



Variability of the Venusian and Martian nightside ionosphere after solar storms

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International Venus Conference
June 2, 2019
Niseko, Japan



NASA Planetary
Science Division
Travel Grant

VARIABILITY OF THE VENUSIAN AND MARTIAN NIGHTSIDE IONOSPHERE AFTER SOLAR STORMS



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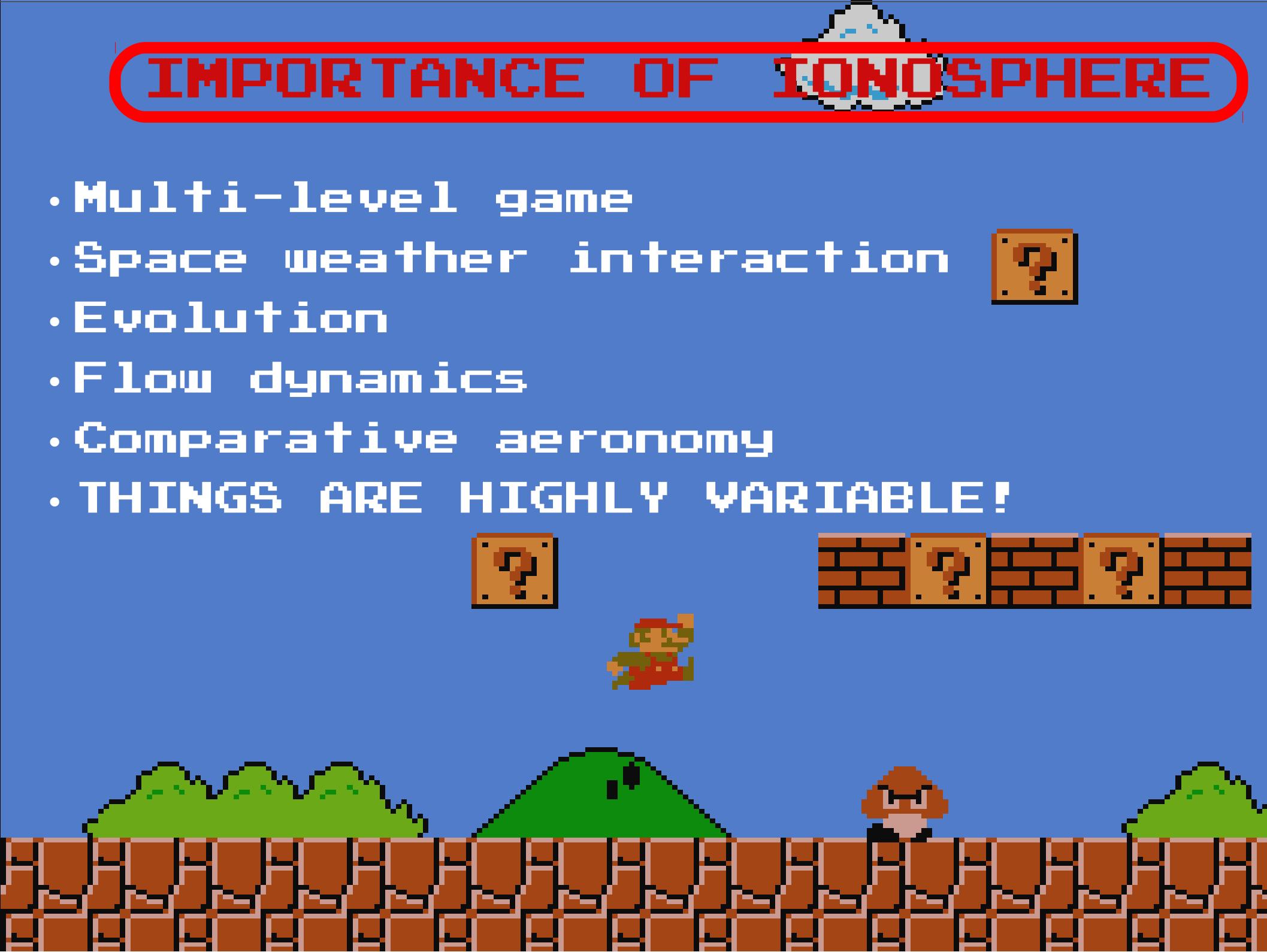
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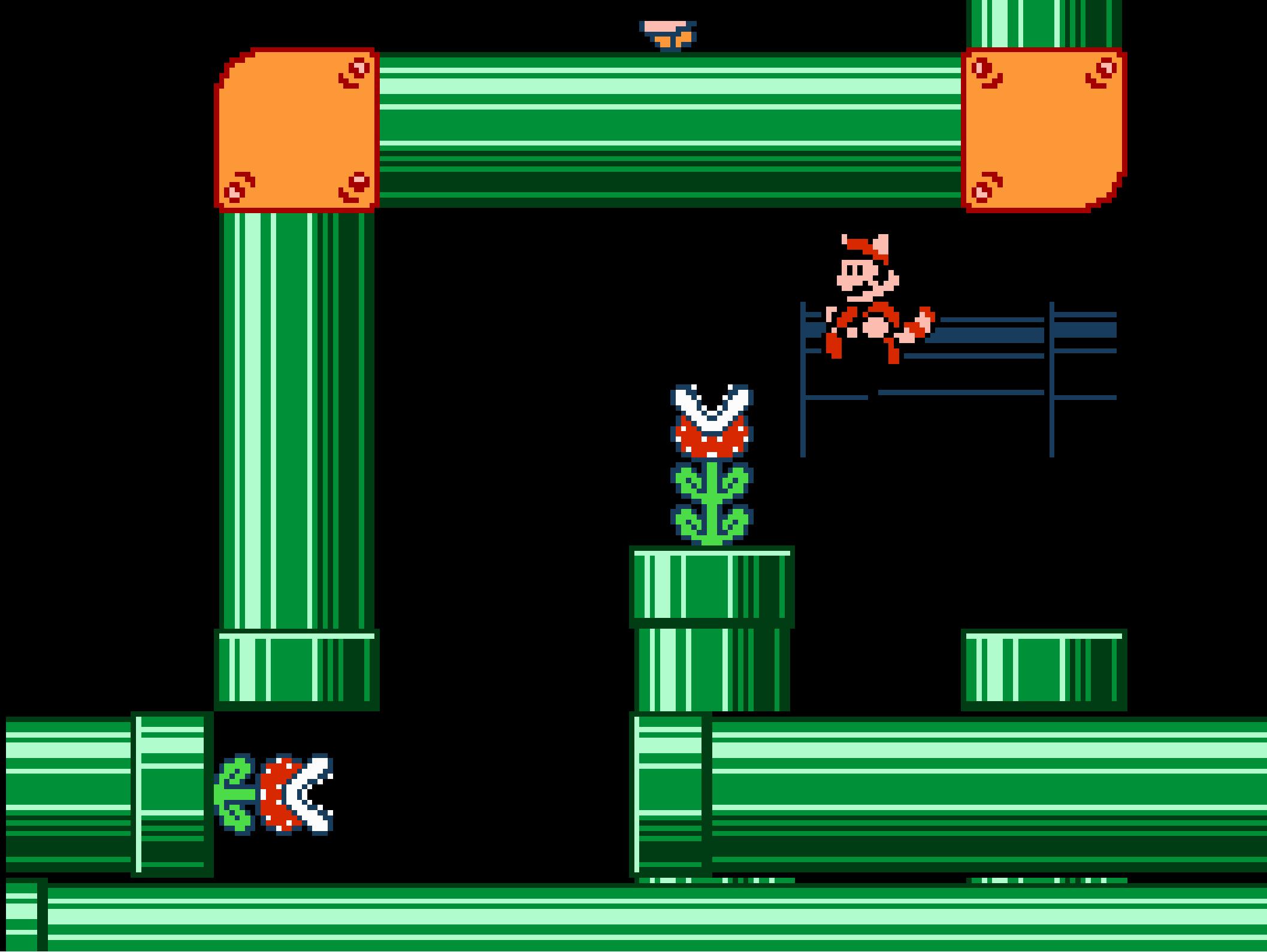
Intern. Venus Conf

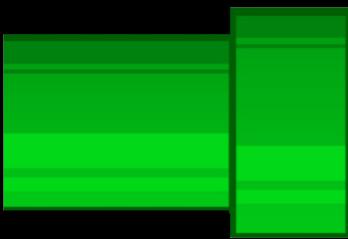
June 2, 2019
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IMPORTANCE OF IONOSPHERE

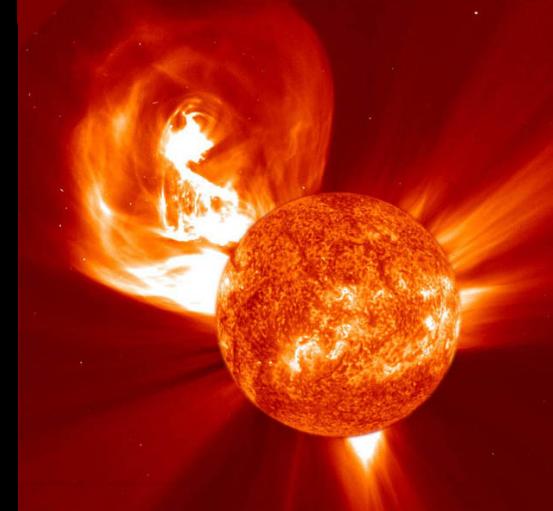
- Multi-level game
- Space weather interaction
- Evolution
- Flow dynamics
- Comparative aeronomy
- THINGS ARE HIGHLY VARIABLE!



