Pulsar Observation Planning

Exercise

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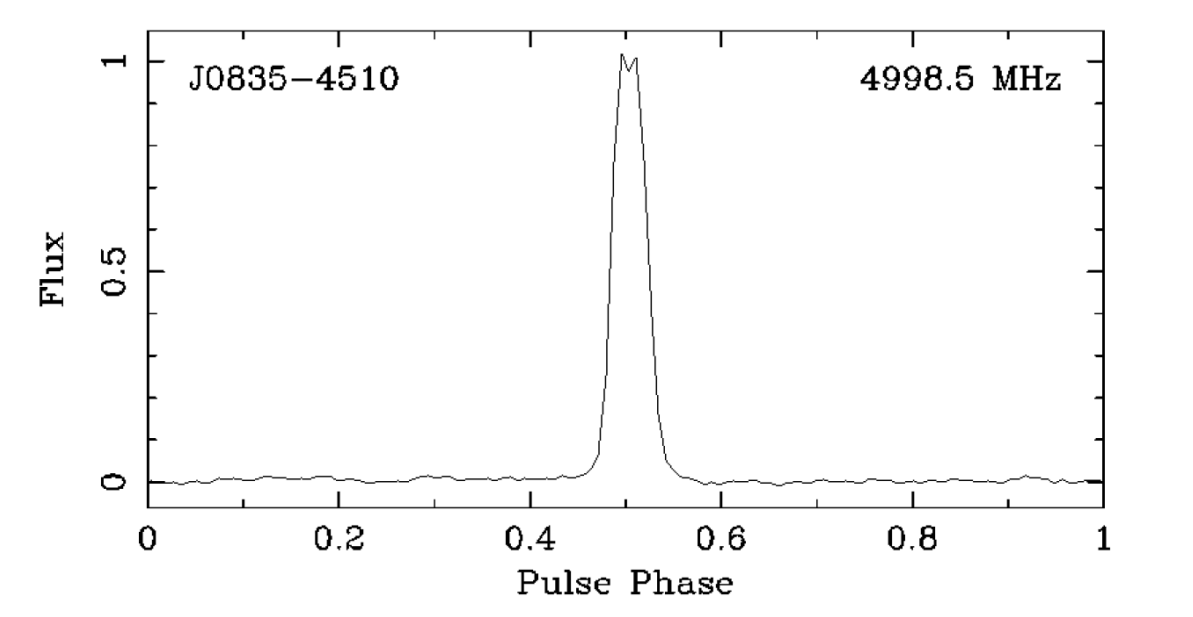
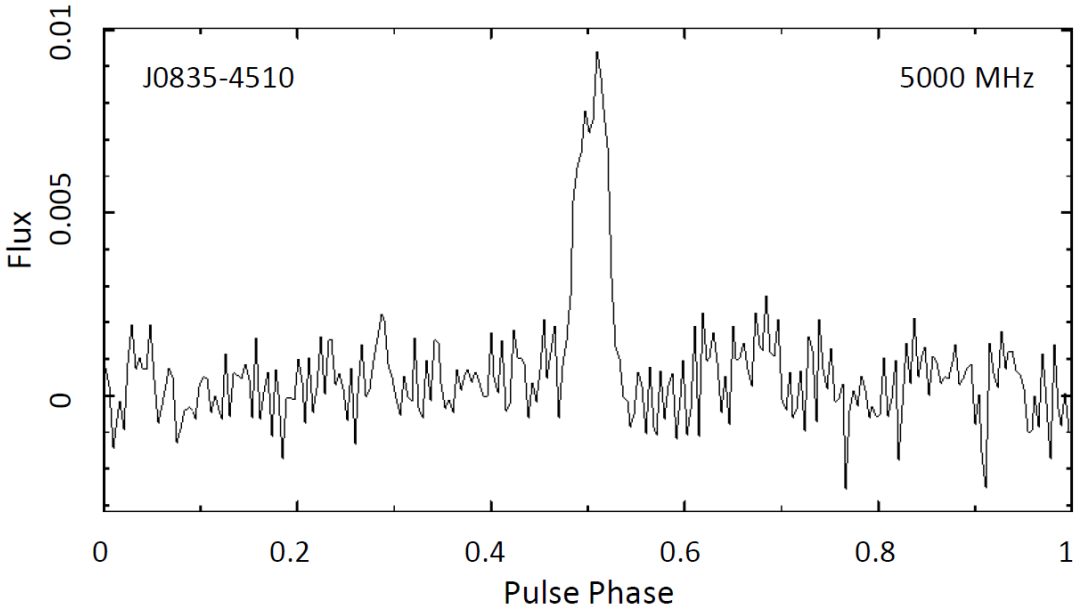
DARA Radio Astronomy Training

HartRAO 13th November 2024

Pulse Profiles for PSR J0835-4510 (Vela)

