

Galactic Hydrogen HI 1.42 GHz RF Emission Radio Astronomy for \$ 300

(note : SARA presentation Aug 2022 : some info may now be dated)



Alex Pettit KK4VB

**Slide Set from Presentation
SARA Eastern Conference Aug 2022**

<https://www.youtube.com/watch?v=C6NCefVxNL8>

'The \$300 SARA Scope in a Box' Radio Telescope System and Beyond

*A beginner's introduction into recording and processing
1.42 GHz RF emission signals from neutral hydrogen regions within the Milky Way*

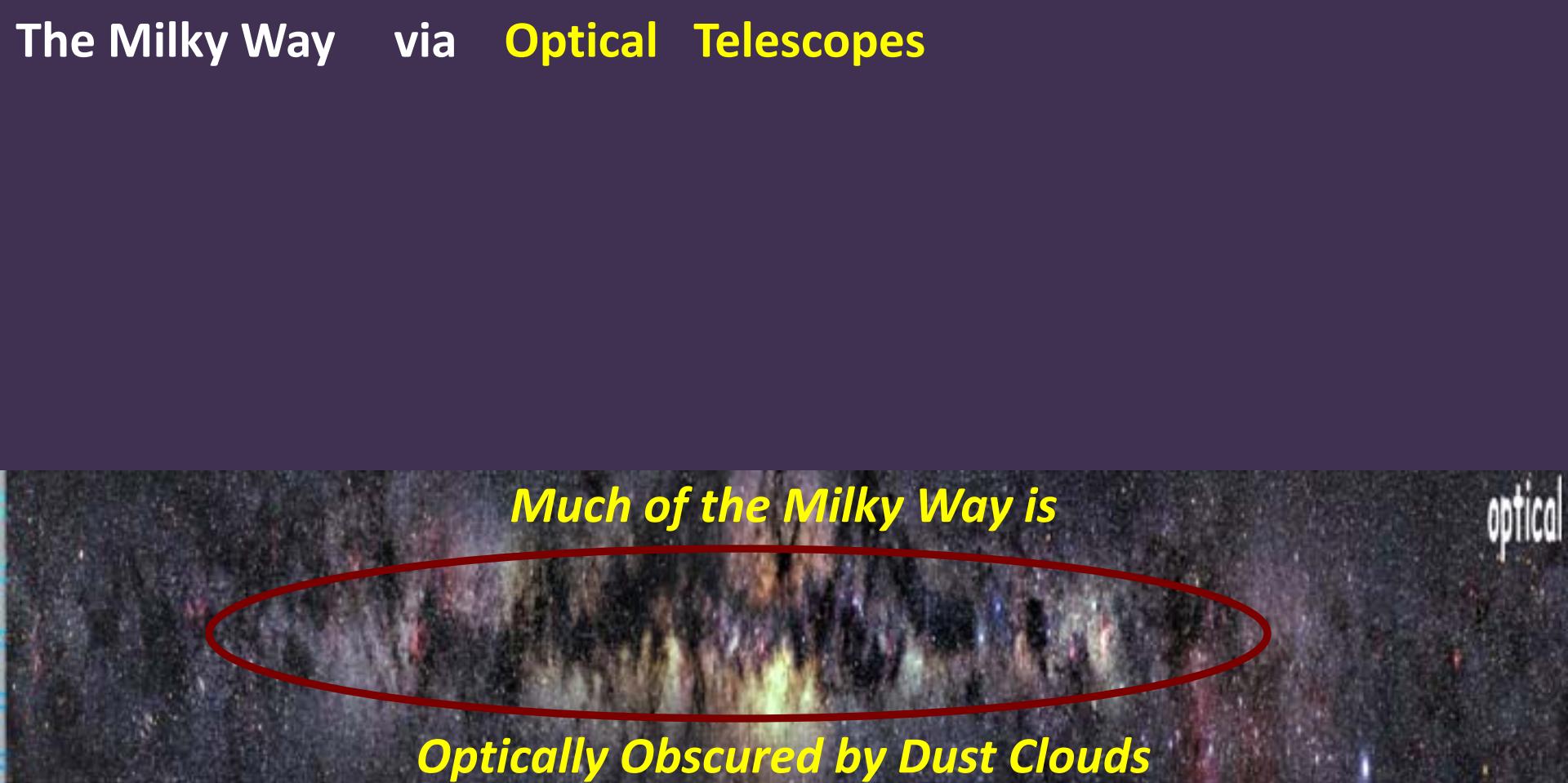
**The Goal of this Project was to 'optimize'
a lightweight, portable 1 meter radio telescope**

- 0) Overview of Hydrogen HI Radio Astronomy.**
- 1) Analog RF and Digital Hardware Components and Basic Software**
- 2) Drift Scan Technique and Data Recording**
- 3) Hardware Upgrades Improving in Signal Amplitude and Quality**
- 4) Processing via MS Excel / Mathworks Matlab**

bits of history

interesting info

The Milky Way via Optical Telescopes

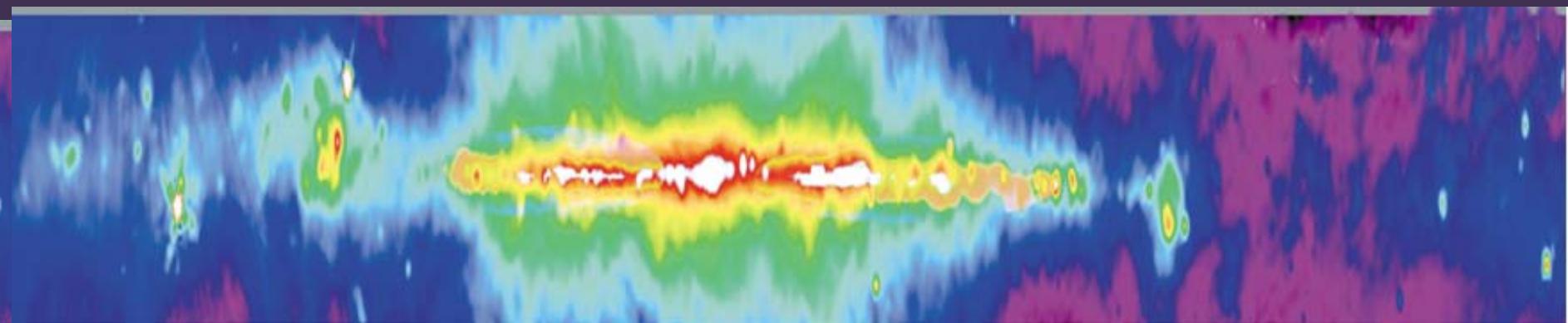


Much of the Milky Way is

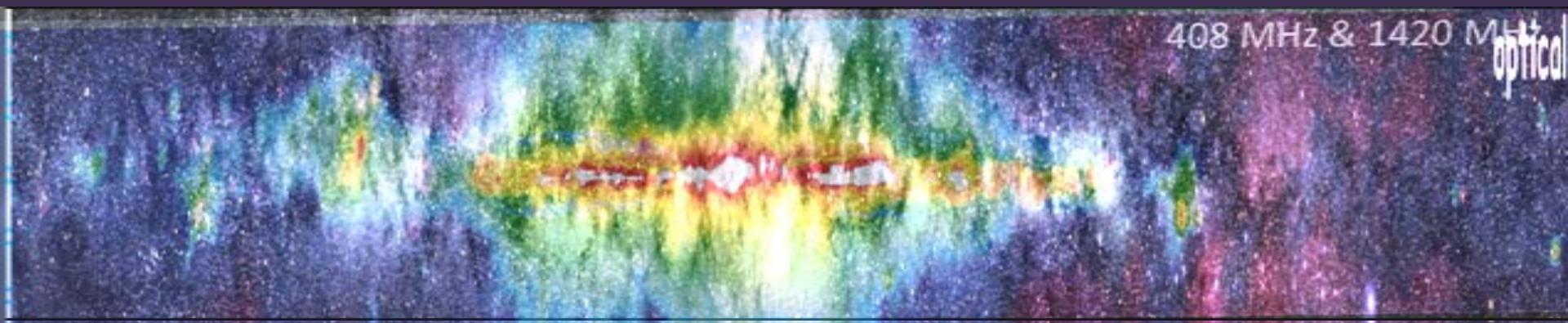
Optically Obscured by Dust Clouds

optical

The Milky Way via Radio Telescopes

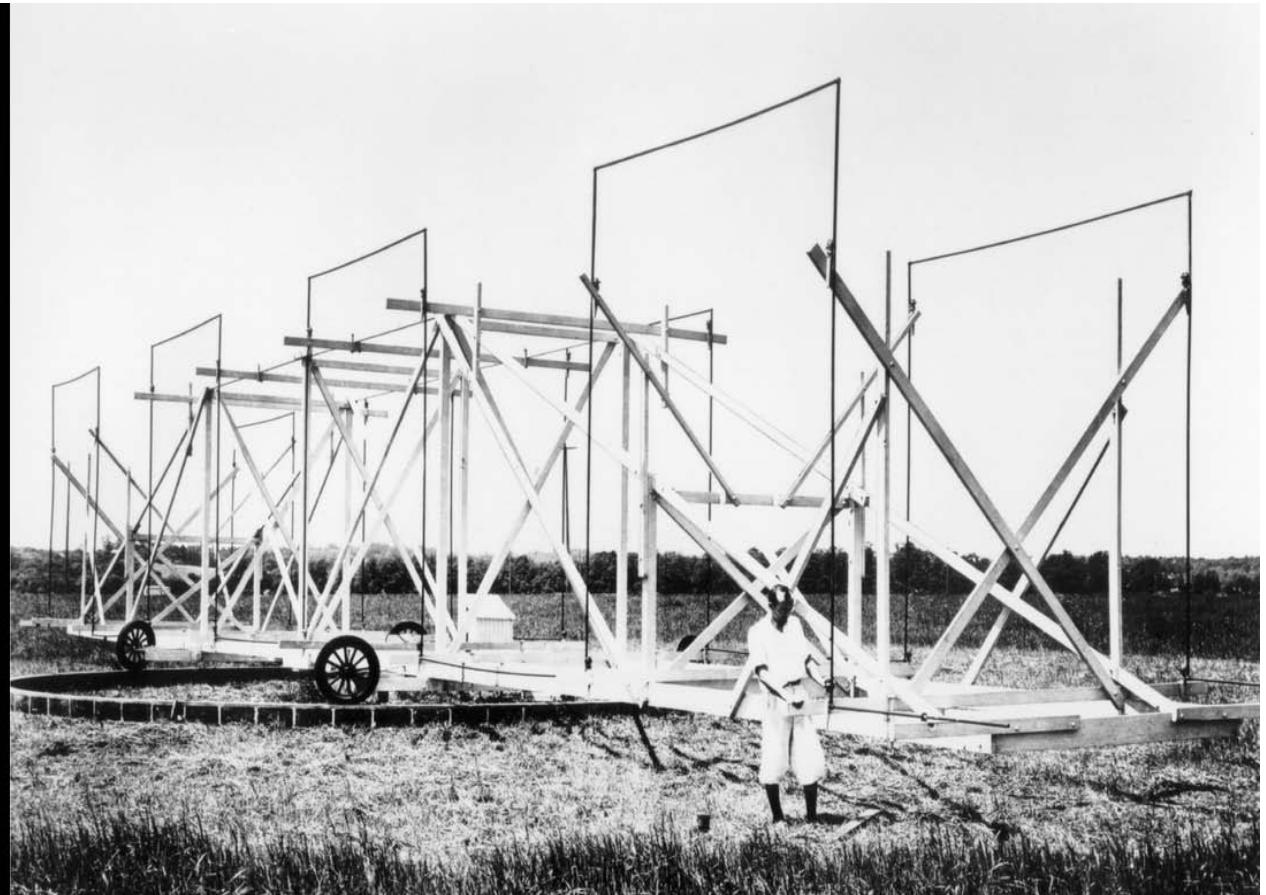


The Milky Way Composite of both Telescopes



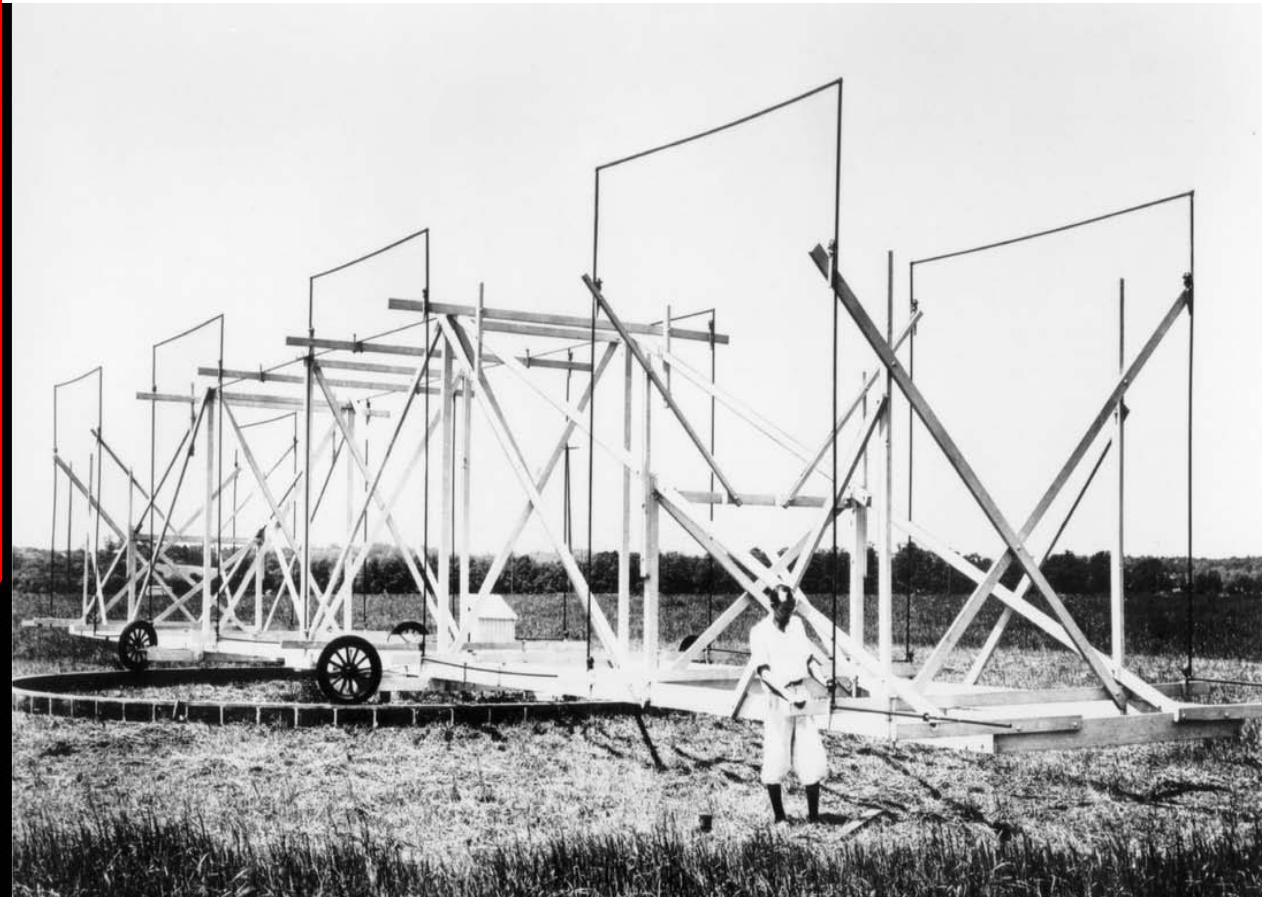
1931 Karl Jansky Bell Laboratories New Jersey

In studying thunderstorm disruption to transatlantic telecommunications
Karl Jansky discovered a source of periodic 23 hr 56 min
Radio Emission which correlated with the Milky Way



1933 Karl Jansky Bell Laboratories New Jersey

May 6th **New York Times newspaper** headlined
“New Radio Waves Traced to the Center of the Milky Way”
May 15th NBC Radio broadcast Jansky's “Star Noise”

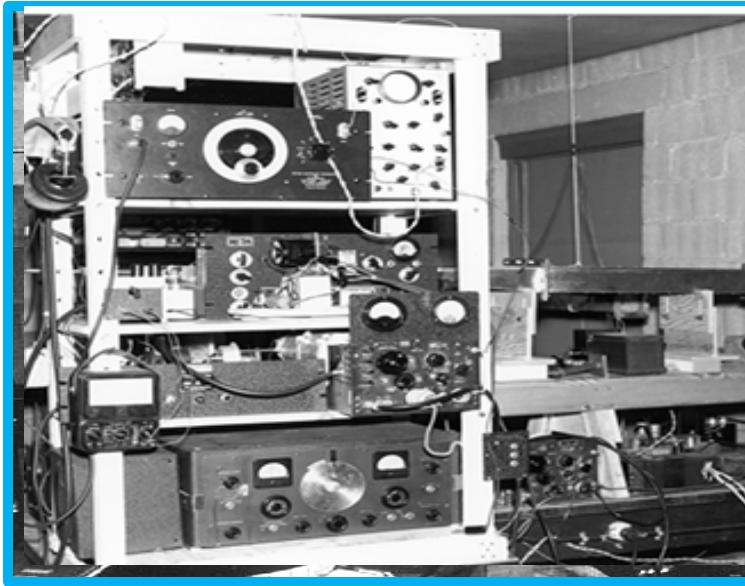


1951 Howard Ewen & Edward Purcell Harvard University

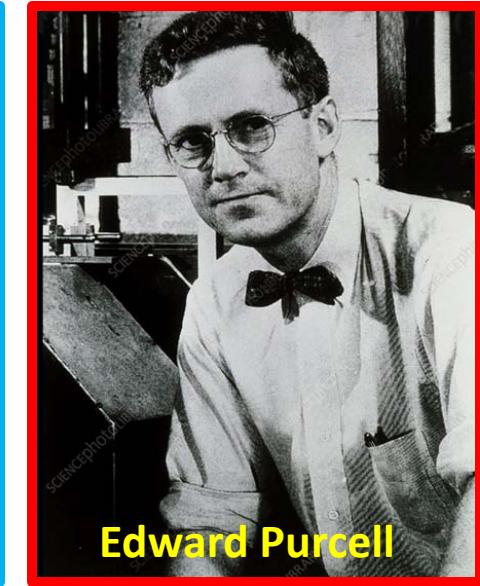
Ewen and Purcell at Harvard University were the first to identify that the RF radio emissions being received from the Milky Way were from Neutral Hydrogen Atoms and provided the first views of its spiral arms.



Howard Ewen



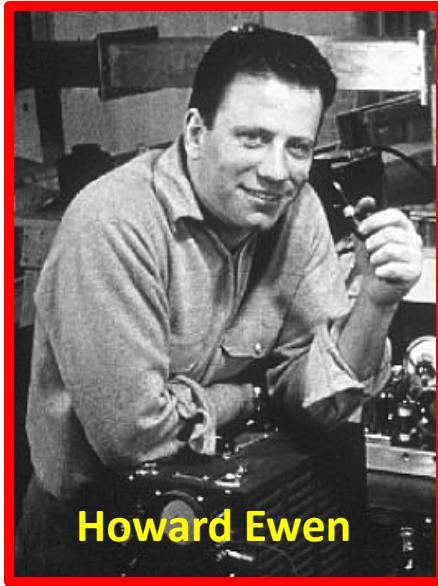
Electronic Systems



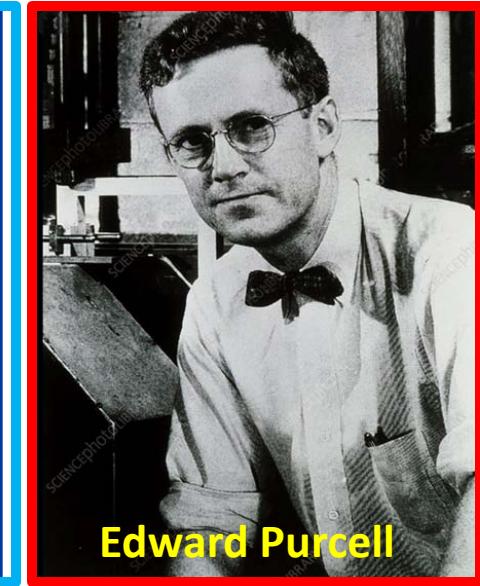
Edward Purcell

1951 Howard Ewen & Edward Purcell Harvard University

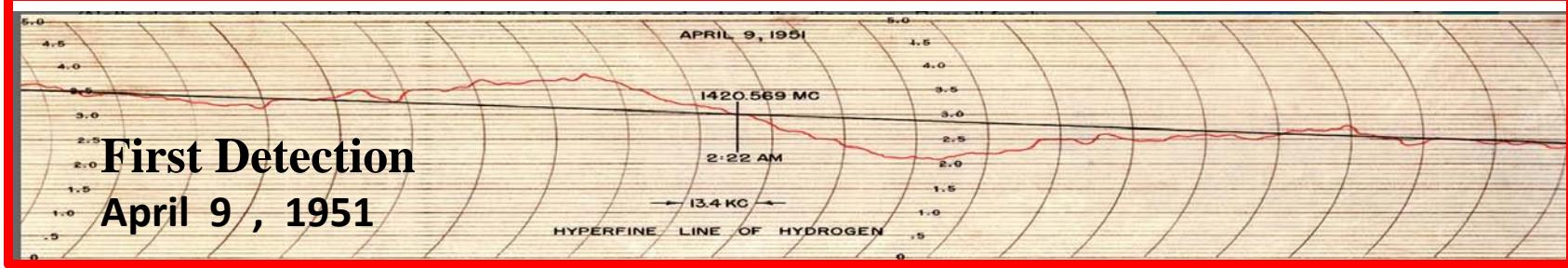
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Howard Ewen

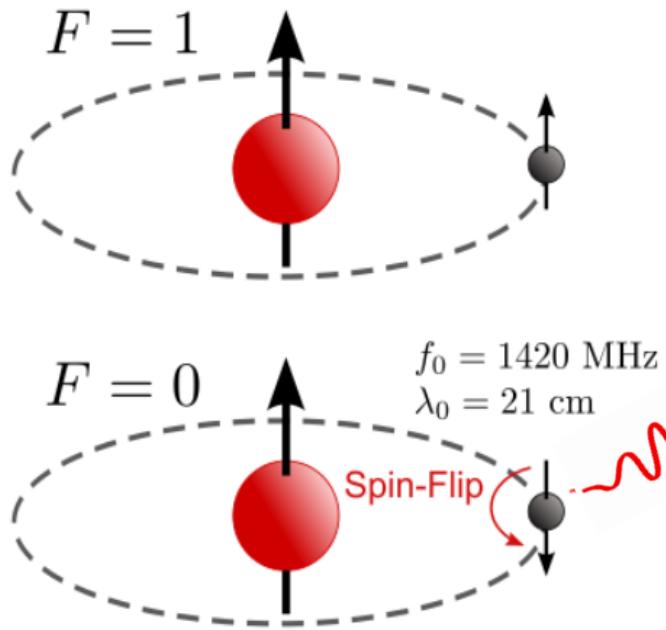


Edward Purcell



Spin - Flip Line

1420405751.786 Hz

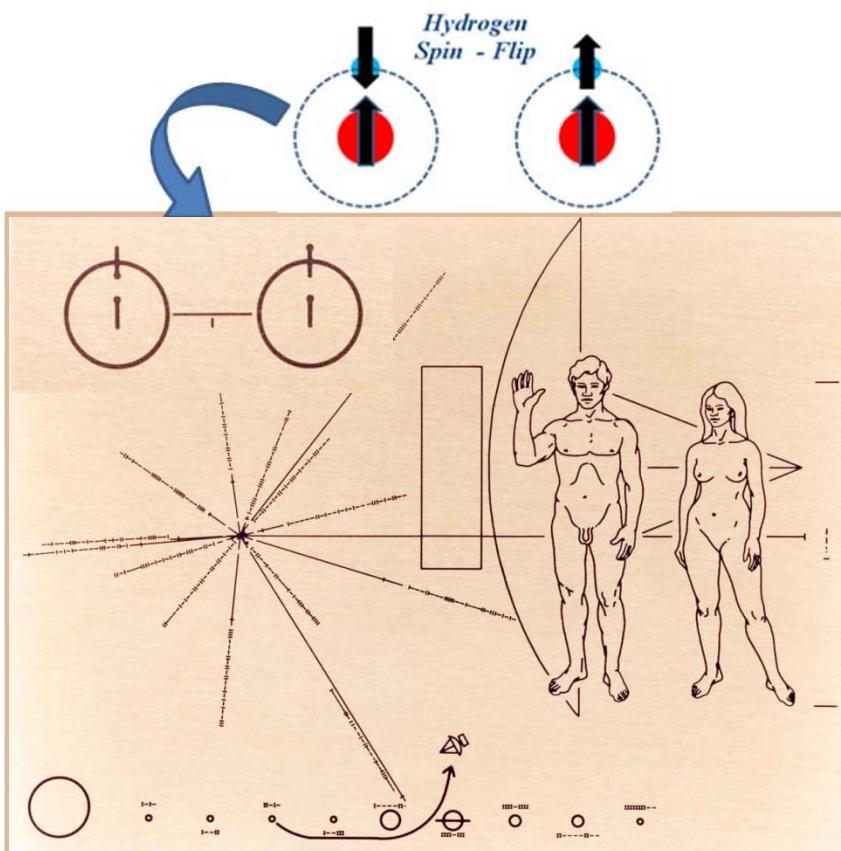


Hydrogen can exist
in two energy states
with the electron - proton spins
parallel & anti-parallel

