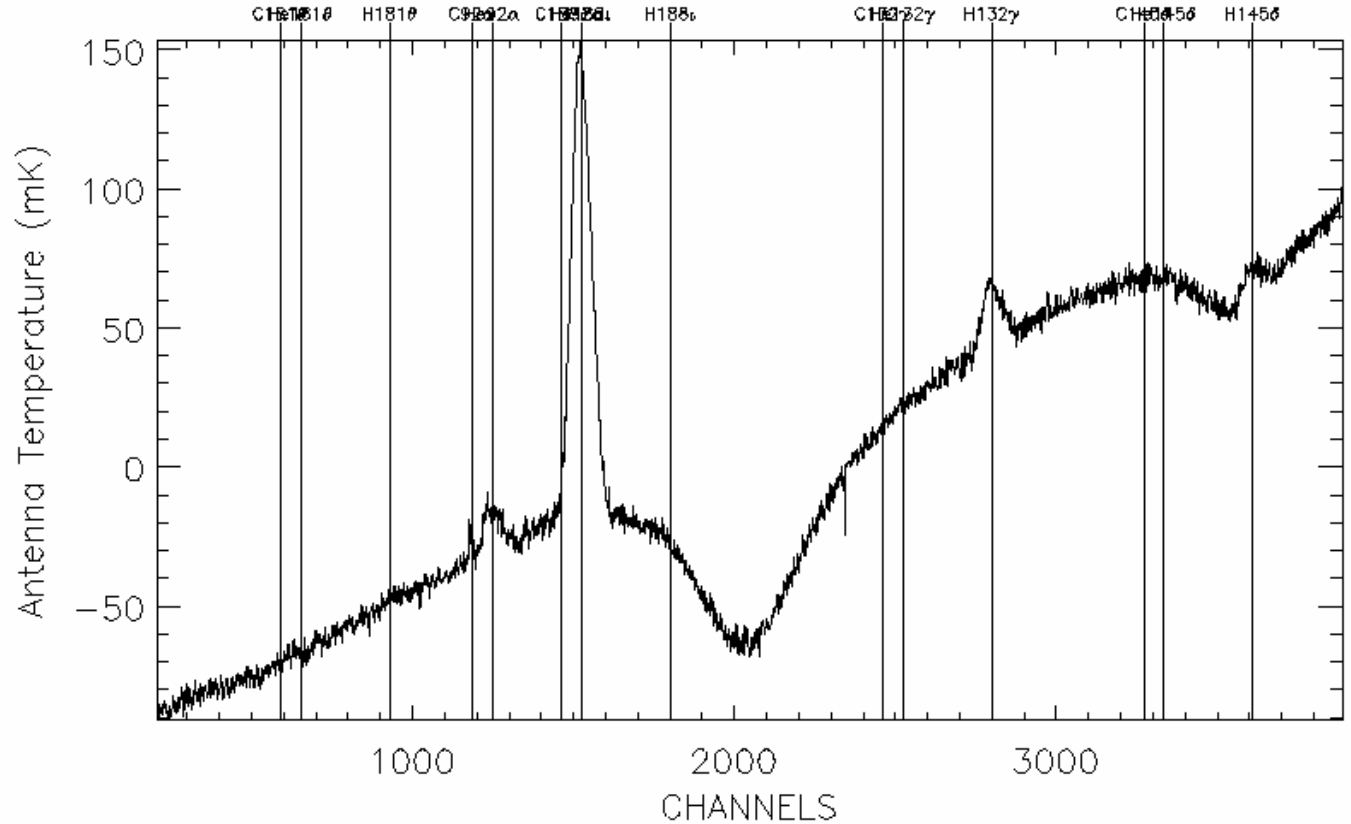
Tcal= 3.3

Tsys= 30.4

Tintg= 436.4

HA= -5.54 ZA= 56.6

AZ= 48.0 EL= 33.4



Rood-Bania-Balser

2003-12-07T22:52:42.00

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



1035 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

HE3a

EPAV2\_TEST

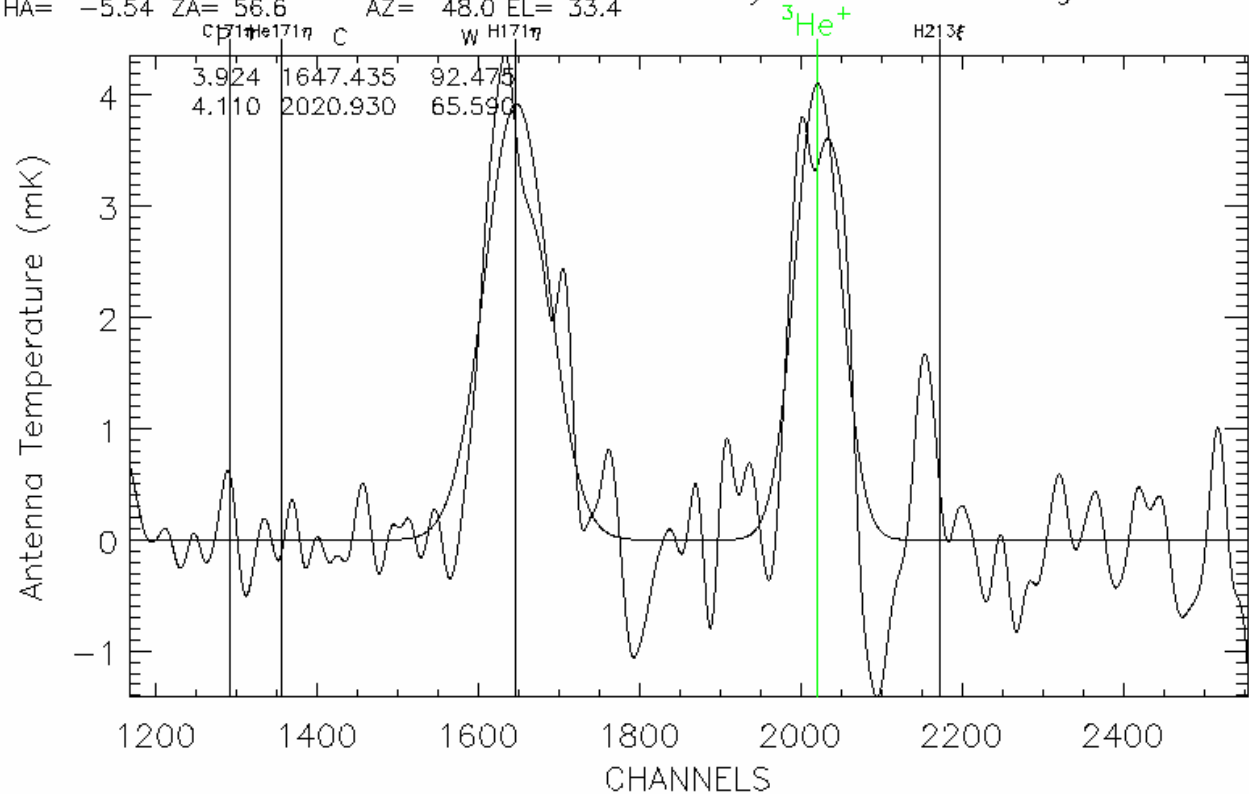
Fsky= 8666.6011

Frest= 8665.3000 BW= 50.0000

Tcal= 3.3

Tsys= 31.0

Tintg= 908.9



Rood-Bania-Balser