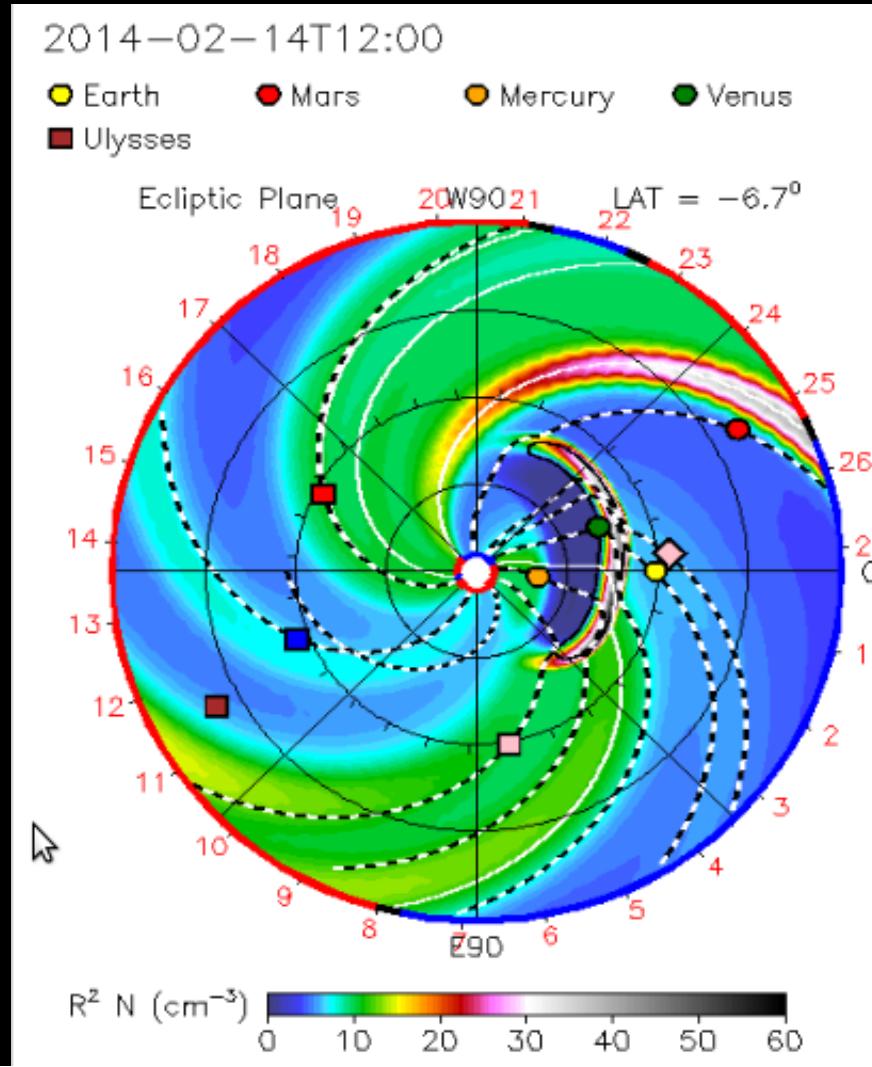




SOLAR INFLUENCE



- **Solar flares**
 - Brightest EUV emission
 - Solar energetic particles
 - Nightglow/aurora
- **Coronal mass ejections**
 - Plasma ejection
 - 1-2 day arrival time
 - Aurora
- **Solar wind streams**
 - Dense solar wind
 - Weaker than CME
 - Longer lasting
 - Aurora



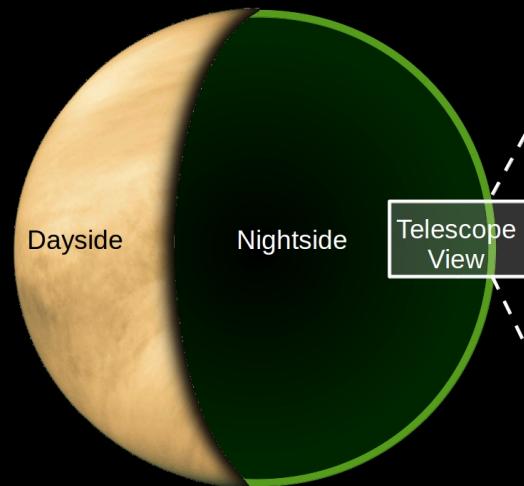
PLAYER ONE

START!

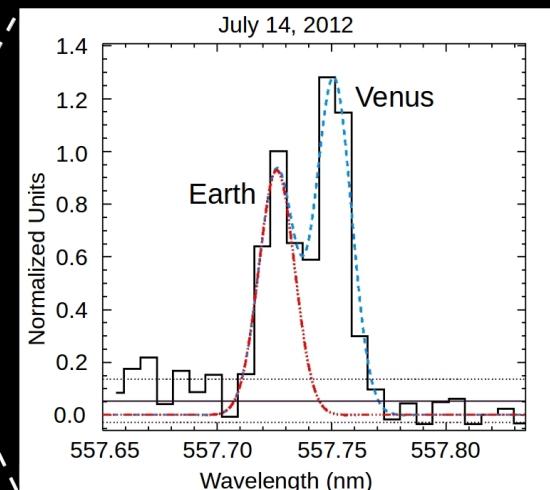


AURORA

- OI 557.7 nm
- Limb
- 2010 – present
- Detected after CMEs

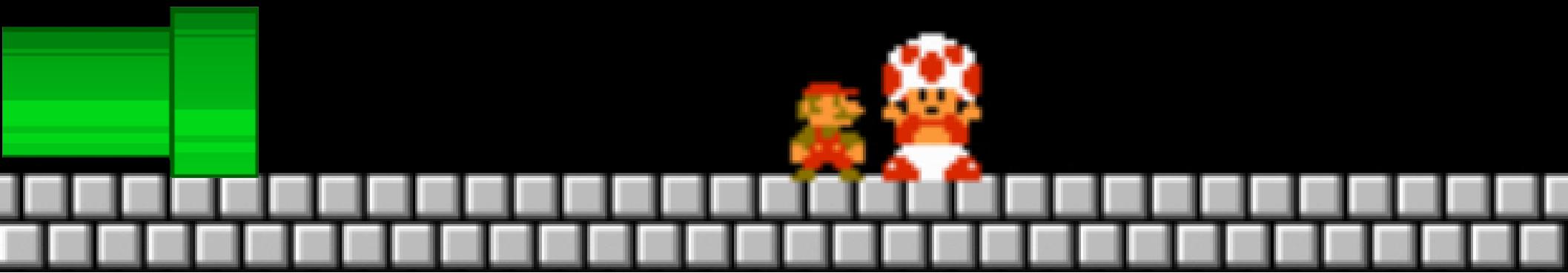


Gray et. al 2014

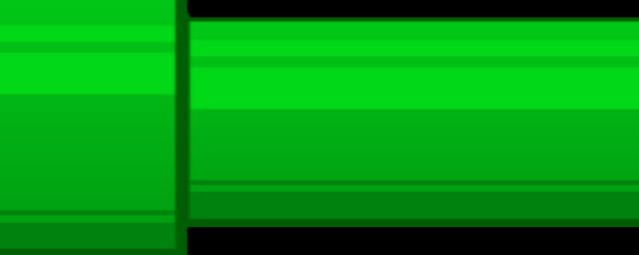


- Apache Point Observatory
- 3.5m ARC telescope
- ARCES high resolution ($R \sim 32,000$) echelle spectrograph

- What space weather conditions trigger auroral emission?
- At what altitude is emission occurring?
- What chemical processes produce auroral emission?
- How does Venus compare with Mars?

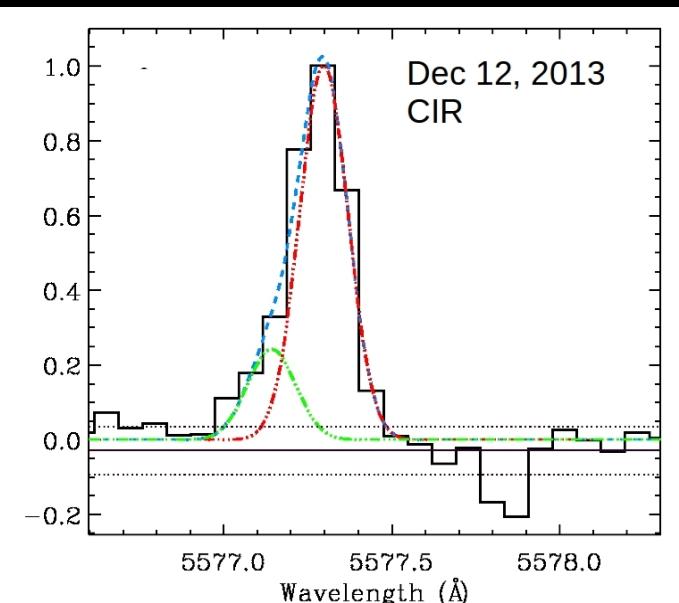
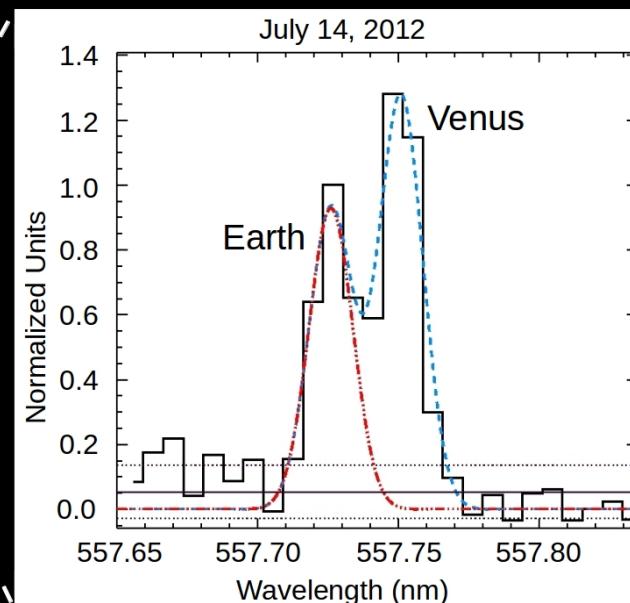
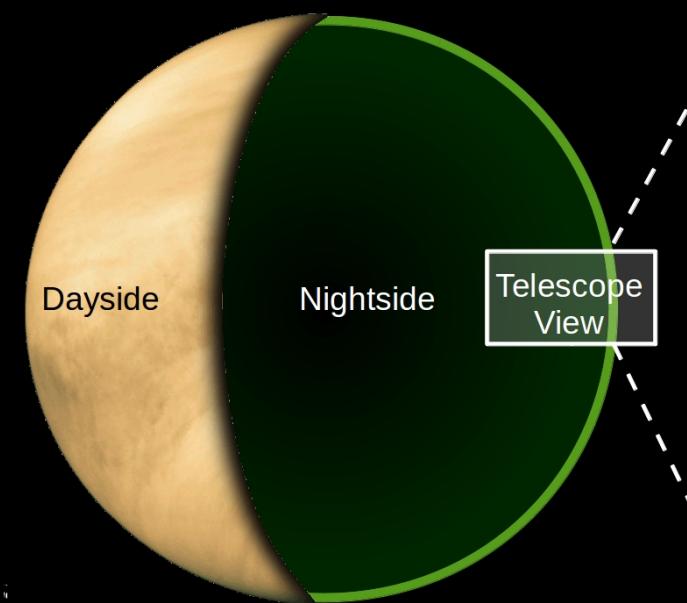