After a period of time, it will flip
(transition) to the
lower energy state

Emit a Photon of Energy at 1420 MHz

Pioneer 10 and 11 Spacecraft Plaque

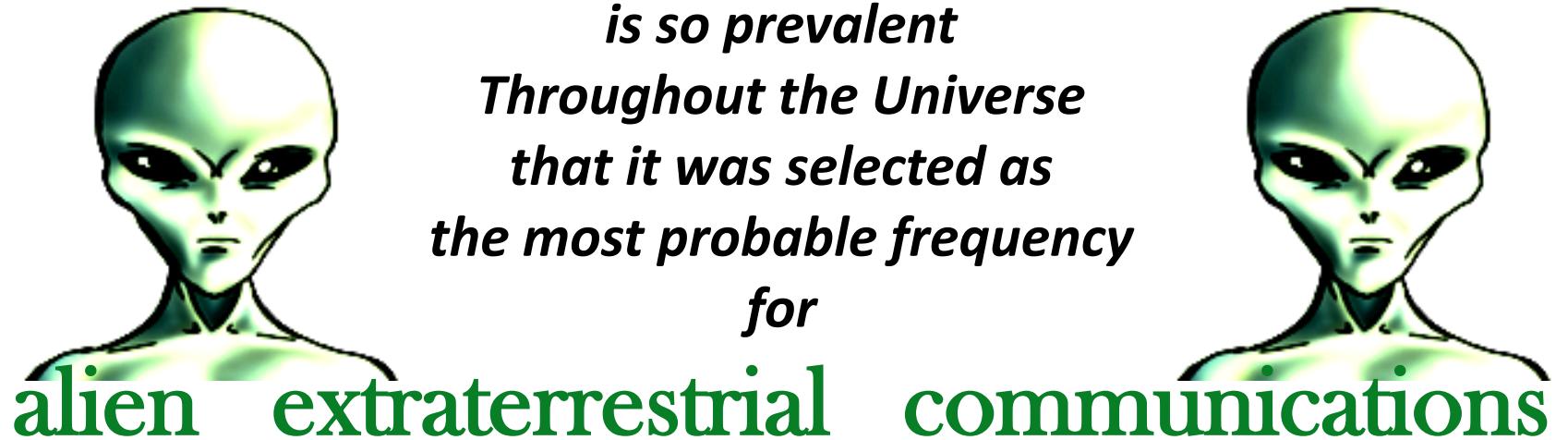


**1420 MHz is an
internationally recognized
"Protected Frequency"**

Radio Astronomy was first officially recognized in 1959 as a radio service of fundamental importance to science and its frequency band has been exclusively allocated by the ITU as a "protected frequency"

No Transmission is Allowed in this Band.

(Switch Mode Power Supplies Didn't Get the Email)



alien extraterrestrial communications

It is the

S E T I

(**S**earch for **E**xtra-**T**errestrial **I**ntelligence)

Frequency .

**Basic
\$ 300
System**

Galactic Hydrogen 1.42 GHz RF Emission

Radio Astronomy for \$ 300



Basic Components Hydrogen 21 cm Radio Telescope



Satellite Mesh Antenna - 21dBi
Parabolic Antenna w/ 1.7GHz
Center Frequency, 200MHz+
Bandwidth, LMR400 Feed
Cable with Male SMA
Connector, Mounting
Hardware, & 2 Year Warranty
Brand: NooElec

Price \$ 109.95



Roll over image to

Nooelec SAWbird+ H1 -
Premium Saw Filter & Cascaded
Ultra-Low Noise Amplifier
(LNA) Module for Hydrogen
Line (21cm) Applications.
1420MHz Center Frequency.
Designed for Software Defined
Radio (SDR)
Brand: NooElec

★★★★★ 26 ratings

Price \$ 44.95



NESDR SMArTee XTR SDR -
Premium RTL-SDR w/Extended
Tuning Range, Aluminum
Enclosure, Bias Tee, 0.5PPM
TCXO, SMA Input. RTL2832U

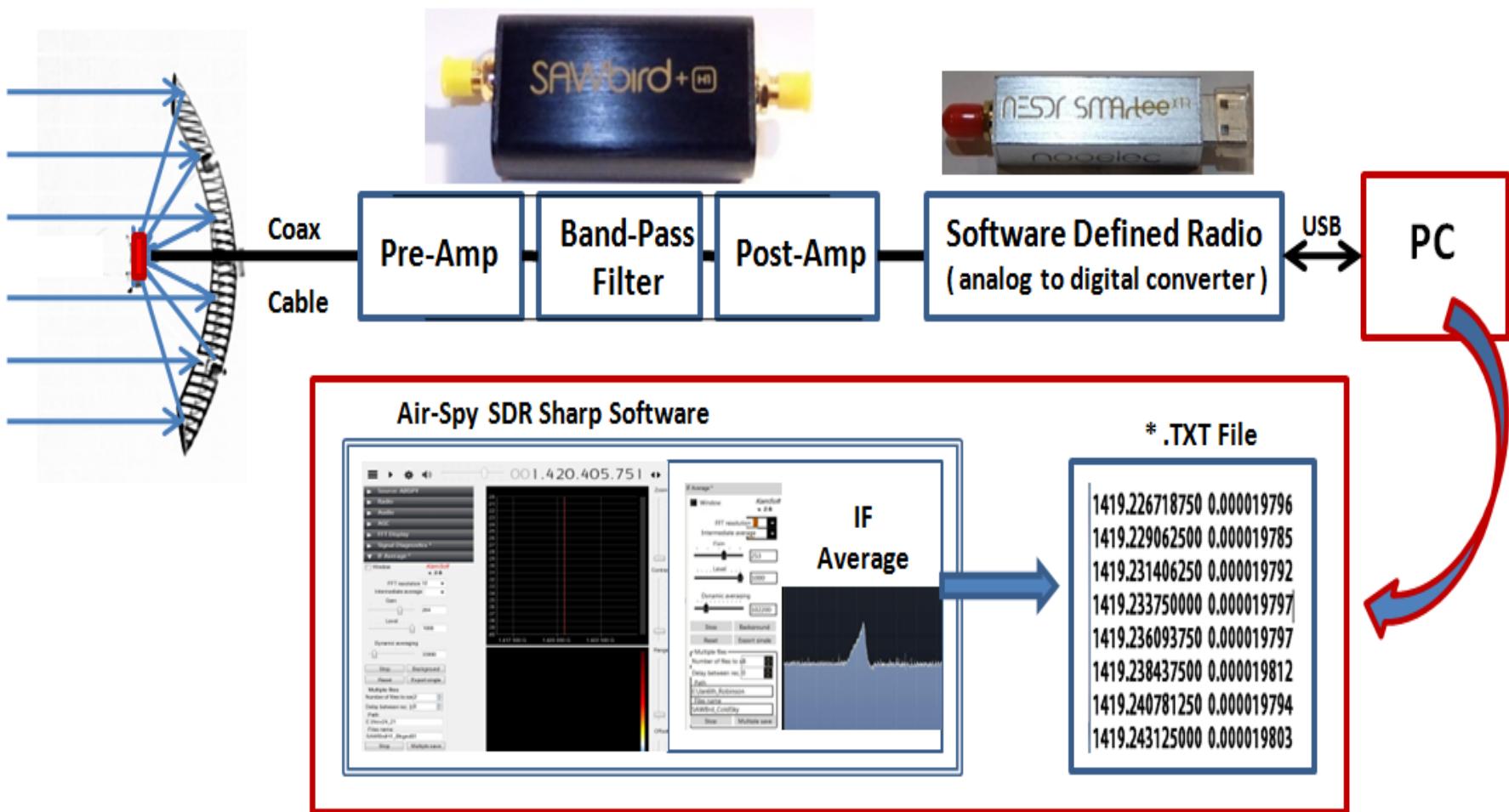
Price \$ 41.95

& FREE Returns

nooelec GOES 1.7GHz Weather Satellite Antenna
nooelec SAWBird H1 LNA & 1.42 GHz BP Filter
nooelec SMArTee SDR

System Hardware and Software

Hardware & Software System Block Diagram



Basic Software Hydrogen 21 cm Radio Telescope

SDR Acquisition :

