Statistical studies of IRIS data towards better understanding of small-scale reconnection

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IRIS-9, Göttingen, 25-29 June 2018

Contributed Talk

1. Fundamental physical processes and modeling

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Magnetic reconnection is a fundamental plasma process that play a critical role in energizing the solar atmosphere. Despite the fact that it is one of the most widely assumed mechanisms in studies of solar eruptive events, it is still not fully understood. Recently, we used spectroscopic data from the Interface Region Imaging Spectrograph (IRIS) mission to reveal the transient evolution of fast reconnection mediated by plasmoids at several small-scale reconnection sites (Innes & Guo et al. 2015, Rouppe van der Voort et al., 2017). In this presentation, we present statistical studies of explosive events on a large amount of samples with the help of artificial intelligence. The IRIS team obtained a significant number of observations of explosive events in Si IV (and other wavelengths) during 2016 and 2017. We apply machine-learning and deep-learning algorithms on these data sets to detect explosive events. All the events we detect are then categorized according to different aspects (e.g. dynamics, absorption features etc.). For each group, we obtain key parameters of reconnection dynamics (e.g. growth time) and by comparing these parameters in different group, we are able to reveal how reconnection proceeds in different regimes on the Sun.

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Search for sit-and-stare data sets for statistic studies of explosive events in IRIS database