AURORA

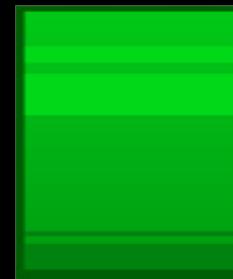


- OI 557.7 nm detected after plasma storms and SEP events
- Weak emission observed after dense solar wind streams
- What's the minimum condition for emission?

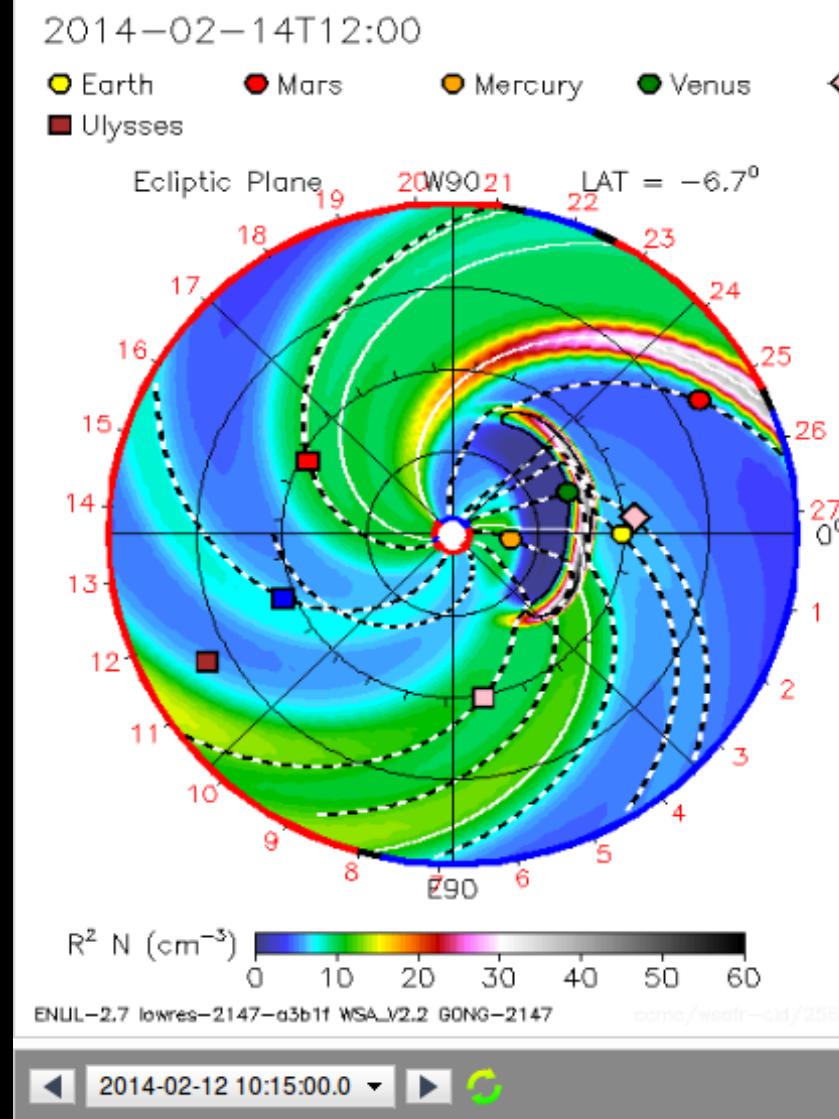
Gray et. al 2014



AURORA



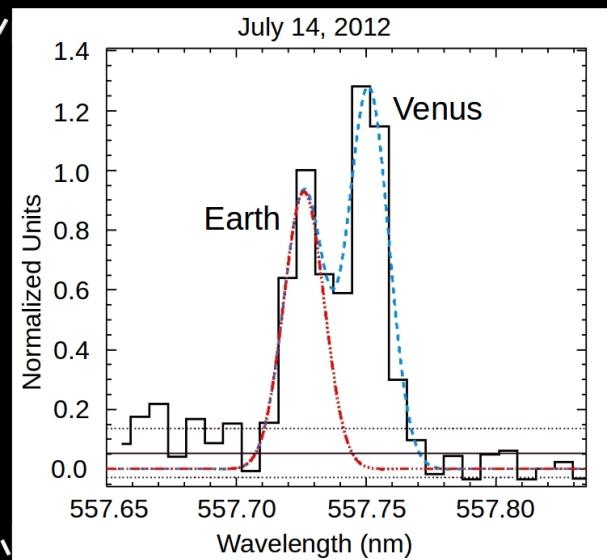
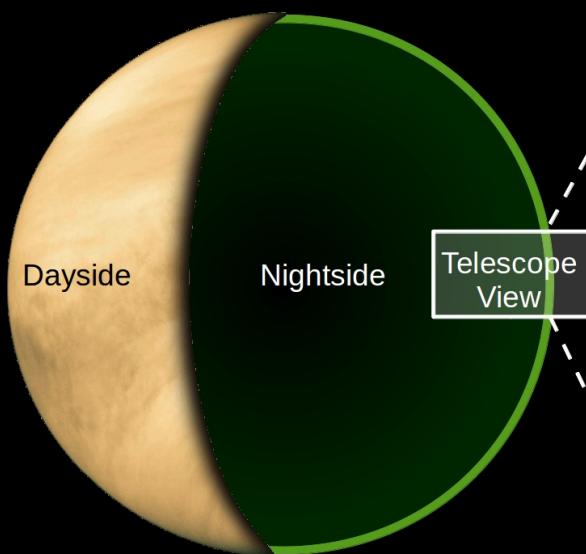
- **13 night campaign at Apache Point Observatory**
- Dec 20 2018 – Jan 7 2019
- **Two solar wind stream passages**
- Stream front conditions vs. full stream



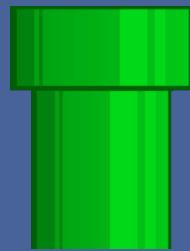
Thank you Observer!
But our data is in another
~~castle!~~
Campaign!

