

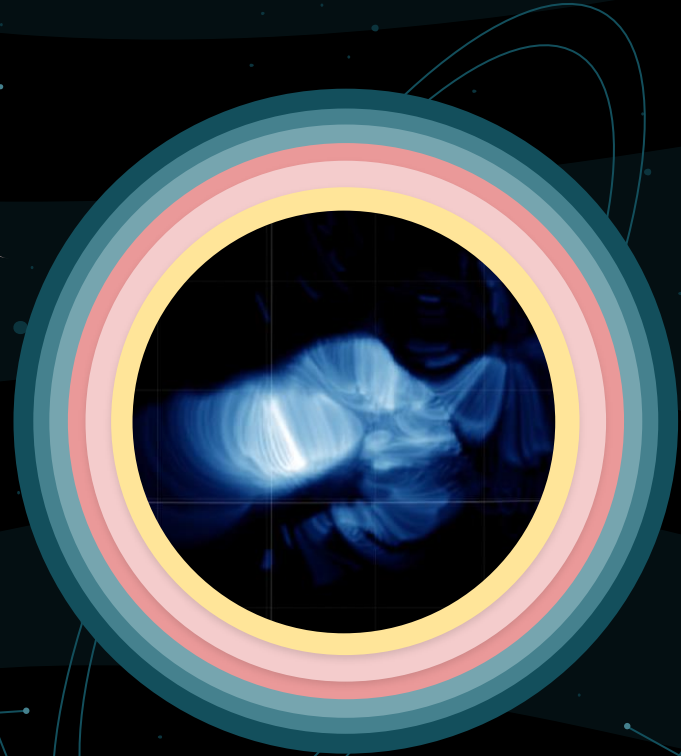
# Energy Release Process in the 2021 October 28 X1.0 Flare

BROCK PARKER

CHUNMING ZHU

JIONG QIU

DANA LONGCOPE



# OVERVIEW

01

## BACKGROUND

Solar flares, SDO,  
EBTEL

02

## PREVIOUS WORK

Magnetic  
Extrapolation, UFC,  
Two-phase Heating

03

## CURRENT WORK

Python SynthesizAR,  
Importing loop  
EBTEL results

04

## EXTENSION

Loop distributions

01

BACKGROUND



# SOLAR FLARES

Intense eruption of electromagnetic radiation from the sun's atmosphere.

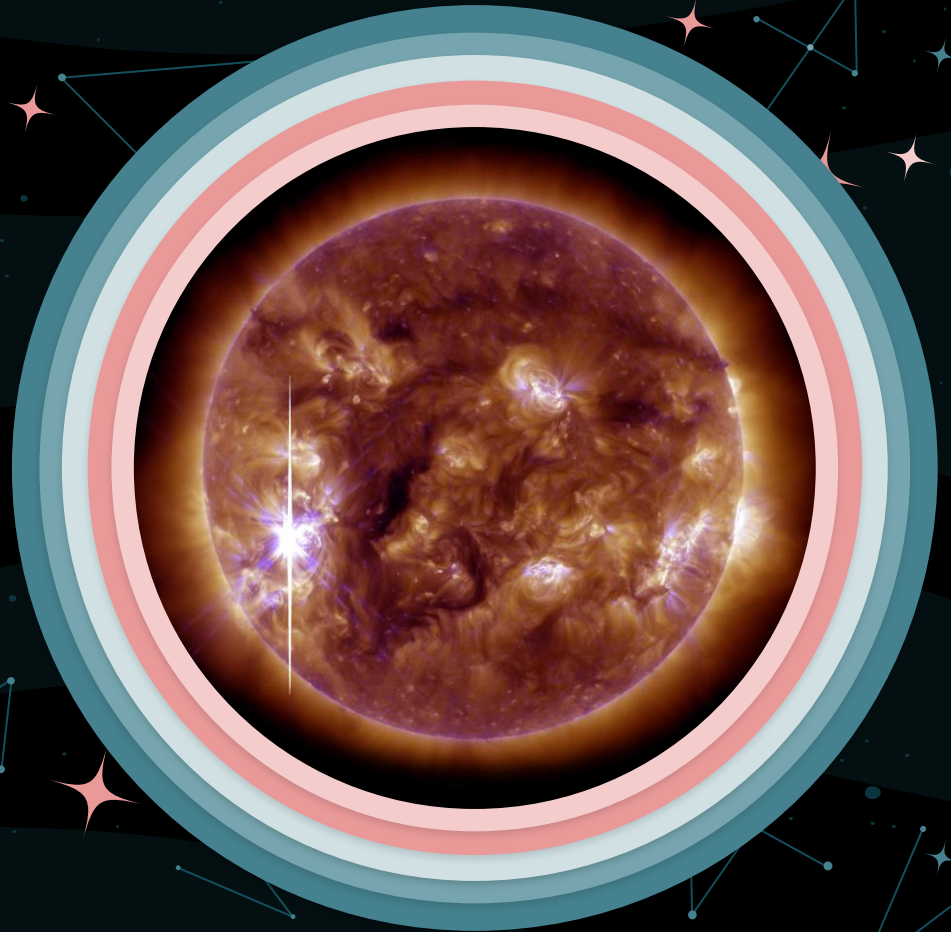


Image Credit: SDO AIA

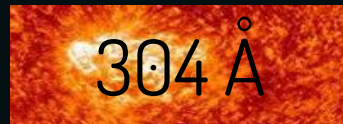
# SDO - Solar Dynamics Observatory



Magnetic Field in  
the Photosphere



Upper Photosphere  
and Transition  
Region, 10,000 K



Transition Region  
and Chromosphere,  
50,000 K



Upper Transition  
Region and Corona,  
600,000 K



Corona,  
1,000,000 K



Flaring Regions,  
10,000,000 K

# EBTEL - Enthalpy Based Time Evolution of Loops

$$\frac{d\bar{P}}{dt} \approx \frac{2}{3} \left[ \bar{Q} - \frac{1}{L} (R_c + R_{tr}) - \frac{F}{L} \left( 1 - \frac{3}{2} \frac{k\bar{T}}{\varepsilon} \right) \right]$$

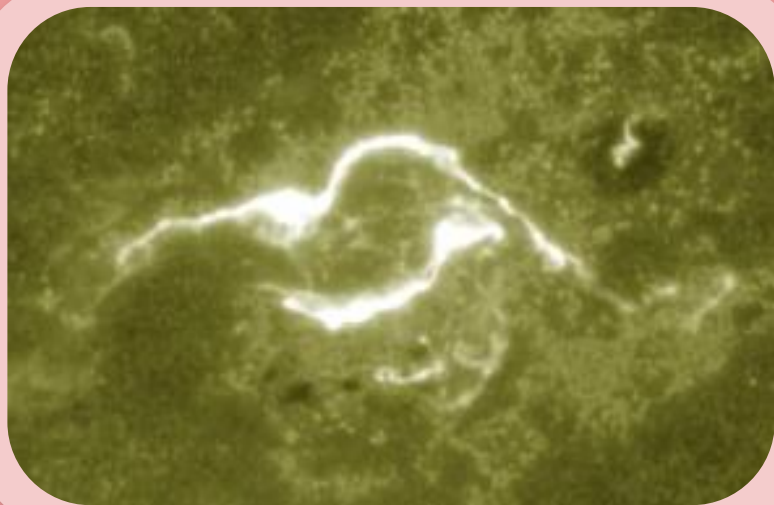
$$\frac{d\bar{n}}{dt} = - \frac{c_2}{5c_3 k L \bar{T}} (F_0 + R_{tr}) + \frac{F}{\varepsilon L} \left( 1 - \frac{c_2}{5c_3} \frac{\varepsilon}{k\bar{T}} \right)$$

## EQUILIBRIUM

Energy balance between coronal heating and losses by radiation and thermal conduction.