INTERFACE REGION IMAGING SPECTROGRAPH
IRIS DATA SEARCH

Help
Export SSW

<< < **Start** > >>
2013-07-20T00:00

<< < **End** > >>
2018-06-08T00:00

min **Raster** max
FOV X
FOV Y
Count 1
Cdnce 6

Raster Step
Count
Size
Cdnce

Exposure Time
Min Exp
Exp Time

Spectral Lines

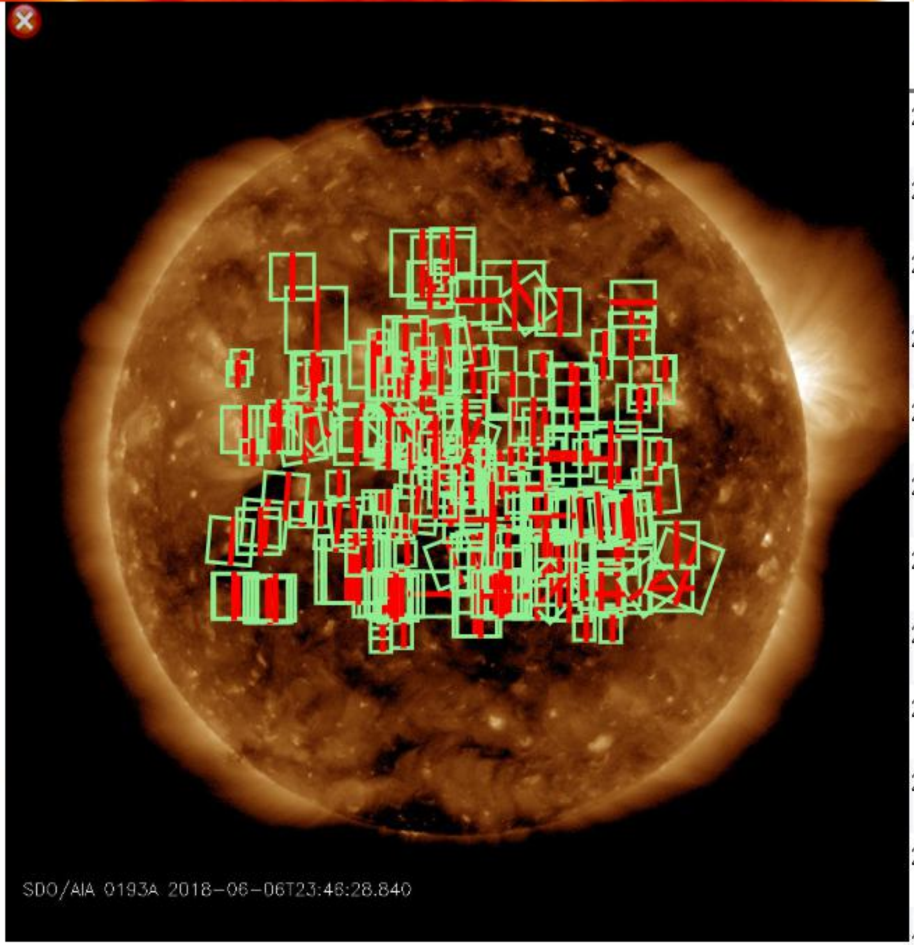
min **SJI** max
FOV X
FOV Y

Cadence
1330
1400
2796
2832

Target
-620 XCEN 620
-620 YCEN 620
Radius
OBSID:
Target:

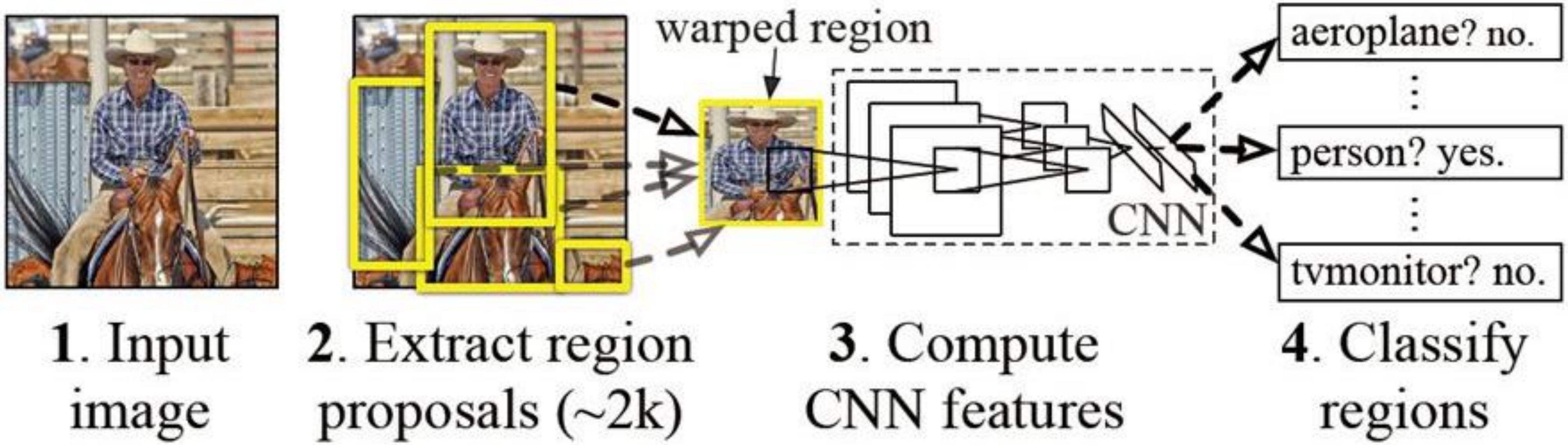
Desc: Events

Count: 264 Limit: 200 Search Reset More...
Only OBS with data Only Annotated 193



Time	Goal	OBS Desc.	X,Y	RX	RY	Raster Cad	Step Cad
2013-12-03 18:19-18:36	Plage near PIL in AR 11909	Large sit-and-stare	41",-268"	0"	119"	5s	5s
2013-12-03 19:34-20:16	More plage in AR 11909	Large sit-and-stare	60",-312"	0"	119"	5s	5s