AURORA

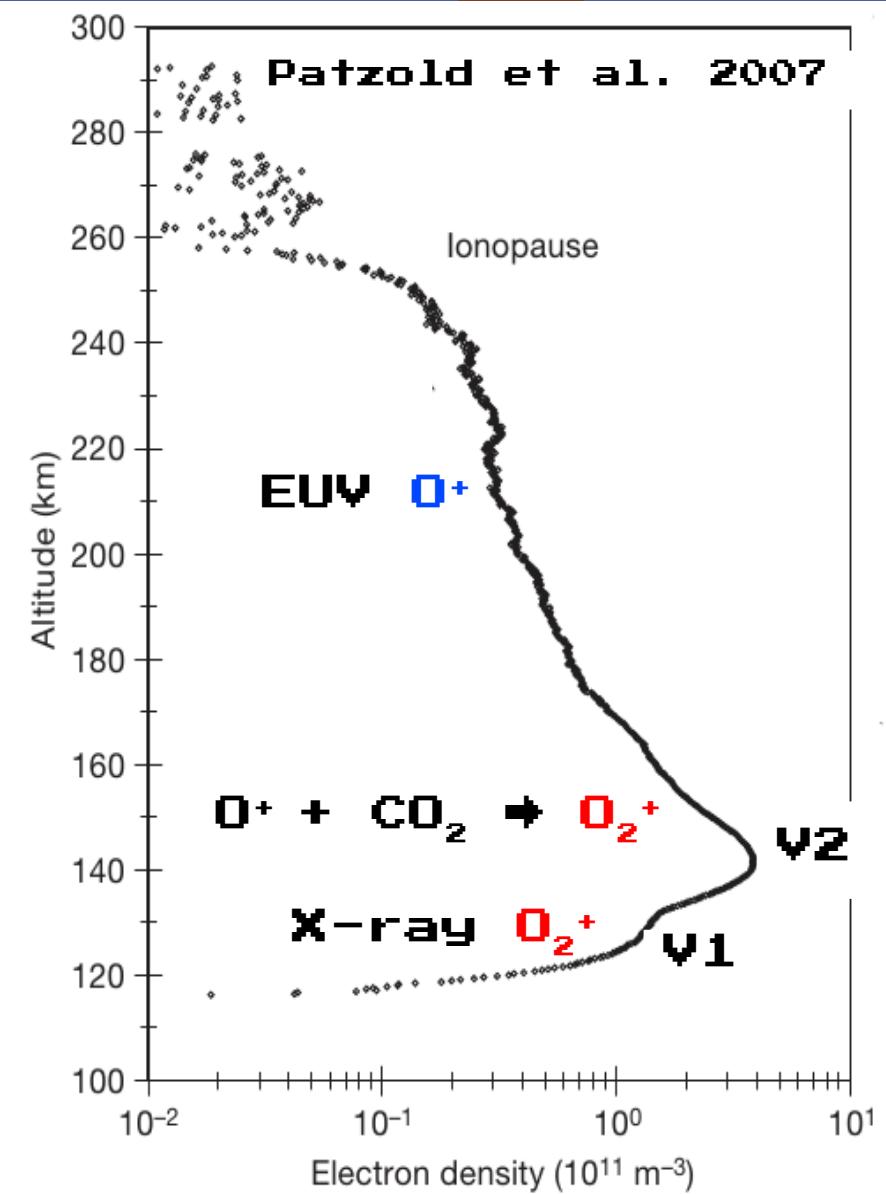
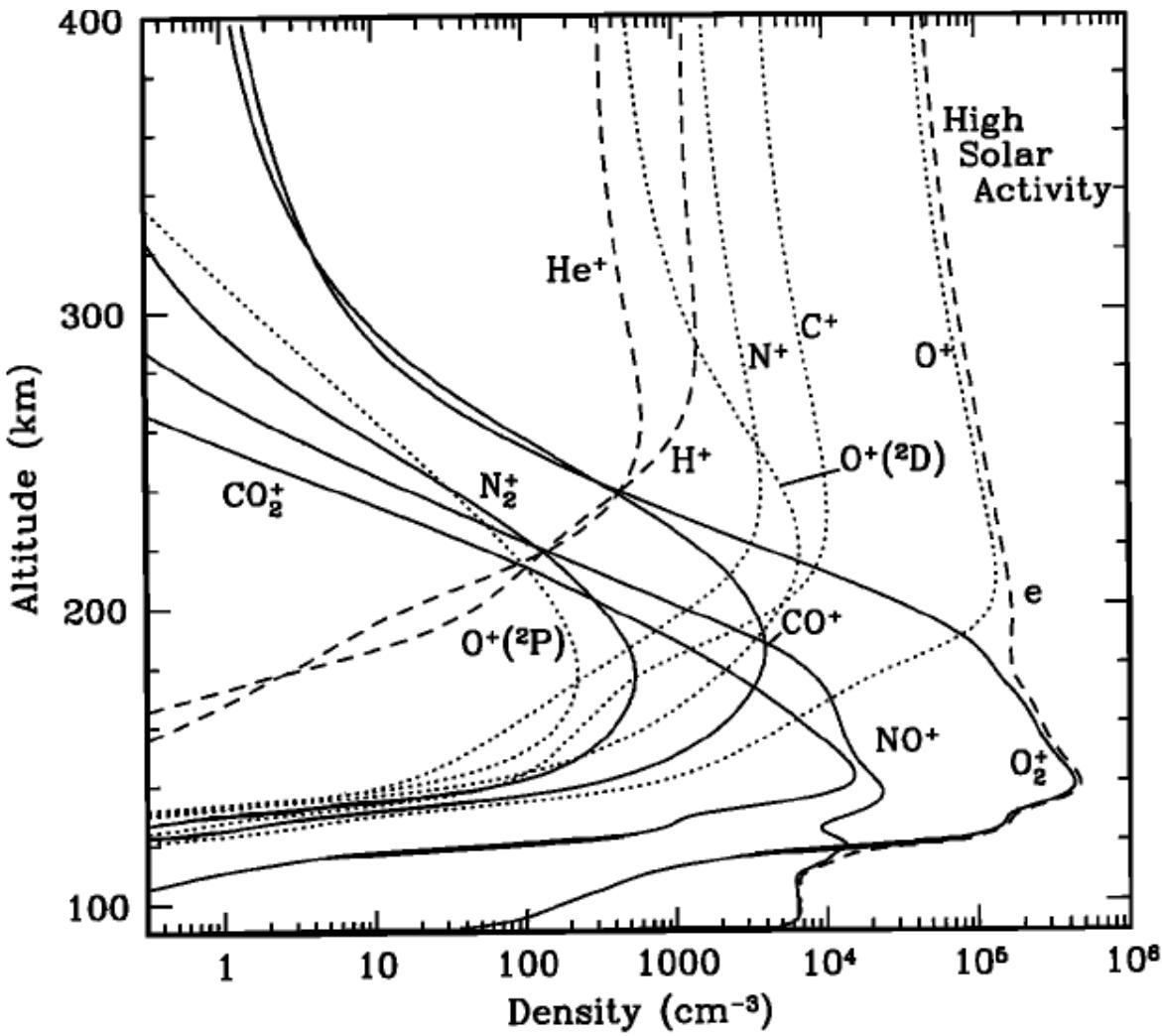
- OI 630.0 nm long lifetime and never detected
- OI 557.7 nm short lifetime
- Indicates deep aurora, below 150 km



VENUS DAY IONOSPHERE

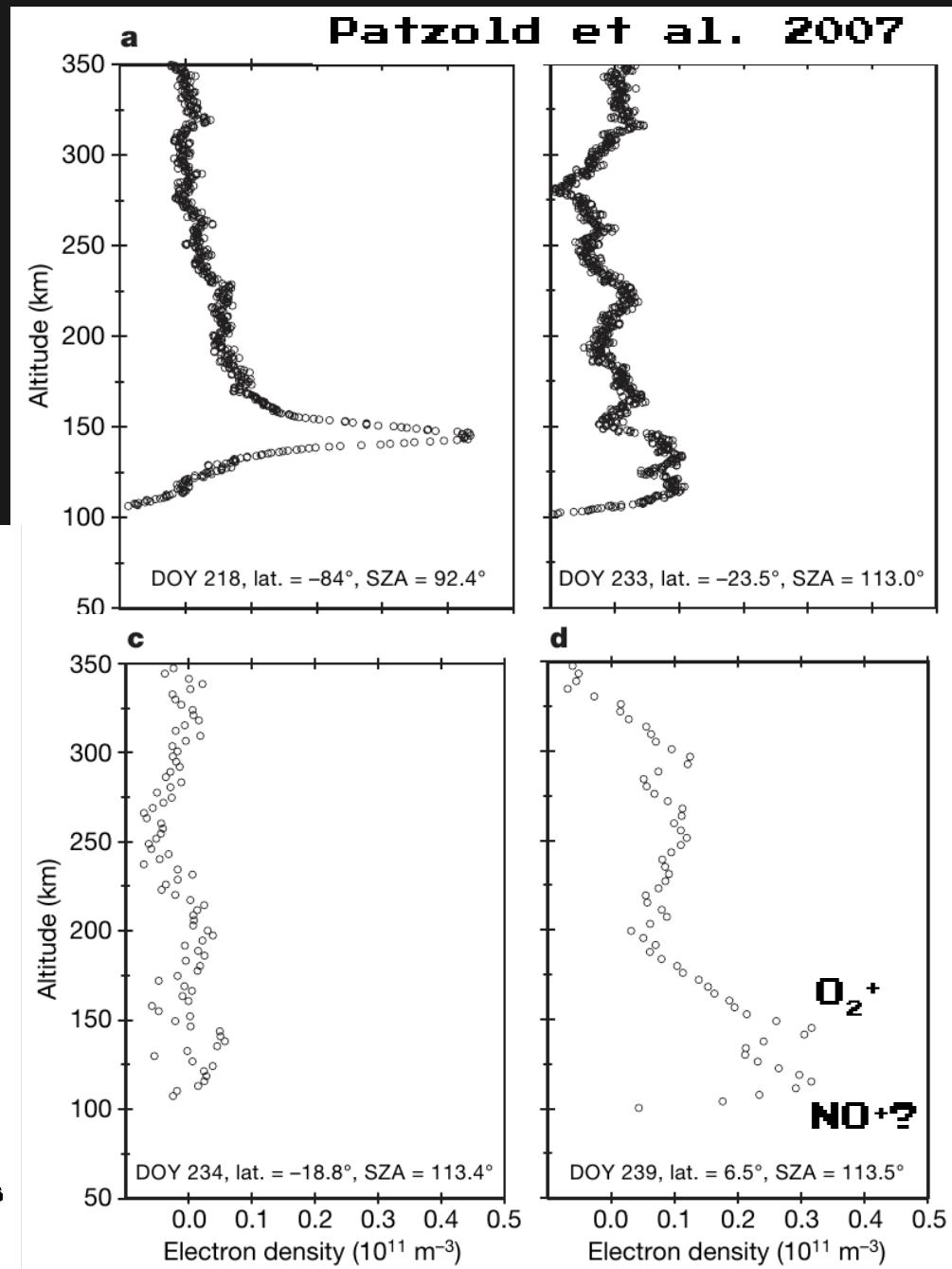
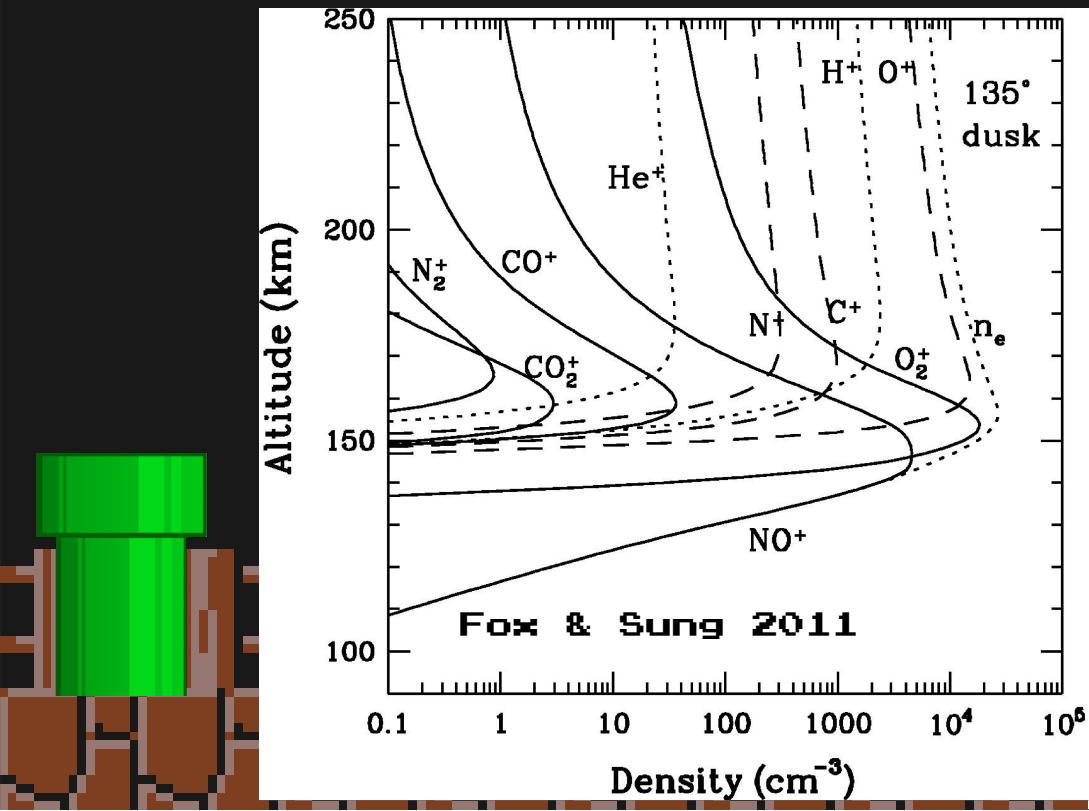


