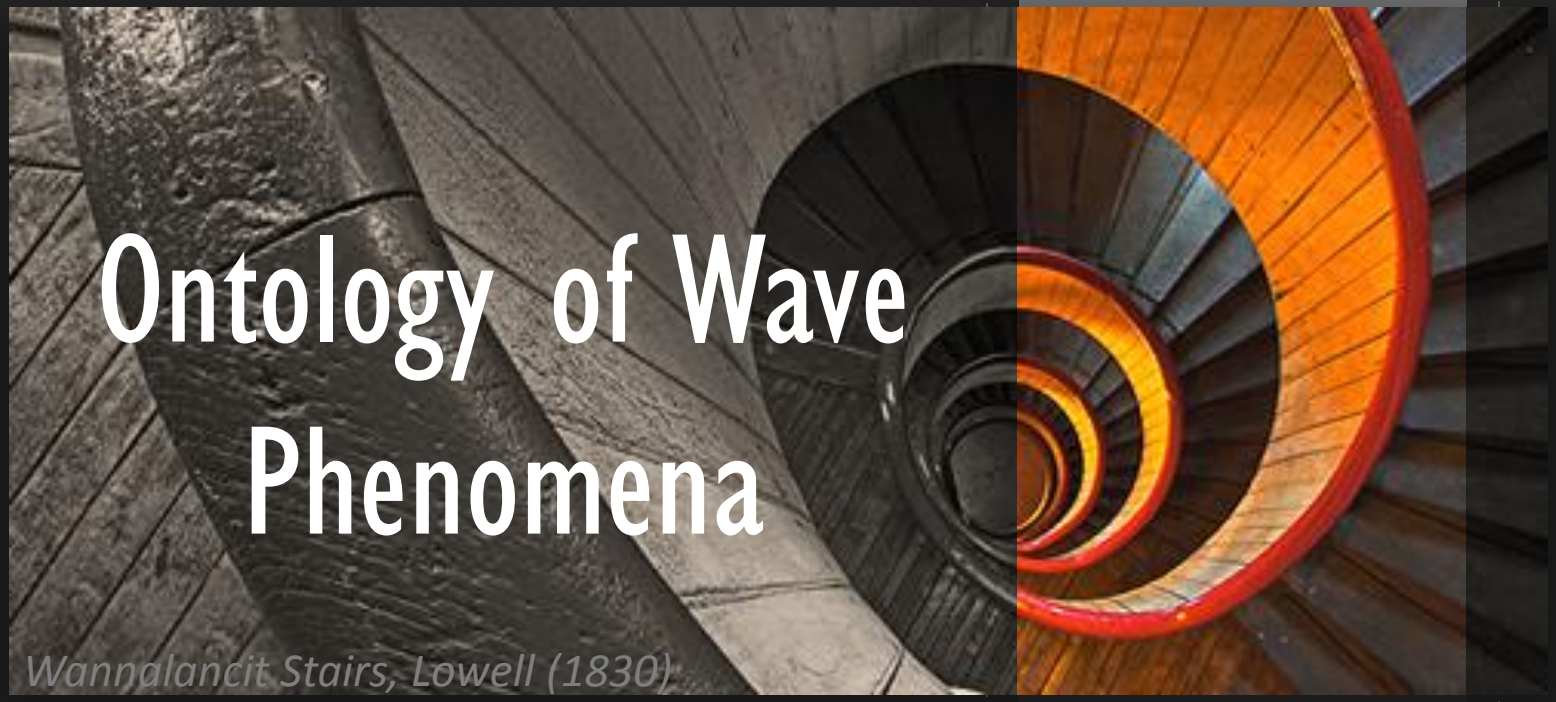
UMLCAR Friday Seminar Series • Lowell, Massachusetts • October 22, 2010

Ontology of Wave Phenomena



Wannalancit Stairs, Lowell (1830)

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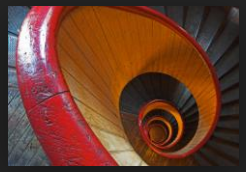
Acknowledge: RPI BinBrowser

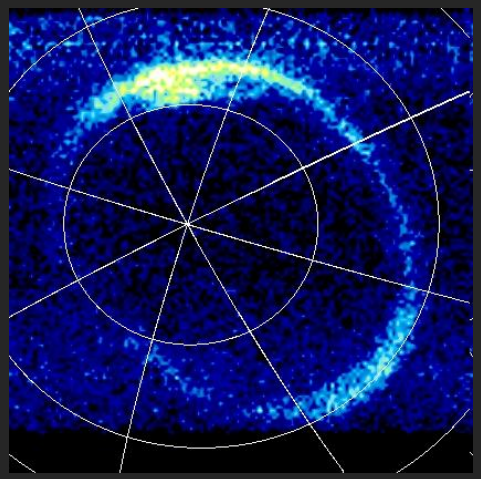
Introduction: Data Analysis Challenges

- Executive summary: DATA AVALANCHE
  - Multi-petabyte capability is NOW
  - Impossible to download
  - Even downloaded, no standard tools to explore data
  - Even with tools, no time to explore data
  - Steep learning curves at each step of the process
    - Especially in our domain

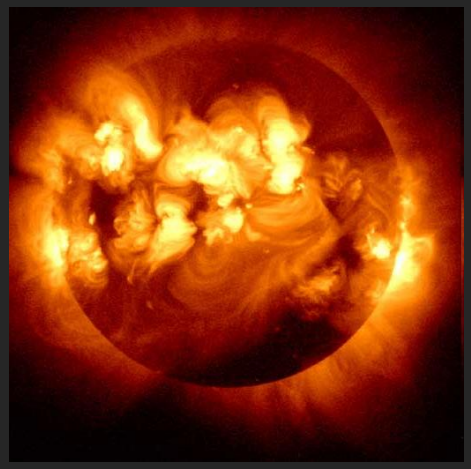
1.2 M images at 5 s/image for 20 hr/week = 2 years of life
More realistically, 10K images per summer student = 30 student-years