Air Spy

SDR Sharp Studio

IF Average Plug-In

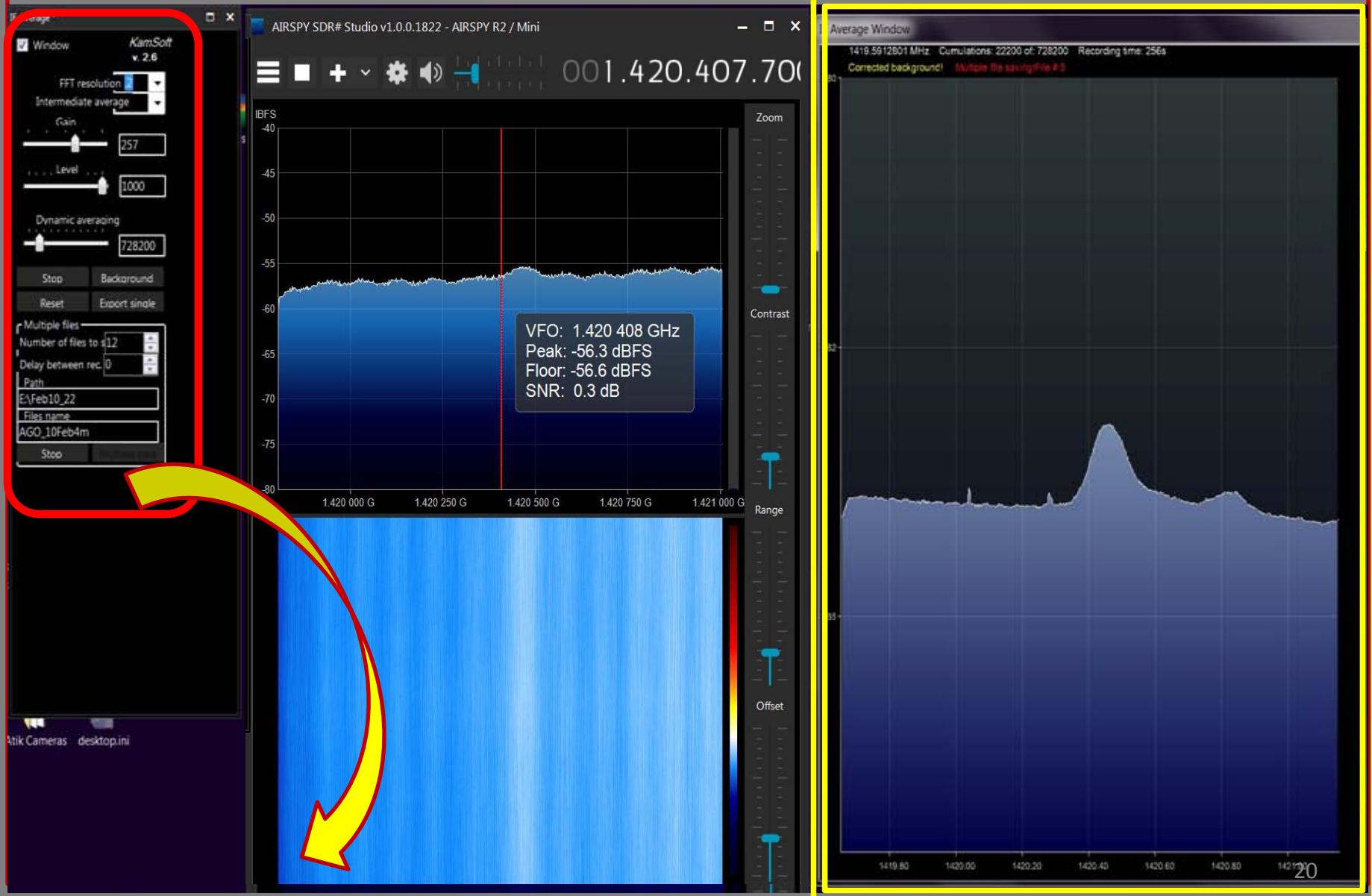


Astronomical Sky Display
Stellarium



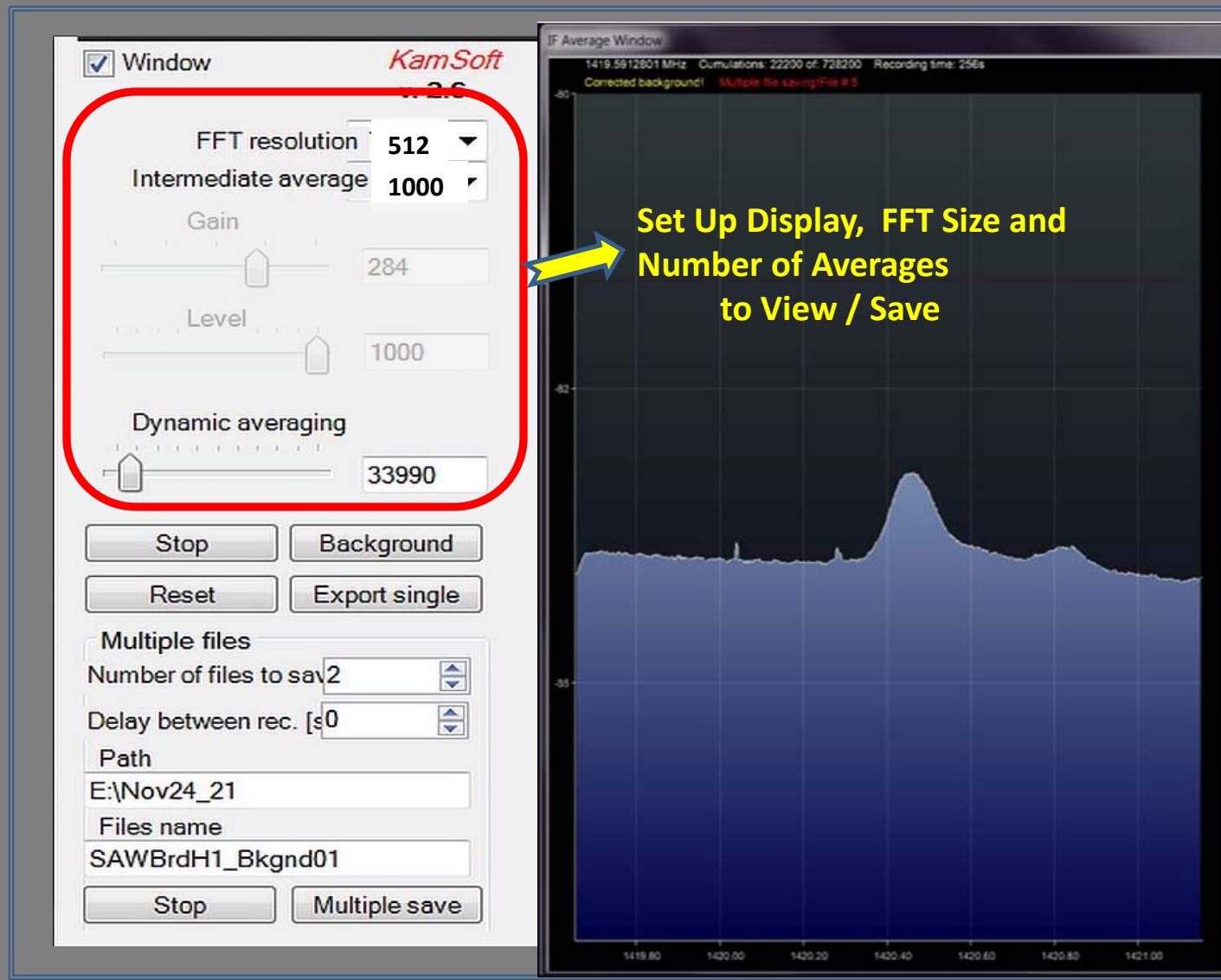
Software Block Diagram

Air-Spy SDR Sharp Software AirSpy SDR# Studio & IF Average



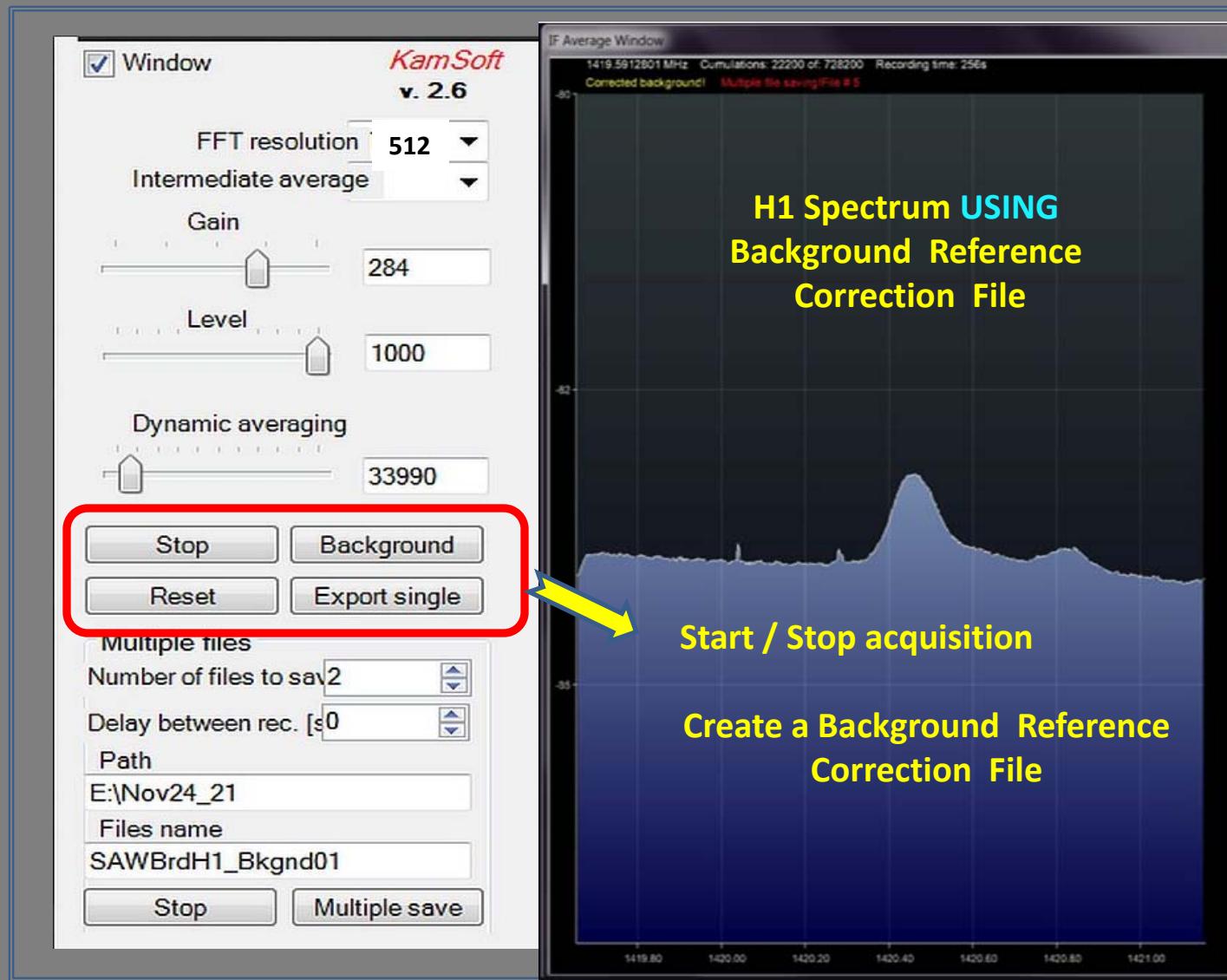
Software Block Diagram

IF_Average Plug-In for AirSpy SDR# Studio



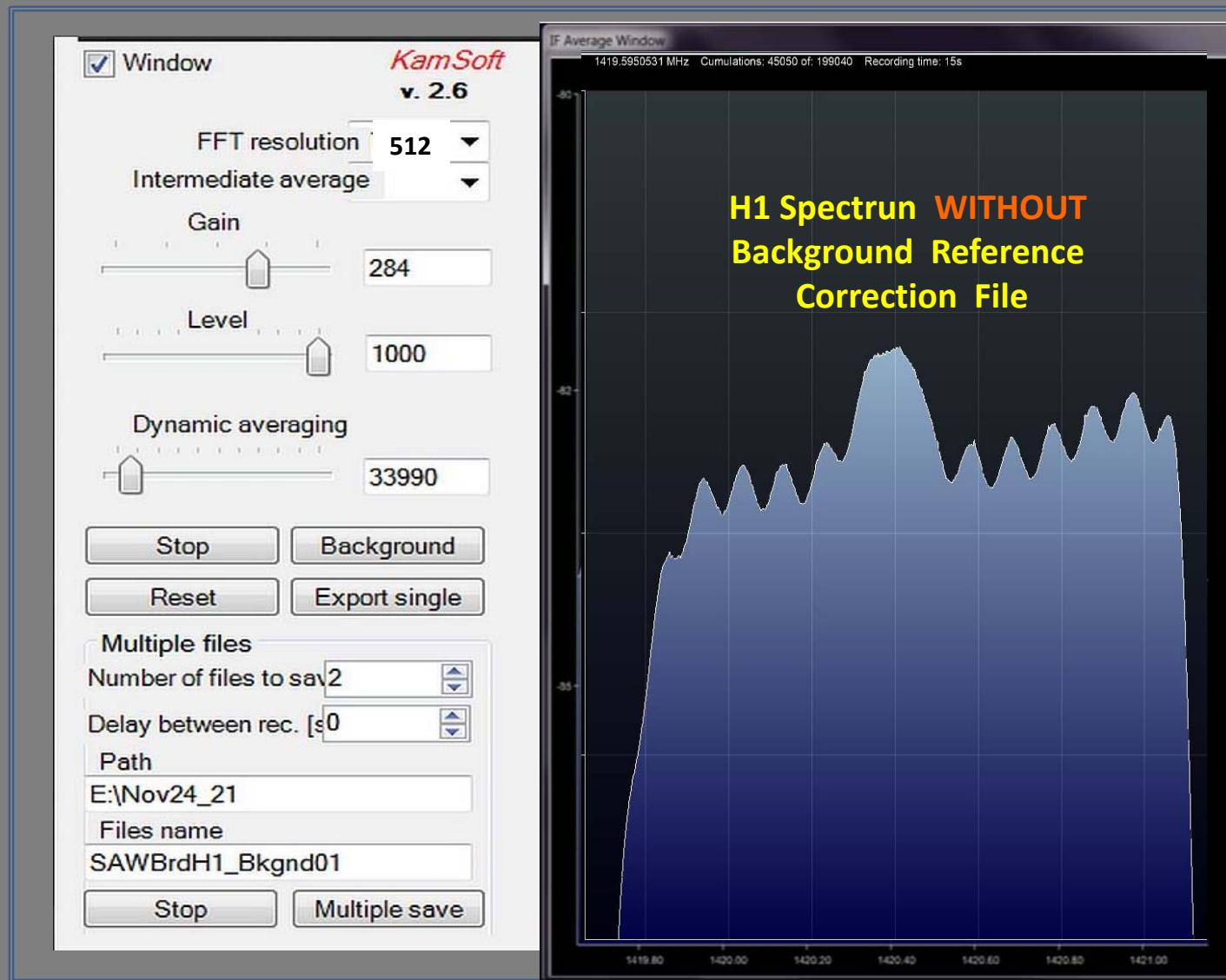
Software Block Diagram

IF_Average Plug-In for AirSpy SDR# Studio



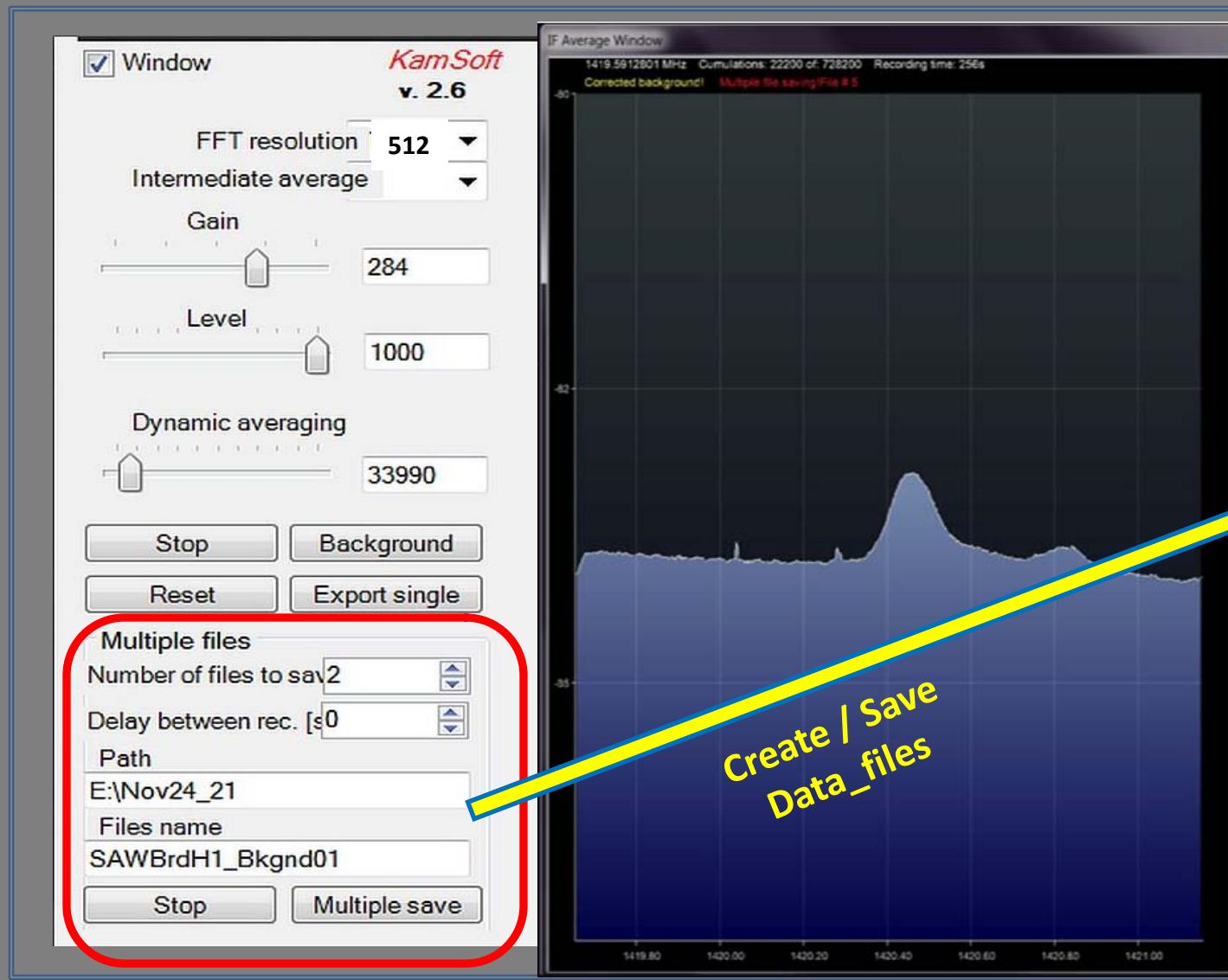
Software Block Diagram

IF_Average Plug-In for AirSpy SDR# Studio



Software Block Diagram

IF_Average Plug-In for AirSpy SDR# Studio



* .TXT File

1419.650000000	0.000014132
1419.651464844	0.000014170
1419.652929688	0.000014190
1419.654394531	0.000014222
1419.655859375	0.000014283
1419.657324219	0.000014371
1419.658789063	0.000014409
1419.660253906	0.000014481
1419.661718750	0.000014577
1419.663183594	0.000014650
1419.664648438	0.000014705
1419.666113281	0.000014777
1419.667578125	0.000014803
1419.669042969	0.000014879
1419.670507813	0.000014919
1419.671972656	0.000014949
1419.673437500	0.000014951
1419.674902344	0.000015012
1419.676367188	0.000014986
1419.677832031	0.000014999
1419.679296875	0.000015044
1419.680761719	0.000015019

Create / Save
Data_files

Allows FFT Size / High Count Averaging / Spectrum Saving at Selected Time Rates

Multiple files

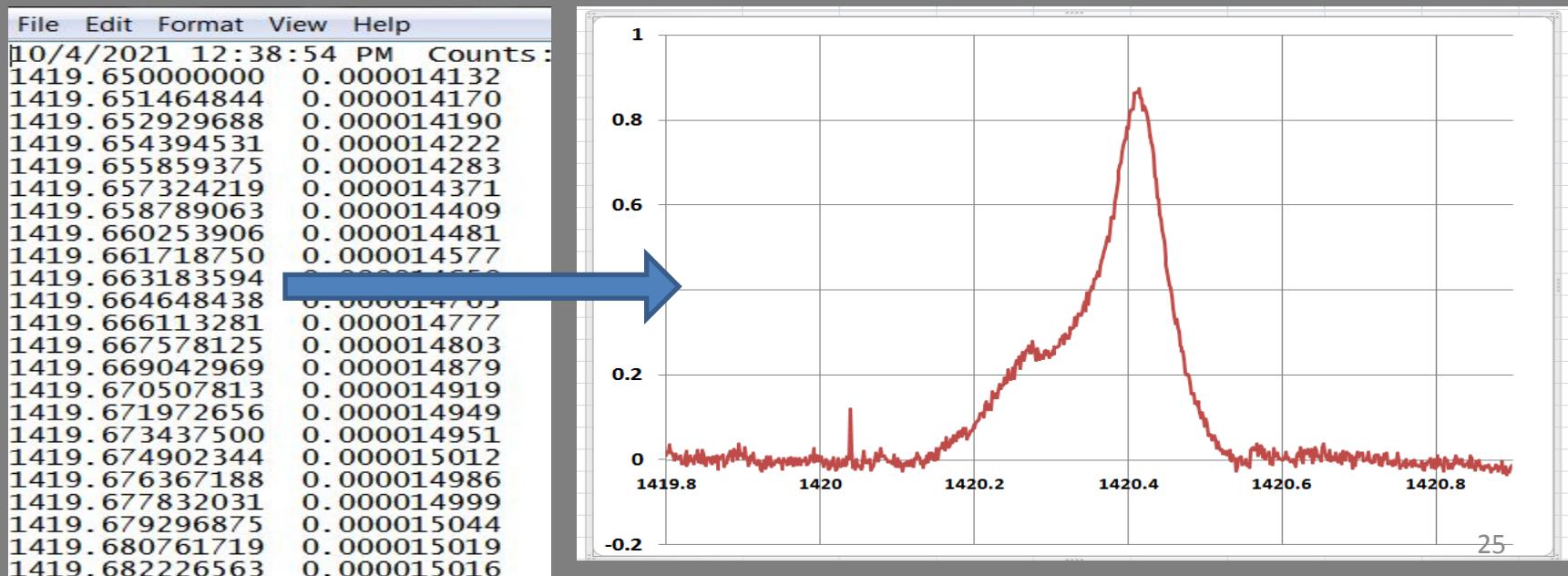
Number of files to save:

Delay between rec. [s]:

Path: E:\Nov24_21

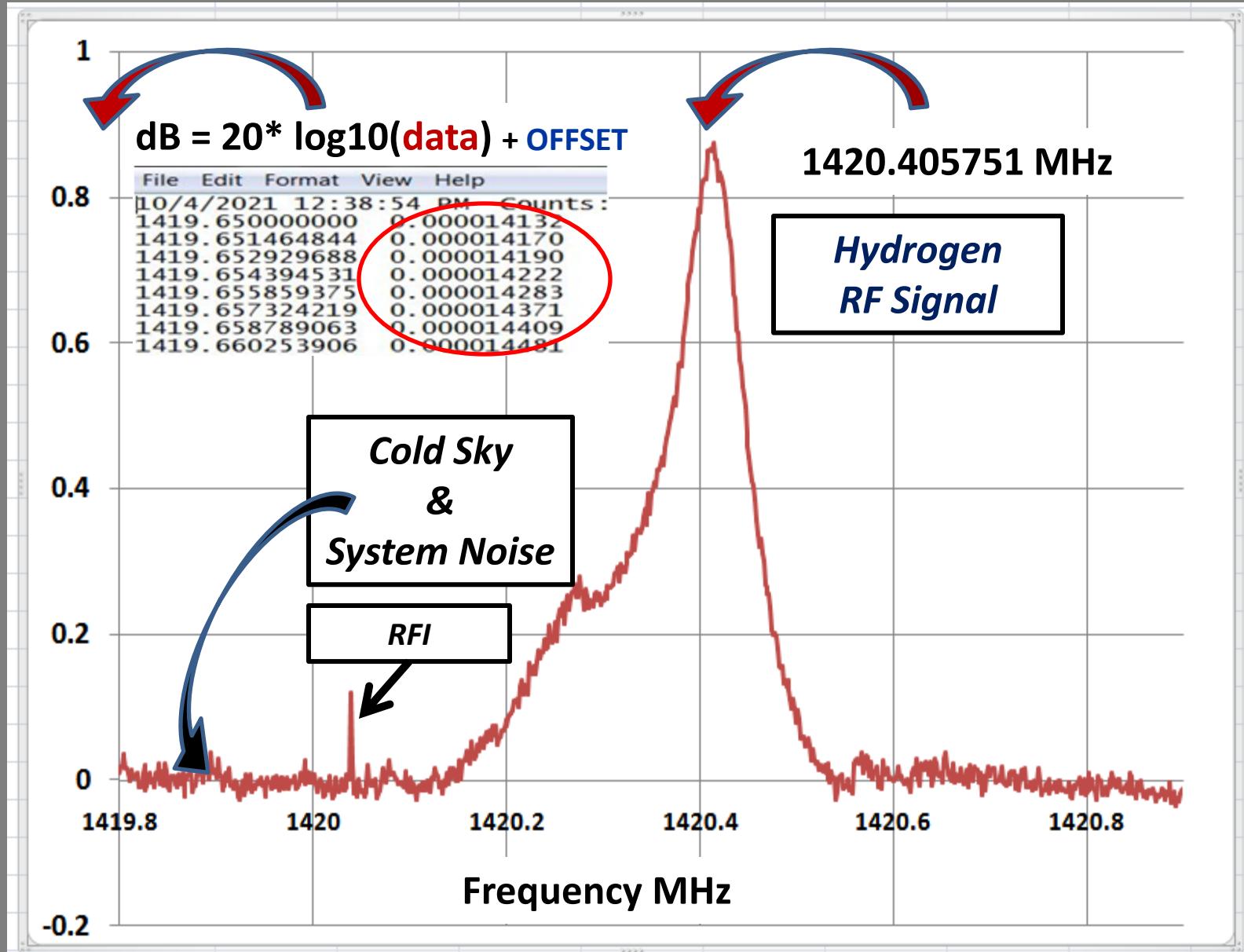
File name: SAWBrdH1_Bkgnd01

Name	Date modified	Type	Size
FLoop_ASmini_5m_D0_RA500_4Oct21_0079.txt	10/4/2021 1:38 PM	Text Document	30 KB
FLoop_ASmini_5m_D0_RA500_4Oct21_0078.txt	10/4/2021 1:33 PM	Text Document	30 KB
FLoop_ASmini_5m_D0_RA500_4Oct21_0077.txt	10/4/2021 1:28 PM	Text Document	30 KB
FLoop_ASmini_5m_D0_RA500_4Oct21_0076.txt	10/4/2021 1:23 PM	Text Document	30 KB
FLoop_ASmini_5m_D0_RA500_4Oct21_0075.txt	10/4/2021 1:18 PM	Text Document	30 KB
FLoop_ASmini_5m_D0_RA500_4Oct21_0074.txt	10/4/2021 1:13 PM	Text Document	30 KB
FLoop_ASmini_5m_D0_RA500_4Oct21_0073.txt	10/4/2021 1:08 PM	Text Document	30 KB
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FLoop_ASmini_5m_D0_RA500_4Oct21_0071.txt	10/4/2021 12:57 PM	Text Document	30 KB



Hydrogen 21-cm wavelength RF Emission Spectrum

dB Relative to Background Noise

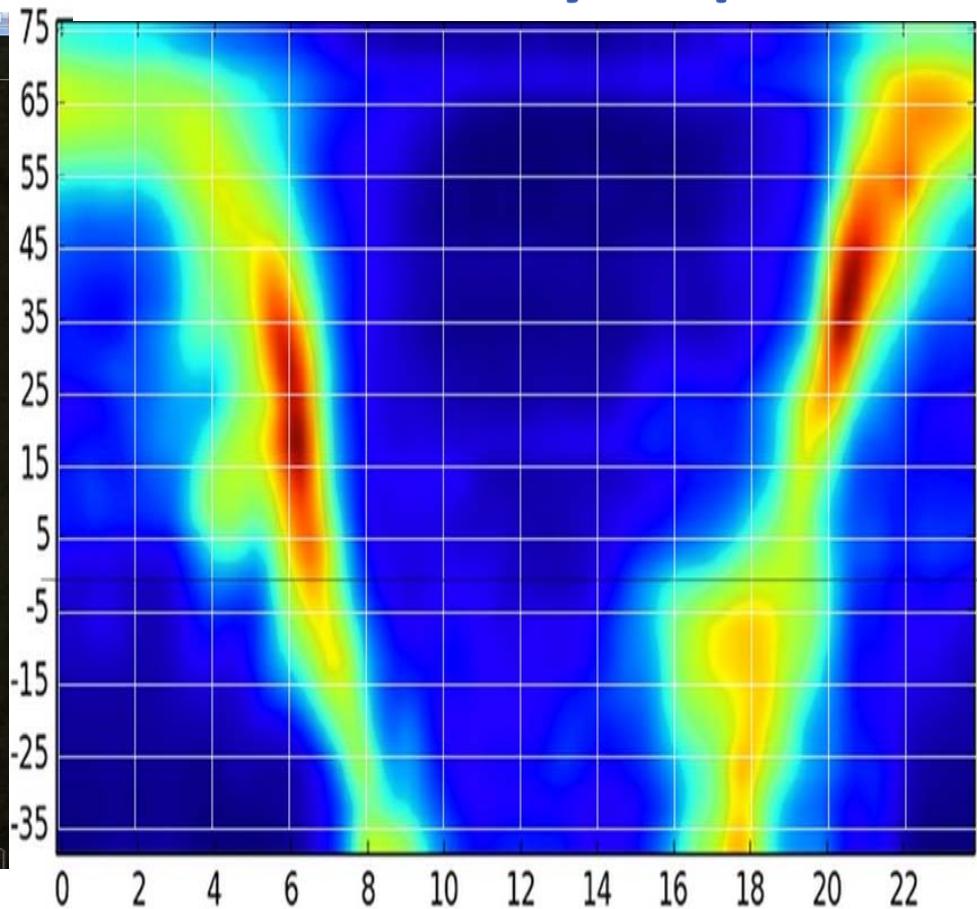
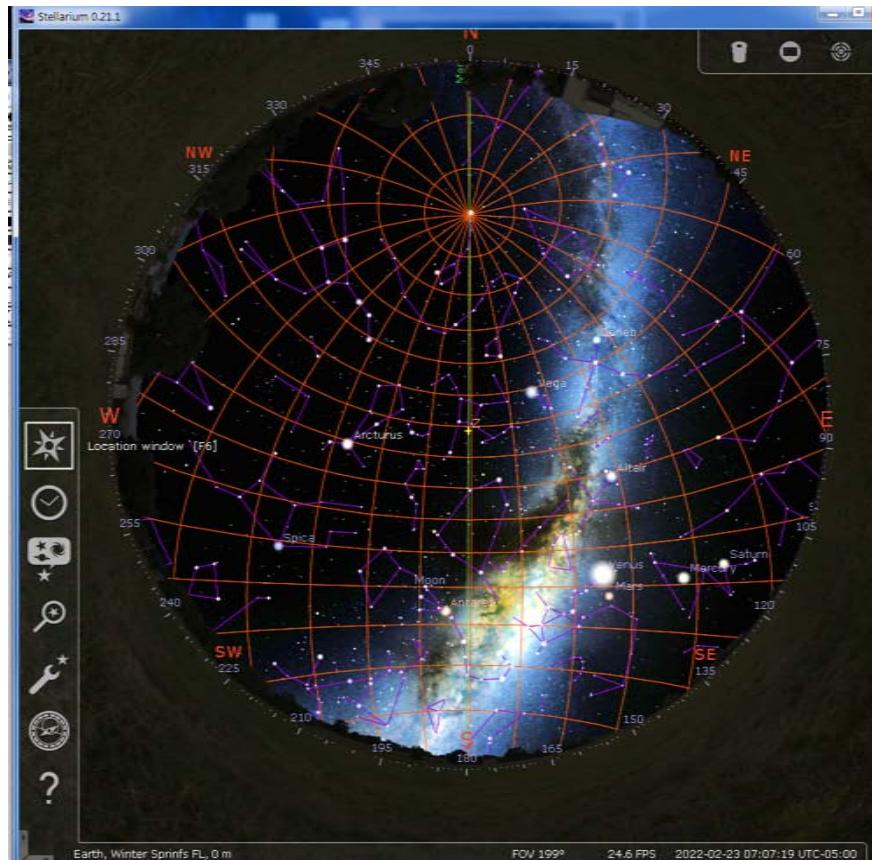


Data Acquisition

Data Acquisition

Where's the Milky Way ?
Stellarium !

21cm HI Hydrogen
Intensity Map

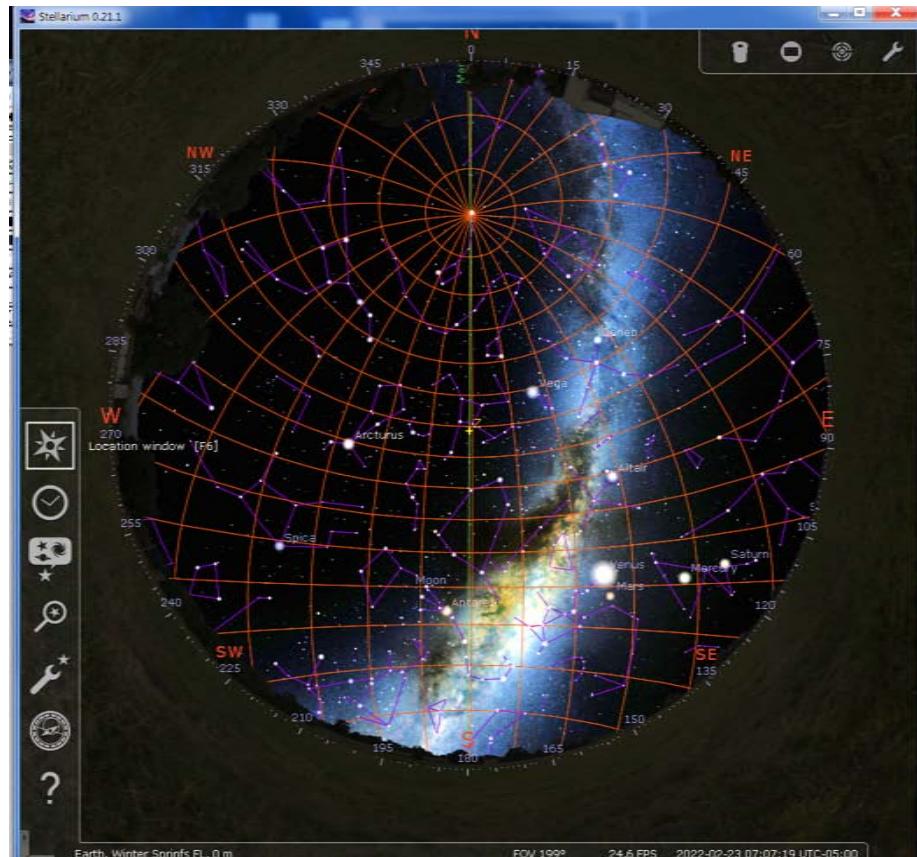


With Permission Marcus Leech : CCERA

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Data Acquisition

Where's the Milky Way ?
Stellarium !

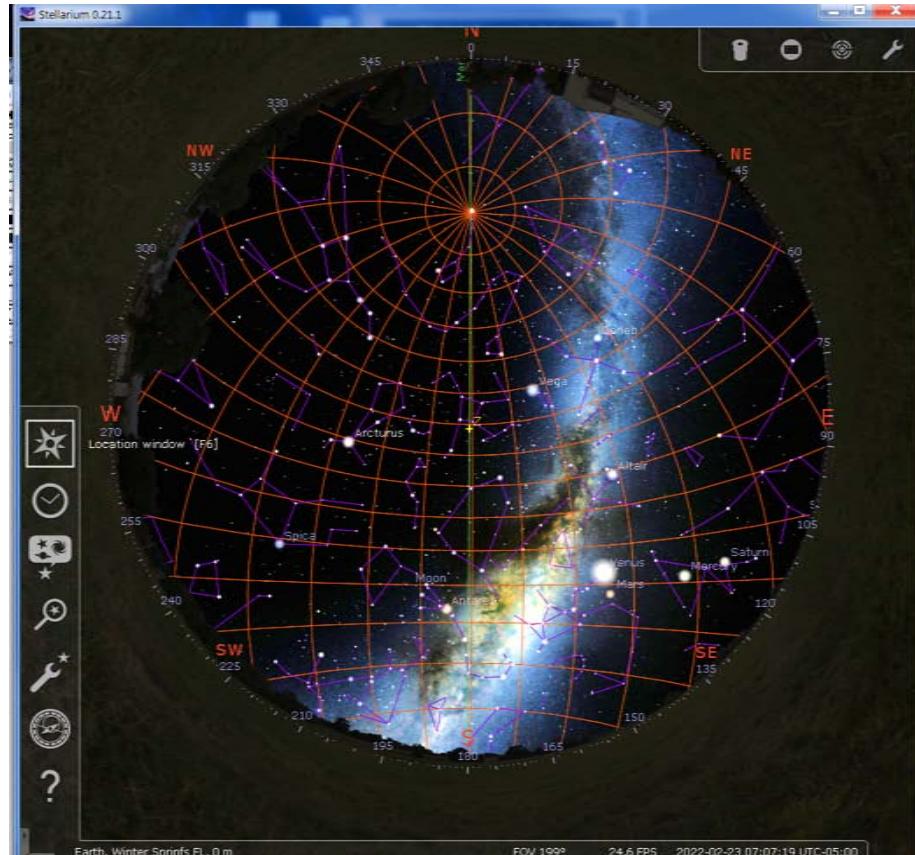


Equatorial Mount

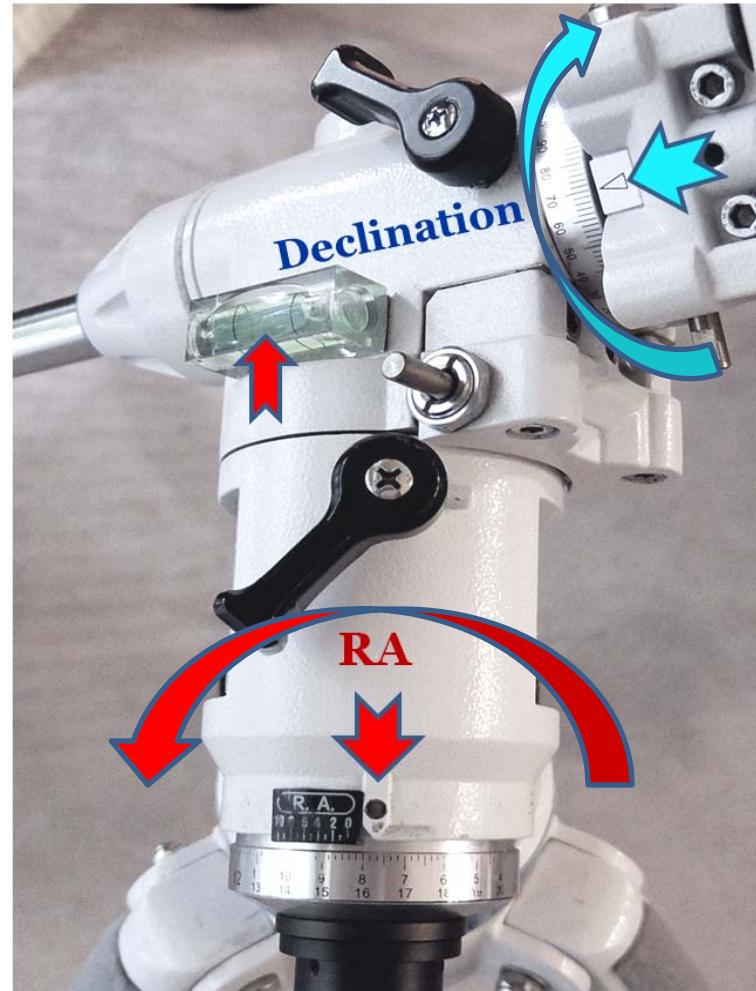


Data Acquisition

Where's the Milky Way ?
Stellarium !



