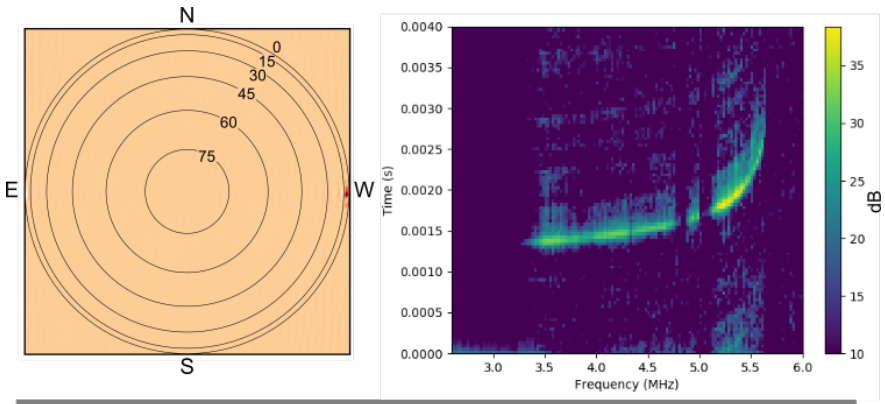
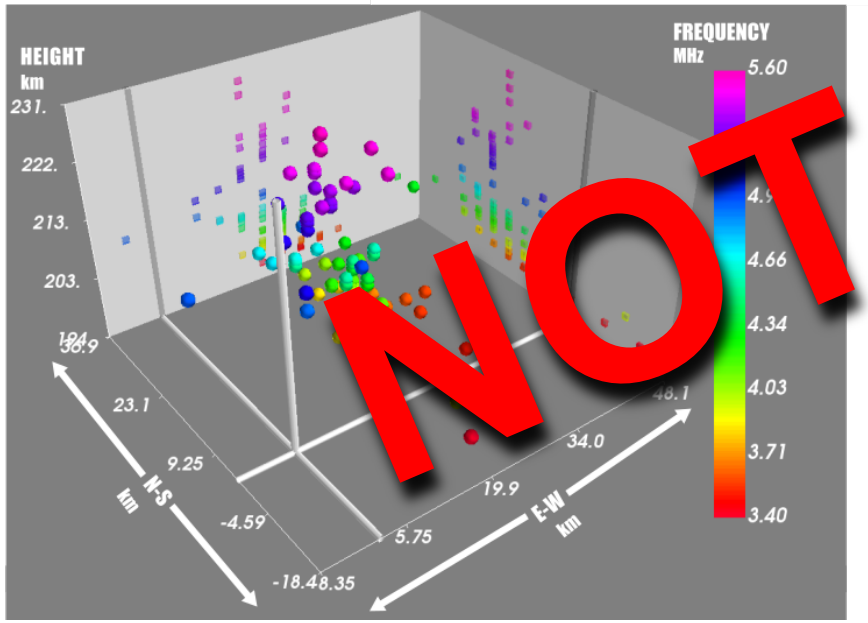
Model Driven Ionospheric Corrections for Radio Telescopes

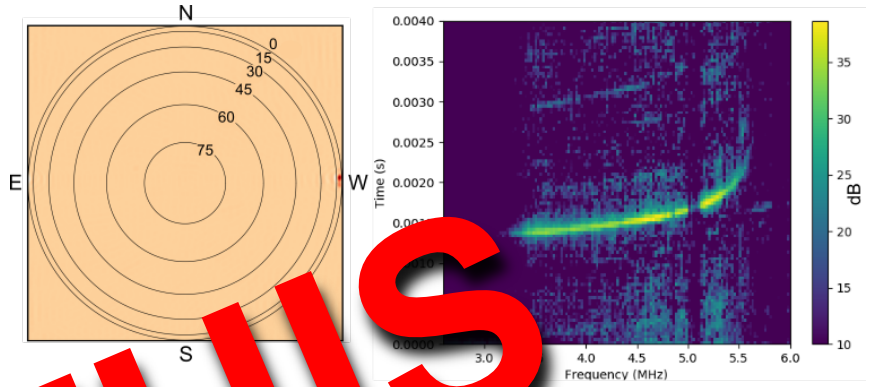
How a bunch of astronomers helped me build an ionospheric correction

