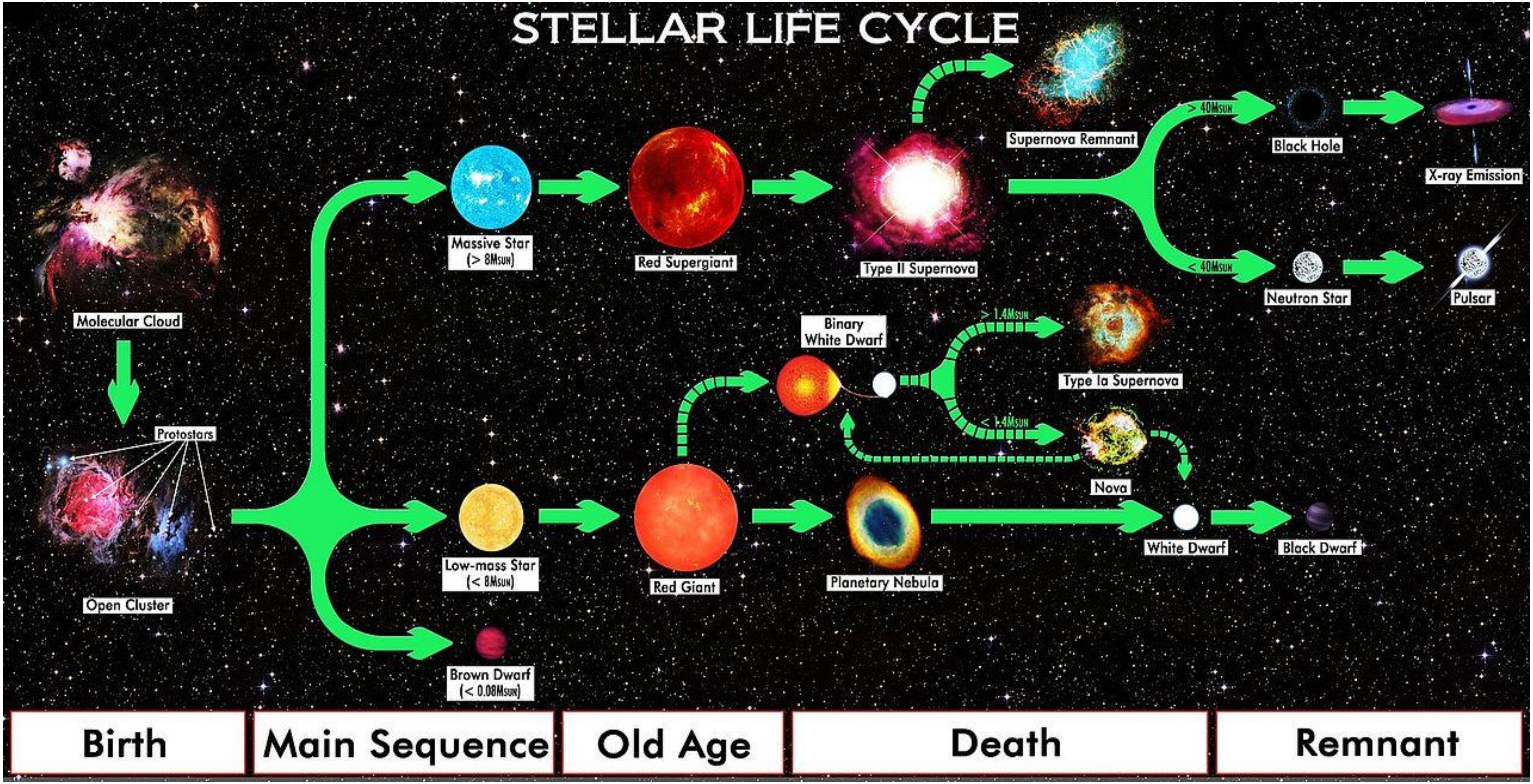
Equinox

Mini-Project Track : Pulsars

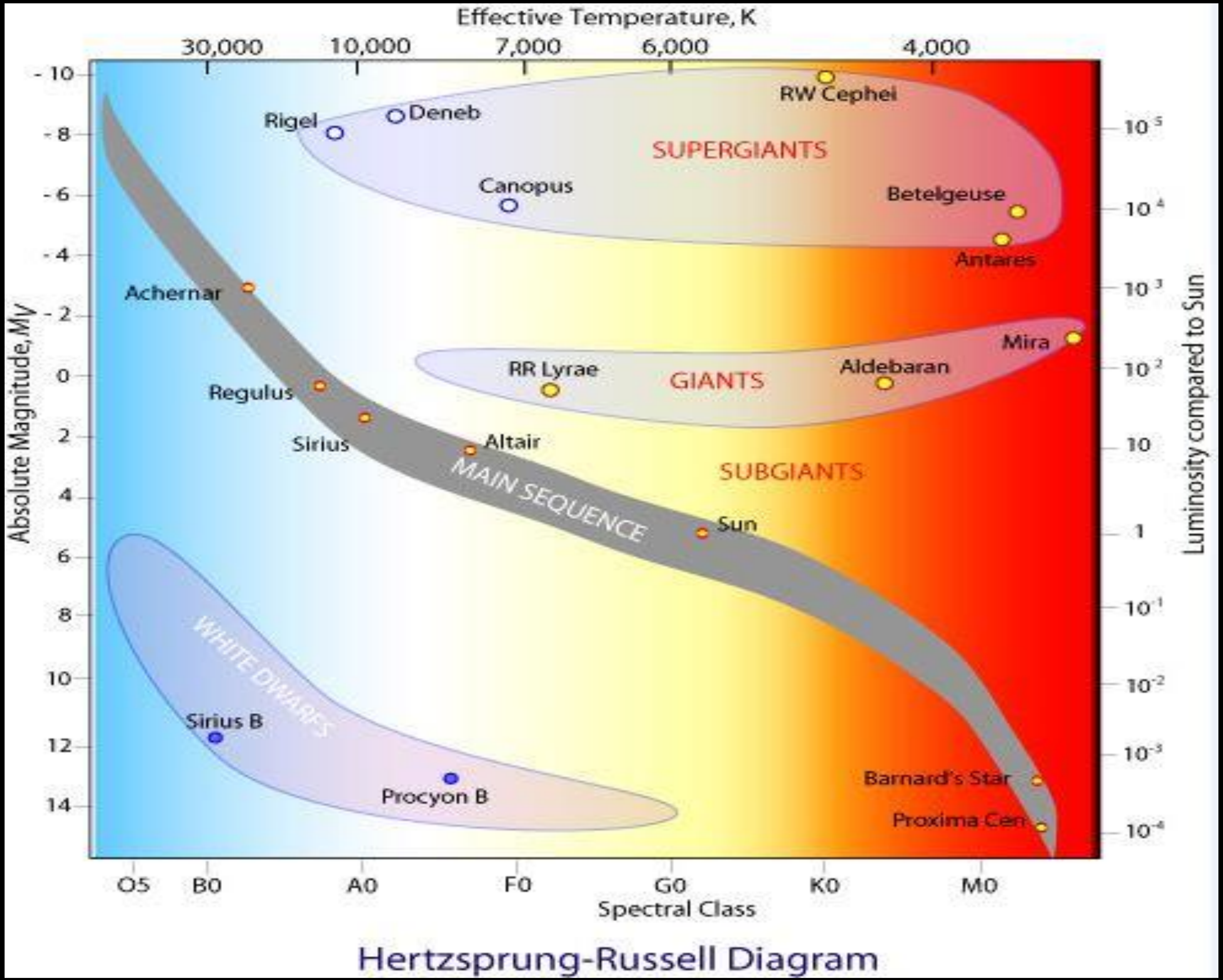
Content :

- Stellar Evolution
- Neutron star
- Pulsars and their properties
- Detection of Pulsars
- Applications of Pulsars
- Challenges in a Modern World
- Project
- Conclusion

STELLAR EVOLUTION


STELLAR LIFE CYCLE
Molecular Cloud
Protostars
Open Cluster
Massive Star
(> 8Msun)
Low-mass Star
(< 8Msun)
Brown Dwarf
(< 0.08Msun)
Red Supergiant
Red Giant
Type II Supernova
Supernova Remnant
> 40Msun
< 40Msun
Black Hole
X-ray Emission
Neutron Star
Pulsar
Binary
White Dwarf
> 1.4Msun
< 1.4Msun
Type Ia Supernova
Nova
Planetary Nebula
White Dwarf
Black Dwarf
Birth
Main Sequence
Old Age
Death
Remnant

HR DIAGRAM



Effective Temperature, K
30,000
10,000
7,000
6,000
4,000
- 10
- 8
- 6
- 4
- 2
0
2
4
6
8
10
12
14
Absolute Magnitude, Mv
10^5
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4
Luminosity compared to Sun
RW Cephei
Rigel
Deneb
SUPERGIANTS
Canopus
Betelgeuse
Antares
Achernar
Mira
RR Lyrae
GIANTS
Aldebaran
Regulus
Sirius
Altair
SUBGIANTS
MAIN SEQUENCE
Sun
WHITE DWARFS
Sirius B
Procyon B
Barnard's Star
Proxima Cen
O5
B0
A0
F0
G0
K0
M0
Spectral Class
Hertzsprung-Russell Diagram

Inference from the HR Diagram

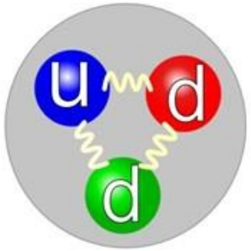
- ✓ Mass
- ✓ Age
- ✓ Size
- ✓ Luminosity
- ✓ Surface Temperature
- ✓ Absolute Magnitude
- ✓ Spectral Type

Neutron Stars

1. These are the densest objects in the universe next to Black Holes

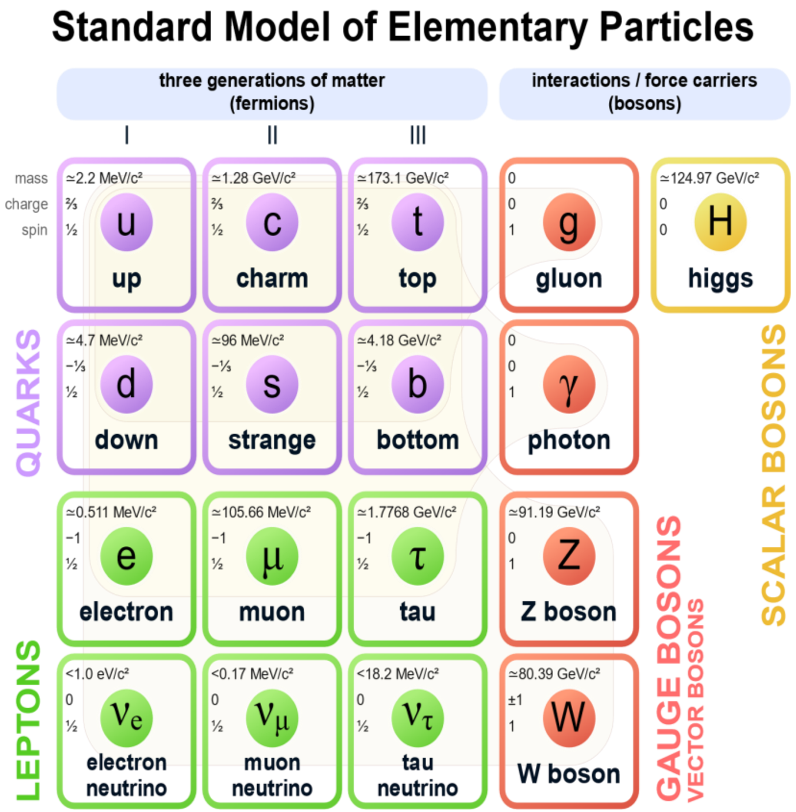
2. Neutron stars are the cores of high mass stars left behind after supernovae.

3. A teaspoon of Neutron stars weigh 40 billion kilograms on Earth

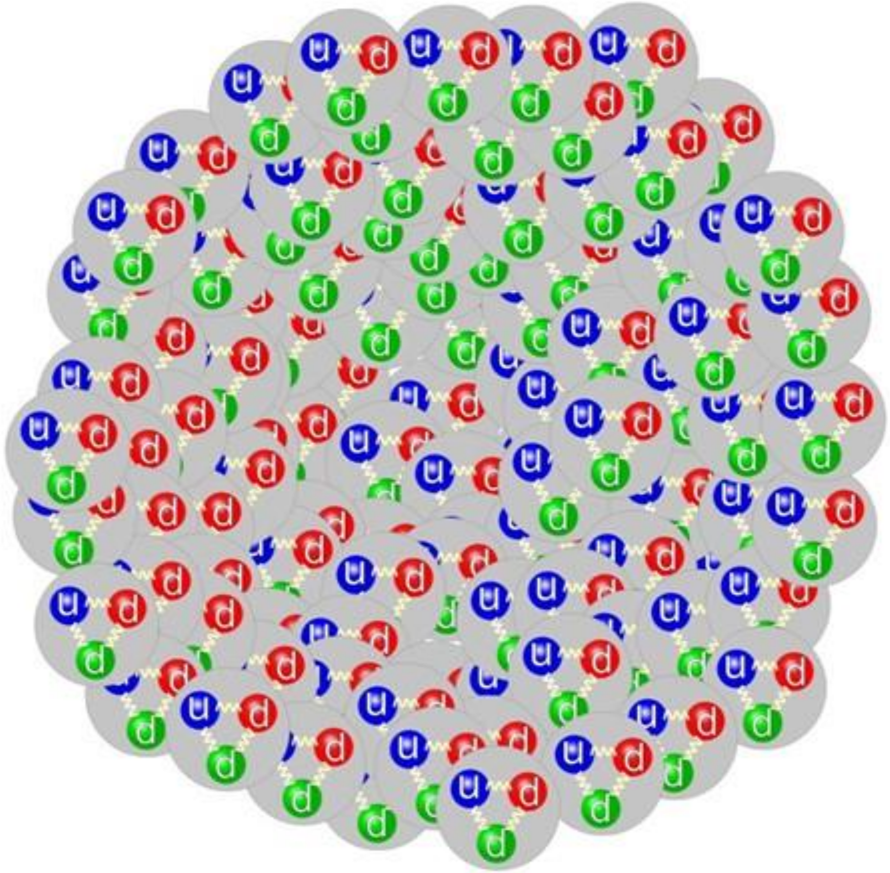


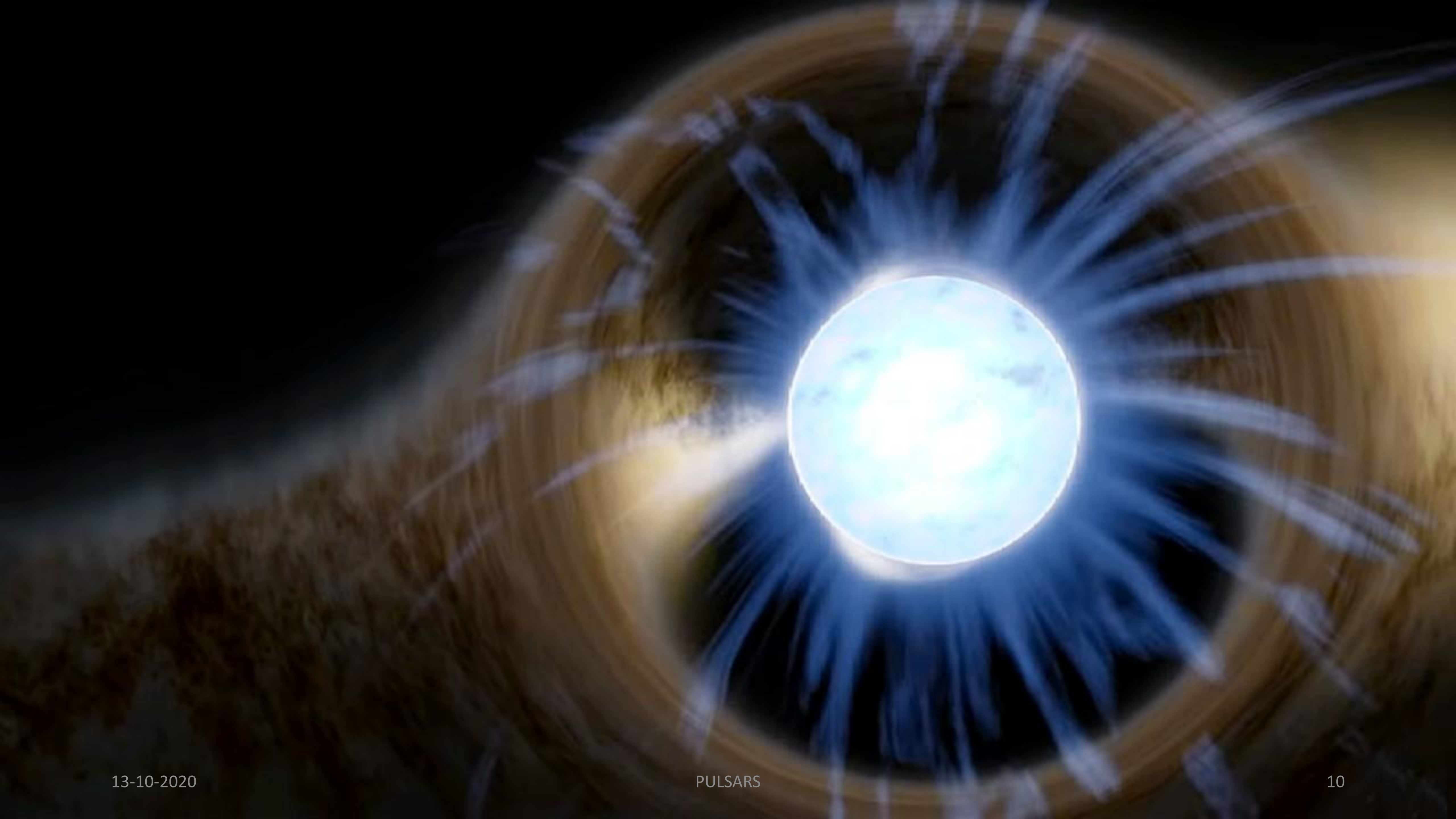
What is Neutron made of?

- Two down quark
- One up quark



1,000,000,000,000 trillion times fused together

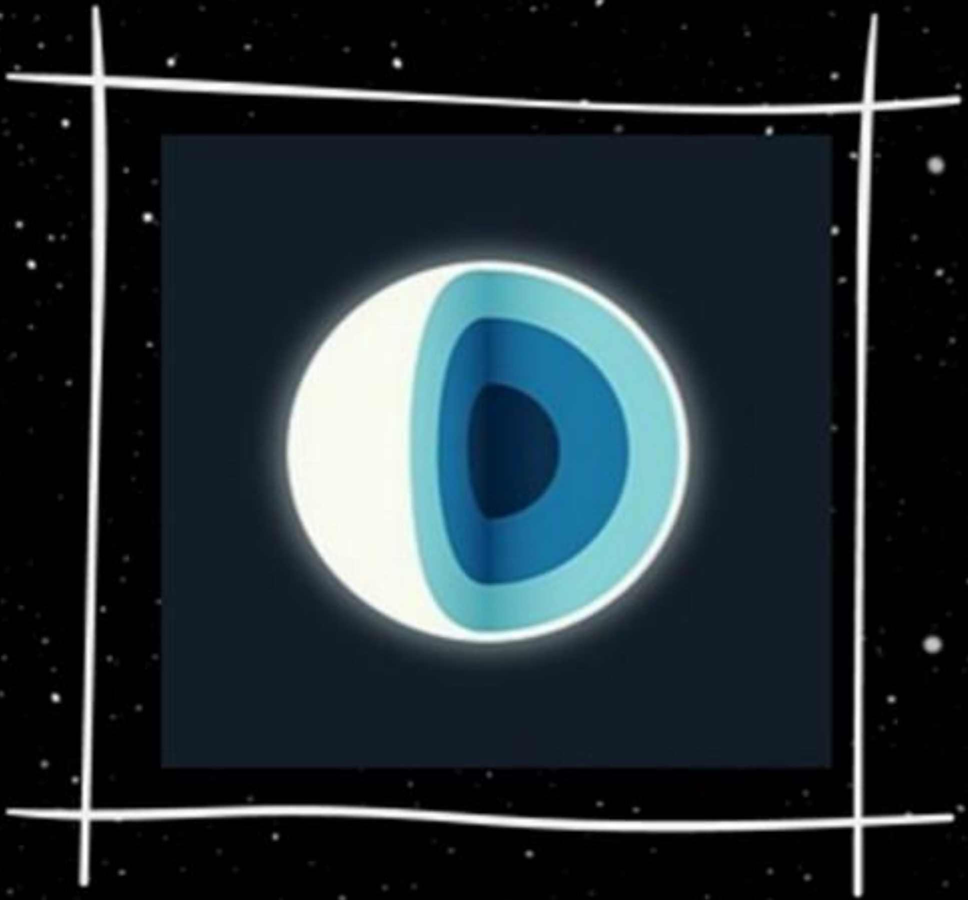




Formation

When a high mass star reaches the white dwarf stage, it's mass determines it's further evolution.