Fox and Sung 2011



VENUS NIGHT IONOSPHERE

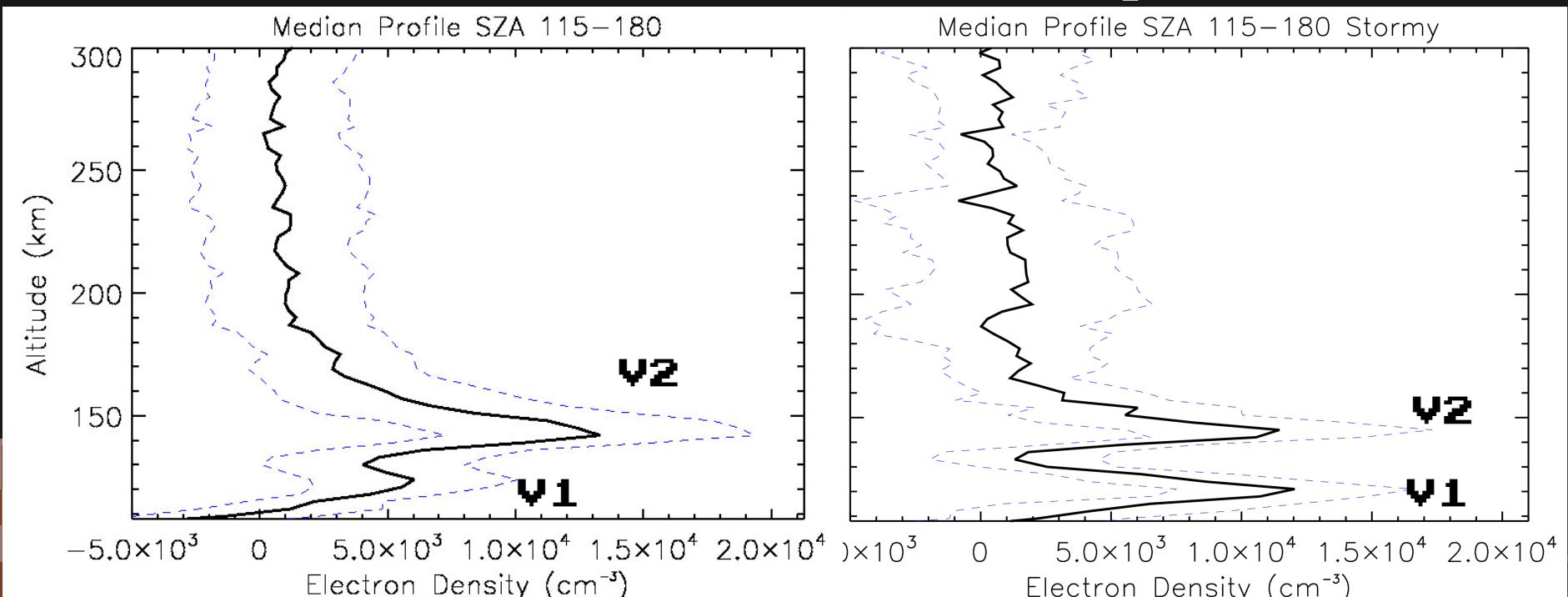
- Nightside ionosphere **HIGHLY** variable
- Ionospheric flow
- Particle precipitation
- V1 source?



VeRA Observations

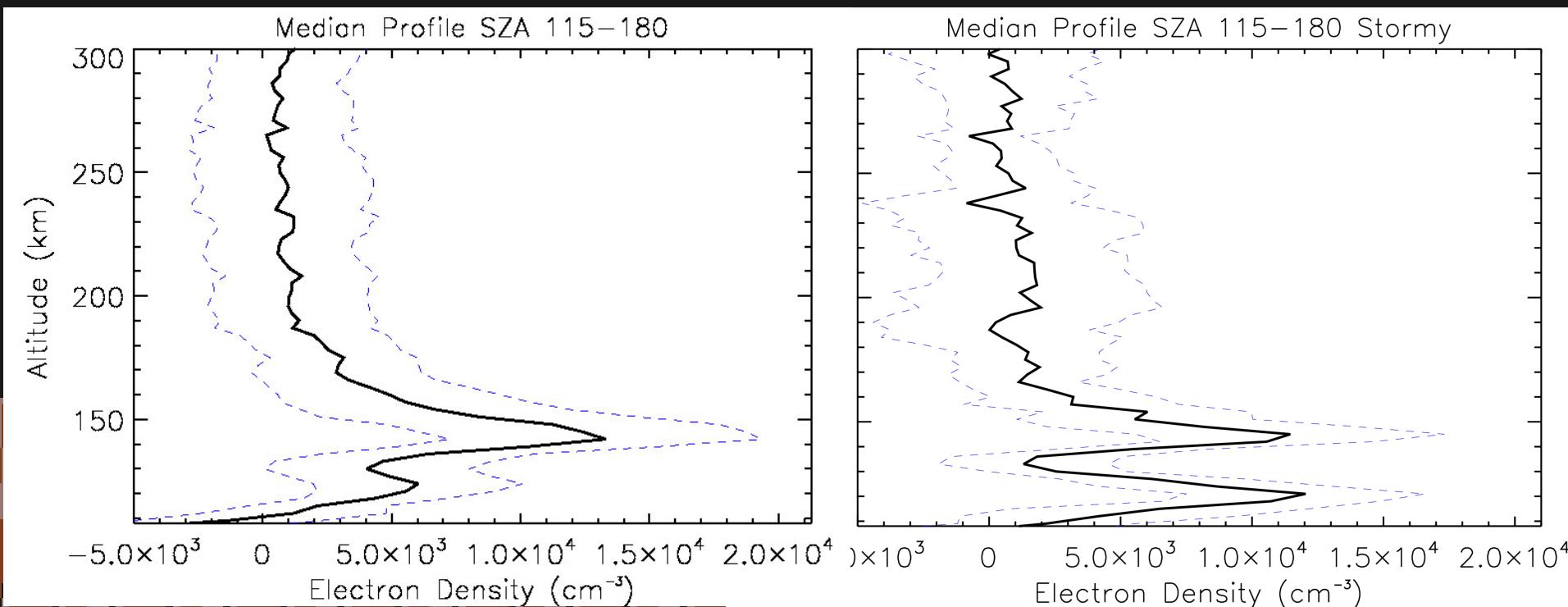
- ψ_1 increase after strong particle storms
- Observed immediately in the deep night
- No time for ion flow
- Coincident with auroral emission
- Aurora from ψ_1 ?