Equatorial Mount



Capture the Data

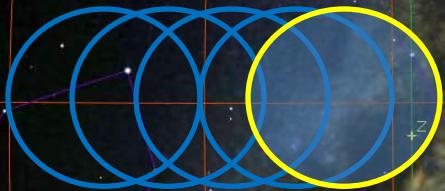
use Drift Scans

Keep the Antenna Fixed

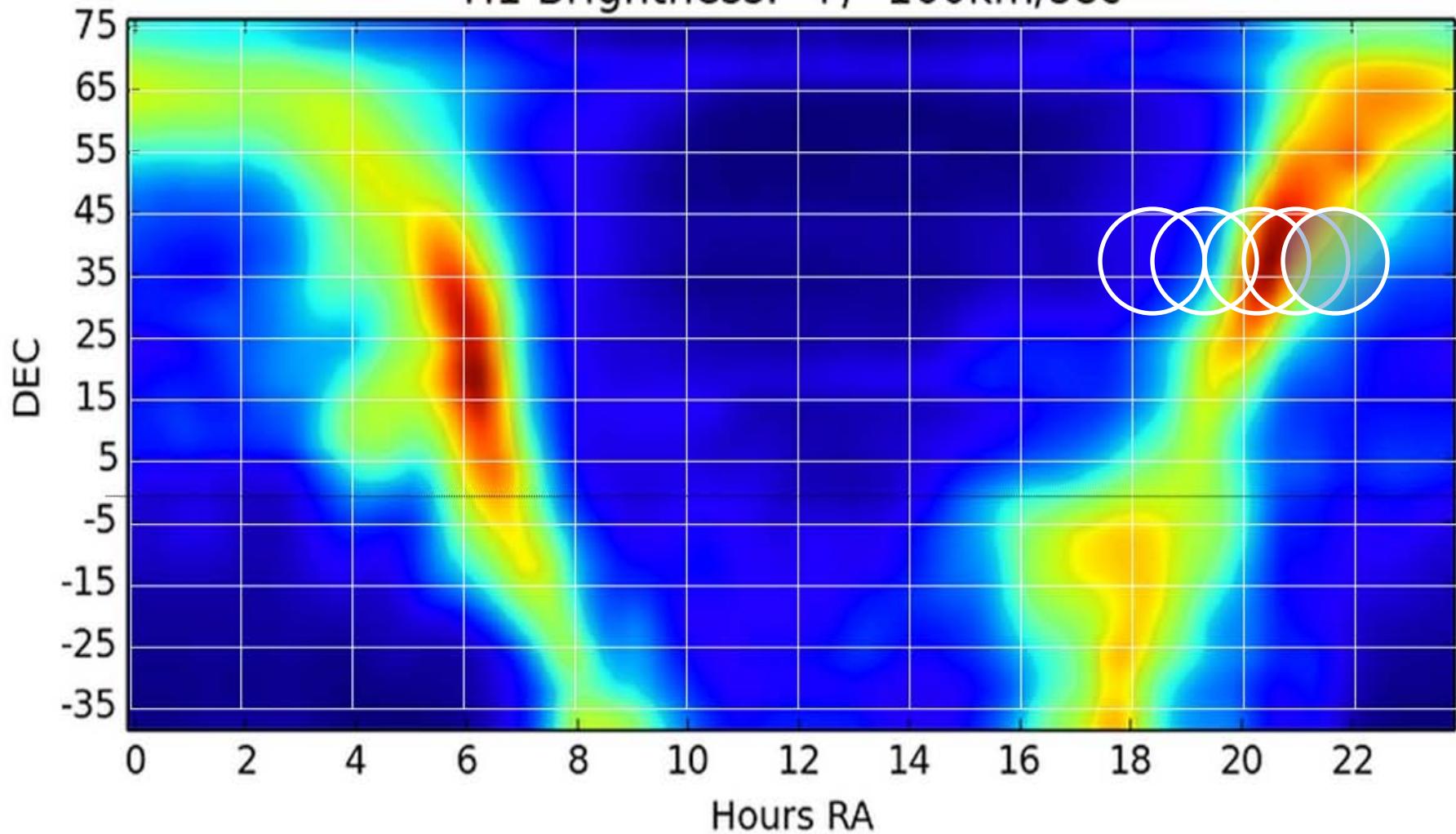
&

Let the Sky Drift By

Keep the Antenna Fixed
&
Let the Sky Drift By

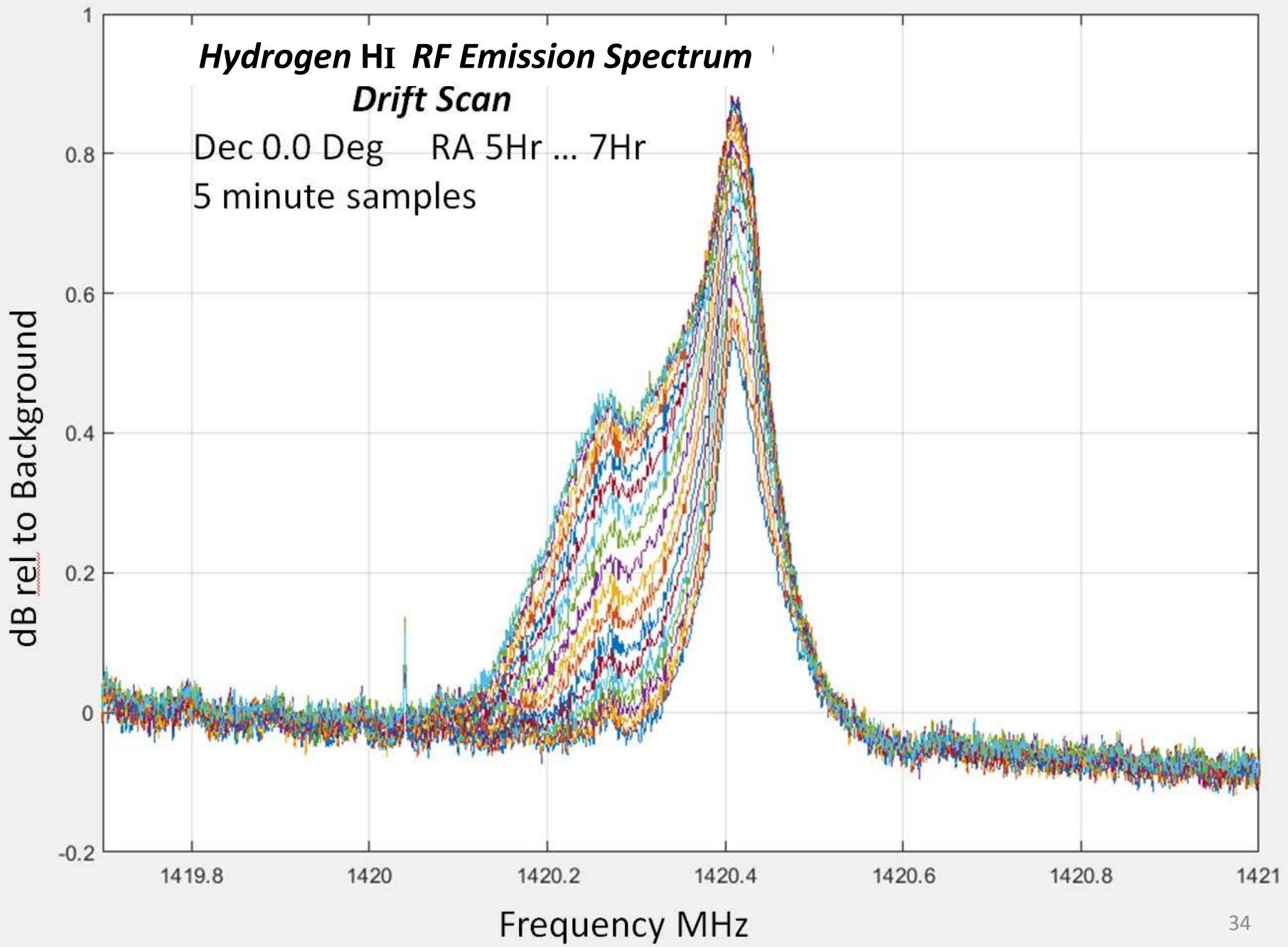


H1 Brightness: +/- 160km/sec



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Canadian Centre for Experimental Radio Astronomy



Hardware Upgrade Level 1

stock GOES 1.7 GHz

vs

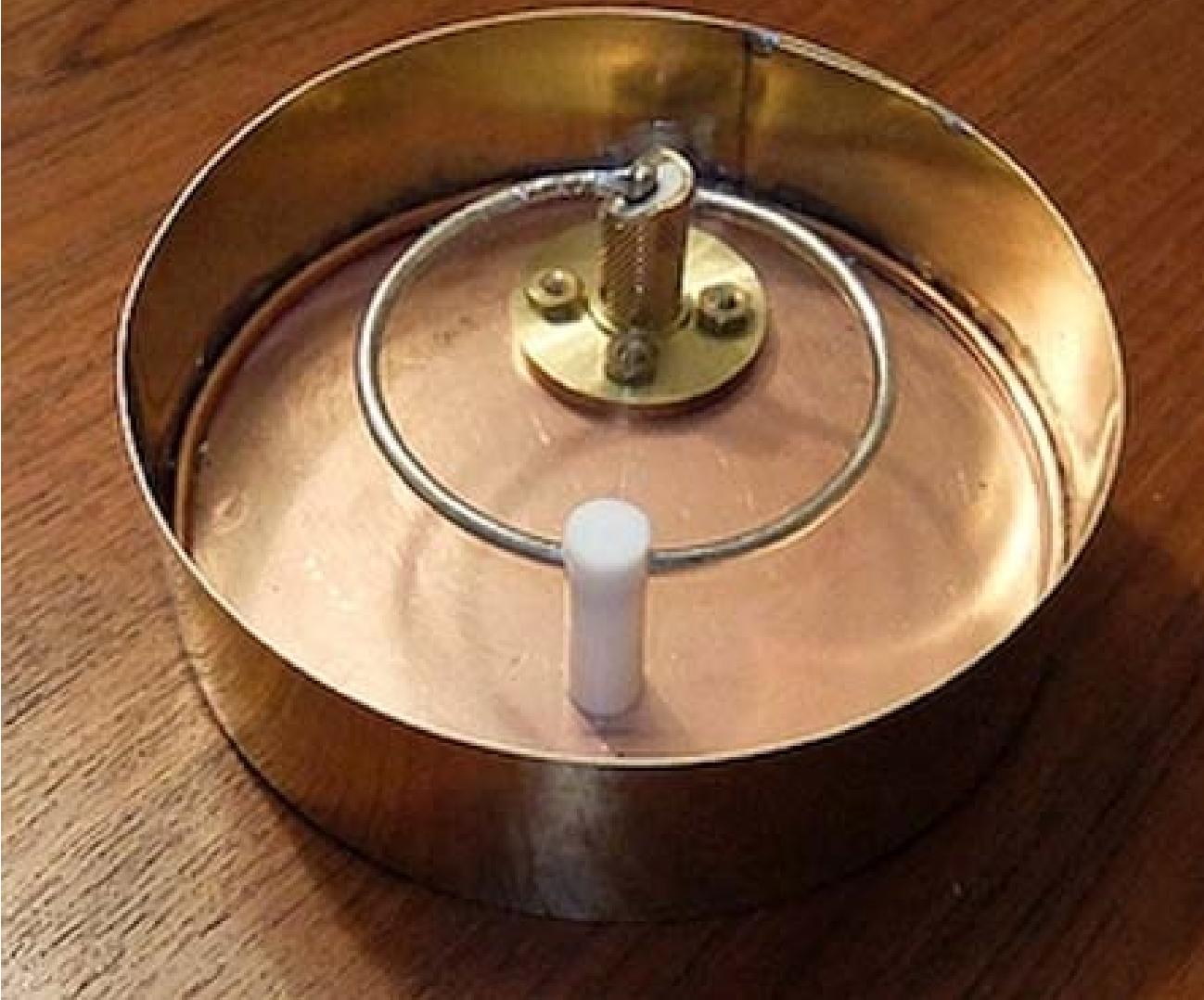
H1 Loop Feed 1.42 GHz



Stock nooelec
Yagi/dipole 1.7GHz Antenna

Tuned OM6AA
1.42 GHz Loop Feed Antenna

**Tuned OM6AA
1.42 GHz Loop Feed Antenna**



Basic System and Upgrade Ideas

nooelec SMarTee SDR



\$ 40

nooelec SAWBird H1



\$ 45

Air Spy mini SDR



\$ 100

GPIO Labs LNA Amps H1_BP filter



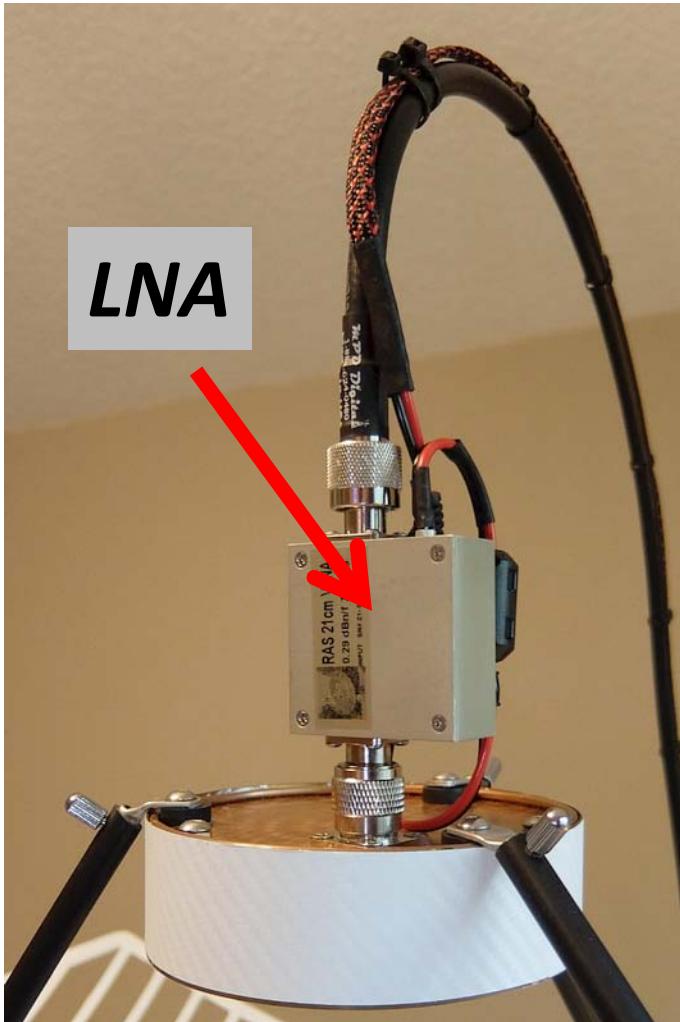
\$60

\$36

\$34

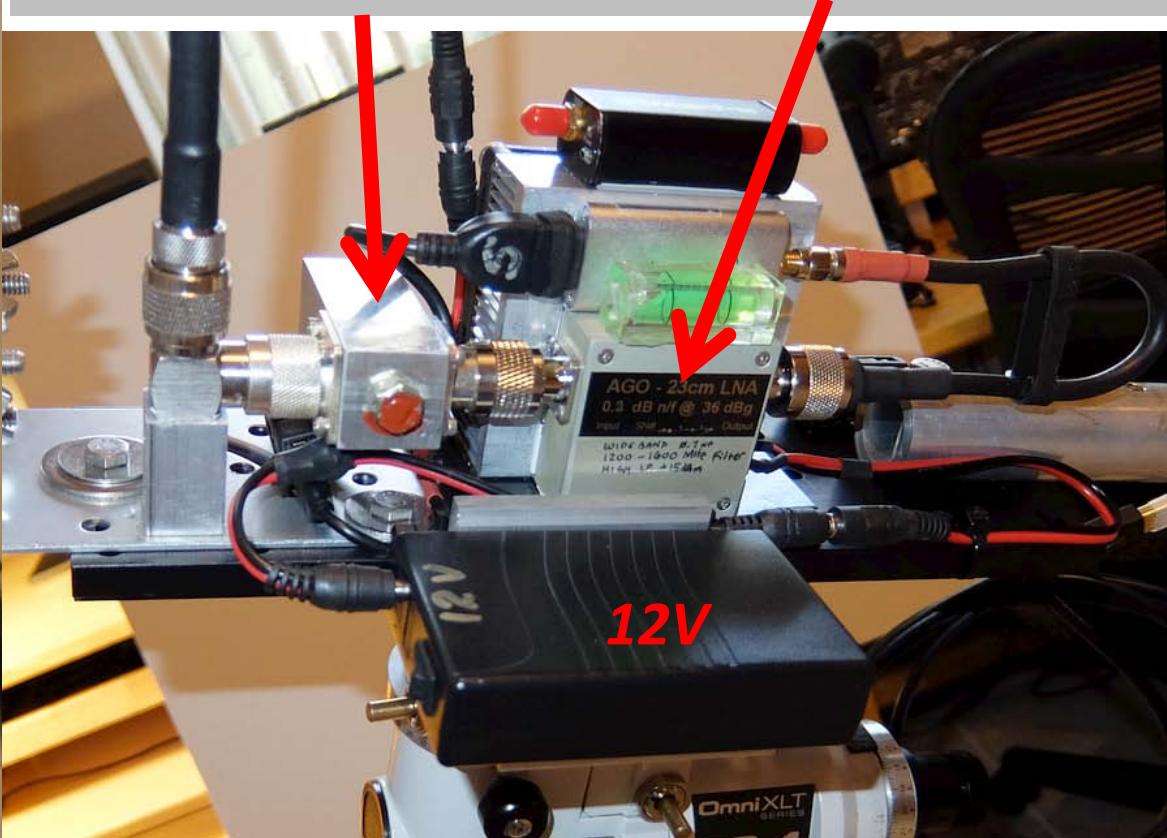
\$30

Basic System and Upgrade Ideas

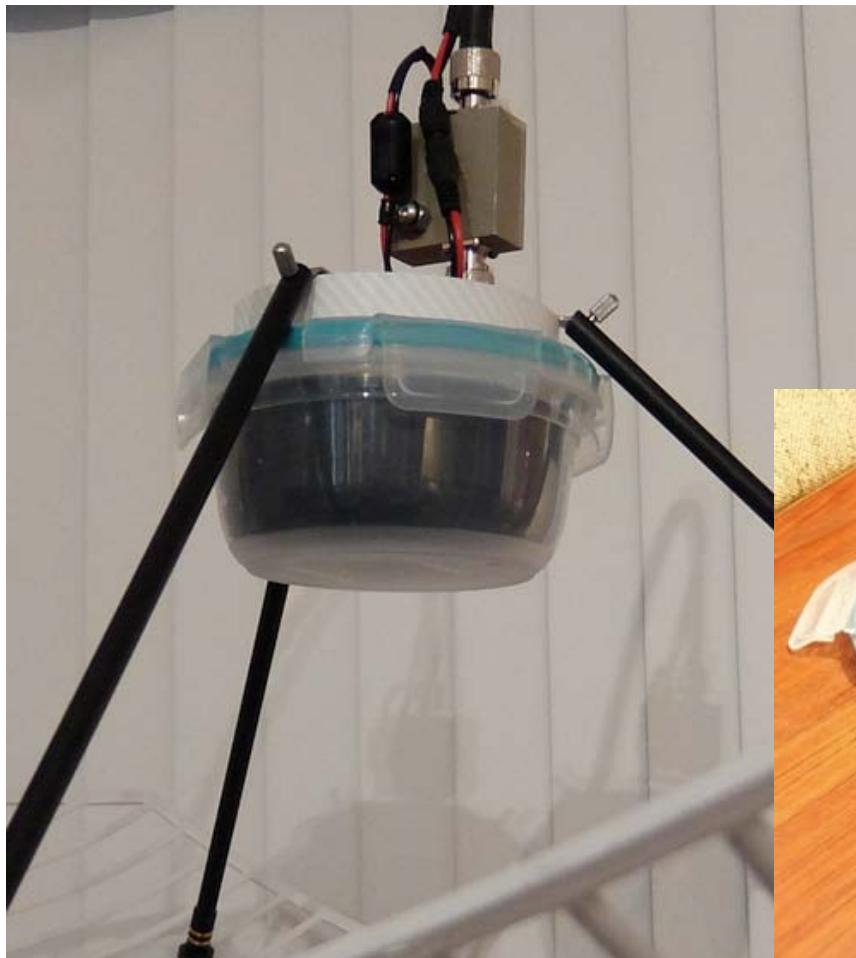


Tommy Henderson WD5AGO \$ 400

1.42GHz Cavity Filter WideBand Amp



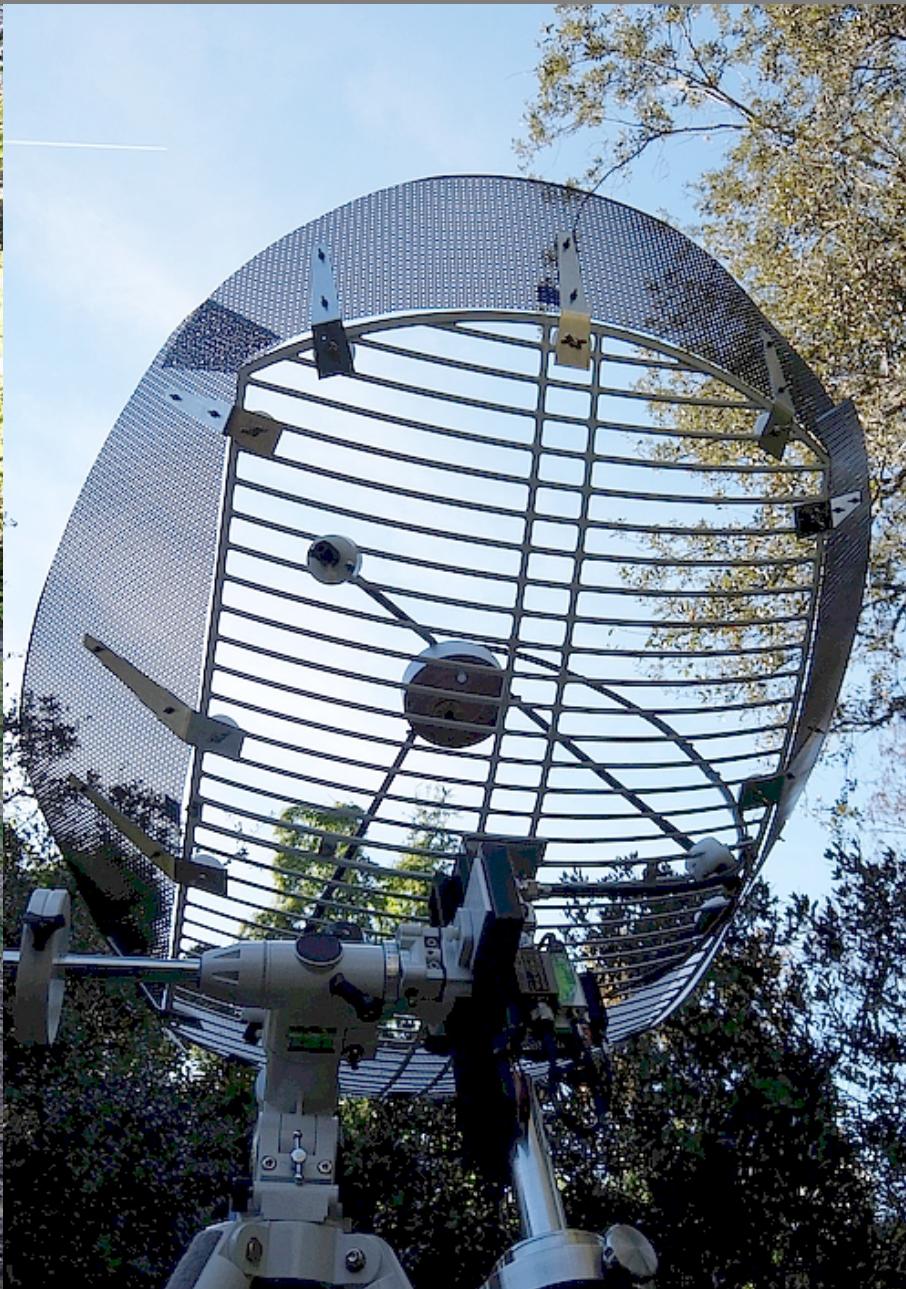
**Calibration Cover
for IF_Average Plug-In Normalization
creates a 290K reference to remove amplifier roll-off / filter ripple**