If it's mass is greater 1.4 solar masses and mostly less than 3 solar masses then it evolves into a neutron star.



WHAT HAPPENS IN THE CORE?

As the mass and density is high, the star collapses

↓

electrons + protons ---> neutrons + neutrinos

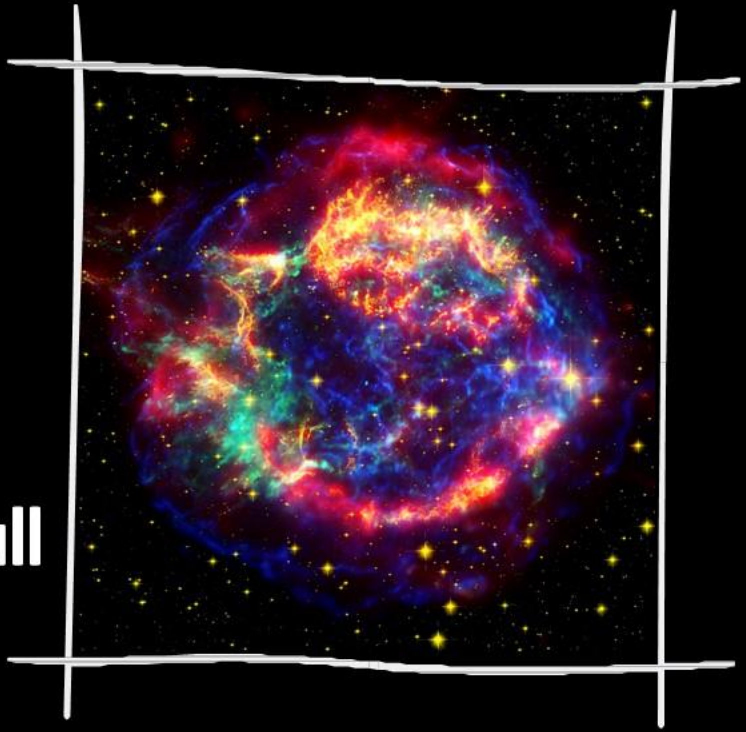
↓

neutrons so formed, will combine to form nuclei

↓

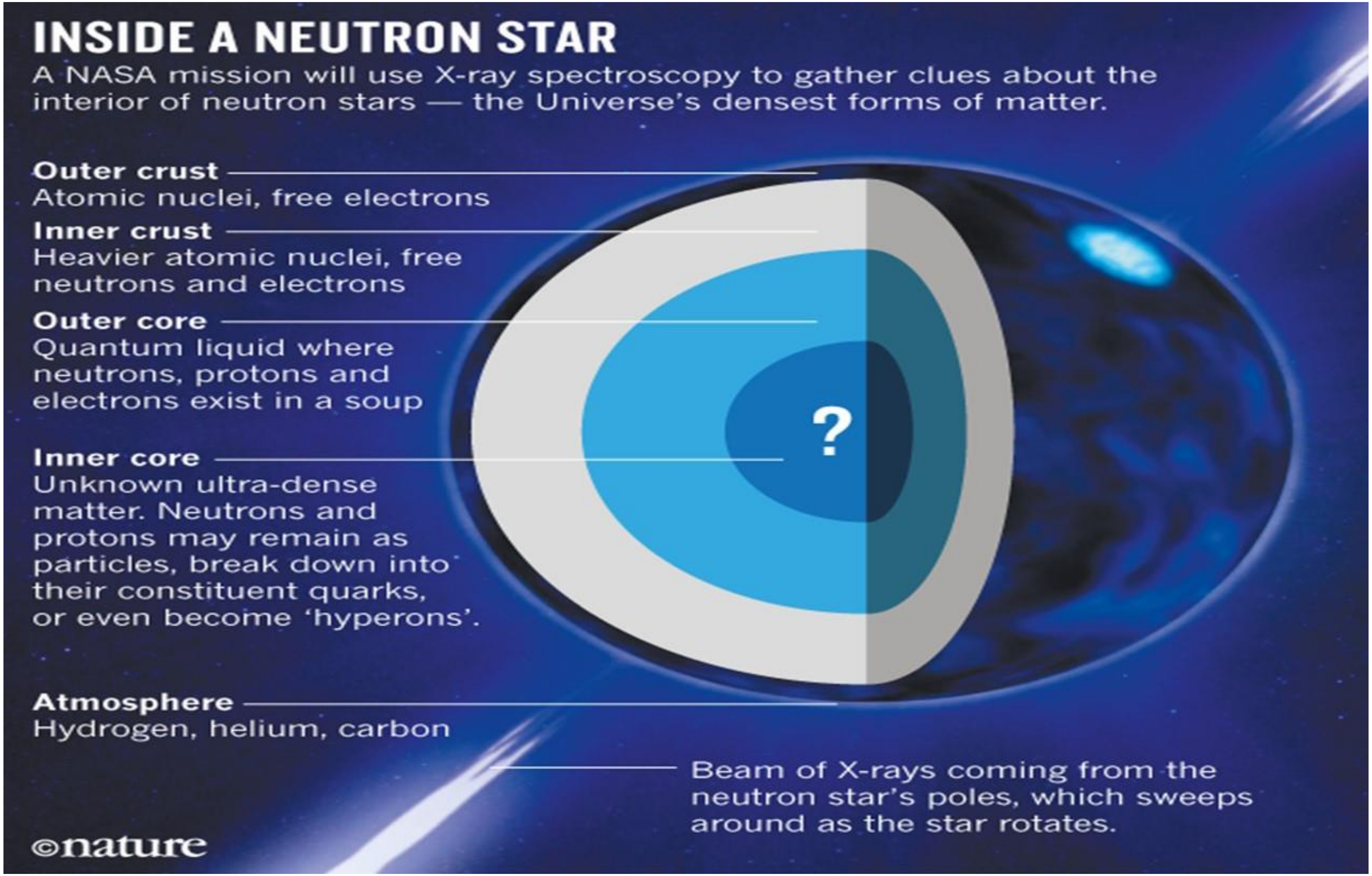
size of the core decreases and density increases

- As density and temperature increases, neutrons stop combining into nuclei
- Hence there forms a gas of neutrons having pressure
- This pressure balances the inward gravitational pull



- The collapse stops and the core is stable
- Outer layer of the star is unstable and implodes under gravity

THE DENSE CORE LEFT BEHIND IS ***THE NEUTRON STAR***


INSIDE A NEUTRON STAR
A NASA mission will use X-ray spectroscopy to gather clues about the interior of neutron stars — the Universe's densest forms of matter.
Outer crust
Atomic nuclei, free electrons
Inner crust
Heavier atomic nuclei, free neutrons and electrons
Outer core
Quantum liquid where neutrons, protons and electrons exist in a soup
Inner core
Unknown ultra-dense matter. Neutrons and protons may remain as particles, break down into their constituent quarks, or even become 'hyperons'.
?
Atmosphere
Hydrogen, helium, carbon
Beam of X-rays coming from the neutron star's poles, which sweeps around as the star rotates.
©nature

PROPERTIES AND TYPES :

- Exotic, tiny and dense objects with extreme gravitational pull.

- Rotation about their axis at high speed -> conservation of angular momentum.

-Types : **PULSARS AND MAGNETARS**

- Some neutron stars show characteristics of both Pulsars and Magnetars.

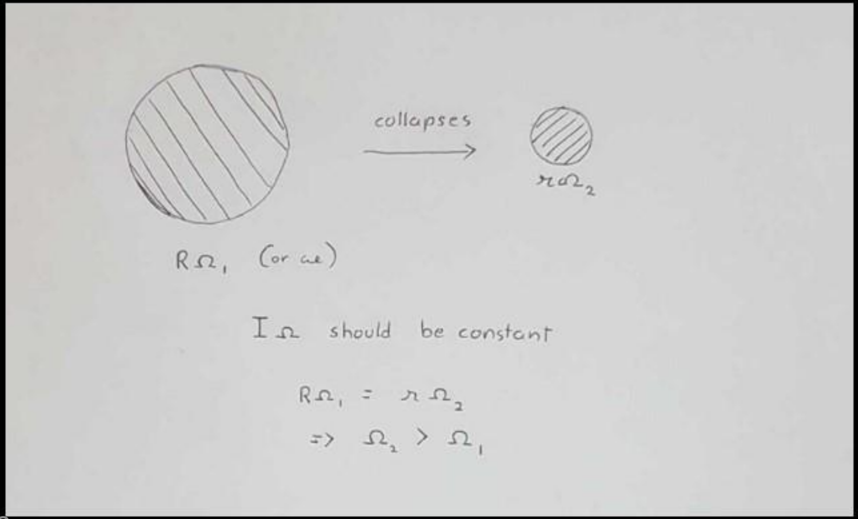
PULSARS

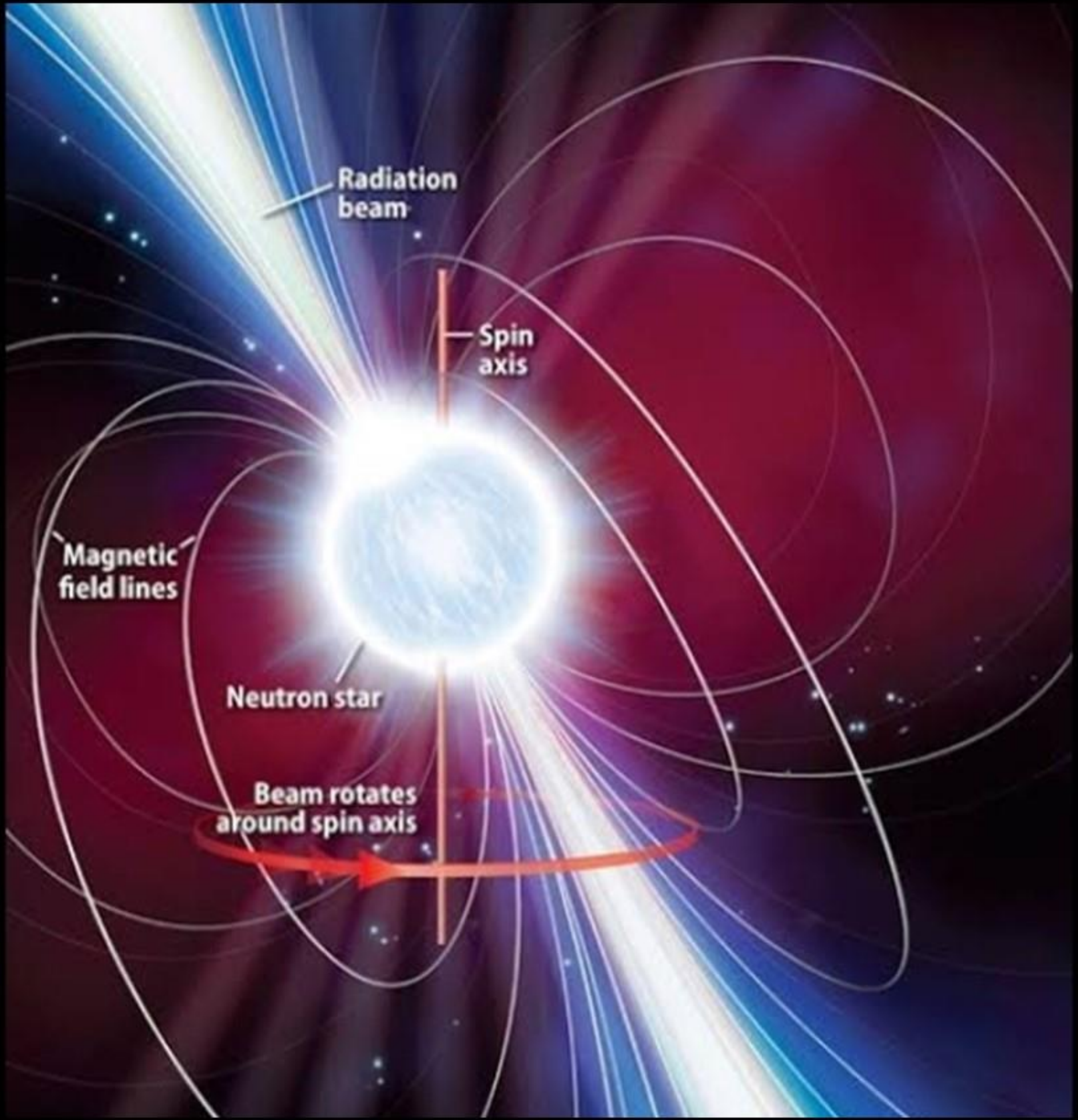
Pulsars are neutron stars which emit beams of radiation through poles

PROPERTIES OF PULSARS :

ROTATION :

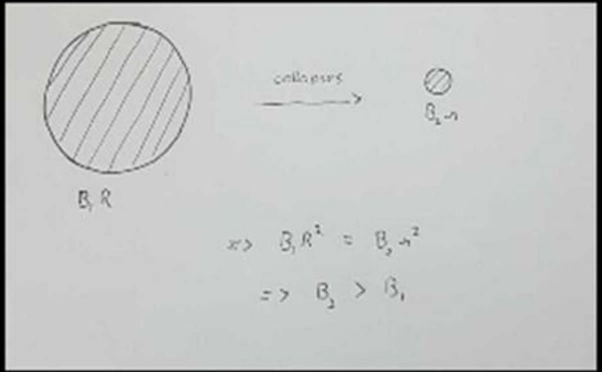
Pulsars rotate at very high speeds which have been hypothesised to be due to conservation of angular momentum of the parent star.





MAGNETIC FIELD :

Pulsars have the strongest magnetic fields ever recorded with Magnetars securing top place.
The reason behind their powerful magnetic fields is not yet completely understood but it is hypothesised that they inherit it from the parent star before it.

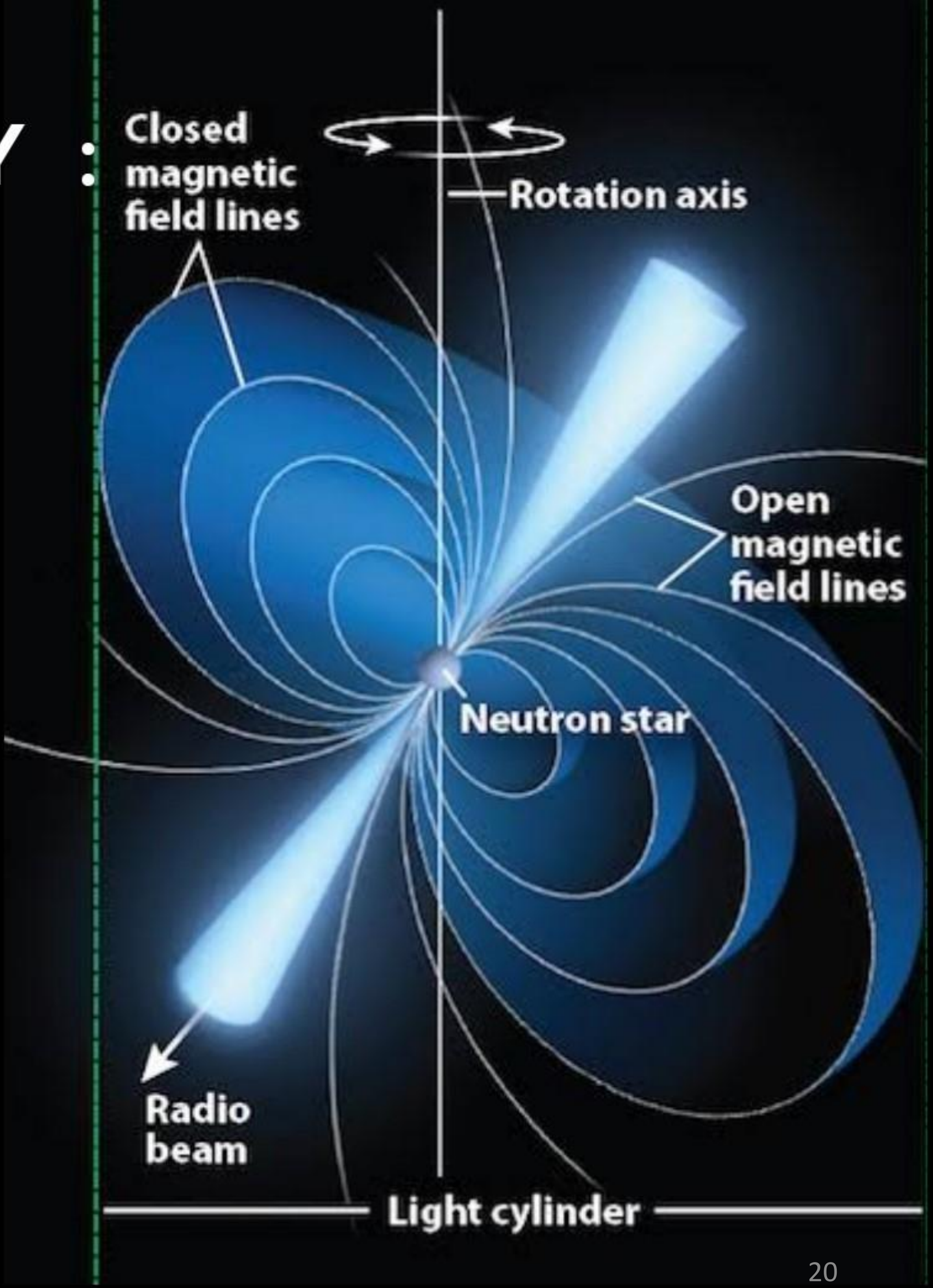


ELECTRIC FIELD :

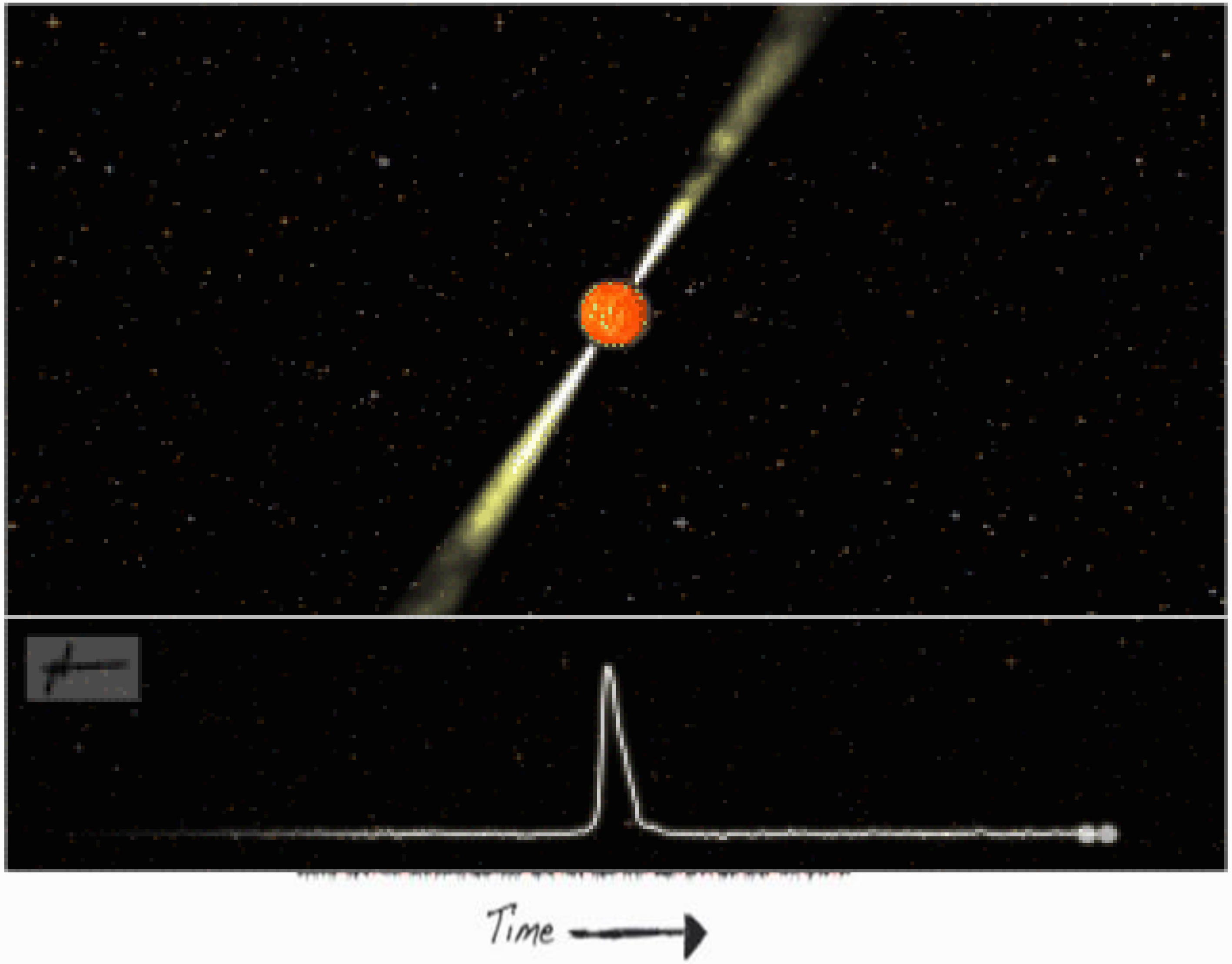
Pulsars have strong electric fields caused by the rotation of charged particles under a magnetic field.

