



University of Applied Sciences and Arts
Northwestern Switzerland

Space & IT @ FHNW

SPACE::LAB summer school

Marius Giger - 24.08.2022 - FHNW - Institute for Data Science (i4DS) - gigermarius@gmail.com

Institute for Data Science (i4DS)

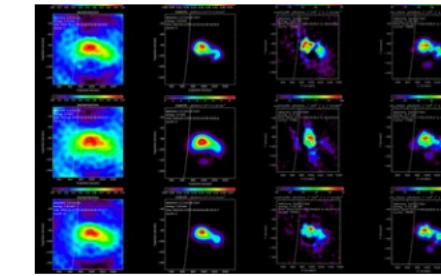
- Machine Learning
- Natural Language Processing
- Exploratory Data Science
- High Performance Computing
- Image Analysis and Processing



STIX for Solar Orbiter
The Spectrometer / Telescope for Imaging X-rays (STIX) is an X-ray telescope that makes images and spectra of solar explosions called flares. It is one of the ...



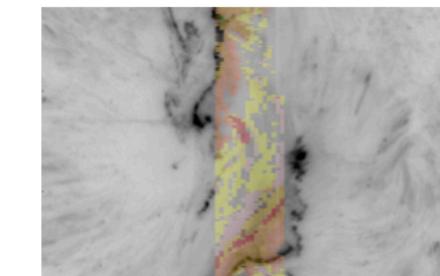
Yooture - The app for job seekers
The School of Engineering FHNW has developed an elaborated matching method for the innovative start-up Yooture.



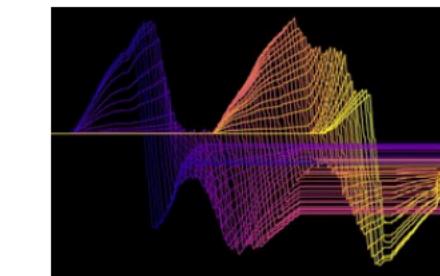
Compressed Sensing for Solar Flares
For the RHESSI satellite we develop an algorithm to reconstruct X-ray images of solar flares.



FHNW Myosotis Garden
Playing games with elderly people can be fun. It can facilitate communication between people from different generations.



IRIS Big Data
Machine learning methodology to detect, analyse and possibly predict solar flares from data provided by NASA's space telescope IRIS.



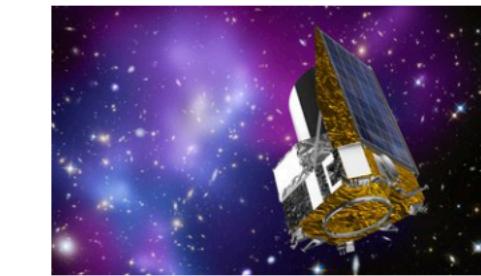
Optimizing hydro power plant maintenance planning
The School of Engineering FHNW has developed a method to support operators of AXPO hydro power plants.



SySTEM2020: Connecting Science Learning Outside The Classroom
Research participant recruitment, data collection and mapping STEAM initiatives in Switzerland.



kennwerte.ch: Web application for estimating construction costs
An innovative solution for the estimation of characteristic values for the construction and real estate industry for the start-up company 'kennwerte ag'.



Euclid Space Telescope – dark energy and dark matter
A software infrastructure that enables efficient and robust pipeline processing of the vast amount of data in distributed processing sites.

Selected Space Projects @ i4DS

- **RODEM:** Finding synergies between high energy physics (HEP) and heliophysics
- **STIX:** Instrument design and construction for the spectrometer telescope for imaging X-rays on board of Solar Orbiter
- **SKAO:** Building software and for the world's largest radio telescope (SKA)
- **EUCLID:** Data management and distribution of processing for the Euclid space telescope

Selected Space Projects @ i4DS

- 👉 Mostly interdisciplinary teams (data science, computer science, physics and project management)
- 👉 Dedicated groups with domain experts (e.g., solar physics group)

Unsupervised Anomaly Detection with Variational Autoencoders in Heliophysics

Current Research

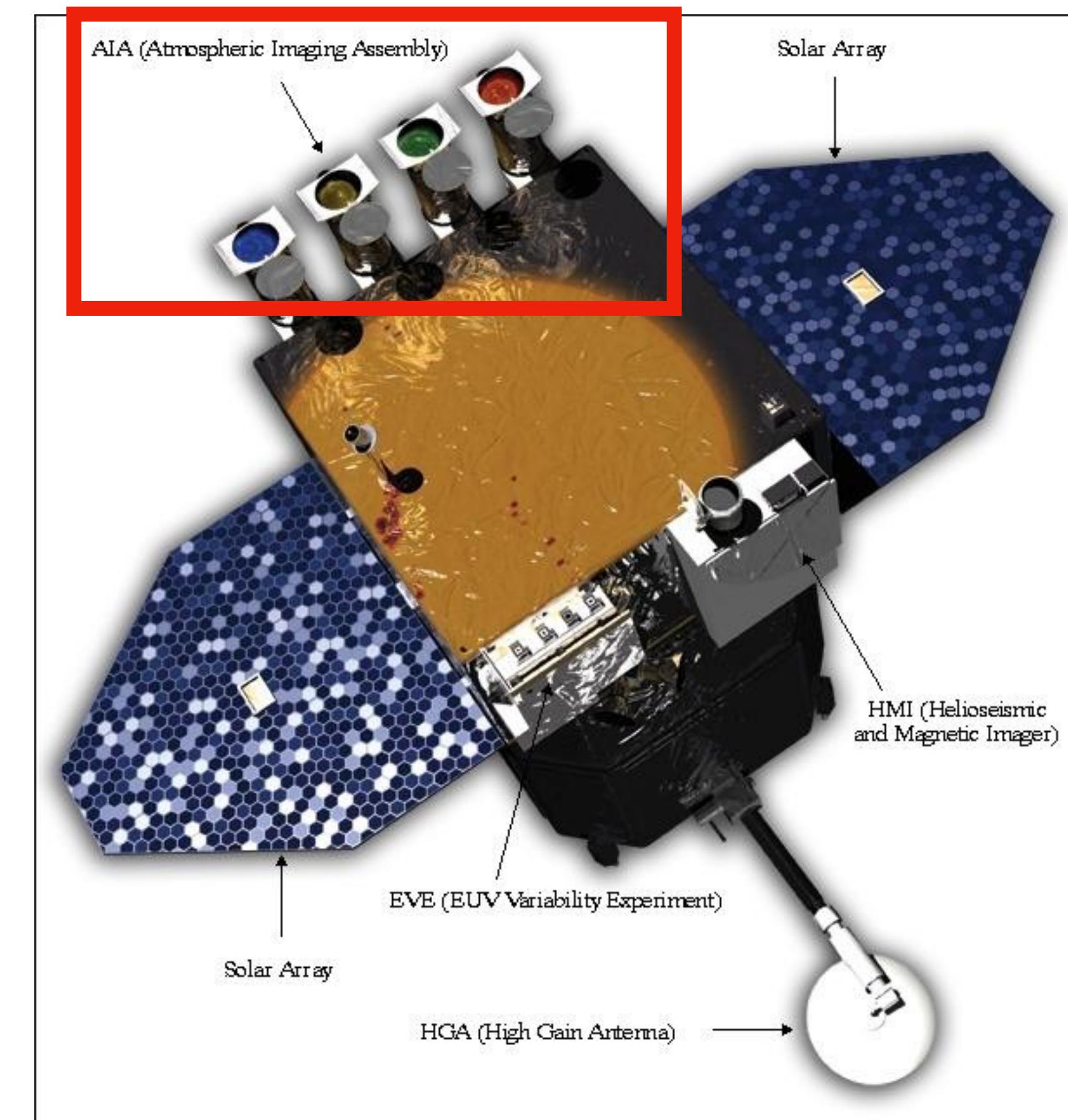
Research Objectives

- ✓ Uncover unknown/interesting structures (**novelty/anomaly detection**)
- ✓ Find ways to overcome the data bottleneck of annotated data, missing or incomplete labels (**unsupervised learning**)
- ✓ Automatically detect different solar phenomena (**representation learning**)
- ✓ Make use of the full available datasets

Data

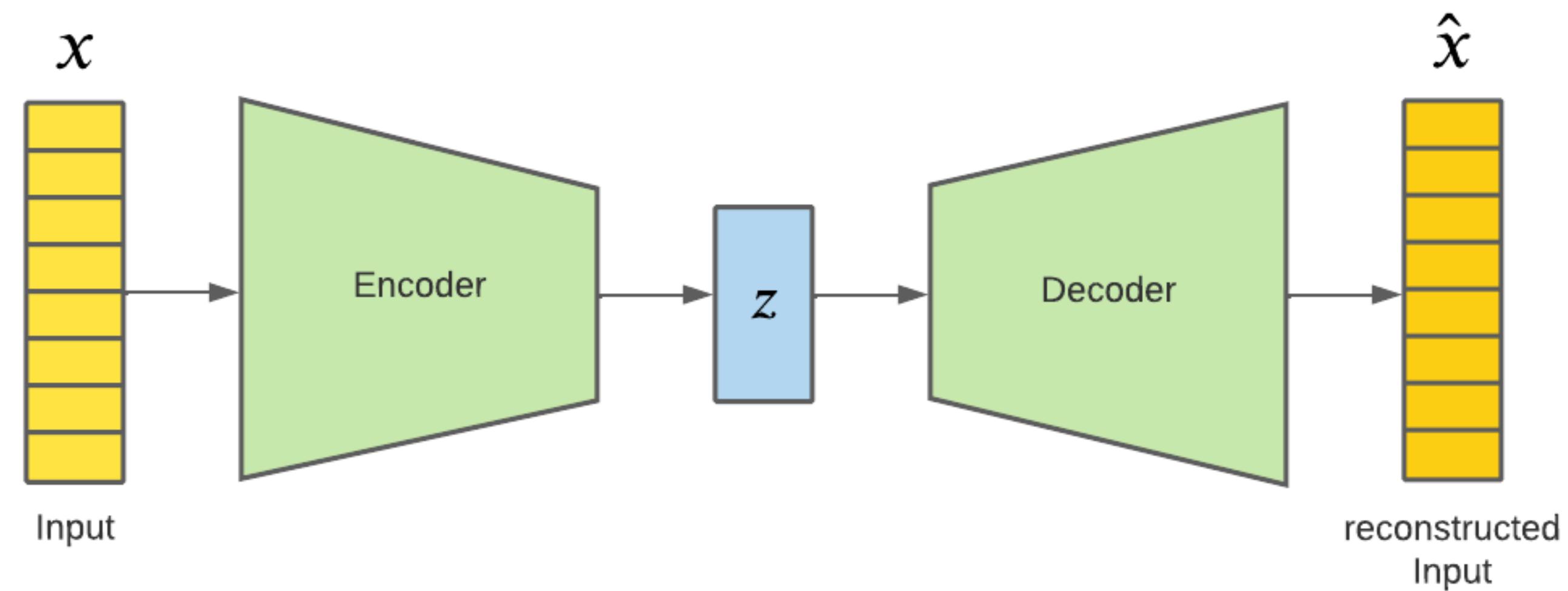
Solar Dynamics Observatory (SDO)

- EUV images from SDO AIA
- Single channel observations (AIA 171 Å)
- SDO ML Dataset v2
 - <https://sdoml.github.io/>