Anti-Static Conductive Foam

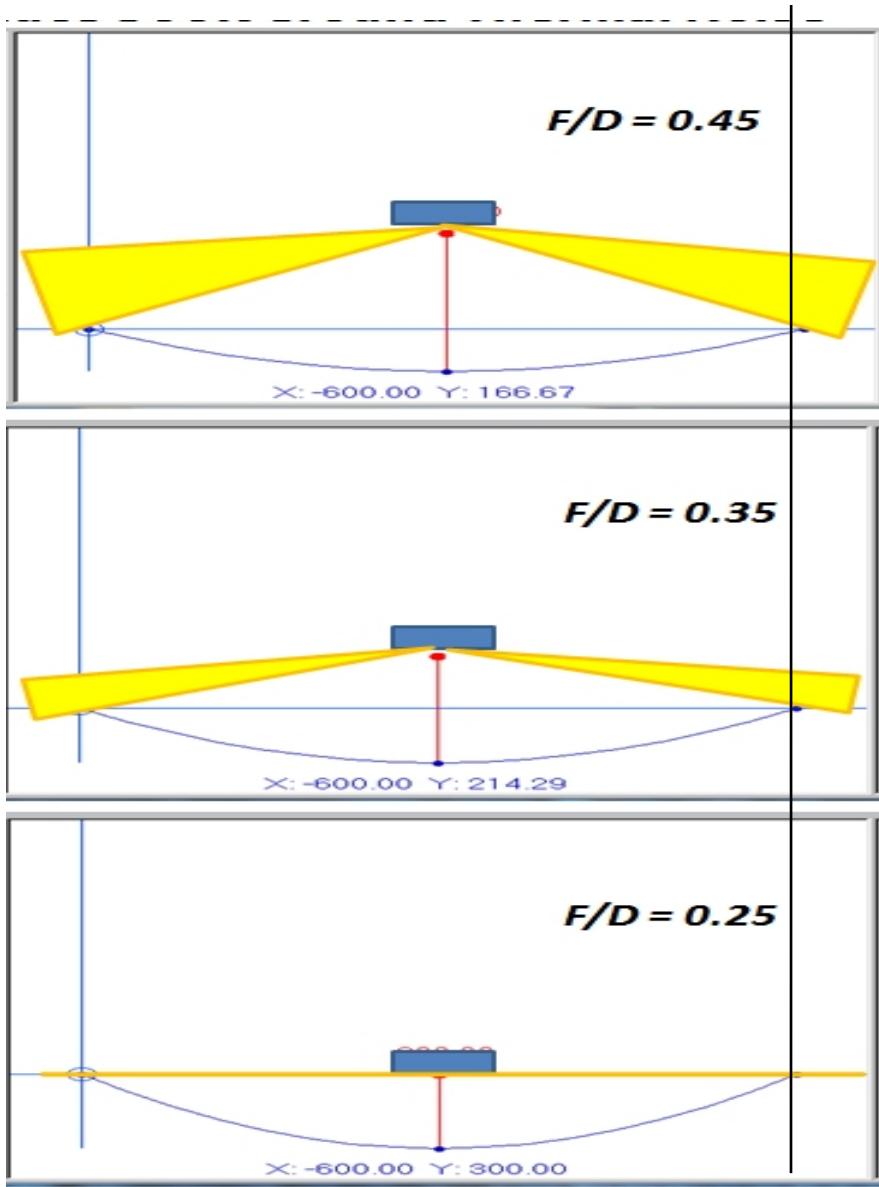
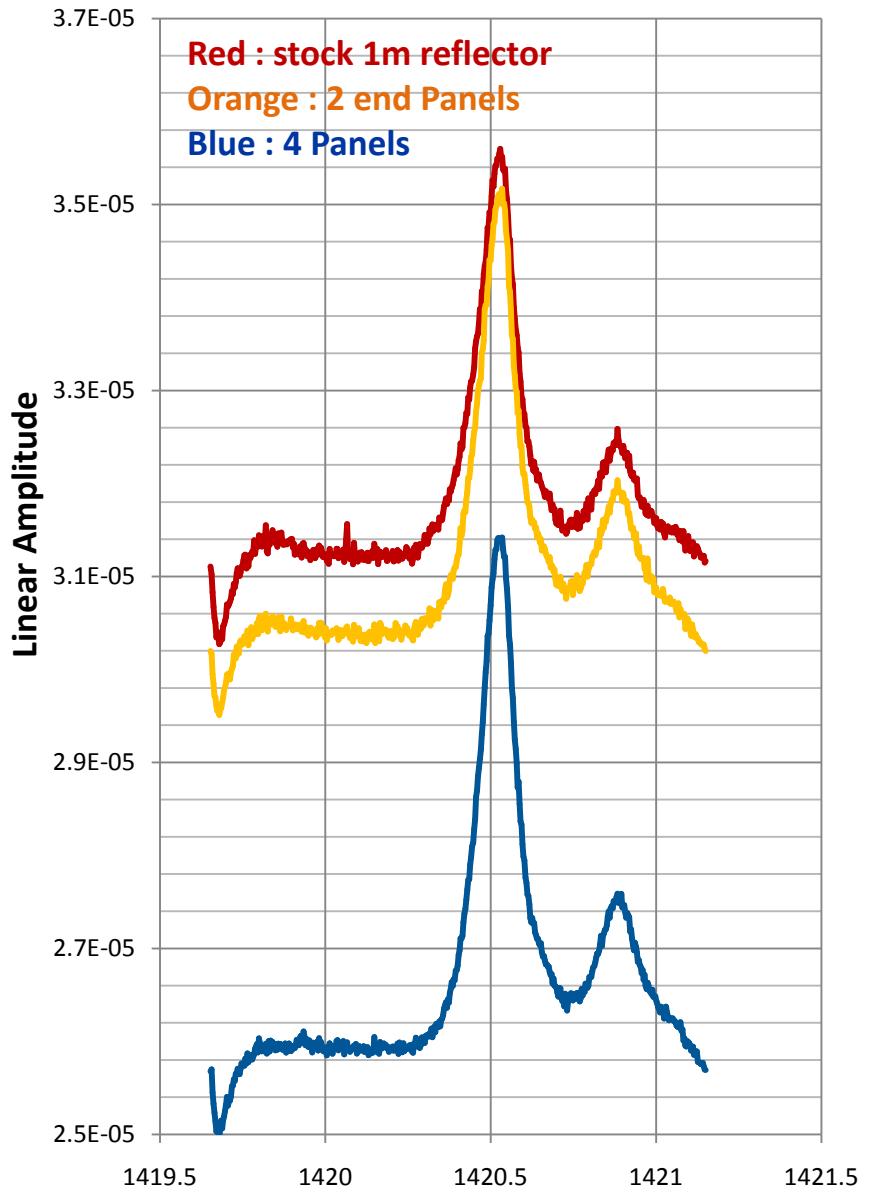


Hardware Upgrade Level 2



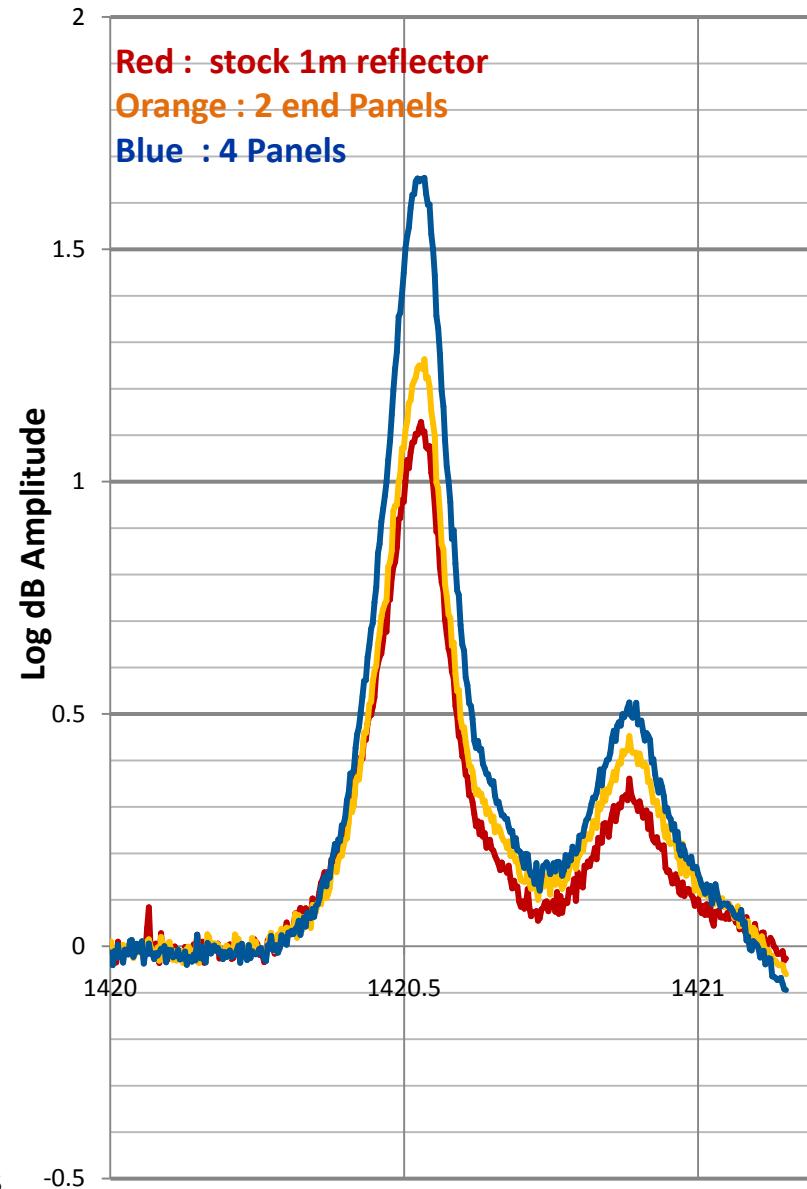
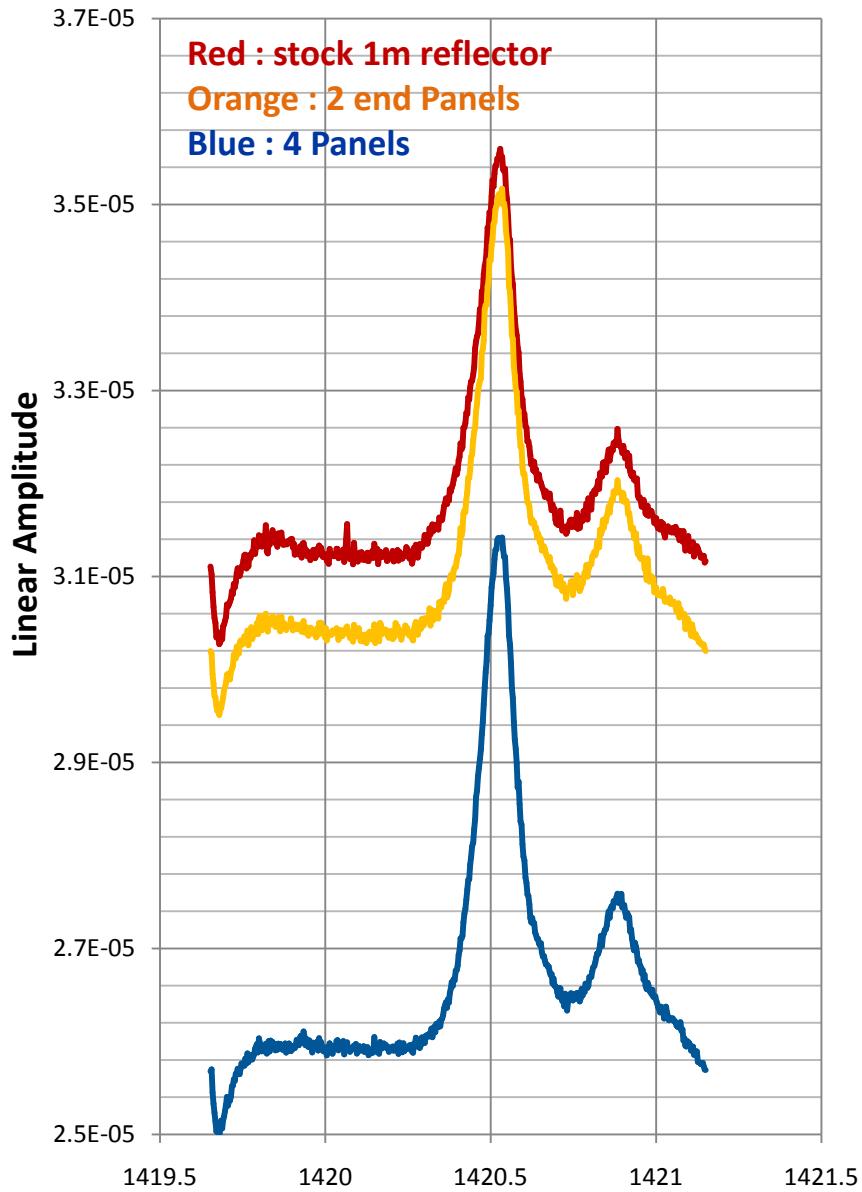
Parabolic Reflector Modifications with OM6AA Loop Feed Antenna

Changing f/D ratio : Deeper Dishes reduce 290K ground noise pickup



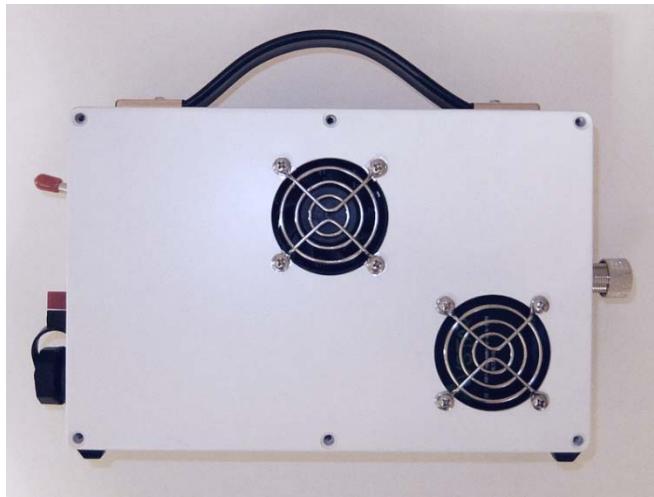
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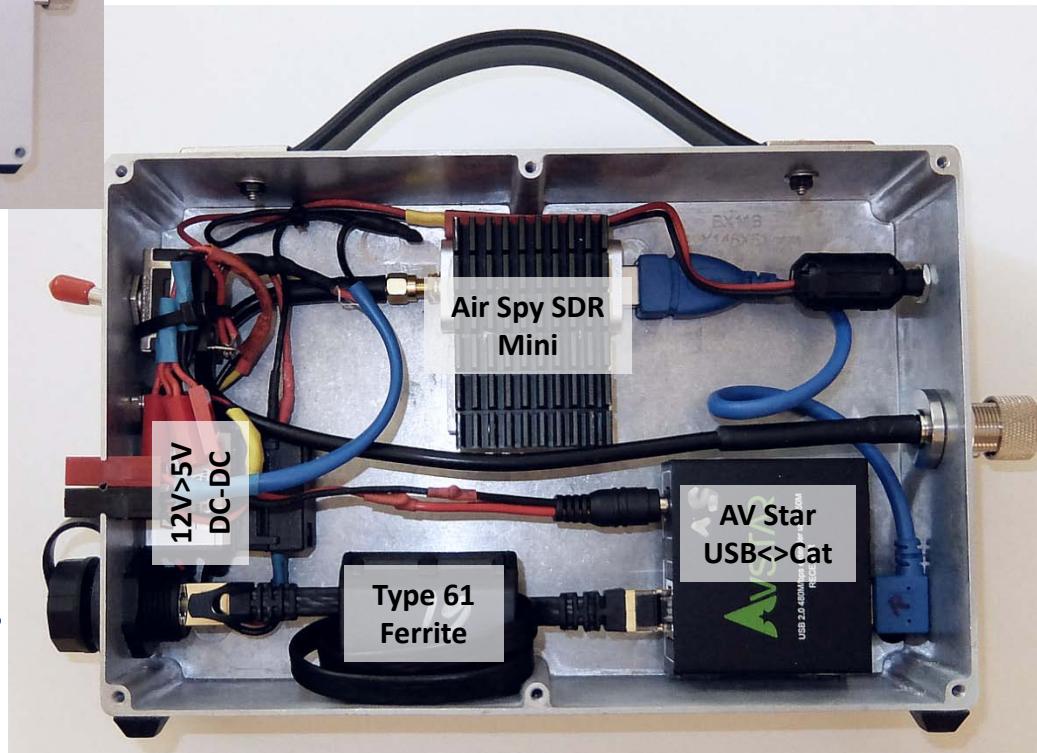