2013-12-04 12:19-12:32	Moss in AR 11909	Large sit-and-stare	217",-331"	0"	119"	5s	5s
2013-12-05 21:58-22:40	Sit n Stare in mixed polarity AR 11909	Very large sit-and-stare	448",-292"	0"	174"	5s	5s
2013-12-06 09:06-09:43	Sit n stare Emerging AR 11916	Large sit-and-stare	43",-227"	0"	119"	5s	5s
2013-12-06 10:44-11:21	Sit n stare on Emergin AR 11916	Large sit-and-stare	63",-221"	0"	119"	5s	5s
2013-12-06 20:52-20:55	Jitter test of FW transient	Large sit-and-stare	239",-218"	0"	119"	5s	5s
2013-12-07 12:48-13:42	Sit n stare AR 11916	Large sit-and-stare	276",-231"	0"	119"	5s	5s
2013-12-07 14:24-15:18	Sit n stare AR 11916	Large sit-and-stare	309",-216"	0"	119"	5s	5s
2013-12-07 16:14-16:53	Sit n stare AR 11916	Large sit-and-stare	318",-223"	0"	119"	5s	5s
2013-12-08 00:09-01:05	Sit n stare Spot AR 11916	Large sit-and-stare	433",-212"	0"	119"	5s	5s
2013-12-14	AR 11921 Sit n						