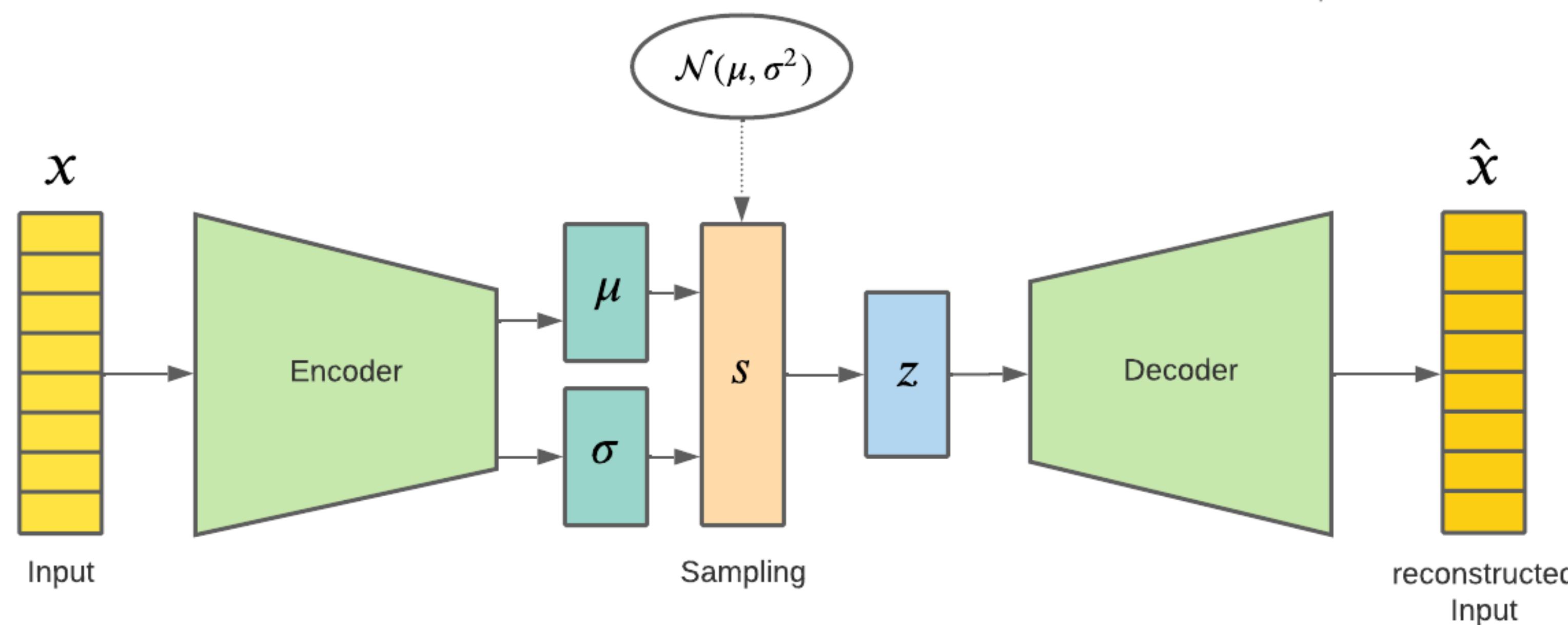
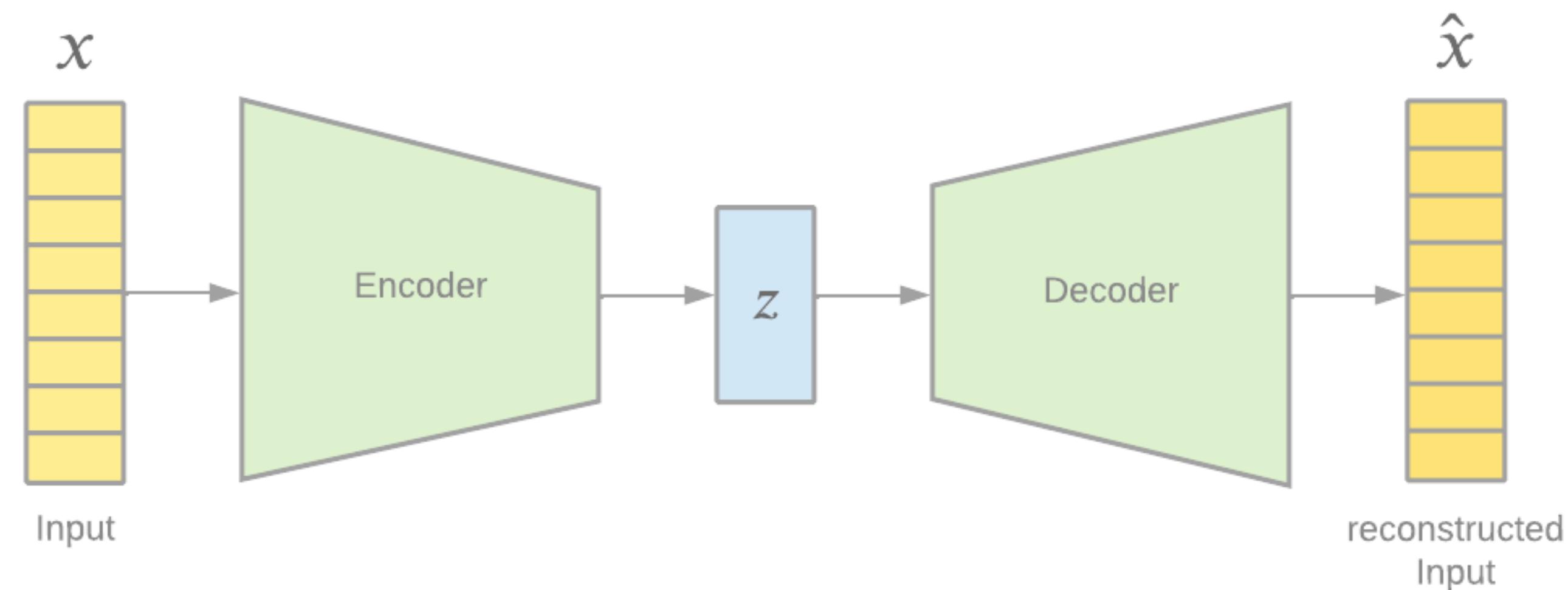
SDO spacecraft, Image Source: NASA

What is an AE?



n|w

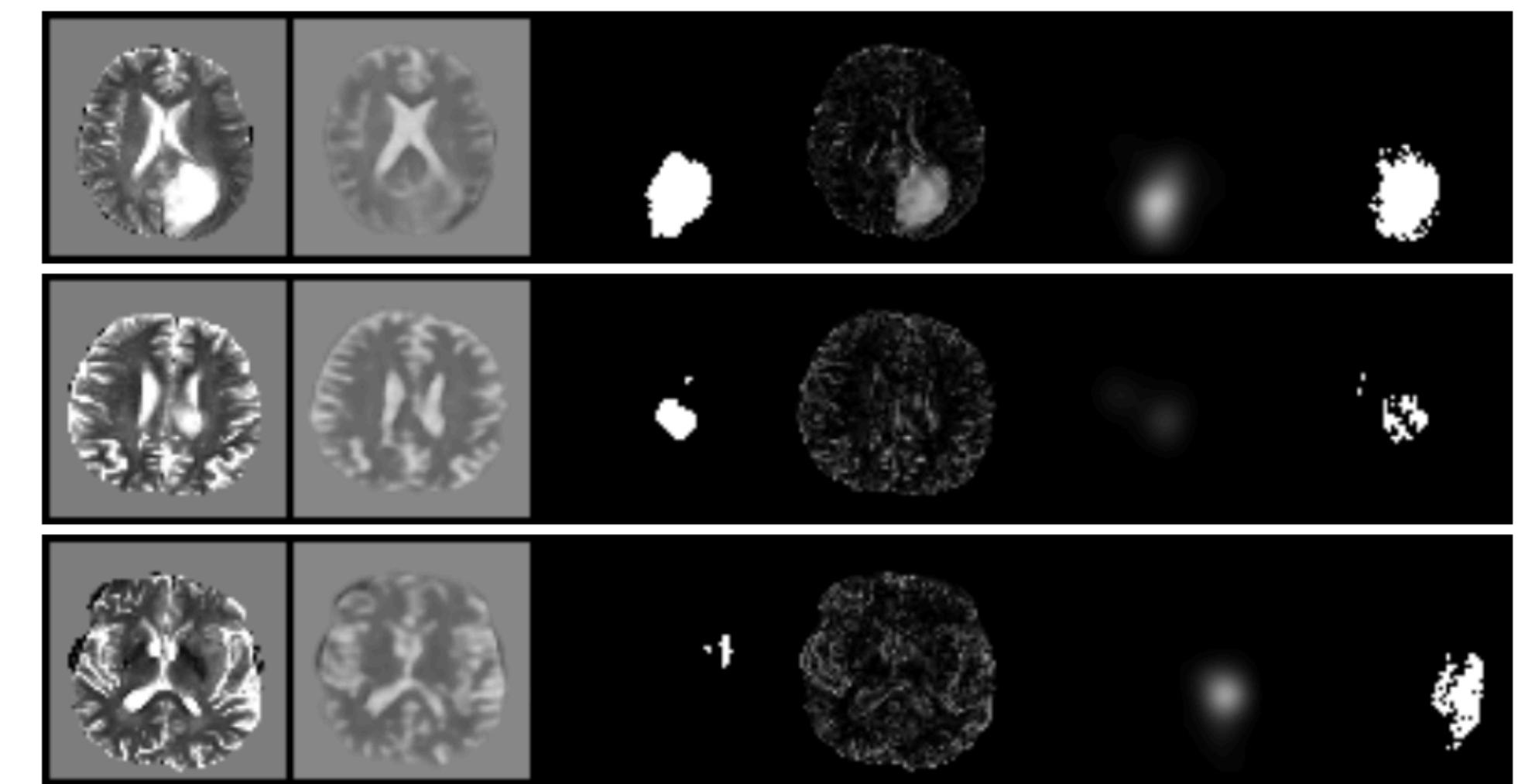
What is a VAE?



Context-Encoding VAE (ceVAE)

Encode Semantic Information in the Latent Space

- Approach from the medical domain for detection of brain tumours (*Zimmerer et al., 2018*)
- Finding and localizing out-of-distribution images and pixels
- Combination of a Context Encoder and a Variational Autoencoder (VAE)
 - CE: denoising auto encoder which masks out local patches of the input, allows capturing semantic information of the input
 - VAE: standard Variational Auto Encoder

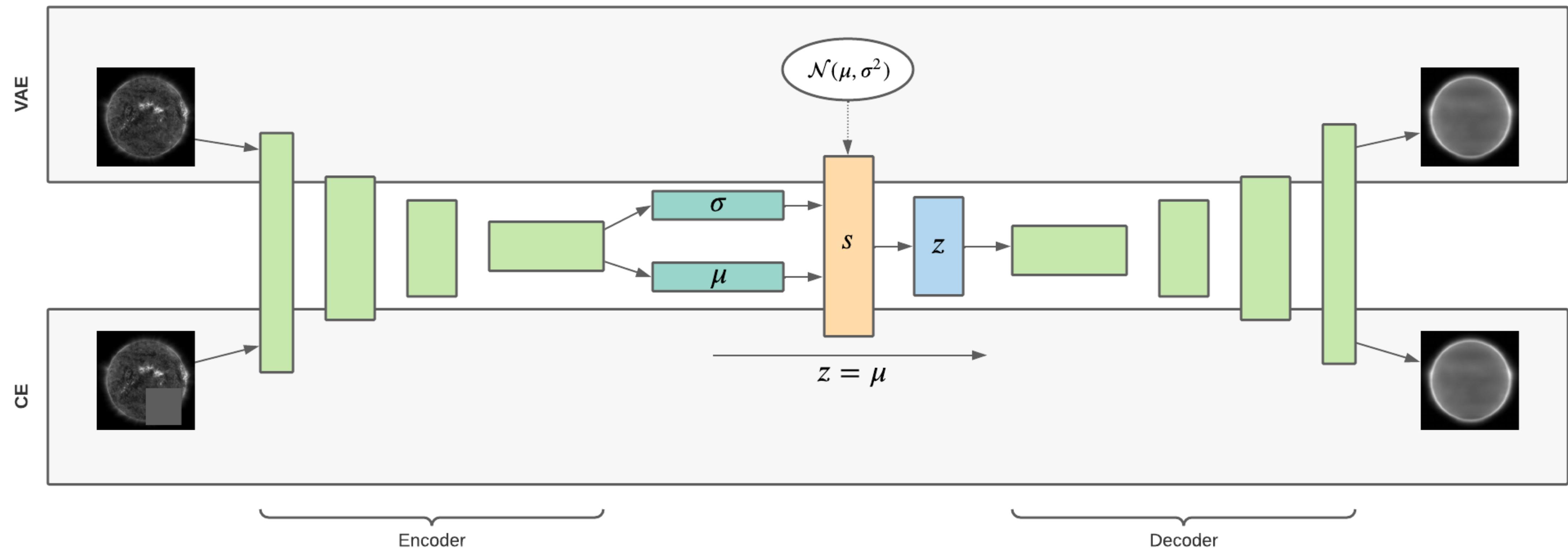


ceVAE applied to medical images, The 1st, 2nd, and 3rd row show a good, medium, and failure case, image source Zimmerer et al., 2018

The ceVAE

Encoding Semantic Information

- Combination of a Context Encoder and a Variational Autoencoder (VAE)