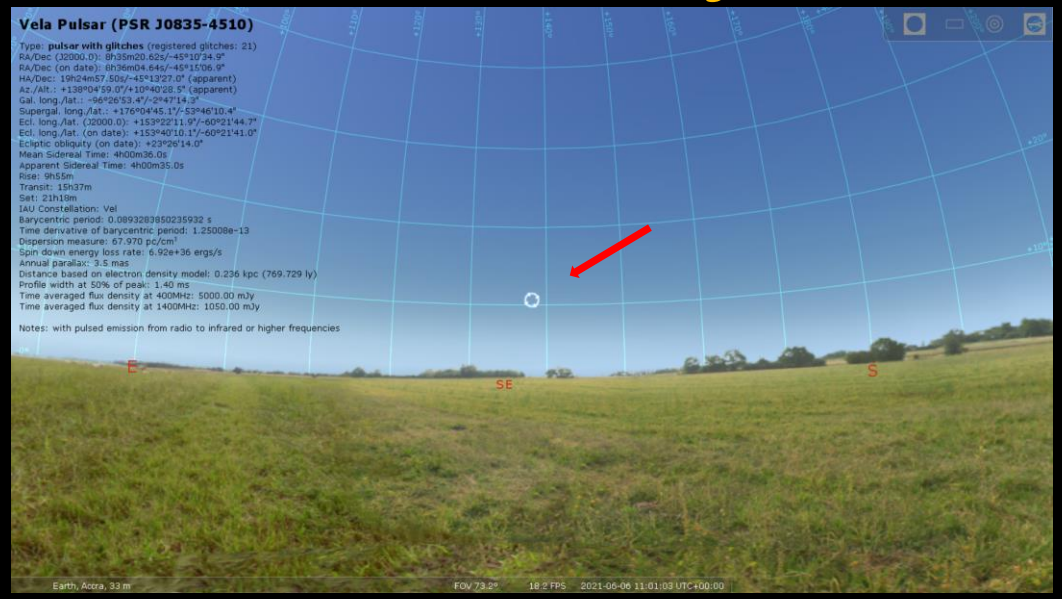


Example profile for Vela from the EPN database of pulsar profiles. The profile was recorded in 1998 at Parkes Observatory by Johnston et al. (1998) at 4998MHz.