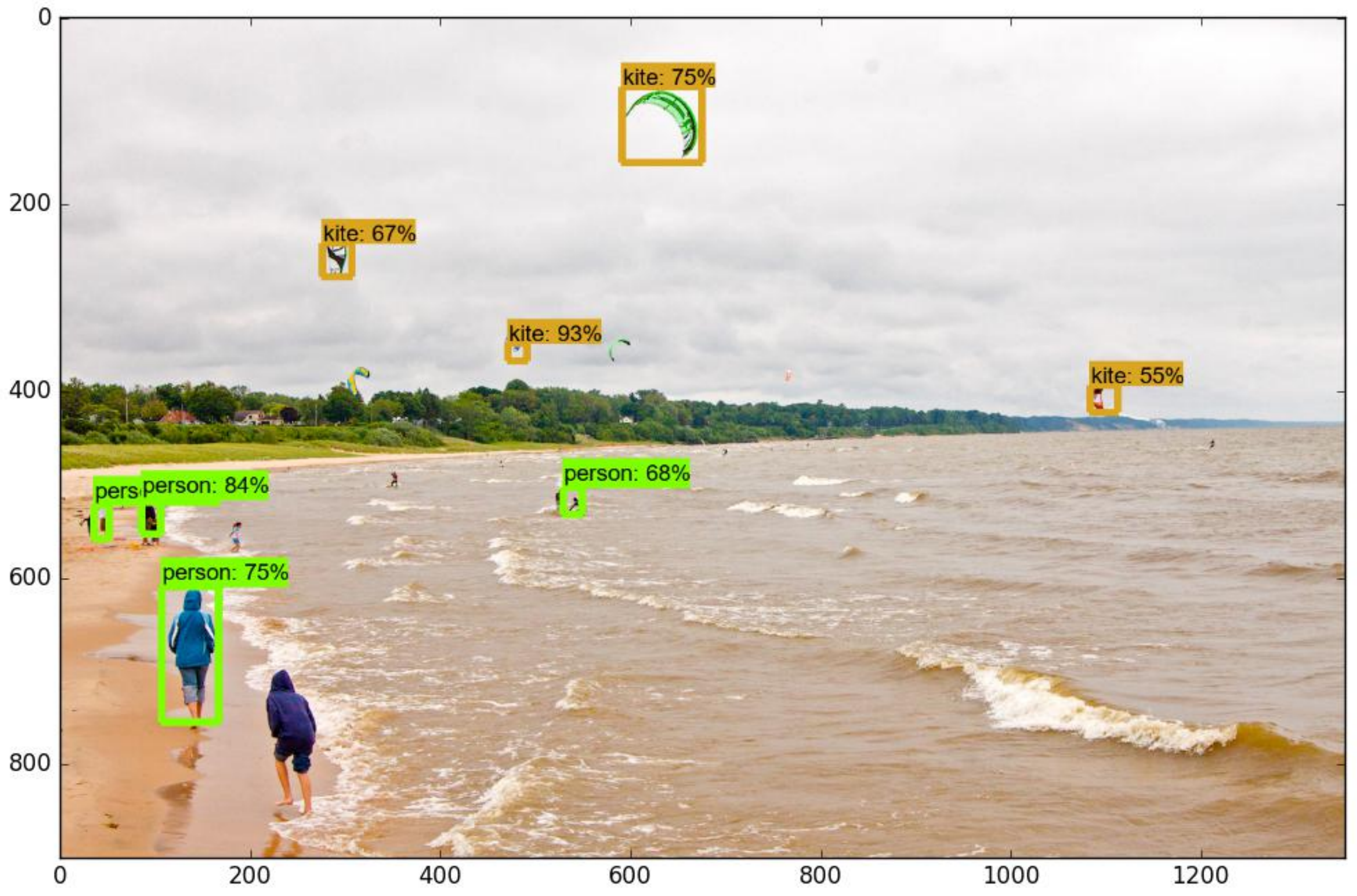
Application of deep-learning algorithms on object detection