RF Lunch_Box

RFI shielded SDR and USB_extender



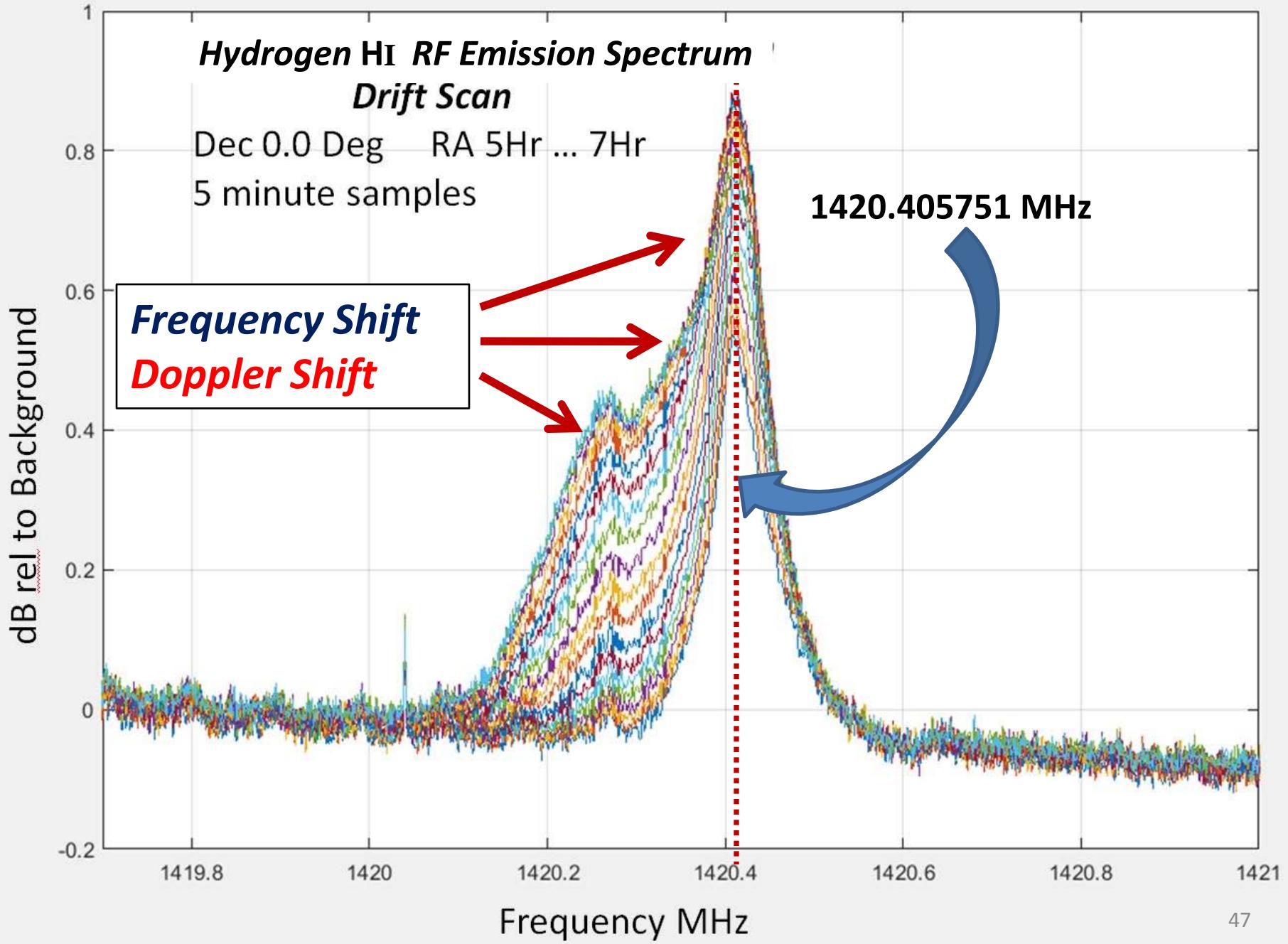
*Cat 7
Cable*



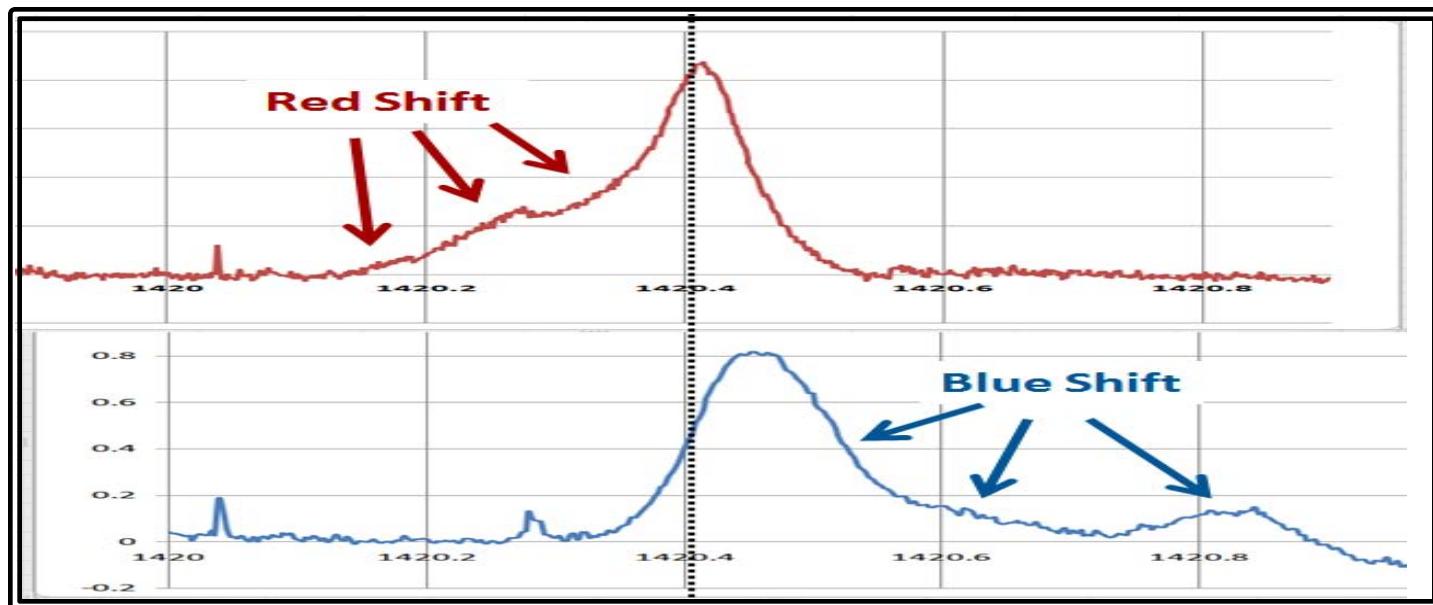
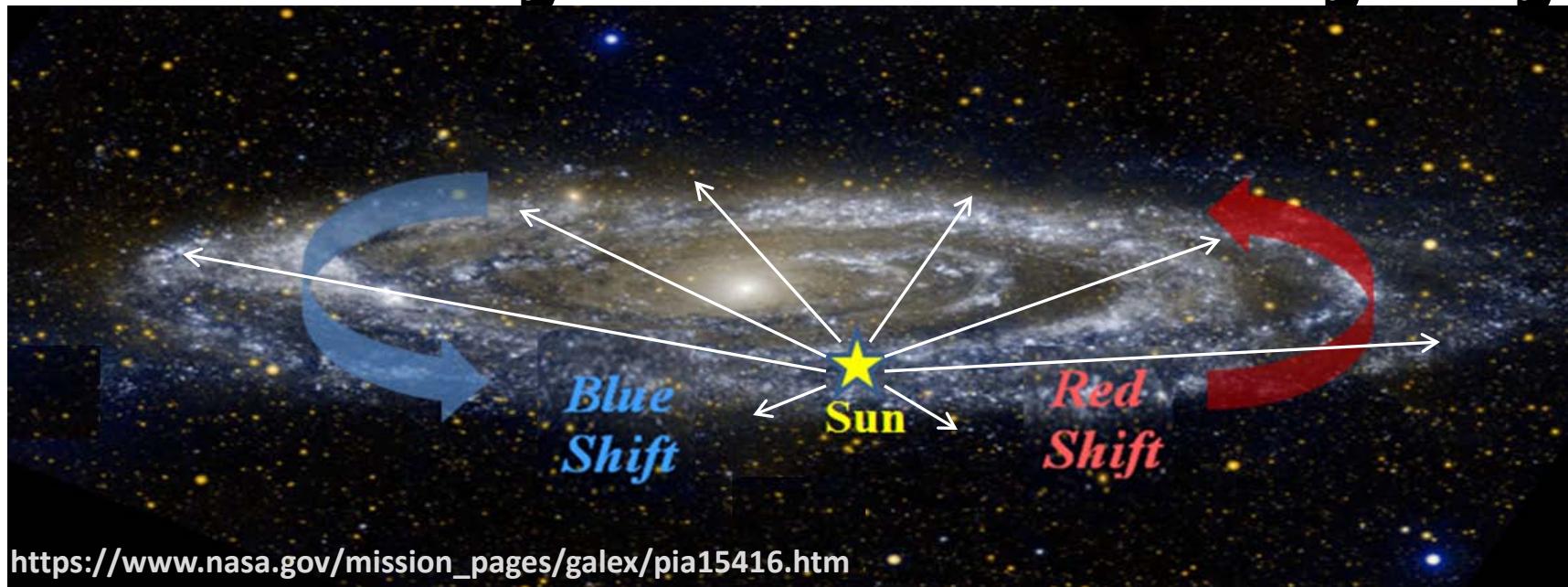
*LMR
400
Coax*

Data Analysis

Red Shift



Galactic Dynamics of the Milky Way



Doppler "Red Shift" Velocity Calculations

The frequency shift can be converted to an actual velocity.

"Red Shift" Equation :

$H1 = 1420.405751 \text{ MHz}$ (non moving 'rest' Spin-Flip frequency)

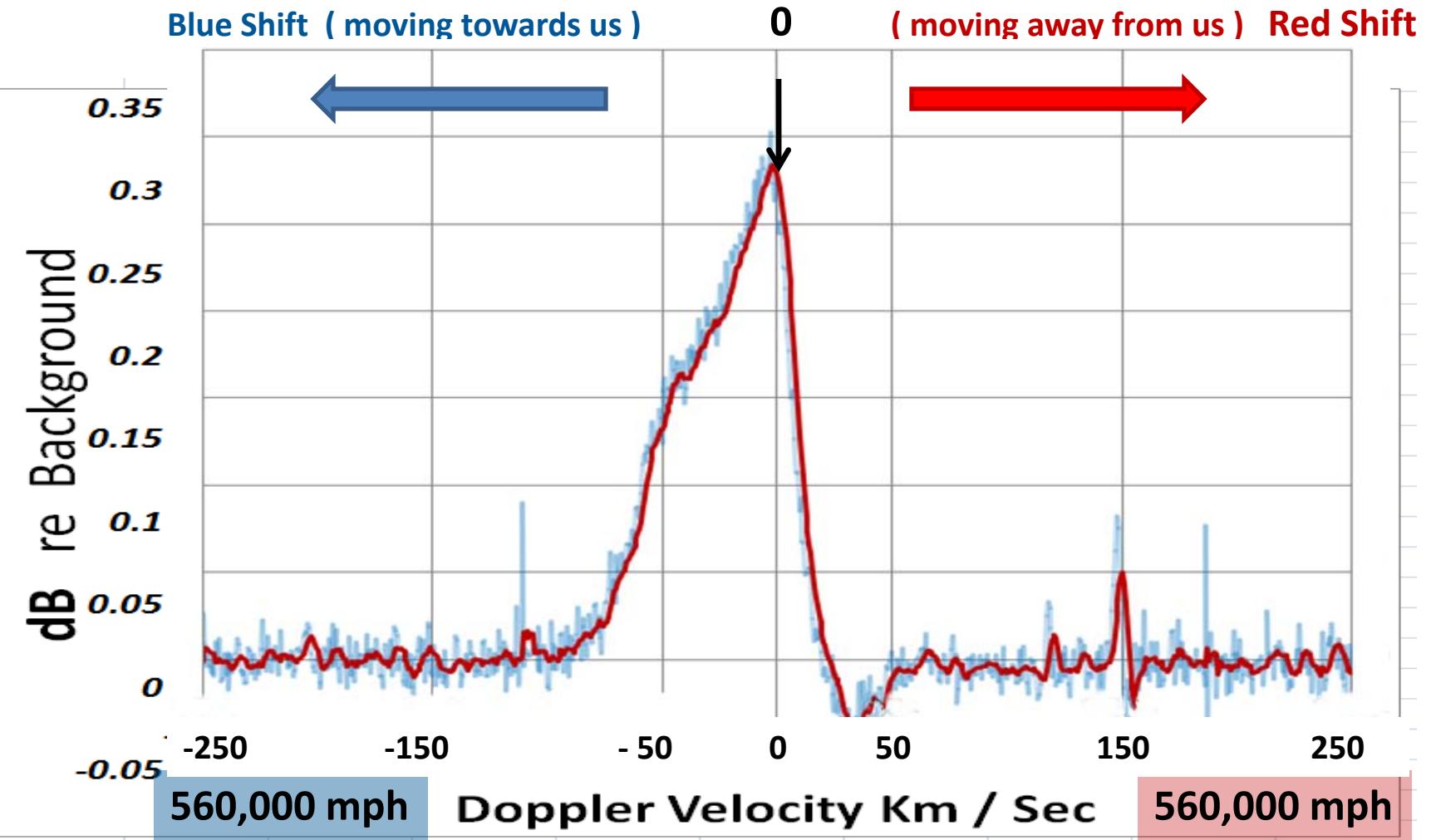
$C = \text{Velocity of Light } 299792 \text{ Km/Sec}$

$F_{measured} = \text{Data values from Spreadsheet}$

$$V = \frac{(H1 - F_{measured})}{F_{measured}} * C$$

	A	B	C	D
1	Frequency MHz	Amplitude	Freq Shift Fraction	Doppler Shift Velocity Km/Sec
2	$F_{emit} = 1420.405751$	signal level	(relative to non moving)	Speed of Light = 299792 Km/S
3	Freq Measured		$(H1 - F_{meas}) / F_{meas}$	$(Freq_Shift_Fract) * Speed of Light$
4	1419.21	0.000070192	0.000842547	252.5888232
5	1419.212344	0.000070083	0.000840894	252.0933163
6	1419.214688	0.000070184	0.000839241	251.5978111
7	1419.217031	0.000070148	0.000837588	251.1023074

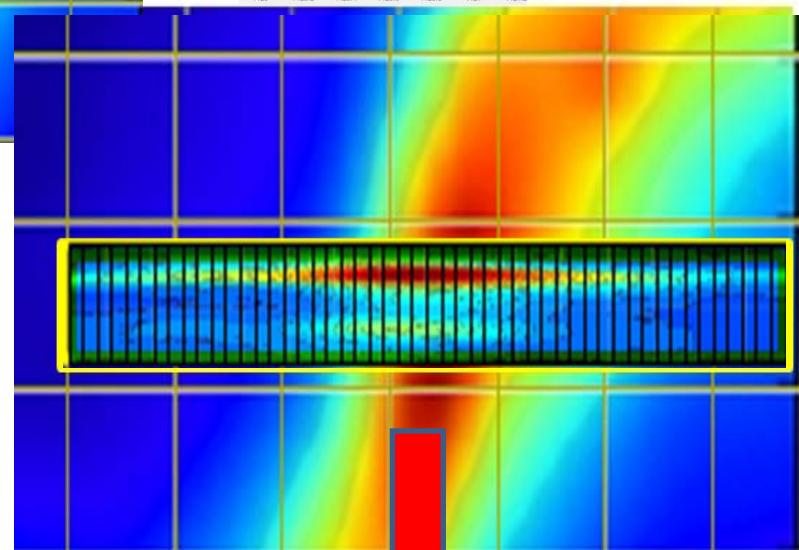
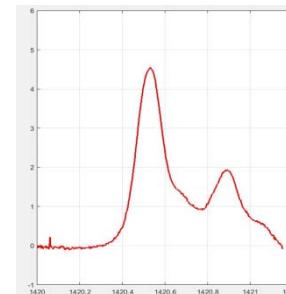
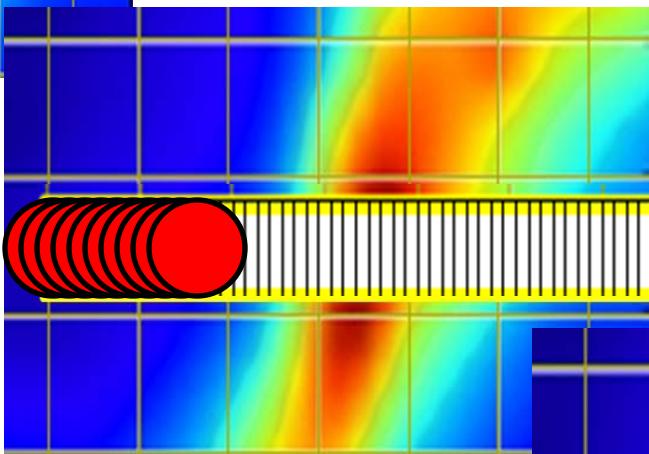
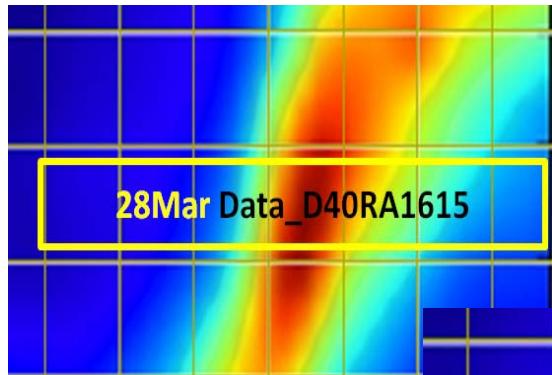
Hydrogen HI 21cm RF Emission Band
Milky Way Galaxy Doppler Shift Analysis
Velocity Relative to Winter Springs Fla
Coordinates of Measurement RA 6hr30min Dec 0.0 Dg



Data Analysis

Advanced

Milky Way HI 1.42 GHz Drift Scan Data



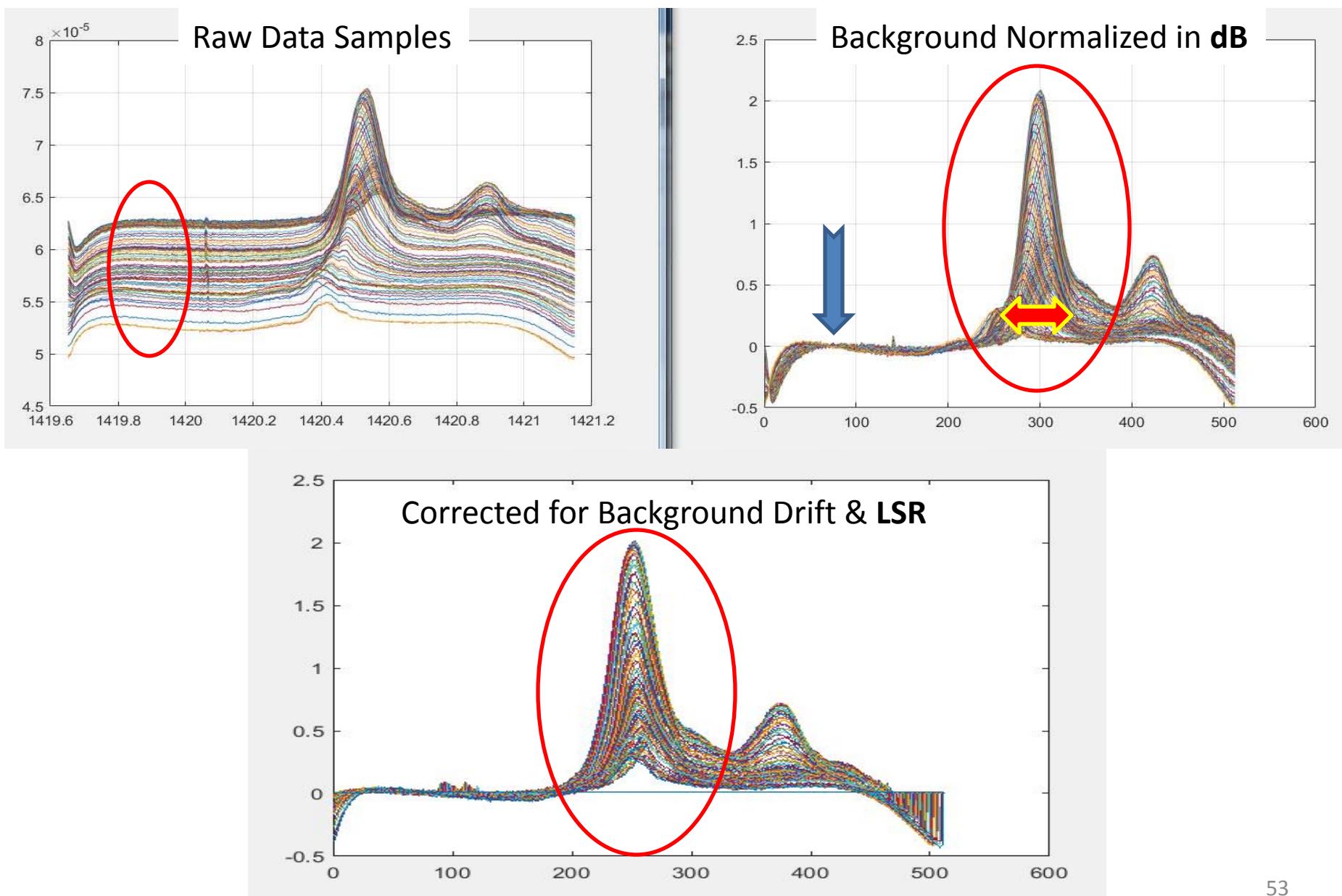
Using Mathworks Matlab Software



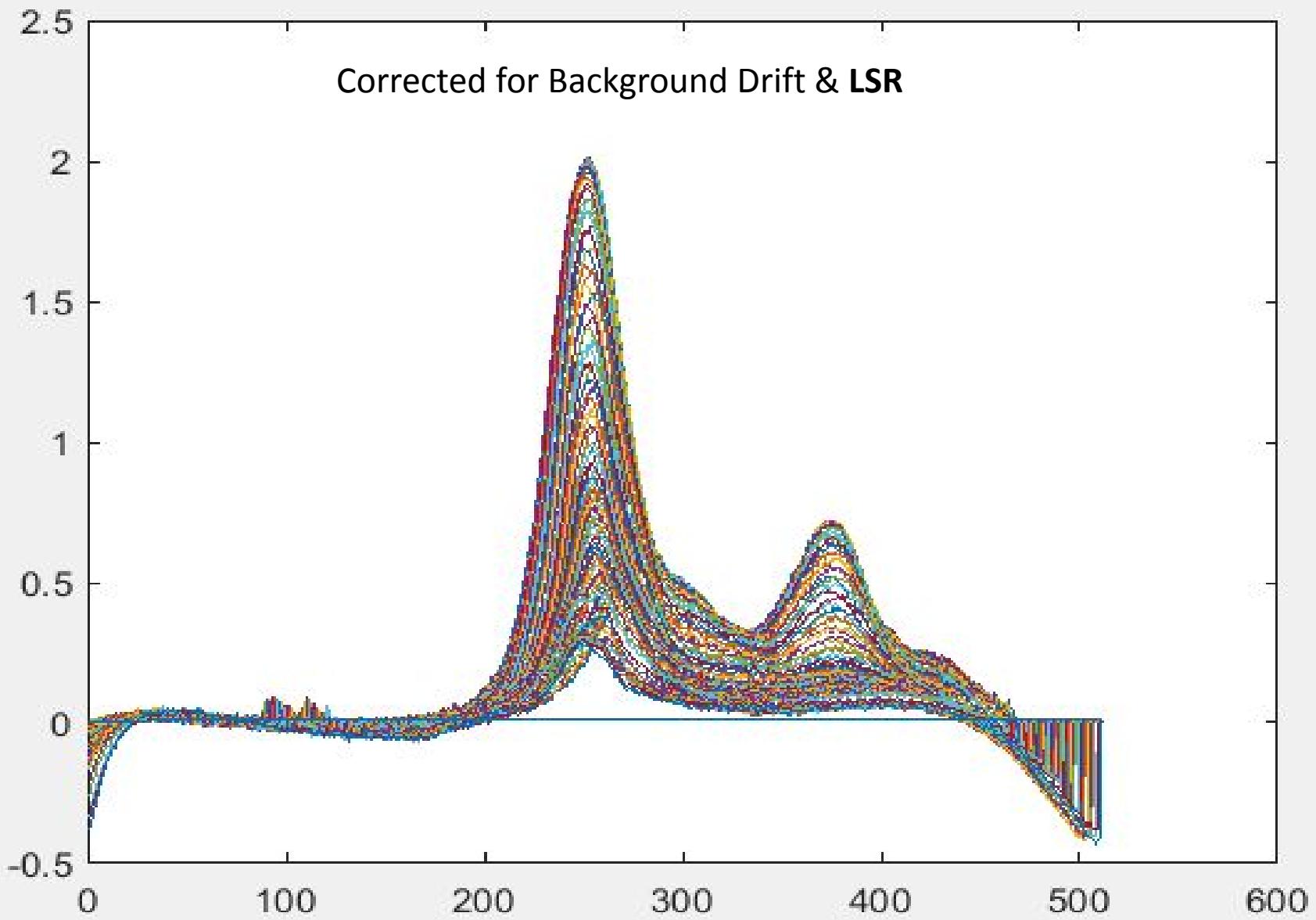
With Permission Marcus Leech : CCERA

Canadian Centre for Experimental Radio Astronomy

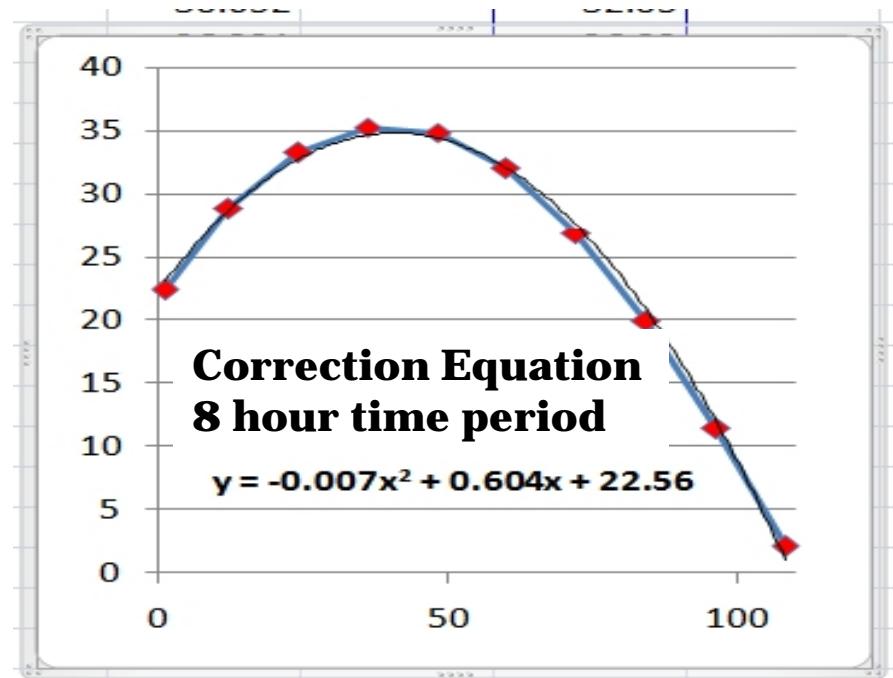
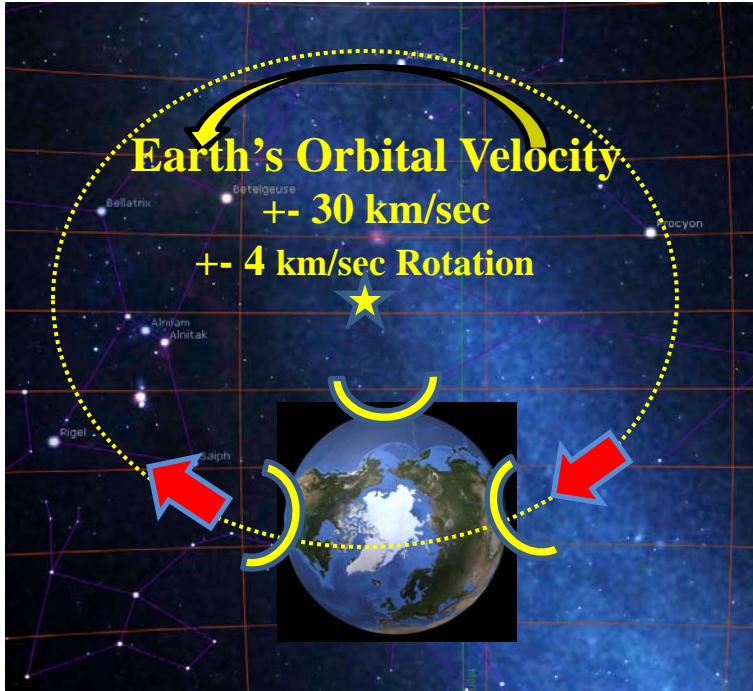
Spectrum Correction Process