Gray et al. 2017



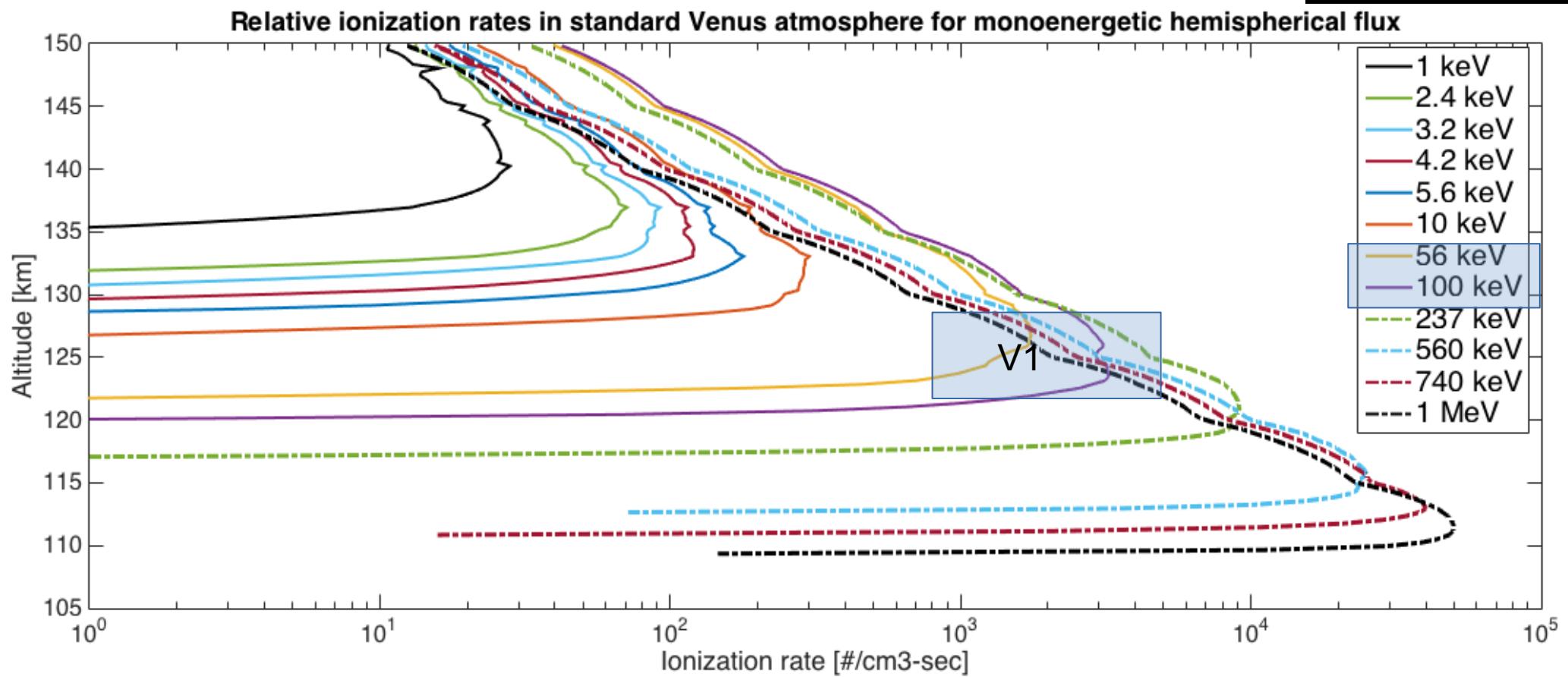
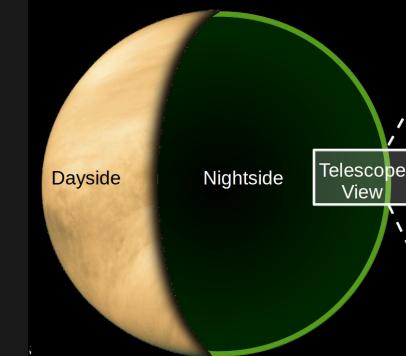
Vera Observations

- What forms the V1 nightside layer?
- NO⁺?
- Proton precipitation known to increase NO⁺ in Earth's ionosphere
- NO⁺ + e \rightarrow O + O(1S)



PROTON PRECIPITATION

- Protons precip directly to nightside
- Gyroradius > Venus radius

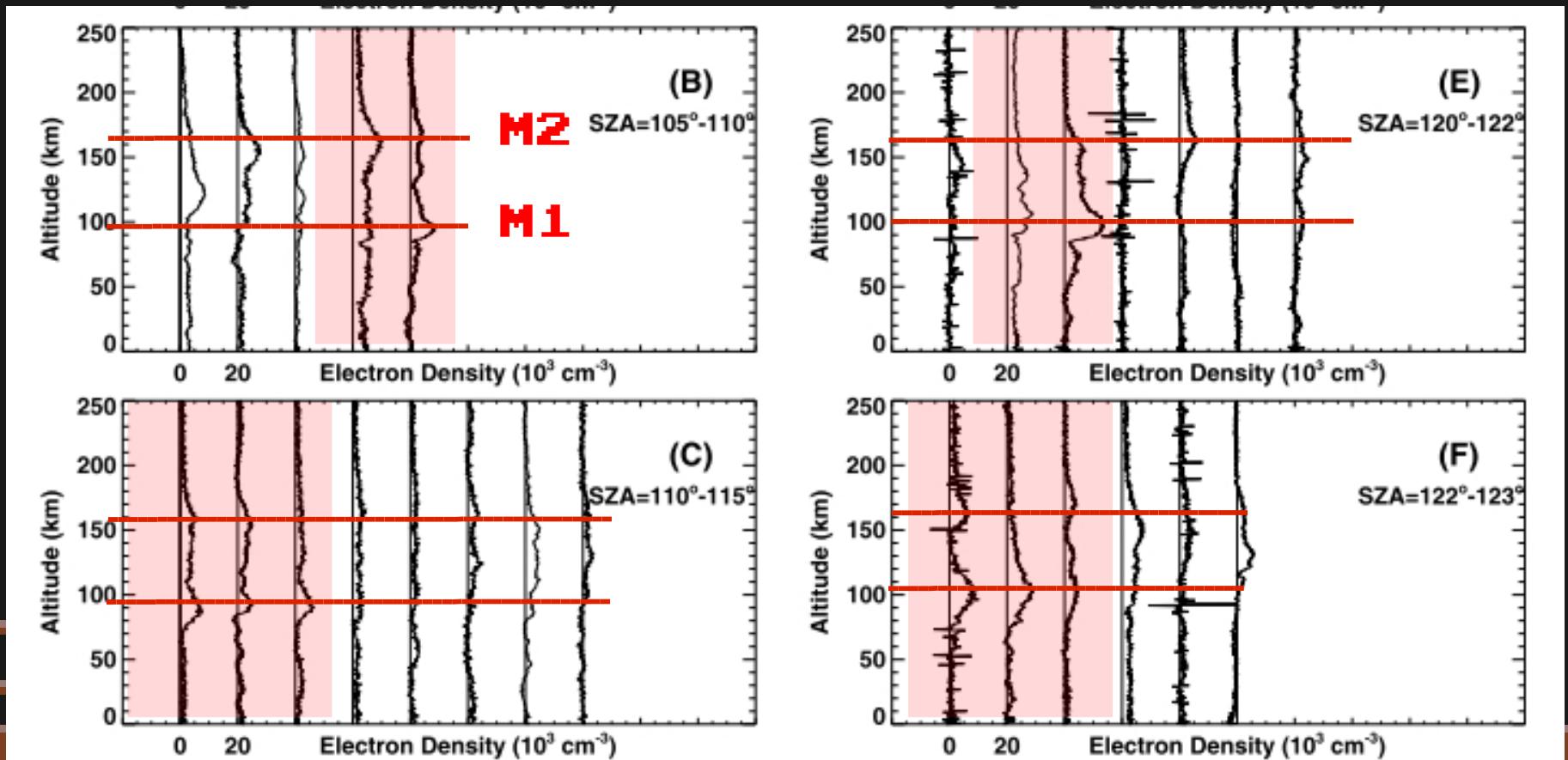


PLAYER TWO

START!

MARS NIGHT IONOSPHERE

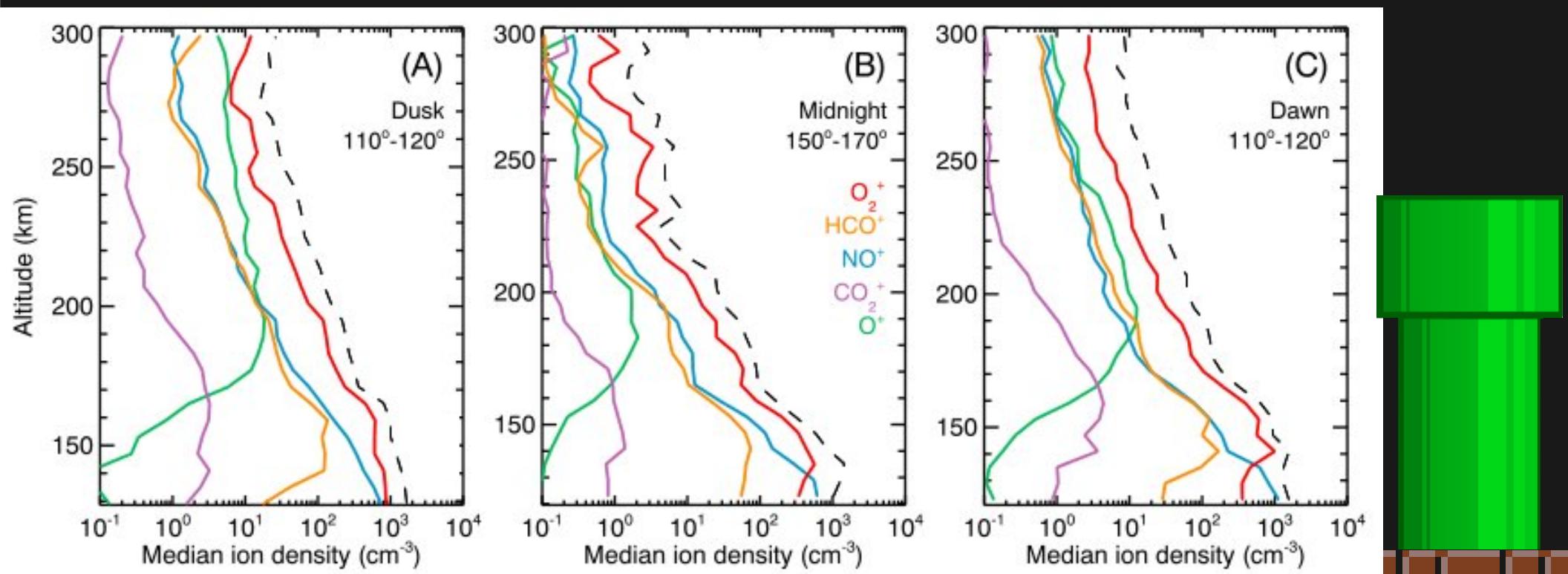
- Nightside ionosphere even more **HIGHLY** variable
- **MAVEN** electron profiles show same behavior as Venus after particle storms



Withers et al. 2012

MARS NIGHT IONOSPHERE

- Median ion profiles measured by MAVEN (Girazian et al. 2017)
- NO^+ increase with decreasing altitude
- What happens after solar storm?



