



# Magnetosphere- Ionosphere Coupling

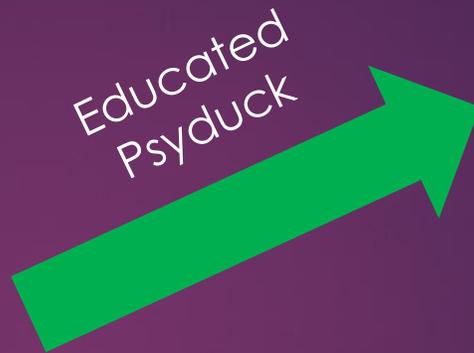
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GEM SUMMER WORKSHOP STUDENT TUTORIAL

19 JUNE 2016

# Outline

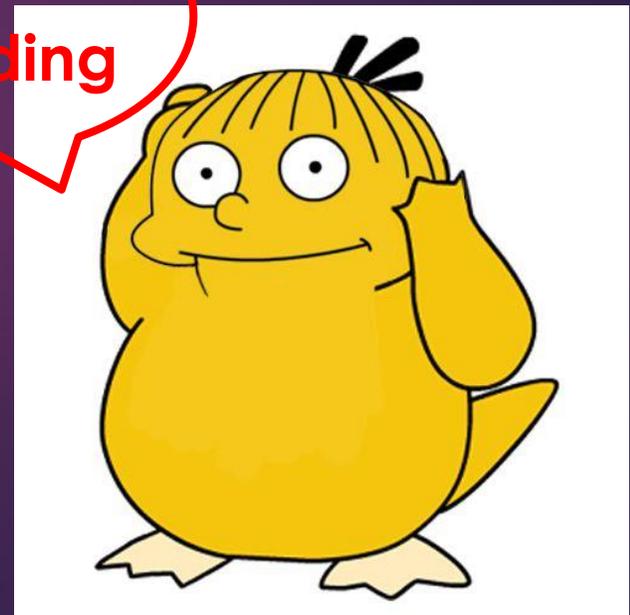
- ▶ Magnetosphere (1 slide)