2003-12-07T22:52:42.00

**He3 in S209 in only 7.5hr!**

818 NGC7009

Vsrc= -46.60 L+R A91

RAV\_MA05

21 04 10.8 -11 21 57

Fsky= 8588.4715 Frest= 8665.3000 BW= 50.0000

LST= +17 21 32.6

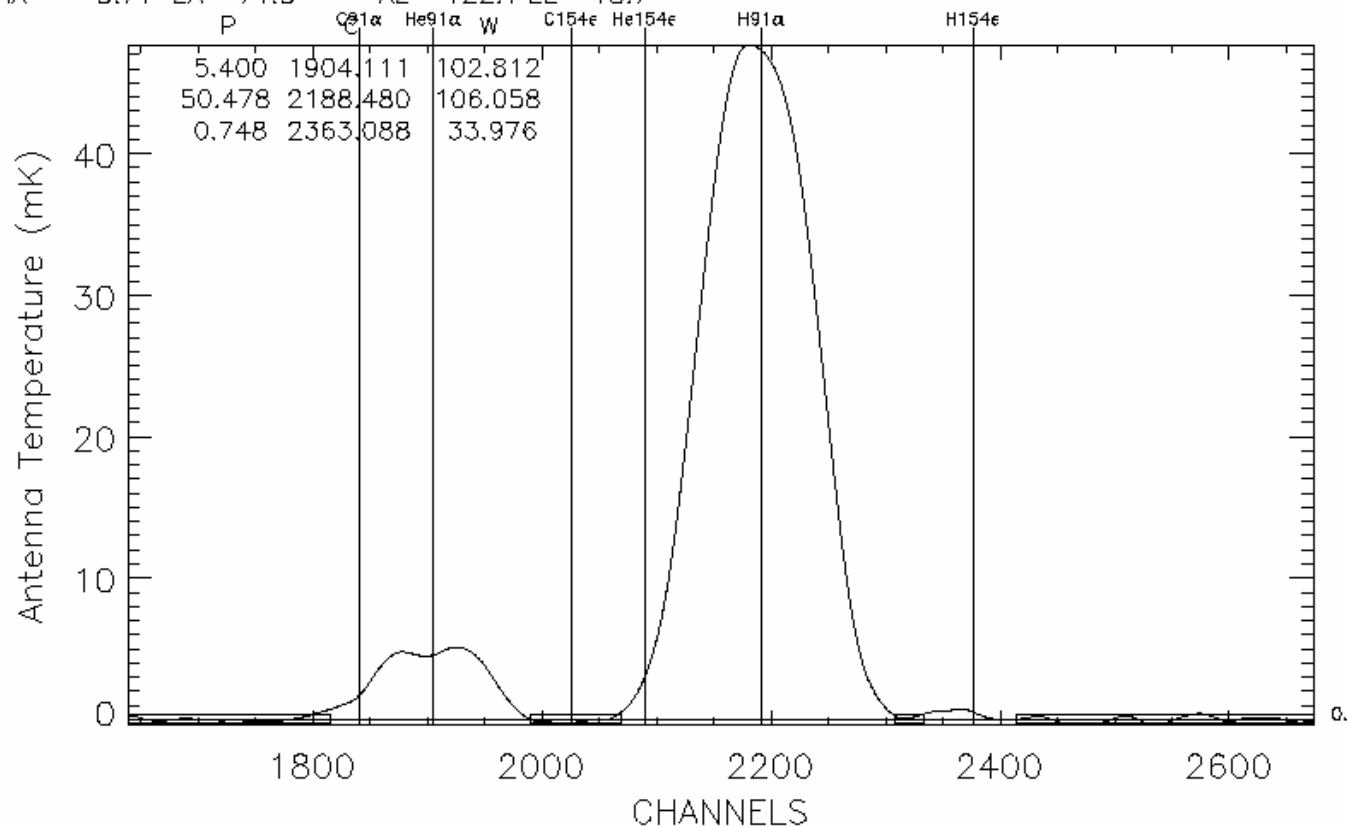
Tcal= 3.0

Tsys= 32.6

Tintg= 3706.9

HA= -3.71 ZA= 71.3

AZ= 122.1 EL= 18.7



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

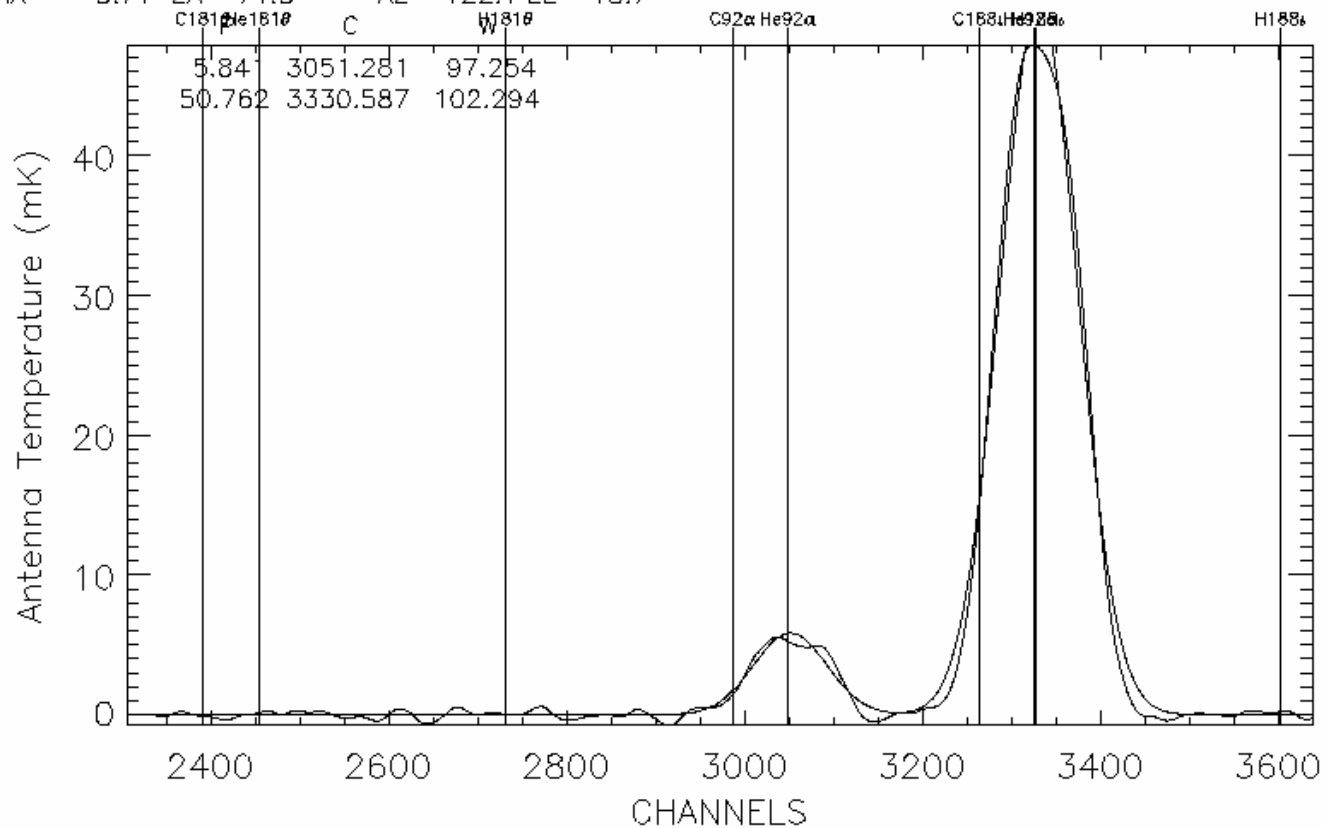
LST= +17 21 32.6

Tcal= 3.4

Tsys= 36.1 Tintg= 3672.5