MARS NIGHT IONOSPHERE

- 4 years of **MAVEN** Ion Neutral Gas Mass Spectrometer (INGMS) data



MARS NIGHT IONOSPHERE

- 4 years of Ion Neutral Gas Mass Spectrometer (INGMS) data
- Nightside



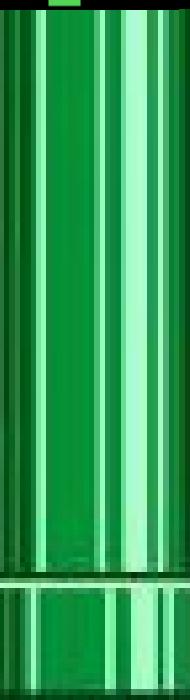
MARS NIGHT IONOSPHERE

- 4 years of Ion Neutral Gas Mass Spectrometer (INGMS) data
- Nightside
- Deep dip < 140 km



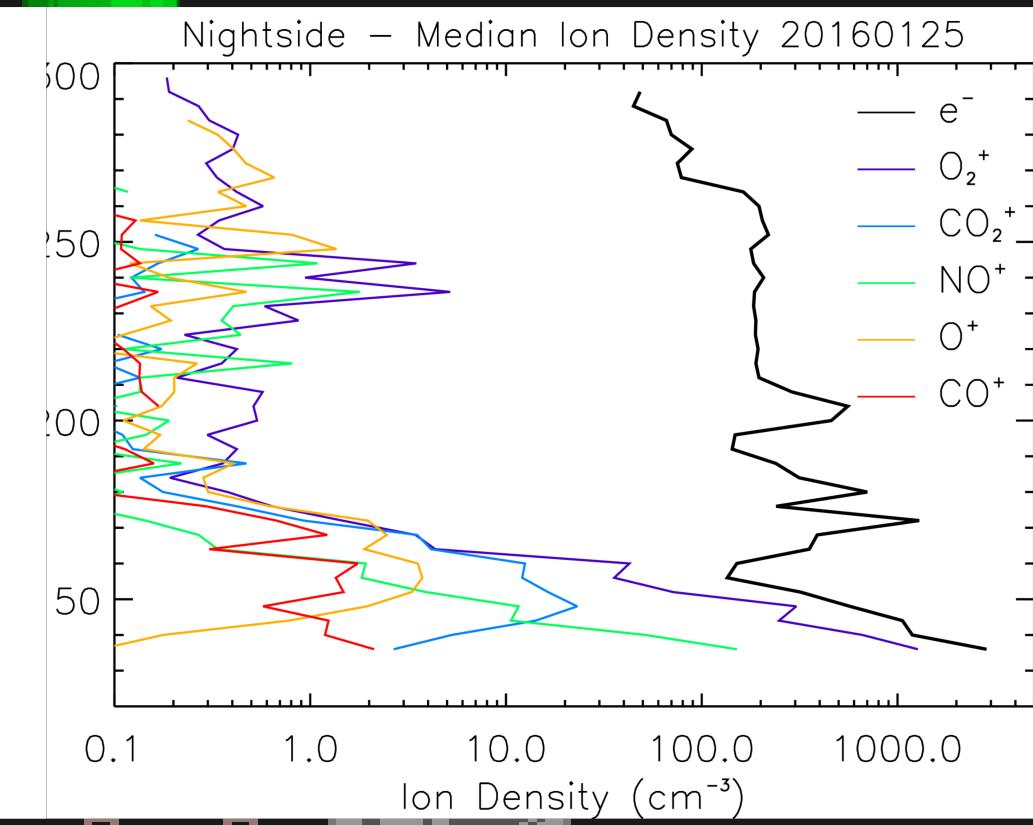
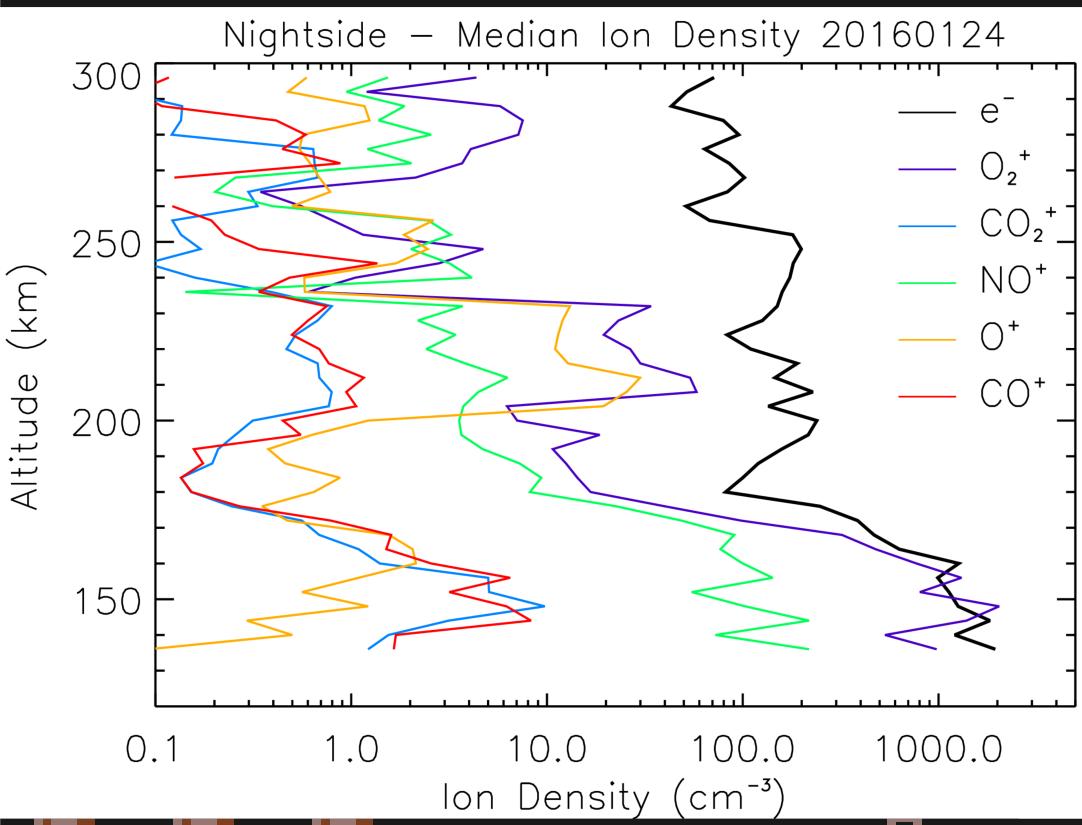
MARS NIGHT IONOSPHERE

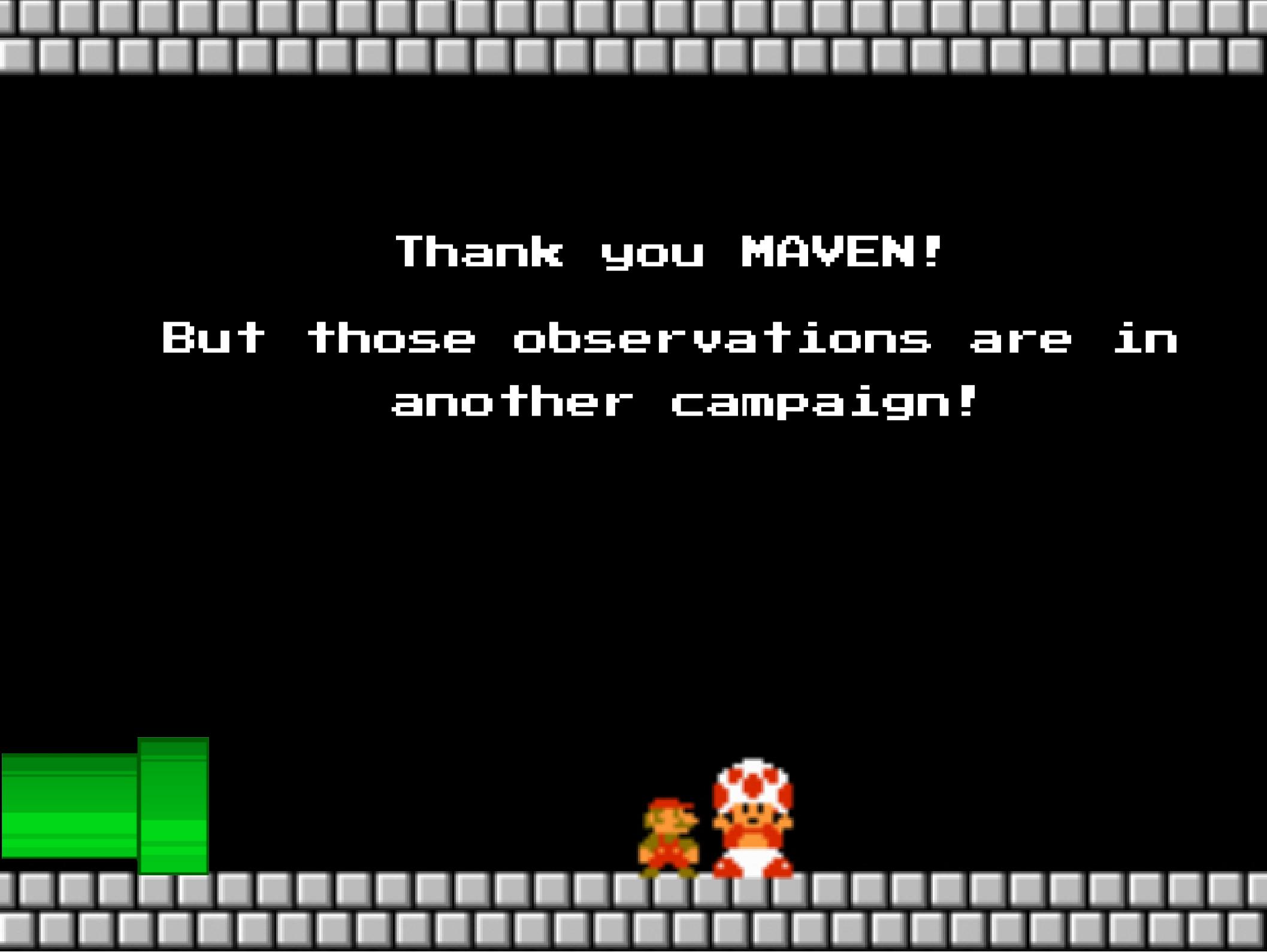
- 4 years of Ion Neutral Gas Mass Spectrometer (INGMS) data
- Nightside
- Deep dip < 140 km
- Northern hemisphere



MARS NIGHT IONOSPHERE

- One dense solar wind stream passage
- Jan 24 – 29, 2016
- Too weak?