Step1. Input an image
Step2. Use selective search to obtain ~2k proposals
Step3. Warp each proposal and apply CNN to extract its features
Step4. Adopt class-specified SVM to score each proposal

CNN stands for convolutional neural network

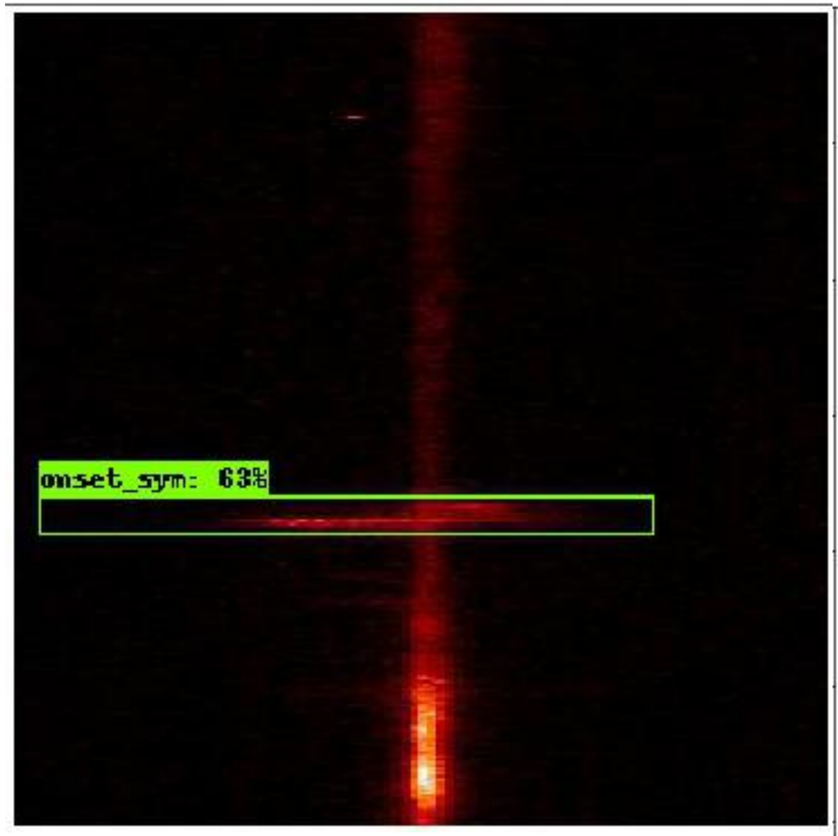
Detection results



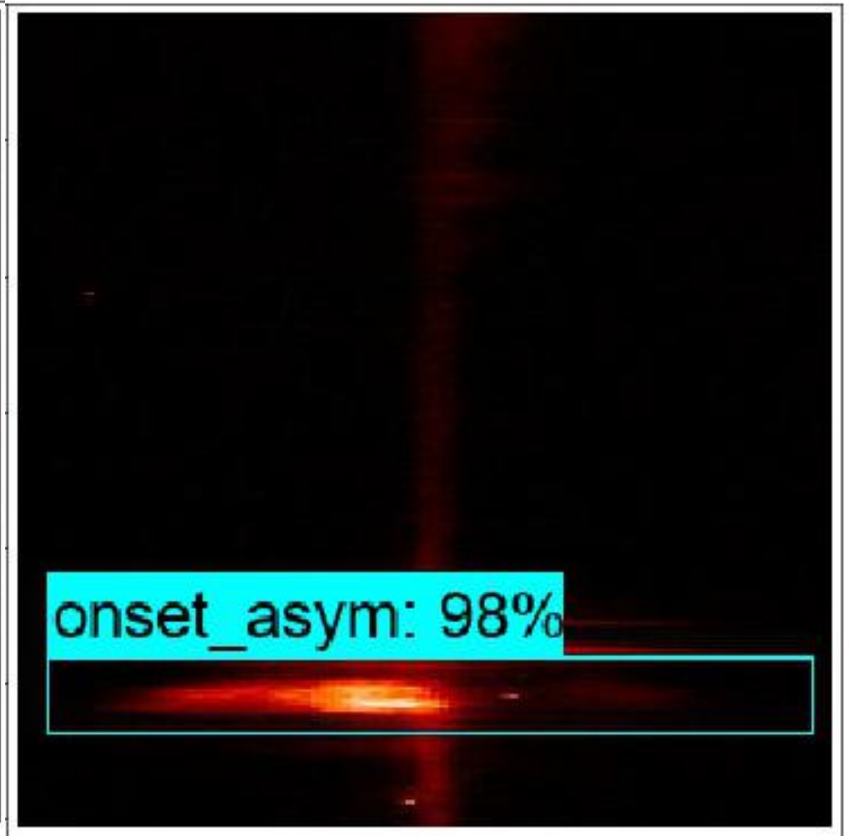
Detection results include: boxes enclosing the objects, classes of the objects and scores showing the confidence level of detect results.