## ENTHALPY

Equate enthalpy flux of plasma with change in heat flux relative to radiation loss rate in the transition region.



## UFC

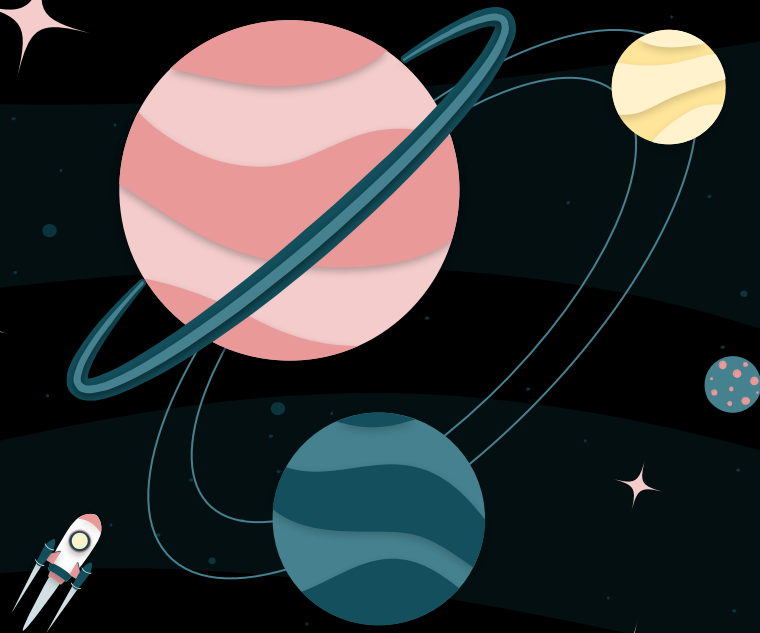
UV Footprint Calorimeter Method,  
assuming the heating of the loops is  
proportional to the brightness of loop feet.

$$H_i(t) = \lambda \left[ I_i q \left( \frac{|t - t_i|}{\tau_i} \right) \right]^\alpha$$

(Qiu et al., 2012)

02

PREVIOUS  
WORK





# PROCESS



## LIGHTCURVES

Flare lightcurves  
for each different  
SDO EUV  
wavelength.



## EBTEL

Run 0D simulations  
of the loops and  
generate synthetic  
lightcurves.



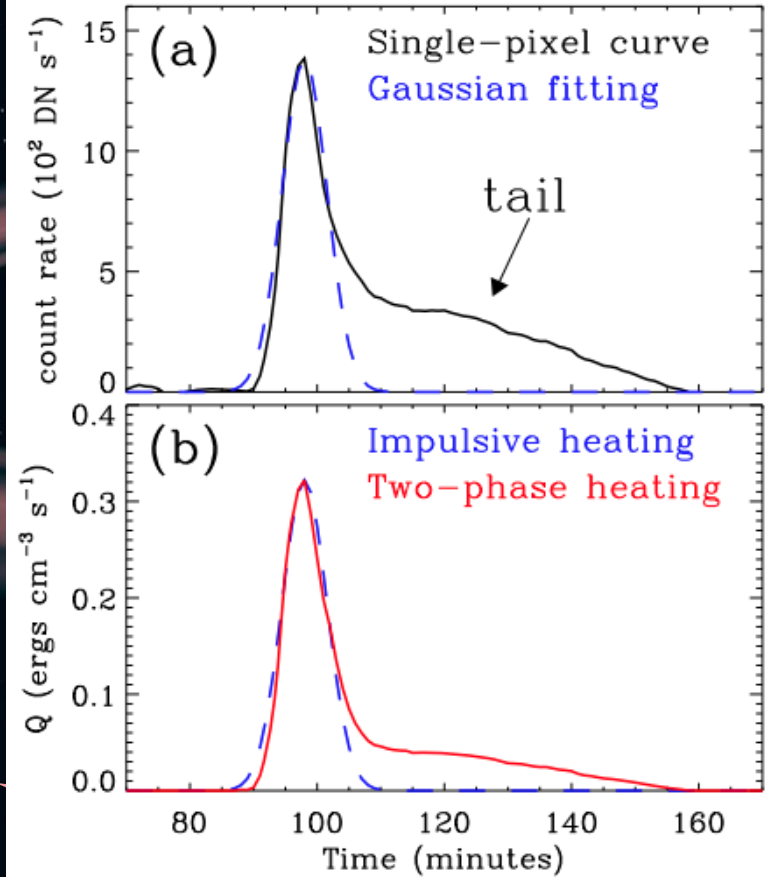
## IMAGES

Load simulations  
and generate  
animations using  
SynthesizAR.

$$H_{grad} = \lambda_1 I_{tail}$$

$$H_{imp} = \lambda_0 I_{imp}$$

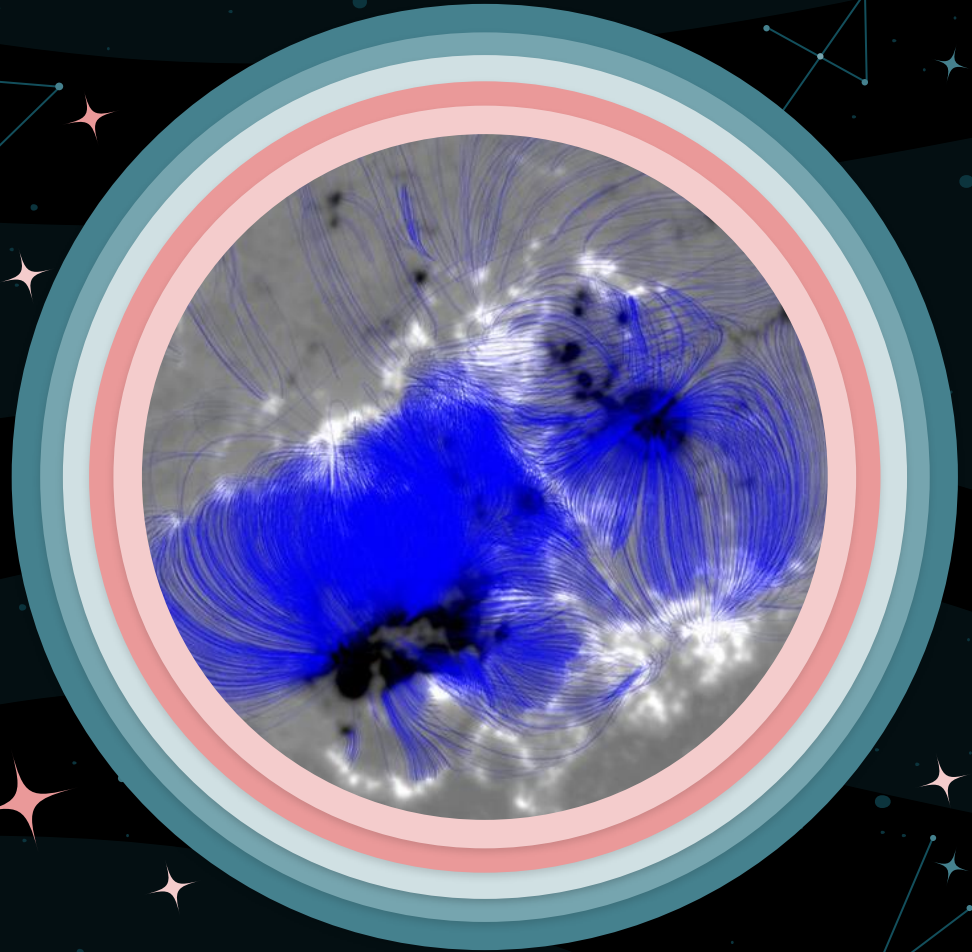
Two-Phase Heating



(Qiu & Longcope, 2016, Zhu et al., 2018)