HA= -3.71 ZA= 71.3

AZ= 122.1 EL= 18.7



Rood-Bania-Balser

2004-06-24T04:30:14.00

817 NGC7009

Vsrc= -46.60 L+R HE3a RAV\_MA05

21 04 10.8 -11 21 57

Fsky= 8667.2115 Frest= 8665.3000 BW= 50.0000

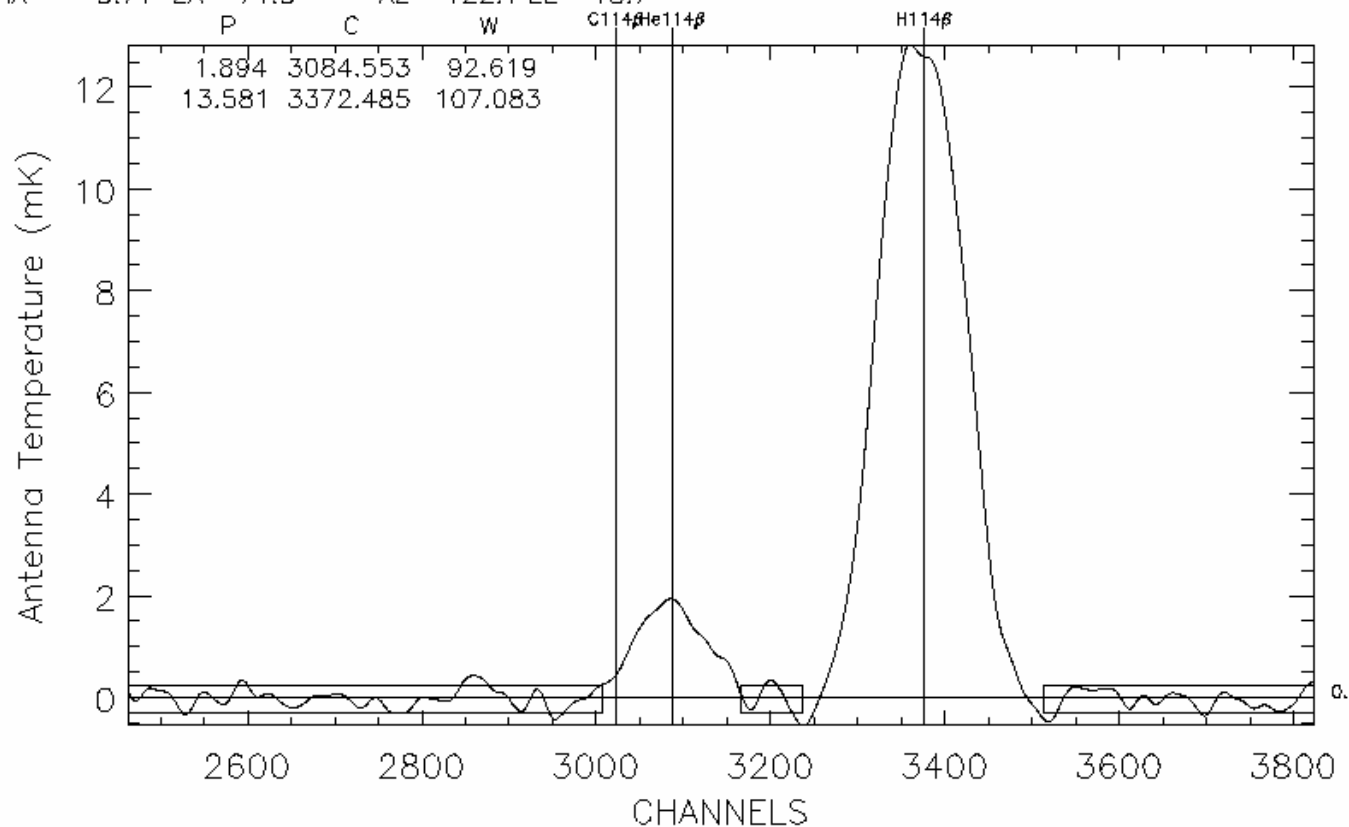
LST= +17 21 32.6

Tcal= 3.3

Tsys= 33.5 Tintg= 3724.1

HA= -3.71 ZA= 71.3

AZ= 122.1 EL= 18.7



Rood-Bania-Balser

2004-06-24T04:30:14.00

817 NGC7009

Vsrc= -46.60 L+R HE3a RAV\_MA05

