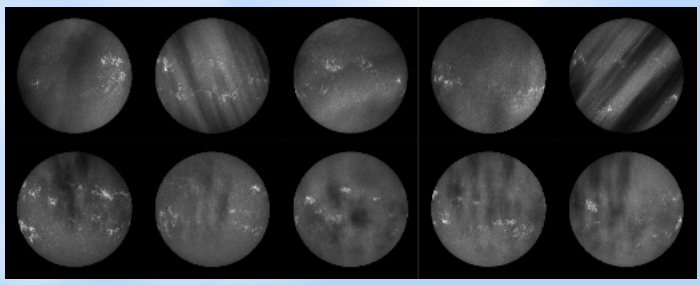
Removing cloud shadows from ground-based solar imagery

[1] [2] [3]

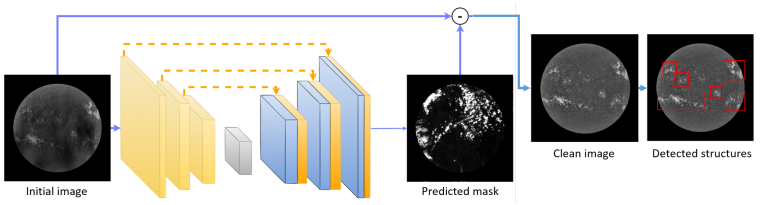
Jay Paul Morgan[1], Amal Chaoui[2], Adeline Paiement[1], Jean Abourdarham[3]

Context

All ground based observatories face a same problem: images may be polluted by terrestrial clouds. These clouds are often thin, due to no observations being usually performed in case of thick clouds. **We propose a new method to remove these cloud shadows, based on deep learning** and recover the underlying solar features.



Methodology



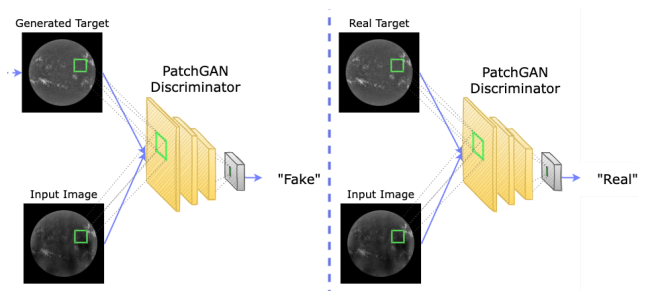
We investigated deep learning methods for removing large cloud shadow contaminants from ground-based solar imagery I_{ini} to create a cleaned image ($\hat{I}_{\text{clean}}$).

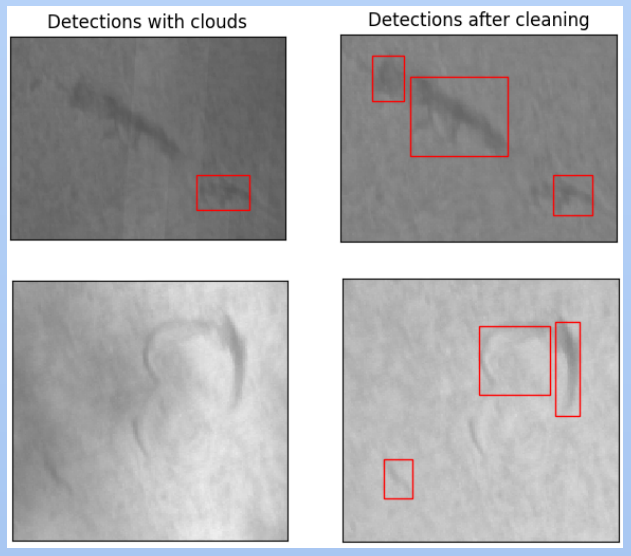
Architecture: We adopted the U-Net-style architecture for more detailed outputs.