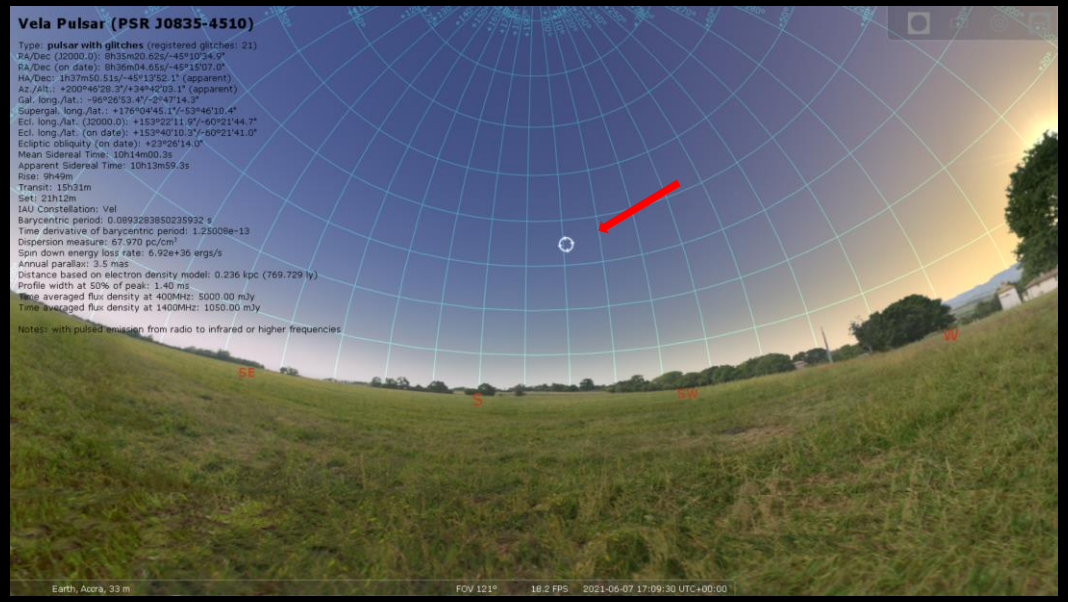


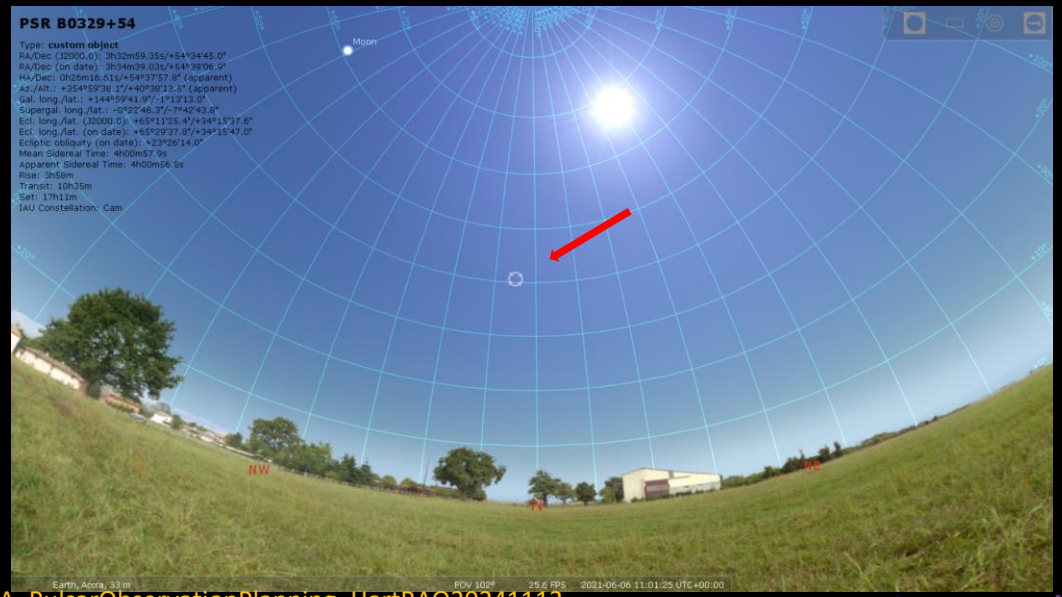
Pulse profile for Vela recorded at Kuntunse in 2018. The profile from a 61 minute observation at 5GHz with a bandwidth of 75 MHz.

Where is the object to be observed?



PSR J0322+5434 at 11:00 and 17:00 GMT Kuntunse 7th June 2021





PSR J0322+5434 at 11:00 and 17:00 GMT Kuntunse 7th June 2021

Image credits: created using Stellarium

Integration Time Calculation

- **The observing time required to achieve a specific Signal to Noise ratio can be calculated using the radiometer equation (Dicke 1946).**
- **As we do not receive radio emissions for the whole of the pulsar period a duty cycle correction, $\sqrt{(W/(P-W))}$, is used to adapt the basic radiometer equation for pulsar observations**
- *Ignoring the effects of Radio Frequency Interference (RFI) on the noise floor (Tsys).*

$$T_{int} = \left(\frac{T_{sys}(S/N)}{G S_{psr} \sqrt{n_{pol} B_w}} \sqrt{\frac{W}{P-W}} \right)^2$$

Key Parameters for a pulsar observation

Pulsar Target:

- S_{psr}: Strength of the radio signal from the pulsar in Janskys (Watts per square meter per Hz)
- P: Pulse Period in seconds
- W: Pulse width in seconds

Telescope:

- T_{sys}: System temperature, a measure of the background noise level of the telescope in degrees Kelvin (K)
- Gain: proportional to the size (collecting area) of the telescope dish and the performance of the amplifier (K per Jansky)
- n_{pol}: Number of polarisations observed (generally 2)
- B_w: Bandwidth of the receiver in MHz

Variable parameters:

- T_{int}: Integration time or duration of the observation in seconds
- S/N: Signal to Noise ratio, how much of a signal do we need for a detection?

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Exercise

Table 1

Pulsar Name	Flux Density @ 5GHz (mJy)	Period (seconds)	Pulse width (milliseconds)	
A) J0835-4510	201	0.089328	1.4	Vela - Brightest Pulsar
B) J0332+5434	26.5	0.714520	6.6	Brightest in Northern hemisphere

Table 2

T_{sys}	n_{pol}	Gain	Bandwidth	S/N
125	2	0.17	100	10

Table 3

Pulsar	S/N 10	S/N 30	S/N 50	S/N 100	S/N 300
A) J0835-4510					
B) J0332+5434					

Plot Integration Time vs S/N for both Pulsars
Repeat with different values for Tsys and Bandwidth

What are the key parameters for a Pulsar Observation?

Pulsar Target:

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Variable parameters:

Tint: Integration time or duration of the observation in seconds

S/N: Signal to noise ratio, how much of a signal do we need for a detection

These parameters are related by the radiometer equation:

Tint = ((Tsys*(S/N))/(G*Spsr*(Npol*BW)-2))(w/(P-W))2

Tint = ((Tsys*(S/N))/(G*Spsr*(Npol*BW)-2))(w/(P-W))2

In [3]:

```
# To begin, we import some libraries that we will need later.
from __future__ import print_function

# The numpy library will allow us to do FFTs
import numpy as np
#import scipy
#from astropy import coordinates as coord
#from astropy import units as u
#from astropy import constants as const
#from astropy import time as astrotime
# pi is a useful value!
#from math import pi

# The pyplot module from matplotlib will allow us to plot things.
from  matplotlib import pyplot as plt
import matplotlib
from matplotlib.font_manager import FontProperties

# This will tell matplotlib that we want to include the plots on our notebook, rather than in a new window.
%matplotlib inline

# Here you can control the font for the plots.
font = {'family' : 'serif',
        'weight' : 'normal',
        'size'   : 12}
matplotlib.rc('font', **font)
```

Now a routine to calculate the integration time using the radiometer equation

In [5]:

```
def PulsarTint(SysTemp,TGain,TPol,TBw,SNR,Period,Pw,Pflux):
    Tint = 0
    if Pw == 0 :
        Pw=Period/10  # If no W10 pulse width assume 10% value
    a=SNR*SysTemp
    b=TGain*Pflux*((TPol*TBw)**0.5)
    c= (Pw/(Period-Pw))**0.5
    Tint=(a/b*c)**2
    return int(np.ceil(Tint))    # Round up value to whole seconds