21 04 10.8 -11 21 57

Fsky= 8667.2115 Frest= 8665.3000 BW= 50.0000

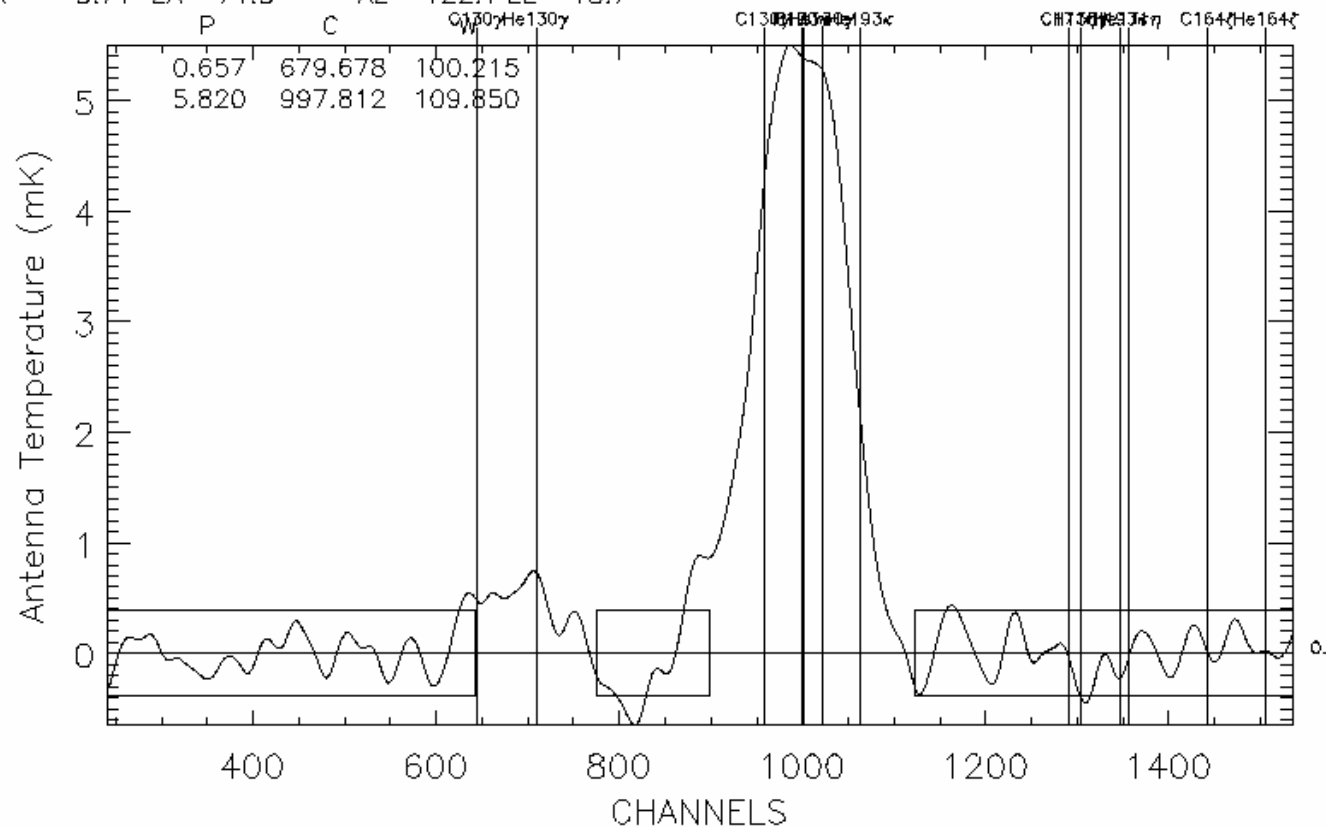
LST= +17 21 32.6

Tcal= 3.3

Tsys= 33.5 Tintg= 3724.1

HA= -3.71 ZA= 71.3

AZ= 122.1 EL= 18.7



Rood-Bania-Balser

2004-06-24T04:30:14.00

819 NGC7009

21 04 10.8 -11 21 57

LST= +17 21 32.6

HA= -3.71 ZA= 71.3

Vsrc= -46.60 L+R B115

RAV\_MA05

Fsky= 8441.9115

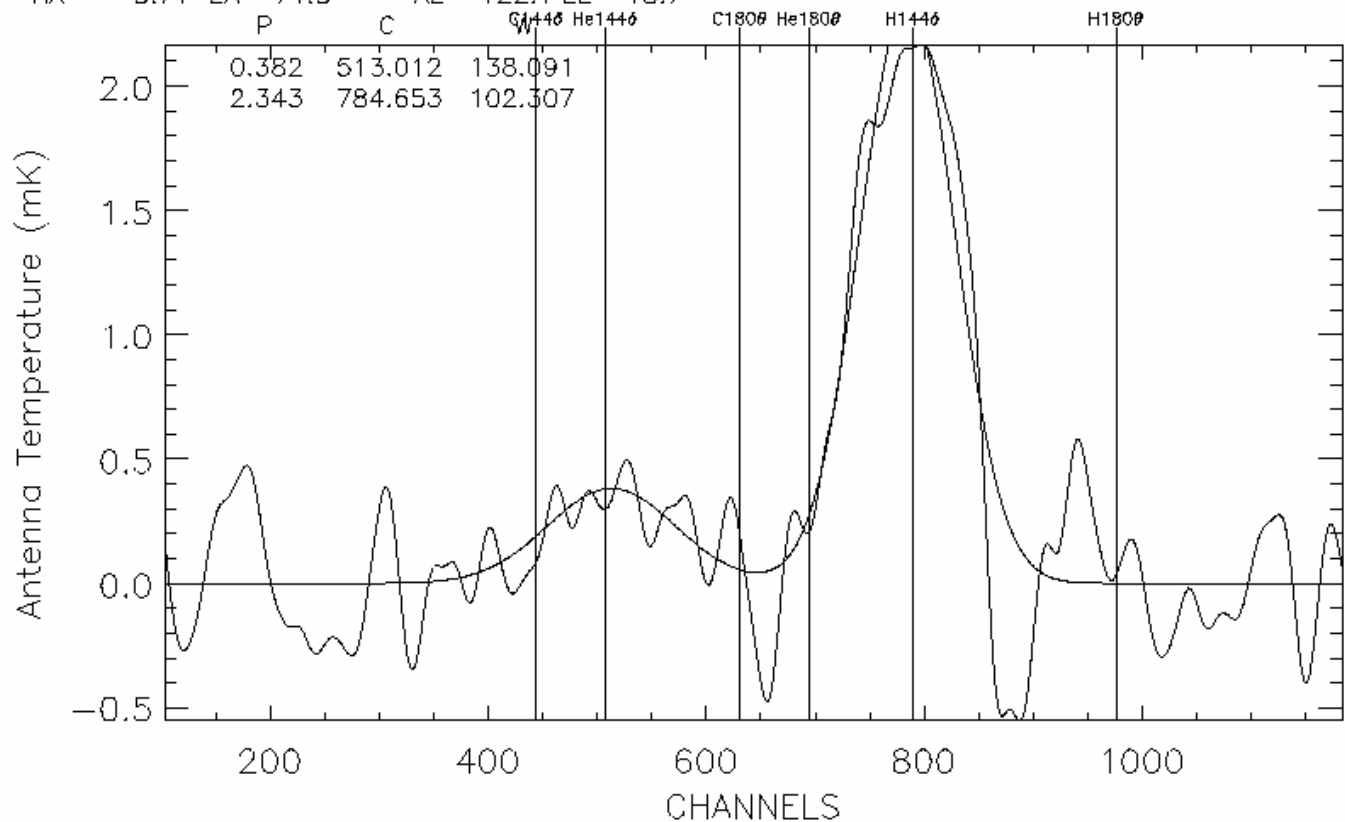
Frest= 8665.3000 BW= 50.0000

Tcal= 3.2