LIGHT CYLINDER THEORY :

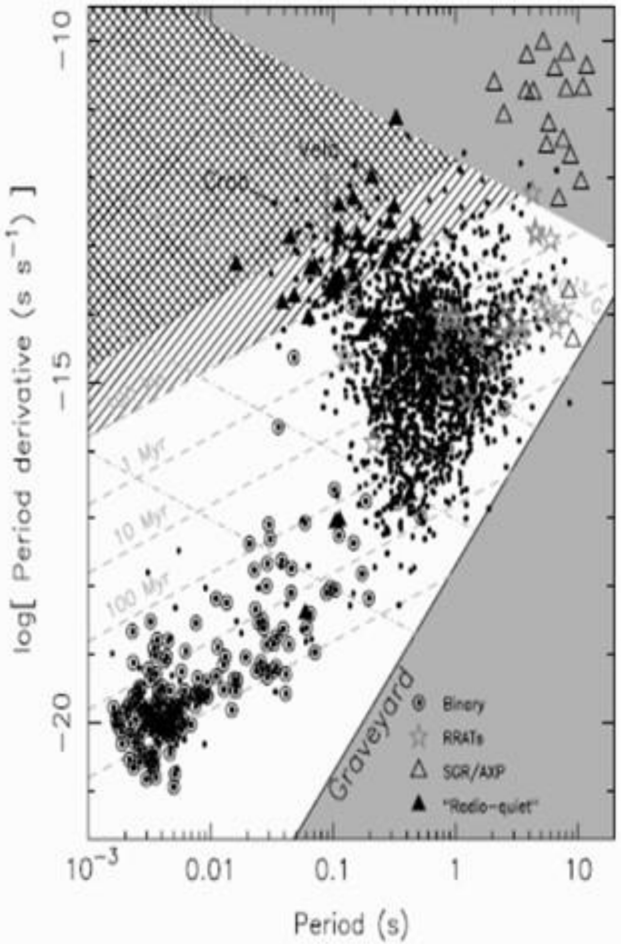
The light cylinder theory suggests that the cause of a pulsars characteristic beams of radiation are caused by its electric and magnetic field. It is widely accepted as it complies with Einstein's Theory of Special Relativity



VISUALIZING A PULSAR:

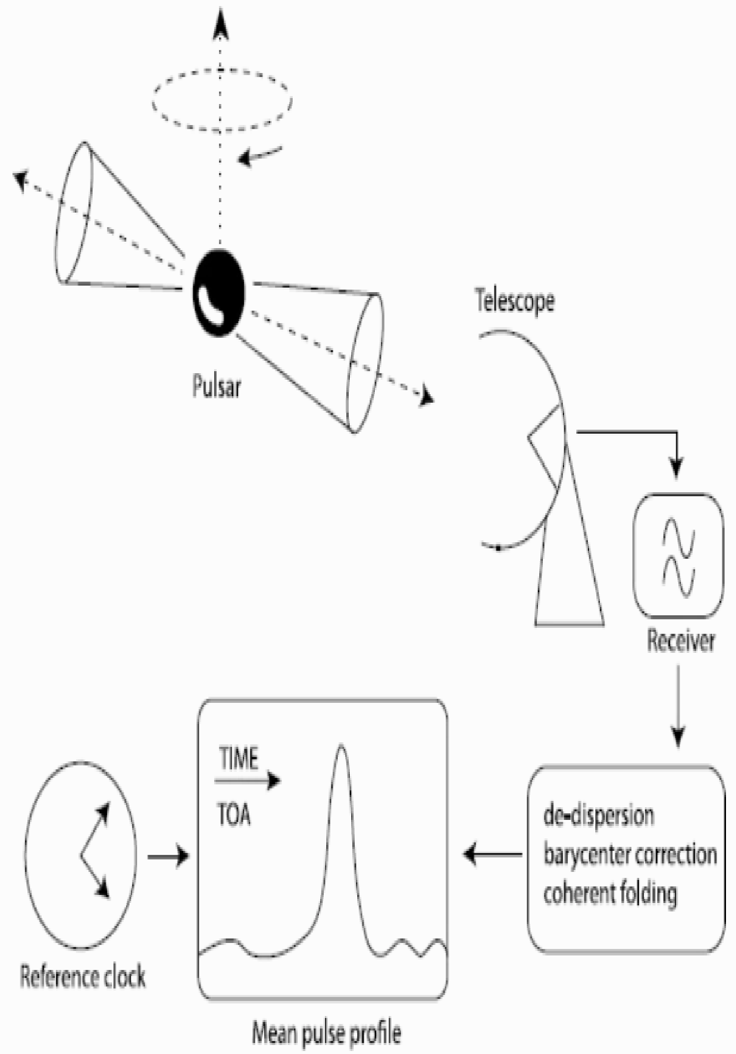


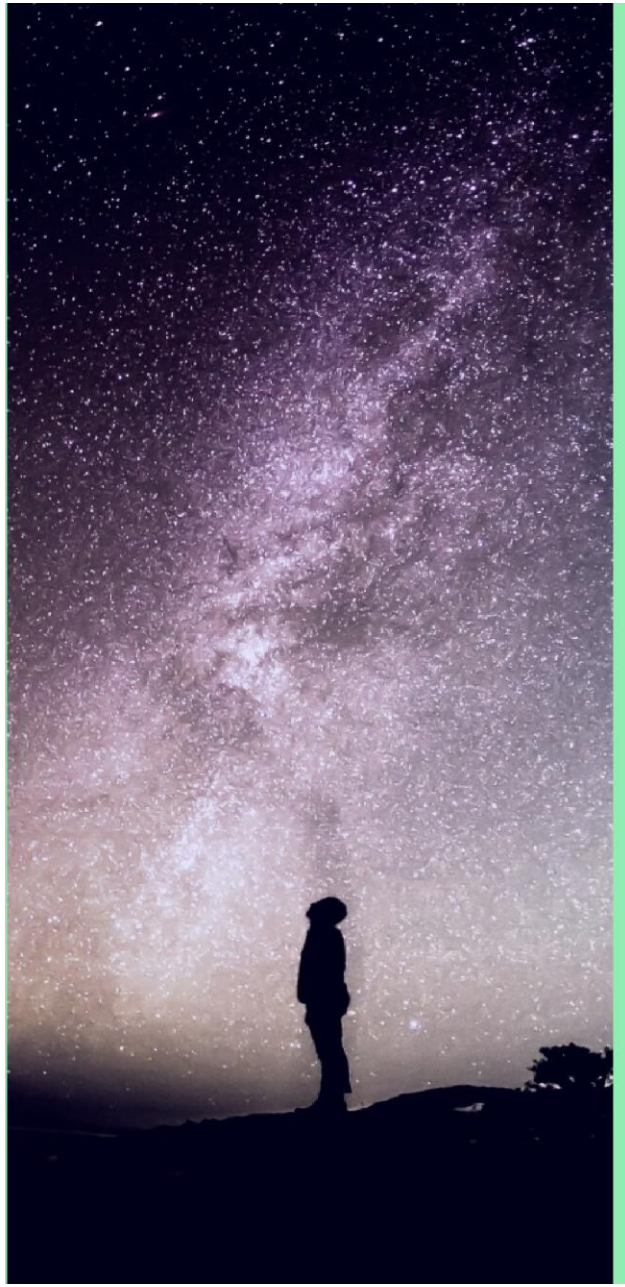
WHAT WE KNOW SO FAR:



The P--$\dot{P}$-diagram for the known pulsar population. Characteristic age ($\tau = P/2\dot{P}$), surface magnetic field ($B = 3.2 \times 10^{19}\sqrt{P\dot{P}}$ G) and spin-down luminosity ($\dot{E} = 4\pi I\dot{P}/P^3$, with I being the moment of inertia) are functions of P and $\dot{P}$ and are hence indicated as lines of corresponding value. Binary pulsars are marked by a *circle*. The *lower solid line* represents the pulsar "death line" enclosing the "pulsar graveyard" where pulsars are expected to switch off radio emission. The *gray area in the top right corner* indicates the region where the surface magnetic field appears to exceed the quantum critical field of 4.4×10^{13} Gauss. For such values, some theories expect the quenching of radio emission in order to explain the radio-quiet "magnetars" (i.e. Soft-gamma ray repeaters, SGRs, and Anomalous X-ray pulsars, AXPs).

DETECTION OF PULSAR:





INVESTIGATING
METHODS OF PULSAR DETECTION IN
RADIO CONTINUUM SURVEYS USING THE
AUSTRALIAN
SQUARE KILOMETER ARRAY PATHNDER.

BY ANDREW D. CAMERON

OBSERVATIONAL PROPERTIES:

- ***Integrated pulses***
- ***Individual pulses***
- ***Period fluctuations***
- ***Flux density spectra***
- ***Dispersion of pulses of higher and lower frequency radio waves caused by interstellar medium***
- ***Scintillation or apparent oscillation of radiations observed***
- ***Polarisation***

(both linearly and circularly polarised

Two of the Prominent ways in which pulsars are detected :

- *Conventional Single-Antenna Searching Techniques.*
  [RADIO INTERFEROMETRY]

- *Radio Continuum Surveys*

Search Techniques :

- *De-dispersion*
- *Barycentric correction*
- *Fourier analysis*
- *Candidate selection*
- *Regions of the sky to survey*

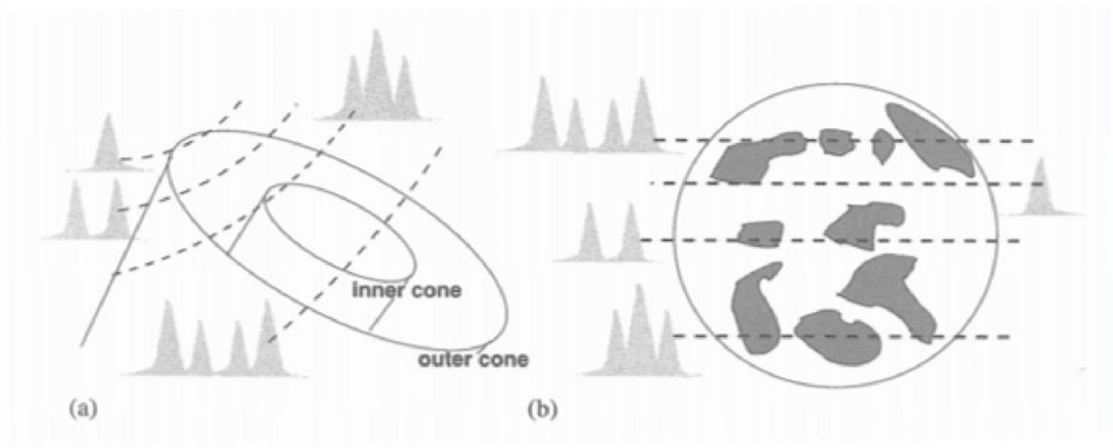
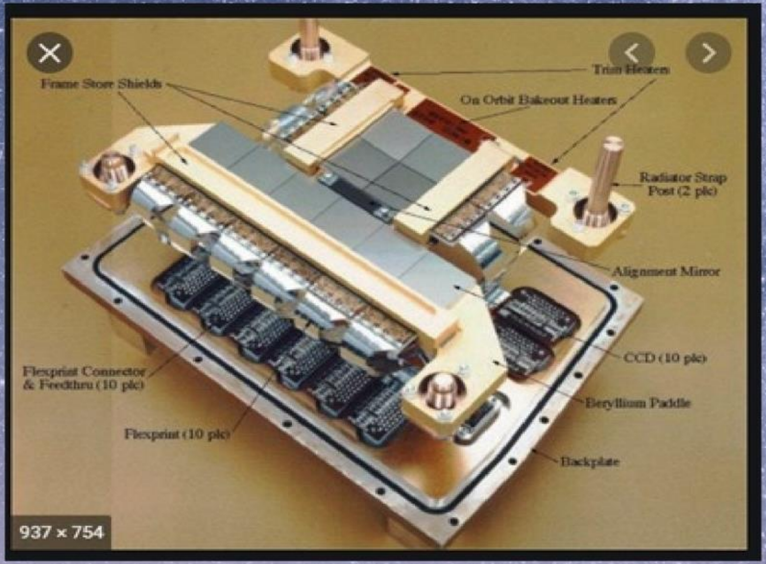


Figure 1.4: Diagram presenting two of the complex cone models described in Section 1.2.1. (a) shows the nested cone model, with several concentric cones of emission nested within each other. (b) shows the "patchy" cone model, where only certain irregular regions within the cone produce emission. The dotted lines show the pulse profiles that would be observed for different lines-of-sight cutting through the cone. Diagram from *Handbook of Pulsar Astronomy*, Lorimer & Kramer, p73 [25].

Advanced CCDImaging Spectrometer (ACIS)



- ***this instrument is an array of charged coupled devices (CCD's)***
- ***can make X-ray images***

THE SECONG MOLONGLO PULSAR SURVEY- DISCOVERY OF 155 PULSARS

- 149 pulsars were detected in the years from 1967 to 1976
- Molonglo survey,Jodrell Bank Survey and The University of Massachusetts Arecibo Survey
- This survey detected 155 new pulsars to the south of declination +20 degrees.

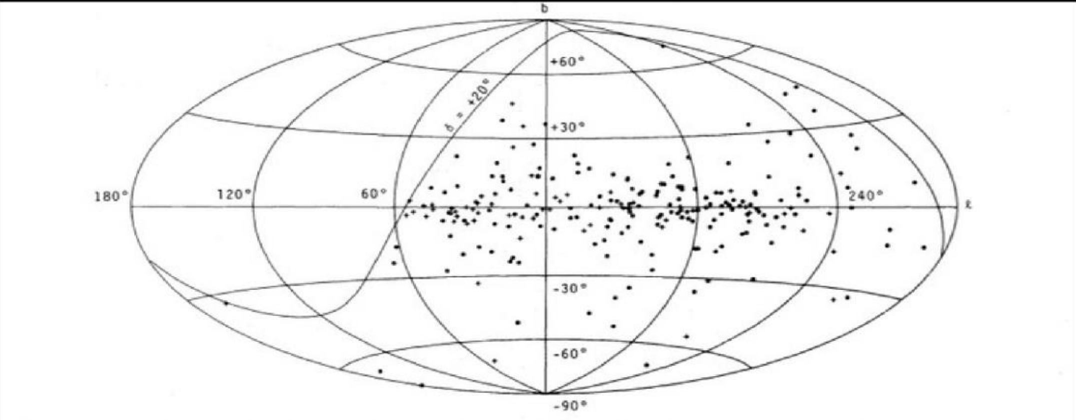


Figure 1. Equal area plot in galactic coordinates of the 224 pulsars detected in the second Molonglo pulsar survey. New detections are marked with a filled circle and previously known pulsars with a cross. The survey covered essentially all of the sky south of declination + 20°.

PULSAR ASTRONOMY

By Andrew Lyne, Francis Graham-Smith

- ***The possibility that pulsars can emit optical pulses was first dtected from PSR B1919+21***
- ***Few months later discovery of optical pulses was also made from the Crab Pulsar***

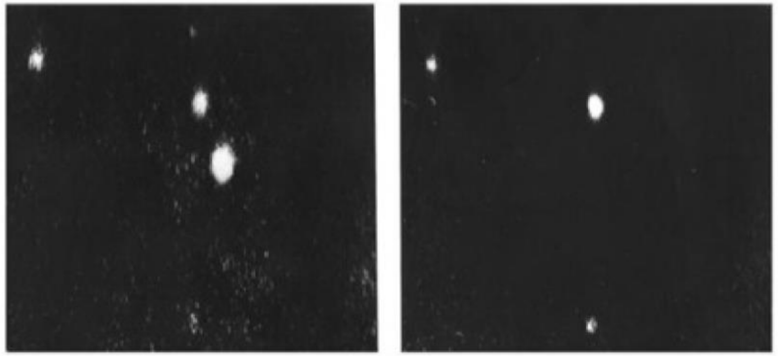
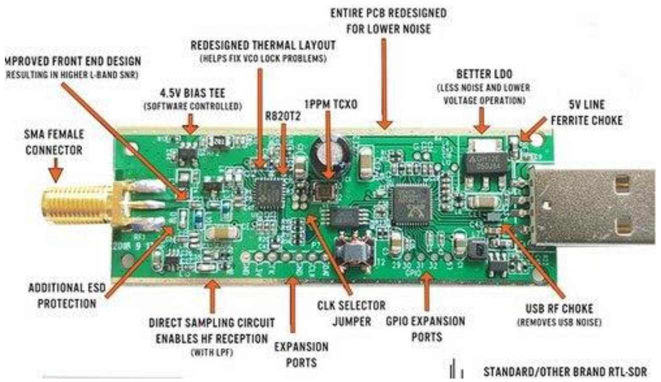


Fig. 1.2. The Crab Pulsar. This pair of photographs was taken by a stroboscopic television technique, showing the pulsar on (left) and off (right). (Lick Observatory, reproduced by kind permission of the Royal Astronomical Society.)

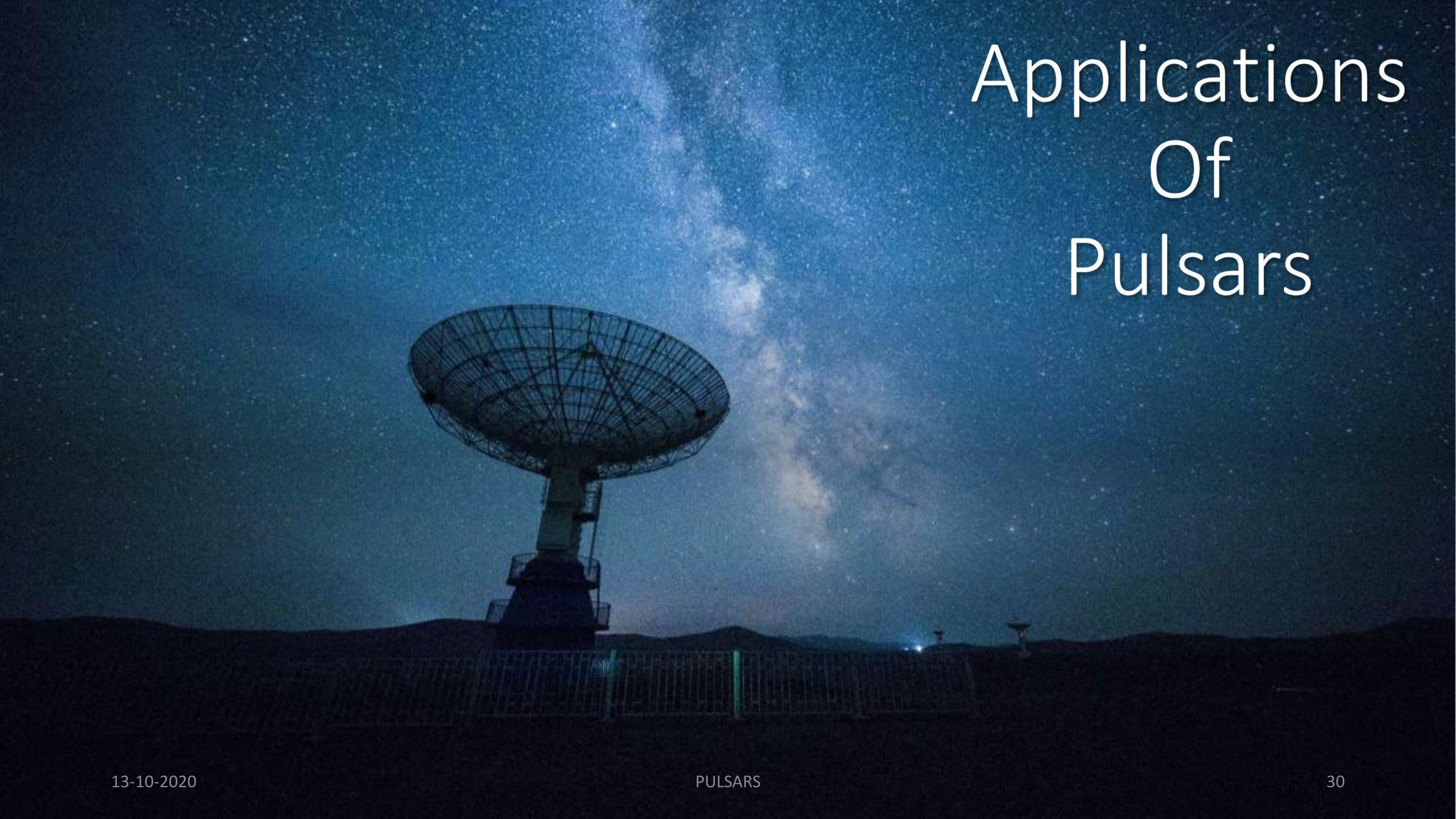
DETECTION WITH RTL-SDR

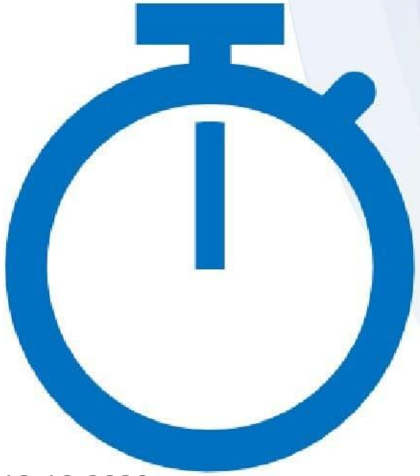
- Pulsars emits a beam of electromagnetic radiation, If this beam points towards the earth, it can then be observed with a large dish antenna and a radio, like the RTL-SDR.
- Pulsars create weakly detectable noise bursts across a wide frequency range.
- They create these noise bursts at precise intervals, so they can be detected from within the natural noise by performing some mathematical analysis on the data
- Typically a few hours of data needs to be received to be able to analyze it, with more time needed for smaller dishes.