Joe Malins
Greg Taylor
Ken Obenberger
Jayce Dowell


N
E
W
S
0
15
30
45
60
75
Time (s)
Frequency (MHz)
dB


HEIGHT
km
FREQUENCY
MHz
5.60
4.66
4.34
4.03
3.71
3.40
N-S
km
E-W
km

NOT


N
E
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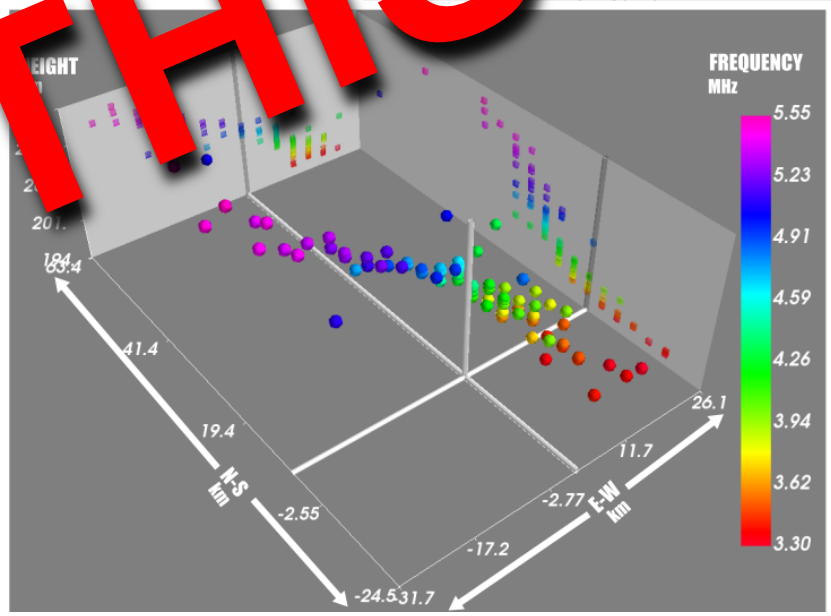
0
15
30
45
60
75
Time (s)
Frequency (MHz)
dB

THIS


FREQUENCY
MHz
5.55
5.23
4.91
4.59
4.26
3.94
3.62
3.30
N-S
km
E-W
km

Challenges

Two Questions:

- ➔ Identify What correction is required to the station
  - ◆ Self correcting model from data
  - ◆ External Model with outside input (GPS, etc.)
  - ◆ Hybrid
- ➔ Impliment the correction into the data
  - ◆ At what step is correction implemented into the process