Apply object-detection neural networks on IRIS data

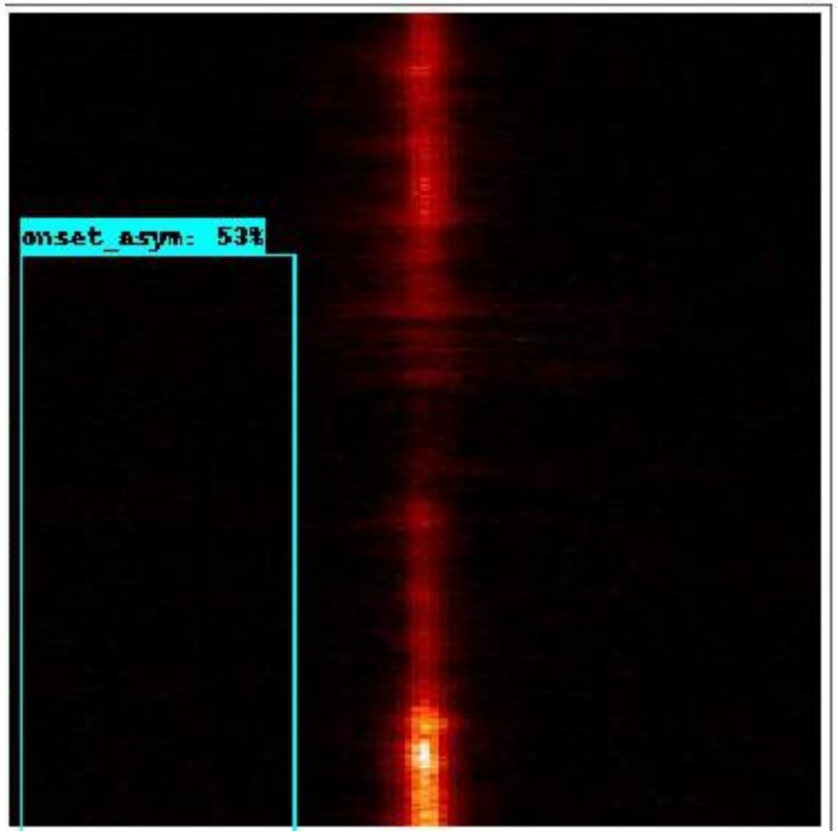
Good detection



Good detection

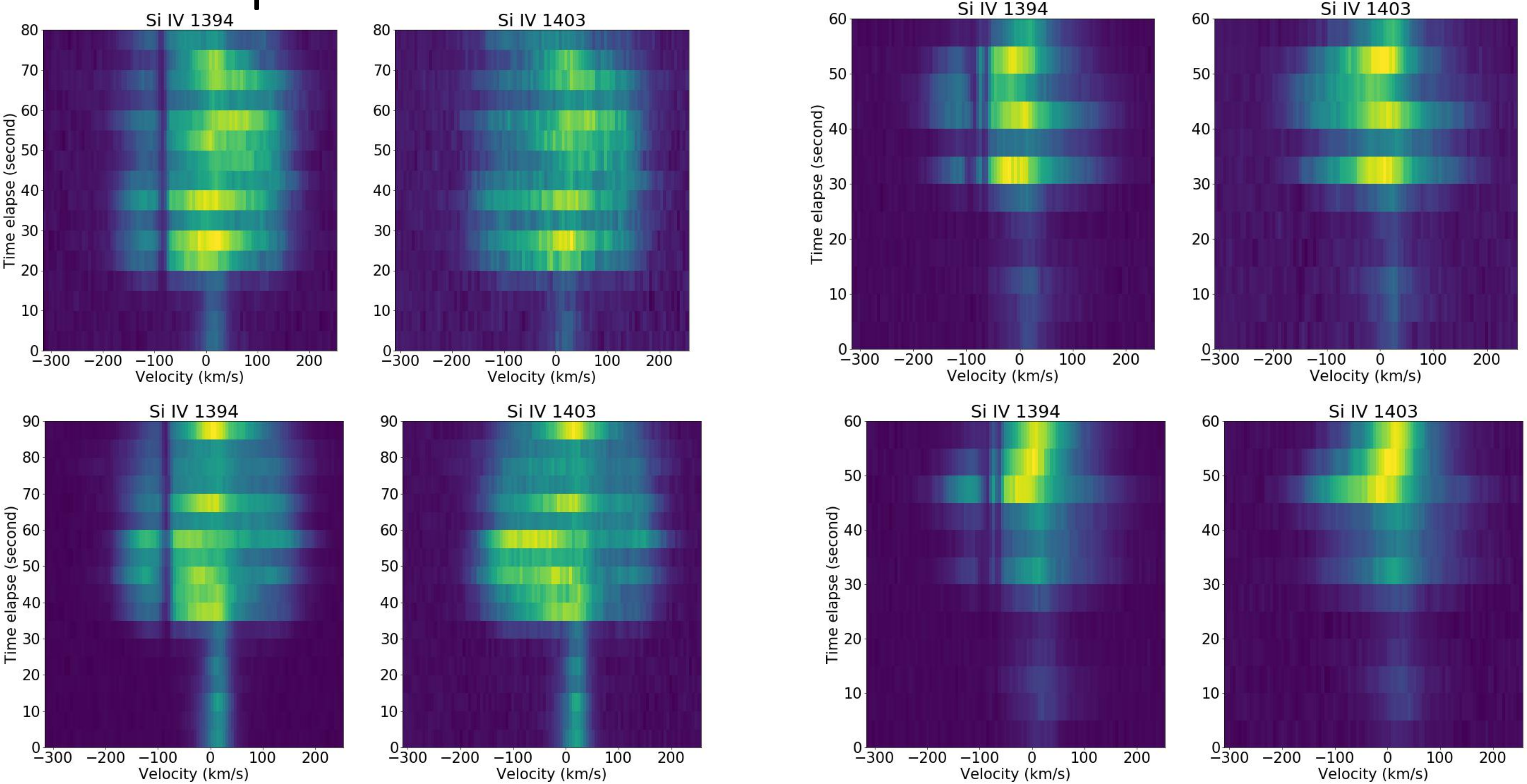


Bad detection



We train and apply neural networks on the time evolution of Si IV 1394 spectra of each pixel along the IRIS slit.
Accuracy for strong events: >96% on tested data sets, on average less than one hour per data set.
In this presentation, we present results from IRIS data set at 2014-05-04 12:09:28-14:29:21.