Thank you MAVEN!

But those observations are in
another campaign!

IT'S DANGEROUS TO GO ALONE!
TAKE THIS.

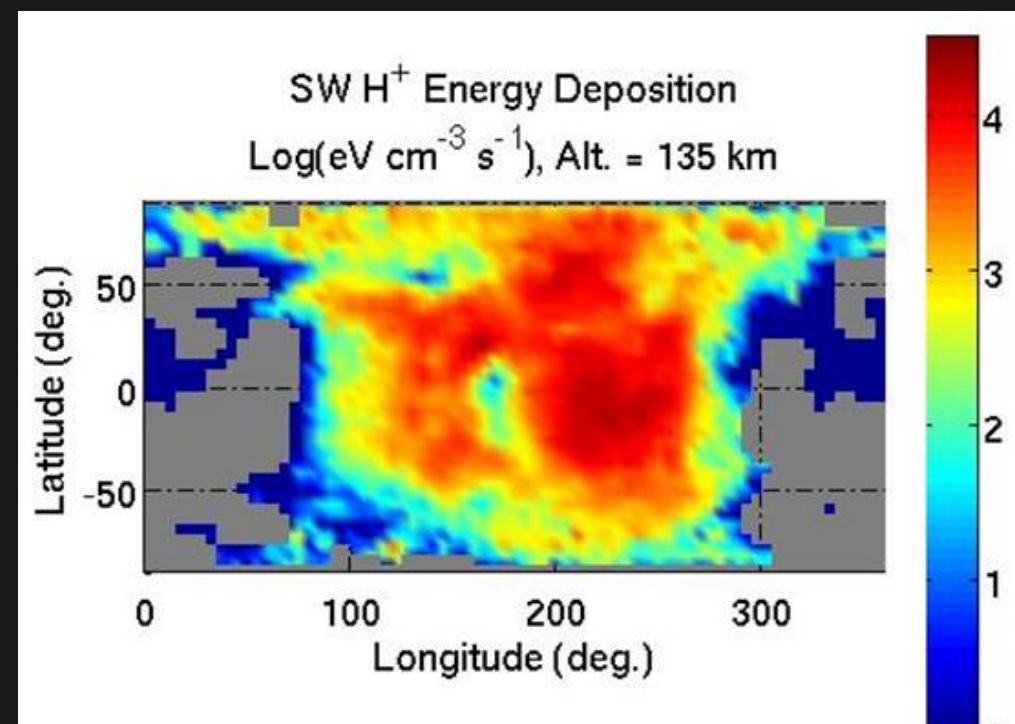


HALFSHEL



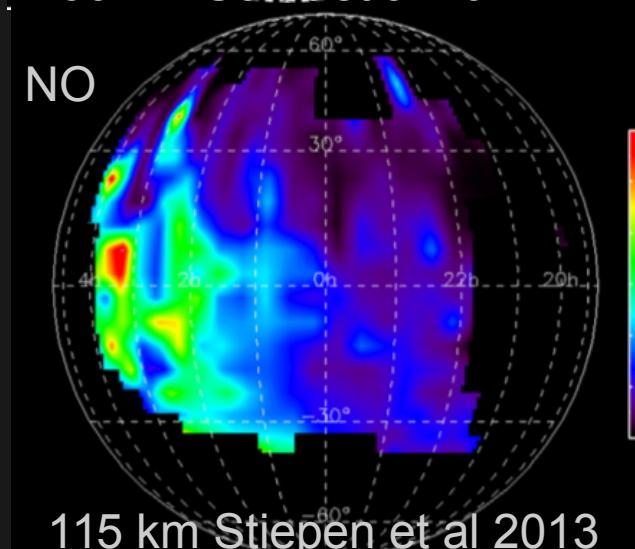
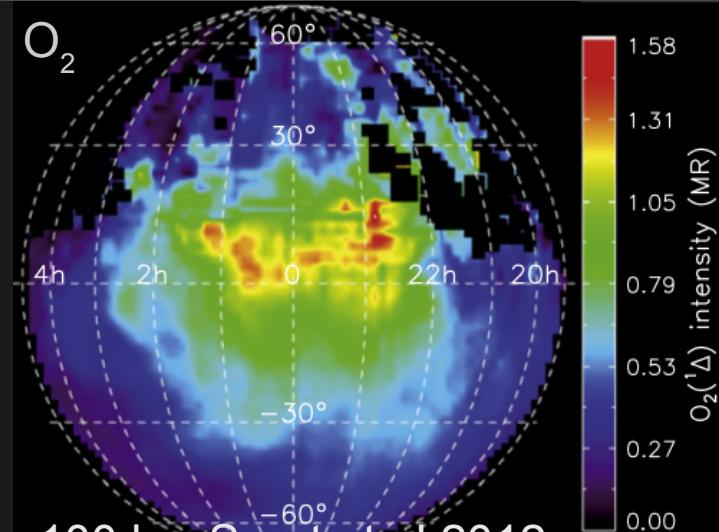
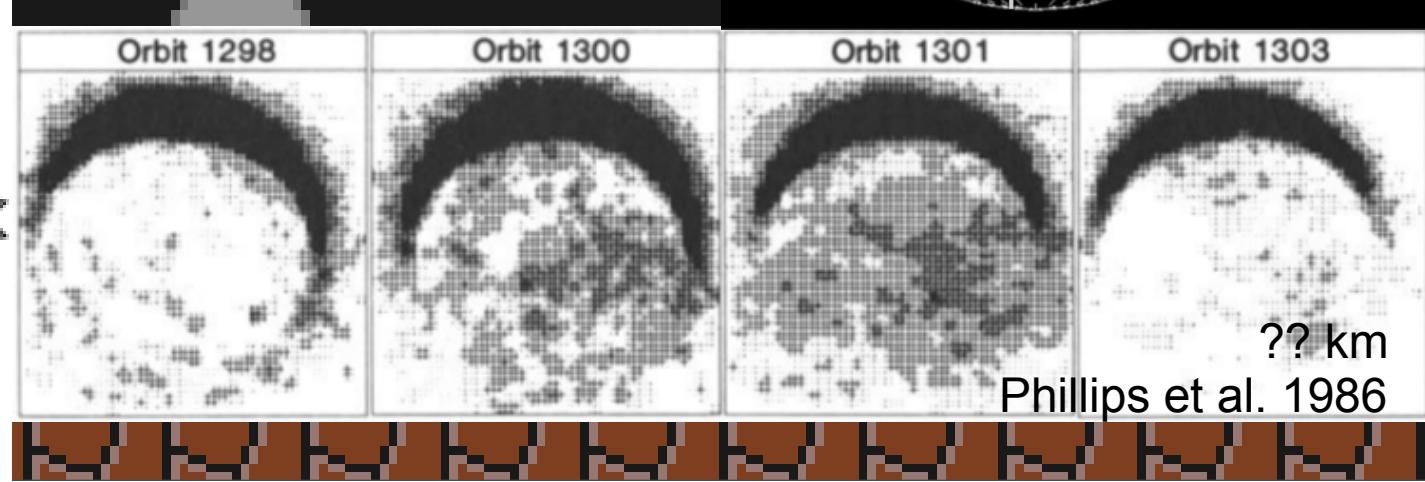
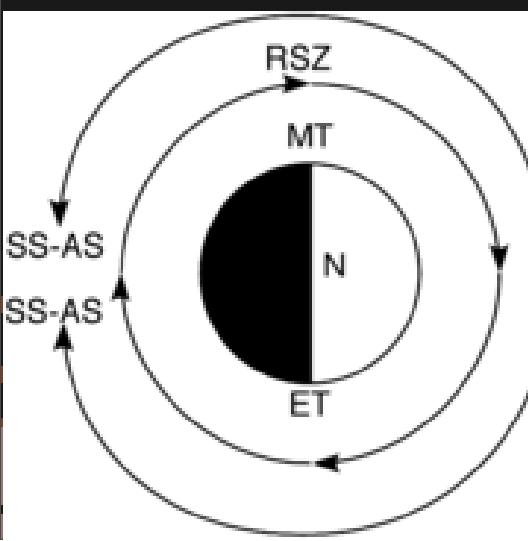
HALFSHEL

- Brecht et al. 2016
- Hybrid particle code
- Solar wind interaction with neutral and ionized upper atmosphere
- Deposition of protons
- Composition of V1/M1
- Auroral emission



HALFSHEL

- **O₂ IR nightglow - SSAS**
- **NO nightglow offset to dawn - retrograde super rotation**
- **Auroral offset to dawn, Phillips et al. 1986**
- **HALFSHEL exhibits dawn offset**
- **Solar wind**

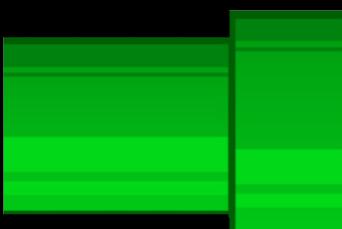


Thank you Observer!

But we really need more data!

Ground Obs - **Spacecraft** - Modeling

- Solar wind sampling - high and low energy
- Nightside IR-UV imaging spectrometer
- Sampling of low ionosphere



Funding



THANK YOU!