Educated  
Psyduck



Ralph Wiggum  
Psyduck



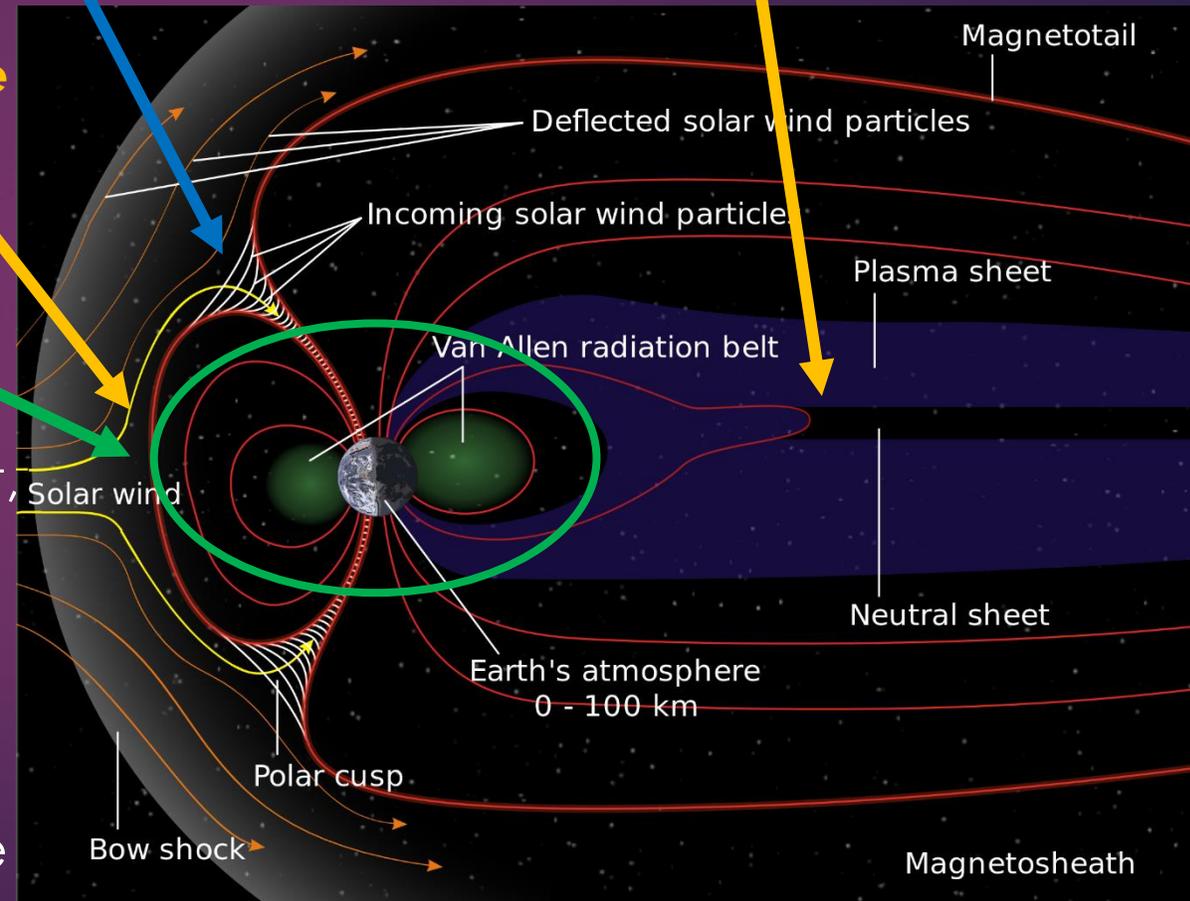
# Magnetosphere

Particles enter via nightside  
Magnetic Reconnection

Solar Wind particles

Particles enter via dayside  
Magnetic Reconnection

Plasma waves (chorus,  
EMIC, ULF, etc.)



▶ Key regions: plasma sheet, ring current, plasmasphere, radiation belts, magnetotail

▶ MI Coupling in a nutshell: any plasma or energy that can travel between the magnetosphere and the ionosphere

Picture courtesy of NASA

# The Ionosphere

- ▶ A region of atmosphere characterized by the presence of neutrals and a source of ionization (typically either photoionization or impact ionization).
- ▶ Earth's Ionosphere: ~60 km - ~1000 km.
- ▶ Provides plasma for plasmasphere (more on this later).
- ▶ Dissipates energy obtained through the magnetosphere by Field Aligned Currents (FAC).

# The Ionosphere

▶ Earth's Ionosphere is comprised of multiple layers:

▶ D (60 km – 90 km)

- $NO^+$
- High recombination rate

▶ E (90 km – 150 km)

- $O_2^+$
- Source high/low ultraviolet/x-rays

▶ F

- Two regions on dayside, merge on night-side

▶ F1 (150 km – 220 km)

- $O_2^+, O^+, \text{ and } NO^+$

▶ F2 (220 km – 1000 km)