Tsys= 35.9

Tintg= 3701.2

AZ= 122.1 EL= 18.7



Rood-Bania-Balser

2004-06-24T04:30:14.00

Conclude reliability level for NGC7009 ~ 0.5 mK

817 NGC7009

Vsrc= -46.60 L+R

HE3a

RAV\_MA05

21 04 10.8 -11 21 57

Fsky= 8667.2115

Frest= 8665.3000 BW= 50.0000

LST= +17 21 32.6

Tcal= 3.3

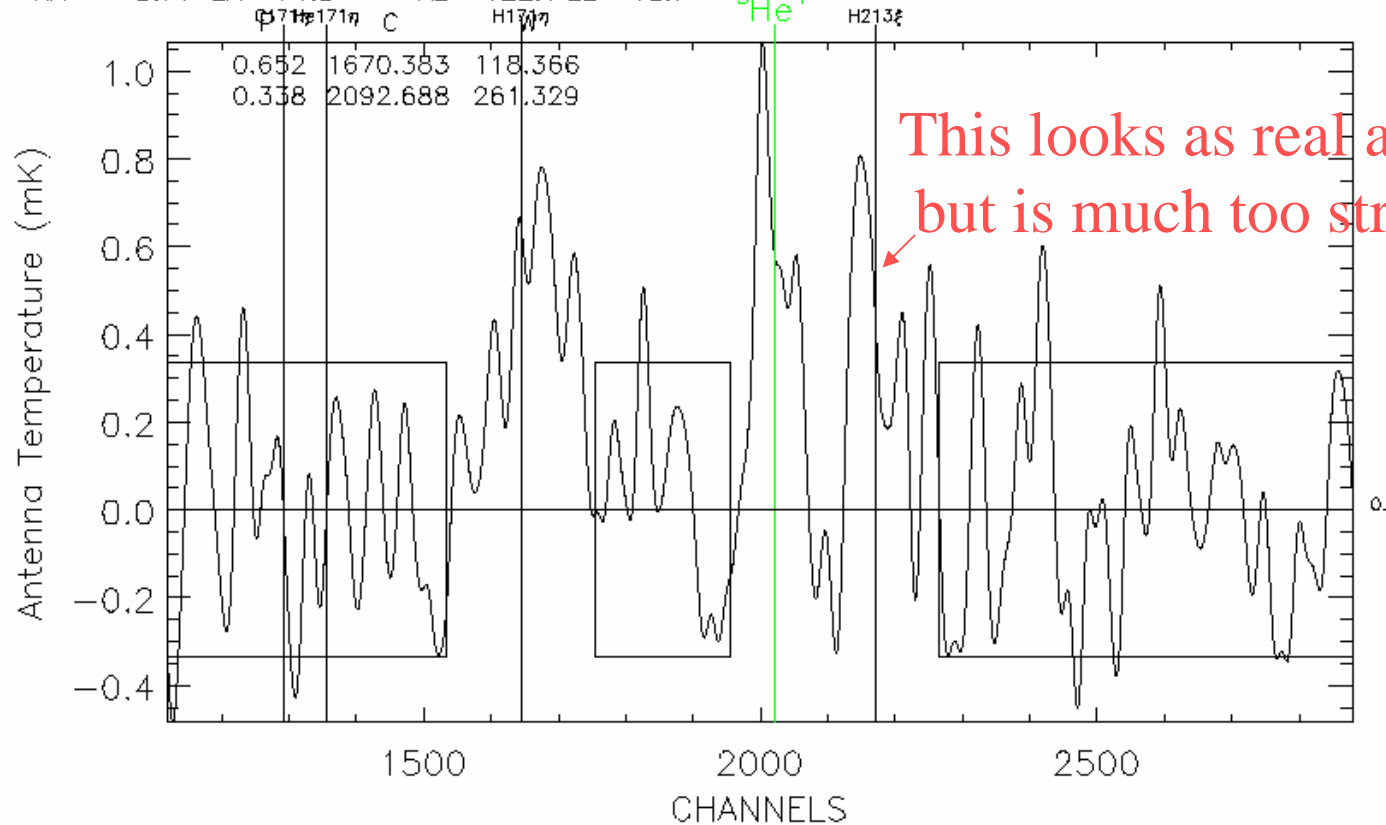
Tsys= 33.5 Tintg= 3724.1

HA= -3.71 ZA= 71.3

AZ= 122.1 EL= 18.7

$^3\text{He}^+$

H213z



Rood-Bania-Balser