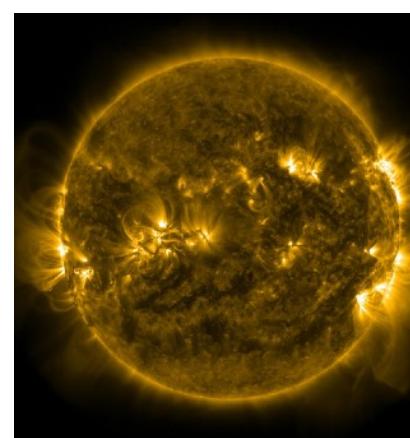


Anomaly Scoring

Image-level

- Express likelihood of an image sample by computing the Evidence Lower Bound (ELBO):

$$\log p(x) \approx L_{KL}(x) + L_{recVAE}(x, g(f(x)))$$



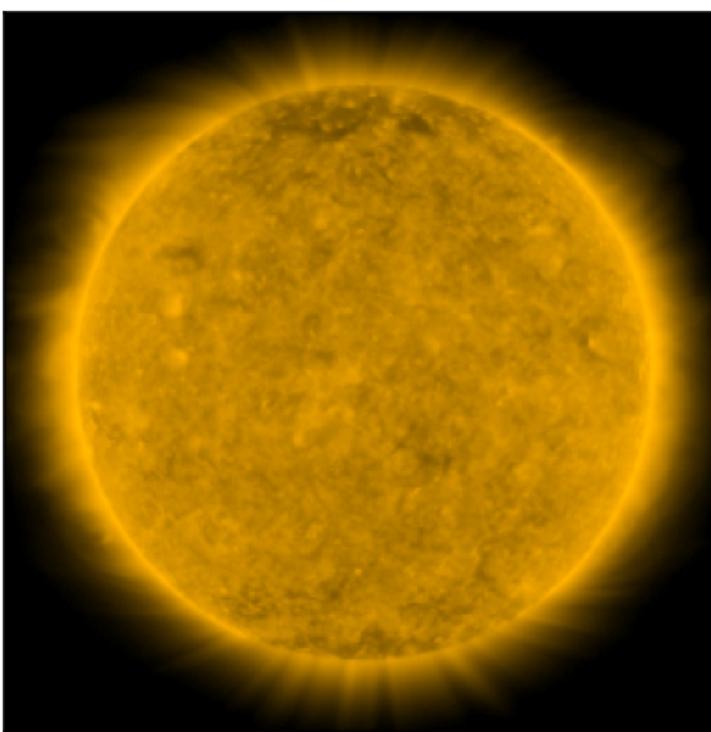
$\approx \log p(x)$

0.078

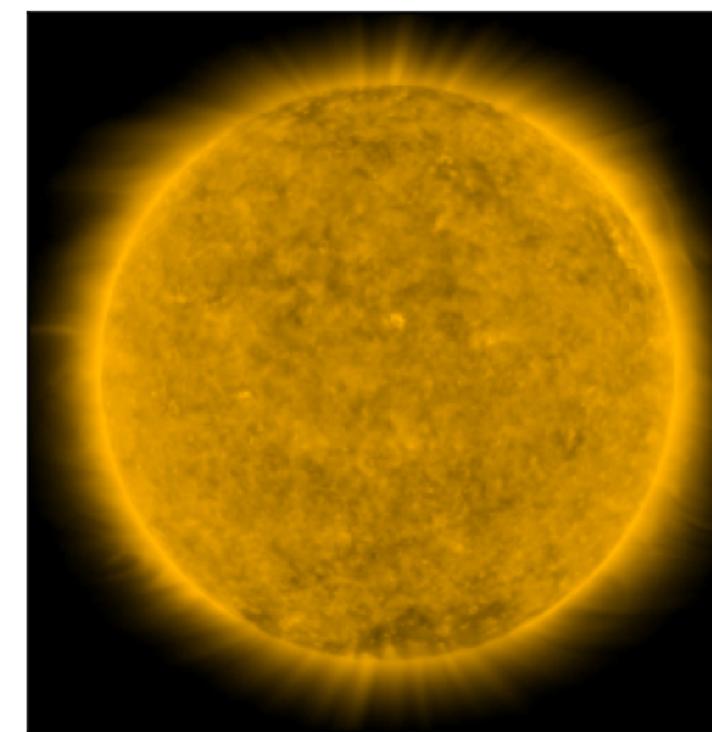
Results

Image-level scoring, **low scores**

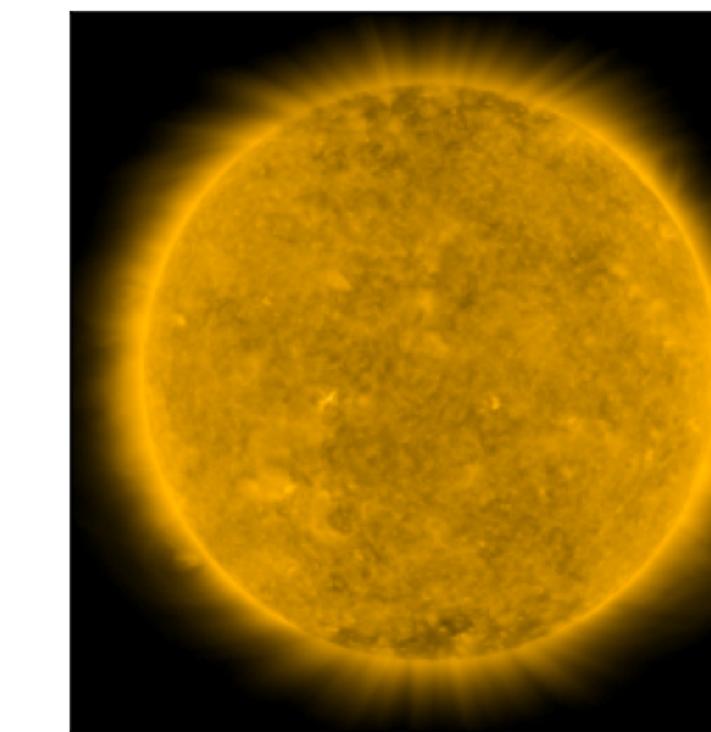
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with score 0.00000



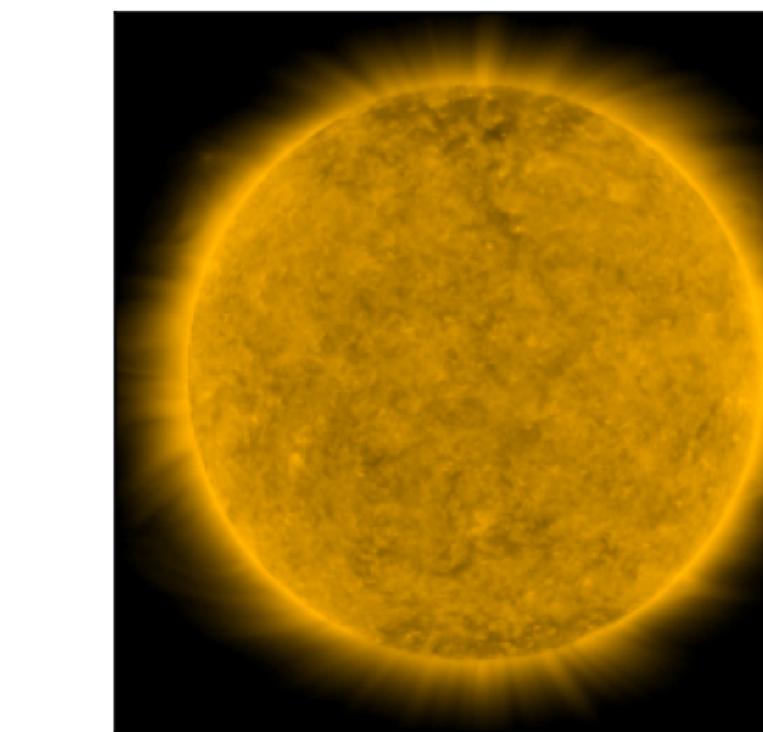
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with score 0.00020



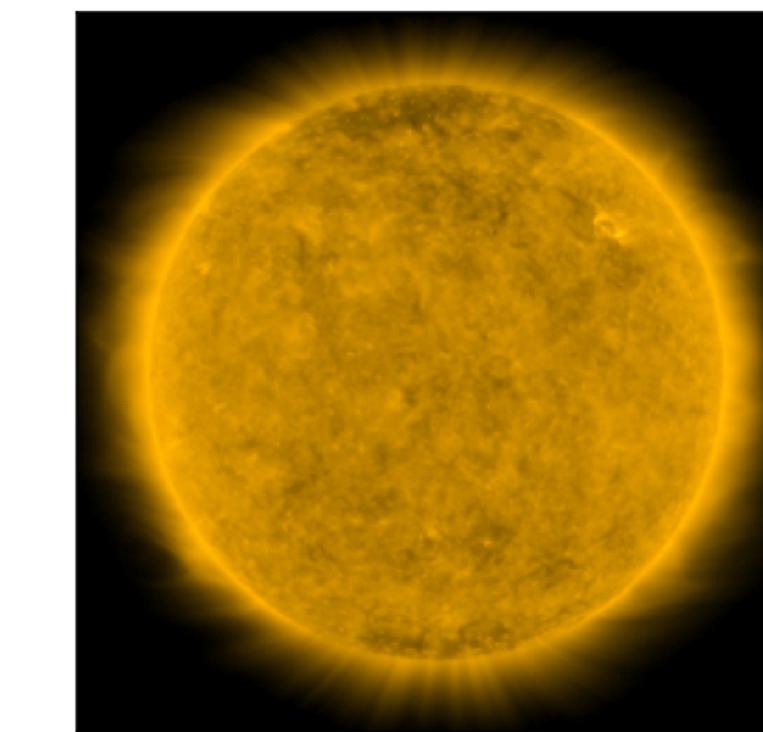
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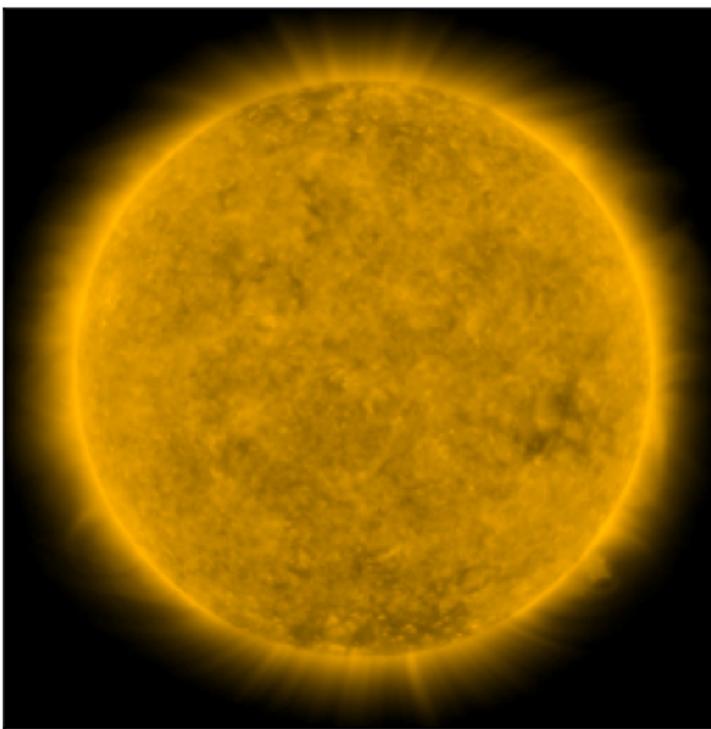
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with score 0.00418



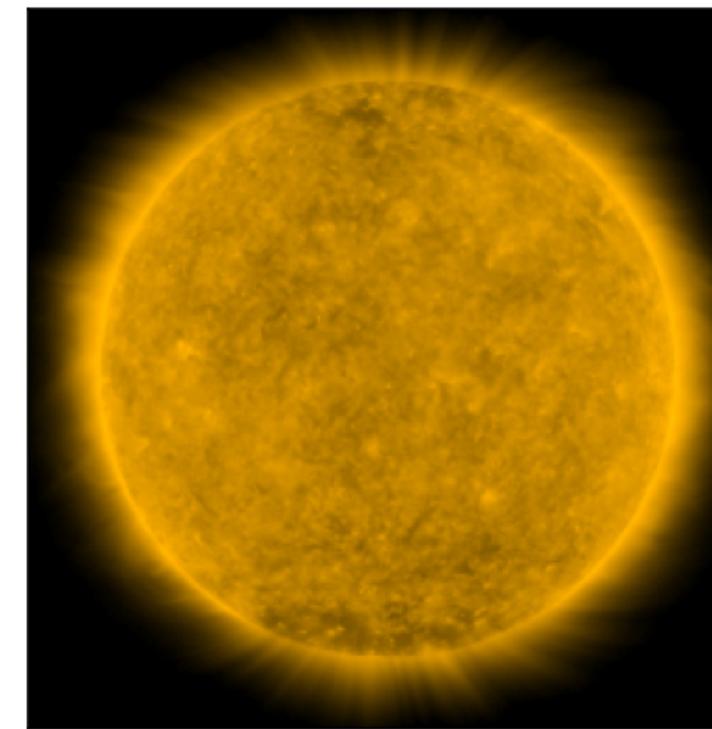
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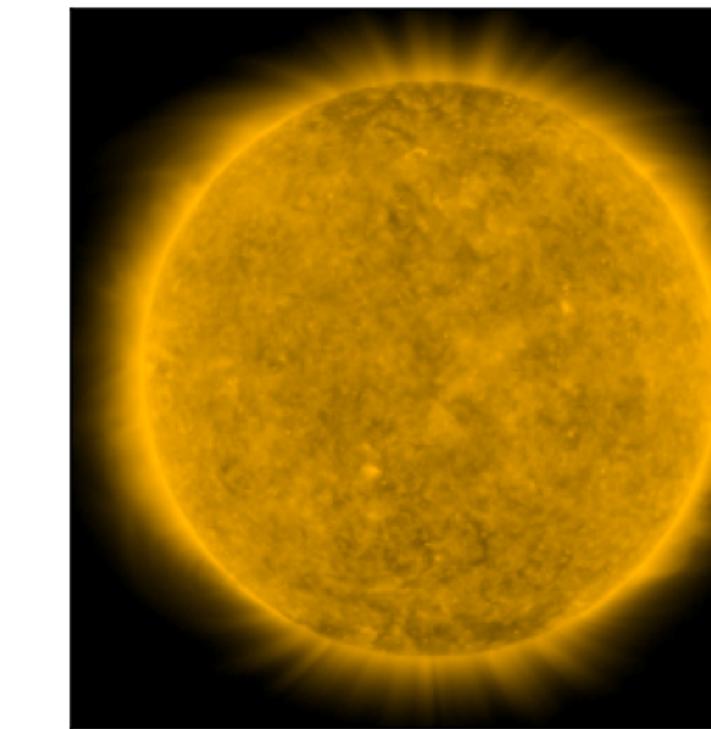
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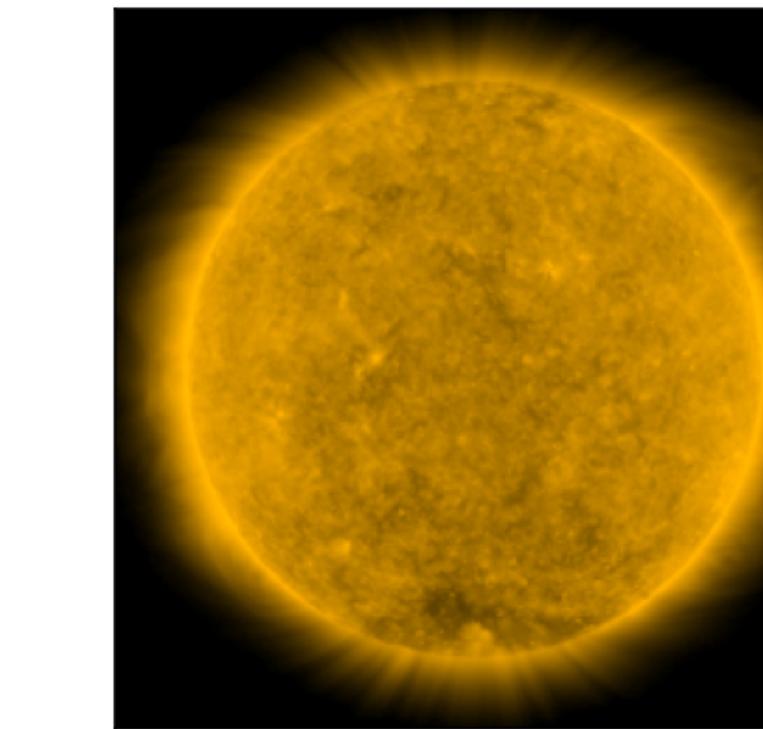
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with score 0.00892