- $H^+ \text{ and } He^+$

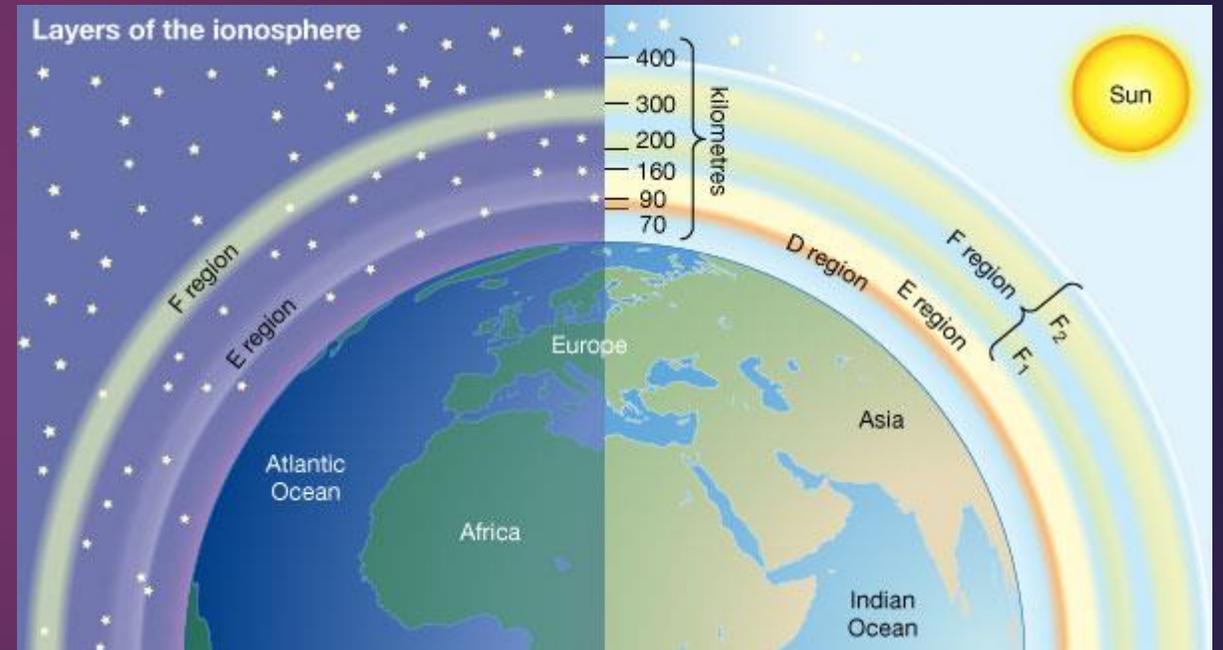


Figure from Encyclopedia Britannica

# MI Coupling

- ▶ Current flows along the field lines between the Ionosphere and Magnetosphere as the field line convect from sunward to tailward.
- ▶ Currents may be driven by solar wind, interplanetary magnetic field, or by bulk plasma movements.
- ▶ As the plasma moves, a dawn to dusk electric field is created. This electric field reaches the high-latitudes of the ionosphere.
- ▶ FAC develop (a.k.a. Birkeland currents).
  - Region 1 ( $67^\circ - 75^\circ$  latitude), flows from dawn to dusk, coupled to outer magnetosphere
  - Region 2 ( $63^\circ - \sim 68^\circ$  latitude), flows from dusk to dawn, coupled to the partial ring current