2004-06-24T04:30:14.00

17 three05

Vsrc= -0.01 LL

HE3a

EPAVE\_MA05

19 44 48.3 +50 31 30

Fsky= 8665.7590

Frest= 8665.3000 BW= 50.0000

LST= +01 08 14.3

Tcal= 2.3

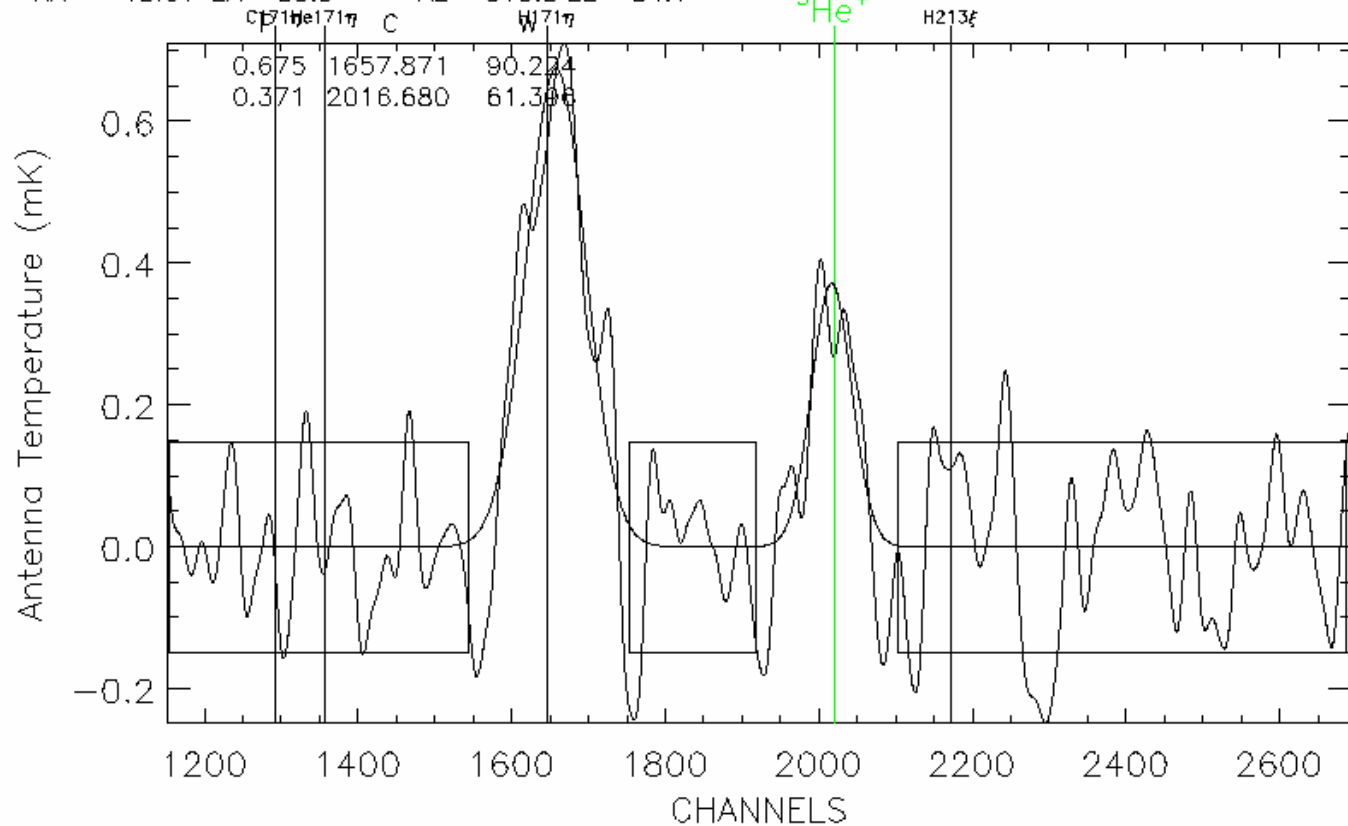
Tsys= 32.7

Tintg= 10816.9

HA= -18.61 ZA= 55.9

AZ= 310.8 EL= 34.1

$^3\text{He}^+$



Tom Bania

2005-05-21T14:27:17.00

**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

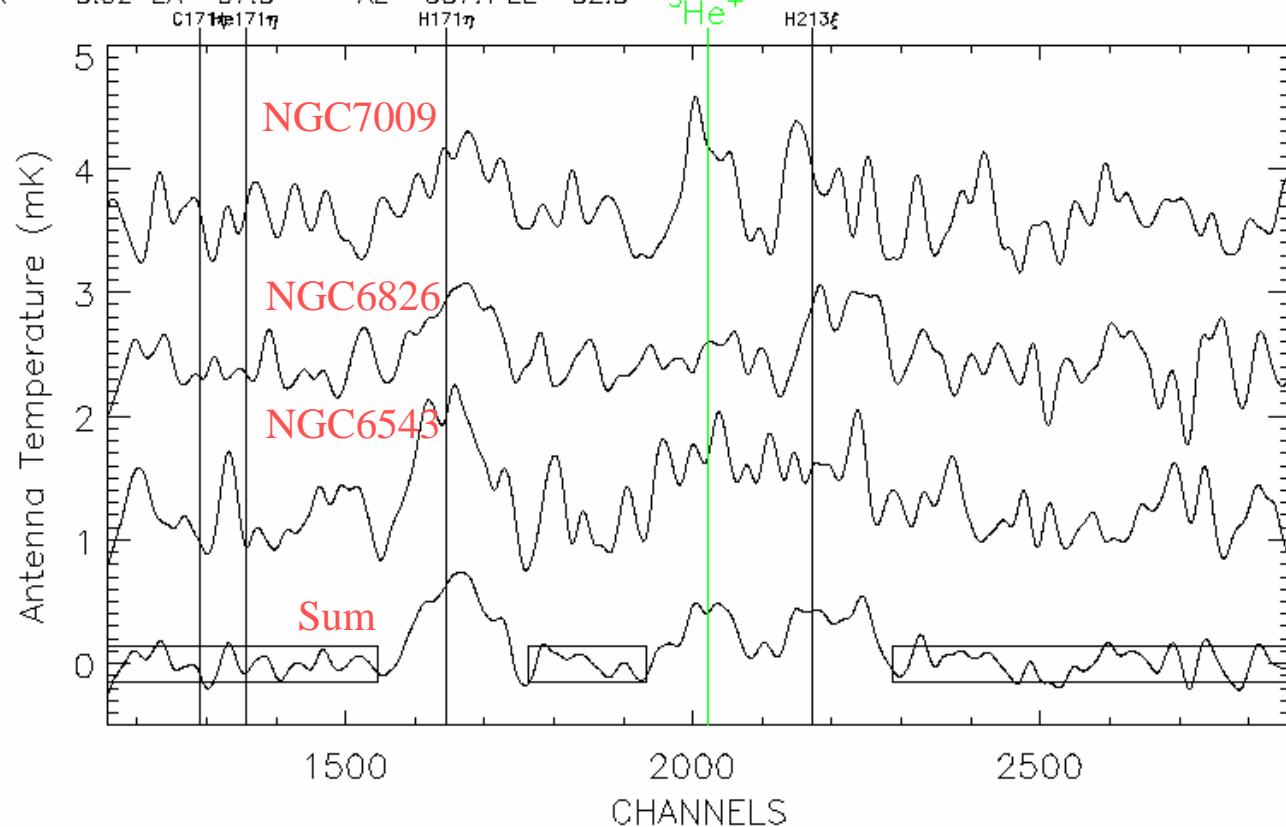
Tcal= 3.3

Tsys= 32.9

