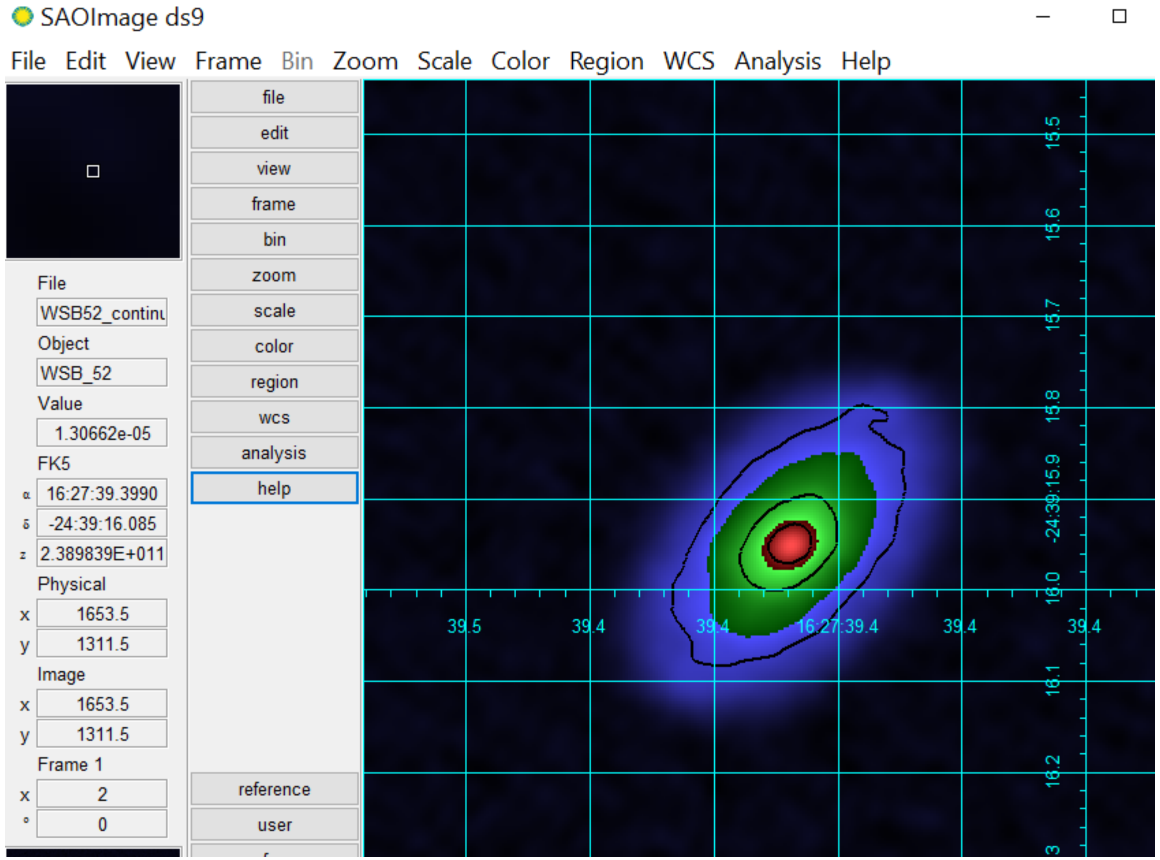
Deep Space Exploration Society Science Meeting



WSB52 Planetary Disk from ALMA FITS File

February 22, 2021

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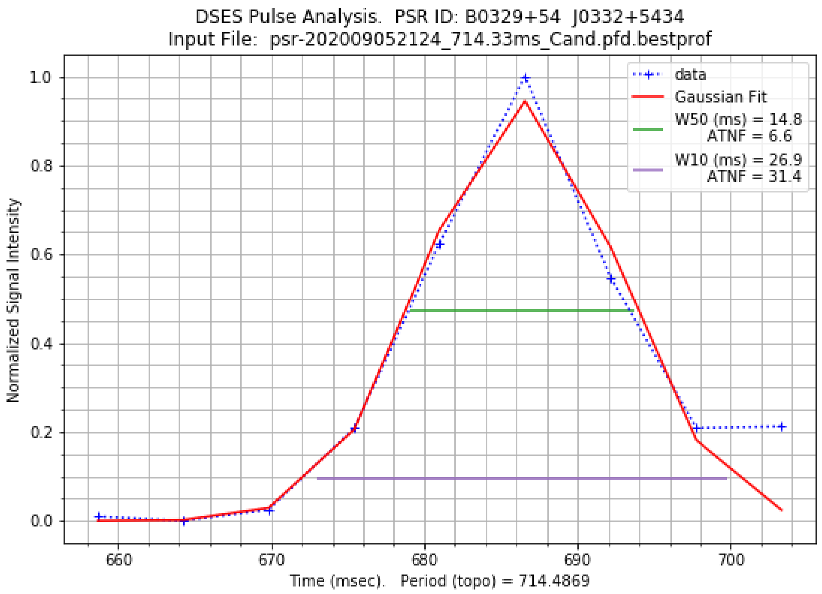
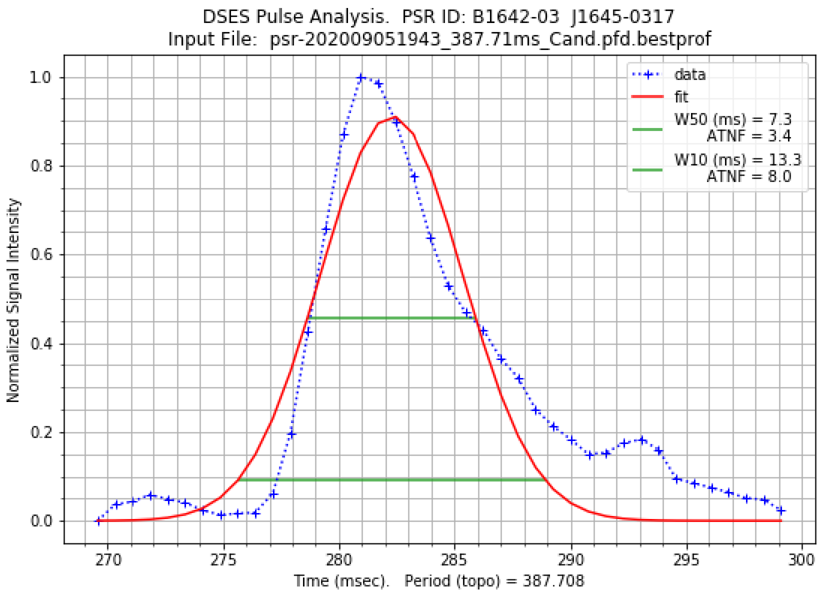
DSES.science