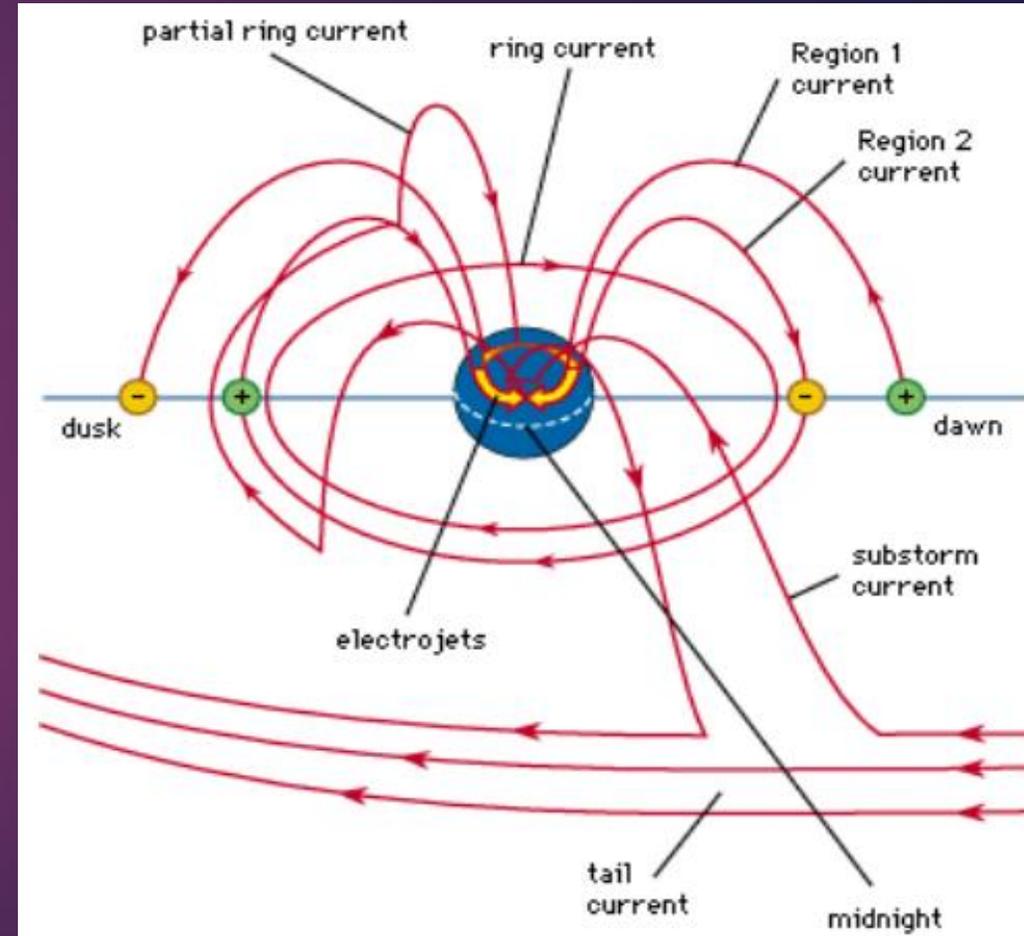


Figure from Encyclopedia Britannica

# MI Coupling Cont.

- ▶ Highly collisional and anisotropic
- ▶ Hall Currents- Orthogonal to  $\vec{E}$  and  $\vec{B}$ 
  - $$\sigma_H = - \left( \frac{\omega_g}{v_e^2 + \omega_e^2} + \frac{m_e}{m_i} \frac{\omega_i}{v_i^2 + \omega_i^2} \right) \frac{n_e e^2}{m_e}$$
- ▶ Pederson Currents- Parallel to  $\vec{E}$ , when  $v > \omega_g$ 
  - $$\sigma_P = \left( \frac{v_e}{v_e^2 + \omega_e^2} + \frac{m_e}{m_i} \frac{v_i}{v_i^2 + \omega_i^2} \right) \frac{n_e e^2}{m_e}$$
- ▶ Horizontal Hall currents add to Pederson currents
- ▶ Parallel Currents

$\omega_{e/i}$  is the electron/ion gyrofrequency  
 $\nu_{e/i}$  is the electron/ion collision frequency

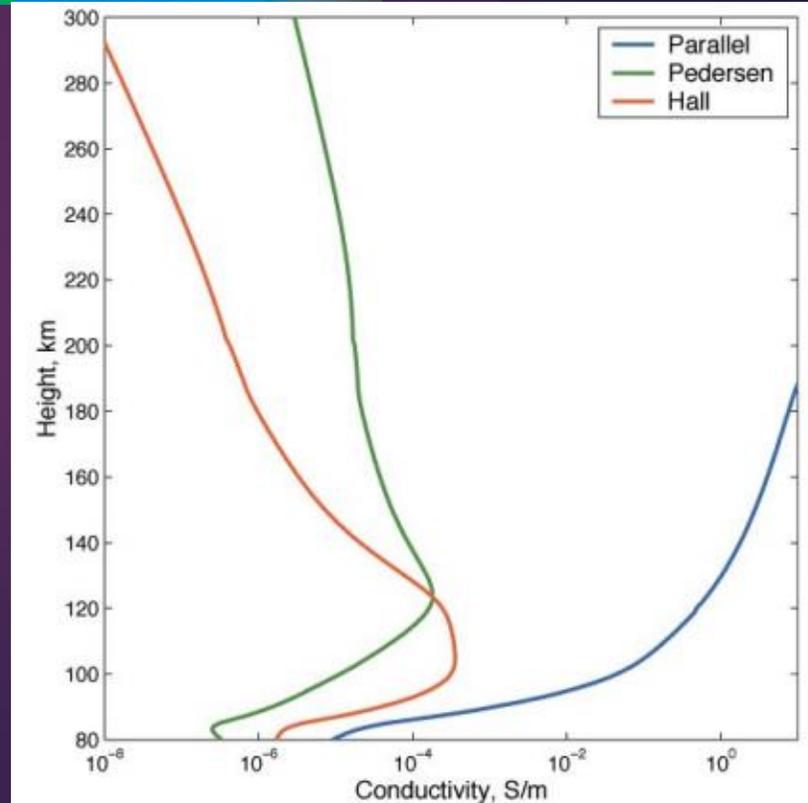
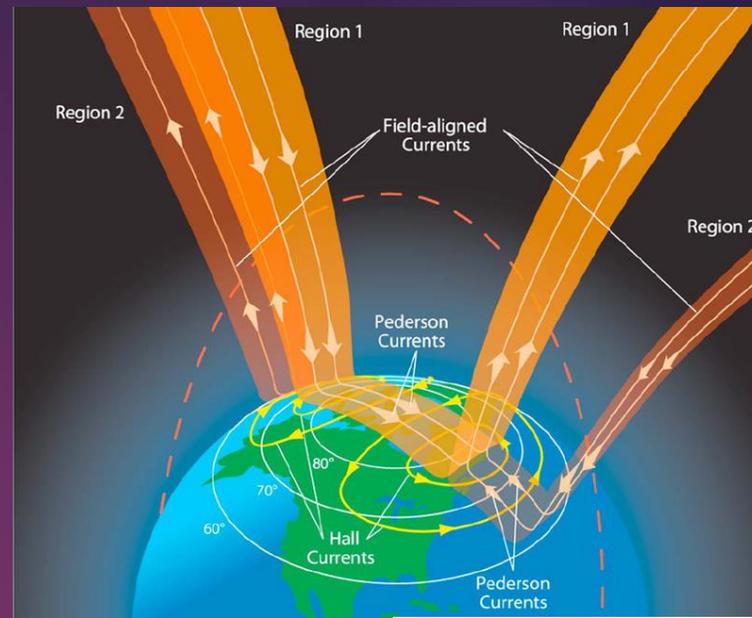