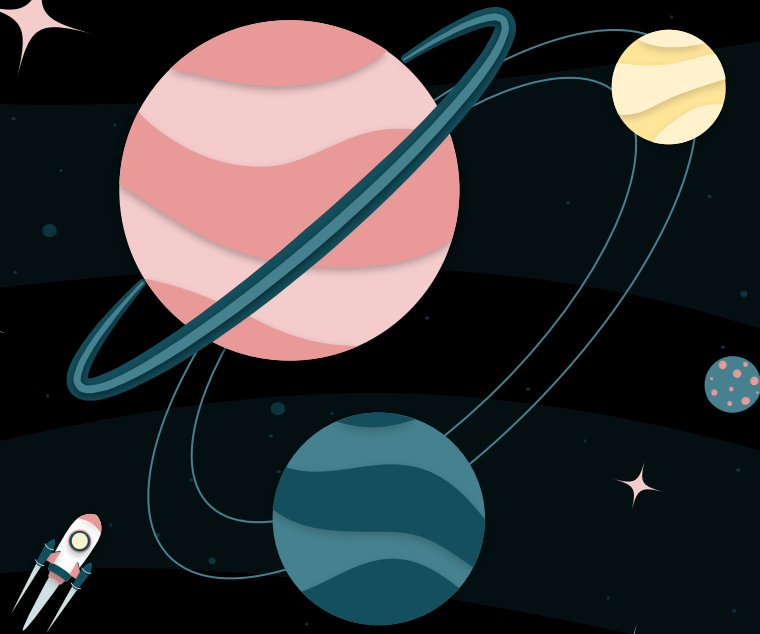
# Magnetic Extrapolation

Simulating magnetic  
field loops from HMI  
data.