Spectrum Correction Process

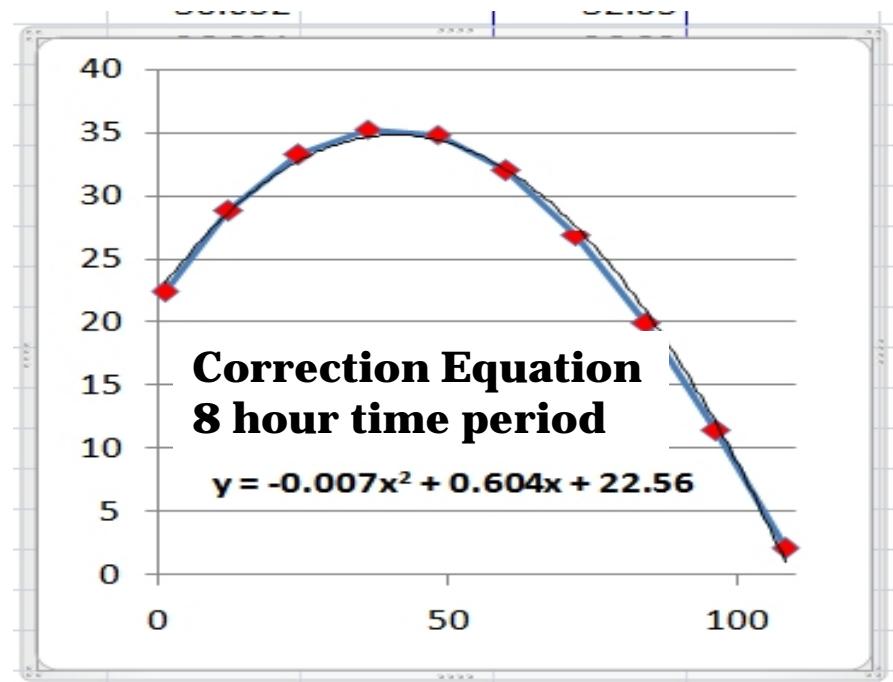
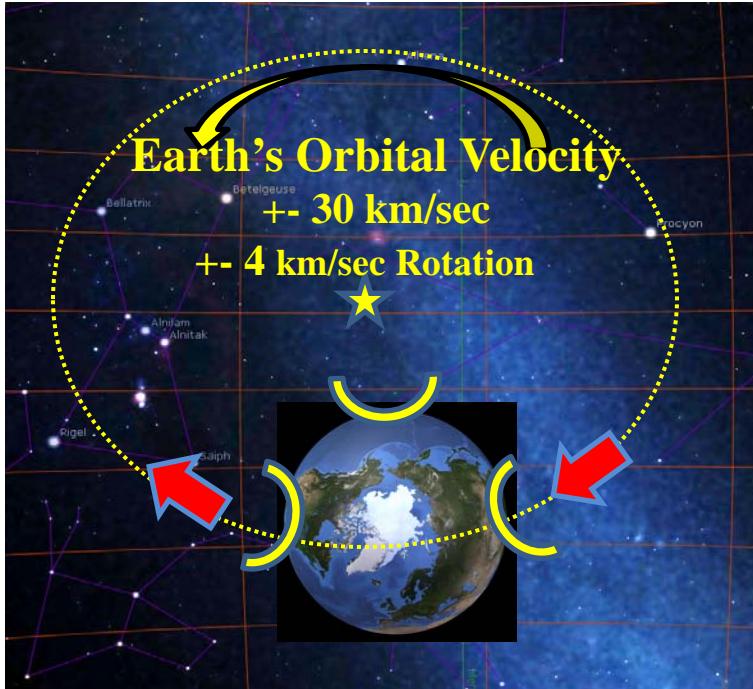


V - Local Standard of Rest – K Correction



The **Local Standard of Rest** or **LSR** follows the mean motion of material in the Milky Way in the neighborhood of the Sun .
(stars in radius 300 light_years from the Sun)

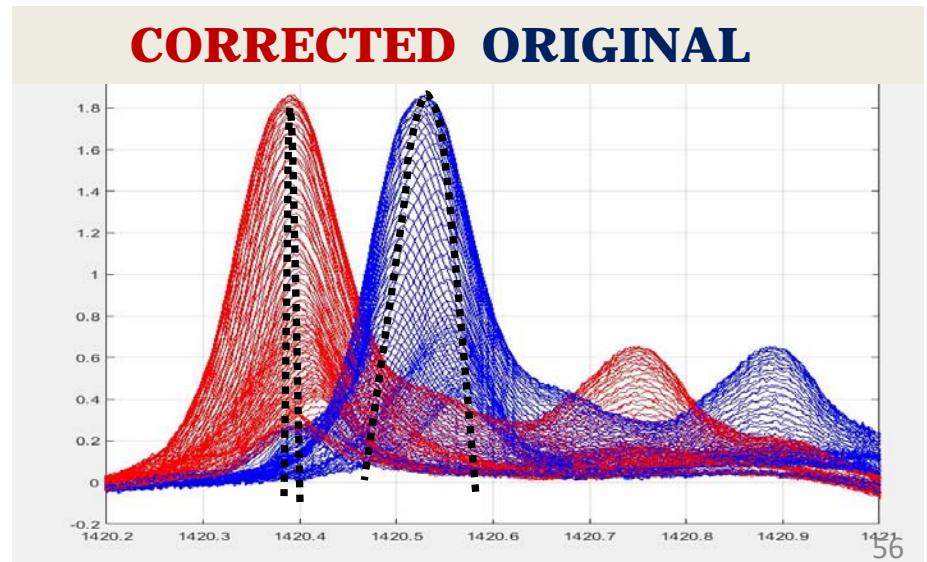
V - Local Standard of Rest – K Correction

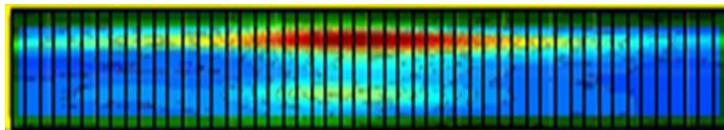


Radial Velocity Calculator

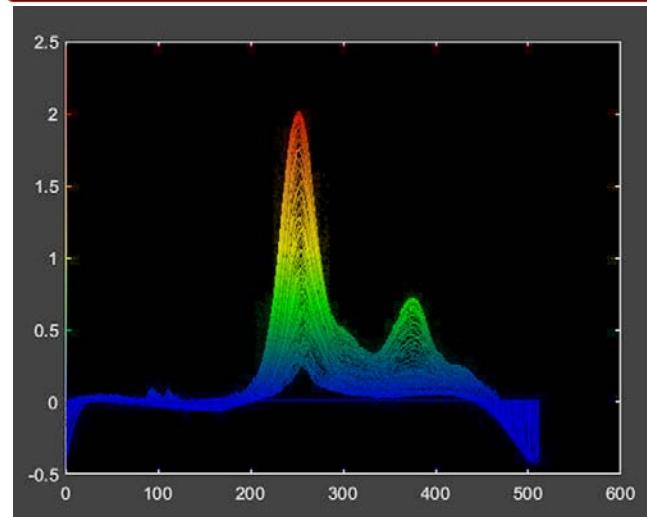
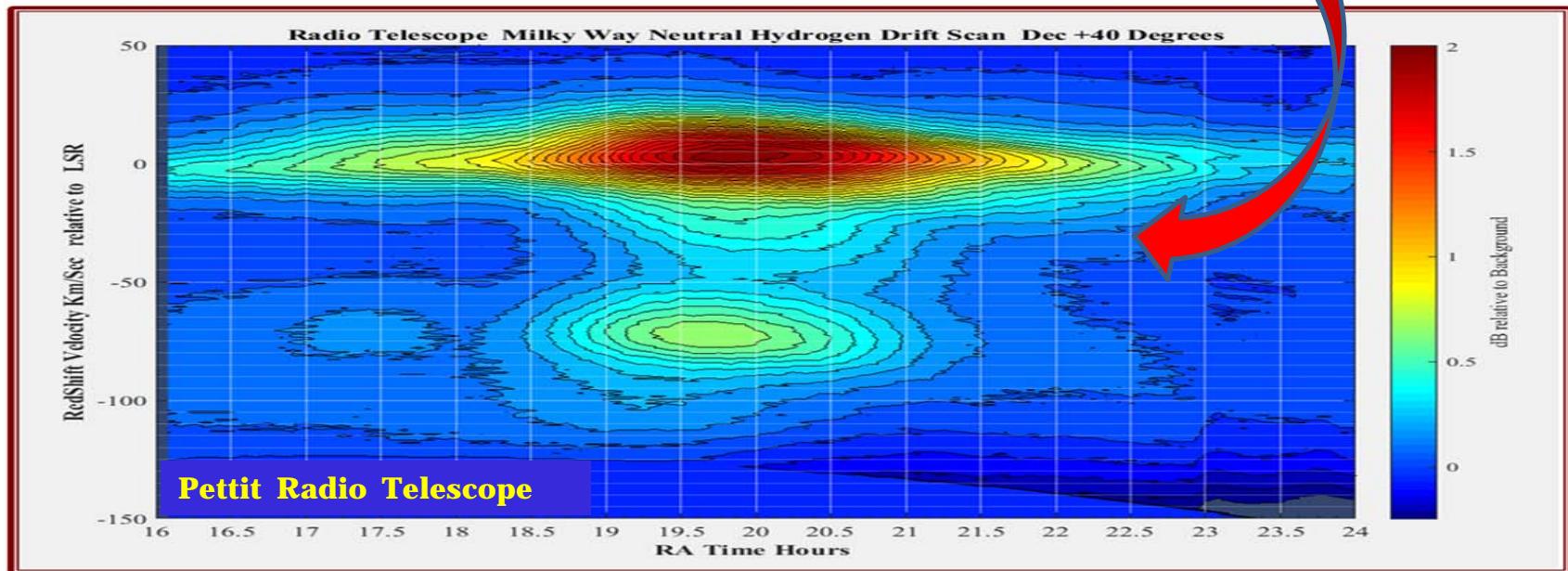
UTC (DD/MM/YYYY hh:mm:ss):	03/07/2022 17:36:t	UTC Now
RA (hh.hhhh):	0.00000	
DEC (+dd.ddddd):	0.00000	
Latitude (+dd.ddddd):	48.893995	North = +
Longitude (+dd.ddddd):	2.3878560	East = +
<input type="button" value="Calculate Radial Velocity"/>		
Radial Velocity (km/s):	<input type="text"/>	
Local Sidereal Time (day):	<input type="text"/>	

<http://f4klo.ampr.org/vlsrKLO.php>

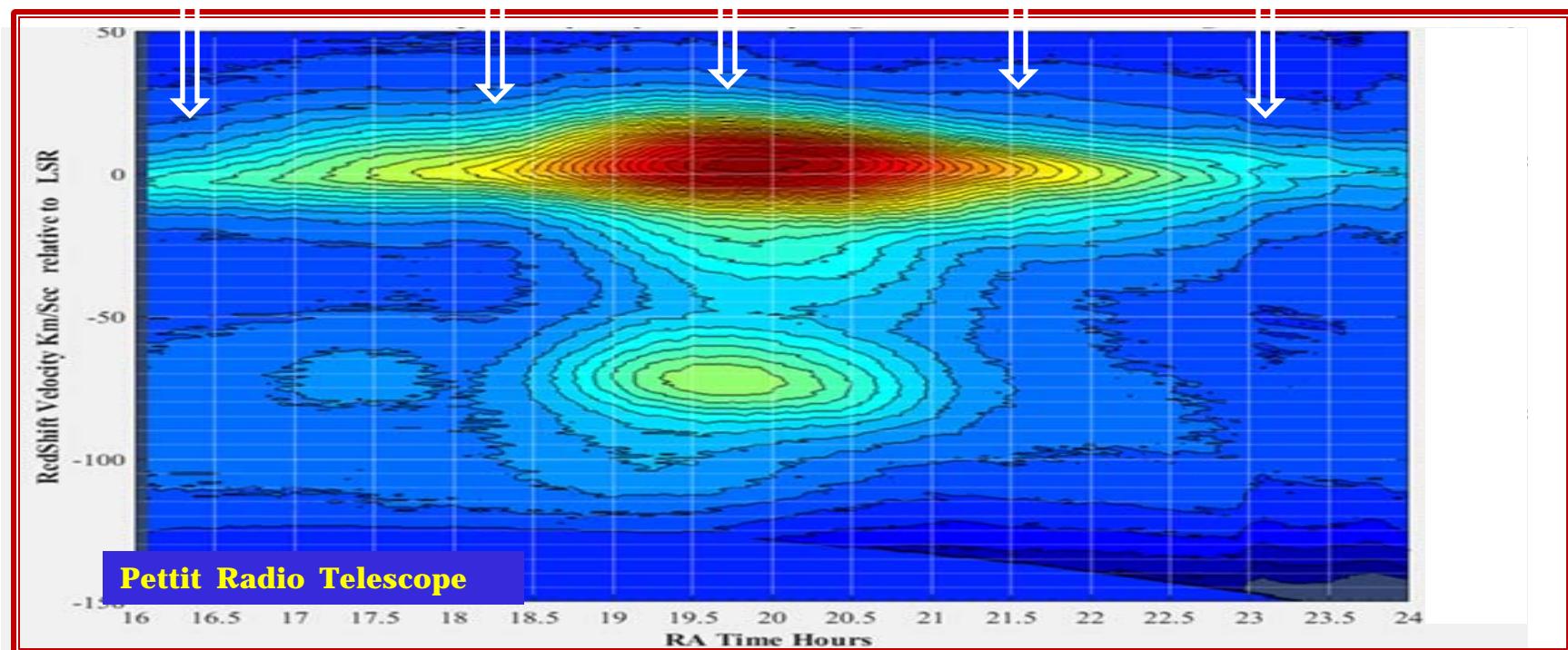
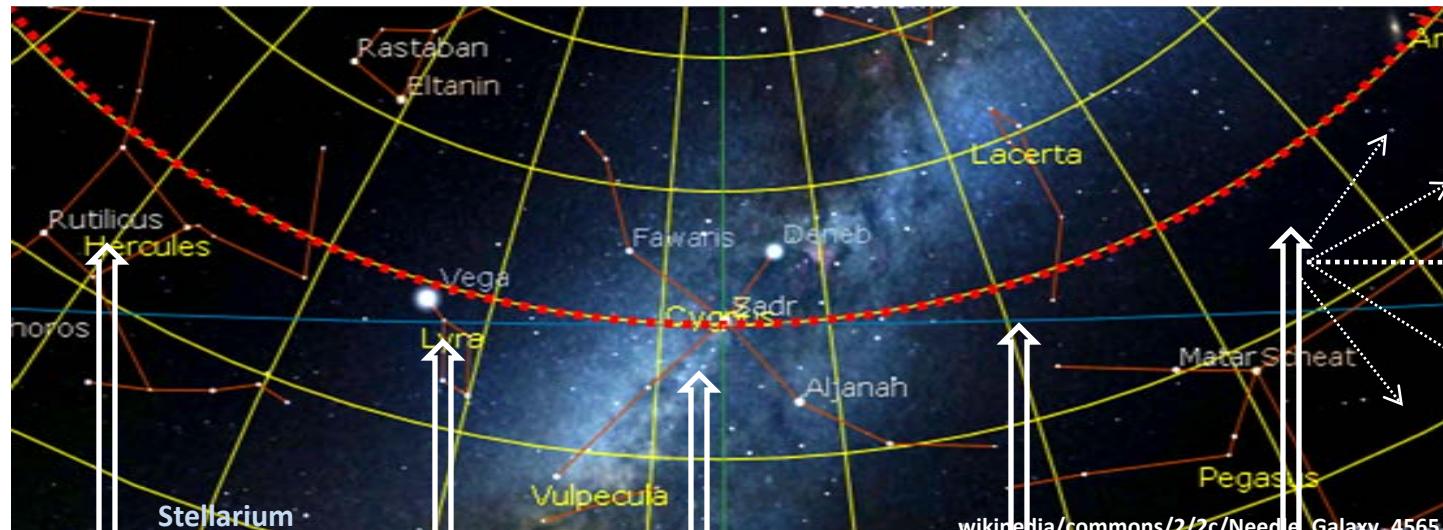




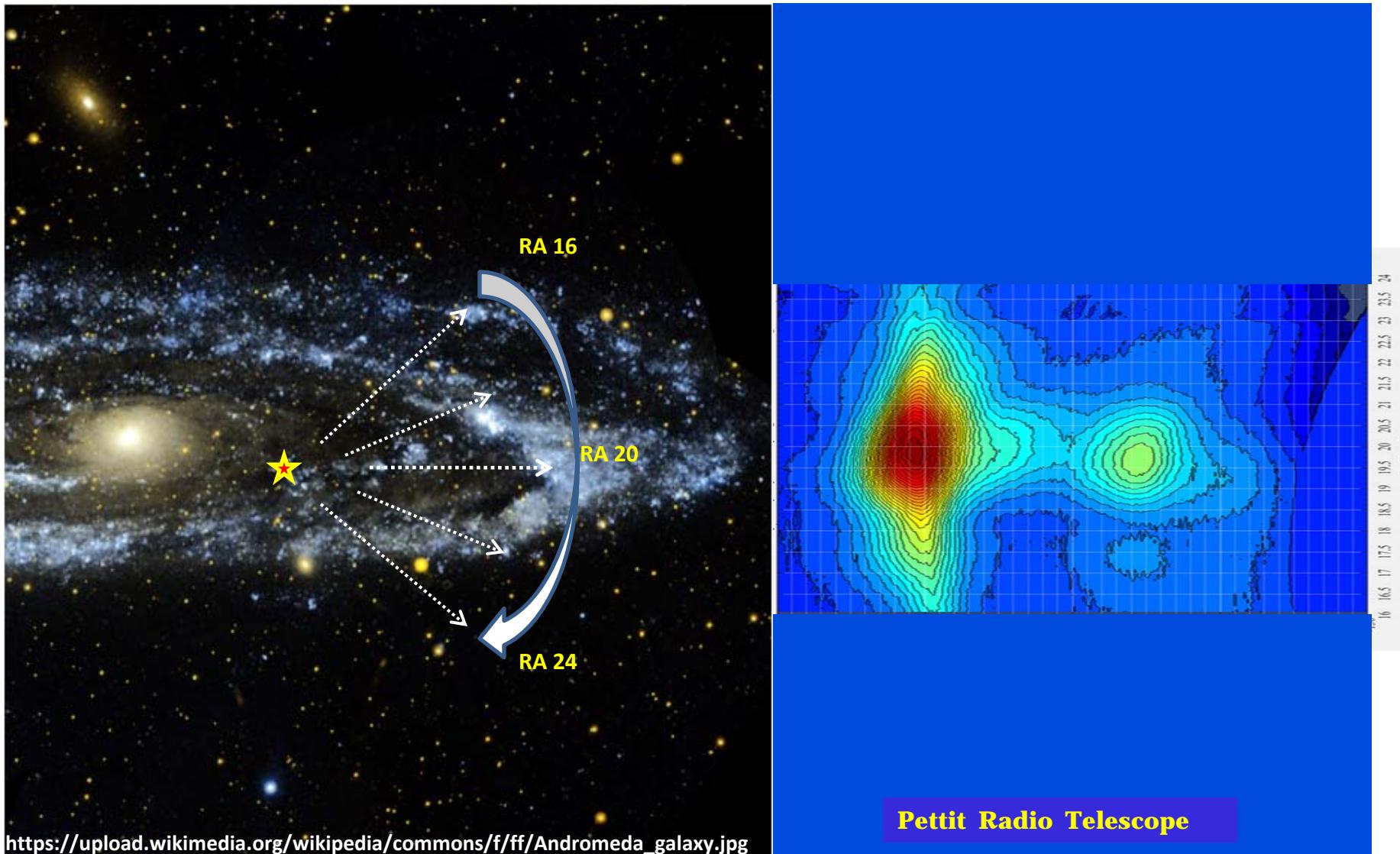
Results : A Spectral Velocity Analysis Graph of the 8 hour 100 sample data set using Matlab