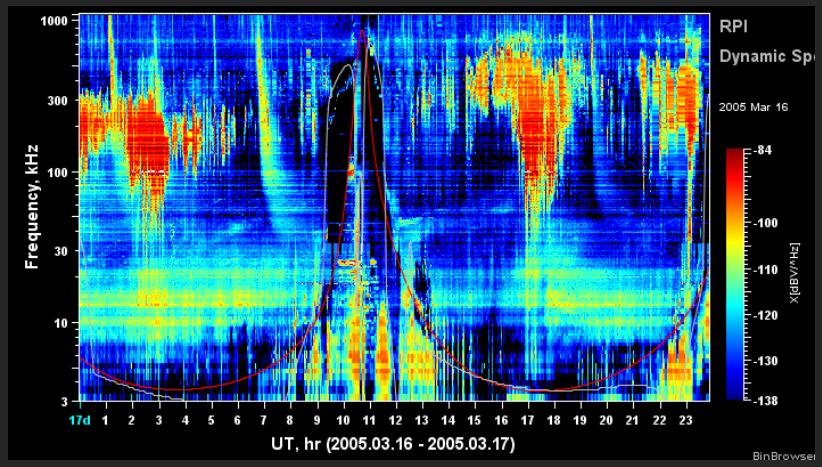
Introduction: Challenges of Wave Data



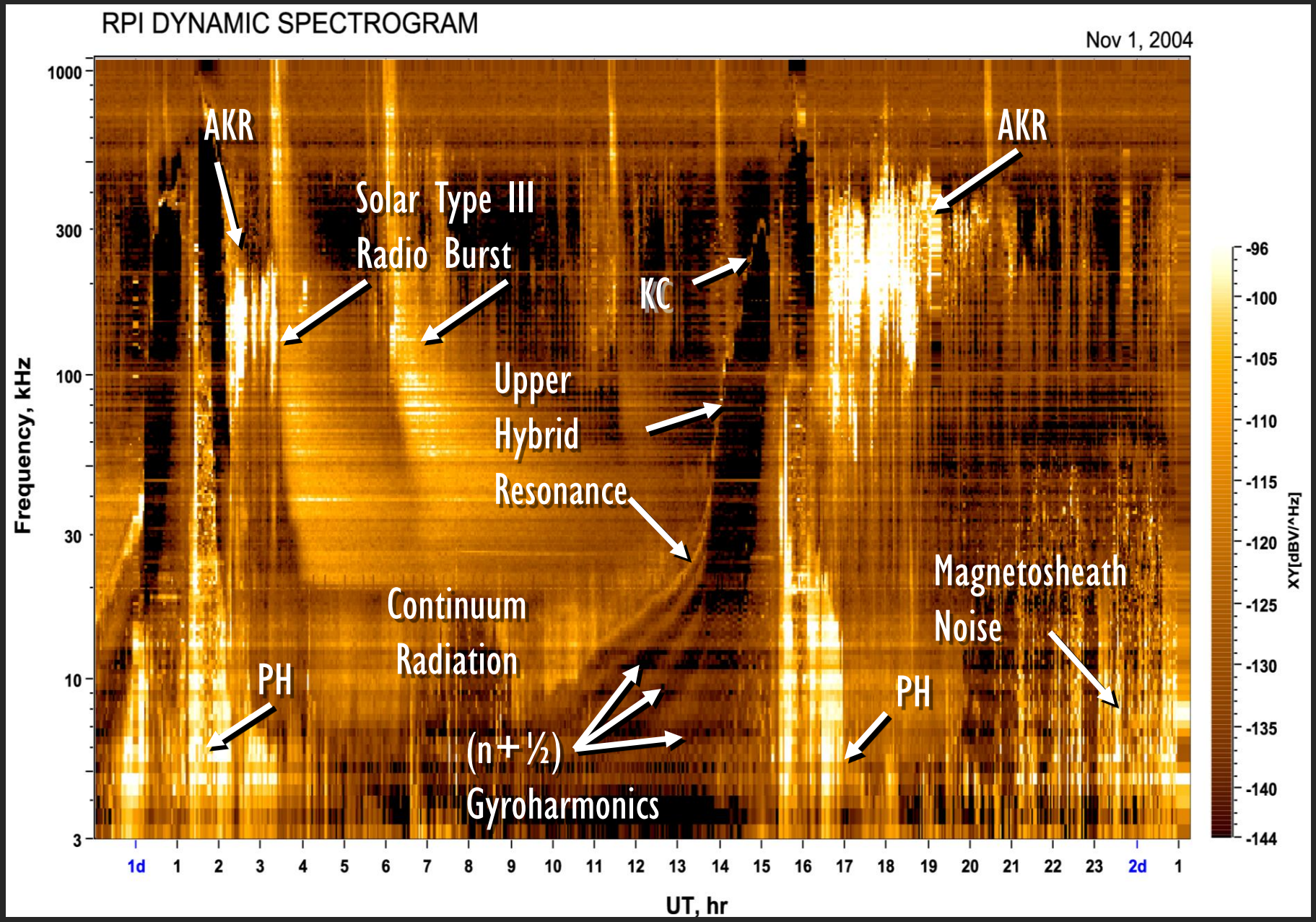
FUV on IMAGE showing brightening of aurora emissions