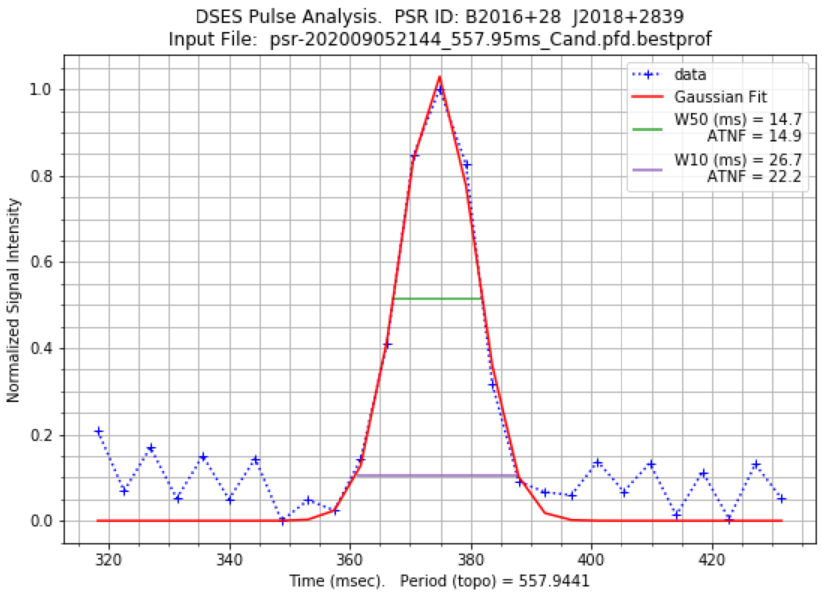
Information

- 9 ft Dish – Spectracyber running
- SuperSID – Working and porting data to Stanford
- Radio Jupiter – still need to get a new receiver and setup at site
- Pulsar – 408 MHz – Waiting on good weather
- Tropospheric transmission – 1296 MHz feed available
- EME systems – 1296 MHz feed available
- Moon Orbit determination using EME equipment