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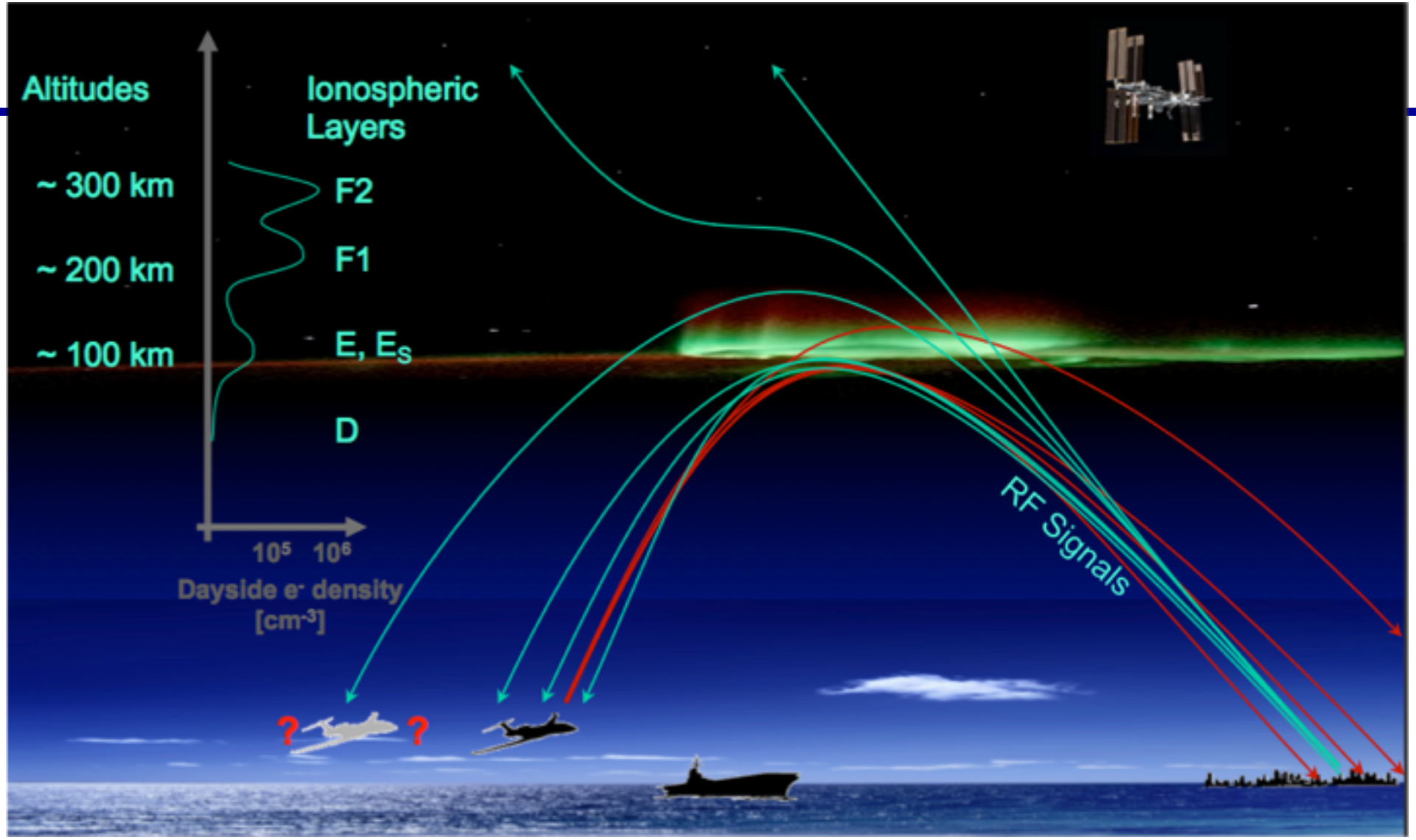
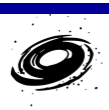