```

Now we will provide the Kuntunse / Ghana values for the Tint Calculation

```
1
2  Tsys=125
3  Npol=2
4  Gain=0.17
5  BandW=75
6  SNR=10
7
8  PulsarAFlux=201
9  PulsarAPeriod=89.328
10 PulsarAWidth=1.4
11
12 PulsarBFlux=26.5
13 PulsarBPeriod=714.52
14 PulsarBWidth=6.6
15
16 values=(5)
17 TintA1 = np.zeros(values)   # Tint times for pulsar A - base case (Kuntunse)
```

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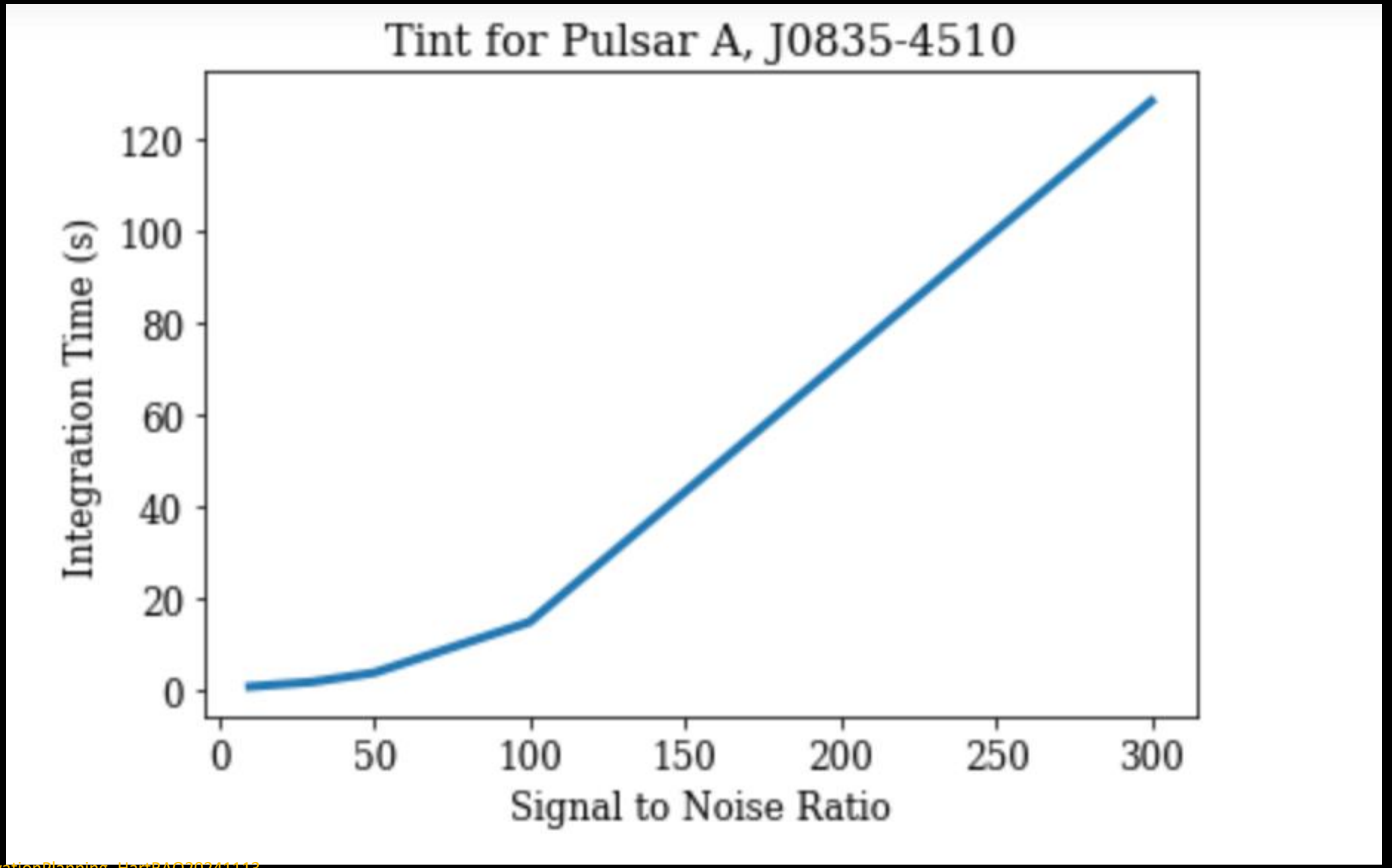
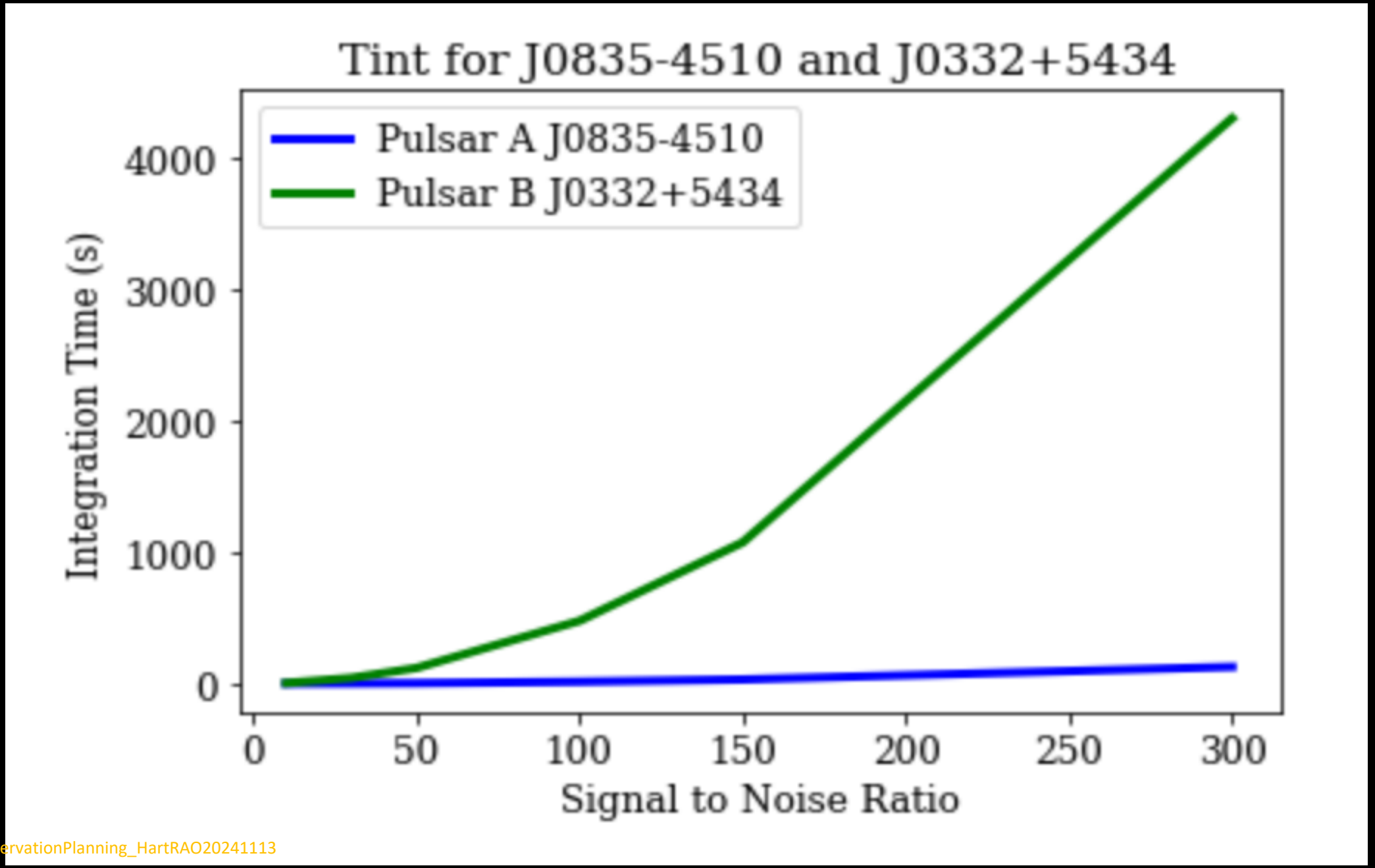
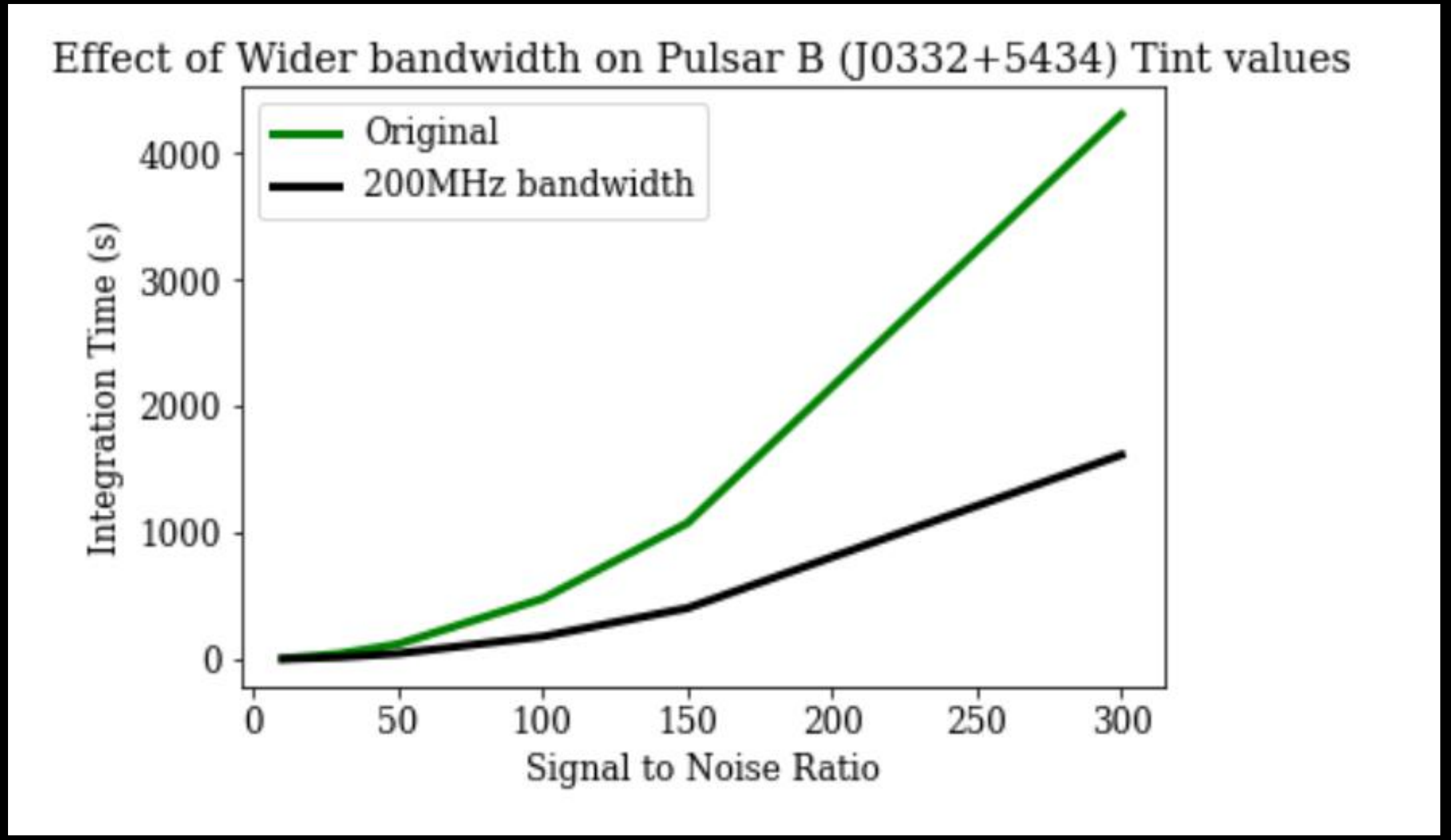