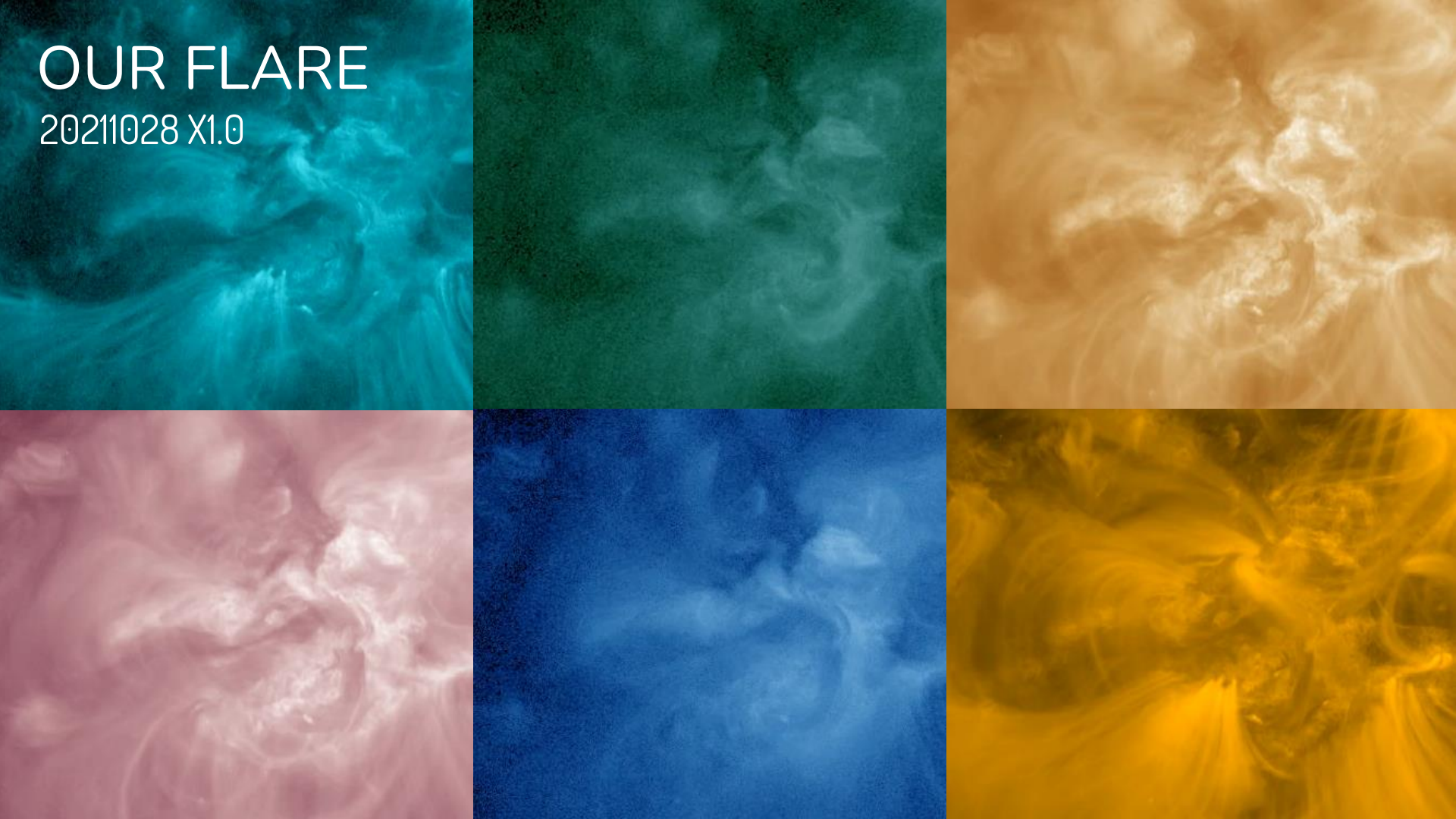
03

CURRENT  
WORK



# OUR FLARE

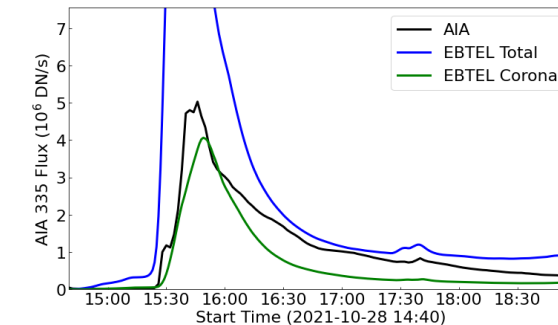
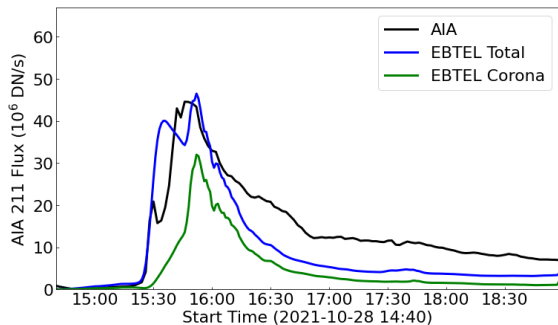
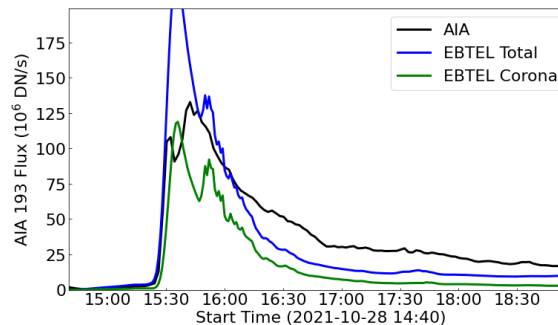
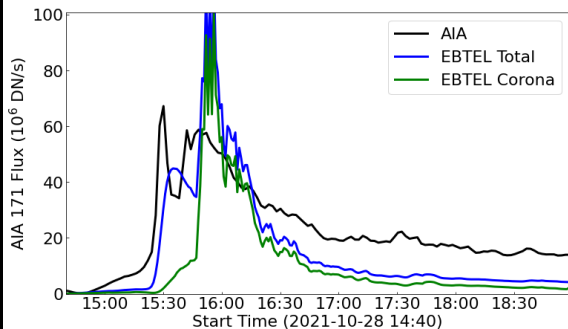
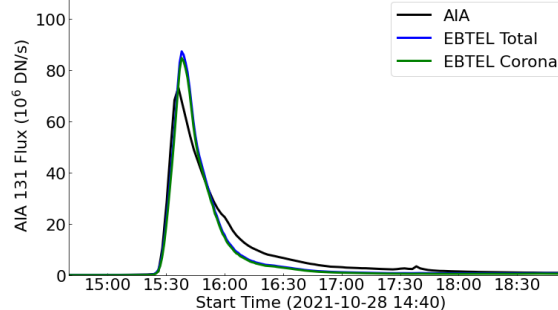
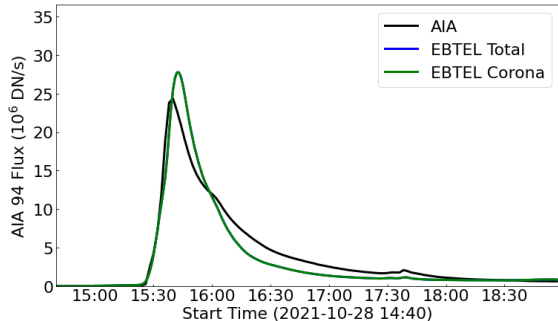
20211028 X1.0



# LIGHT CURVES

Light curves of the entire flaring region from observational data compared with synthetic emissions.

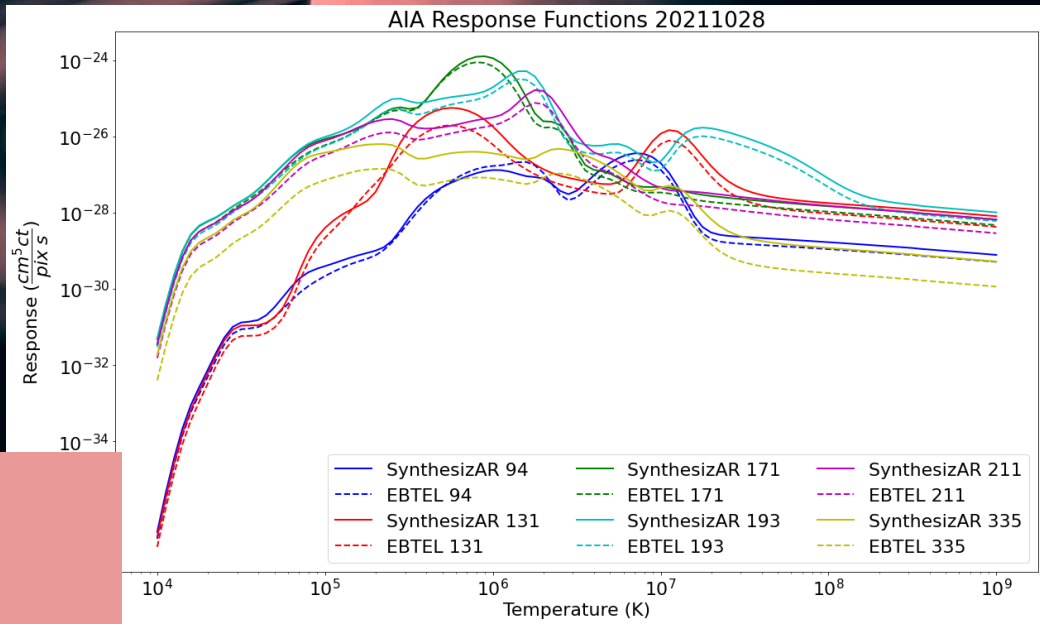
Light Curves 2021-10-28 All Loops



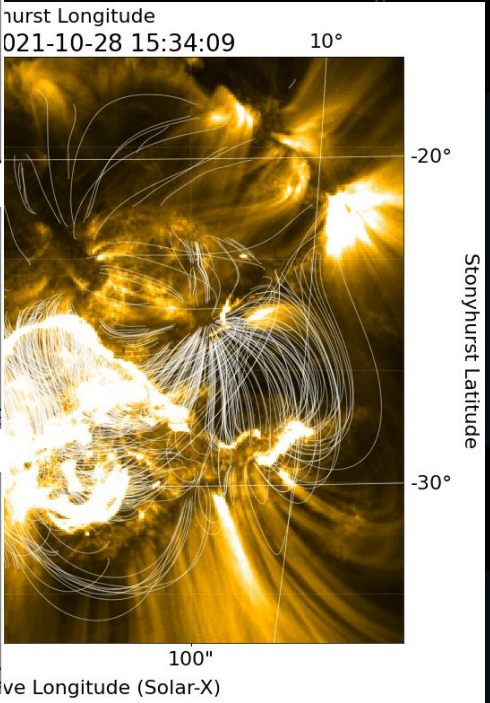
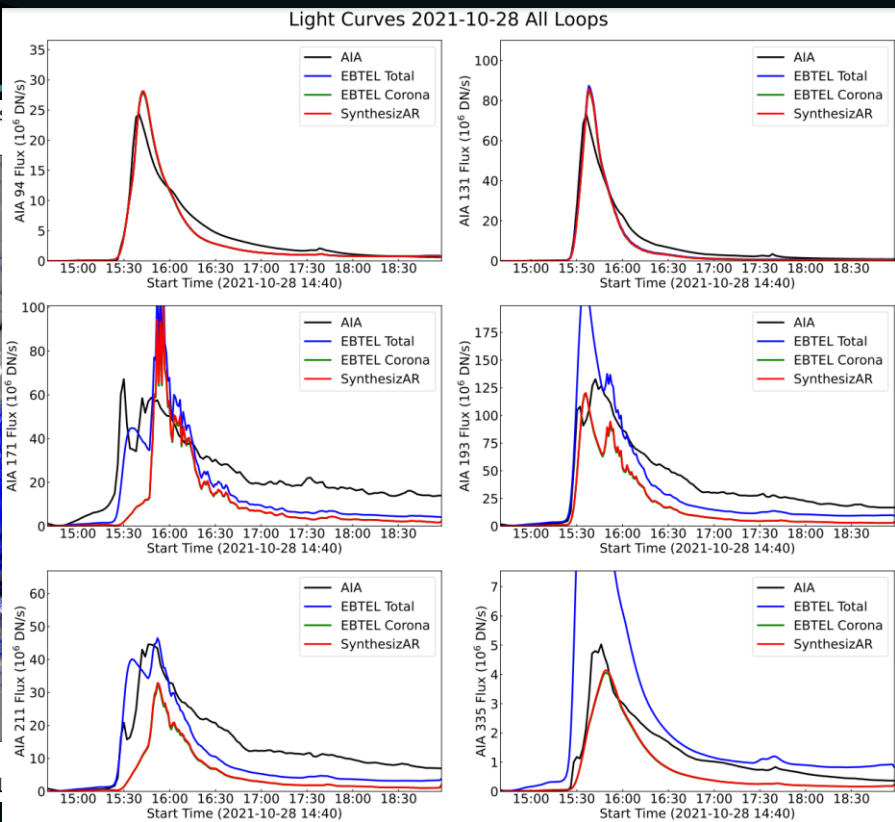
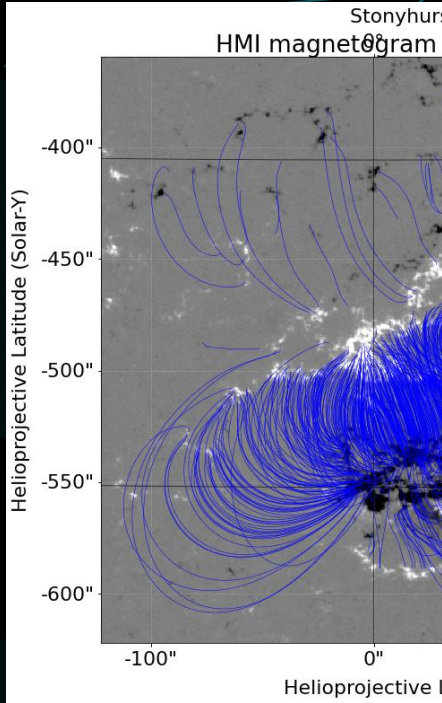
$$p_c = \int dh K_c(T_e) n_e^2$$