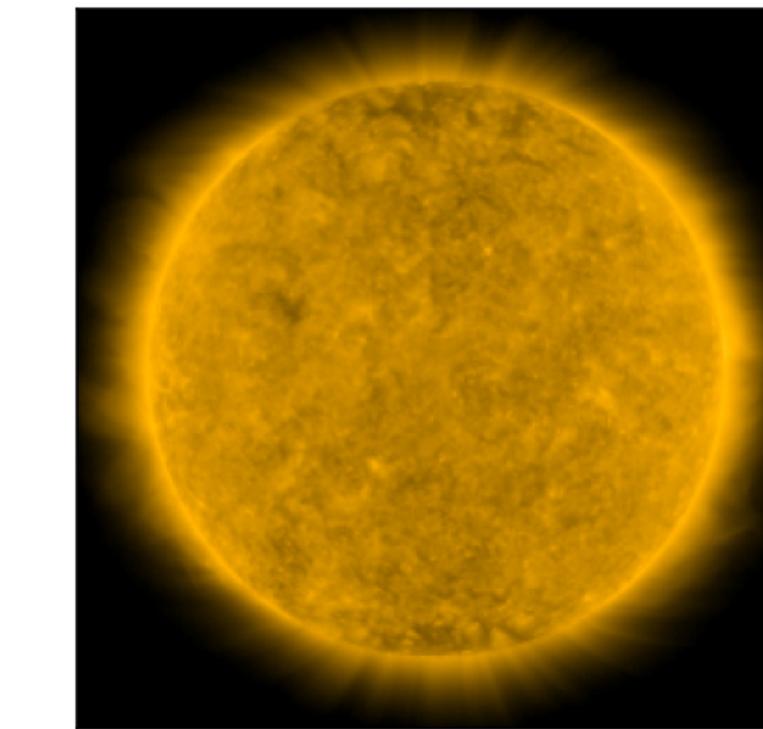
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2019-09-12T01:54:10.35Z 171A
with score 0.01528



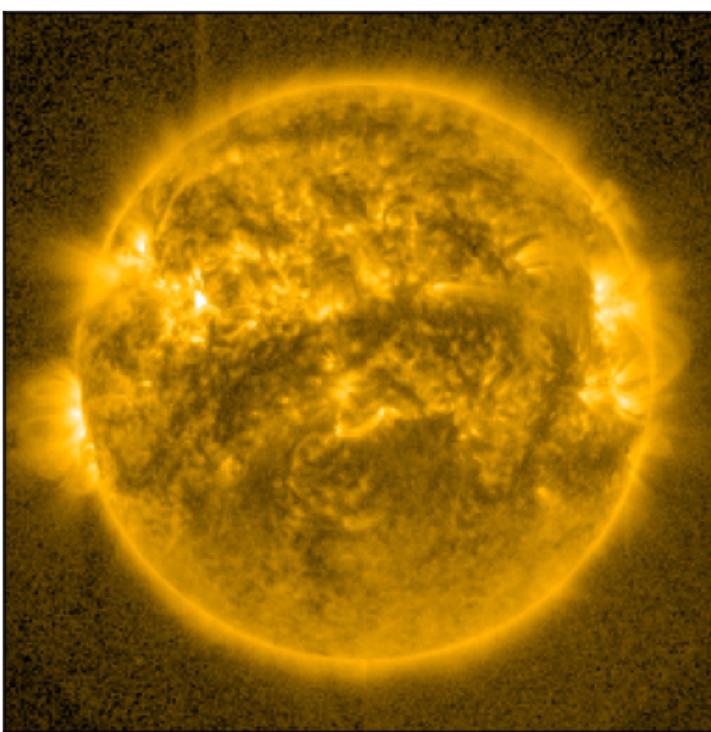
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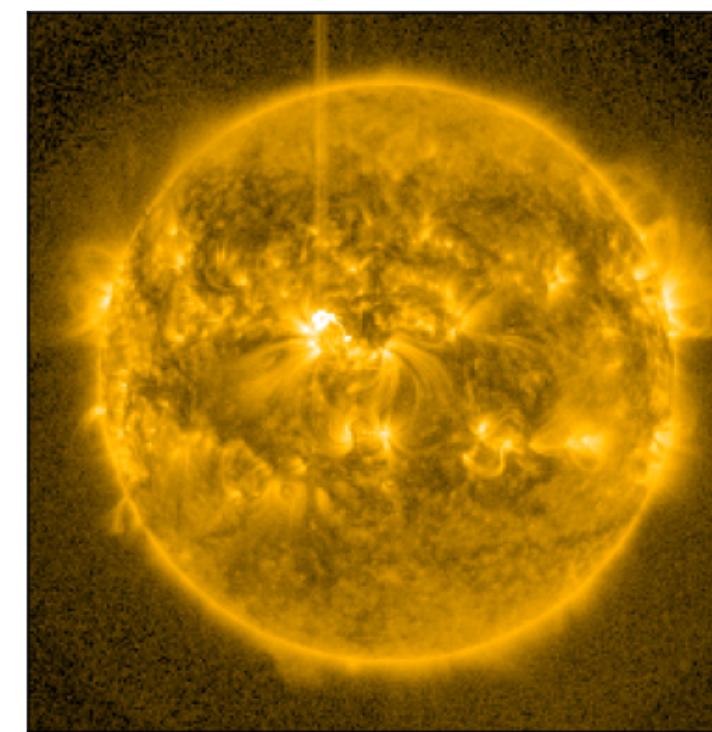
Results

Image-level scoring, **high** scores

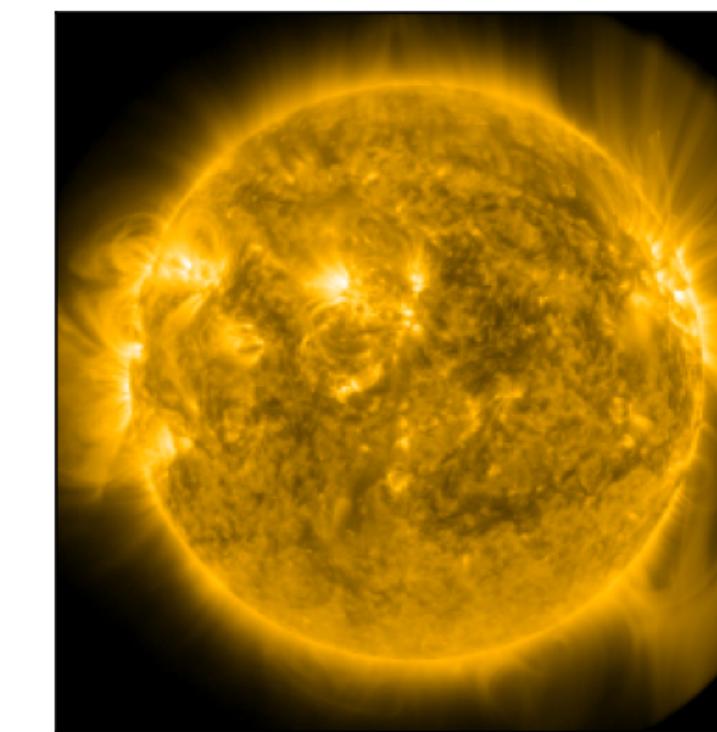
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with score 1.00000



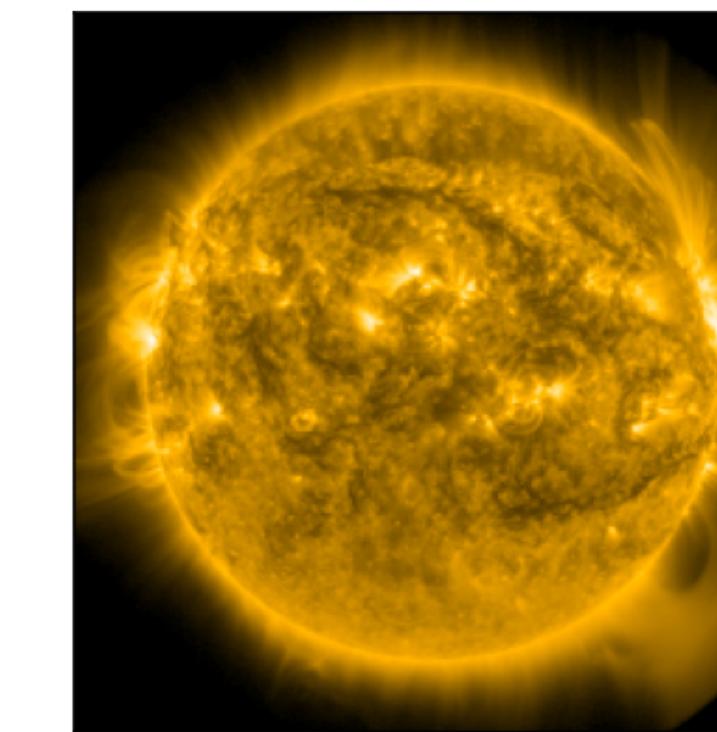
2014-01-07T10:12:13.73Z 171A
with score 0.89402



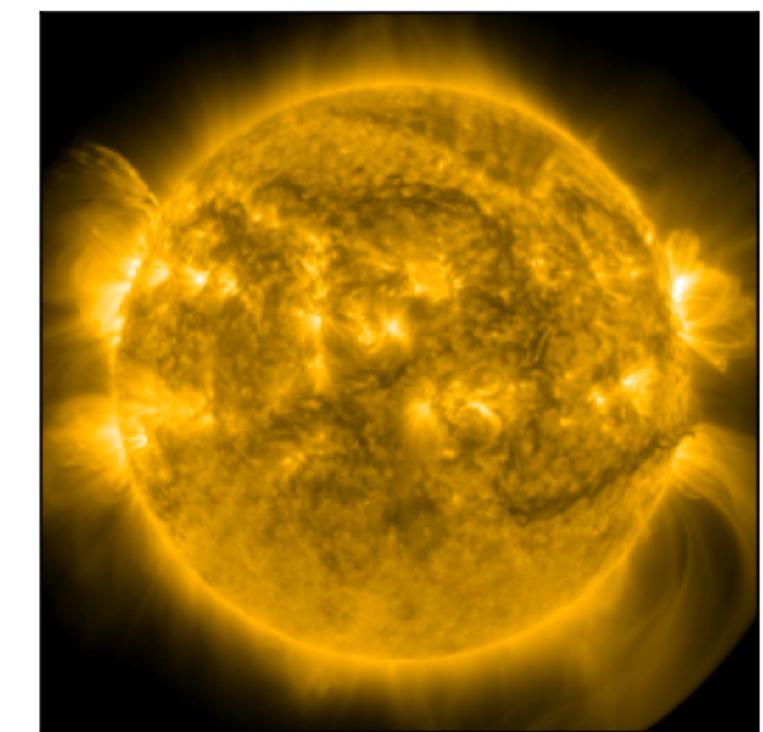
2014-11-25T12:48:12.34Z 171A
with score 0.82590



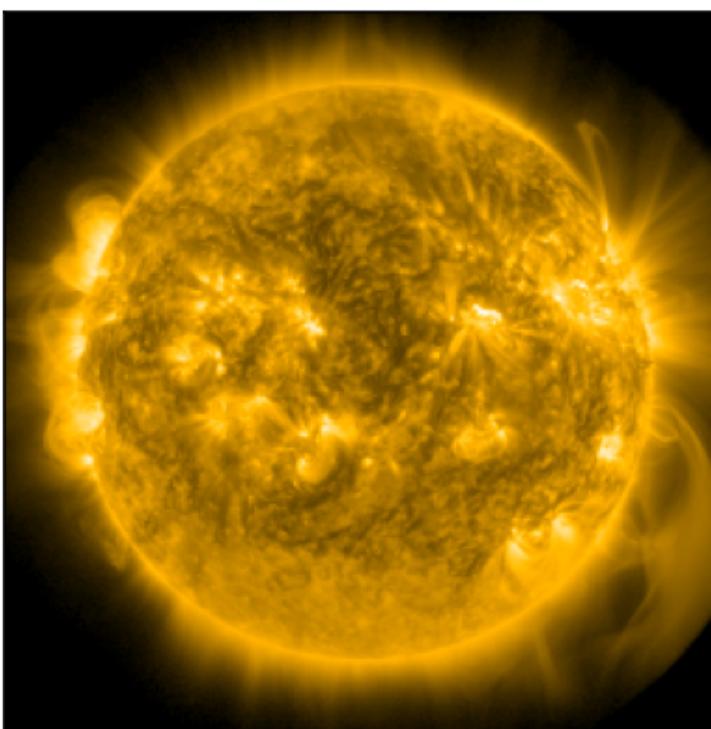
2014-10-30T04:42:13.47Z 171A
with score 0.82523



