Name: Radio Astronomy 423

Midterm Exam #2

__________________________ April 21, 2021

1. Emission Mechanisms. In a sentence or two and a simple sketch (a) describe an emission mechanism that produces thermal radiation, and give two examples of types of cosmic radio sources that emit this way.

(b) with a sketch and a couple sentences describe an emission mechanism that produces non-thermal radiation, and give two examples of types of cosmic radio sources that emit this way.

2. Interferometry (a) Sketch a simple, two-element interferometer. Label and define (where necessary) the following parts: source direction, baseline, geometrical delay. (b) Describe in words what the "(u,v) plane" is. (c) What is the relationship between the (u,v) plane and the (ra, dec) image plane? (d) name three different types of weighting for the visibility data when constructing images.

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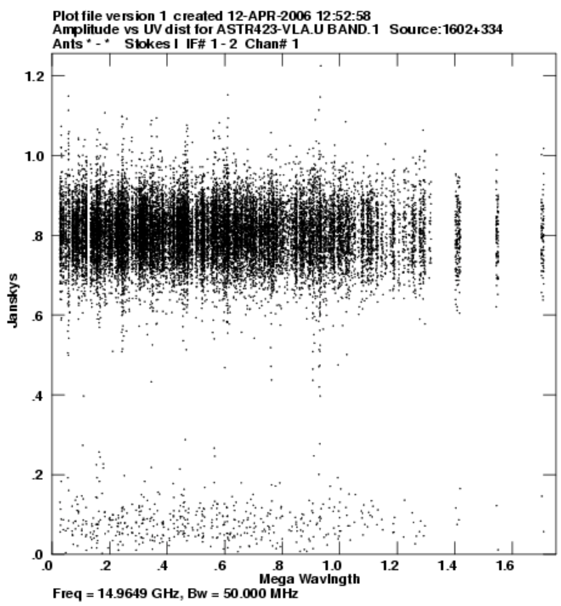
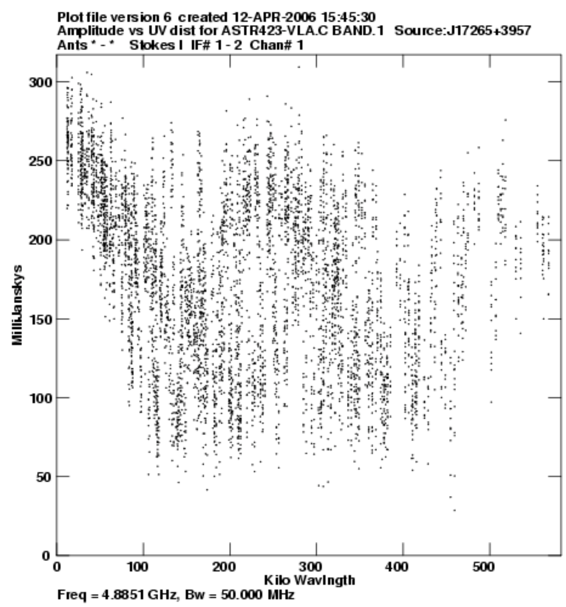
3. Synthesis Imaging. The two figures below show the visibility plots (visibility amplitude versus radial (u,v) distance, for VLA observations at 5 and 15 GHz. Answer the following questions about these observations:

a. Is there any bad data on the 15 GHz source? Circle it.
b. What total flux density and source structure does the 15 GHz source have?
c. What total flux density and source structure (roughly) does the 5 GHz source have?
d. What is the expected synthesized beamsize for the 5 GHz source?
e. What would be a good cell size for imaging the 5 GHz source in arcsec/pixel?