(Boerner et al., 2012)

SynthesizAR



(Barnes et al., 2019)

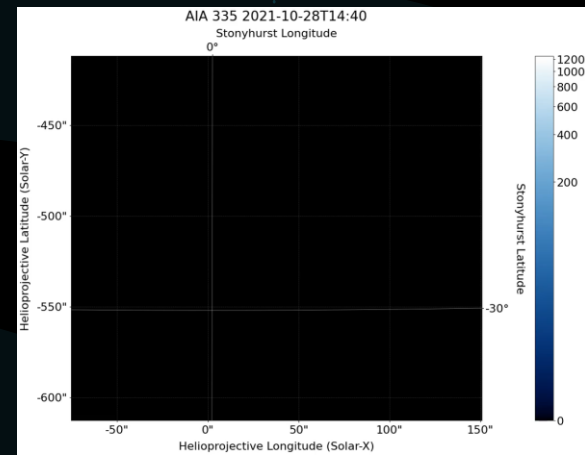
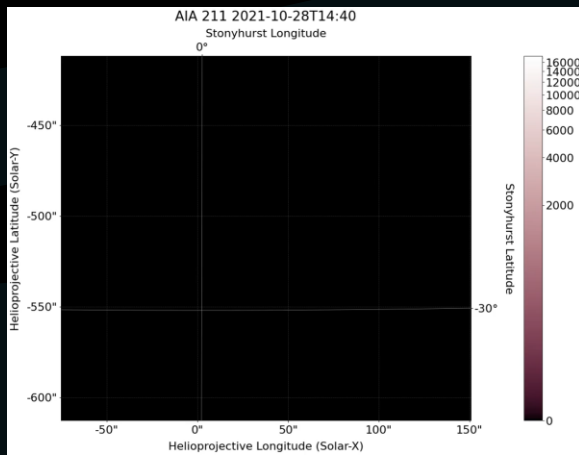
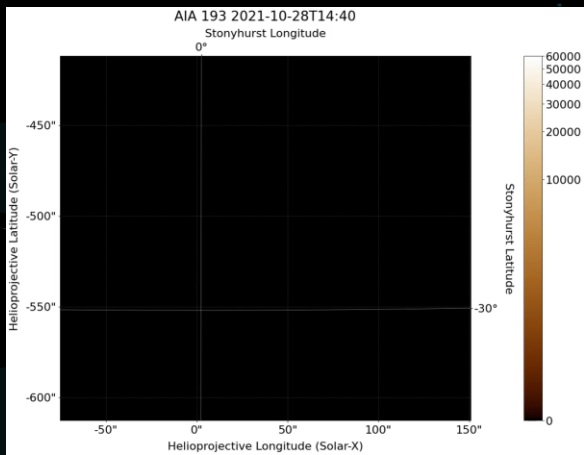
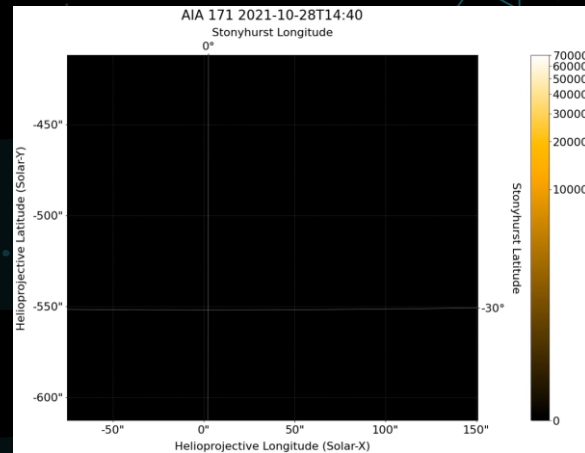
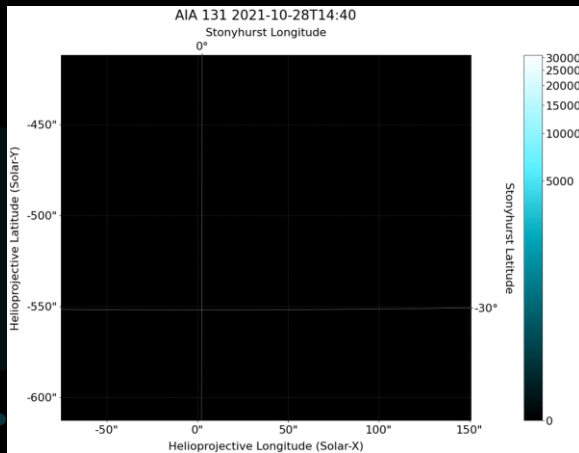
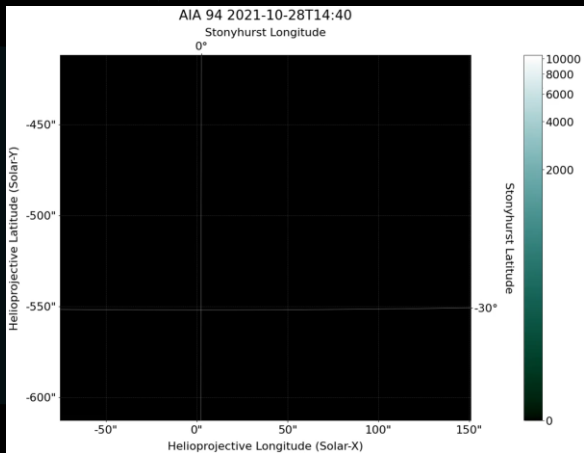


# IMPORTING LOOPS

EBTEL and Coordinates. Uniform temperature and density.