Figure from Baumjohann and Treumann, [1997]

# MI Coupling Effects

## ► Ionospheric outflow

- Dissipated energy from magnetosphere energizes ionosphere plasma populations.
- Enhanced electric and magnetic fields give the ions an  $\vec{E} \times \vec{B}$  drift. Ions then collide with neutrals. This heats the ions and generates a pressure gradient which draws them up the field line into the magnetosphere.
- Electrons that precipitate into the ionosphere also cause pressure gradients and ambipolar electric fields. Ions react to this ambipolar electric field, and move up the ionosphere.
- $O^+$  populations, during geomagnetic storms, are given enough energy to escape the ionosphere and get into the magnetosphere.

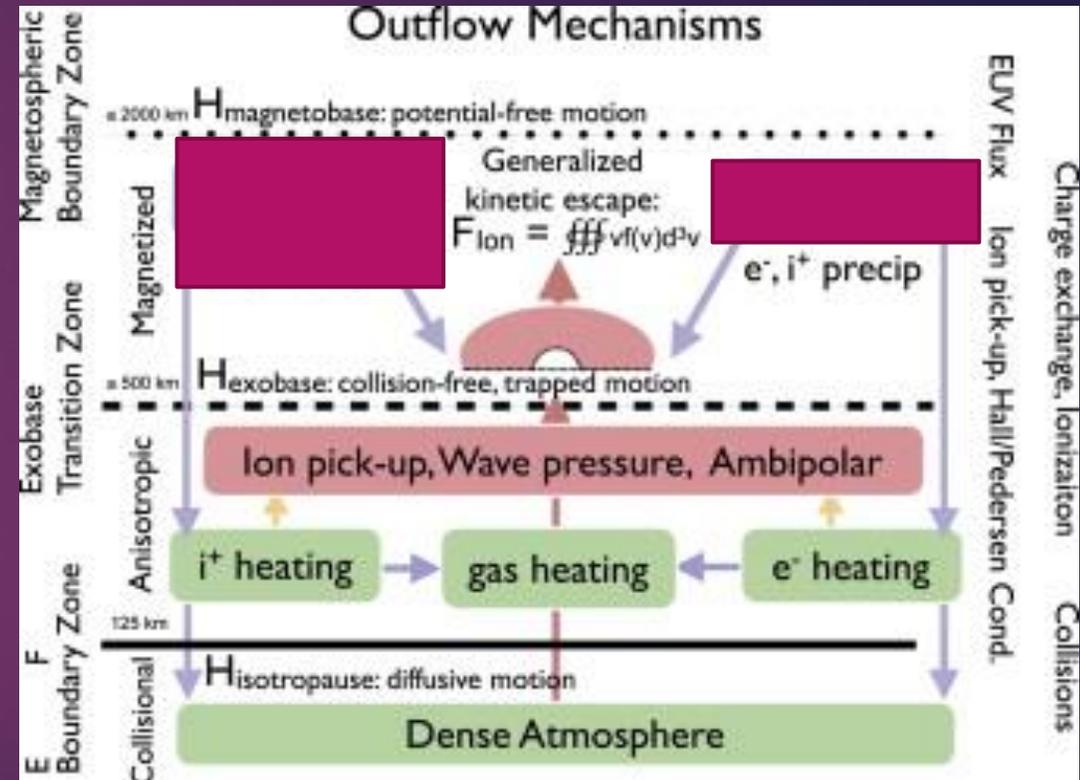


Figure from Moore *et al.*, [2014]