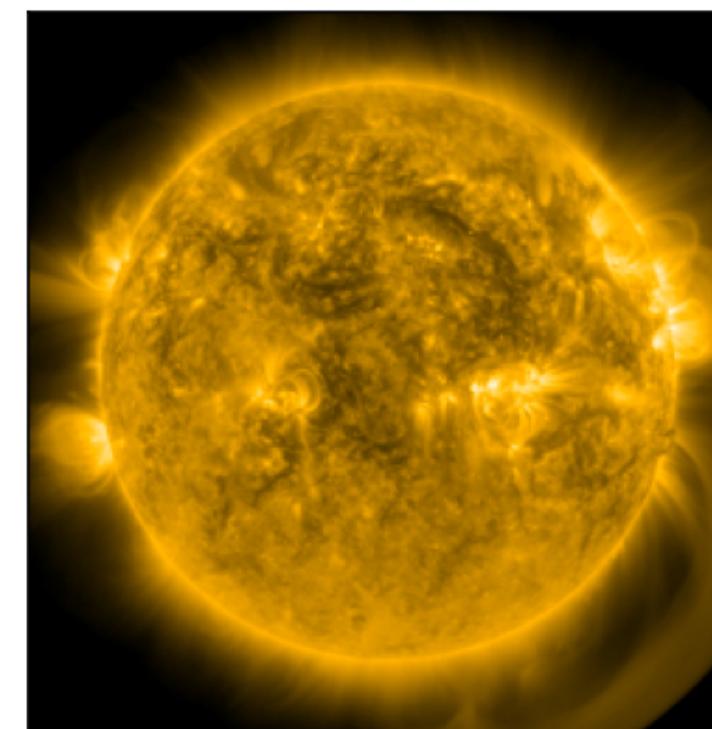
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with score 0.81870



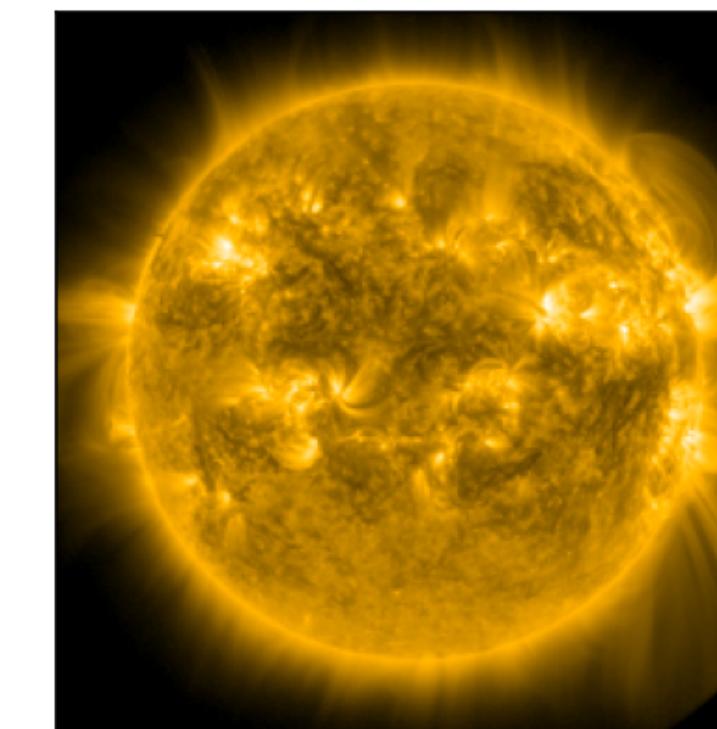
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with score 0.79630



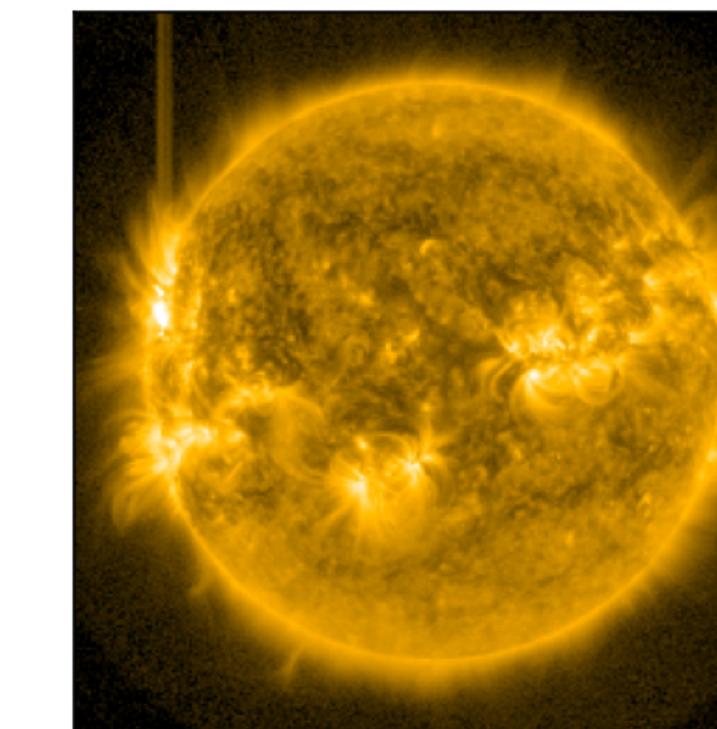
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with score 0.76041



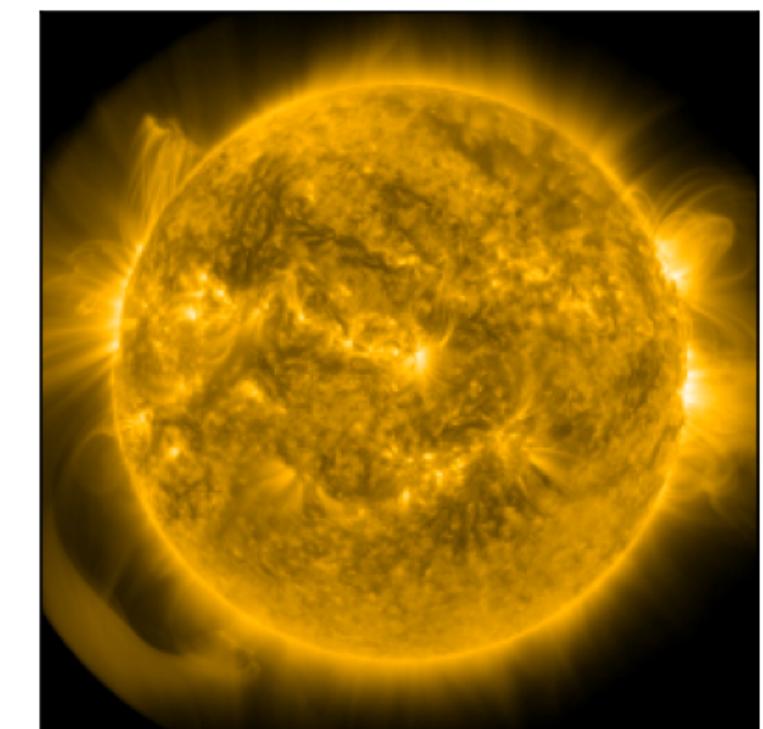
2014-07-11T03:00:13.36Z 171A
with score 0.75853



2014-02-25T00:54:12.99Z 171A
with score 0.75816



2014-12-08T19:12:12.34Z 171A
with score 0.74217

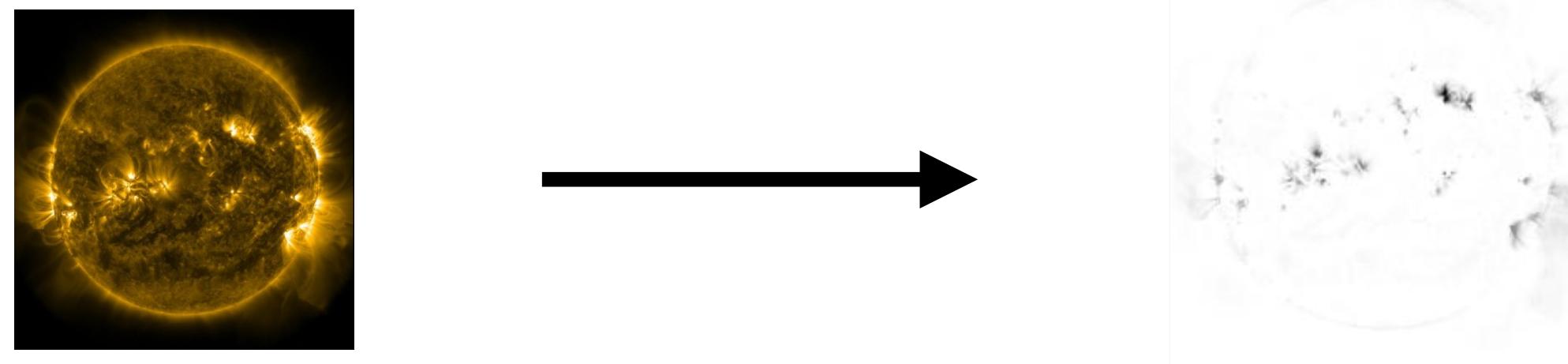


Anomaly Scoring

Pixel-level

- Combine reconstruction-loss and KL-gradients by function h (i.e. pixel-wise multiplication)

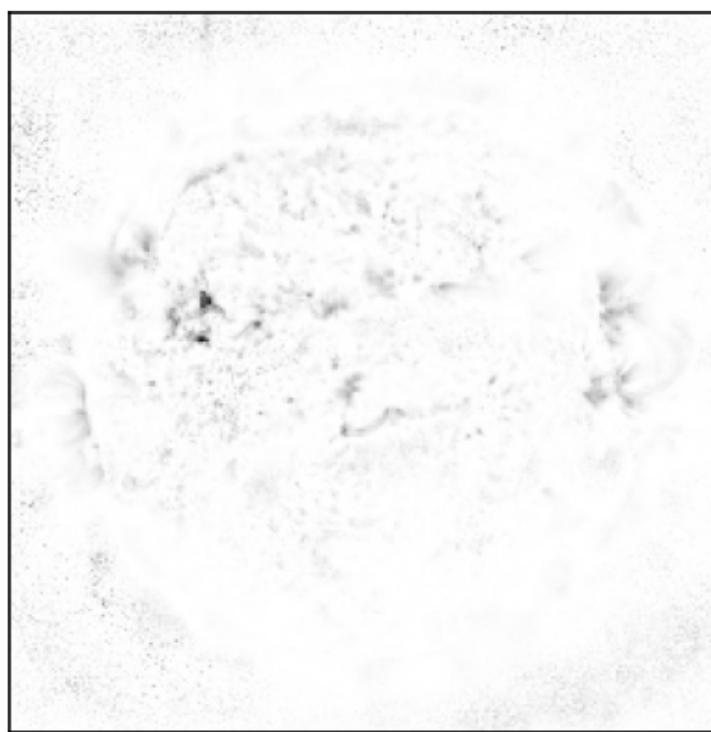
$$h \left(|x - g(f(x))|, \frac{\delta(L_{KL}(x))}{\delta x} \right)$$