Dan Layne Analysis of Pulsar Data







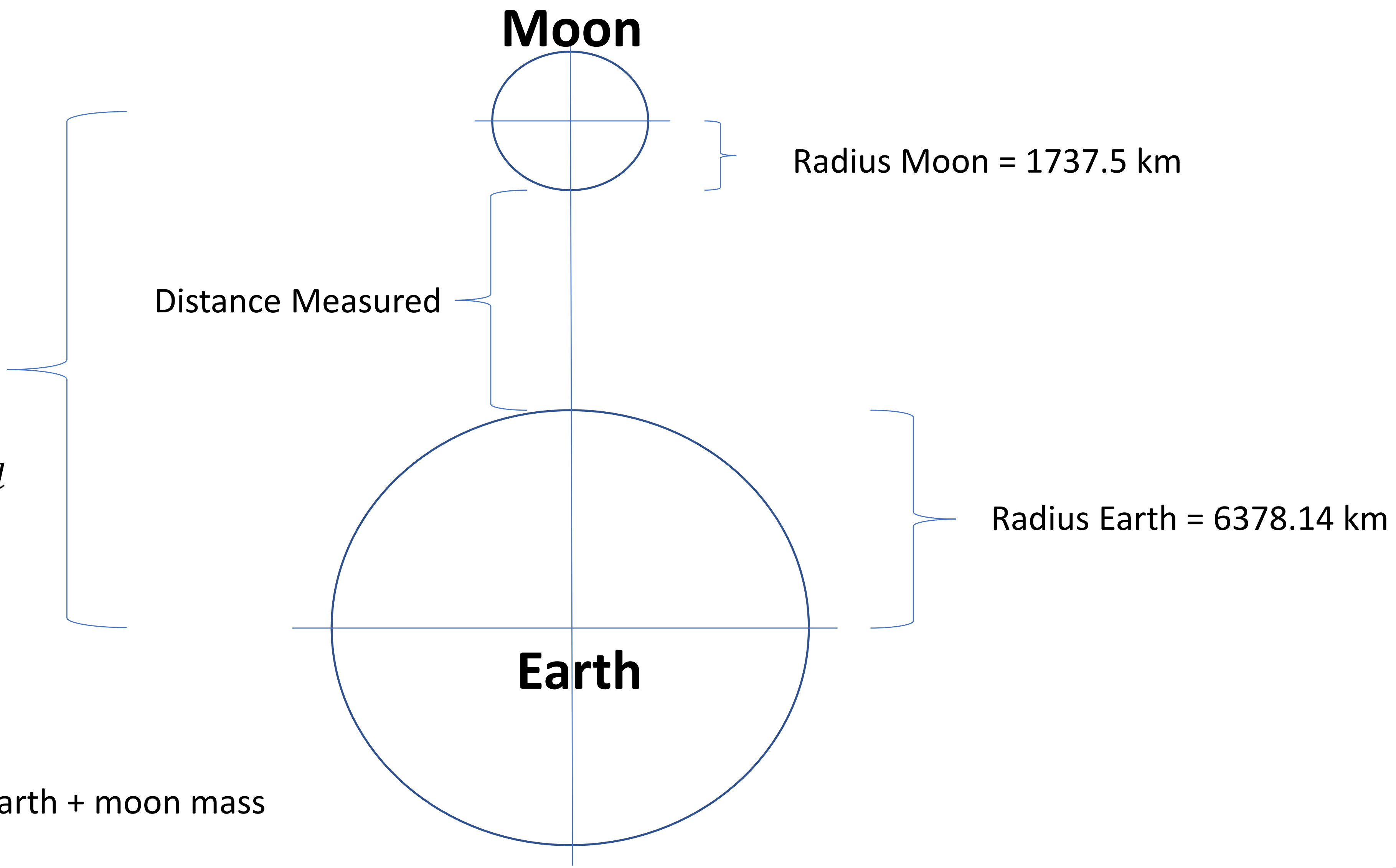
Moon Range and Orbit determination

- Use CW transmit and receive
- Measure difference between transmit and arrival times
- Determine moon distance

$$\text{Distance}\ Measured\ = 299{,}792.458\ \text{km/sec x}\ \Delta t/2 + calibration$$

- Read the Azimuth and elevation angles from the pointing system
- Record time in UTC

What distance are we measuring?



$$radius(r) = distance\ measured + Moon\ radius + Earth\ radius$$

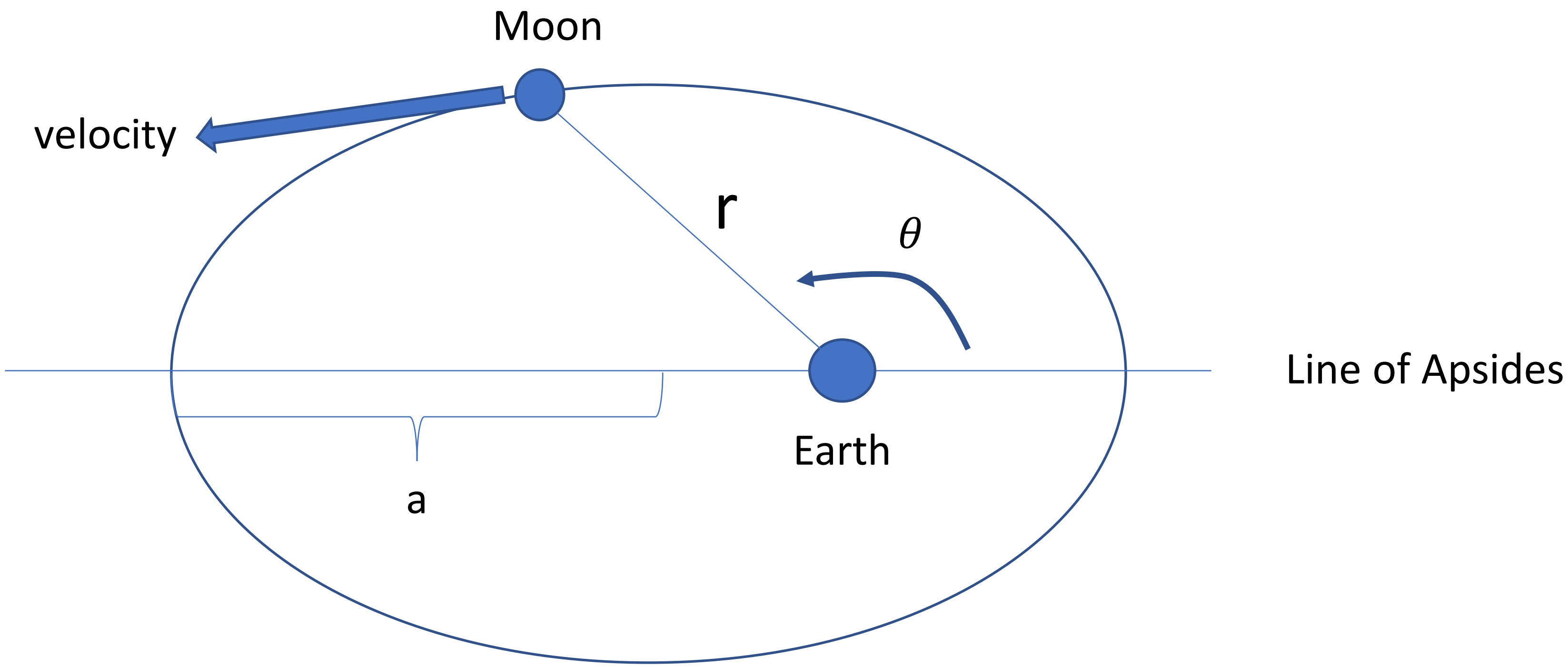
Note: the total mass is Earth + moon mass

Orbital Mechanics

a= semimajor axis (km)
e = eccentricity km²/s²
r_a = apogee radius (km)
r_p = perigee image (km)

Θ = True Anomaly (degrees)
V = velocity km/s
P = period (seconds)
μ = gravitational parameter for Earth

$$\mu = 398{,}600.4\,\frac{km^3}{s^2}$$



$$e = \frac{(r_a - r_p)}{(r_a + r_p)}$$

$$\cos(\theta) = \frac{a(1-e^2)}{re} - \frac{1}{e}$$

$$P = 2\pi\sqrt{\frac{a^3}{\mu}}$$

$$a = (r_a + r_p)/2$$

$$\mathrm{v} = \sqrt{\frac{2\mu}{r} - \frac{\mu}{a}}$$

Earth to Moon Distances for 2021

Perigees

Date	Local Time	Distance in km	Distance in miles
Jan 9	8:36 am	367,387 km	228,284 mi
Feb 3	12:03 pm	370,116 km	229,980 mi
Mar 1	10:18 pm	365,423 km	227,063 mi
Mar 30	12:16 am	360,309 km	223,886 mi
Apr 27	9:22 am	357,378 km	222,064 mi
May 25	7:50 pm	357,311 km	222,023 mi
Jun 23	3:54 am	359,956 km	223,666 mi
Jul 21	4:23 am	364,520 km	226,502 mi
Aug 17	3:15 am	369,124 km	229,363 mi
Sep 11	4:03 am	368,461 km	228,951 mi
Oct 8	11:27 am	363,386 km	225,797 mi
Nov 5	4:17 pm	358,844 km	222,975 mi
Dec 4	3:03 am	356,794 km	221,702 mi