RTL SDR V3
USB Dongle

Applications Of Pulsars





Pulsars as Clocks

Pulsar Planets

The 6.2 ms pulsar PSR B1257+12, an old neutron star, was detected by a large, all-sky survey conducted during the telescope maintenance period in early 1990.

The two planets circling the pulsar were discovered in 1991 with the 1000 ft Arecibo radio telescope.

Einstein and Gravitational Waves

The Fabric of the Cosmos!

Space and time, according to Einstein are interwoven into a flexible fabric of Space-Time

Matter bends the Space-Time Fabric

The magnitude of bending depends on the mass of the object

More the mass more the bending

When 2 objects, especially celestial bodies, spin rapidly around a common center, the Fabric of Space-Time gets 'Ripples' in it

These 'Ripples' are called Gravitational Waves

Currently the one way(or one of the ways, if any more know ones exist) you can detect thee waves, as they are too minute to be felt by us, is using LIGO

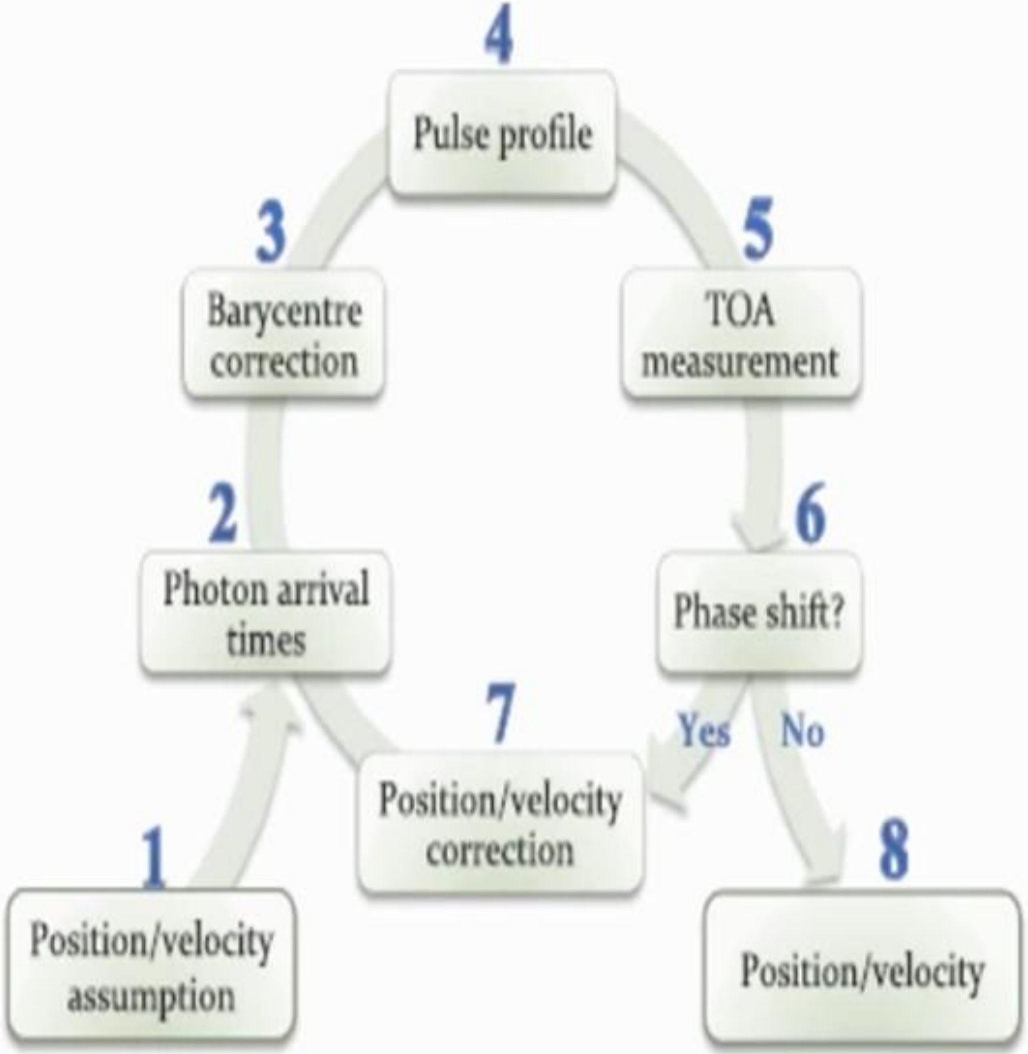
Ripples in the Fabric!

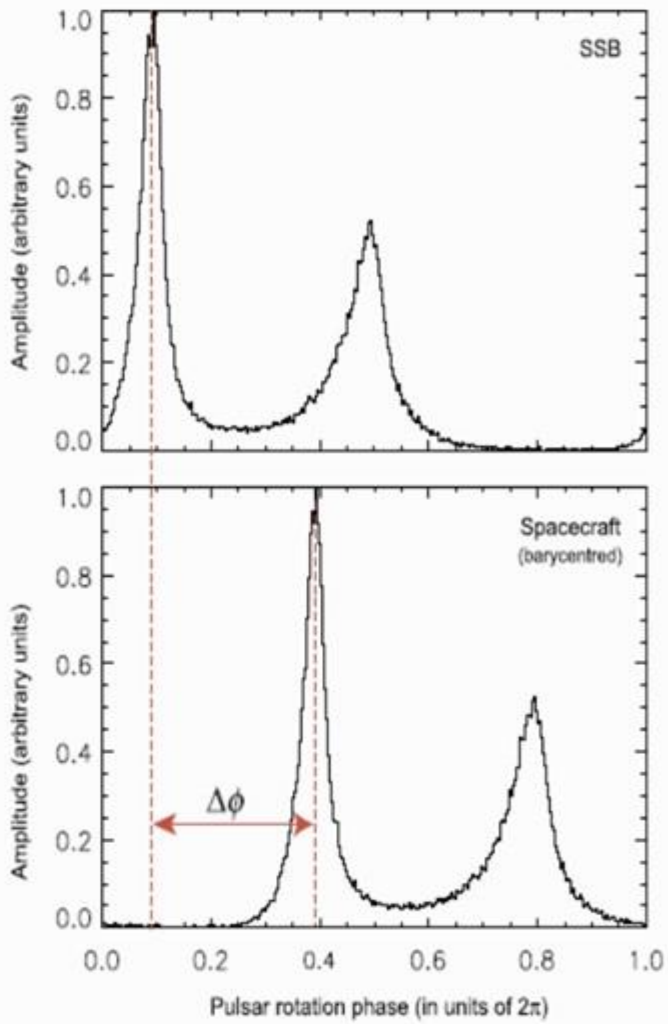

Started making it.
Had a breakdown.
Bon appetite.

Applications:

- Autonomous Spacecraft Navigation Based on Pulsar Timing
- Timing Irregularities
- Gravitational Wave Detection Based on Pulsar Timing
- High Performance Clocks with Special Emphasis on Geodesy and Geophysics and Applications to Other Bodies of the Solar System

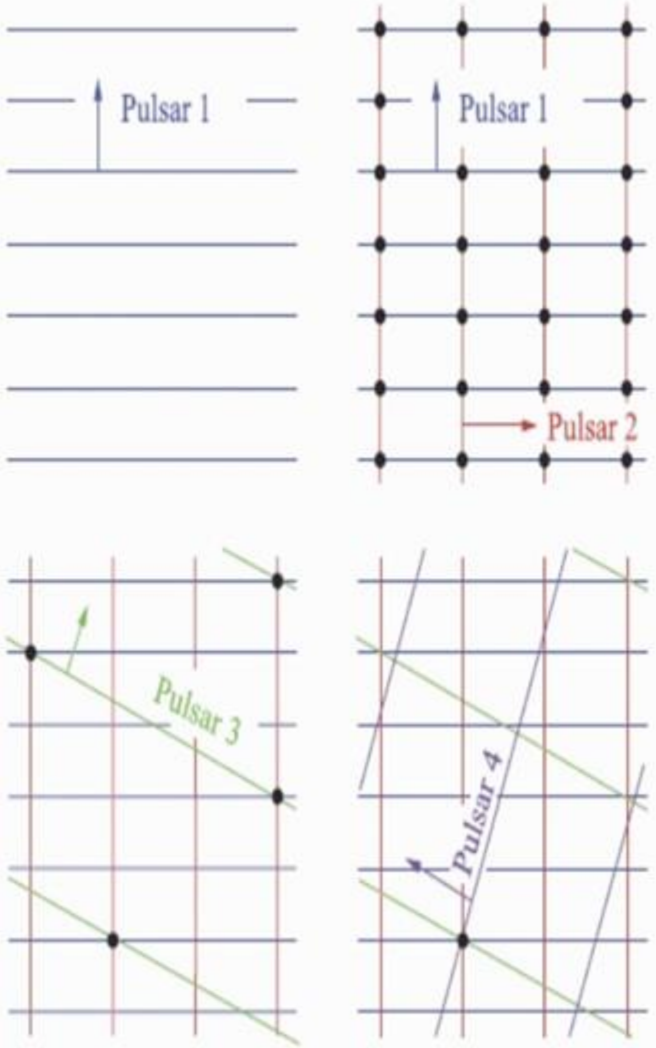
PULSAR BASED NAVIGATION:





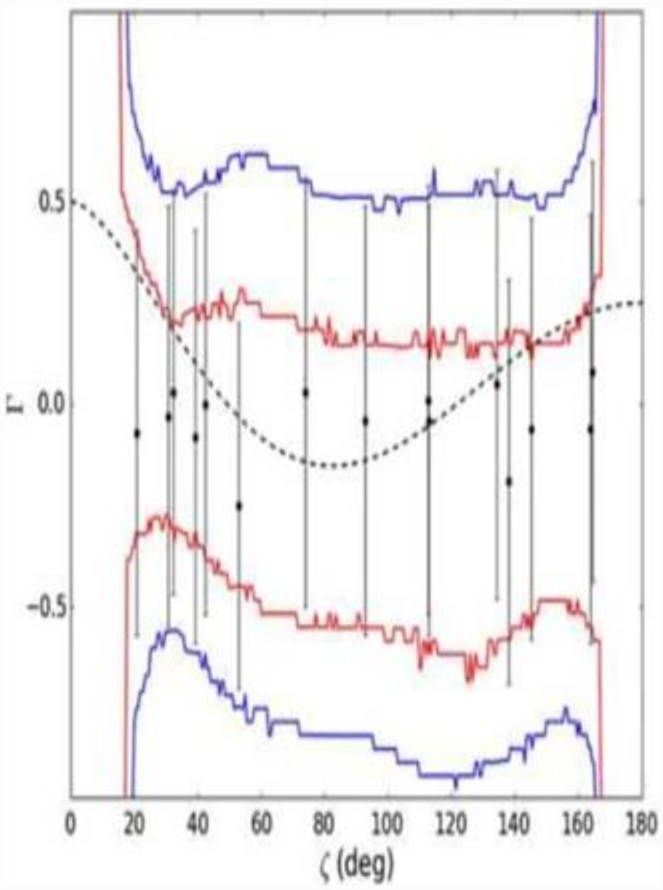
Measuring the phase difference between the expected and measured pulse peak at an inertial reference location; e.g., the solar system barycenter (SSB). The *top profile* shows the main pulse peak location as expected at the SSB. The *bottom profile* is the one measured at a spacecraft and transformed to the SSB by assuming the spacecraft position and velocity during the observation. If the position and velocity assumption was wrong, a phase shift $\Delta\phi$ is observed (Becker et al. 2015)

Detection of an object using pulsars:

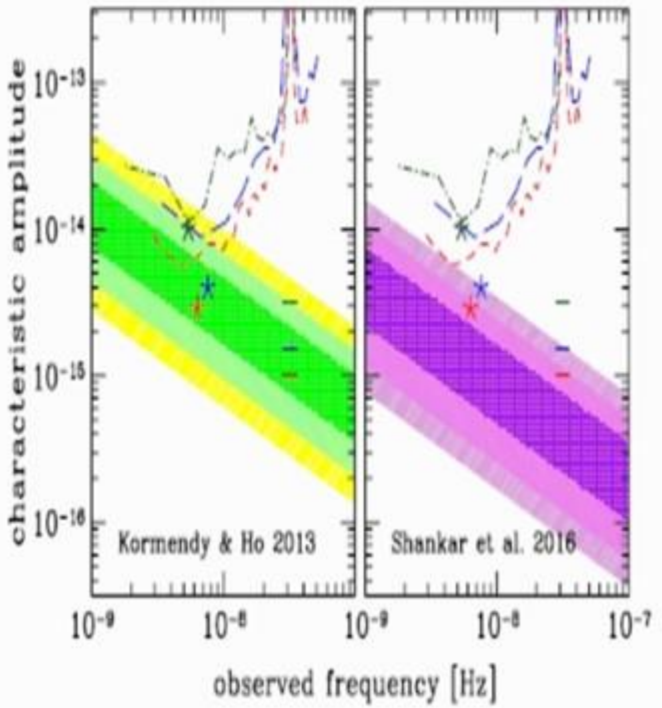


Solving the ambiguity problem by observing four pulsars (drawn in two dimensions). The *arrows* point along the pulsar's lines-of-sight. *Straight lines* represent planes of constant pulse phase; *black dots* indicate intersections of planes (Becker et al. 2015)

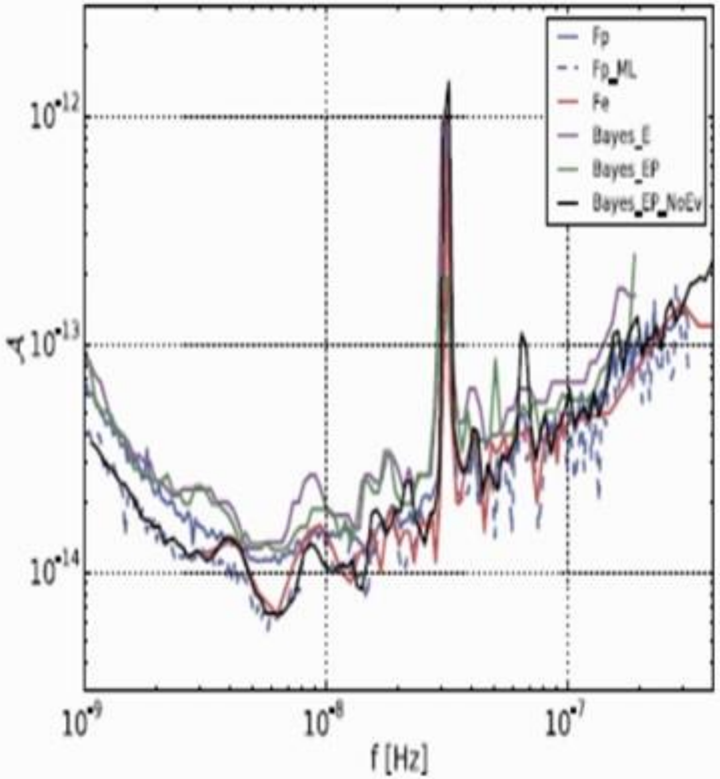
GRAVITATIONAL WAVES DETECTION:



The recovered correlation between pulsars as a function of angular separation on the sky for a power law noise process in the EPTA analysis. The *red* and *blue lines* represent the 68% and 95% confidence intervals for the correlation function when modeled by the lowest 4 Chebyshev polynomials, while the individual points are the mean correlation coefficient with 1σ uncertainty for each pulsar pair when fitting without assuming a smooth model. The Hellings–Downs correlation is represented by the *dotted line*. From Lentati et al. (2015)



From Sesana et al. 2016. PTA limits on the amplitude of a stochastic GWB. The jagged curves are current PTA sensitivities: EPTA (*dot-dashed green*), NANOGrav (*long-dashed blue*), and PPTA (*short-dashed red*). For each sensitivity curve, *stars* represent the integrated upper limits to an $f^{-2/3}$ background, and the *horizontal ticks* are their extrapolation at $f = 1\ \mathrm{yr}^{-1}$, i.e. the upper limit on $A(f = 1\ \mathrm{yr}^{-1})$ quoted in the main text. The *shaded areas* represent the 68% 95% and 99.7% confidence intervals of the characteristic amplitude $h_c(f)$ of the expected GWB form SMBHBs. The *two panels* represent predictions from models employing two different M_{BH}-host bulge mass relations: the one from Kormendy and Ho 2013 (*left*) and the one from Shankar et al. 2016 (*right*). See Sesana et al. (2016) for full details of the employed models



The 95% upper limit on the gravitational wave strain A_{gw} for the 3 frequentist methods, i.e. $\mathscr{F}_p$ varying noise (*Fp*), $\mathscr{F}_p$ fixed noise (*Fp_ML*) and $\mathscr{F}_e$, and the 3 Bayesian methods, i.e. "evolving source" with Earth term only (*Bayes_E*) and with Earth and Pulsar terms (*Bayes_EP*) and "non-evolving source" with Earth and Pulsar terms (*Bayes_EP_NoEv*), performed in the EPTA single source analysis. From Babak et al. (2016), where the detailed descriptions of each method can be found

Limitations:

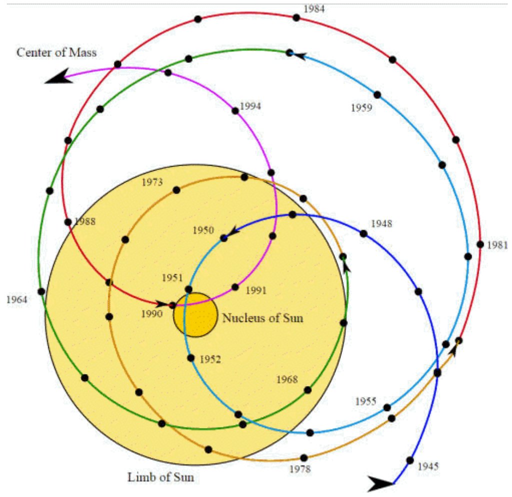
- The disadvantage of radio observations in a navigation application, though, is the large size and mass of the phased-antenna array
- the observing time is limited by the Allen variance of the receiving system and, therefore, cannot become arbitrarily large

REFERENCE :

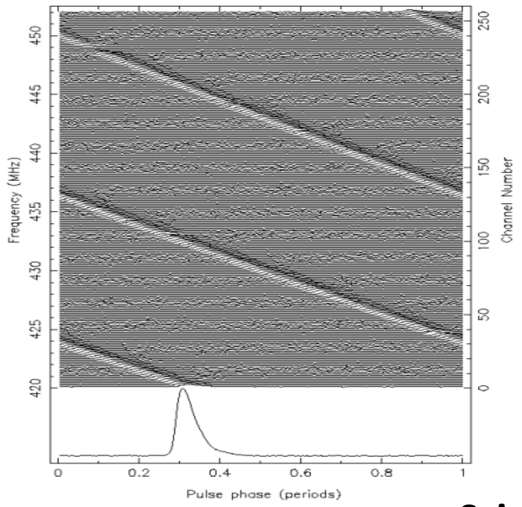
https://link.springer.com/article/10.1007/s11214-017-0459-0#additional-information