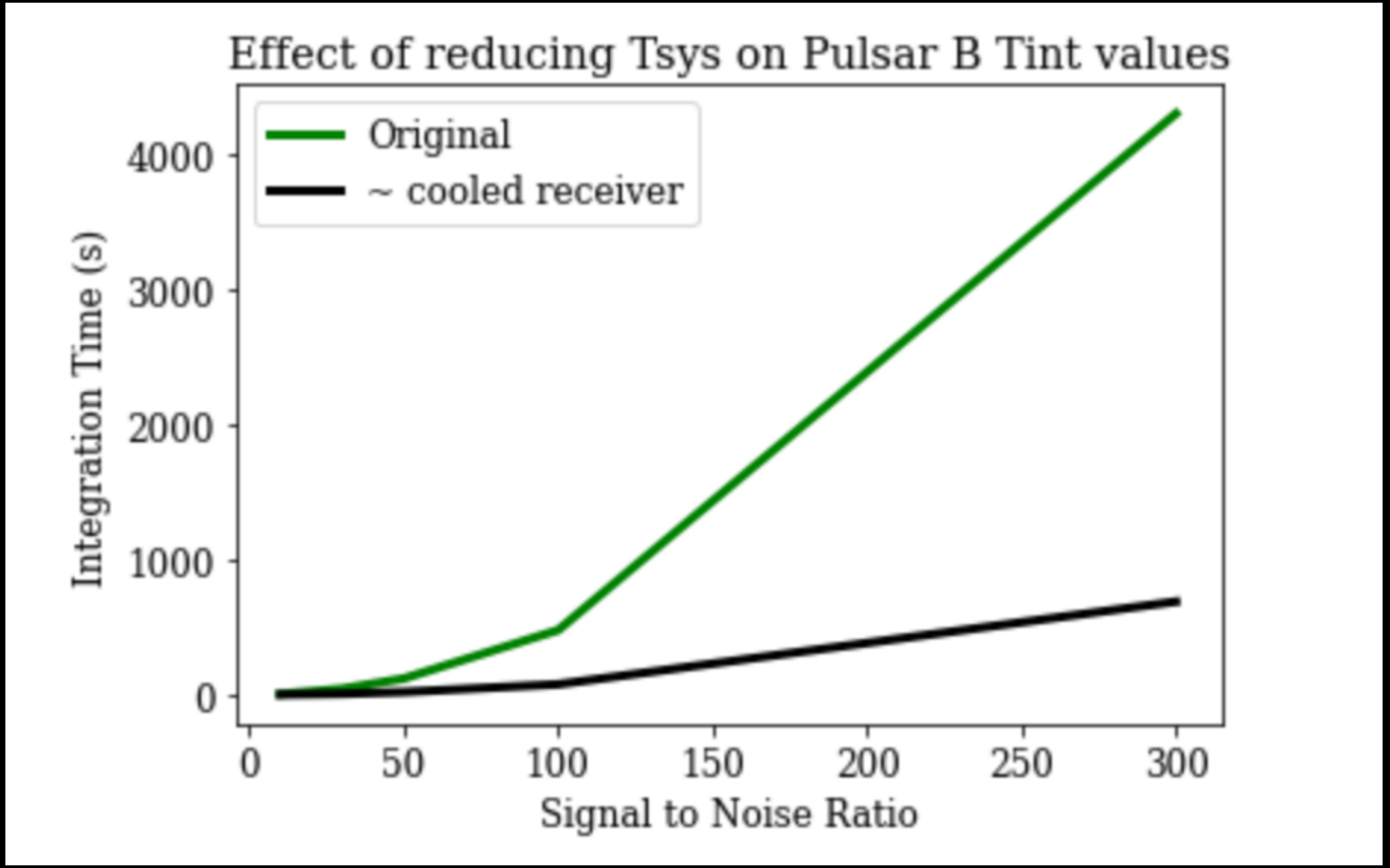
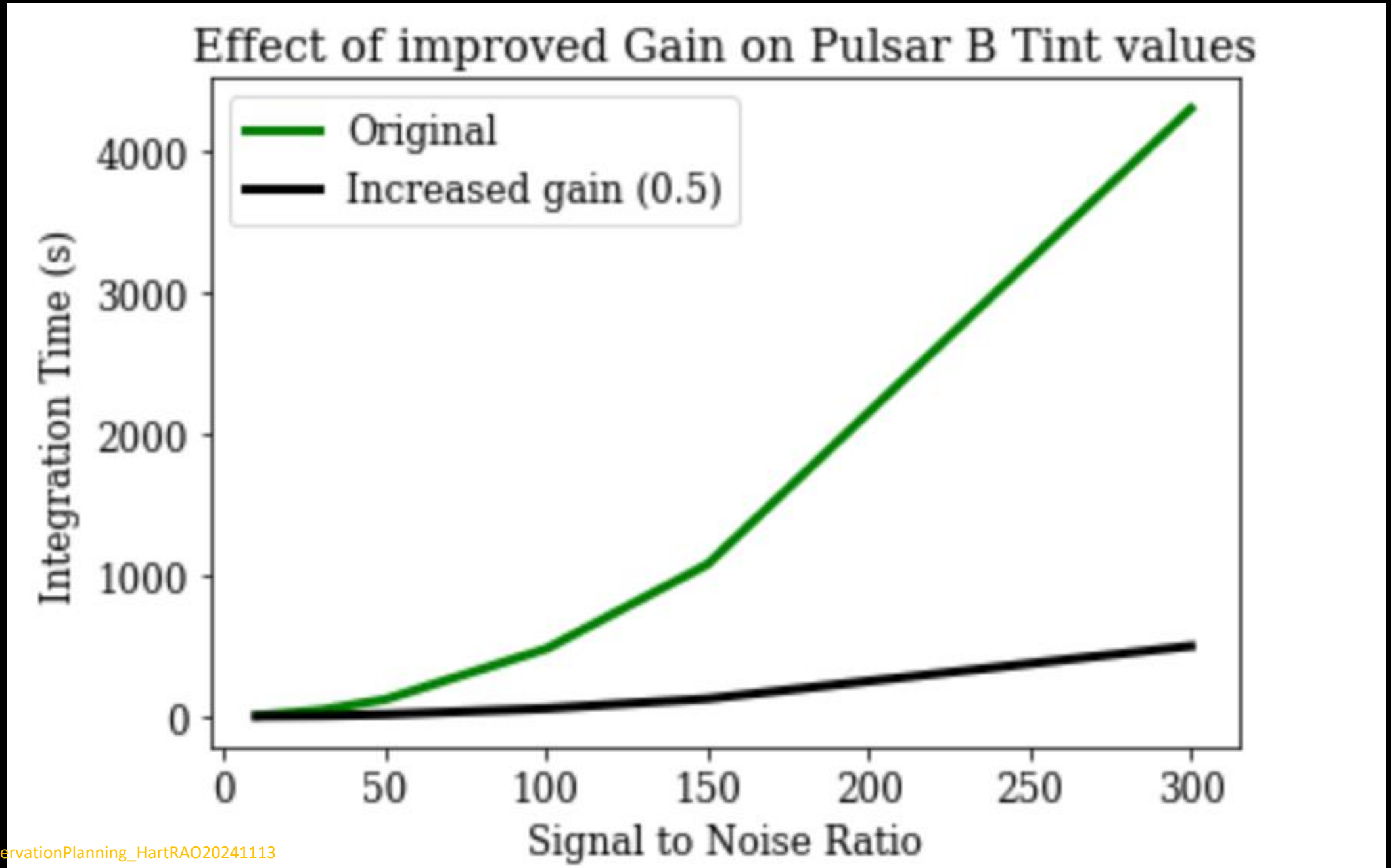
Plot Integration Time vs S/N for both Pulsars
Repeat with different values for Tsys and Bandwidth