Examples of detected events

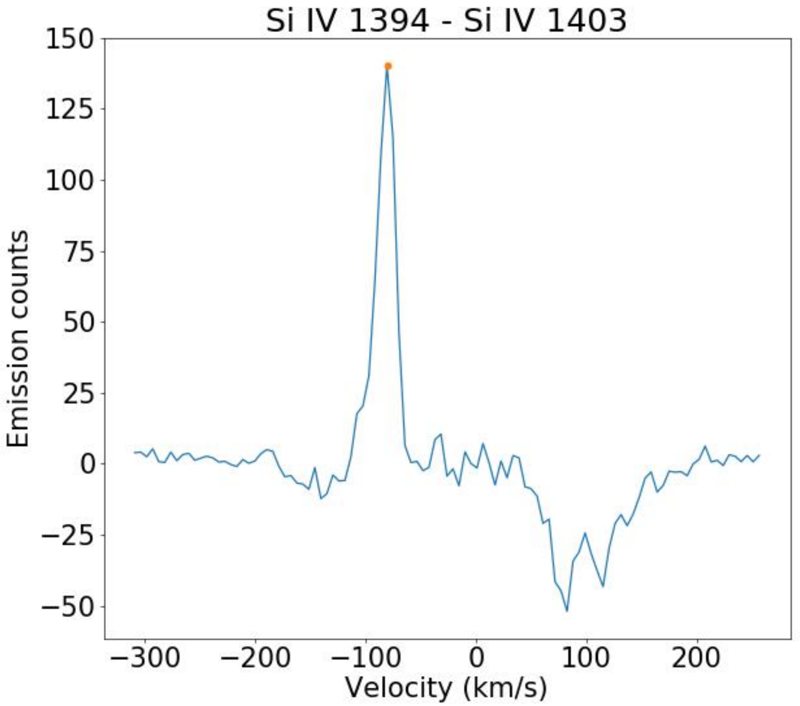


Detection results and preliminary diagnostics

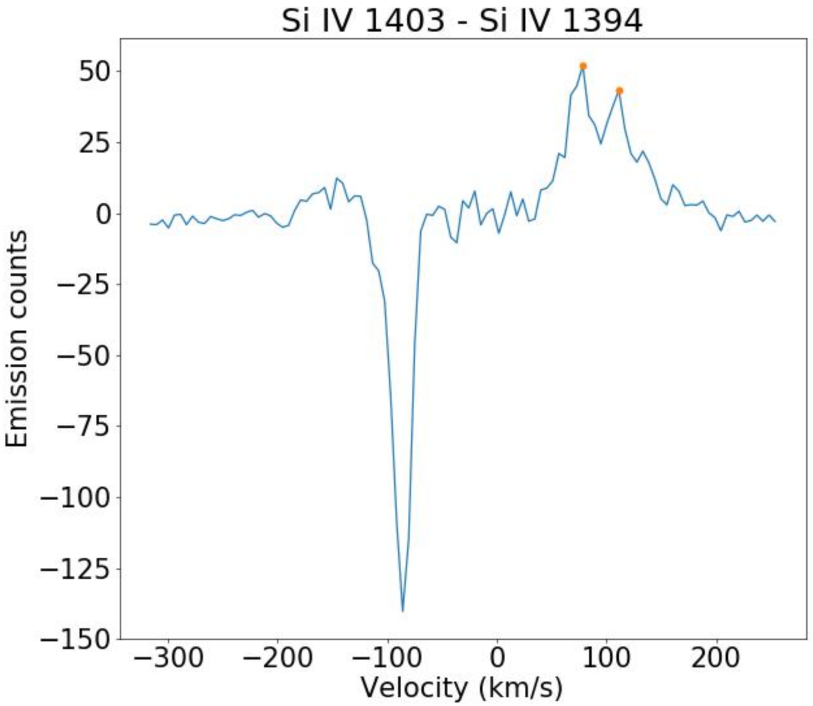
	B	C	D	E	F	G	H	I	J	K	L	M
1	pix	t_start	t_end	sym	score	strong	Si IV/O IV	Si 1394/1403	CII_resp	MgII_resp	Ni_absorb	Fe_absorb
2	1	38	43	asymmetric	0.78724	no	19.3497	2.059360561	no	yes	no	no
3	1	909	916	asymmetric	0.844379	no	14.2195	1.910840931	no	yes	yes	no
4	1	1051	1055	asymmetric	0.791152	no	22.2903	1.896400905	no	yes	no	no
5	4	511	517	asymmetric	0.999254	no	15.126	2.056310714	no	yes	no	no
6	5	512	517	asymmetric	0.998429	no	13	2.04837822	no	yes	no	no
7	6	1256	1264	asymmetric	0.776505	no	28.8171	2.057692207	no	yes	no	no
8	7	703	709	asymmetric	0.963353	no	16.8503	1.991366853	no	yes	no	no
9	7	1626	1633	asymmetric	0.864544	no	17.2506	2.020466199	no	yes	no	no
10	8	9	14	asymmetric	0.828118	no	18.1082	1.998461502	no	yes	no	no
11	8	1627	1634	asymmetric	0.997785	no	19.603	2.037374686	no	yes	no	no
12	9	8	12	asymmetric	0.999096	no	14.2204	2.038894702	no	yes	no	no
13	11	1386	1392	asymmetric	0.812479	no	18.2733	2.003063473	no	yes	no	no
14	13	310	316	asymmetric	0.769788	no	20.5636	1.954596343	no	yes	no	no
15	14	585	597	asymmetric	0.857771	no	18.6446	2.168740335	no	yes	no	no
16	15	585	597	asymmetric	0.79004	no	24.6329	2.081346908	no	yes	no	no
17	16	713	719	asymmetric	0.7657	no	-435.091	1.931338139	no	yes	no	no
18	16	1340	1345	asymmetric	0.7717	no	13.9403	2.034792403	no	yes	no	no
19	17	87	93	asymmetric	0.887149	no	28.2689	2.119247678	no	yes	no	no
20	18	87	93	asymmetric	0.677204	no	21.7399	1.964422257	no	yes	no	no
21	18	363	369	asymmetric	0.998273	no	30.4256	1.983283023	no	yes	no	no
22	18	454	461	symmetric	0.918432	no	20.8525	2.042559572	no	yes	no	no
23	18	997	1004	asymmetric	0.858464	no	15.7505	2.076275216	no	yes	no	no