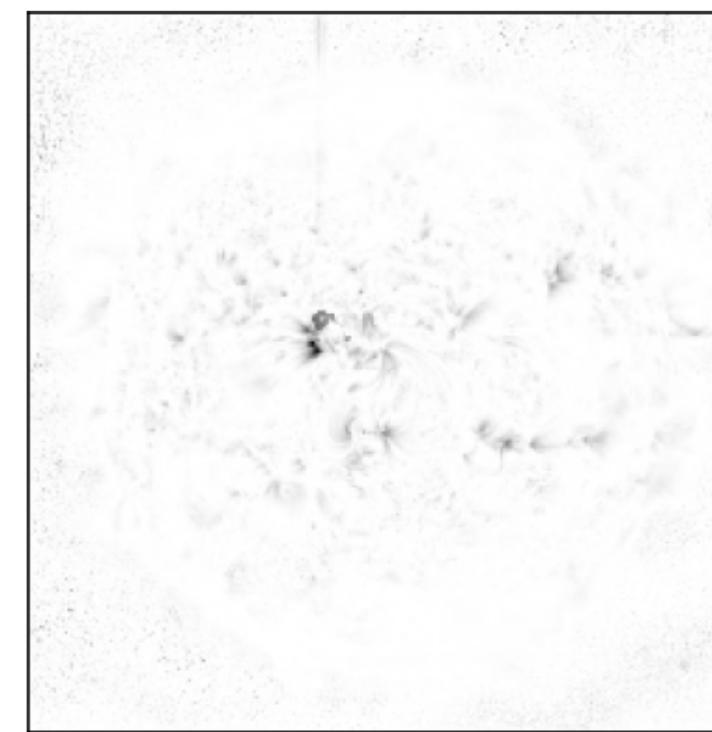
Results

Pixel-level scoring

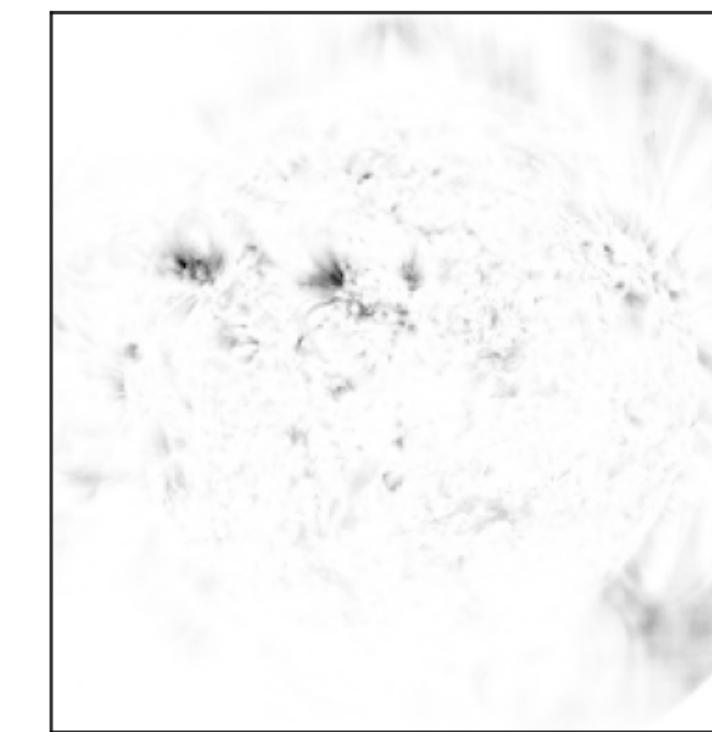
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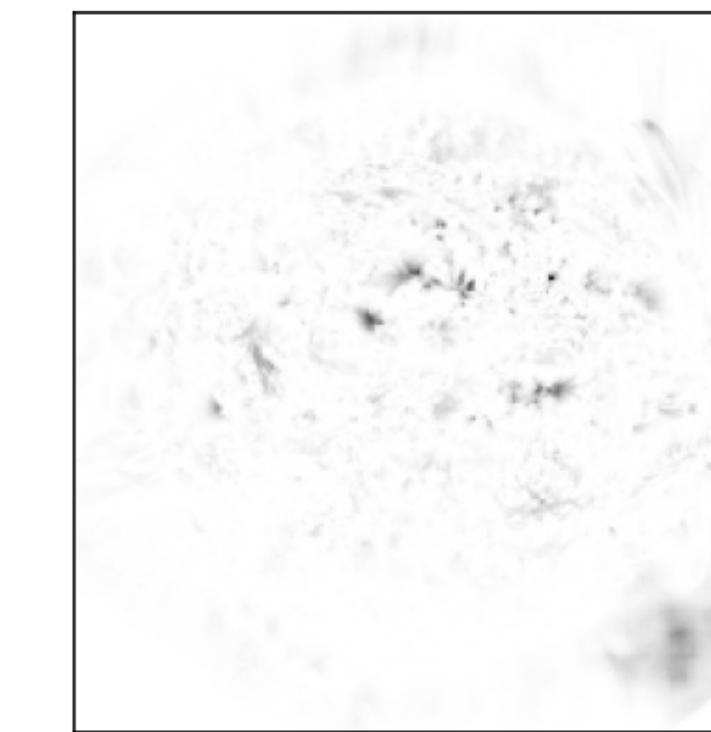
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with score 0.89402



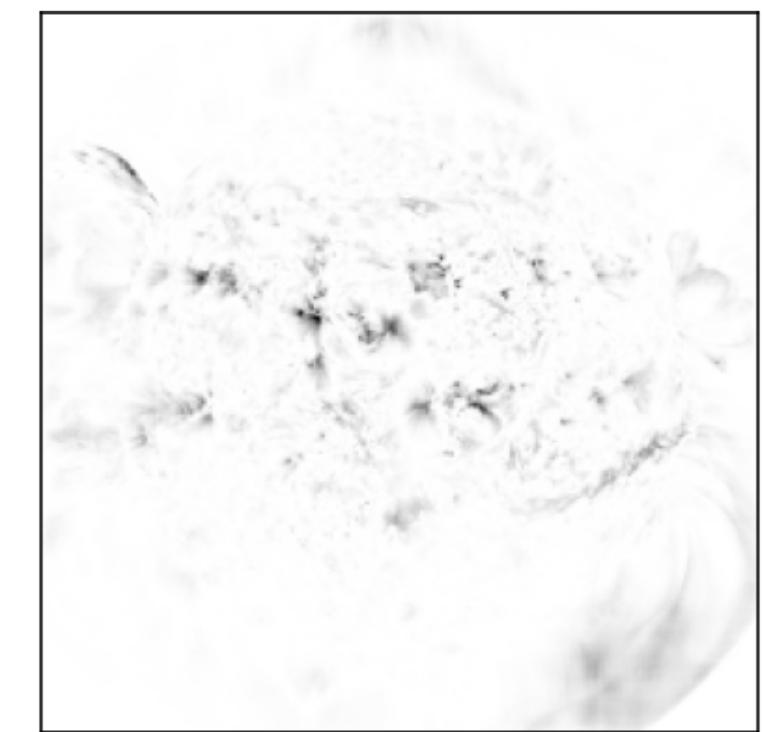
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with score 0.82590



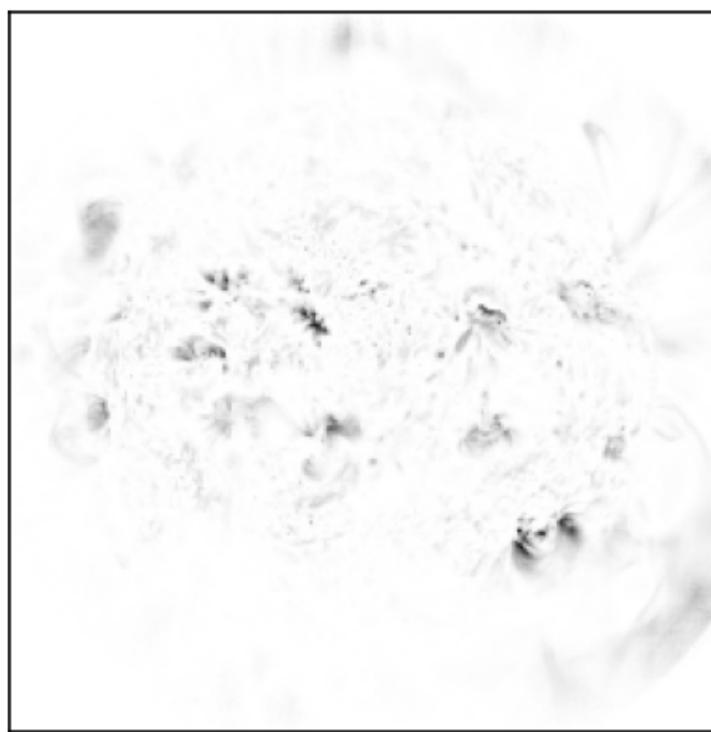
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with score 0.82523



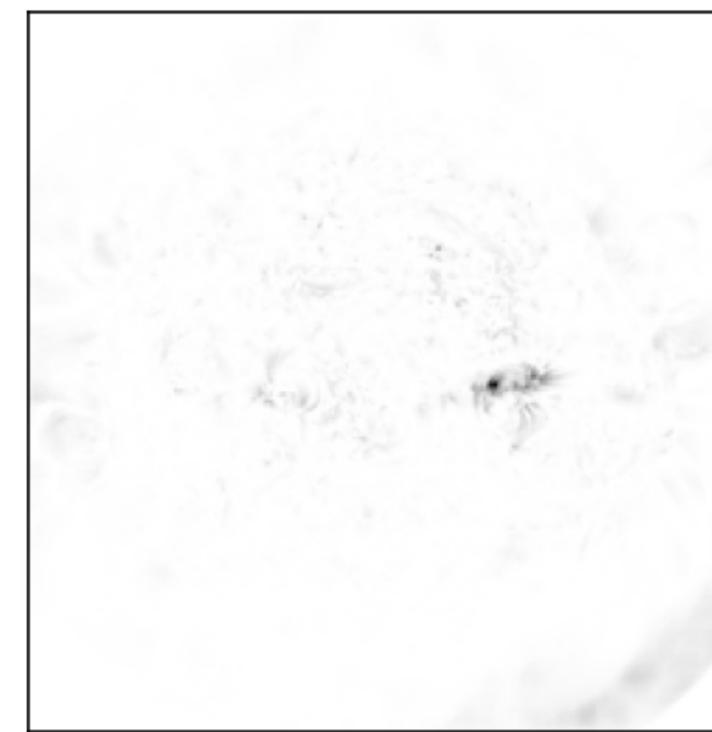
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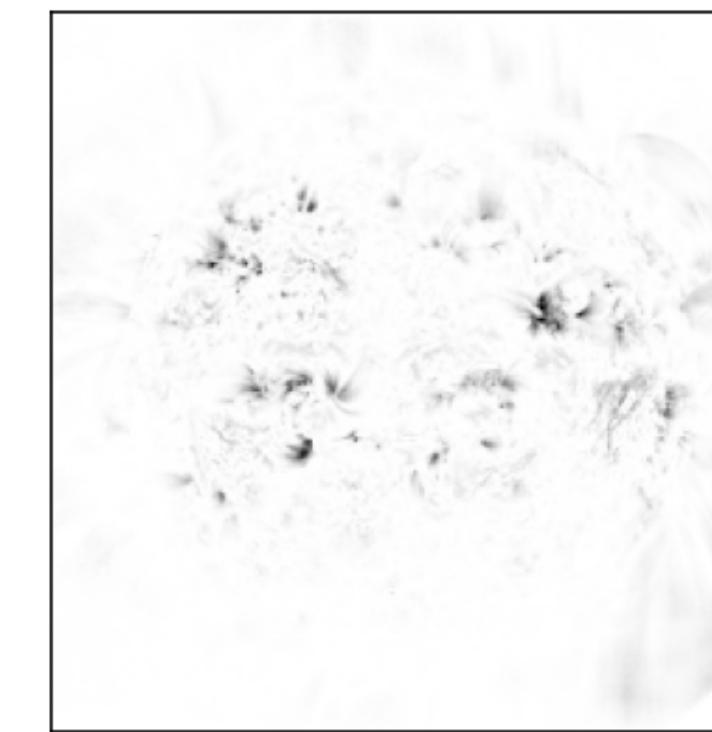
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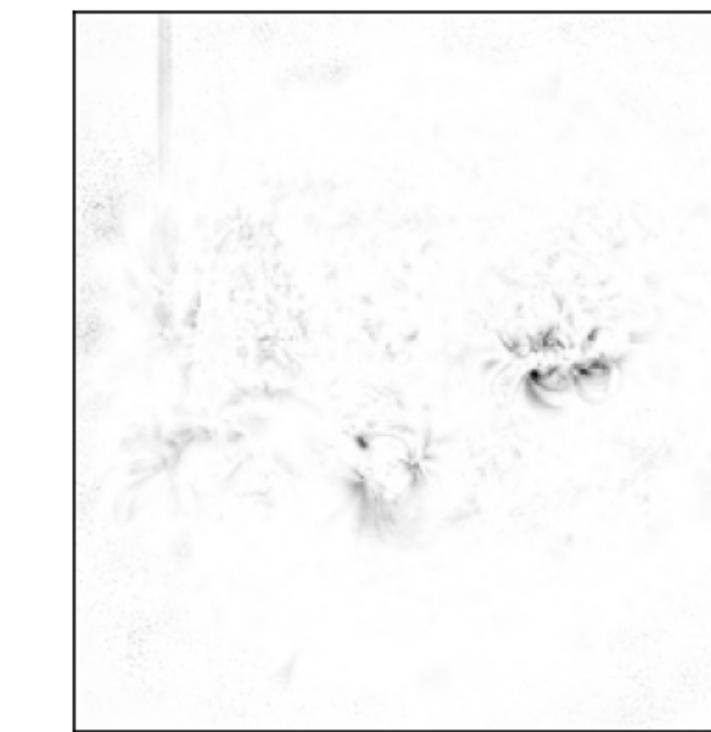
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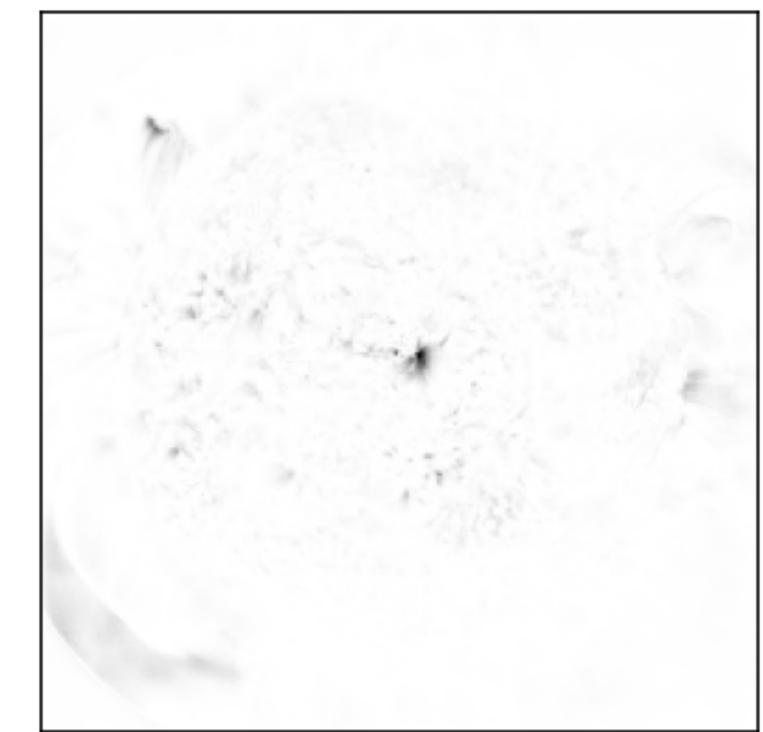
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with score 0.75853