15 GHz source



5 GHz source

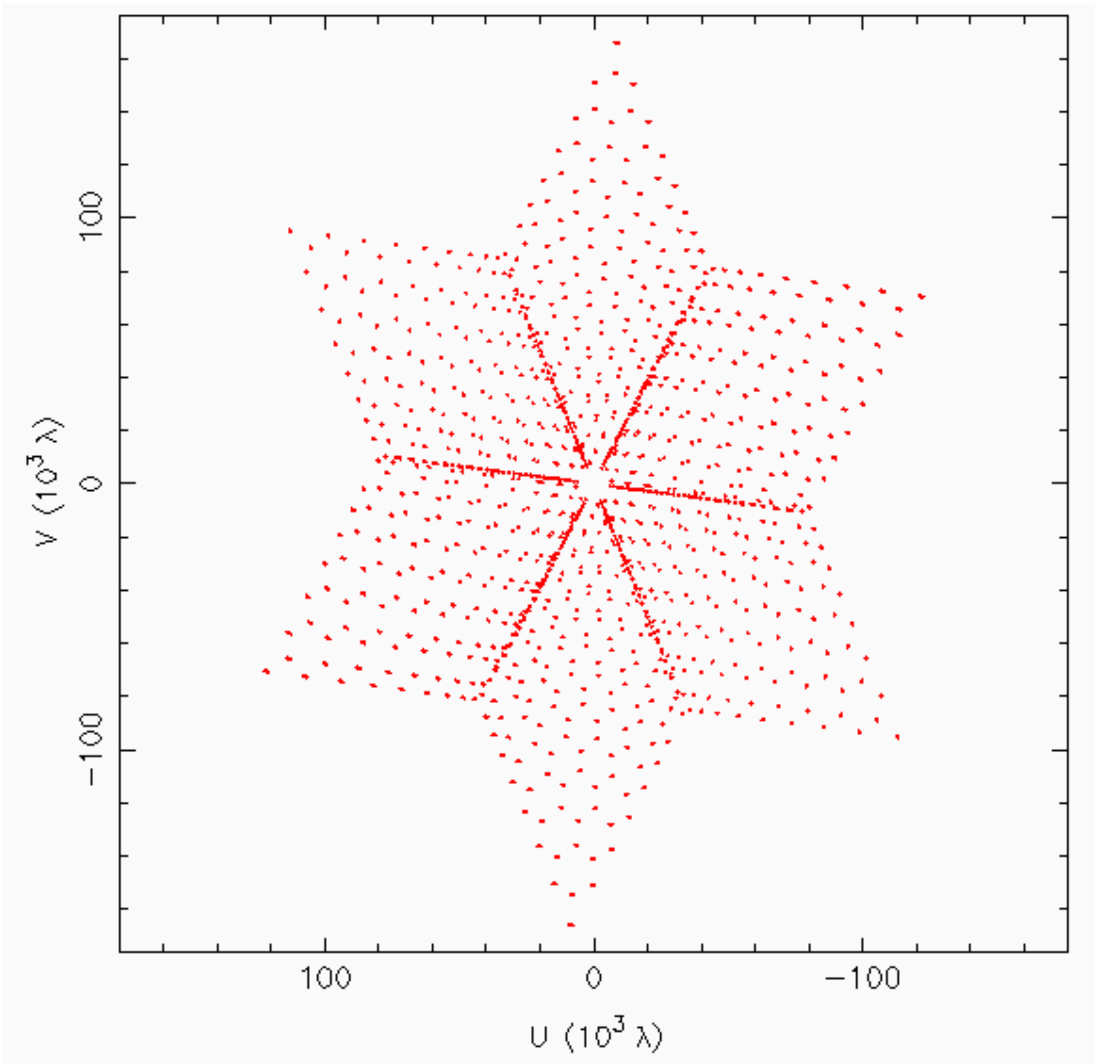
4. Describe how to self-calibrate observations from an interferometer by listing the steps that one should take (pretend you are telling somebody who has calibrated data how they can obtain improved images of their sources).

a) List the steps they should follow, 1 through N

b) Are there any instances when self-calibration may not work?

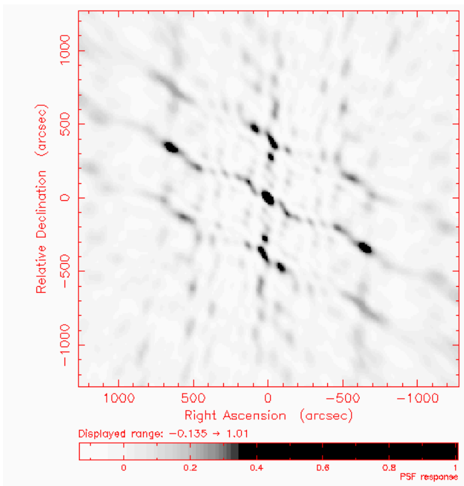
5. a) Why is the LWA1 a good instrument to use for studying pulsars? b) Provide a list of the steps needed to search for a pulsar of unknown period and dispersion measure starting with a raw (voltage time-series) LWA1 observation.

6. Suppose you observe with the VLA and obtain the (u,v) coverage below. (a) What is the largest angular scale structure that you could hope to image in arcseconds?

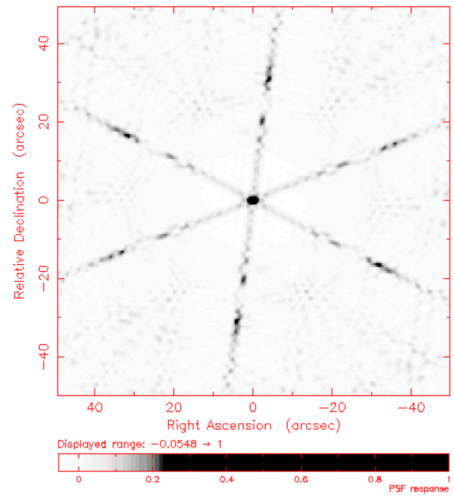


b) Indicate which PSF (point spread function or dirty beam) matches with the (u,v) coverage shown in part (a) above.