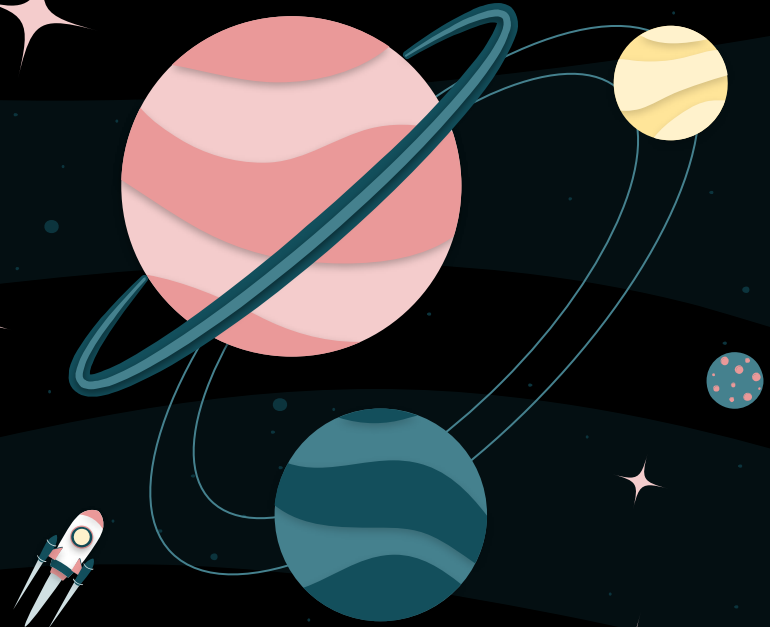


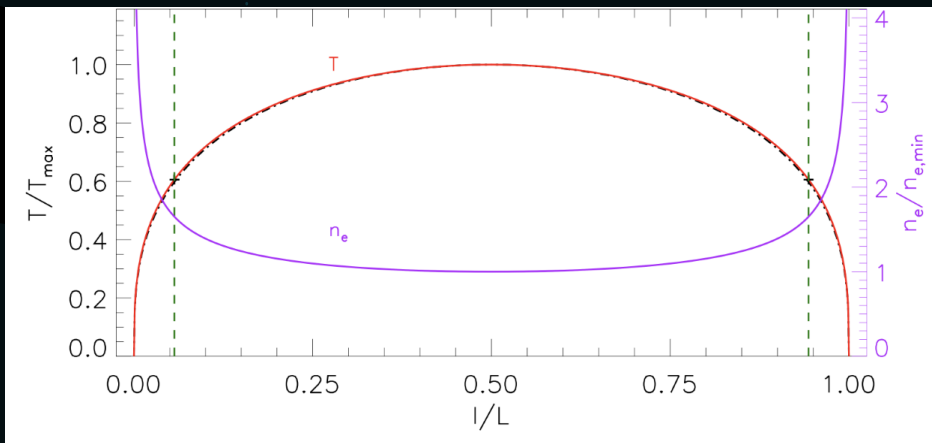
# ANIMATIONS



04

EXTENSIONS





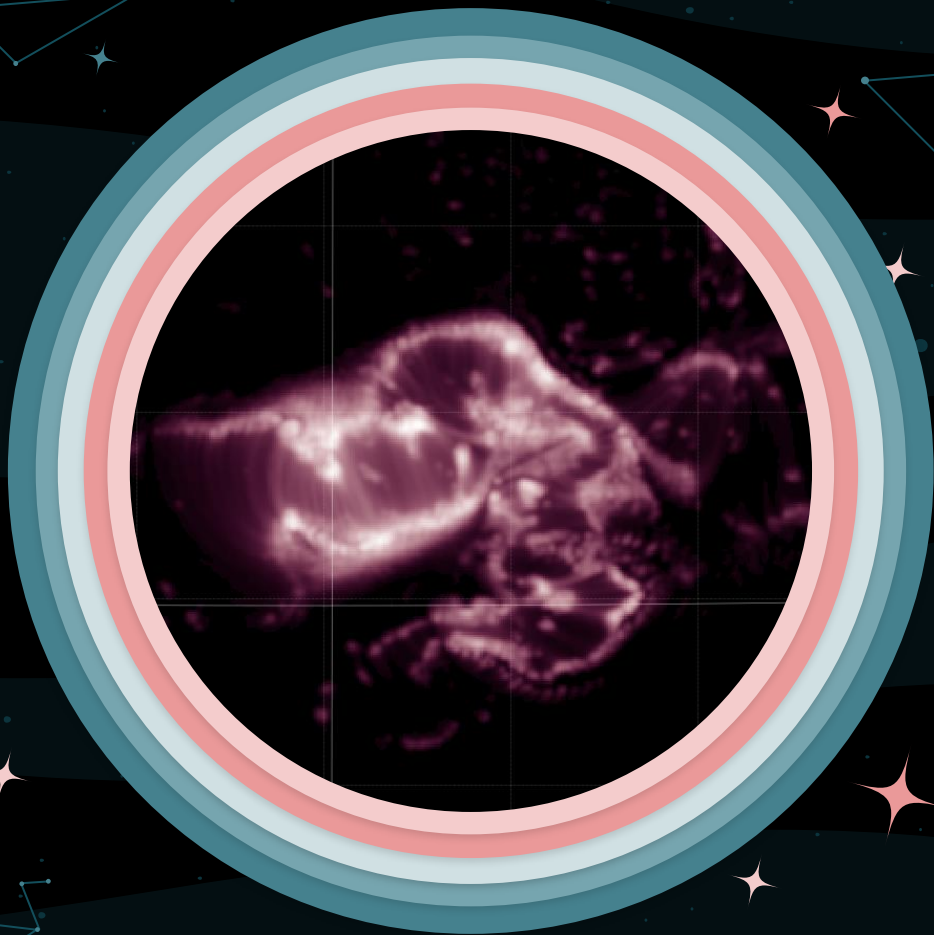
$$T(s) = 1.29\langle T \rangle (1 - (s/L)^2)^{1/3}$$

$$n(s) = 0.77\langle n \rangle (1 - (s/L)^2)^{-1/3}$$

## LOOP DISTRIBUTIONS

RTV distributions for  
temperature and density.