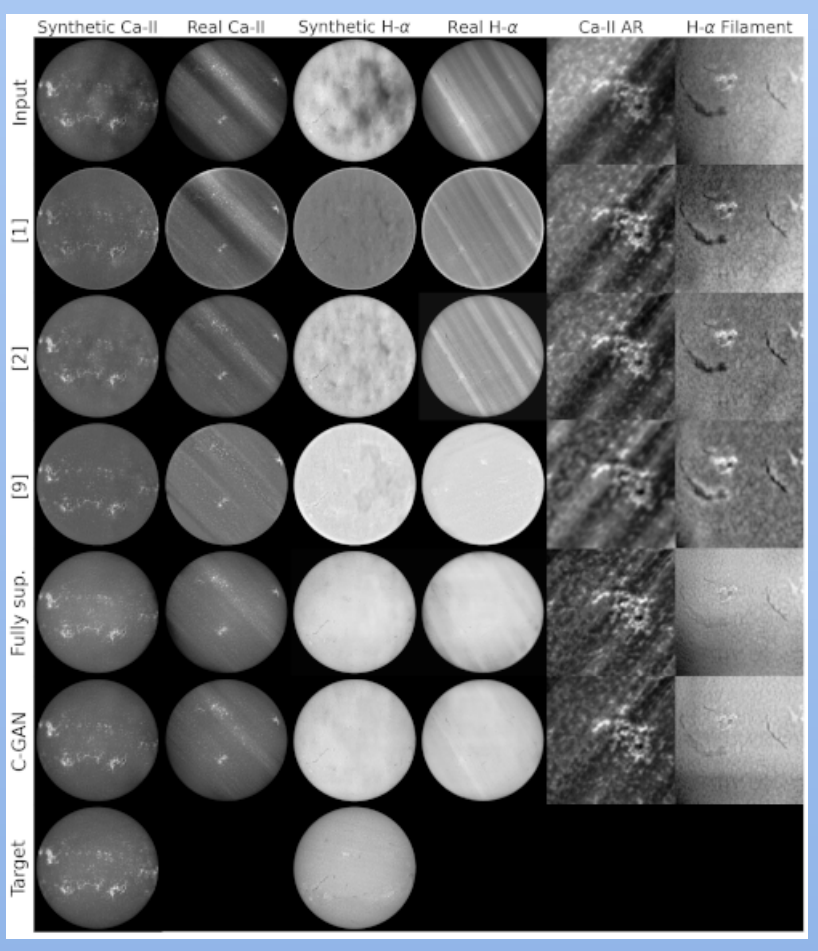
Our network adds in the intensity that was removed by clouds:

$$\hat{I}_{\text{clean}} = I_{\text{ini}} + \hat{M}$$

We compared two training setups: fully-supervised and C-GAN.







Evaluation and results

Data: Ca-II and H-α images from three different observatories, and a new dataset of synthetic clouds applied to real observations.

Metrics:

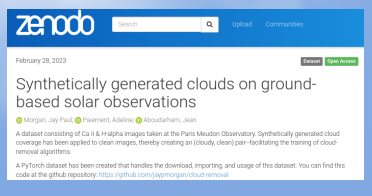
- Quantitative image restoration quality metrics: Root Mean Squared Error (RMSE), Peak Signal-to-Noise Ratio (PSNR), and Structural SIMilarity (SSIM).
- Qualitatively: effect on automatic filament detection [2].

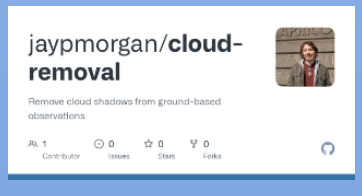
Comparison against traditional cloud removal technique [1,2] and a non-learning method [9]: higher quality restoration of solar structures, and faster computation times.

The two training setups have different strengths and weaknesses: full supervision produces more homogeneous solar disks, and C-GAN better handles strong clouds.

Data	Method	PSNR ↑	SSIM ↑	RMSE ↓
Ca-II	[1] (15 failures)	21.90	94.8	8.6
	[2]	26.0	98.1	5.4
	[9]	23.2	92.7	7.3
	Fully sup.	**30.6(0.3)**	**98.9(0.1)**	**3.7(0.1)**
	C-GAN	30.0(0.4)	98.8(0.2)	3.9(0.1)
H-α	[1] (5 failures)	14.8	91.4	19.6
	[2]	23.3	98.4	7.0
	[9]	21.0	96.0	9.2
	Fully sup.	**28.6(0.3)**	**98.9(0.1)**	**4.5(0.2)**
	C-GAN	28.3(0.5)	98.9(0.2)	4.6(0.2)

All data and models are publicly available at github.com/jaypmorgan/cloud-removal and https://zenodo.org/record/7684201





References:
[1] Song Feng, Jiaben Lin, Yunfei Yang, Haibo Zhu, Feng Wang, and Kaifan Ji, "Automated Detecting and Removing Cloud Shadows in Full-Disk Solar Images," New Astronomy, vol. 32, pp. 24–30, 2014.
[2] N. Fuller and J. Aboudarham, "Automatic detection of solar filaments versus manual digitization," in Knowledge-Based and Intelligent Information and Engineering Systems (KES), 2004, pp. 467–475.
[9] Remya K. Sasi and V.K. Govindan, "Shadow Removal Using Sparse Representation Over Local Dictionaries," Engineering Science and Technology, an International Journal, vol. 19, no. 2, pp. 1067–1075, 2016

This work was funded by ANR grant N° ANR-20-CE23-0014-01. JA thanks CNES (Centre National d'Etudes Spatiale, the French space agency) for its support in this project.