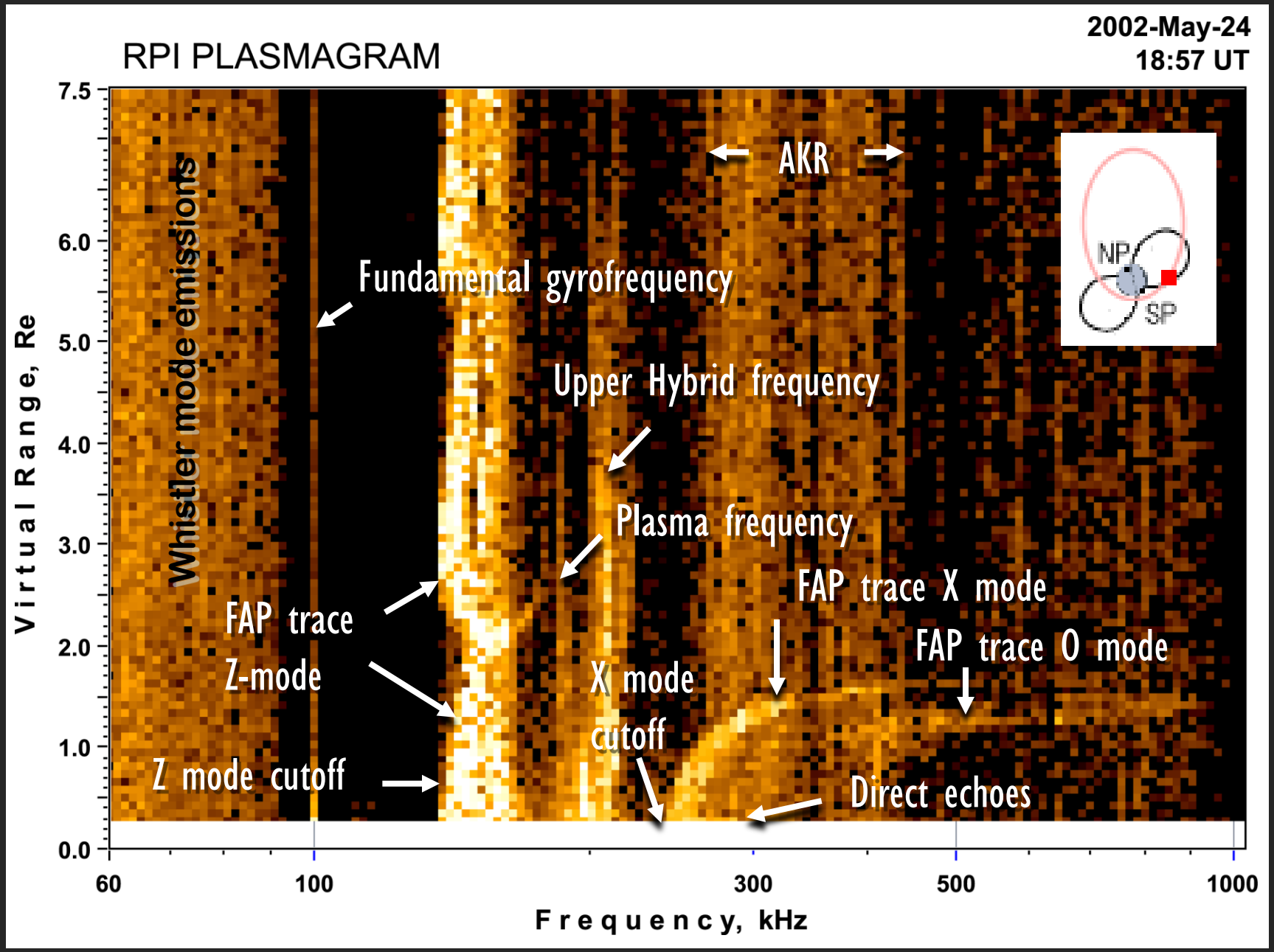


Hinode telescope showing multiple solar flares



RPI dynamic spectrogram in 3-1000 kHz showing… err… hmm… what the heck is this

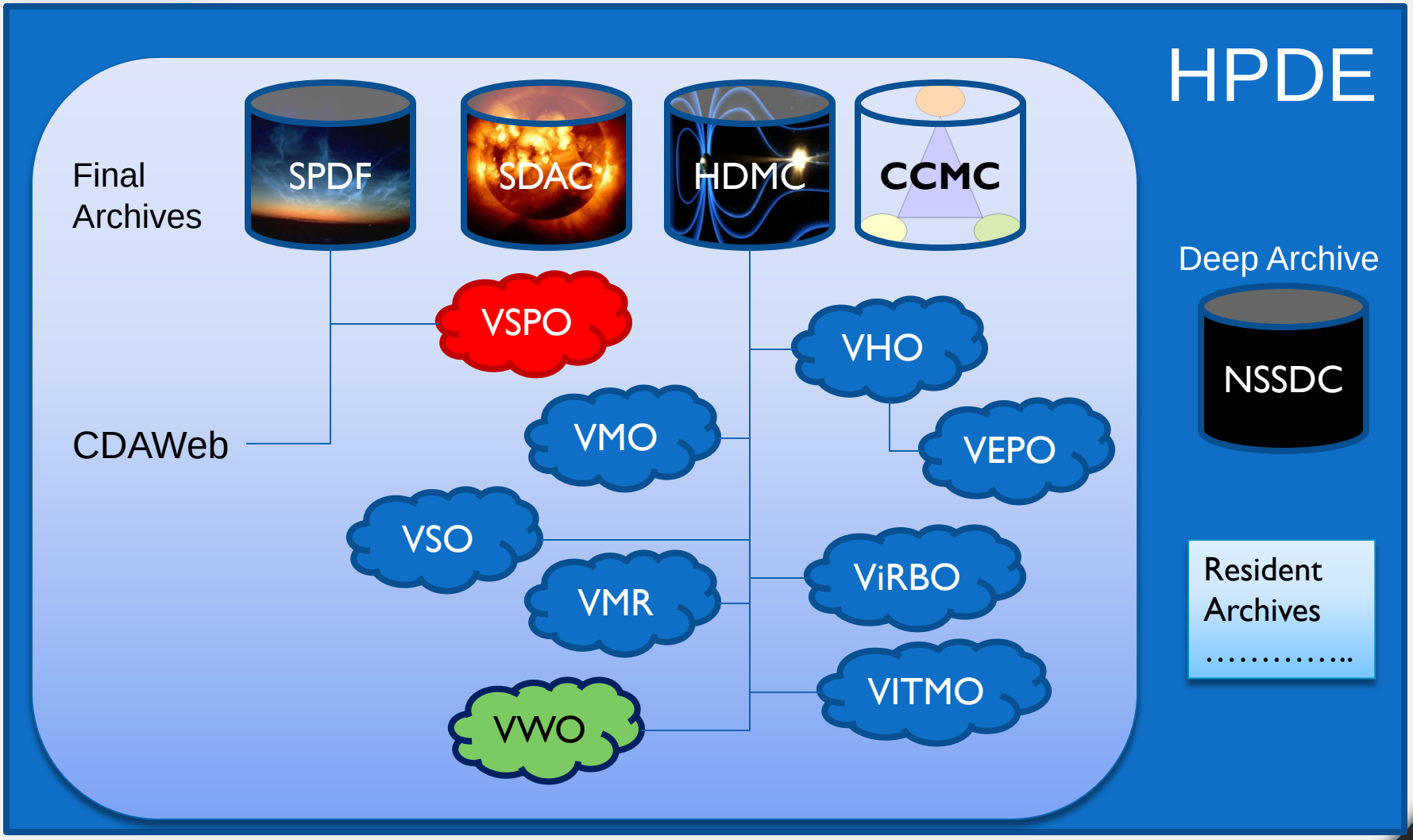

RPI DYNAMIC SPECTROGRAM
Nov 1, 2004
AKR
AKR
Solar Type III
Radio Burst
KC
Upper
Hybrid
Resonance
Continuum
Radiation
Magnetosheath
Noise
PH
PH
(n+½)
Gyroharmonics
Frequency, kHz
1000
300
100
30
10
3
UT, hr
1d
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
2d
1
XY[dBV/^Hz]
-96
-100
-105
-110
-115
-120
-125
-130
-135
-140
-144


RPI PLASMAGRAM
2002-May-24
18:57 UT
Virtual Range, Re
7.5
6.0
5.0
4.0
3.0
2.0
1.0
0.0
60
100
300
500
1000
Frequency, kHz
Whistler mode emissions
AKR
Fundamental gyrofrequency
Upper Hybrid frequency
Plasma frequency
FAP trace X mode
FAP trace O mode
FAP trace
Z-mode
X mode
cutoff
Z mode cutoff
Direct echoes
NP
SP

Introduction: Virtual Observatory

- VO is the astronomical community response to the data avalanche challenges
  - Defined in mid-1990s
  - Single scientific organization
    - Inherently distributed
    - Inherently multidisplinary
    - Unusually broad spectrum of users
- NASA VxO – space physics community response to the data avalanche challenges

Introduction: NASA HP Data Environment



HDMC Goals (1990)

NASA

What scientists want to do

- Model physical processes
- Study physical interactions
- Use multi-source data

NASA

What scientists don't want to do

- Wonder if they have all the data available
- Wait a long time to get the data
- Spend time and money getting data into a useable format
- Spend time and money fighting computers

NASA

What scientists want a data system to do

- Locate relevant data
- Access data quickly
- Create versatile data sets
- Use the data easily

NASA

What data systems managers want scientists to do

- Hold to agreed upon standards
- Submit all relevant data
- Document all relevant data
- Report location of relevant data

Introduction: HDMC Vision Statement

- The HDMC is designed to facilitate Heliophysics science research by making data and models freely available to scientists
  - Important policy! A very big deal some 15 years ago
- NASA HQ to require every new mission to include Data Scientist from the Development Day One
  - Mission proposals rejected if they do not have a data plan