2014-02-25T00:54:12.99Z 171A
with score 0.75816



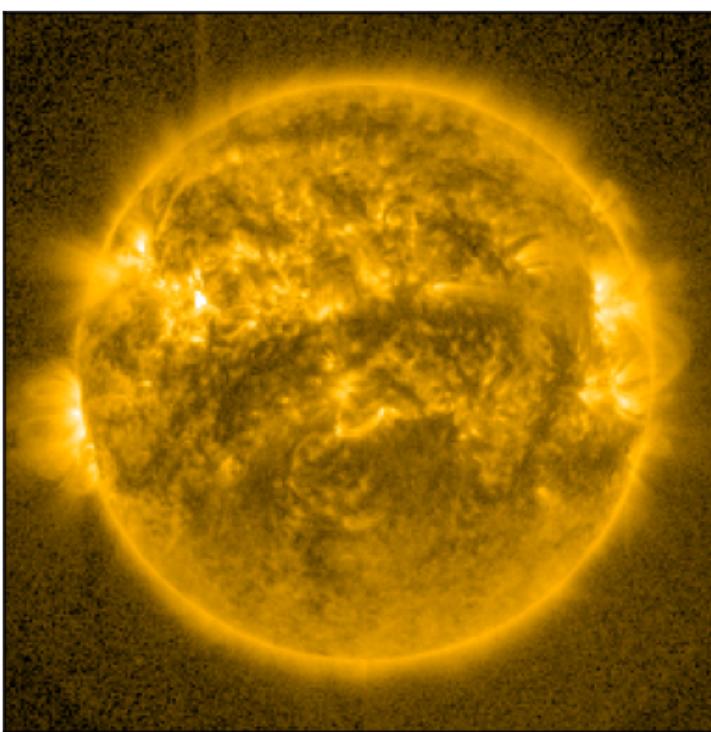
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with score 0.74217



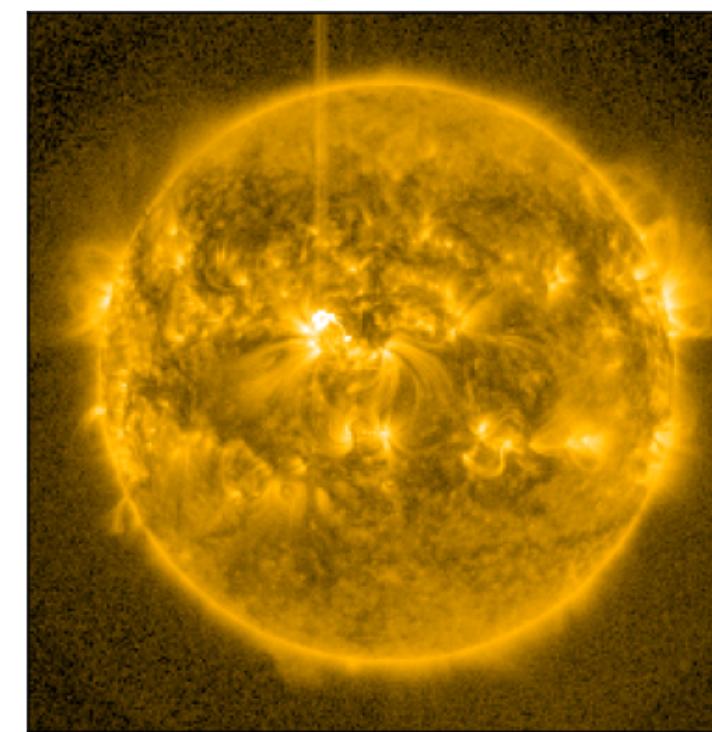
Results

Image-level scoring, **high** scores

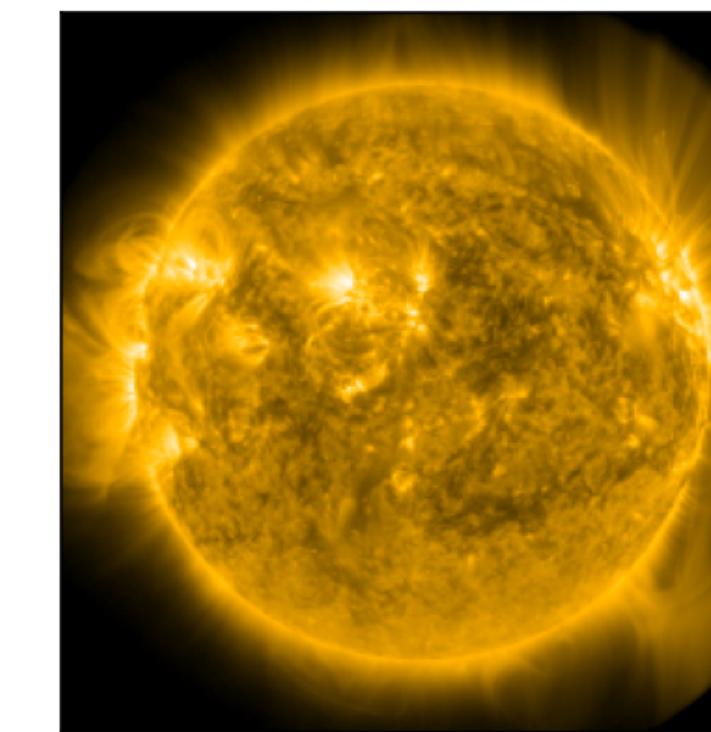
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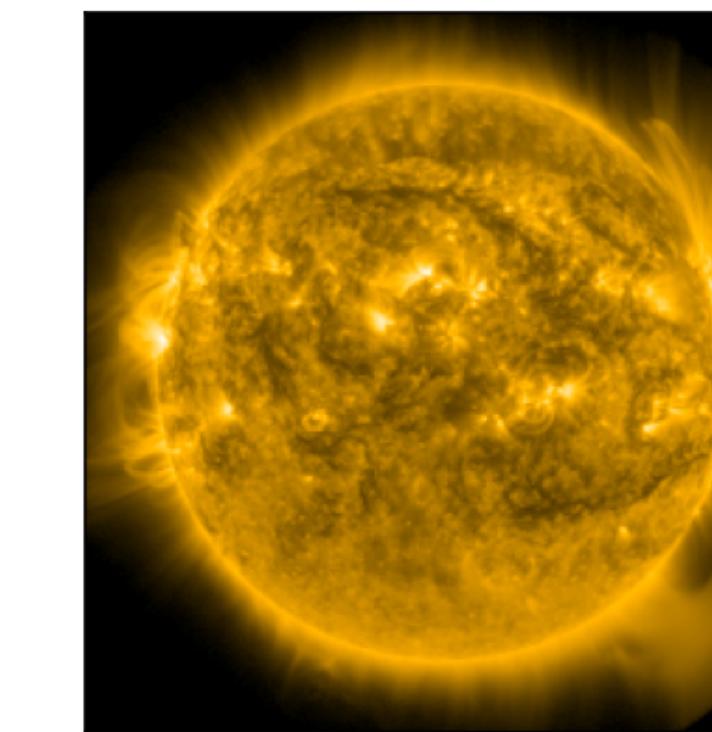
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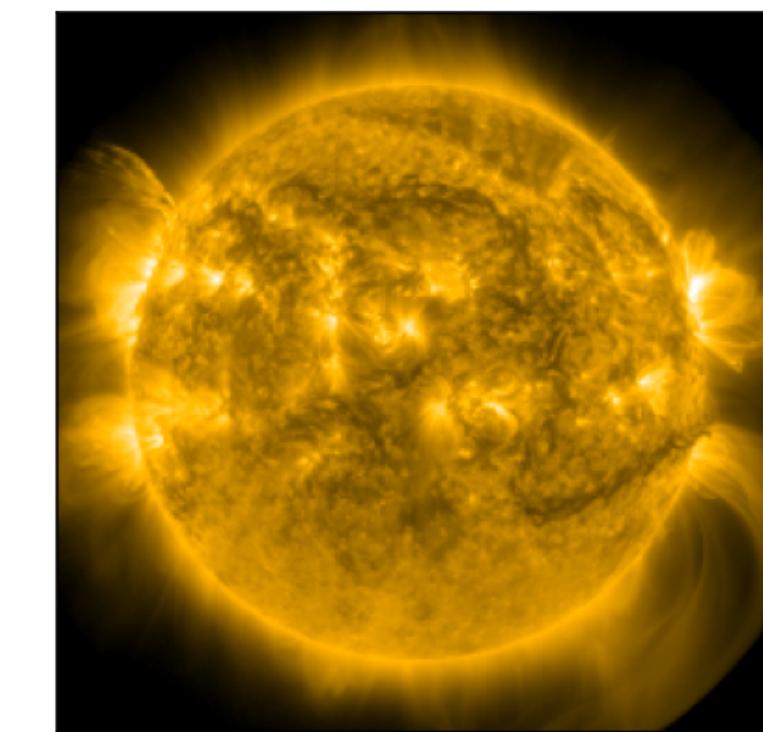
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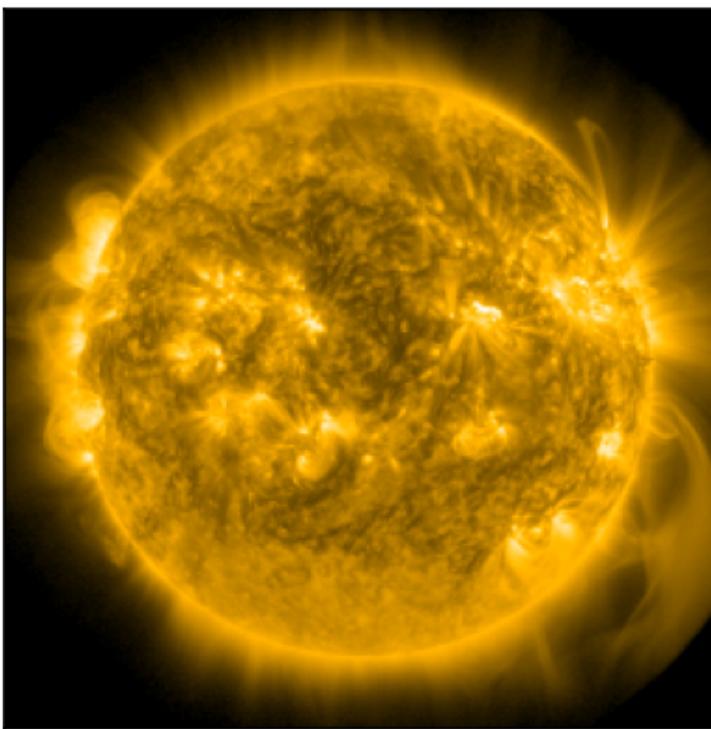
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with score 0.82523



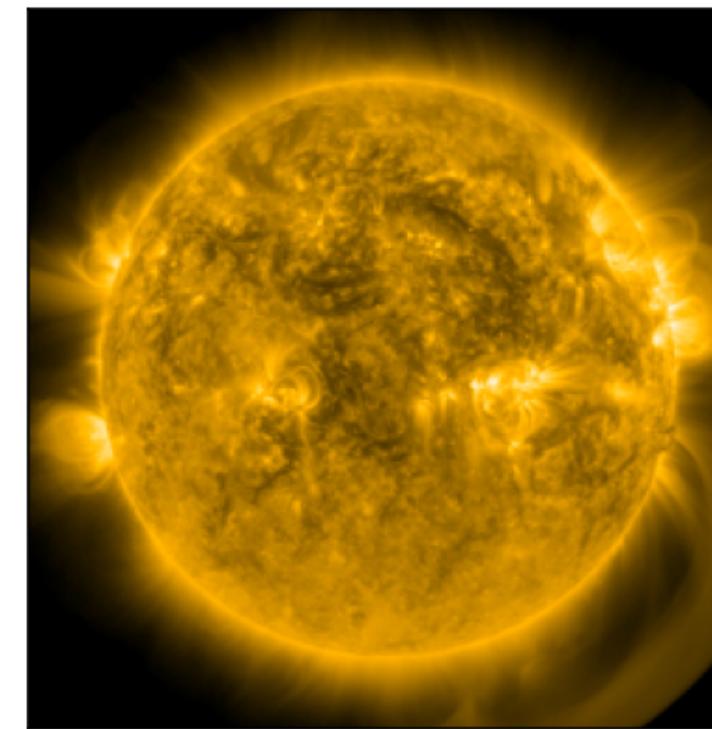
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with score 0.81870