Apogees

Date	Local Time	Distance in km	Distance in miles
Jan 21	6:11 am	404,360 km	251,258 mi
Feb 18	3:21 am	404,467 km	251,324 mi
Mar 17	11:03 pm	405,253 km	251,812 mi
Apr 14	11:45 am	406,119 km	252,350 mi
May 11	3:53 pm	406,512 km	252,595 mi
Jun 7	8:27 pm	406,228 km	252,418 mi
Jul 5	8:46 am	405,341 km	251,867 mi
Aug 2	1:35 am	404,410 km	251,289 mi
Aug 29	8:22 pm	404,100 km	251,096 mi
Sep 26	3:43 pm	404,640 km	251,432 mi
Oct 24	9:28 am	405,615 km	252,038 mi
Nov 20	7:12 pm	406,279 km	252,450 mi
Dec 17	7:14 pm	406,320 km	252,475 mi

Moon Distance Calculator – How Close is Moon to Earth? (timeanddate.com)

Calculate the Moon's orbit

- Measure the distance to the moon: example
  - March 1: measure delta time Δt1 (seconds): 2.38 seconds (for 357,307 km)
  - March 17: measure delta time Δt2 (seconds): 2.64 seconds (for 397,137 km)
- Calculate r_a and r_p
  - March 1 measurement r_p= 299,792.458 km/sec x $(2.38\ seconds)/2$ + 6378.14 km + 1737.5 km= 365,423 km
  - March 17 measurement r_a= 299,792.458 km/sec x $(2.64\ seconds)/2$ + 6378.14 km + 1737.5 km= 405,253 km
- Semimajor axis (a) $a = (r_a + r_p)/2$

$$a = \frac{(405{,}253\ km + 365{,}423 km)}{2} km = 384{,}360\ km$$

Actual = 384,400 km

- Eccentricity

$$e = \frac{(r_a - r_p)}{(r_a + r_p)}$$

$$e = \frac{(405{,}253\ km - 365{,}423 km)}{(405{,}253 km + 365{,}423 km)} = 0.0517$$

Actual = 0.0549

- Period

$$P = 2\pi\sqrt{\frac{a^3}{\mu}}$$

$$P = 2\pi\sqrt{\frac{(384{,}360 km)^3}{398{,}600.4 \frac{km^3}{s^2}}} = 2{,}371{,}428.87\ seconds = 27.45\ days$$

Actual = 27.32 days

Measured Mass of Earth-Moon System

$$Mass_{Earth-Moon} = \frac{4\pi^2 r^3}{Gt^2}$$

$$G = 6.67x10^{-11}\ \frac{m^3}{kgs^2}$$

$$r = 384.360\ x\ 106\ m$$

t =2,371,428.87 seconds

$$Mass_{Earth-Moon} = \frac{4\pi^2(384.360\ x\ 10^6\ m)^3}{\left(6.67x10^{-11}\ \frac{m^3}{kgs^2}\right)(2{,}371{,}428.87 seconds)^2}$$

$$Mass_{Earth-Moon} = 5.976\ x\ 10^{24}\ kg\ (measured)$$

Accuracy

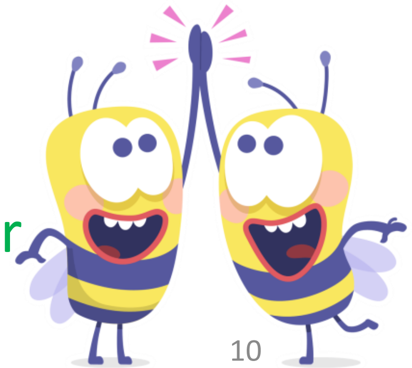
$$Mass_{Earth-Moon} = 5.976\ x\ 10^{24}\ kg\ (measured)$$

$$Mass_{Moon} = 7.347\ x\ 10^{22}\ kg\ (given)$$

$$Mass_{Earth\ measured} = 5.9035\ x\ 10^{24}\ kg$$

$$Mass_{Earth\ actual} = 5.98\ x\ 10^{24}\ kg$$

$$\text{error} = \frac{Mass_{Earth\ measured} - Mass_{Earth\ actual}}{Mass_{Earth\ actual}} = \frac{5.9035\ x\ 10^{24} kg - 5.98\ x\ 10^{24}\ kg}{5.98\ x\ 10^{24} kg} = -0.0128 =$$ -1.28% error