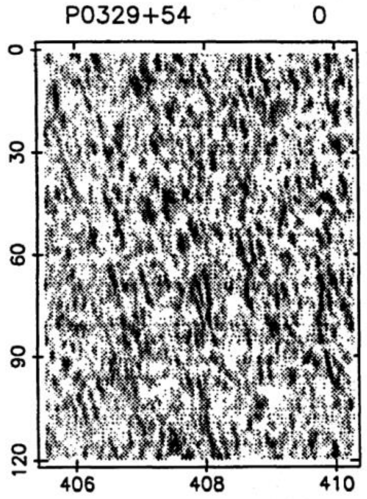
CHALLENGES FACED DURING PULSARS DETECTION

I. The 'EME' Factor
II. Strength of the Pulsar Signal
III. Nature of the Signal
IV. Effects of Scintillation
V. Effects of Dispersion
VI. Doppler Effects
VII. Polarisation Effects



Vela Dispersion @ 430 MHz



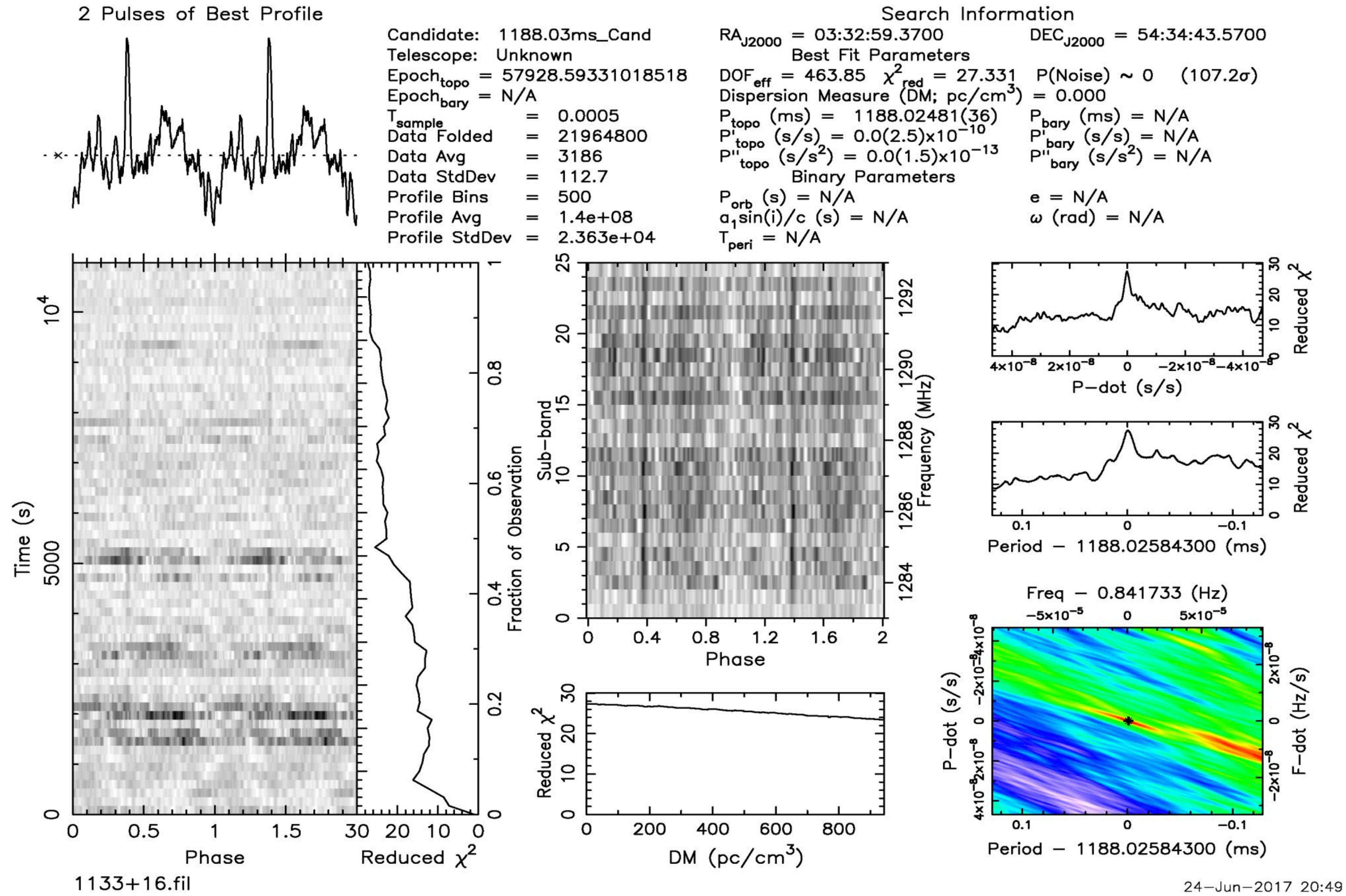


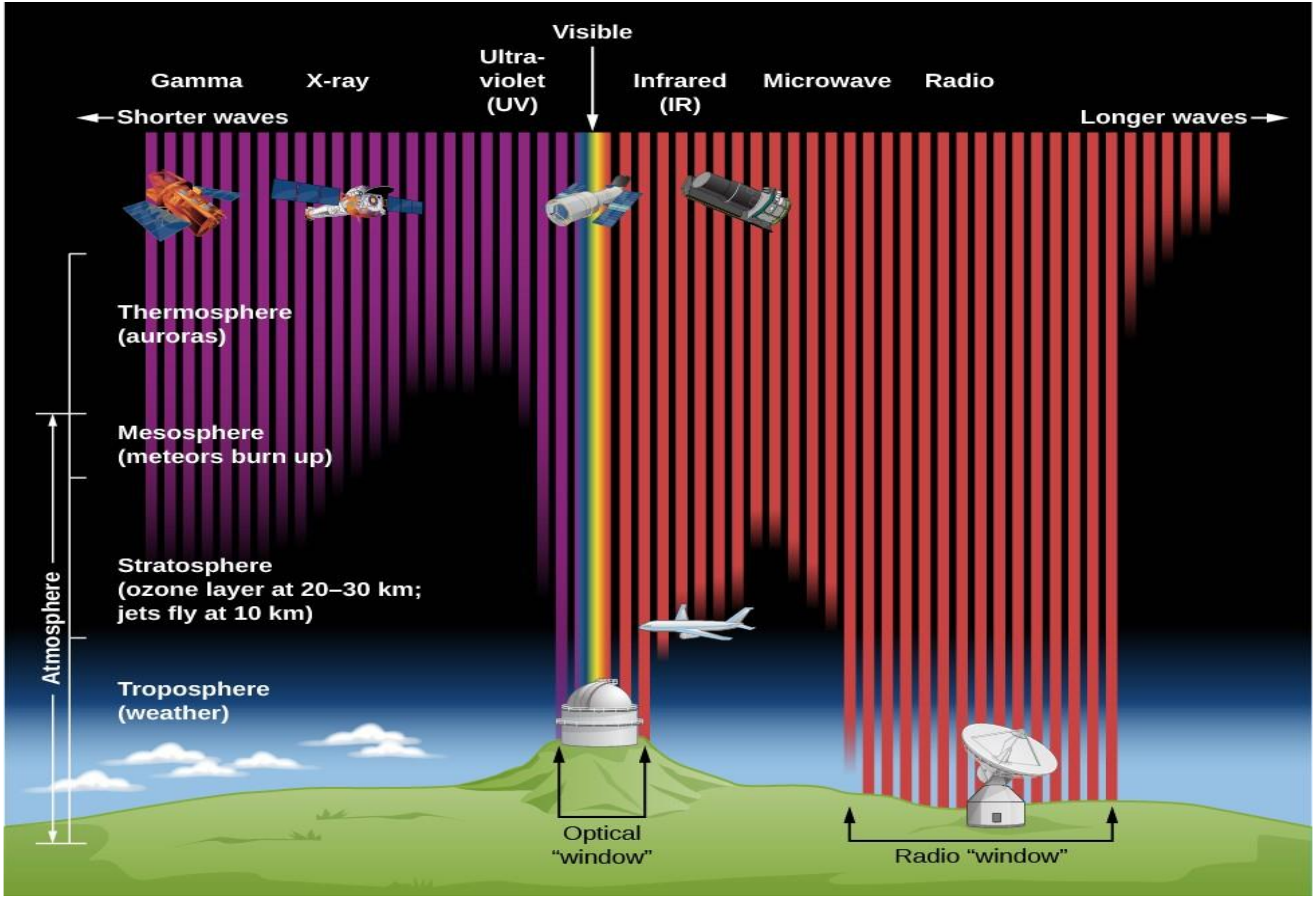
Scintillation Effects on the B0329+54 Pulsar @ 408 MHz

MODIFIED RADIOMETER EQUATION

$$\Delta S_{min} = \beta \frac{2k_b\,(S/N_{min})T_{sys}}{A_e\sqrt{n_p\,t_{int}\,\Delta f}}\sqrt{\frac{W}{P-W}}$$

Where,
Δs_{min} = minimum detectable flux density (watts per square metre per hertz - averaged over the period of the pulse)
β = factor for imperfections in the observatory system, usually near to 1 (values >1 makes the system less sensitive)
k_b = Boltzmann's constant ($1.38064852 \times 10^{-23}$ Joules / K)
S/N_{min} = required minimum linear S/N for validation of result (professional require at least 6, amateurs ≥ 4)
T_{sys} = System noise temperature (K^o)
A_e = antenna aperture (m^2)
n_p = number of polarisations (usually 1 for amateurs, generally a maximum of 2)
t_{int} = integration time (observation time in seconds)
Δf = pre-detection bandwidth (Hz)
W = width of pulse (seconds)
P = period of pulse (seconds)


2 Pulses of Best Profile
Search Information
Candidate: 1188.03ms_Cand
Telescope: Unknown
Epoch$_{topo}$ = 57928.59331018518
Epoch$_{bary}$ = N/A
T$_{sample}$ = 0.0005
Data Folded = 21964800
Data Avg = 3186
Data StdDev = 112.7
Profile Bins = 500
Profile Avg = 1.4e+08
Profile StdDev = 2.363e+04
RA$_{J2000}$ = 03:32:59.3700
DEC$_{J2000}$ = 54:34:43.5700
Best Fit Parameters
DOF$_{eff}$ = 463.85 χ^2_{red} = 27.331 P(Noise) ~ 0 (107.2σ)
Dispersion Measure (DM; pc/cm^3) = 0.000
P$_{topo}$ (ms) = 1188.02481(36)
P$_{bary}$ (ms) = N/A
P'$_{topo}$ (s/s) = 0.0(2.5)x10^{-10}
P'$_{bary}$ (s/s) = N/A
P''$_{topo}$ (s/s^2) = 0.0(1.5)x10^{-13}
P''$_{bary}$ (s/s^2) = N/A
Binary Parameters
P$_{orb}$ (s) = N/A
e = N/A
a$_1$sin(i)/c (s) = N/A
ω (rad) = N/A
T$_{peri}$ = N/A
Time (s)
Phase
Reduced χ^2
Fraction of Observation
Sub-band
Frequency (MHz)
DM (pc/cm^3)
P-dot (s/s)
Period – 1188.02584300 (ms)
Freq – 0.841733 (Hz)
F-dot (Hz/s)
1133+16.fil
24–Jun–2017 20:49


Visible
Gamma
X-ray
Ultra-
violet
(UV)
Infrared
(IR)
Microwave
Radio
Shorter waves
Longer waves
Thermosphere
(auroras)
Mesosphere
(meteors burn up)
Stratosphere
(ozone layer at 20–30 km;
jets fly at 10 km)
Troposphere
(weather)
Atmosphere
Optical
"window"
Radio "window"

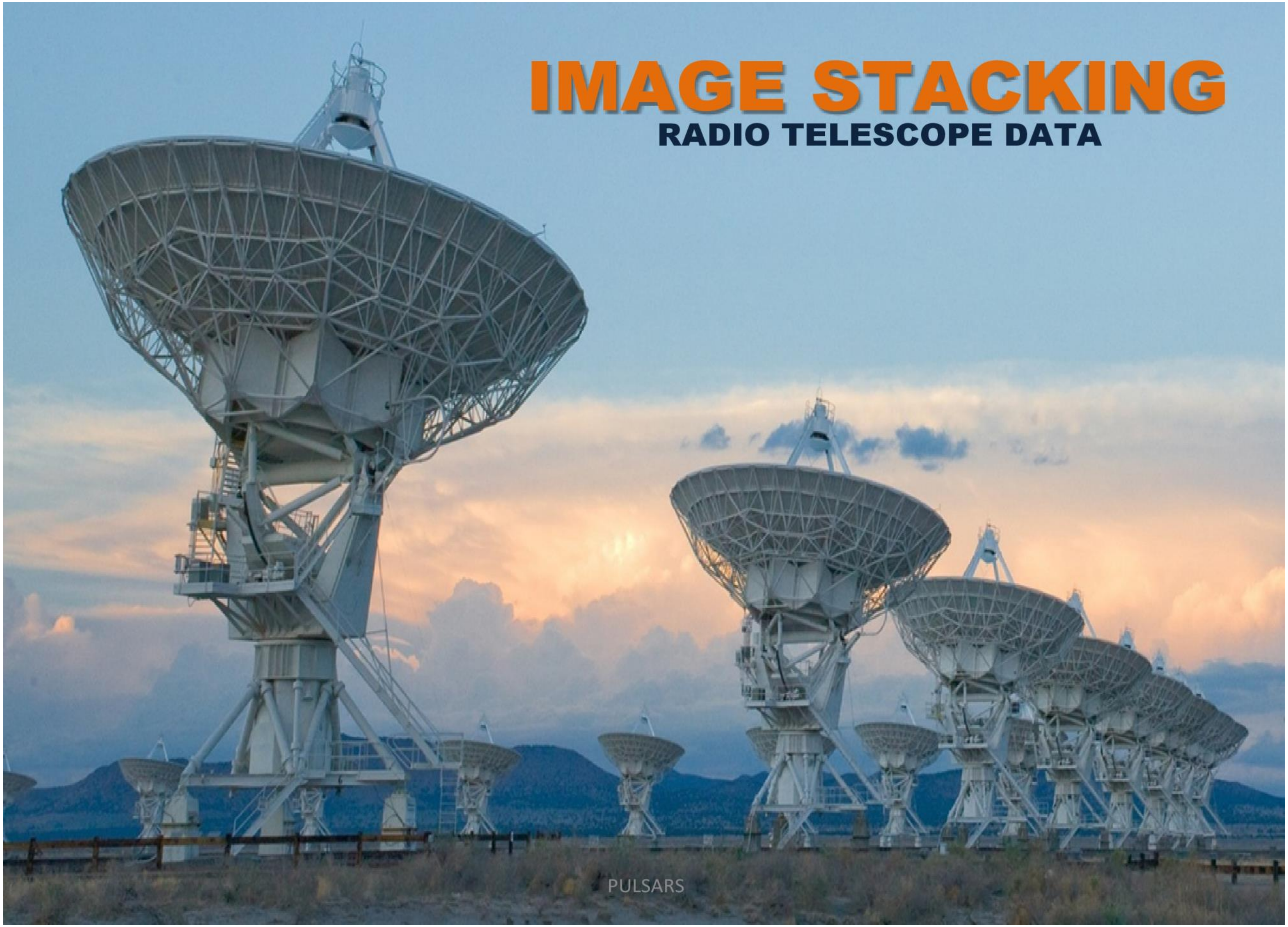
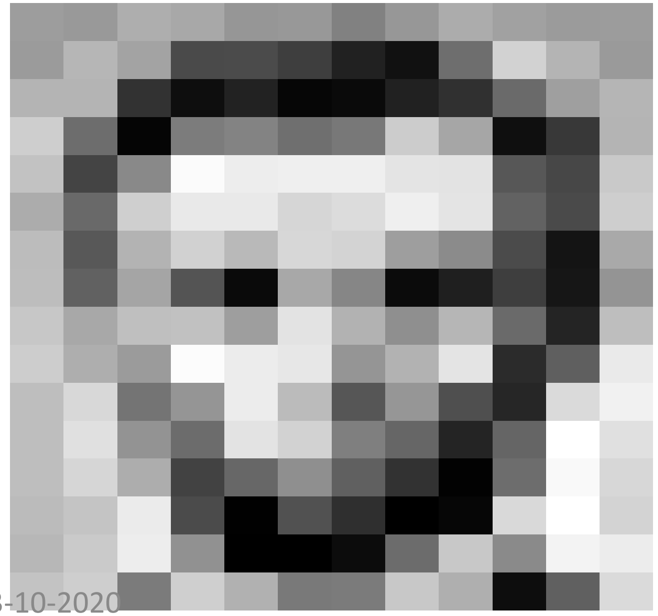
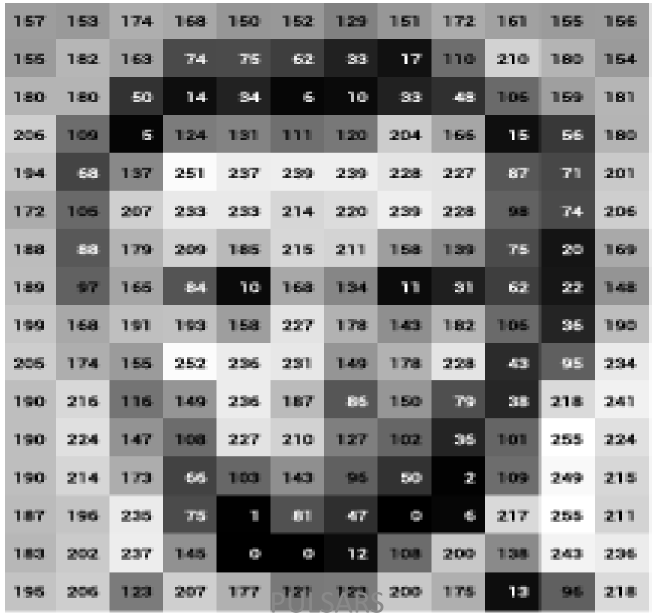


IMAGE STACKING
RADIO TELESCOPE DATA

What is Image?

Make a representation of the external form of
Pixel is the smallest element of an image
Each pixel correspond to any one value.
In an 8-bit gray scale image, the value of the pixel between 0 and 255.

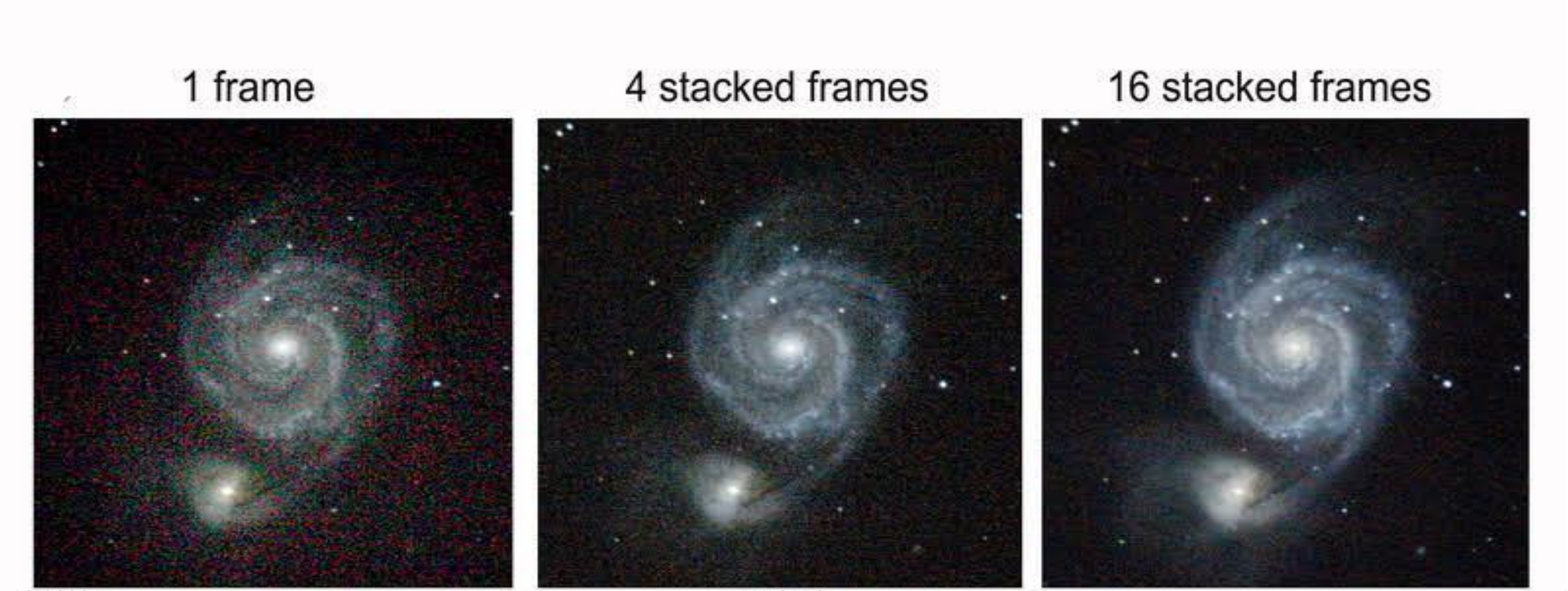




157	153	174	168	150	152	129	151	172	161	155	156
155	182	163	74	75	62	33	17	110	210	180	154
180	180	50	14	34	6	10	33	48	106	159	181
206	109	5	124	131	111	120	204	166	15	56	180
194	68	137	251	237	239	239	228	227	87	71	201
172	105	207	233	233	214	220	239	228	98	74	206
188	88	179	209	185	215	211	158	139	75	20	169
189	97	165	84	10	168	134	11	31	62	22	148
199	168	191	193	158	227	178	143	182	106	36	190
205	174	155	252	236	231	149	178	228	43	95	234
190	216	116	149	236	187	86	150	79	38	218	241
190	224	147	108	227	210	127	102	36	101	255	224
190	214	173	66	103	143	95	50	2	109	249	215
187	196	235	75	1	81	47	0	6	217	255	211
183	202	237	145	0	0	12	108	200	138	243	236
195	206	123	207	177	121	123	200	175	13	96	218

What is Stacking?