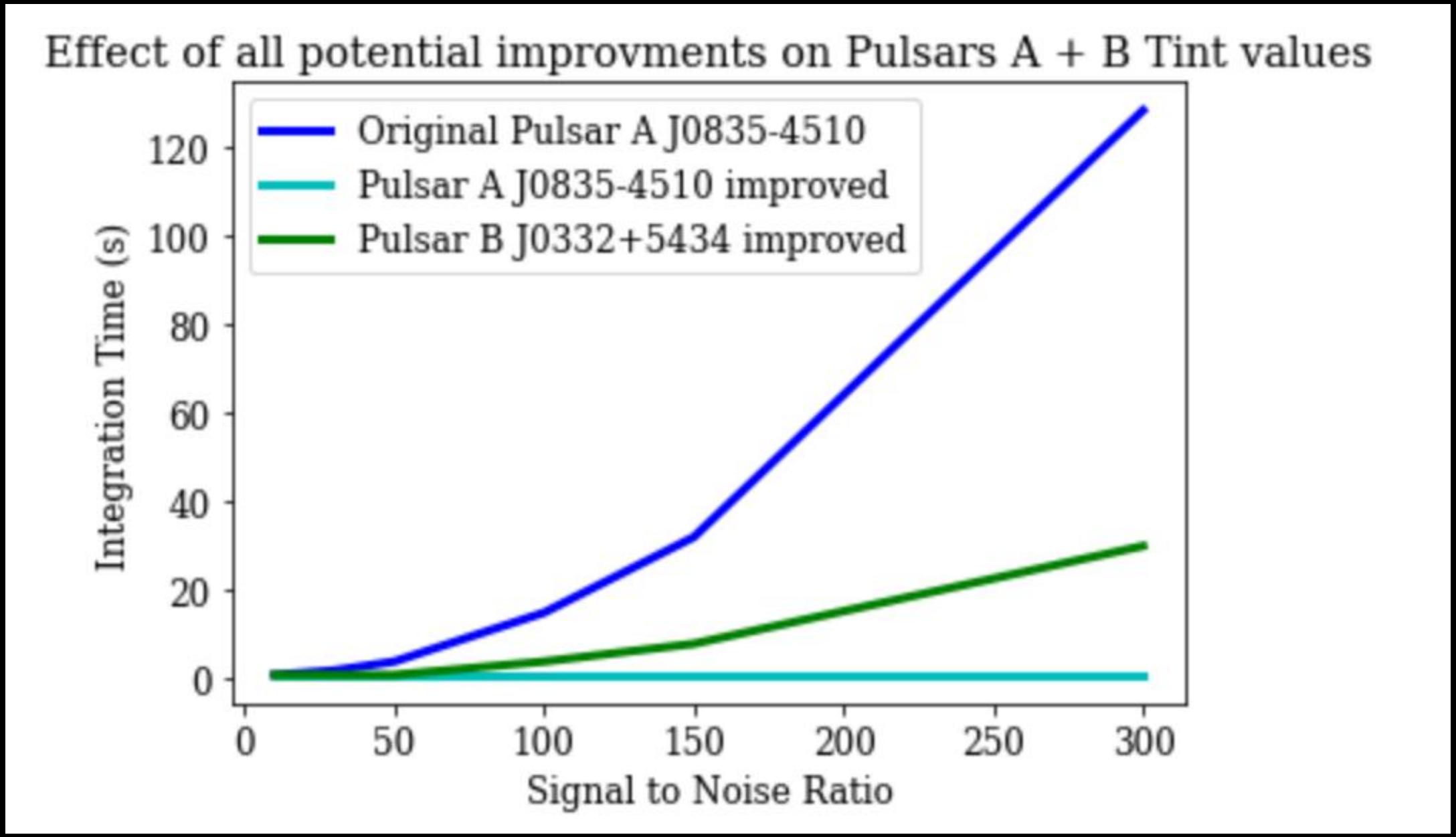

Tint for Pulsar A, J0835-4510
Integration Time (s)
120
100
80
60
40
20
0
0
50
100
150
200
250
300
Signal to Noise Ratio


Tint for J0835-4510 and J0332+5434
Pulsar A J0835-4510
Pulsar B J0332+5434
Integration Time (s)
0
1000
2000
3000
4000
0
50
100
150
200
250
300
Signal to Noise Ratio


Effect of Wider bandwidth on Pulsar B (J0332+5434) Tint values
Original
200MHz bandwidth
Integration Time (s)
4000
3000
2000
1000
0
0
50
100
150
200
250
300
Signal to Noise Ratio


Effect of reducing Tsys on Pulsar B Tint values
Original
~ cooled receiver
Integration Time (s)
4000
3000
2000
1000
0
0
50
100
150
200
250
300
Signal to Noise Ratio


Effect of improved Gain on Pulsar B Tint values
Original
Increased gain (0.5)
Integration Time (s)
4000
3000
2000
1000
0
0
50
100
150
200
250
300
Signal to Noise Ratio


Effect of all potential improvments on Pulsars A + B Tint values
Original Pulsar A J0835-4510
Pulsar A J0835-4510 improved
Pulsar B J0332+5434 improved
Integration Time (s)
0
20
40
60
80
100
120
0
50
100
150
200
250
300
Signal to Noise Ratio