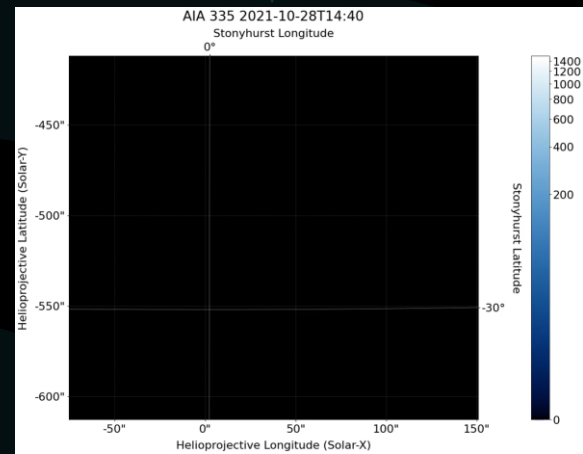
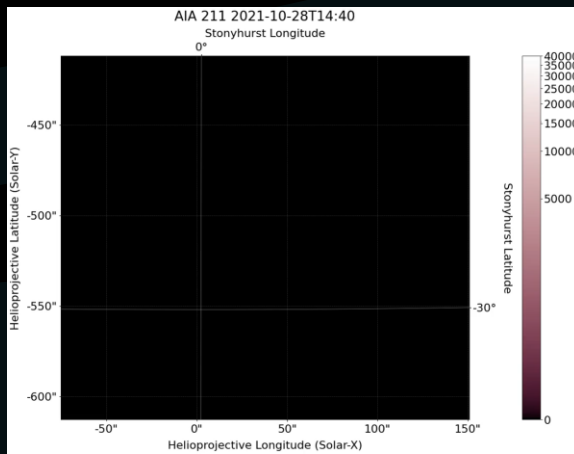
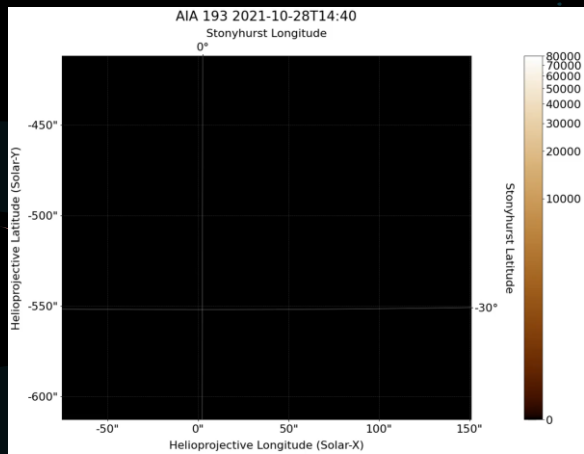
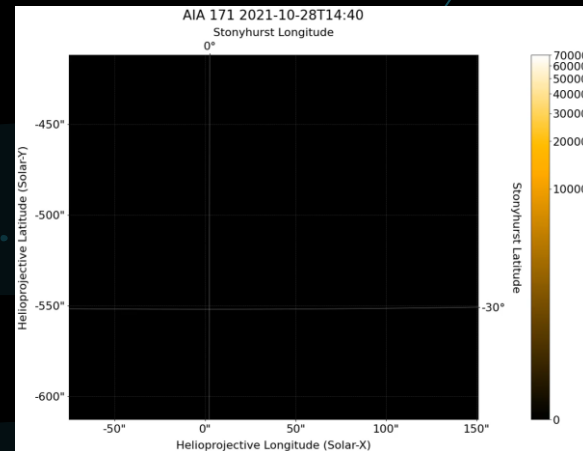
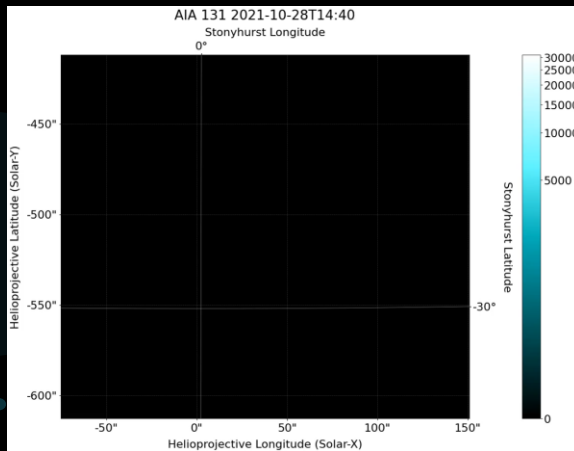
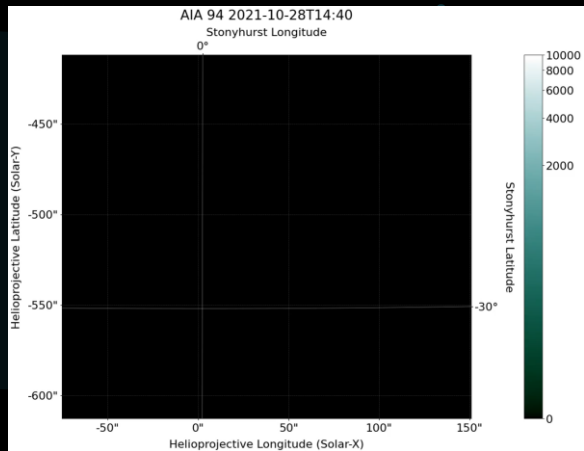
(Rosner et al. 1978; Credit: Dana Longcope)