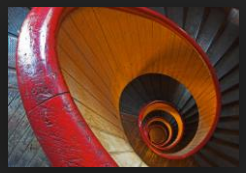
UMLCAR Data Science of Interest to VWO

- Data Prospectors

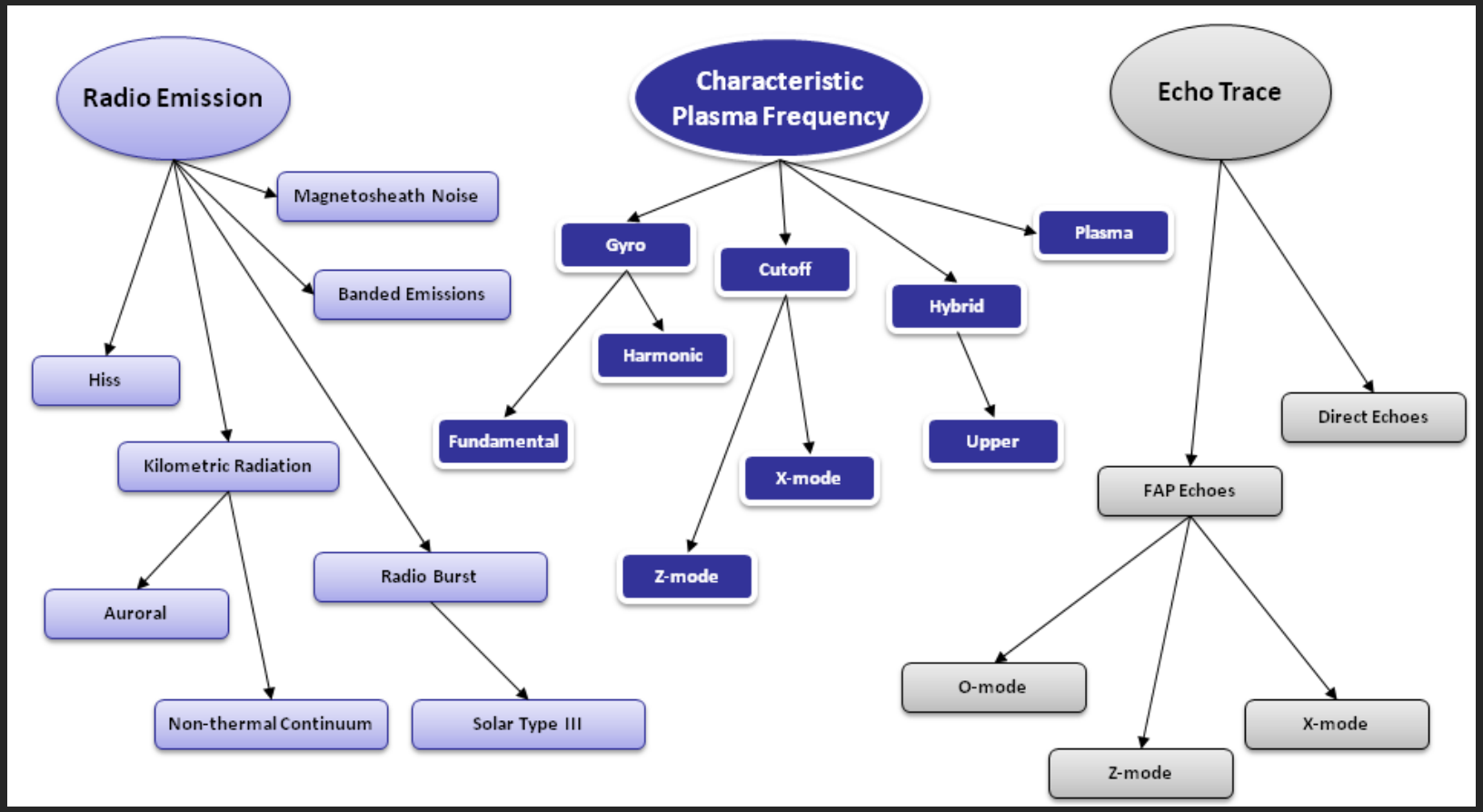
ARTIST-5

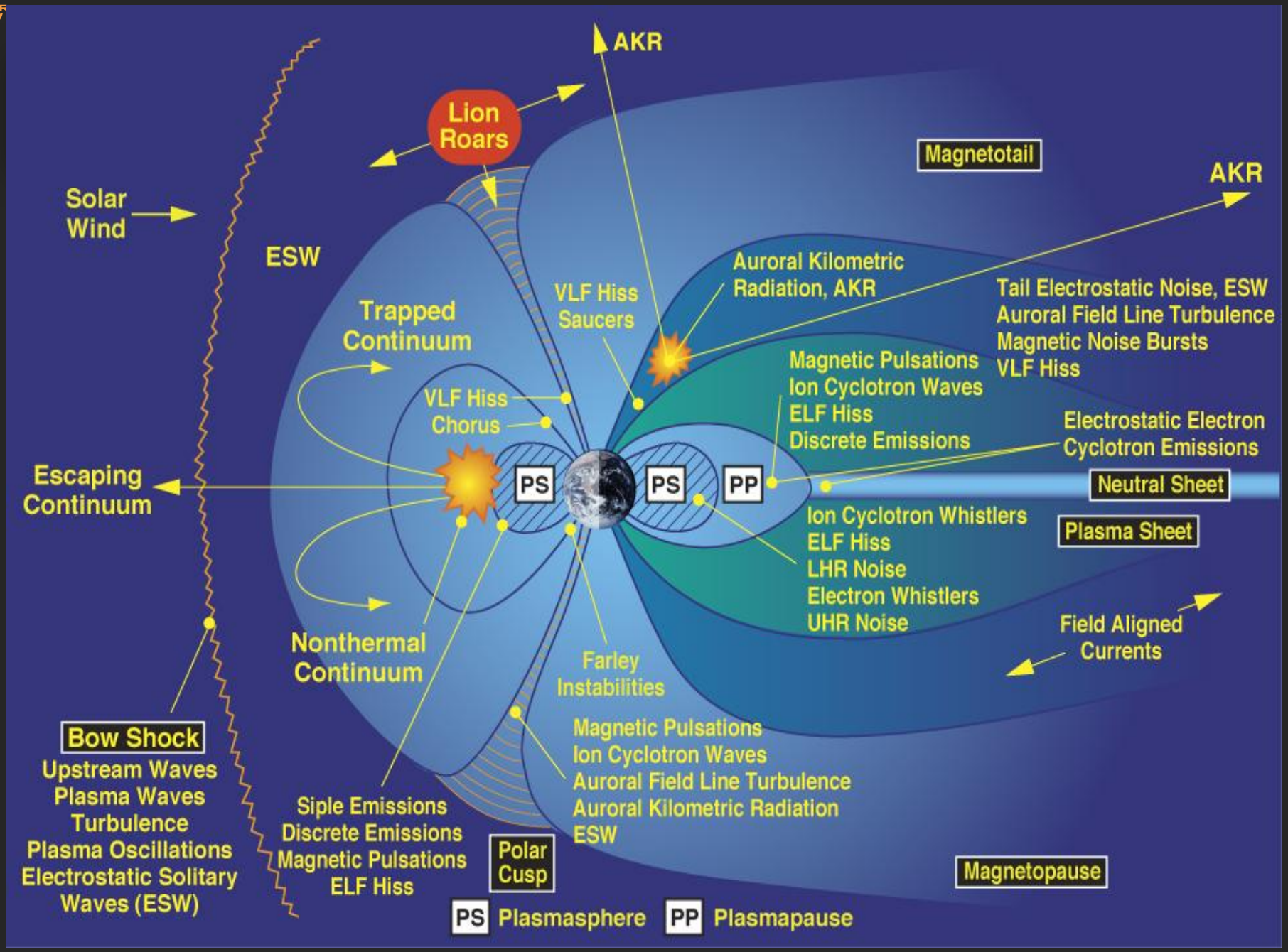
Other applications?
VLF ground receivers?
(AISRP)