Arrange (a number of things) in a pile, typically a neat one.



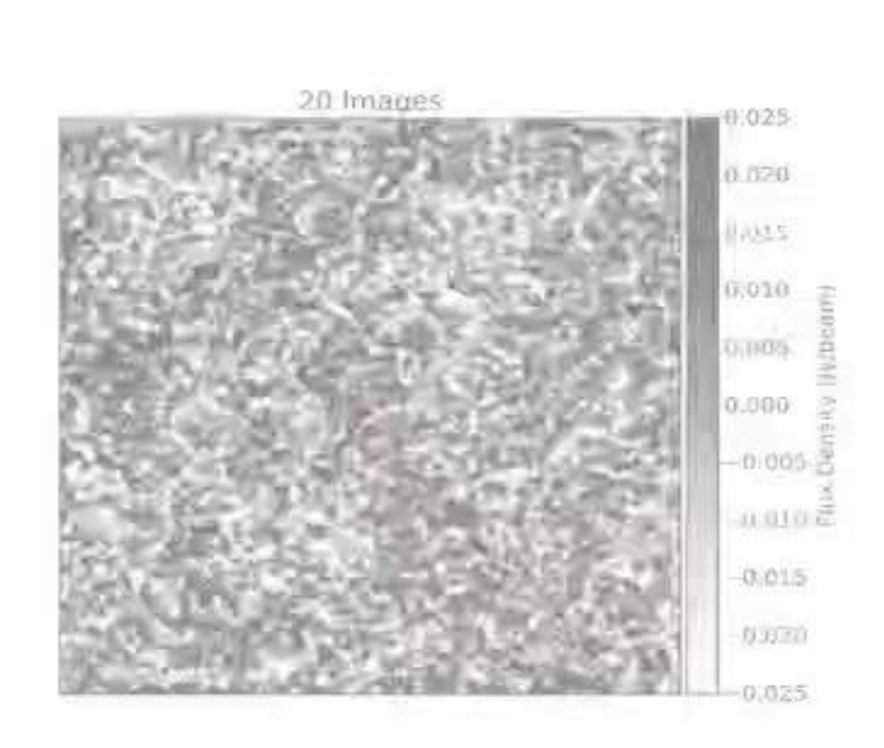
WHY IMAGE STACKING??

- **Detection** = If the flux density is more than five standard deviations higher than the noise in the local region.

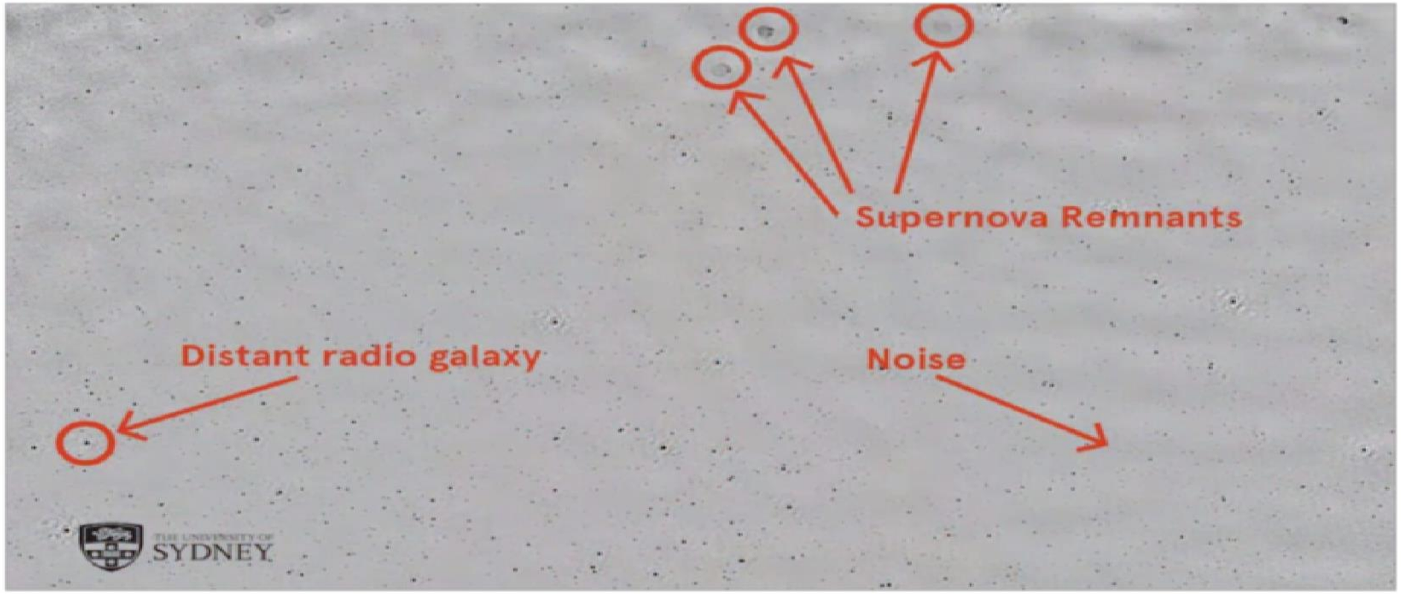
REASONS

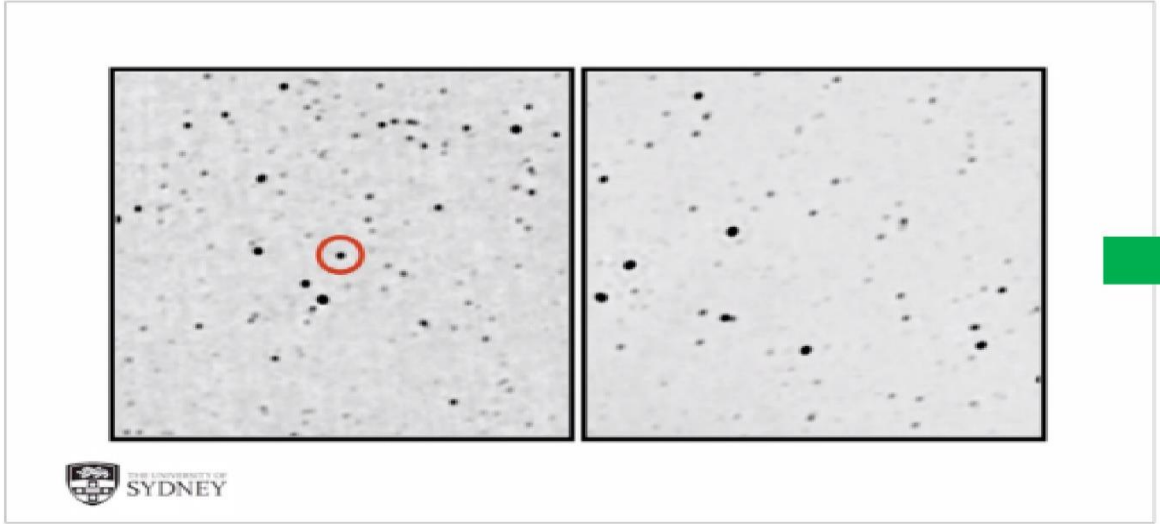
- It could be that the pulsar is too far away
- Could be the intrinsic emission isn't strong at these frequencies
- It could be that the emission is intermittent and switched off.

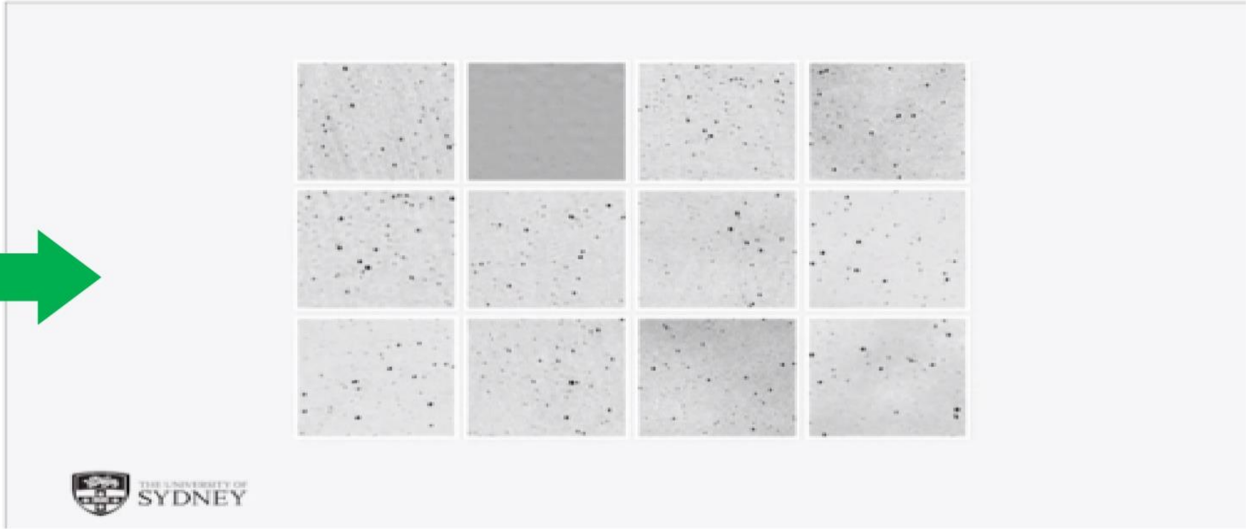
$$1\ \text{Jy} = 10^{-26}\ \frac{\text{W}}{\text{m}^2 \cdot \text{Hz}}$$


20 Images
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
Flux Density (Jy/beam)

The **Murchison Widefield Array** (MWA) radio **telescope**.



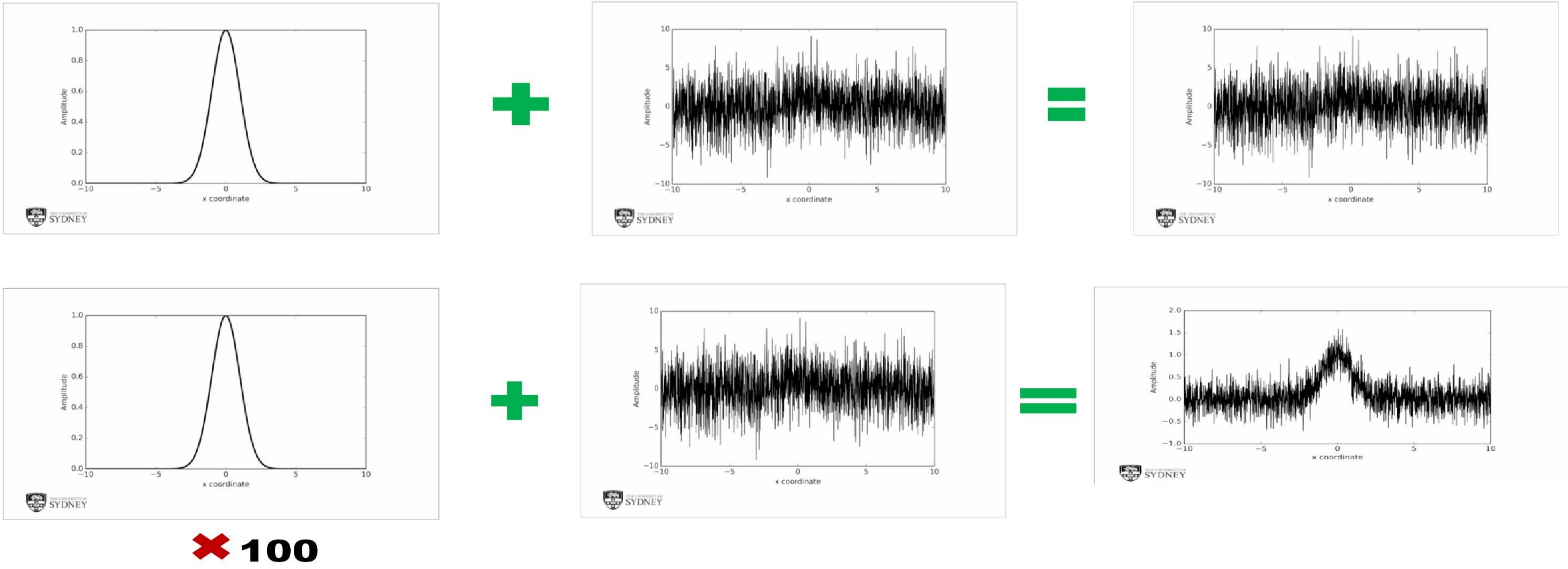




Radio emission at MWA frequencies at the location of known pulsars

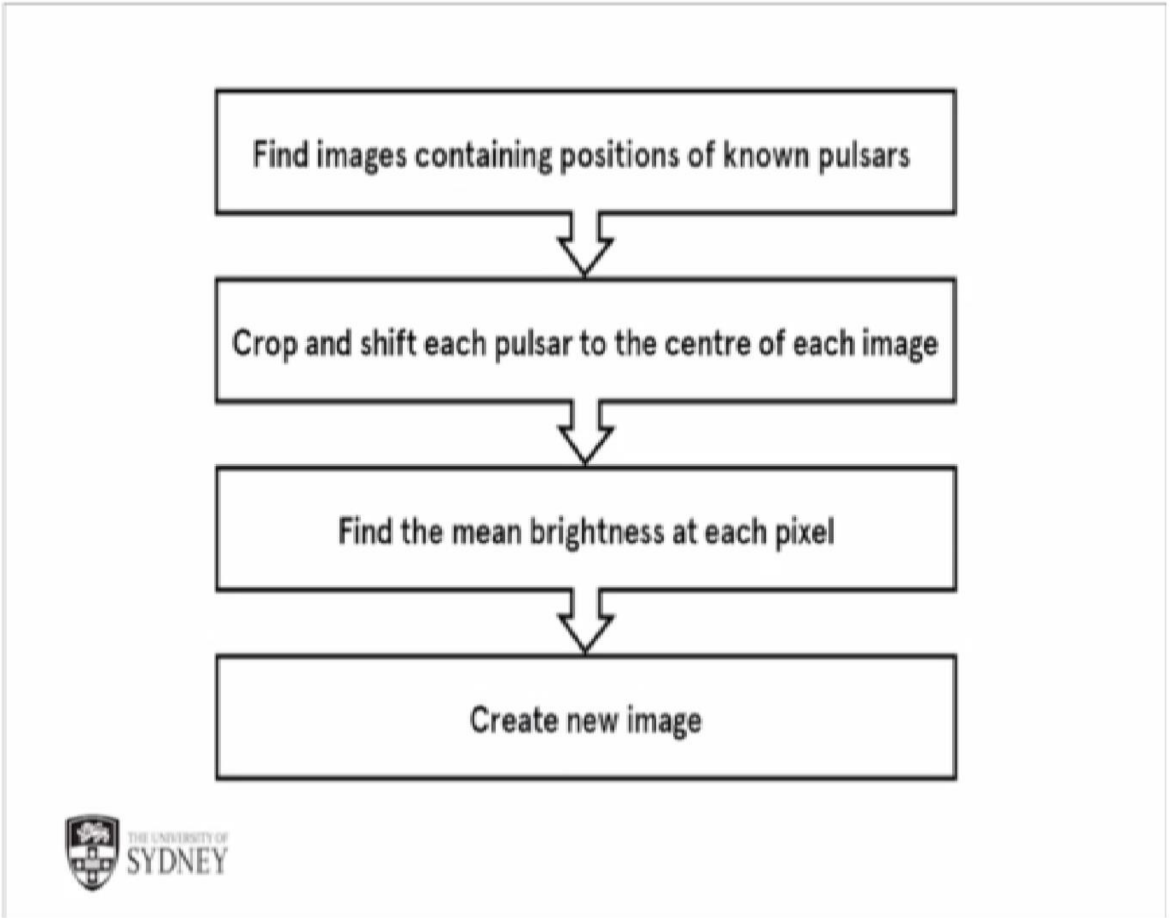
Working

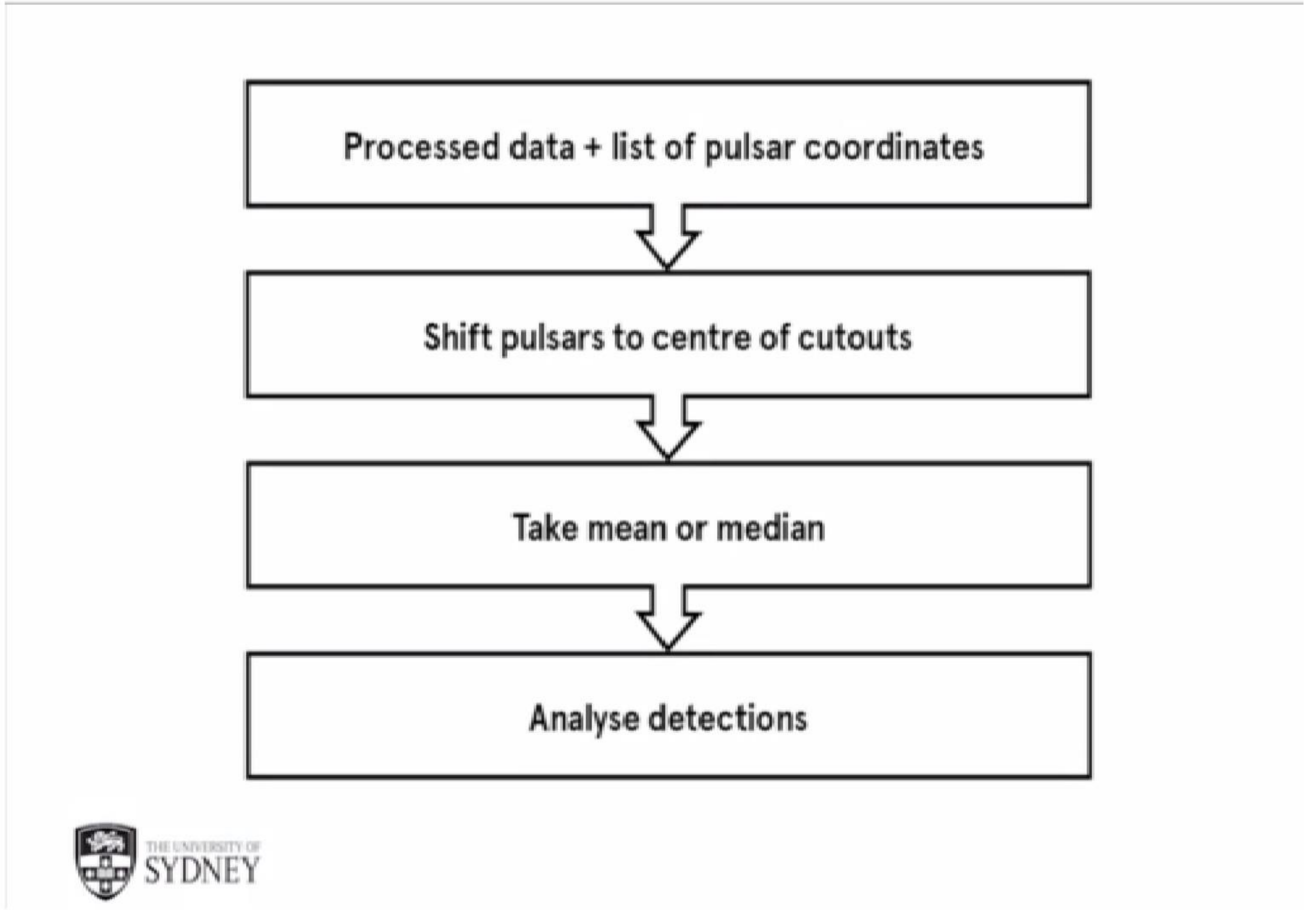
- statistical properties
- Gaussian distribution
- Regions of an image in which there are signals



CHALLENGES

- ❑ **Robustness**
- ❑ **Non scaling of solution**





Algorithms used to tackle the challenges

1. The quickselect algorithm

Quickselect(A, k):

1. Given an array A, choose a pivot element p
2. Partition A around p; let A_1, A_2, A_3 be the subarrays of points $<, =, > p$
3. If $k \leq \text{len}(A_1)$: return Quickselect(A_1, k)
4. Else if $k > \text{len}(A_1) + \text{len}(A_2)$: return Quickselect$(A_3, k - \text{len}(A_1) - \text{len}(A_2))$
5. Else: return p

DRAWBACKS

- Rearranges the array
- Updating with the addition of more data

2. Binmedian

Given data points $x_1, \ldots x_n$ and assuming that n is odd[1], the basic strategy of the binmedian algorithm is:

1. Compute the mean μ and standard deviation σ
2. Form B bins across $[\mu - \sigma, \mu + \sigma]$, map each data point to a bin
3. Find the bin b that contains the median
4. Recurse on the set of points mapped to b

DRAWBACKS

- Faster with fewer points
- Swamped with points for many iterations.