Tintg= 11321.0

AZ= 387.1 EL= 52.5

$^3\text{He}^+$



Rood-Bania-Balser

2004-06-22T02:14:34.00

# GBT Conclusions

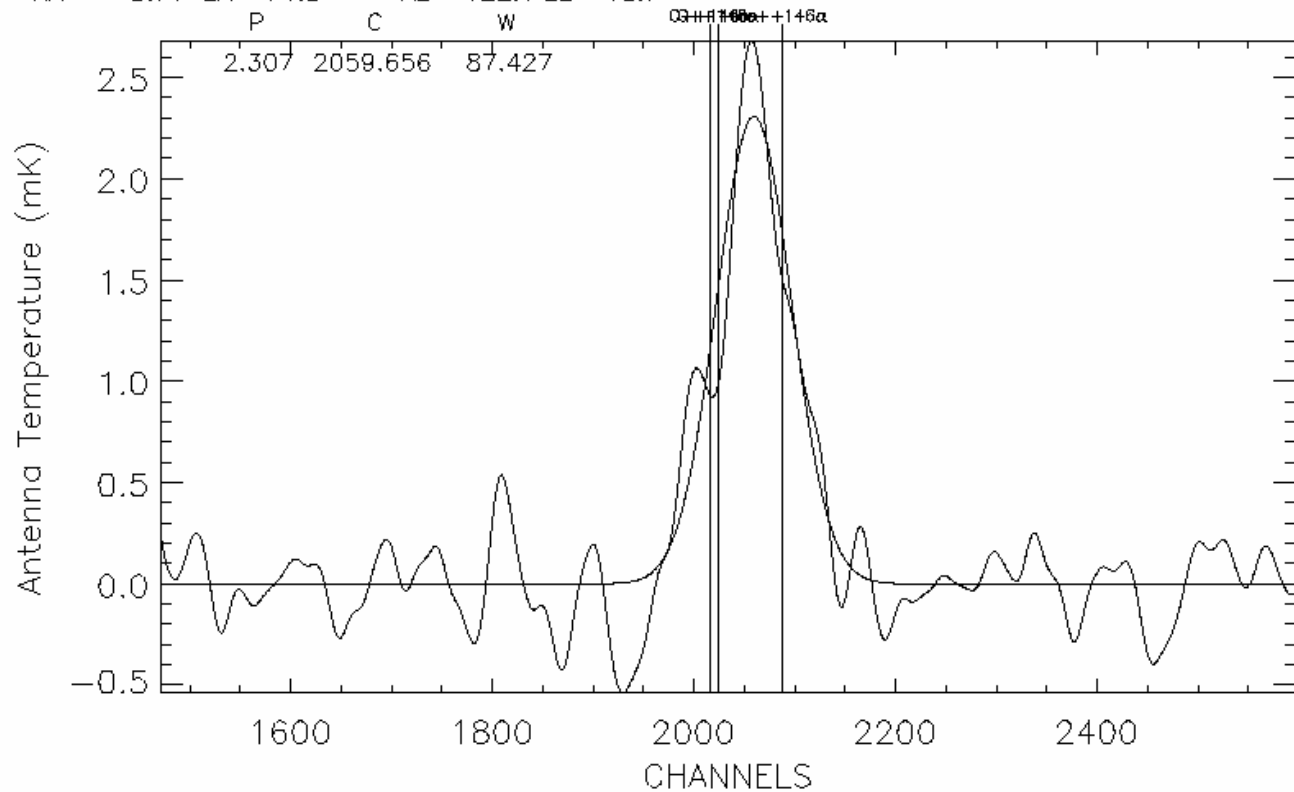
- Standing waves are not a problem
- There is still baseline structure (BS) probably resulting from mismatches in the IF system.
  - BS varies with frequency sometimes almost invisible other times very problematic
  - BS amplitude is proportional to source continuum and moves with sky frequency
- At 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
- The scheduling mode and proposal pressure on the GBT may not allow us to solidify these results in the near future.

# A bonus: He<sup>++</sup> or O<sup>++</sup> RRL (a first?)

822 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 HE++ RAV\_MA05  
Fsky= 8371.9115 Frest= 8665.3000 BW= 50.0000  
Tcal= 3.5 Tsys= 36.4 Tintg= 3597.1



Rood-Bania-Balser

2004-06-24T04:30:14.00