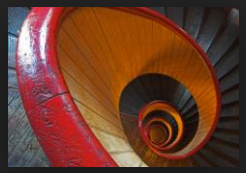
- Data Annotations



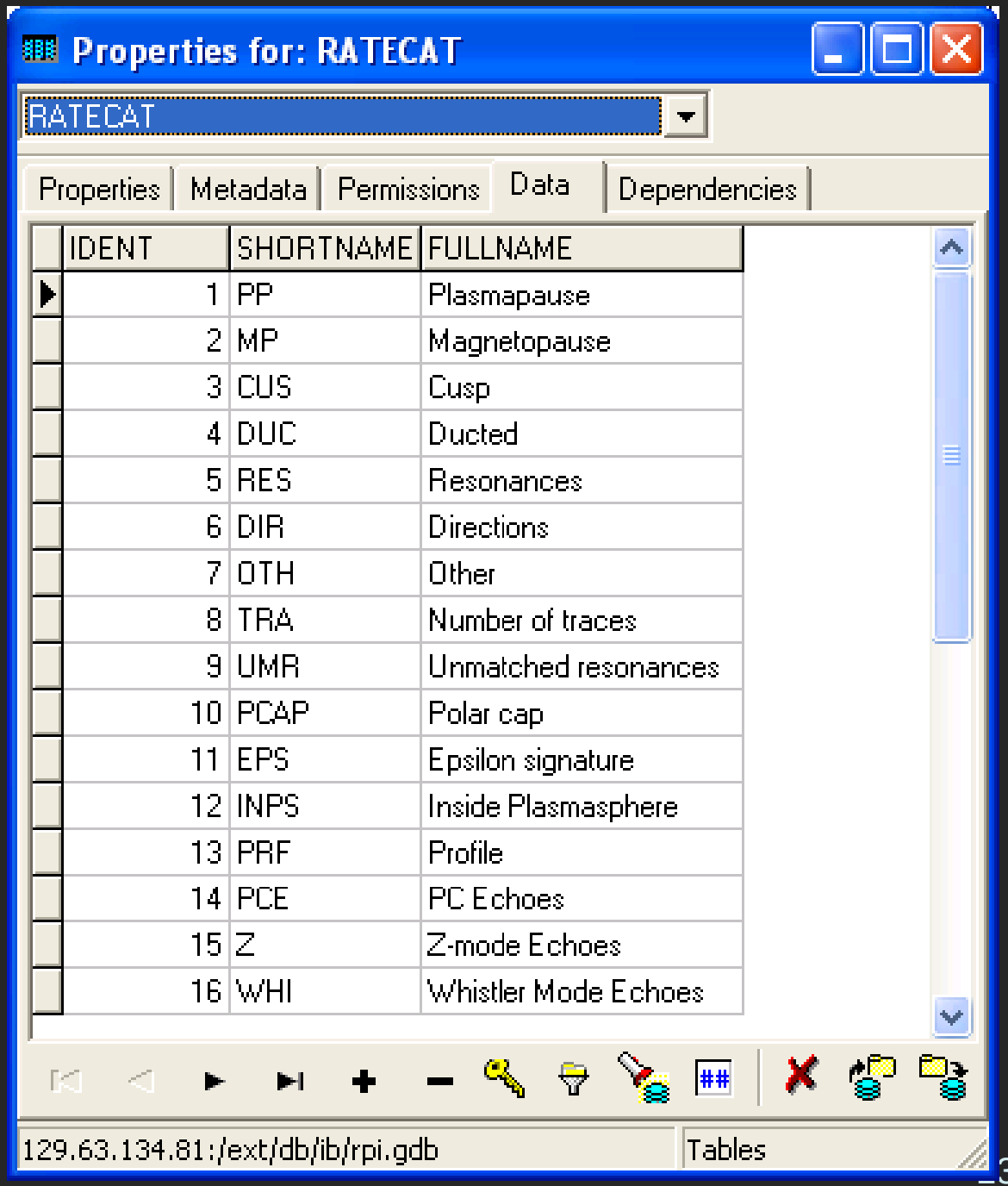
- Ontology (*computer science*)= a list of domain concepts and their relationships
- Domain = waves
- Concepts = wave phenomena
- Relationships