CODE
1001101001
JAVA
PYTHON
100110

Mean

The mean (average) of a data set is found by summing the numbers in the data set and then dividing it by number of values in the set.

Median

1. A value separating the higher half from the lower half of a data sample.

2 sometimes used as opposed to the mean.

MEAN

In [1]:
```
#calculating manually
fluxes = [23.3, 42.1, 2.0, -3.2, 55.6]
m = sum(fluxes)/len(fluxes)
print(m)
```

```
23.96
```

In [2]:
```
from statistics import mean
fluxes = [23.3, 42.1, 2.0, -3.2, 55.6] #calculating using mean function from statistics module in python
m = mean(fluxes)
print(m)
```

```
23.96
```

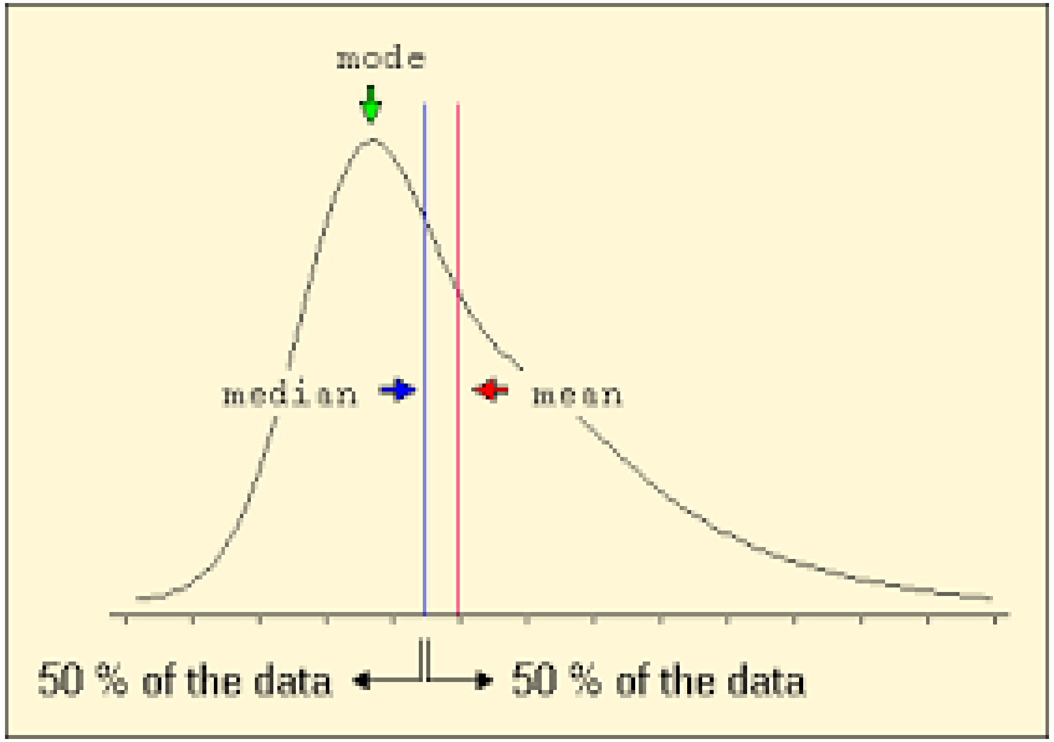
MEDIAN

In [3]:
```
#odd
fluxes = [17.3, 70.1, 22.3, 16.2, 20.7]
fluxes.sort()
mid = len(fluxes)//2
median = fluxes[mid]
print(median)
```

```
20.7
```

In [4]:
```
#even
fluxes = [17.3, 70.1, 22.3, 16.2, 20.7, 19.3]
fluxes.sort()
mid = len(fluxes)//2
median = (fluxes[mid - 1] + fluxes[mid])/2
print(median)
```

```
20.0
```



Using of pre-existing module

NUMPY

```
In [6]: #Compairing between Mean and Median
        import numpy as np

        def list_stats(data):
          return np.median(data),np.mean(data)

        if __name__ == '__main__':
          m = list_stats([1.3, 2.4, 20.6, 0.95, 3.1, 2.7])
          print(m)

        (2.55, 5.175)
```

jupyter Intro to Numpy Last Checkpoint: 09/19/2020 (autosaved)

Logout

File Edit View Insert Cell Kernel Widgets Help

Not Trusted | Python 3

Run | Markdown

In [25]:
```
import numpy as np
a=np.linspace(1,100,9)
print(a) #it has printed 10 values between 1 to 3.
```

```
[  1.     13.375  25.75   38.125  50.5    62.875  75.25   87.625 100.   ]
```

Min, max, mean, sum ,Square Root, Standard Deviationetc

In [28]:
```
# import numpy as np

a= np.array([19,23,56,10,19,76,84,90,12])
print(a.min())
print(a.max())
print(a.sum())
print(a.mean())
print(np.sqrt(a)) # math.sqrt()
print(a.std())
```

```
10
90
389
43.22222222222222
[4.35889894 4.79583152 7.48331477 3.16227766 4.35889894 8.71779789
 9.16515139 9.48683298 3.46410162]
31.179686327899013
```

Time isn't enough

In [2]:
```
#handwritten code
import time, numpy as np
n = 10**8
data = np.random.randn(n)

start = time.perf_counter()
mean = sum(data)/len(data)
seconds = time.perf_counter() - start

print('That took {:.2f} seconds.'.format(seconds))
```

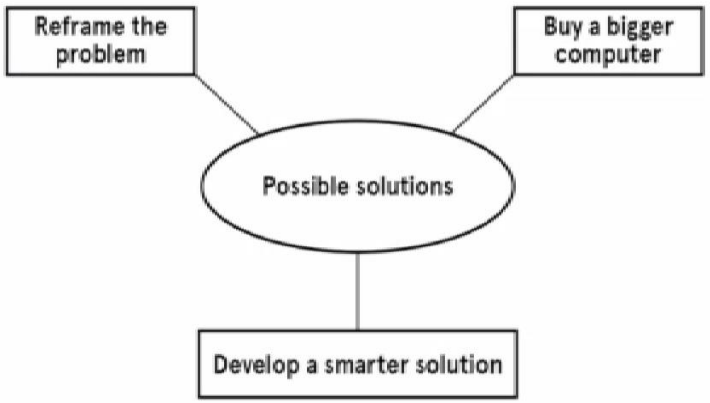
```
That took 16.26 seconds.
```

In [3]:
```
#optimised version
import time, numpy as np
n = 10**8
data = np.random.randn(n)

start = time.perf_counter()
mean = np.mean(data)
seconds = time.perf_counter() - start

print('That took {:.2f} seconds.'.format(seconds))
```

```
That took 2.71 seconds.
```

IMPROVING METHOD

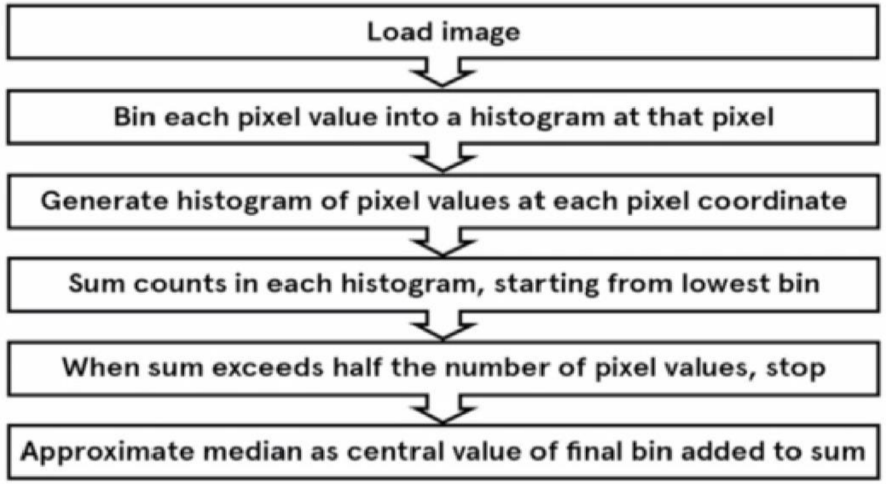
600,000 images
1 image = 200×200 = 40,000 pixels
1 pixel = 8 bytes
Total Memory = 600,000 × 40,000 × 8
= 192 GB



2

200×200 → 50×50
200÷50 = 4
4×4 = 16
Memory needed = 192 ÷ 16 GB
= 12 GB

3



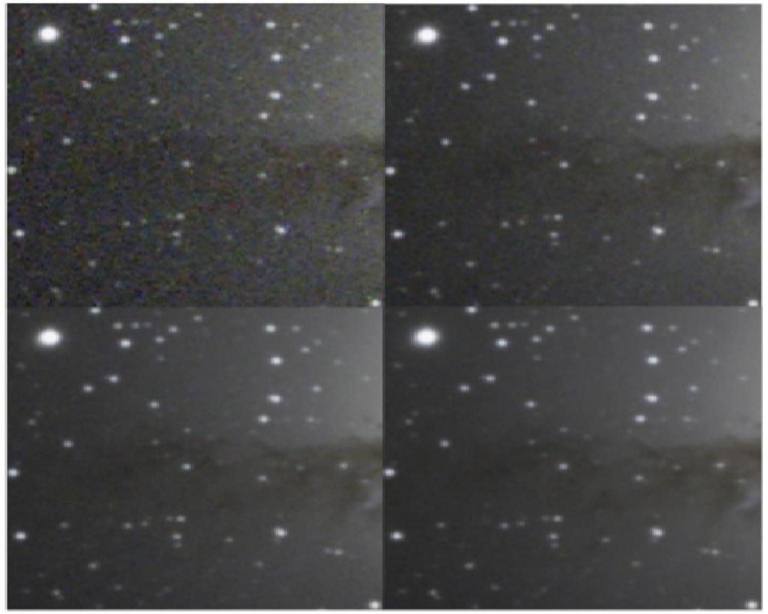
3. Binapprox

The full algorithm for a set of N data points works as follows:

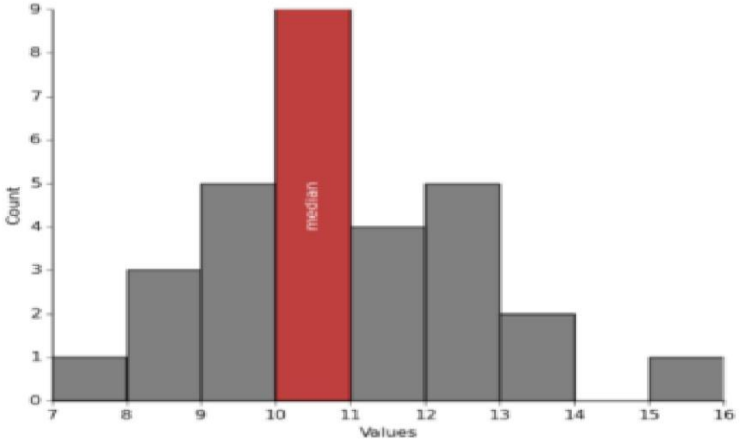
1. Calculate their mean and standard deviation, μ and σ;
2. Set the bounds: `minval` = $\mu - \sigma$ and `maxval` = $\mu + \sigma$. Any `value >= maxval` is ignored;
3. Set the bin width: `width` = $2\sigma/B$;
4. Make an ignore bin for counting `value < minval`;
5. Make B bins for counting values in `minval` and `maxval`, e.g. the first bin is `minval <= value < minval + width`;
6. Count the number of values that fall into each bin;
7. Sum these counts until `total >= (N + 1)/2`. Remember to start from the ignore bin;
8. Return the midpoint of the bin that exceeded `(N + 1)/2`.

The midpoint of a bin is just the average of its min and max boundaries, i.e. the lower boundary + `width/2`.

Single frame 5 frames



15 frames 30 frames



1. **median_bins** to calculate the mean, standard deviation and the bins (steps 1-6 on the previous slide);
2. **median_approx** which calls **median_bins** and then calculates the approximated median (steps 7-8).

$$\frac{\sigma}{B}$$

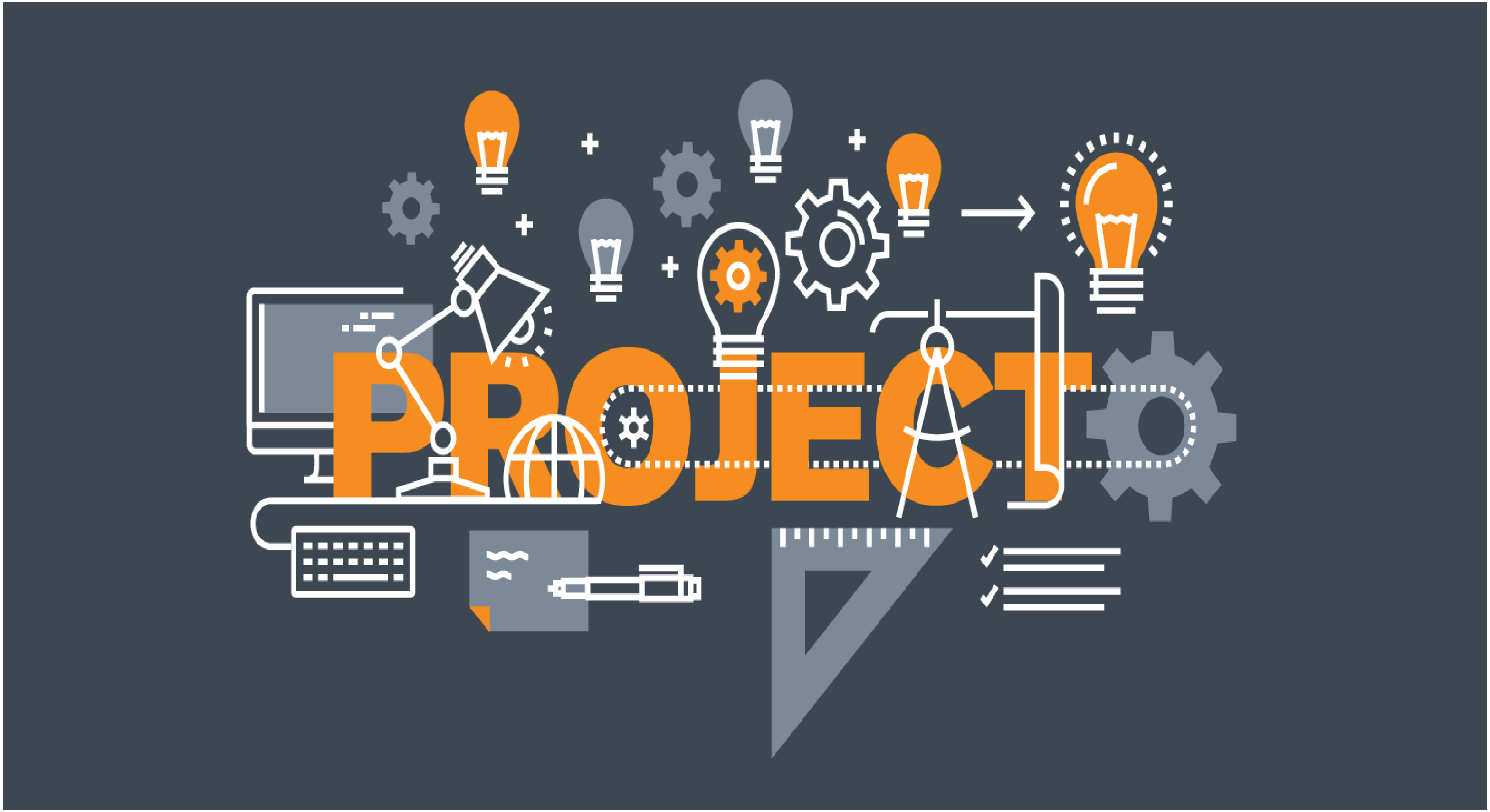
DRAWBACKS

standard deviation is extremely large= reported approx. **deviates** actual median.

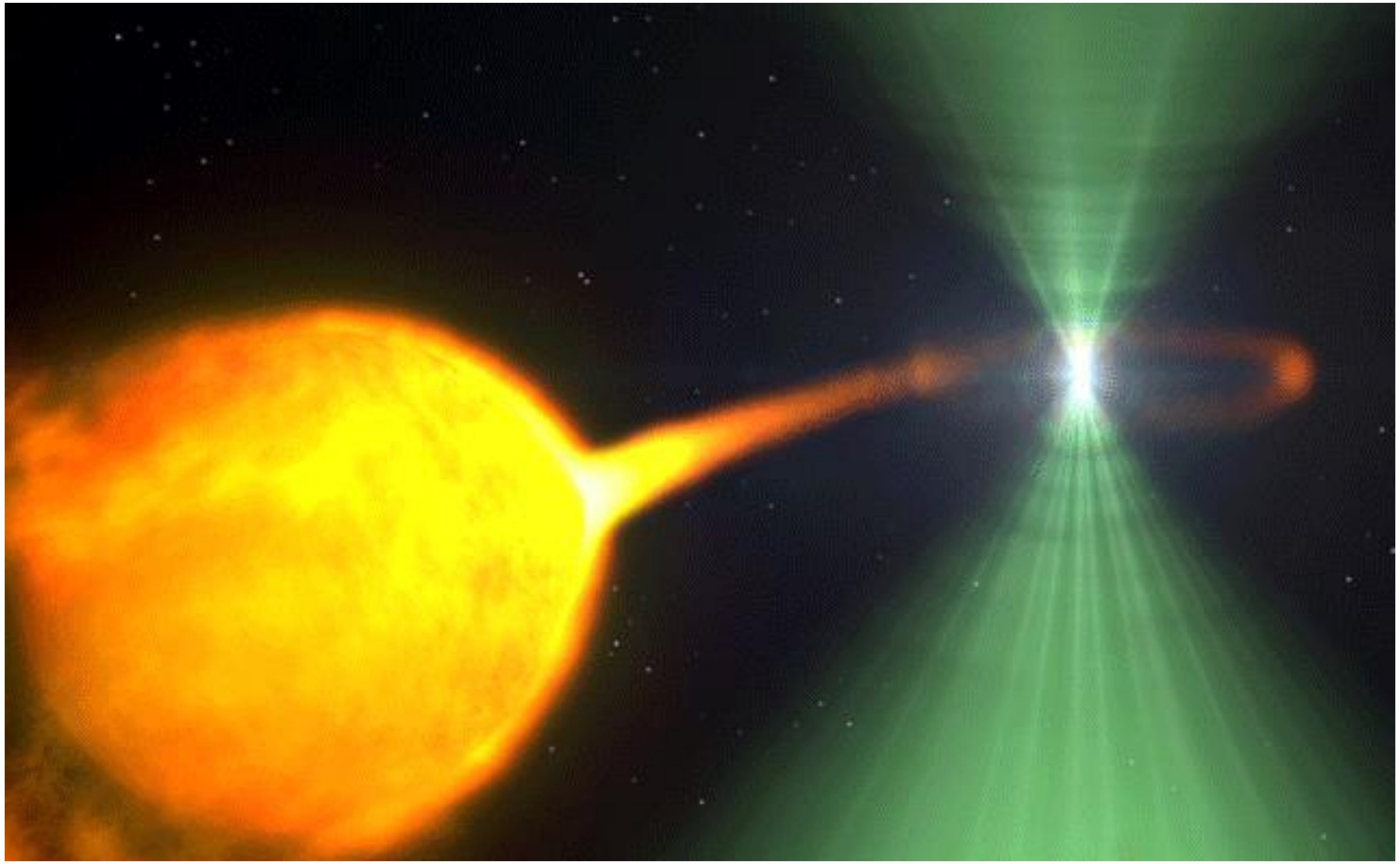
SPEED COMPARISONS ON SINGLE DATA SETS

	$U(0,1)$		$N(0,1)$	
	time	ratio	time	ratio
Quickselect	107.05 (0.47)	1.17	99.70 (1.05)	1.17
Binmedian	112.45 (0.55)	1.23	106.95 (1.51)	1.25
Binapprox	91.30 (0.32)	1	85.35 (0.86)	1
Sort	3205.84 (5.97)	35.11	3231.22 (4.24)	37.86
	$E(1)$		χ^2_5	
	time	ratio	time	ratio
Quickselect	106.75 (0.83)	1.62	107.80 (4.29)	1.32
Binmedian	87.25 (0.96)	1.32	104.65 (4.12)	1.28
Binapprox	65.90 (0.75)	1	81.75 (3.97)	1
Sort	3217.51 (5.40)	48.82	3225.82 (4.70)	39.46
	$N(0,1)$ and $U(-10^3,10^3)$		$N(0,1)$ and $U(-10^4,10^4)$	
	time	ratio	time	ratio
Quickselect	103.65 (1.15)	1.33	101.00 (0.96)	1.30
Binmedian	126.65 (1.20)	1.62	130.90 (1.25)	1.69
Binapprox	78.15 (1.02)	1	77.50 (1.28)	1
Sort	3225.40 (5.58)	41.27	3214.16 (3.89)	41.47
	$N(0,1)$ and $E(10^{-3})$		$N(0,1)$ and $E(10^{-4})$	
	time	ratio	time	ratio
Quickselect	98.45 (1.13)	1.59	100.90 (1.23)	1.58
Binmedian	88.90 (1.63)	1.43	106.85 (0.89)	1.67
Binapprox	62.10 (1.16)	1	63.80 (1.25)	1
Sort	3228.93 (5.56)	52.00	3236.71 (2.95)	50.73