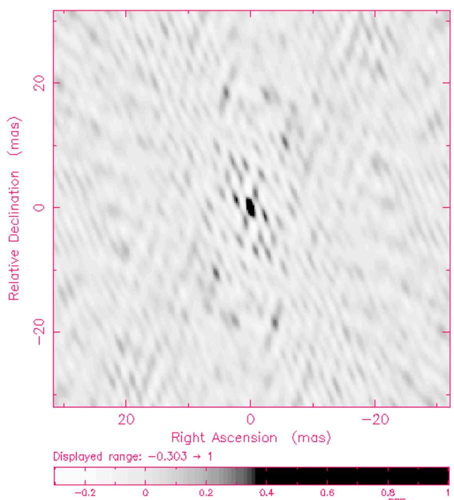
1)



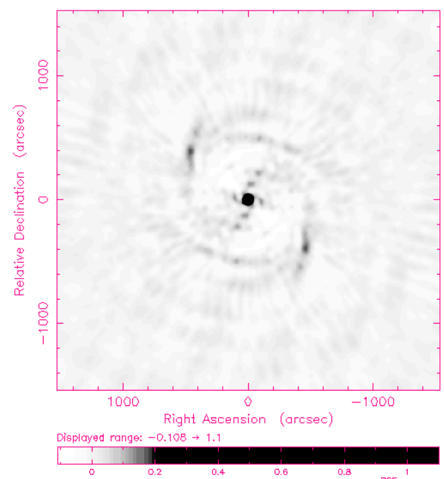
2)



3)



4)



c) Explain your reasoning for the match you made in part (b):

Constants and astronomical quantities:

Speed of light	$c = 3 \times 10^{10}$ cm s^{-1}
Planck's constant	$h = 6.626 \times 10^{-27}$ erg s
Gravitational constant	$G = 6.67 \times 10^{-8}$ cm^3 g^{-1}s^{-2}
Stefan-Boltzmann's constant	$\sigma = 5.67 \times 10^{-5}$g s^{-3} K^{-4}
Boltzmann's constant	$k = 1.38 \times 10^{-16}$ erg K^{-1}
Mass of the Sun	$M_\odot = 1.99 \times 10^{33}$ g
Surface temperature of the Sun	$T_\odot = 5800$ K
Mass of a hydrogen atom	$M_H = 1.67 \times 10^{-24}$ g
Mass of an electron	$m_e = 9.11 \times 10^{-28}$ g
Astronomical unit	1 AU = 1.496×10^{13} cm
Parsec	1 pc = 3.26 ly = 3.086×10^{18} cm = 206,265 AU
1 Jy	10^{-23} erg s^{-1} cm^{-2} Hz^{-1}
Conversion Kelvin (K) to Celsius (C)	T[K]=T[C]+273
Conversion Celsius (C) to Fahrenheit (F)	T[F]=$\frac{9}{5}$T[C]+32
1 radian	206,265 arcseconds

Useful equations:

$\lambda_{max} = \frac{0.29cmK}{T}$ Wien's Law and $F = \sigma T^4$ Stefan - Boltzmann Law

$B_\nu = \frac{2h\nu^3}{c^2}\frac{1}{e^{h\nu/kT}-1}$ Planck Function

$T_b = \frac{\lambda^2 S_\nu}{2k\Omega}$ Brightness Temperature

$K.E. = 3/2kT$ (per particle) and $V = \sqrt{(3kT/m)}$ (average velocity of particle)

$\theta = 1.02\lambda/D$ (in radians) resolution for diameter or baseline length,D

$V = \frac{\lambda_{\rm obs}-\lambda_0}{\lambda_0}c$ doppler velocity

$\nu_G = \frac{eB}{2\pi m} = 2.8\frac{B}{\rm Gauss}$MHz gyro frequency

$\nu_c = 1.5\gamma^2\nu_G$ synchrotron characteristic frequency

Synchrotron Lifetime = $\frac{16.4yr}{B^2\gamma}$ where B is in Gauss

$T_b(s) = T_{back}(s_0)e^{-\tau_\nu(s)} + T_{emit}(1-e^{-\tau_\nu(s)})$ radiative transfer
$\tau(\nu) = 8.235 \times 10^{-2}\nu^{-2.1}T_e^{-1.35}EM$ free-free optical depth
$EM = \int n_e^2 ds$ emission measure
$RM = 812\int Bn_e ds$ rad m^{-2} rotation measure