Excel Model

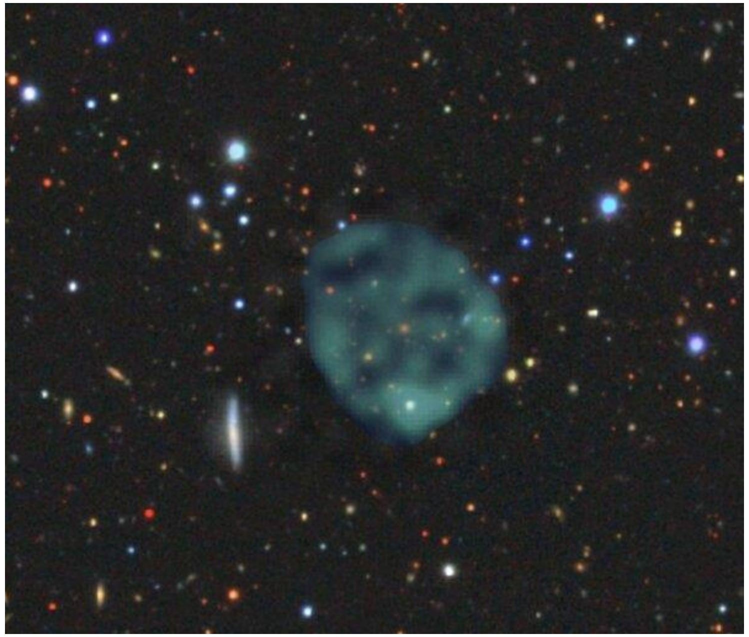
	Parameter	Value	Units				
2	delta t perigee	2.38	seconds				
3	delta t apogee	2.64	seconds				
4	speed of light (c)	299792.458	km/s				
5	r perigee	3.6487E+05	km				
6	r apogee	4.0384E+05	km				
7	semi-major axis (a)	3.8436E+05	km				
8	eccentricity	0.05070					
9	Period	2,371,428.87	seconds				
10	Period (days)	27.45	days				
11	G	6.67E-11	m^3/(kgs^2)				
12							
13	Earth-Moon mass measured	5.9760E+24	kg				
14	Earth - Moon Mass actual	6.0535E+24	kg				
15		-1.28%	error				
16							
17	Ratio Earth/Moon mass	81.39377	ratio		Use Solver		
18	Earth mass measured	5.9035E+24	kg		Total	Earth Mass	Moon Mass
19	Moon Mass measured	7.2530E+22	kg	Measure	5.9760E+24		
20					5.9760E+24	5.9035E+24	7.2530E+22
21	Moon mass actual	7.347E+22	kg	Delta	0.0000E+00		
22		-1.28%	error				
23							
24	Earth mass actual	5.9800E+24	kg				
25		-1.28%	error				

What do we need to do to measure this?

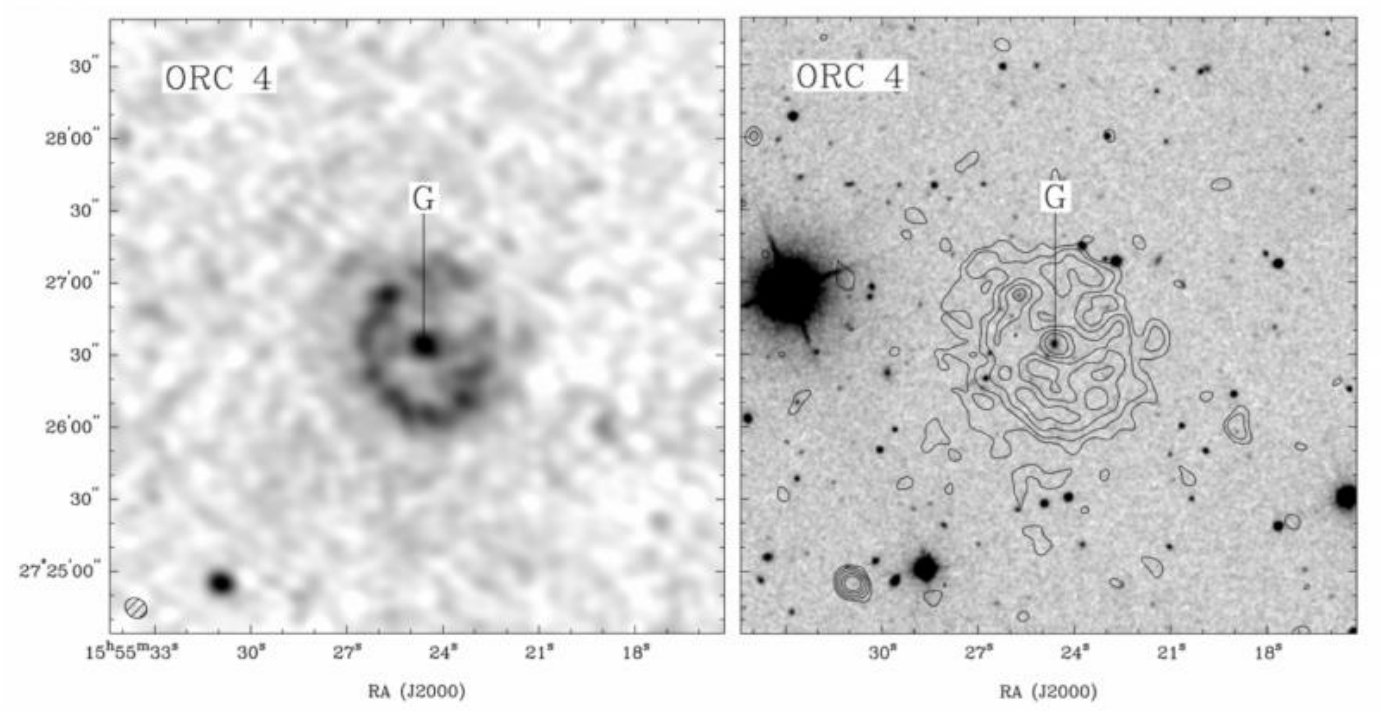
- Need to measure the delay between transmit and receive from Earth to Moon and Back within 100th of a second
- Possible Approaches
  - Build arduino stopwatch
    - Arduino controls relay that sends CW pulse (starts clock)
    - Arduino receiver receives return pulse (stops clock)
    - Arduino can automatically calculate Earth to Moon radius
  - Measure time delay with oscilloscope
- Take multiple measurements to find the highest (apogee) and lowest (perigee) distances – the accuracy should improve with more measurements
- Use EME video to get first measurements of time delays
- Calibration can be accomplished by comparing measured vs. actual values
  - Most likely the calibration would subtract from the delay time
- Calculate the rest of the Moon orbit values – left to student

Odd Radio Circle (ORC)