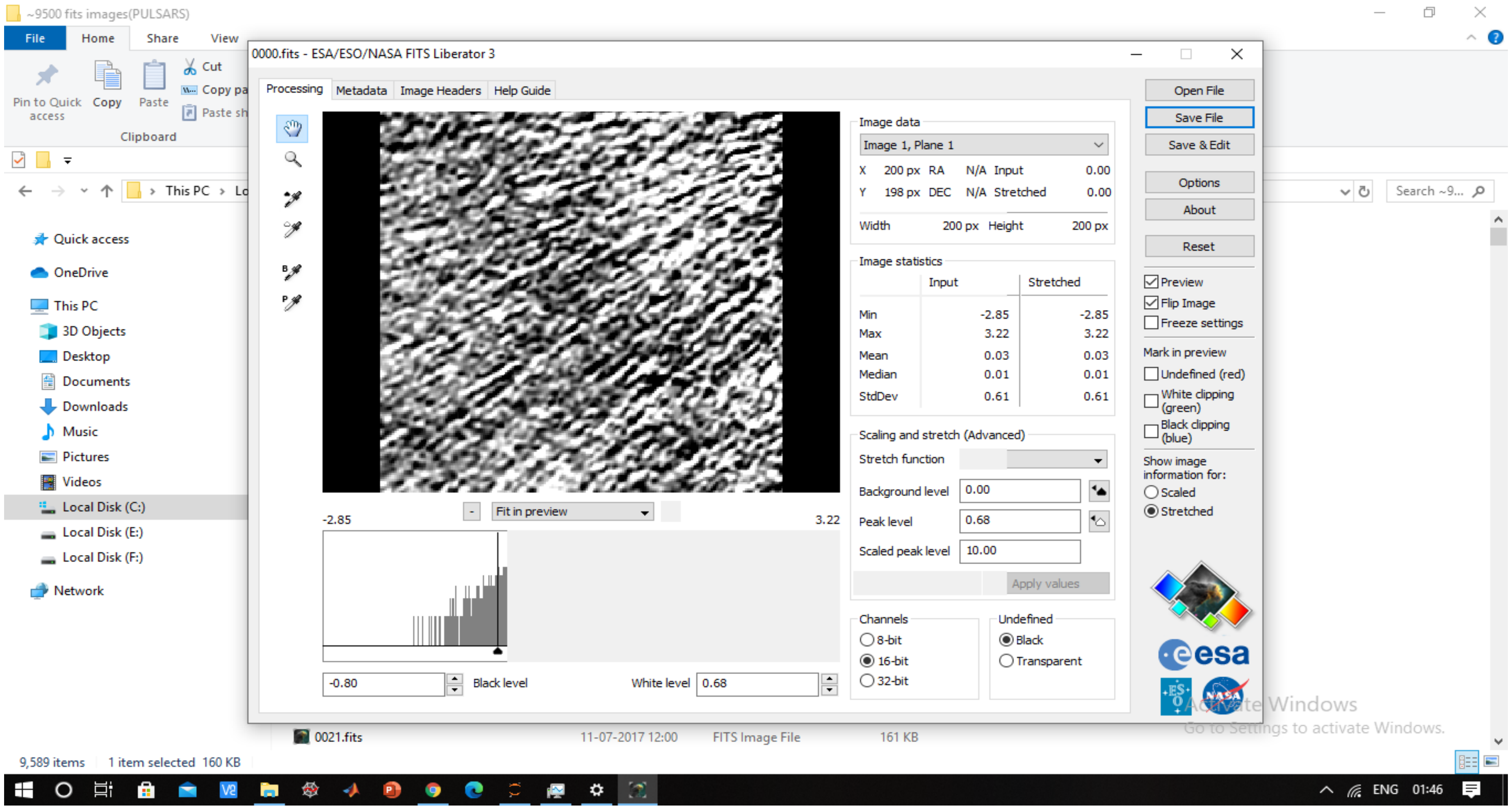
$1+10^7$ pts $\sim N(0,25)$ and then $20\times(10^5$ pts $\sim N(0,25))$		
	time	ratio
Quickselect	2236 (8.23)	22.36
Binmedian	584 (5.27)	5.84
Binapprox	100 (9.42)	1
$1+10^7$ pts $\sim N(0,25)$ and then $20\times(10^5$ pts $\sim N(2,4))$		
	time	ratio
Quickselect	2234 (7.07)	24.55
Binmedian	563 (10.75)	6.19
Binapprox	91 (12.65)	1
$1+10^6$ pts $\sim N(0,25)$ and then $20\times(10^6$ pts $\sim N(1/2\cdot j,25), j=1,\ldots 20)$		
	time	ratio
Quickselect	2429 (11.36)	18.99
Binmedian	616 (9.94)	4.81
Binapprox	128 (5.27)	1
$1+10^6$ pts $\sim N(0,25)$ and then $20\times(10^6$ pts $\sim N(10,25))$		
	time	ratio
Quickselect	2376 (16.19)	19.01
Binmedian	629 (11.01)	5.03
Binapprox	125 (5.68)	1


PROJECT

Detection of Pulsars by Image stacking in larger datasets using Binapprox algorithm



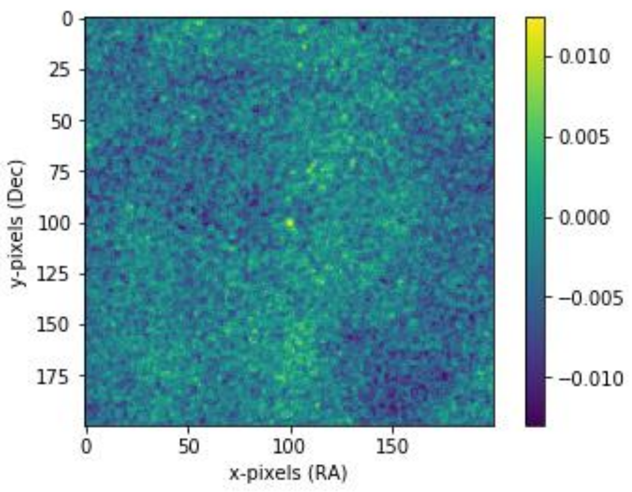
Sample FIT Imagefile (0000.fits)

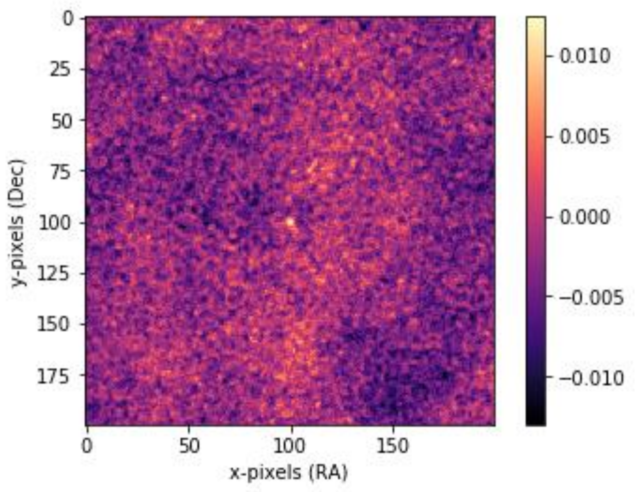


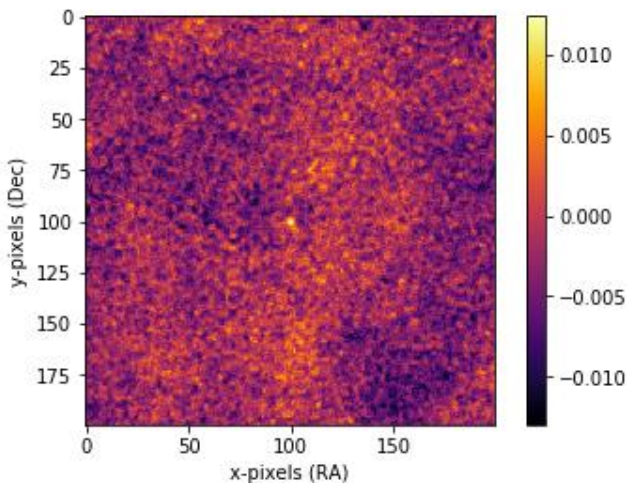
Let’s hop into Jupyter Environment

Task 1 : Perform image stacking using binapprox algorithm in 12 fits file.

Output/Result :

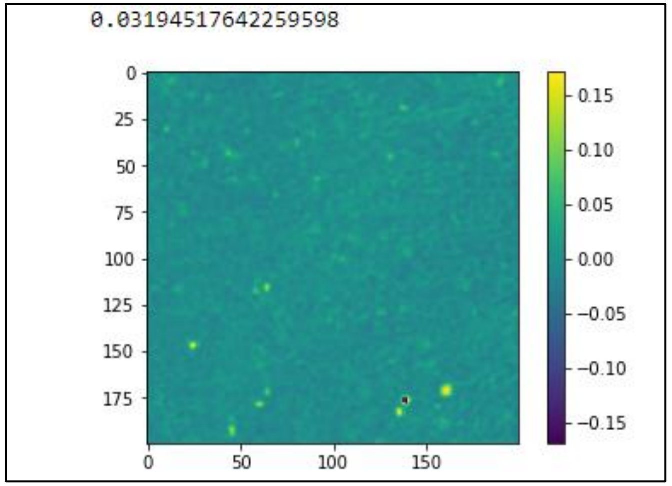






Task 2 : Perform image stacking using binapprox algorithm in 1000 fits file.

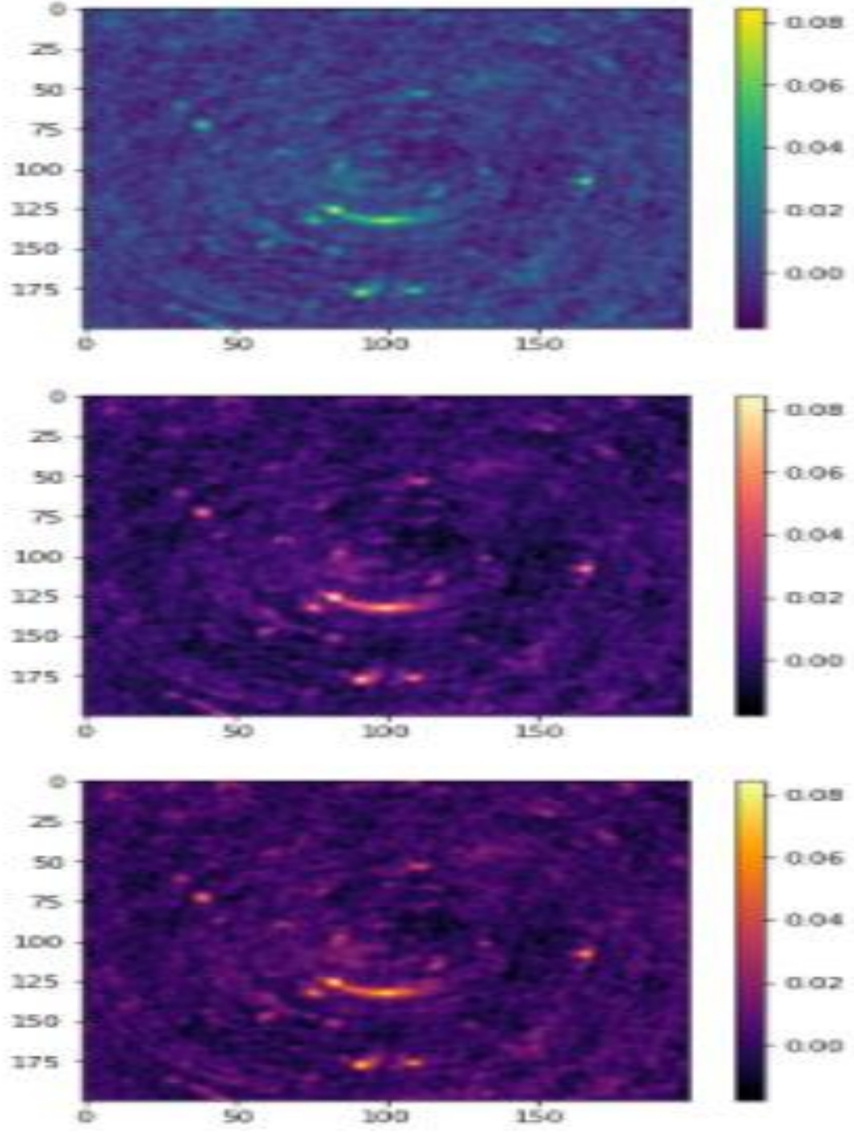
Output/Result : It took 16 minutes around to run the code in my system



Task 3 : Perform image stacking using binapprox algorithm in larger datasets ~10000 fits file.

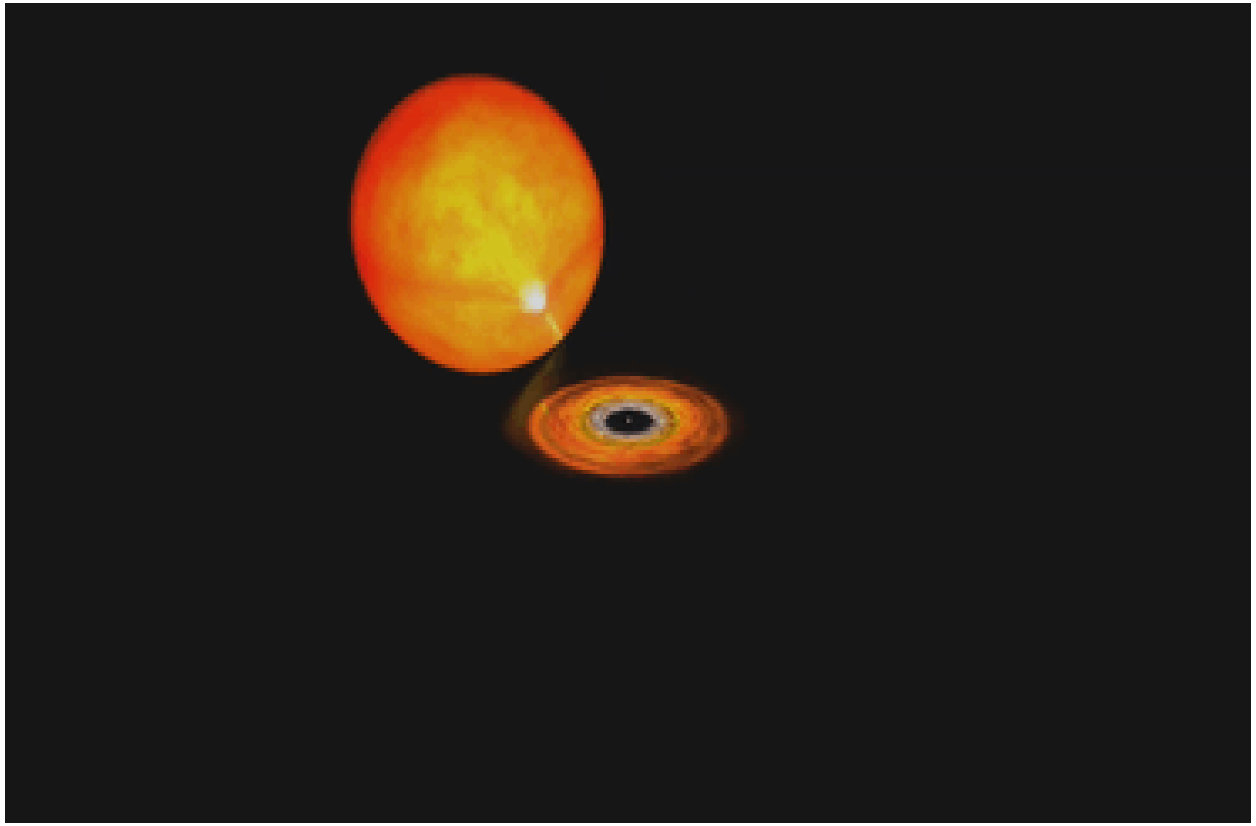
Output/Result :

- 9587 image fits files
- Size : 1.3Gb
- 5.13pm(8th October,2020) -1.30am(9th October,2020)
- Total time:- 8hours 17minutes



0
25
50
75
100
125
150
175
0
50
100
150
0.08
0.06
0.04
0.02
0.00

CONCLUSION



- Binary System
- Gravitational Lensing

Bibliography

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- https://iopscience.iop.org/article/10.1086/308859/pdf
- https://iopscience.iop.org/article/10.1086/313060/pdf
- http://hyperphysics.phyastr.gsu.edu/hbase/Astro/pulsar.html
- https://www.youtube.com/watch?v=o9Vbw7W2708&feature=youtu.be
- https://iopscience.iop.org/article/10.1086/306742/pdf https://hubblesite.org/
- https://www.aanda.org/articles/aa/abs/2012/05/aa18798-12/aa18798-12.html
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- https://www.space.com/32661-pulsars.html

- https://arxiv.org/abs/2002.08519
- https://link.springer.com/article/10.1007/s11214-017-0459-0
- https://asd.gsfc.nasa.gov/archive/ixo/science/exampleScience/EquationOfState.pdf
- https://www.nature.com/articles/d41586-020-00590-8
- https://people.nscl.msu.edu/~witek/Classes/PHY802/Essays/Coulter.pdf
- https://media.nature.com/original/magazine-assets/d41586-020-00590-8/d41586-020-00590-8.pdf
- https://www.sciencedirect.com/science/article/abs/pii/S1387647311000418
- http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1971ApJ...164..529S&defaultprint=YES&filetype=.pdf
- https://www.ias.ac.in/article/fulltext/joaa/038/03/0042
- https://www.rtl-sdr.com/overview-neutron-star-group-pulsar-detection-projects-rtl-sdr/

- https://people.nscl.msu.edu/~witek/Classes/PHY802/Essays/Coulter.pdf
- https://media.nature.com/original/magazine-assets/d41586-020-00590-8/d41586-020-00590-8.pdf

Team Pulsars Members

- **Presenters:** Biswajit Jana, Mariam Hashim, Shreejaya Karantha, Priyansh Joshi, Hemanth, Anindri Laha, Vishal Garela, Ashutosh Kammar

- **Other Team Members :** Aarti Dhopawkar, Kisore G, Jaskirat Singh, Vishnu Thirtha SH, Soumyadeep Das, Dijin Dominic, Sreejith P.C, Hrishabh Srivastava, Kiran Chhablani, Kurapati Bhavana, Patnala Susmitha, Manav Madan Rawal, Sunethra Ratnakar, Siddharth P Bharadwaj

THANKYOU

TEAM PULSARS