AKR
Lion Roars
Magnetotail
AKR
Solar Wind
ESW
Auroral Kilometric Radiation, AKR
Tail Electrostatic Noise, ESW
Auroral Field Line Turbulence
Magnetic Noise Bursts
VLF Hiss
VLF Hiss Saucers
Trapped Continuum
Magnetic Pulsations
Ion Cyclotron Waves
ELF Hiss
Discrete Emissions
VLF Hiss
Chorus
Electrostatic Electron Cyclotron Emissions
Escaping Continuum
PS
PS
PP
Neutral Sheet
Ion Cyclotron Whistlers
ELF Hiss
LHR Noise
Electron Whistlers
UHR Noise
Plasma Sheet
Field Aligned Currents
Nonthermal Continuum
Farley Instabilities
Bow Shock
Upstream Waves
Plasma Waves
Turbulence
Plasma Oscillations
Electrostatic Solitary Waves (ESW)
Magnetic Pulsations
Ion Cyclotron Waves
Auroral Field Line Turbulence
Auroral Kilometric Radiation
ESW
Siple Emissions
Discrete Emissions
Magnetic Pulsations
ELF Hiss
Polar Cusp
Magnetopause
PS Plasmasphere
PP Plasmapause



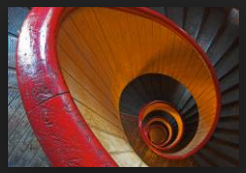
BinBrowser Ontology of Phenomena in RPI plasmagrams



IDENT	SHORTNAME	FULLNAME
1	PP	Plasmapause
2	MP	Magnetopause
3	CUS	Cusp
4	DUC	Ducted
5	RES	Resonances
6	DIR	Directions
7	OTH	Other
8	TRA	Number of traces
9	UMR	Unmatched resonances
10	PCAP	Polar cap
11	EPS	Epsilon signature
12	INPS	Inside Plasmasphere
13	PRF	Profile
14	PCE	PC Echoes
15	Z	Z-mode Echoes
16	WHI	Whistler Mode Echoes

This ontology is a list

Epsilon and Ducted
may apply simultaneously



Adding Relationships to Ontology

RPI Plasmagrams:

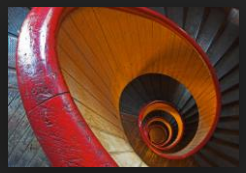
- Resonance
  - Resonance.Unmatched
- Ducted
  - Ducted.Epsilon
  - Ducted.PolarCap

RPI Spectrograms:

- SolarRadioBurst.TypeIII
- RadioBurst
  - RadioBurst. Solar
    - RadioBurst..Solar.TypeIII
- Earth.Plasmashere.Hiss
- Radiation.Auroral.Kilometric

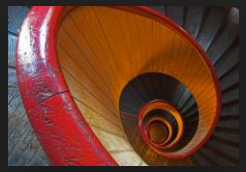
Parent-child relationship does not work!

Attributes of phenomena are grouped in independent categories



Defining Attributes of Wave Phenomena

- **AKR**
  - Radiation *(class)*
  - Auroral *(point of origin)*
  - Kilometric *(spectral range)*
- **Plasmaspheric Hiss**
  - Plasmasphere *(observed region)*
  - Hiss *(frequency character)*
- **Solar Radio Burst Type III**
  - Solar *(point of origin)*
  - Radio *(class)*
  - Burst *(temporal character)*
  - Type III *(subclass of bursts)*
- **Plasmagram Epsilon**
  - Traces *(class)*
  - Ducted *(propagation)*
  - Multi-Hop *(qualifier)*
- **Electron Cyclotron Resonance**
  - Resonance *(class)*
  - Electron Cyclotron *(propagation mode)*
- **Atmospheric Gravity Wave**



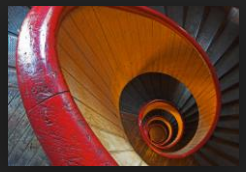
Wave Phenomenon Ontology... drumroll...

Standard VWO Phenomenon Type						
Class	Qualifier	Propagation	Propagation Mode	Frequency Character	Spatio-temporal Character	Point of Origin

Existing SPASE Components		
Wave Type	Spectral Range	Observed Region

- Auroral Kilometric Radiation
  - Class = Radio Emission
  - Qualifier = Natural
  - Propagation = Free Space
  - Frequency Character = Wideband
  - Point of Origin = Earth.NearSurface.AuroralRegion
  - Wave Type = Electromagnetic
  - Spectral Band = Kilometric
  - Observed Region = Earth.Magnetosphere

10 subtypes



Examples, cont.

- Atmospheric Gravity Wave
  - Class = Gravity Wave
  - Qualifier = Natural
  - Propagation = Free Space
  - Propagation Mode = ?
  - Frequency Character = ?
  - Spatial-Temporal Character = ?
  - Point of Origin = Earth.NearSurface.Atmosphere
  - Wave Type = Density.Gas
  - Spectral Range = Megametric

I. Class

1 Radio Emission
2 Plasma Wave
3 Plasma Wave.Resonance
4 Echo
5 Echo.Trace
6 Gravity Wave

(of interest to wave community)

2. Frequency Character

1 Continuum
2 Line
3 Narrowband
4 Wideband
5 Wideband.Chorus
6 Wideband.Hiss
7 Banded
8 Sweep
9 Sweep.Upward
10 Sweep.Downward
11 Sweep.Whistler
12 Sweep.Saucer
13 Sweep.Epsilon
14 Noise

3. Spatio-Temporal Character

- 1 Burst
- 2 Burst.Short-lived
- 3 Burst.Long-lived
- 4 Continuous
- 5 Soliton
- 6 Standing Wave

4. Wave Type

1 Electromagnetic
2 Electrostatic
3 Density
4 Density.Fluid
5 Density.Gas
6 Density.Interface
7 Photon
8 Undetermined

5. Propagation

1 Free Space
2 Trapped
3 Trapped.Field-aligned

6. Propagation Mode

1 R
2 L
3 O
4 X
5 R-X
6 L-O
7 L-X
8 Z

9 Electron
10 Electron.Whistler
11 Electron.Plasma
12 Electron.Cyclotron
13 Electron.UpperHybrid
14 Electron.Hole
15 Electron.Acoustic
16 Electron.Bernstein
17 Electron.SolitaryWave

18 Ion
19 Ion.Alfven
20 Ion.Magnetosonic
21 Ion.Plasma
22 Ion.Acoustic
23 Ion.Hole
24 Ion.Cyclotron
25 Ion.LowerHybrid
26 Ion.Berstein
27 Ion.SolitaryWave
28 MHD
29 MHD.FastMode
30 MHD.SlowMode
31 Non-linear

Proton.Cyclotron?