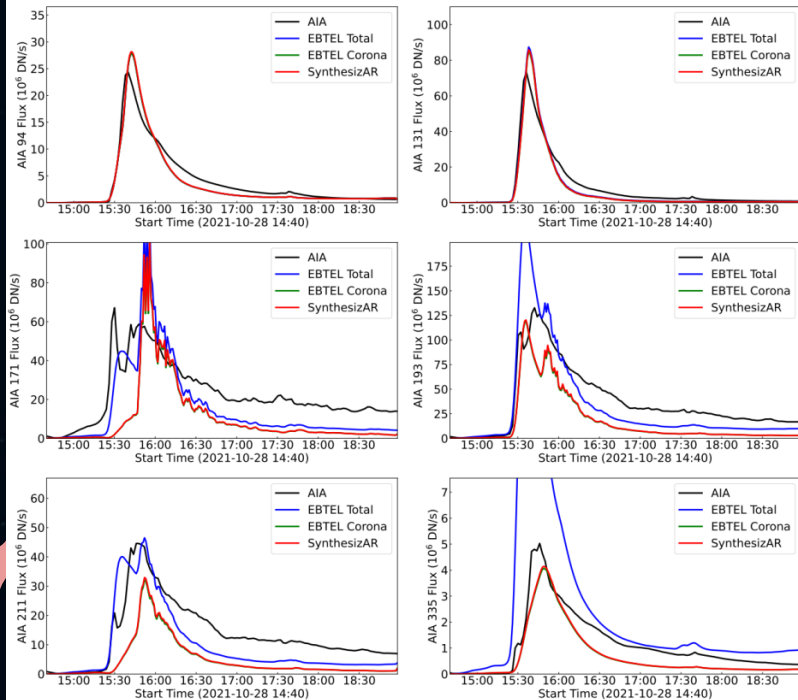
# LOOP DISTRIBUTIONS

Footpoint brightness

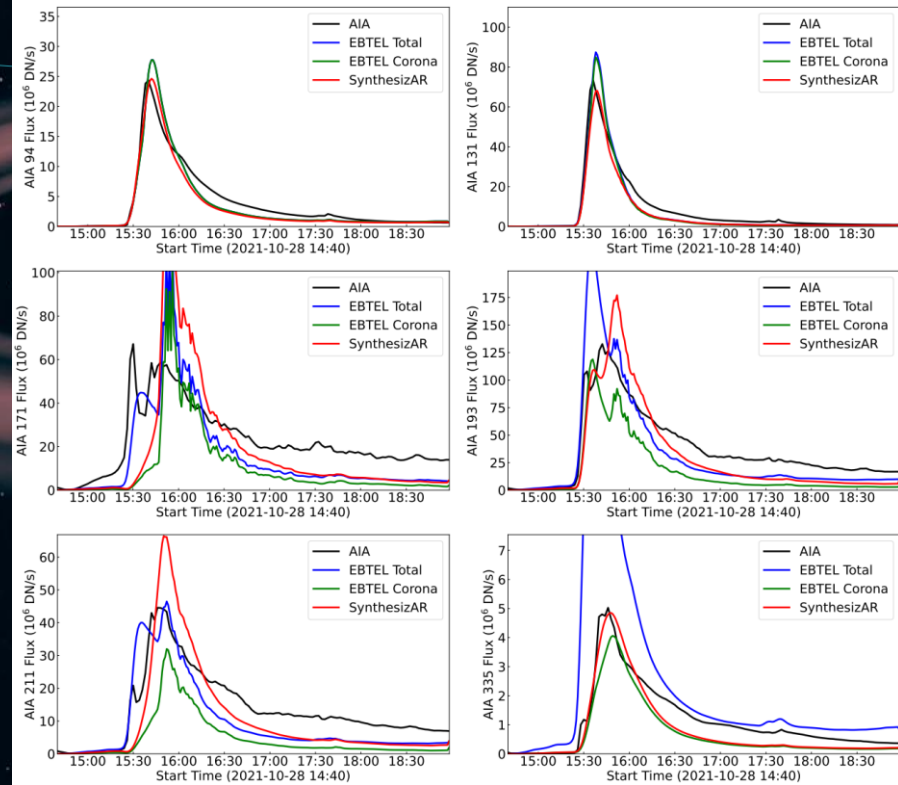
# ANIMATIONS



Light Curves 2021-10-28 All Loops



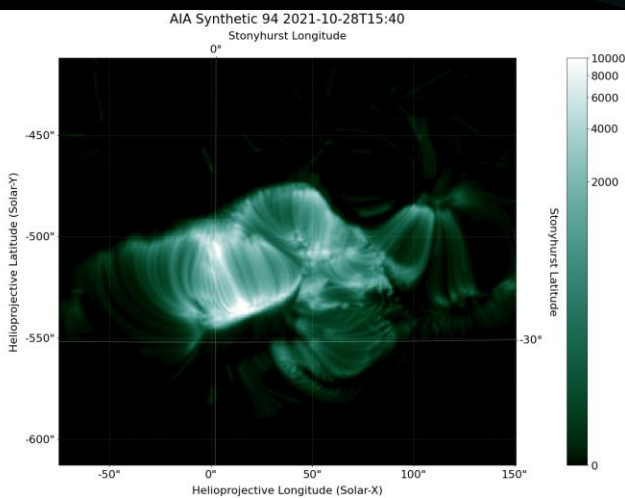
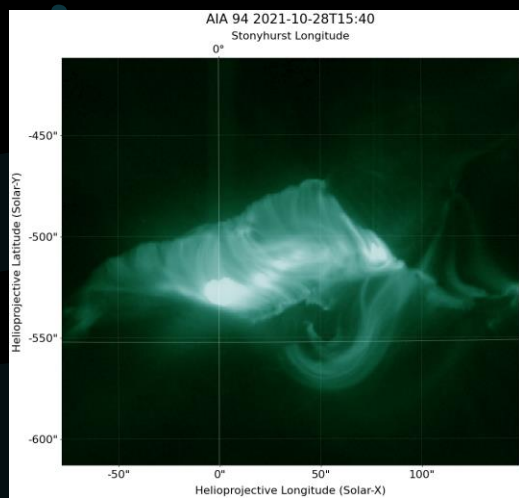
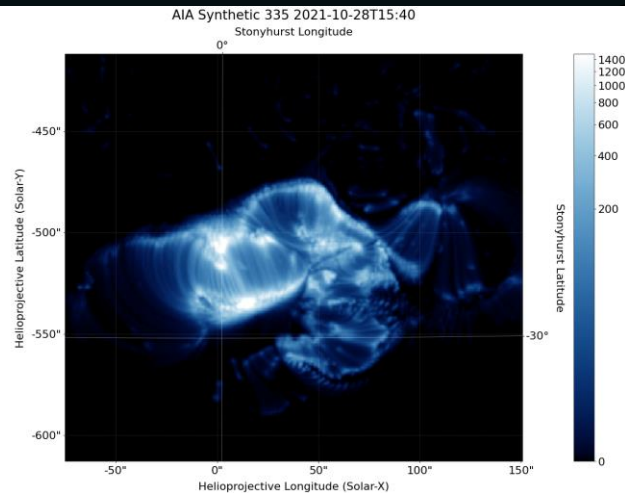
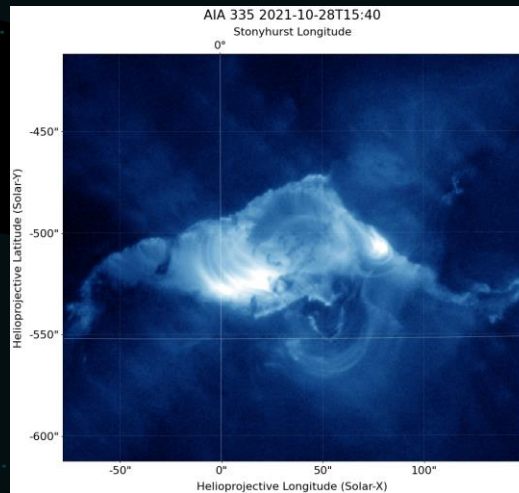
Light Curves 2021-10-28 All Loops With Loop Distributions



LIGHTCURVES

# COMPARISON

Comparing synthetic images to actual data.



# BIBLIOGRAPHICAL REFERENCES

- **J. A. Klimchuk, et al. 2008, *ApJ*, 682, 1351.**

Highly Efficient Modeling of Dynamic Coronal Loops

- **Jiong Qiu, et al. 2012, *ApJ*, 752, 124.**

Heating of Flare Loops with Observationally Constrained Heating Functions (UFC or UV Footprint Calorimeter Method)

- **Jiong Qiu and Longcope, Dana 2016, *ApJ*, 820, 14.**

Long Duration Flare Emission: Impulsive Heating or Gradual Heating?

- **Chunming Zhu, et al. 2018, *ApJ*, 856, 27.**

Two-Phase Heating in Flaring Loops

- **W. T. Barnes, et al. 2019, *ApJ*, 880, 56.**

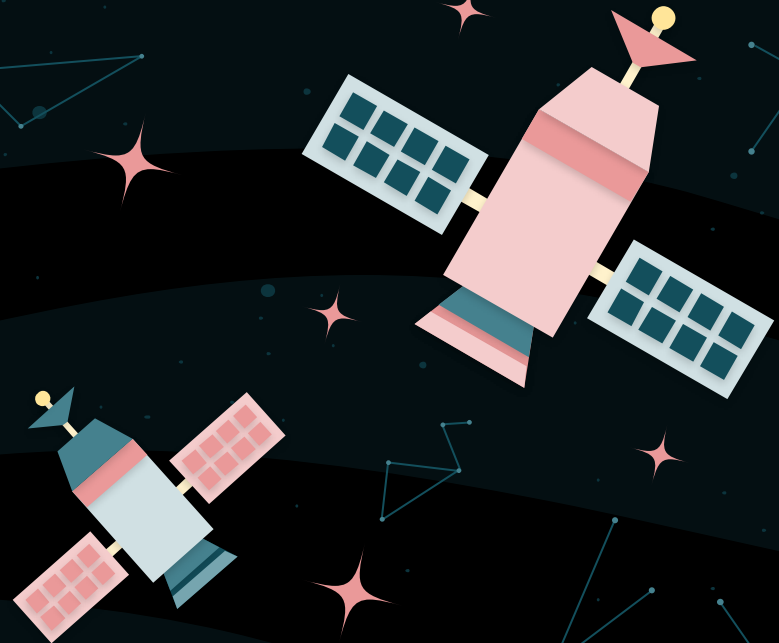
Understanding Heating in Active Region Cores through Machine Learning. I. Numerical Modeling and Predicted Observables

- **R. Rosner, et al. 1978, *ApJ*, 220, 634.**

Initial Calibration of the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory (SDO)

- **Paul Boerner, et al. 2012, *Solar Physics* 275, 41.**

Dynamics of the quiescent solar corona





# THANKS!

Do you have any questions?



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[https://solar.physics.montana.edu/home/w  
ww/reu/2022/bparker/index.html](https://solar.physics.montana.edu/home/www/reu/2022/bparker/index.html)

Advisor: Dr. Chunming Zhu

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