# MI Coupling Effects Cont.

- ▶ Ionospheric outflow gets plasma into the magnetosphere.
- ▶ New plasma populations can lead to the generation of plasma waves (e.g., EMIC).
- ▶ These newly generated waves interact with particles. Some energized particles precipitate back to the Earth.

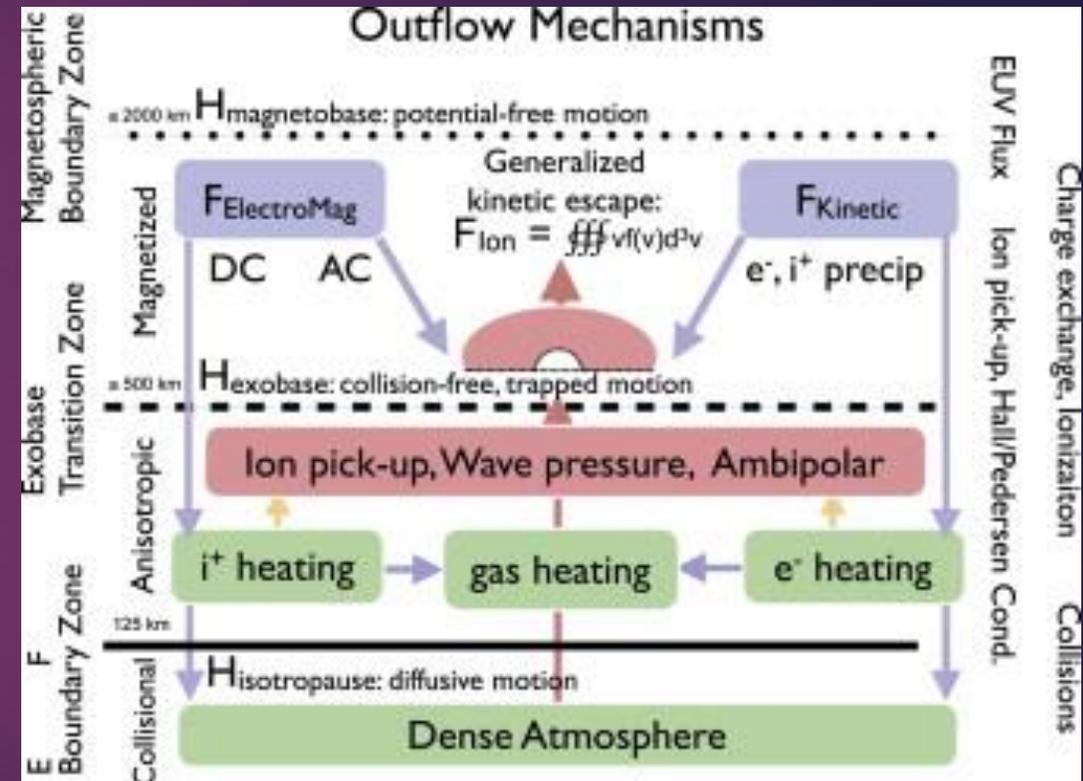


Figure from Moore *et al.*, [2014]

# Some GEM S

- ▶ “Storm-time Inner M  
Magnetosphere Cr
- ▶ “Merged Modeling  
into the Magnetosp

THIS LOOKS  
LIKE A JOB



FOR PSYENCE

on + Inner

eric Plasma

# Questions, Comments, Concerns?



# Bibliography

## ▶ Psyduck photos

- “Lights, Camera, Quack-tion.” *Pokémon*. 4Kids. 8 Oct. 1999. Television
- amy-liu. *A+ Psyduck*. 2011. Tues. 14 June 2016. Deviant Art
- “30 Examples Of Terrible And/Or Wonderful Fan Art” *Buzzfeed*, 14 June 2016.
- “Psyduck” *The Sinkhole*, 14 June 2016.
- Animemaniac, *Zerochan*, 14 June 2016.

## ▶ References

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