Electron.Dn?

7. Spectral Range

1	?	THz	300-3000 GHz
2	Millimetric	EHF	30-300 GHz
3	Centimetric	SHF	3-30 GHz
4	Decimetric	UHF	300-3000 MHz
5	Metric	VHF	30-300 MHz
6	Decametric	HF	3-30 MHz
7	Hectometric	MF	300-3000 kHz
8	Kilometric	LF	30-300 kHz
9	Myriametric	VLF	3-30 kHz
10	?	ULF	300-3000 Hz
11	?	SLF	30-300 Hz
12	Megametric	ELF	3-30 Hz
13	?	subHz	< 3 Hz

8. Point of Origin

1 Active Instrument
2 Asteroid
3 Comet
4 Earth
5 Earth.Magnetosheath
6 Earth.Magnetosphere
7 Earth.Magnetosphere.Magnetotail
8 Earth.Magnetosphere.Main
9 Earth.Magnetosphere.Polar
10 Earth.Magnetosphere.Radiation Belt
11 Earth.Near Surface
12 Earth.Near Surface.Atmosphere
13 Earth.Near Surface.Auroral Region
14 Earth.Near Surface.Equatorial Region
15 Earth.Near Surface.Ionosphere
16 Earth.Near Surface.Ionosphere.D-Region
17 Earth.Near Surface.Ionosphere.E-Region
18 Earth.Near Surface.Ionosphere.F-Region
19 Earth.Near Surface.Ionosphere.Topside
20 Earth.Near Surface.Mesosphere
21 Earth.Near Surface.Plasmasphere
22 Earth.Near Surface.Polar Cap
23 Earth.Near Surface.South Atlantic Anomaly Region
24 Earth.Near Surface.Stratosphere
25 Earth.Near Surface.Thermosphere
26 Earth.Near Surface.Troposphere
27 Earth.Surface
28 Heliosphere
29 Heliosphere.Inner
30 Heliosphere.Near Earth
31 Heliosphere.Outer
32 Heliosphere.Remote 1AU
33 Interstellar
34 Jupiter
35 Mars
36 Mercury
37 Neptune
38 Pluto
39 Saturn
40 Sun
41 Sun.Chromosphere
42 Sun.Corona
43 Sun.Interior
44 Sun.Photosphere
45 Sun.Transition Region
46 Uranus
47 Venus

9. Observed Region

1 Active Instrument
2 Asteroid
3 Comet
4 Earth
5 Earth.Magnetosheath
6 Earth.Magnetosphere
7 Earth.Magnetosphere.Magnetotail
8 Earth.Magnetosphere.Main
9 Earth.Magnetosphere.Polar
10 Earth.Magnetosphere.Radiation Belt
11 Earth.Near Surface
12 Earth.Near Surface.Atmosphere
13 Earth.Near Surface.Auroral Region
14 Earth.Near Surface.Equatorial Region
15 Earth.Near Surface.Ionosphere
16 Earth.Near Surface.Ionosphere.D-Region
17 Earth.Near Surface.Ionosphere.E-Region
18 Earth.Near Surface.Ionosphere.F-Region
19 Earth.Near Surface.Ionosphere.Topside
20 Earth.Near Surface.Mesosphere
21 Earth.Near Surface.Plasmasphere
22 Earth.Near Surface.Polar Cap
23 Earth.Near Surface.South Atlantic Anomaly Region
24 Earth.Near Surface.Stratosphere
25 Earth.Near Surface.Thermosphere
26 Earth.Near Surface.Troposphere
27 Earth.Surface
28 Heliosphere
29 Heliosphere.Inner
30 Heliosphere.Near Earth
31 Heliosphere.Outer
32 Heliosphere.Remote 1AU
33 Interstellar
34 Jupiter
35 Mars
36 Mercury
37 Neptune
38 Pluto
39 Saturn
40 Sun
41 Sun.Chromosphere
42 Sun.Corona
43 Sun.Interior
44 Sun.Photosphere
45 Sun.Transition Region
46 Uranus
47 Venus

10. Qualifier

1 Harmonics
2 Multi-hop
3 Dayside
4 Nightside
5 Duskside
6 Dawnside
7 Discrete
8 Diffuse
9 Ducted
10 Direct
11 Stimulated
12 Natural
13 Sequence

Use of common names

- Expert adding the annotation
  - Looks up <u>common name</u> in the master list
  - If the name found
    - Translator uses given common name to produce the 10-tuple of the phenomenon type
  - If the name is not found
    - Expert specified 10-tuple and adds to the master list

Use of common names

- User looking for annotations. Two possibilities:
  - Looks up <u>common name</u> in the master list
  - Specifies all or some subtypes of the phenomenon type
- Example: look for wideband emissions in magnetosphere
  - Class = Radio Emission
  - Frequency Character = Wideband
  - Observed Region = Earth.Magnetosphere

Summary

- RPI Expert Rating System is expanded to a wider domain of wave phenomena in Heliophysics
- Wave ontology has to be defined to capture phenomena definitions
  - 10-tuple combinatorial model is suggested
- Common phenomenon names will remain important means to simplify annotation interface for both experts and users