- Phenomenon seen only radio frequencies where the object is circular and brighter along the edges



wtfnewlydisc.jpg (600×512) (b-cdn.net)



odd radio circle alma - Bing images

Displaying and Analyzing Planetary Disks

Disk Substructures at High Angular Resolution Project (DSHARP)

Goal is to display and analyze planetary disks that were measured by ALMA

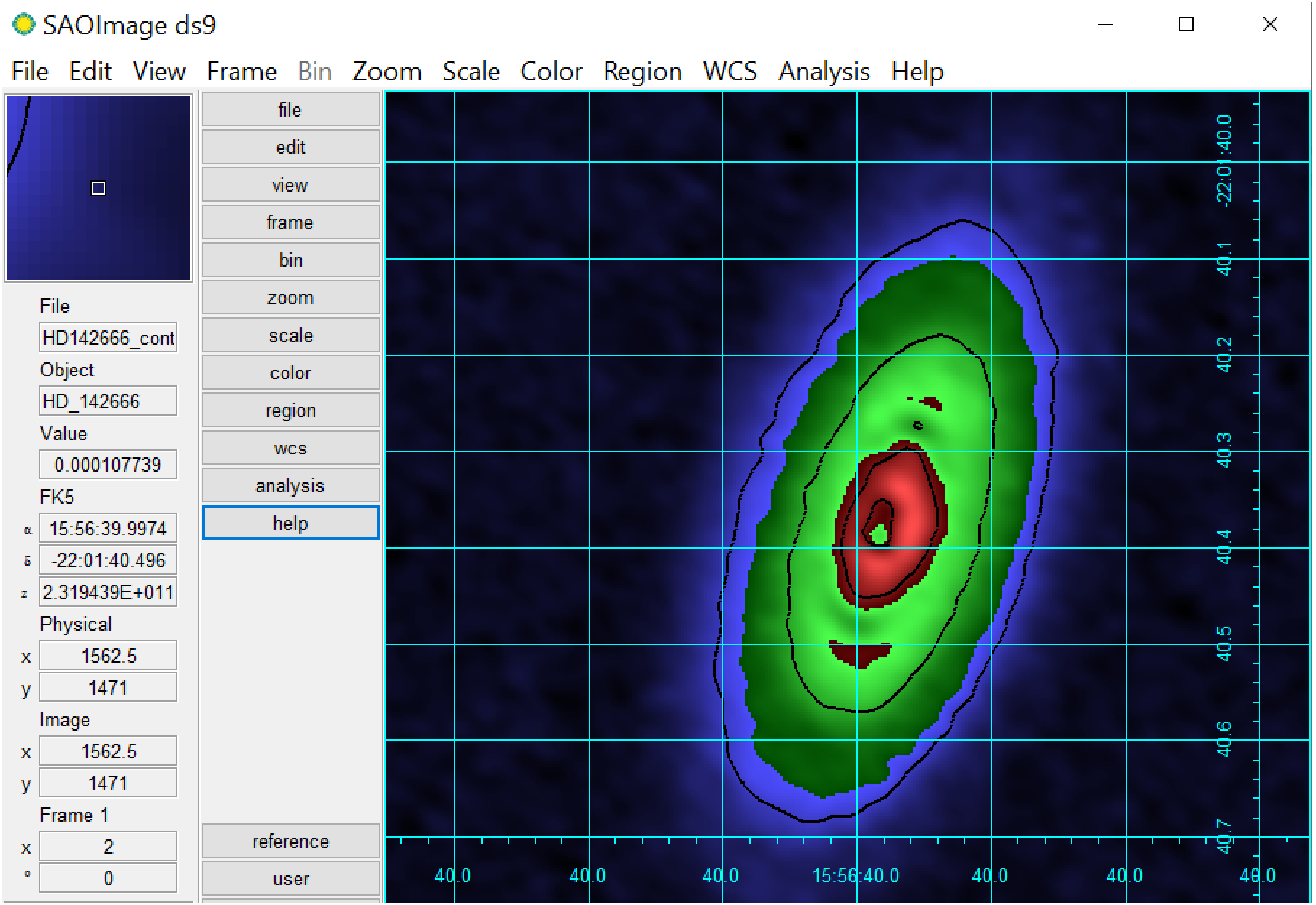
1) Download FITS viewer (selected SAO Image DS9 viewer
2) Download DSHARP FITS files
3) Use the FITS viewer to analyze the data

- SAOImageDS9 (google.com) https://sites.google.com/cfa.harvard.edu/saoimageds9/home