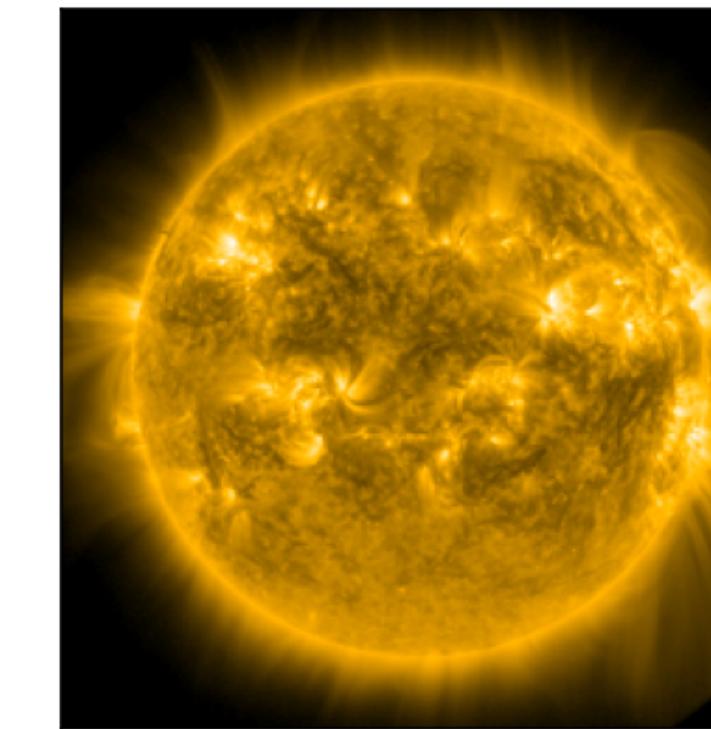
2014-12-21T13:00:13.74Z 171A
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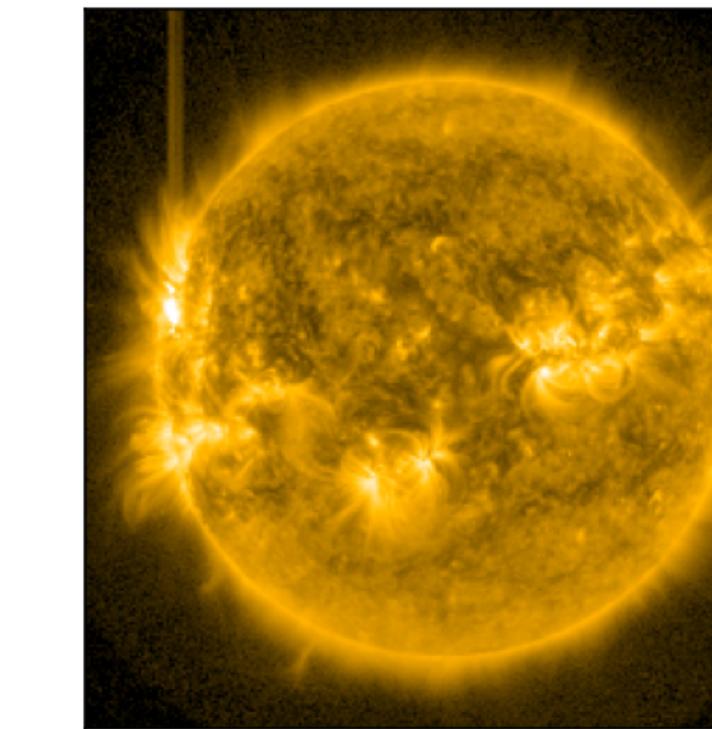
2014-08-10T01:12:12.34Z 171A
with score 0.76041



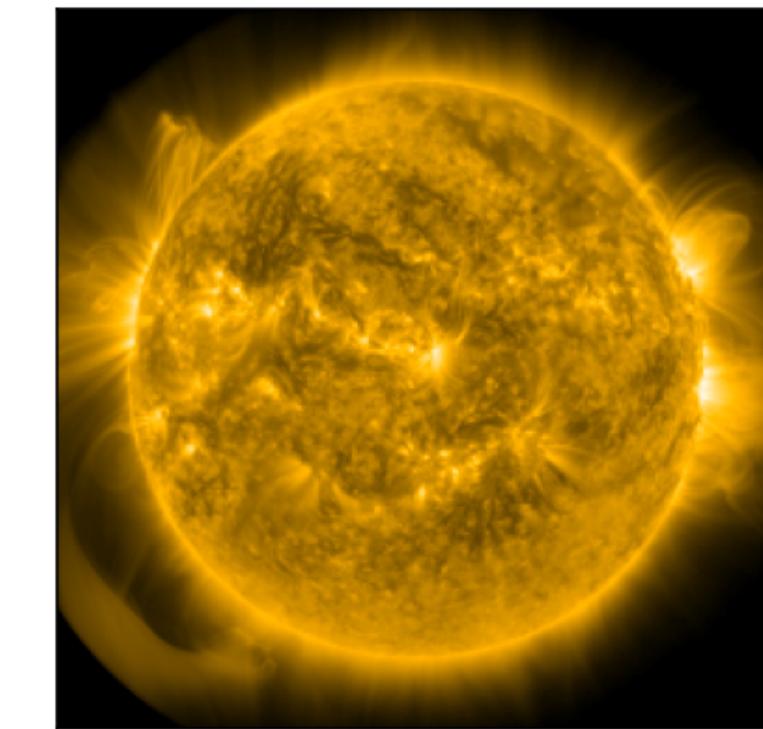
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2014-02-25T00:54:12.99Z 171A
with score 0.75816



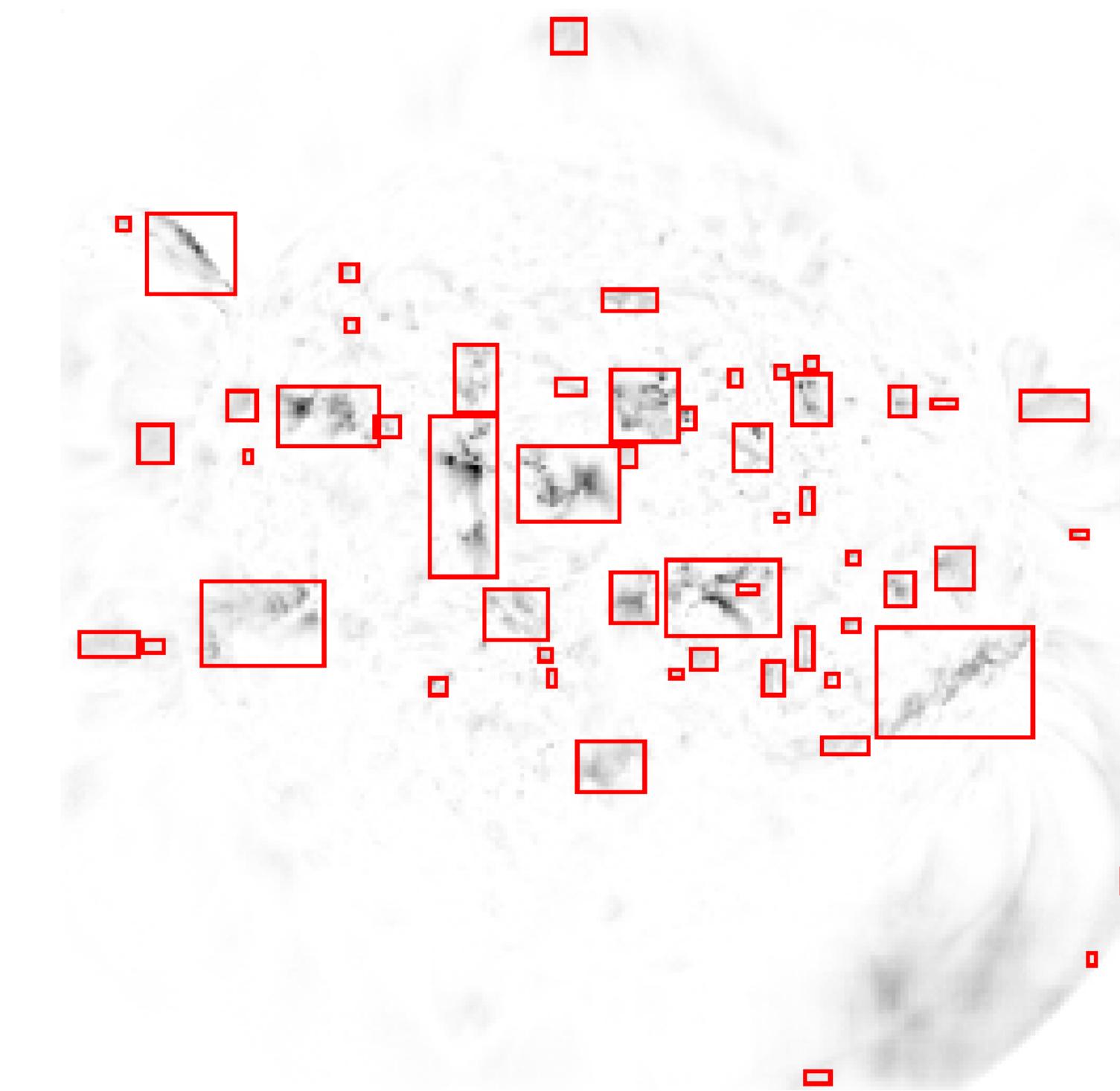
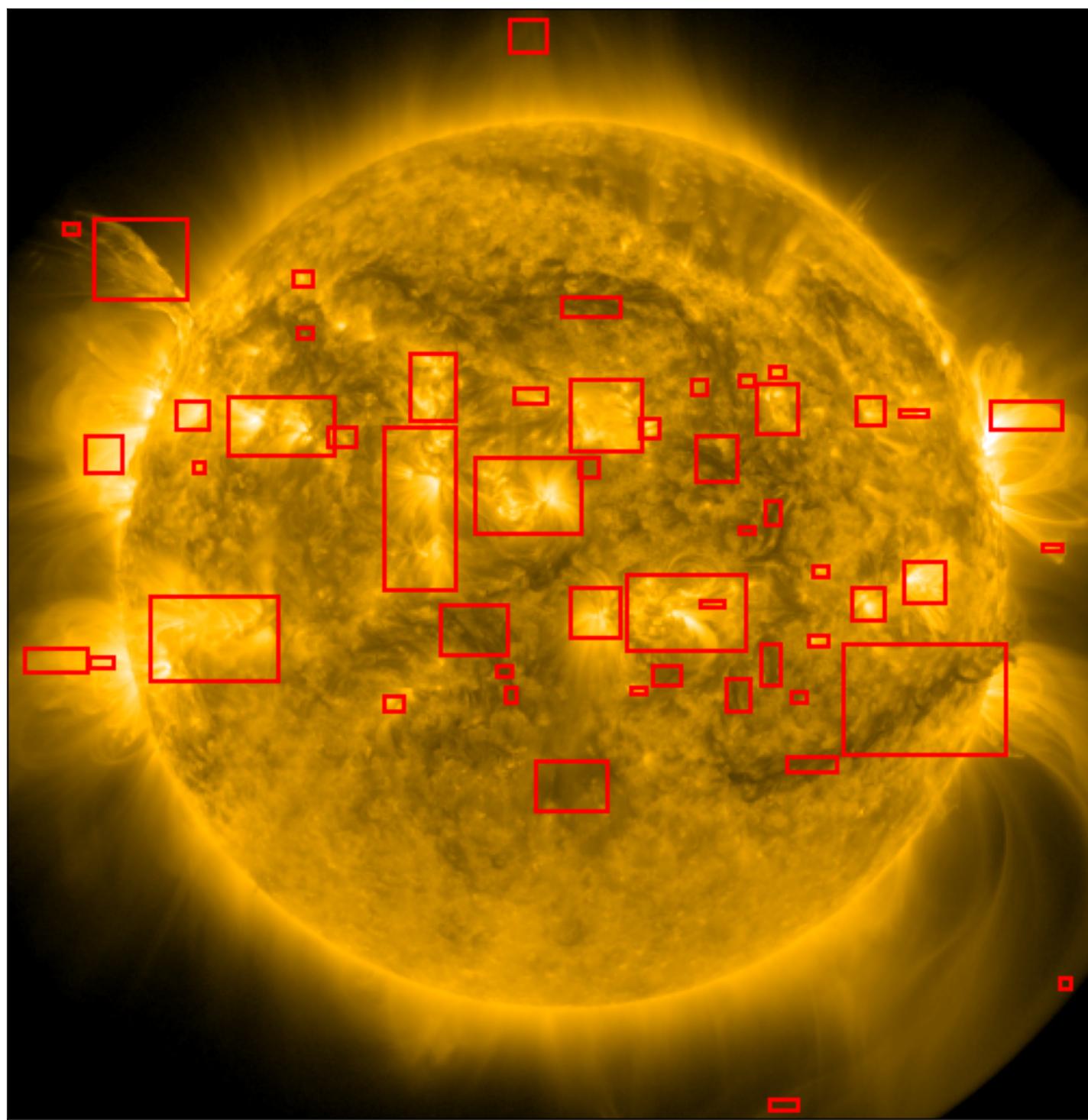
2014-12-08T19:12:12.34Z 171A
with score 0.74217



n|w

Bounding Box Extraction

2014-10-03 03:54:12 171A



n|w

Thank you!