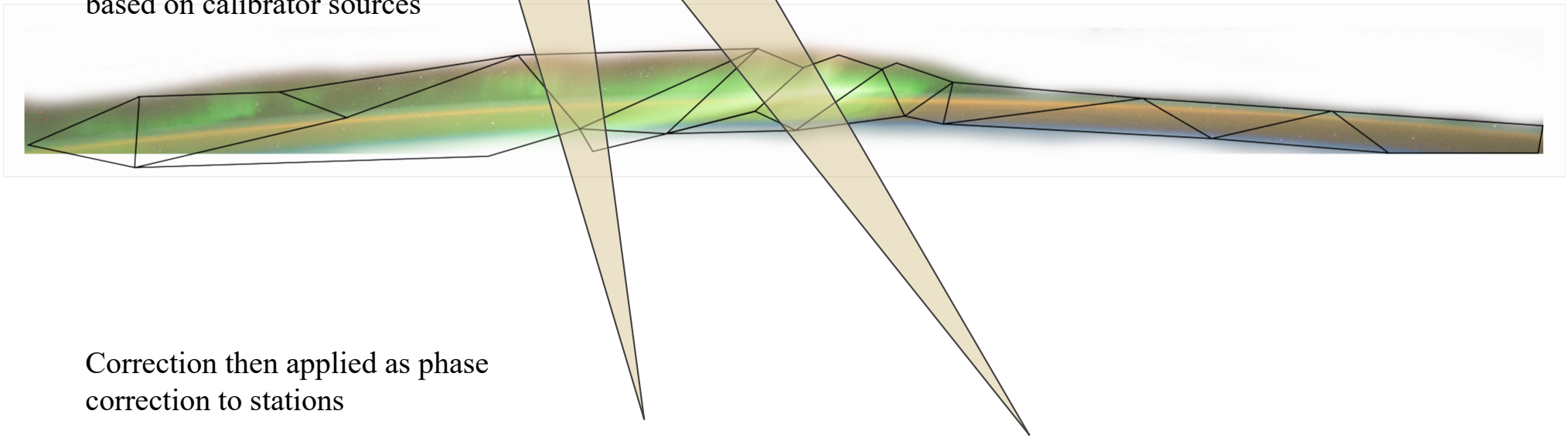
Courtesy NRL https://www.nrl.navy.mil

Traditional Correction

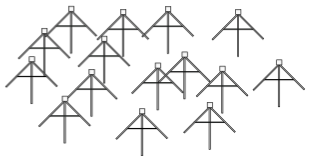


Model created from observations

Sky broken into various sections based on calibrator sources



Correction then applied as phase correction to stations



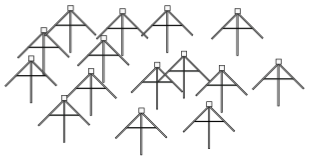


Image Mapping Correction

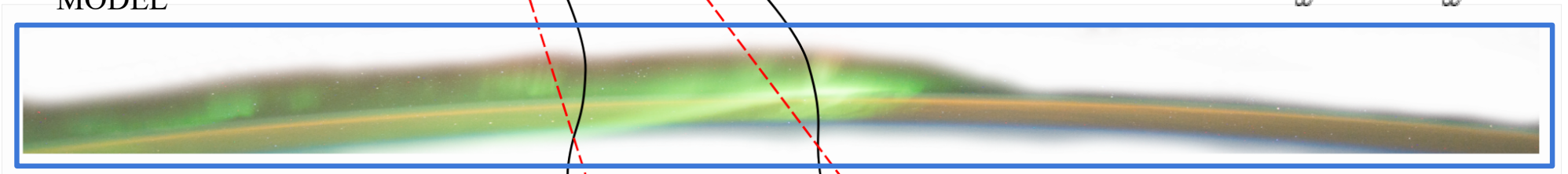
Ray Tracing Through The Atmosphere

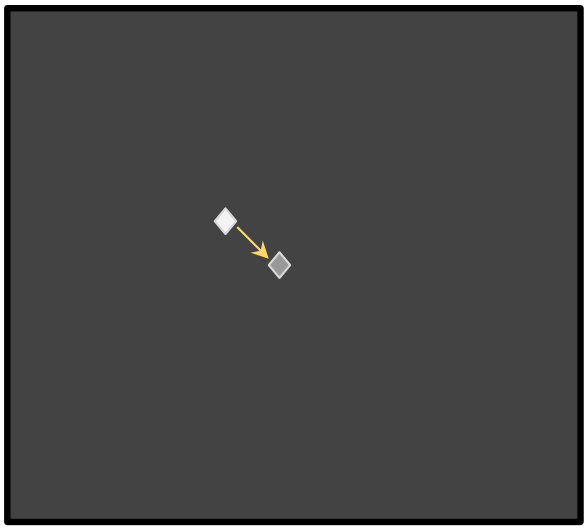
Appleton-Hartree Equation

$$n^2 = 1 - \frac{X(1-X)}{1 - X - \frac{1}{2}Y^2\sin^2\theta \pm \left(\left(\frac{1}{2}Y^2\sin^2\theta\right)^2 + (1-X)^2Y^2\cos^2\theta\right)^{1/2}}$$