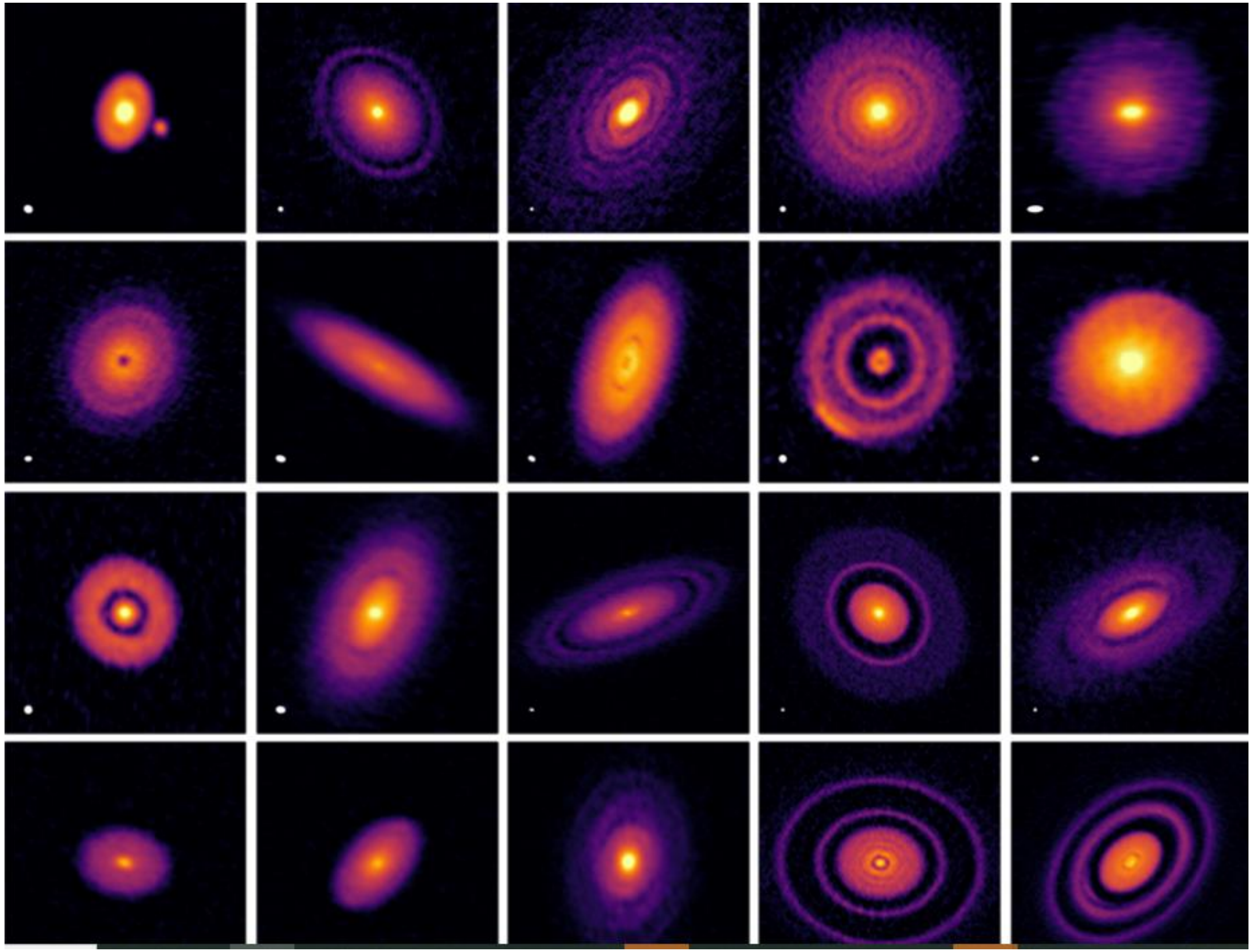
- DSHARP DATA RELEASE (nrao.edu)

https://almascience.nrao.edu/almadata/lp/DSHARP/

FITS Image Viewer (SAOImage ds9)



ALMA Imaging for DSHARP Project



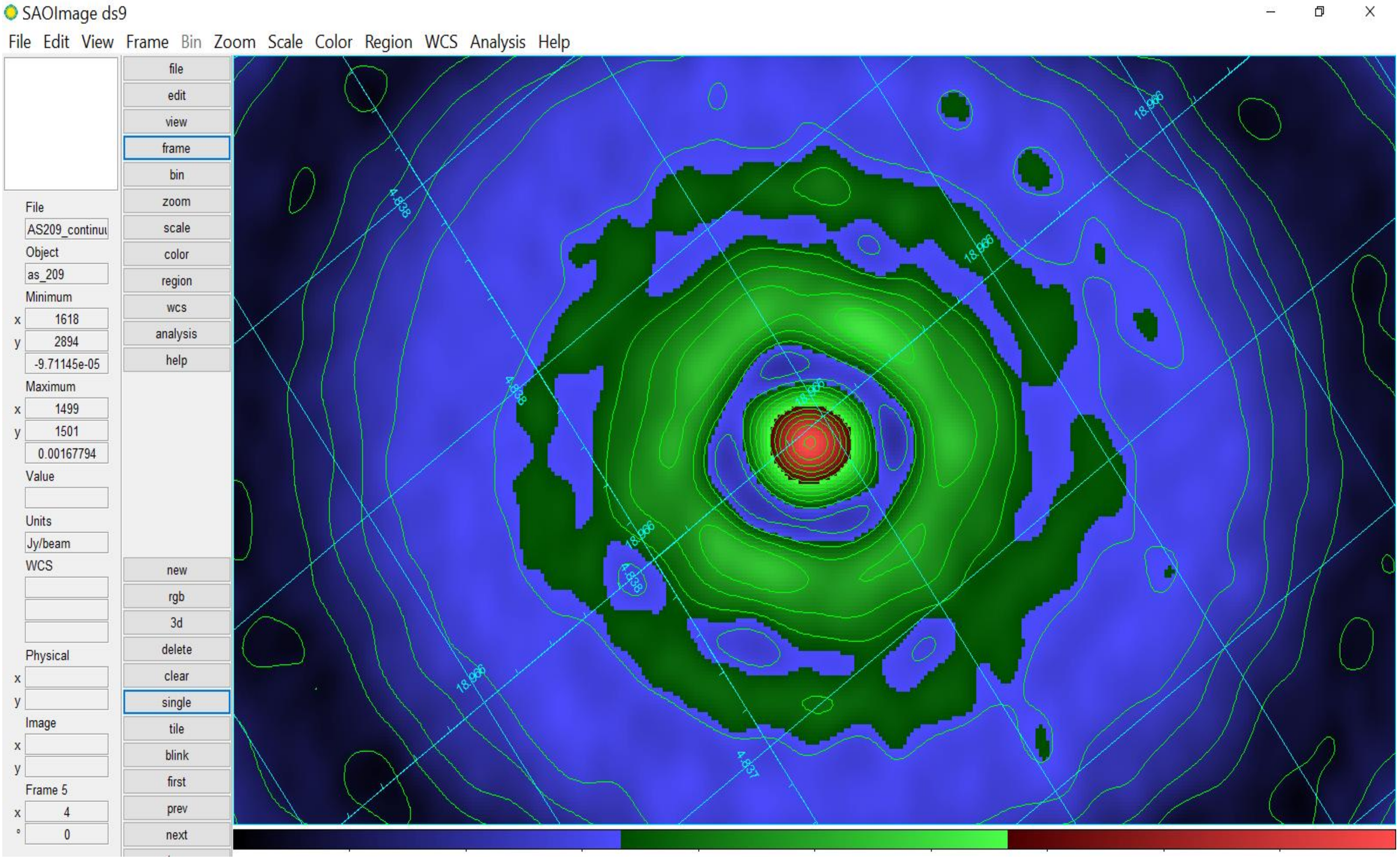
https://almascience.nrao.edu/almadata/lp/DSHARP/