Velocity Spectrum of Neutral Hydrogen Declination +40 deg RA 16 <> 24 hrs

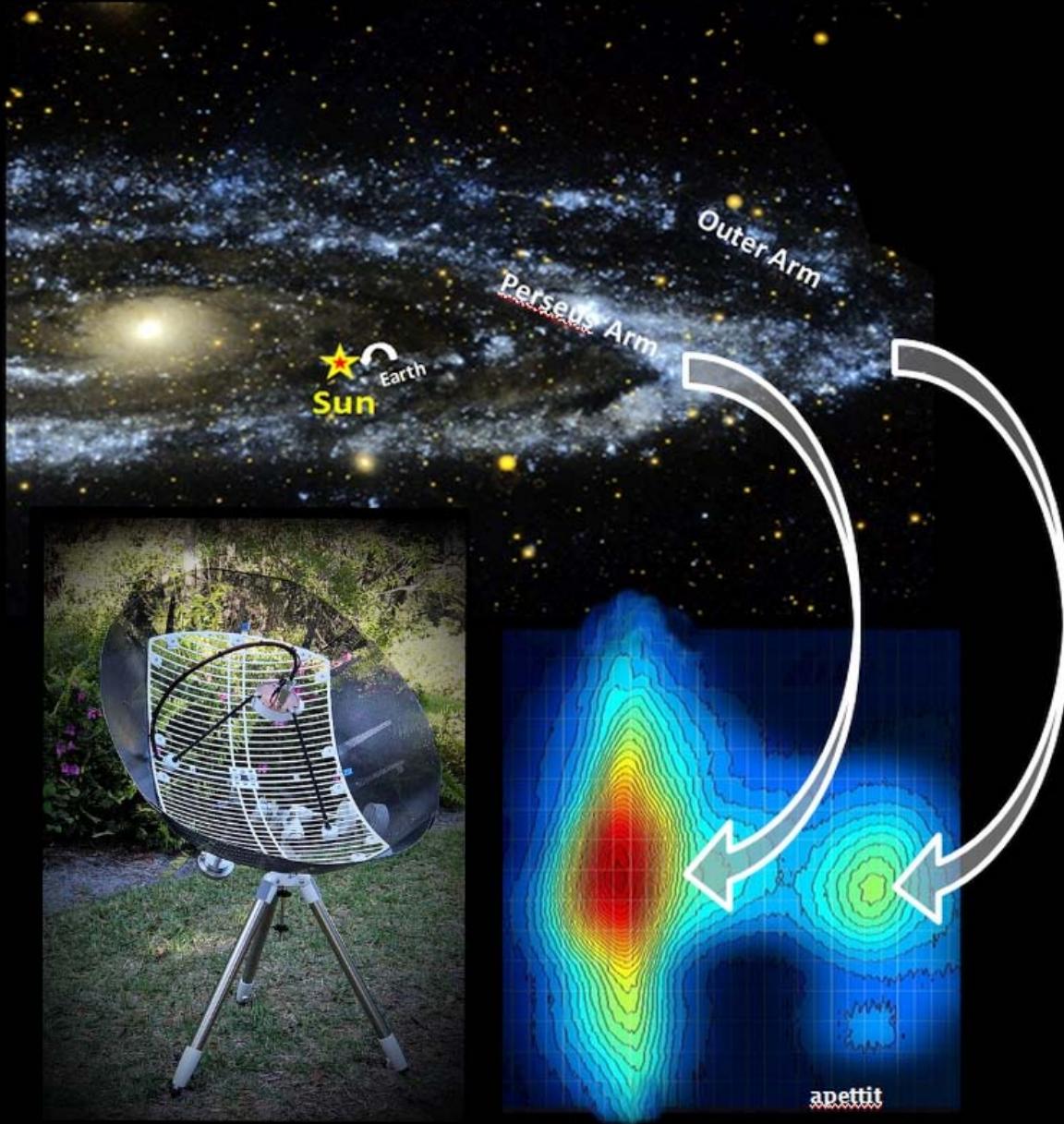


Velocity Spectrum of Neutral Hydrogen Declination +40 deg RA 16 <> 24 hrs

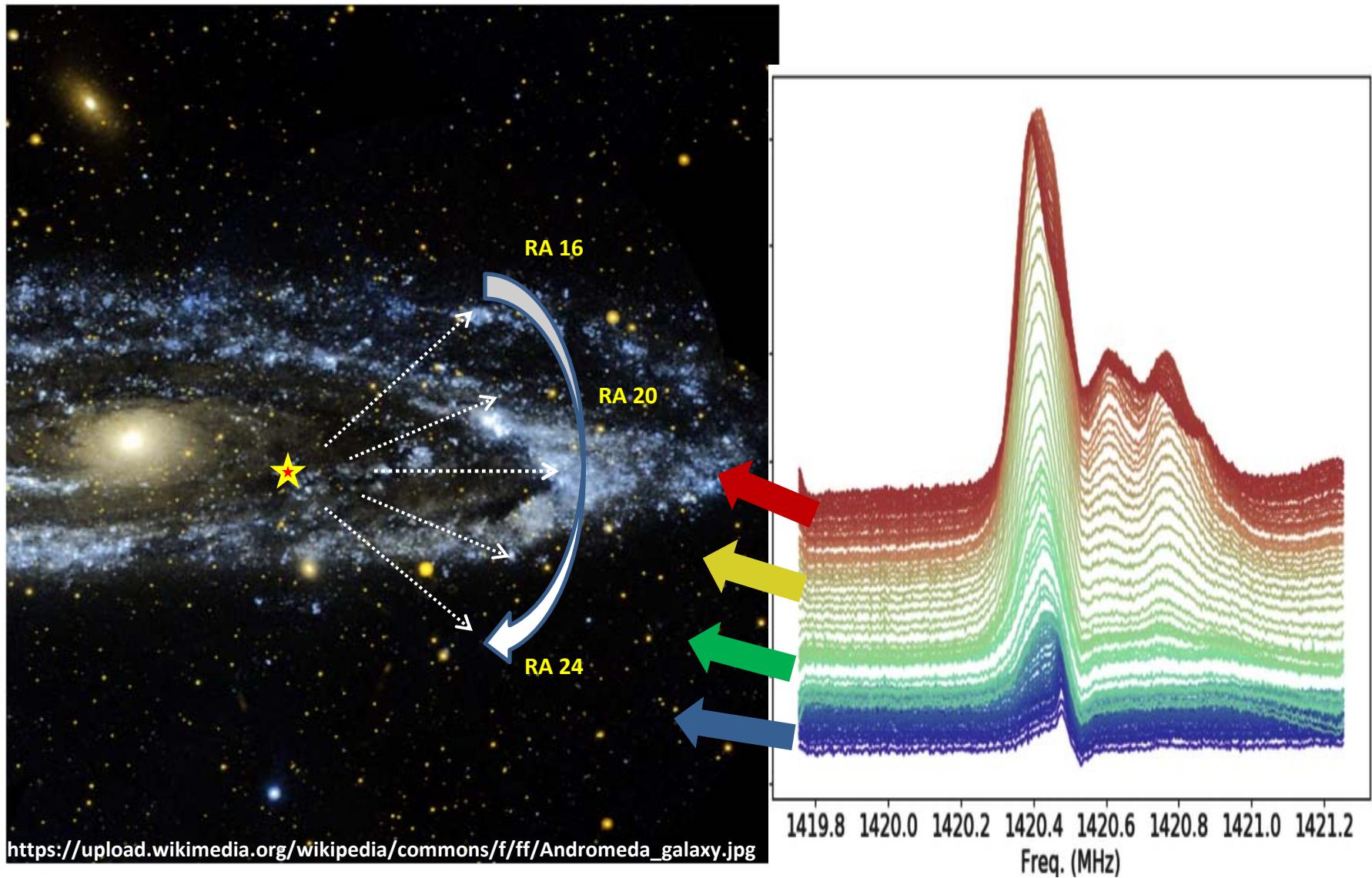


https://upload.wikimedia.org/wikipedia/commons/f/ff/Andromeda_galaxy.jpg

A Slice Through the Milky Way
21 cm Microwave RF Emission from Galactic Hydrogen Gas
~ Celestial ~~Coords~~ Dec+40 RA20:30

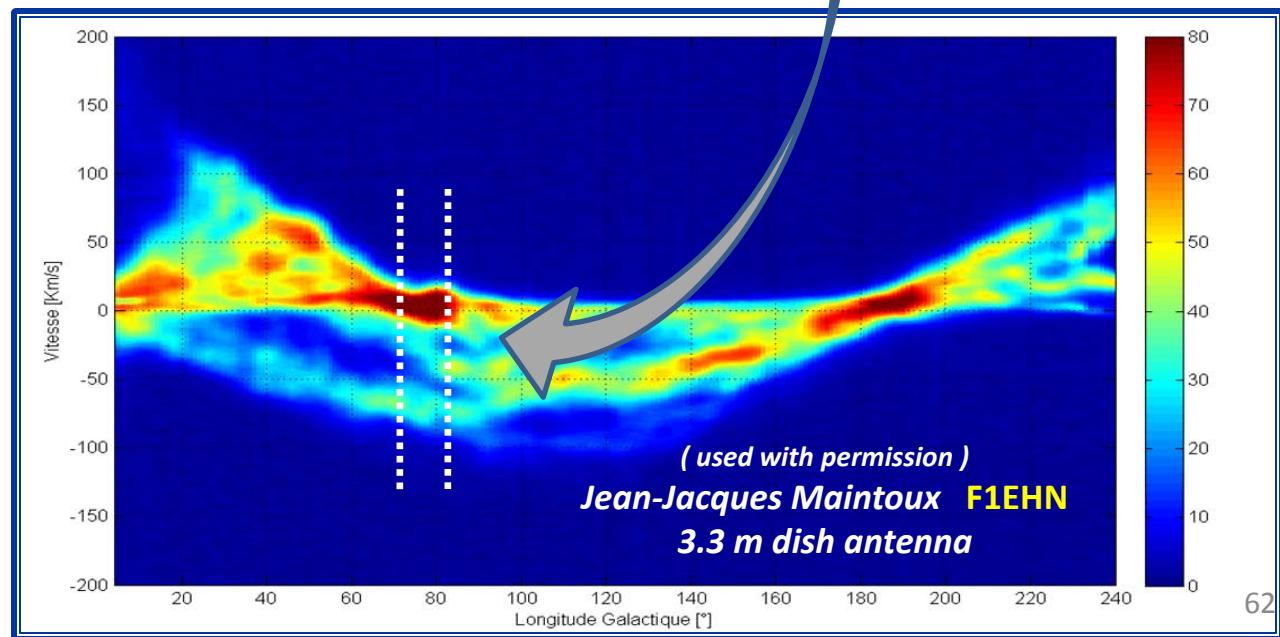
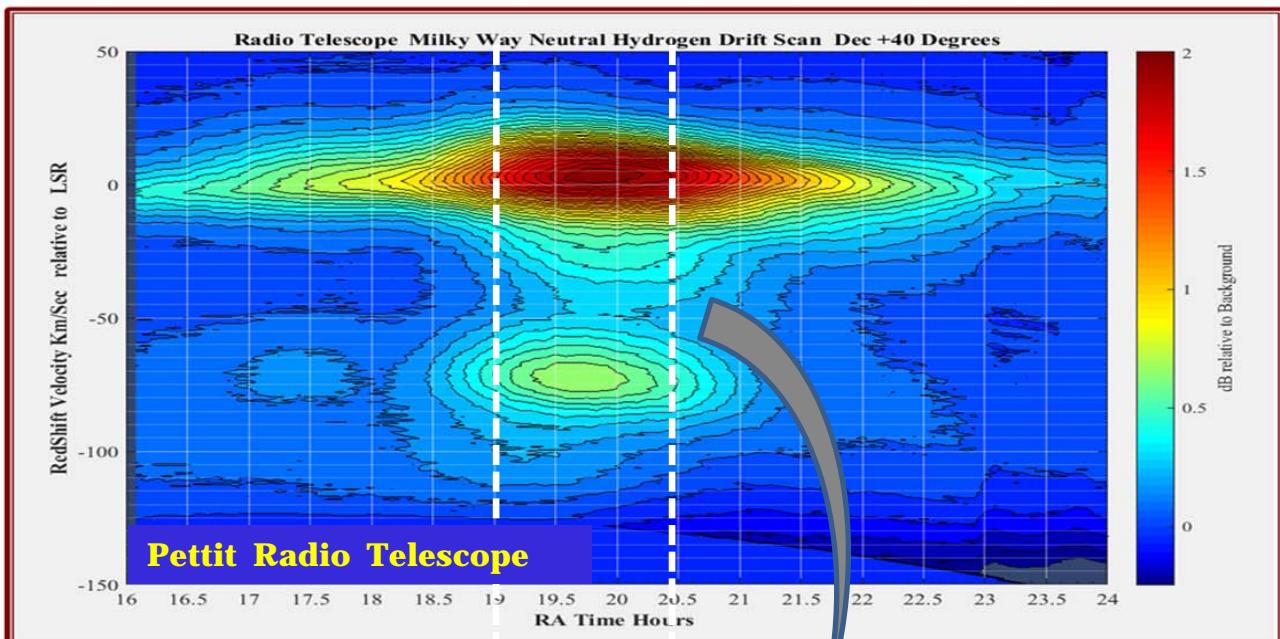


Velocity Spectrum of Neutral Hydrogen Declination +40 deg RA 16 <> 24 hrs

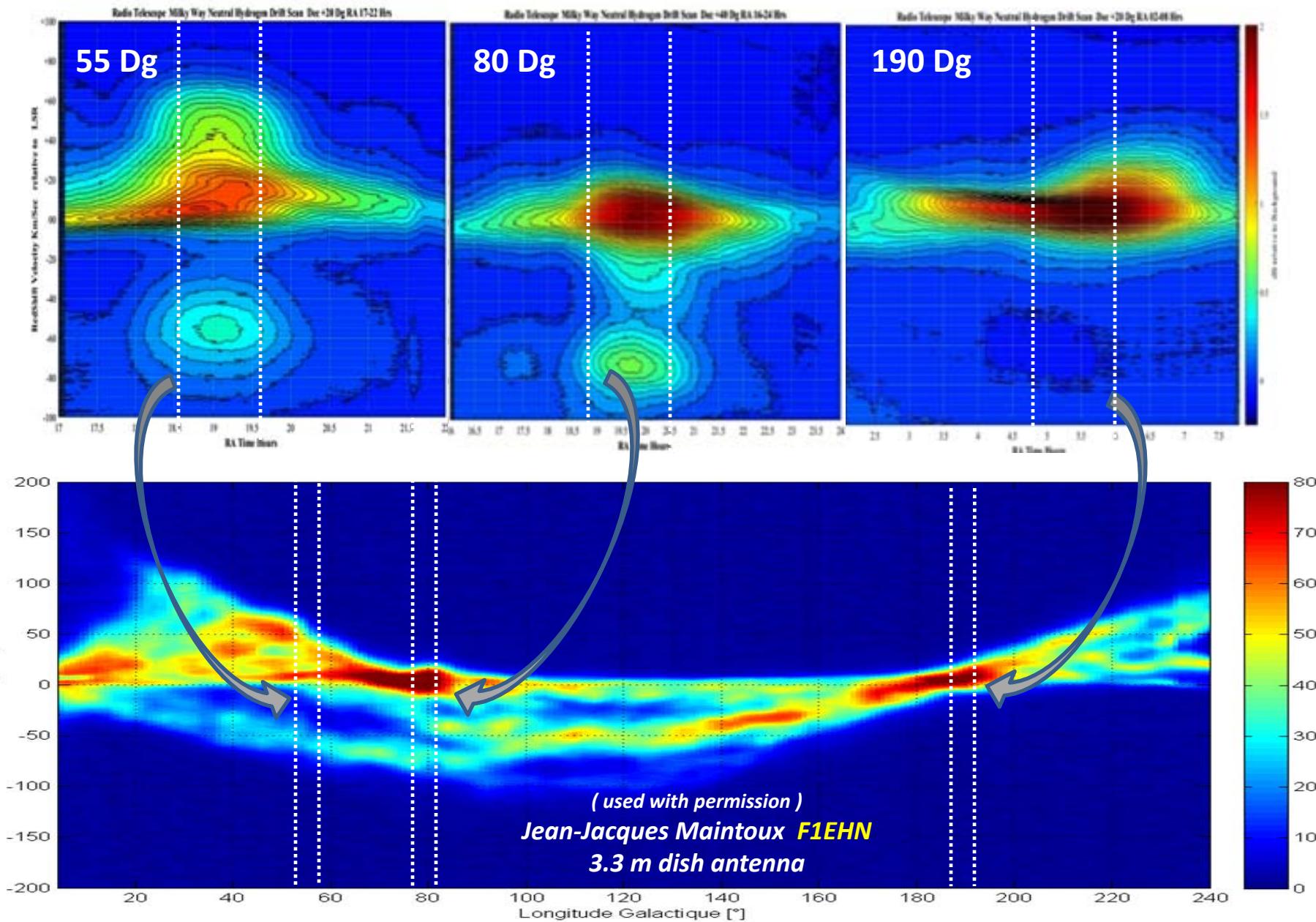


https://upload.wikimedia.org/wikipedia/commons/f/ff/Andromeda_galaxy.jpg

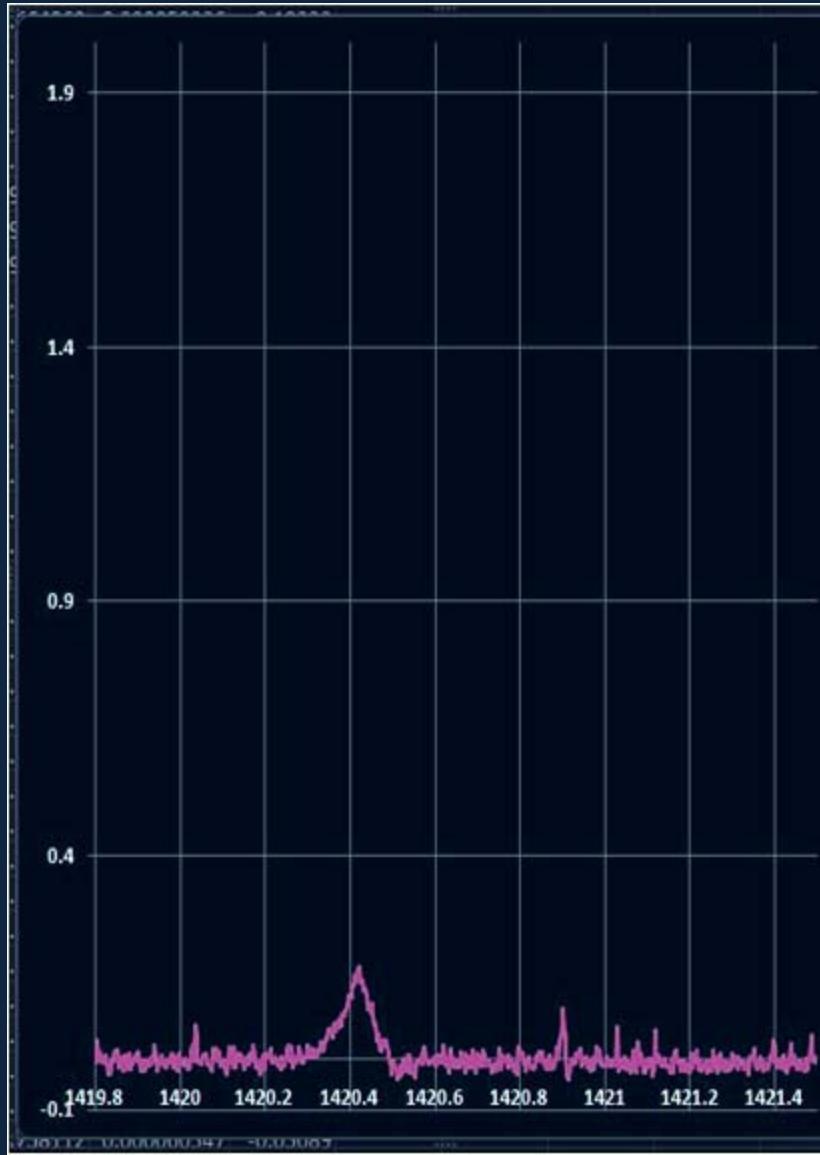
Results : A Spectral Velocity Analysis Graph of the 8 hour 100 sample data set using Matlab



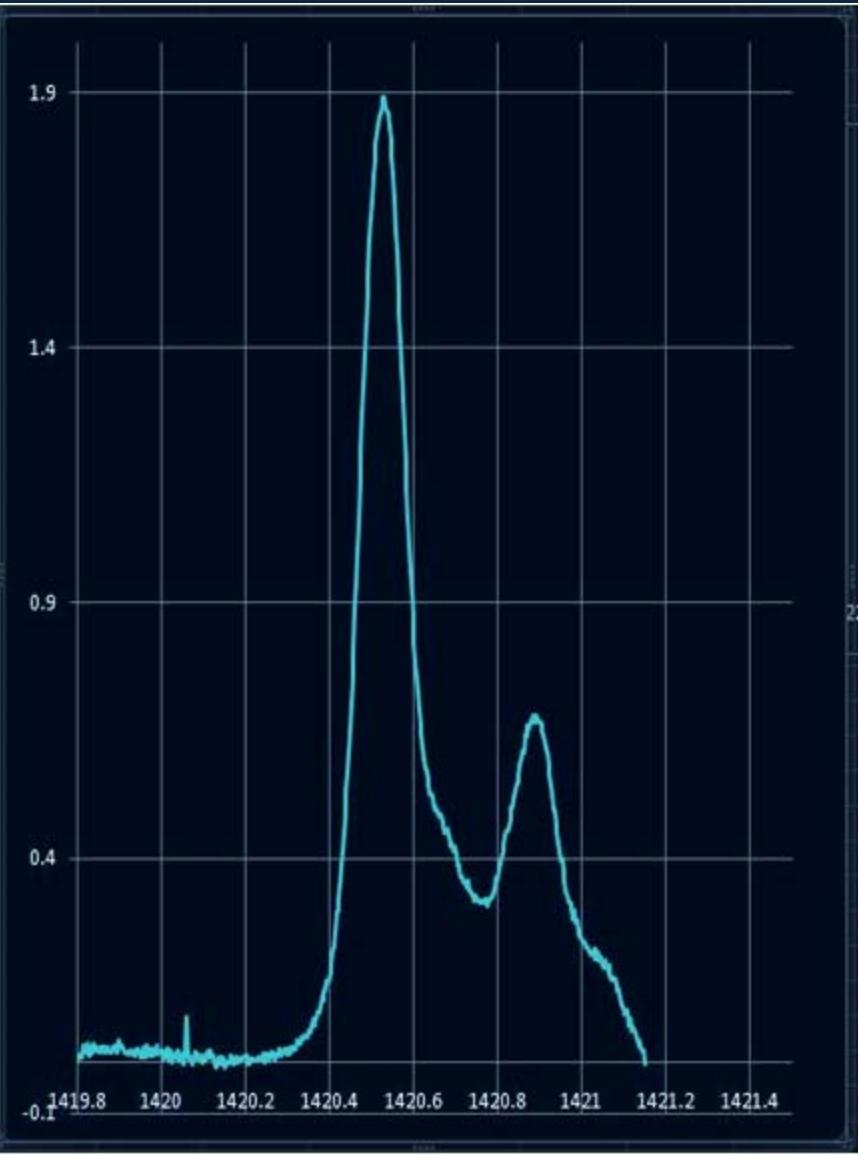
Pettit 1m Radio Telescope Velocity Spectral Analysis 28 March 2022



First Acquisition 30 August 2021



29 March 2022





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2021 Spring Conference



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SARA 2021 Eastern Conference Keynote Speaker



Dr. Weinreb was awarded the 2008 Grote Reber Medal for lifetime innovative contributions to radio astronomy. His pioneering developments of novel techniques and instrumentation over nearly half a century helped to define modern radio astronomy.

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70th Anniversary of the Discovery of Radio Emissions from Neutral Hydrogen



We are approaching the celebration of the 70th anniversary of the discovery on March 25, 2021 of radio emissions from neutral hydrogen near 1420 MHz. On March 25th, 1951, the very first detection of hydrogen using a radio telescope with a horn antenna sticking out of a window on the 4th floor of the

Lyman Physics laboratory at Harvard University was accomplished. This capability is the foundation of further discoveries allowing us to see the universe in a way never possible before.

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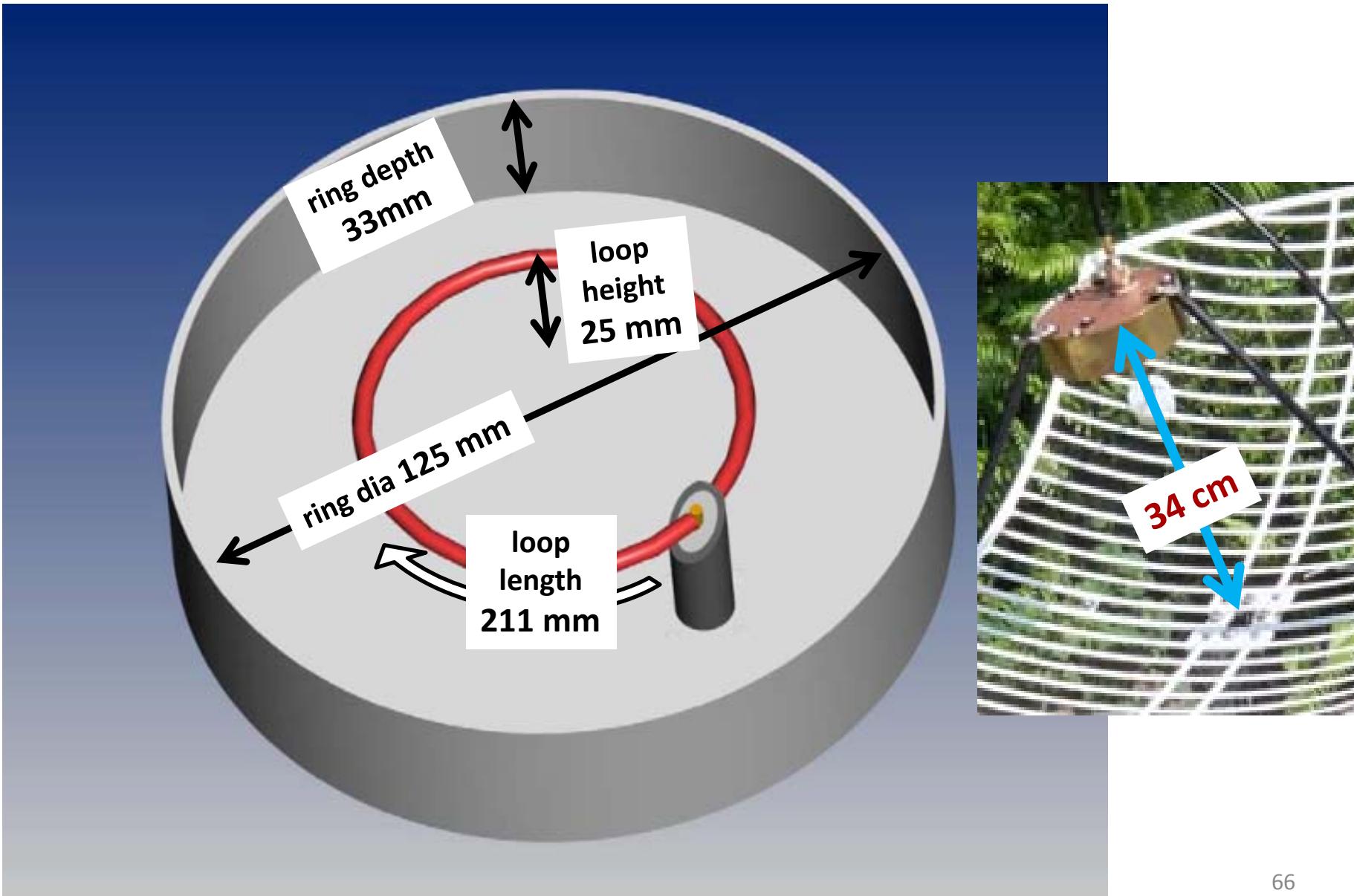
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Spectral Slice Through The Milky Way

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