$$X = \frac{\omega_p^2}{\omega^2} \qquad Y = \frac{\omega_H}{\omega}$$

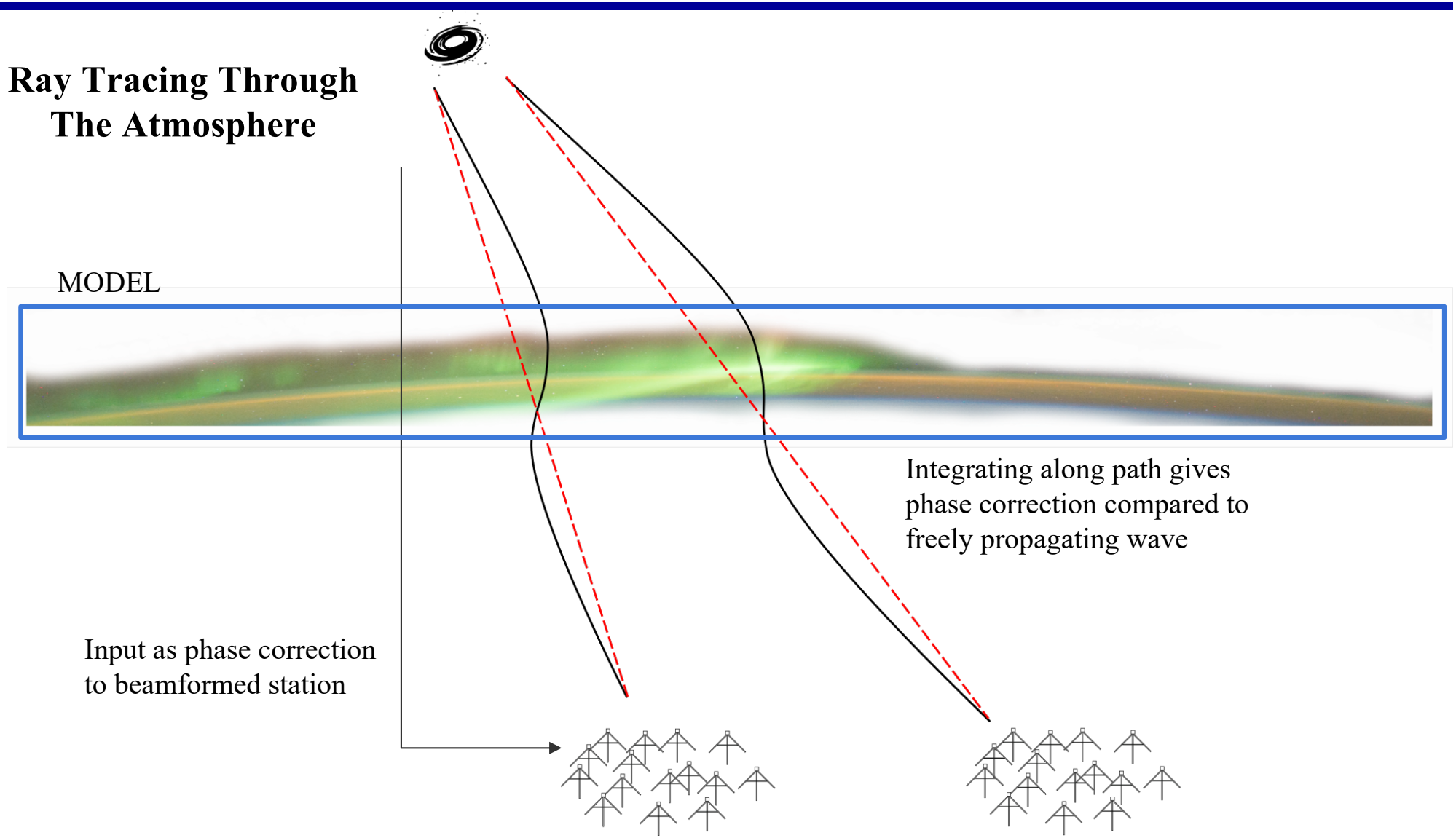
MODEL





Integrating along path gives phase correction compared to freely propagating wave

Ray Tracing Through The Atmosphere



Model

GPSII: GPS Ionosphere Inversion Model

- ➔ Assimilative model
- ➔ Accepts GPS, Digisonde, Known Reference Point
- ➔ Local to Regional Model
- ➔ Second Time Step
- ➔ Generates 3D plasma frequency map

Implement the correction into the data with ray tracer

- ➔ Can be combined with IGRF data

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Final Thoughts

- ➔ Ray Tracing Does Not Provide Wave Effects (Won't predict scintillation)
- ➔ Realtime vs Post Processing
- ➔ Time and Space Resolution
- ➔ Sources of Data: GPS, digisonde, beacon, integrate LWA?
- ➔ LWA astronomic observations integrated into GPSII