Data Downloads

Target	Scripts (.py)	Final Calibrated MS (.tar.gz)	Fiducial Images (.fits)	profiles (ascii); README	SEDs (ascii)
HT Lup	continuum; CO	continuum (0.8 GB); CO (0.6 GB); CO+cont (0.6 GB)	continuum (62 MB); CO (1.9 GB)	continuum profile	SED
GW Lup	continuum; CO	continuum (0.8 GB); CO (0.5 GB); CO+cont (0.5 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
IM Lup	continuum; CO	continuum (1.8 GB); CO (0.8 GB); CO+cont (0.8 GB)	continuum (62 MB); CO (920 MB)	continuum profile	SED
RU Lup	continuum; CO	continuum (0.9 GB); CO (0.7 GB); CO+cont (0.7 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
Sz 114	continuum; CO	continuum (0.5 GB); CO (0.4 GB); CO+cont (0.4 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
Sz 129	continuum; CO	continuum (0.9 GB); CO (0.6 GB); CO+cont (0.6 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
MY Lup	continuum; CO	continuum (0.9 GB); CO (0.6 GB); CO+cont (0.6 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
HD 142666	continuum; CO	continuum (0.8 GB); CO (0.6 GB); CO+cont (0.6 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
HD 143006	continuum; CO	continuum (1.0 GB); CO (0.8 GB); CO+cont (0.8 GB)	continuum (35 MB); CO (1.3 GB)	continuum profile	SED
AS 205	continuum; CO	continuum (0.5 GB); CO (0.4 GB); CO+cont (0.4 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
SR 4	continuum; CO	continuum (1.1 GB); CO (0.8 GB); CO+cont (0.8 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
Elias 20	continuum; CO	continuum (1.0 GB); CO (0.6 GB); CO+cont (0.6 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
DoAr 25	continuum; CO	continuum (0.5 GB); CO (0.4 GB); CO+cont (0.4 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
Elias 24	continuum; CO	continuum (0.8 GB); CO (0.5 GB); CO+cont (0.5 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
Elias 27	continuum; CO	continuum (1.0 GB); CO (0.7 GB); CO+cont (0.7 GB)	continuum (62 MB); CO (920 MB)	continuum profile	SED
DoAr 33	continuum; CO	continuum (1.1 GB); CO (0.7 GB); CO+cont (0.7 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED
WSB 52	continuum; CO	continuum (1.0 GB); CO (0.6 GB); CO+cont (0.6 GB)	continuum (35 MB); CO (518 MB)	continuum profile	SED

https://almascience.nrao.edu/almadata/lp/DSHARP/

AS 209



SAOImage ds9
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y 2894
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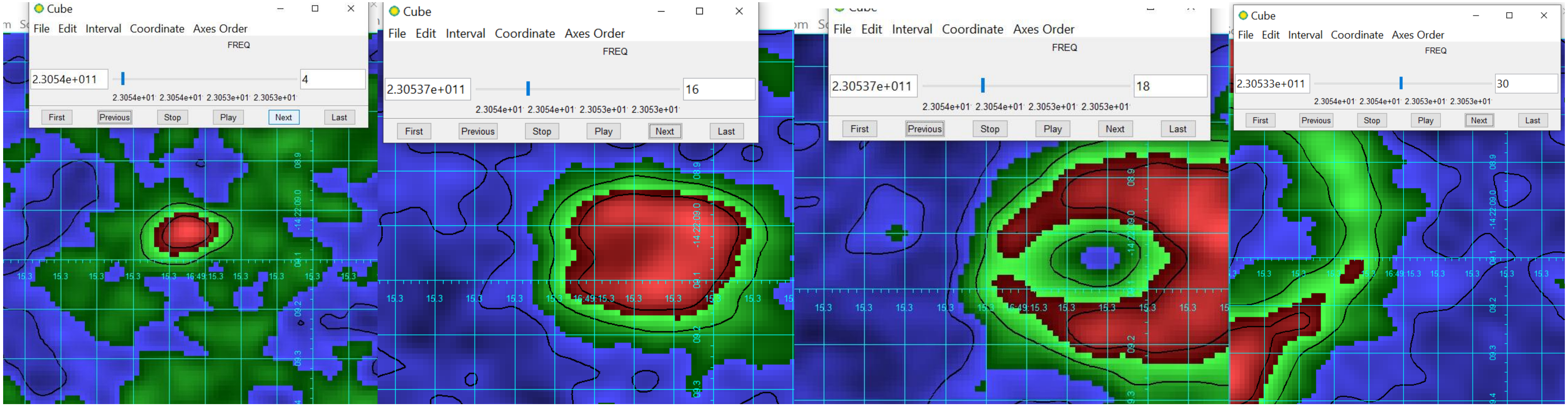
AS209 CO Analysis
Frequency Mapping



Measured frequency increases

2020/21 Observation/ Feed Schedule

- February 2021
  - 408 MHZ Feed for pulsar observations
  - 1296 MHz if EME team wants it
- March 2021
  - 408 MHZ Feed for pulsar observations
  - 1296 MHz if EME team wants it
- April 2021
  - 408 MHZ Feed for pulsar observations
  - 1296 MHz if EME team wants it

Questions?