718 events are detected.

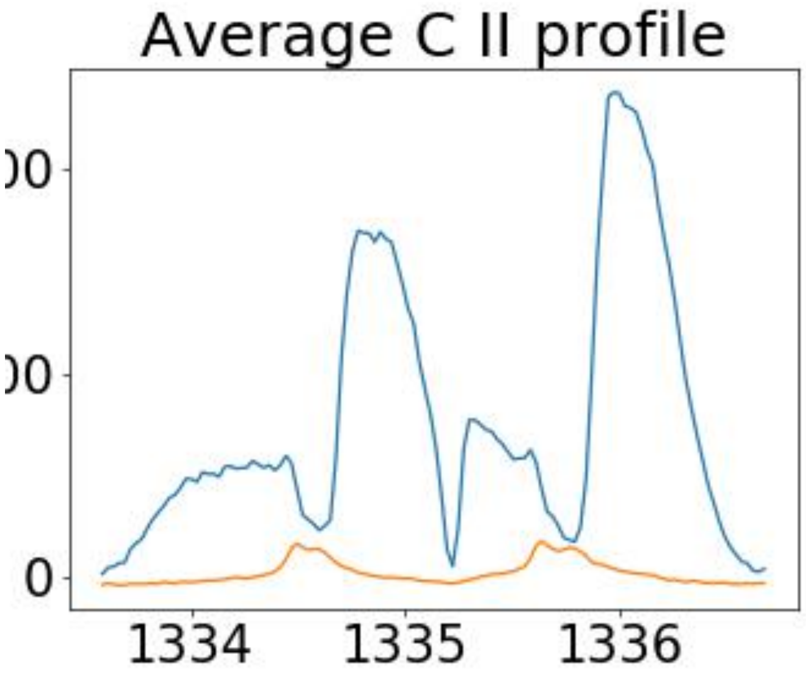
Methods to determine absorption features and chromospheric response



Ni II absorption



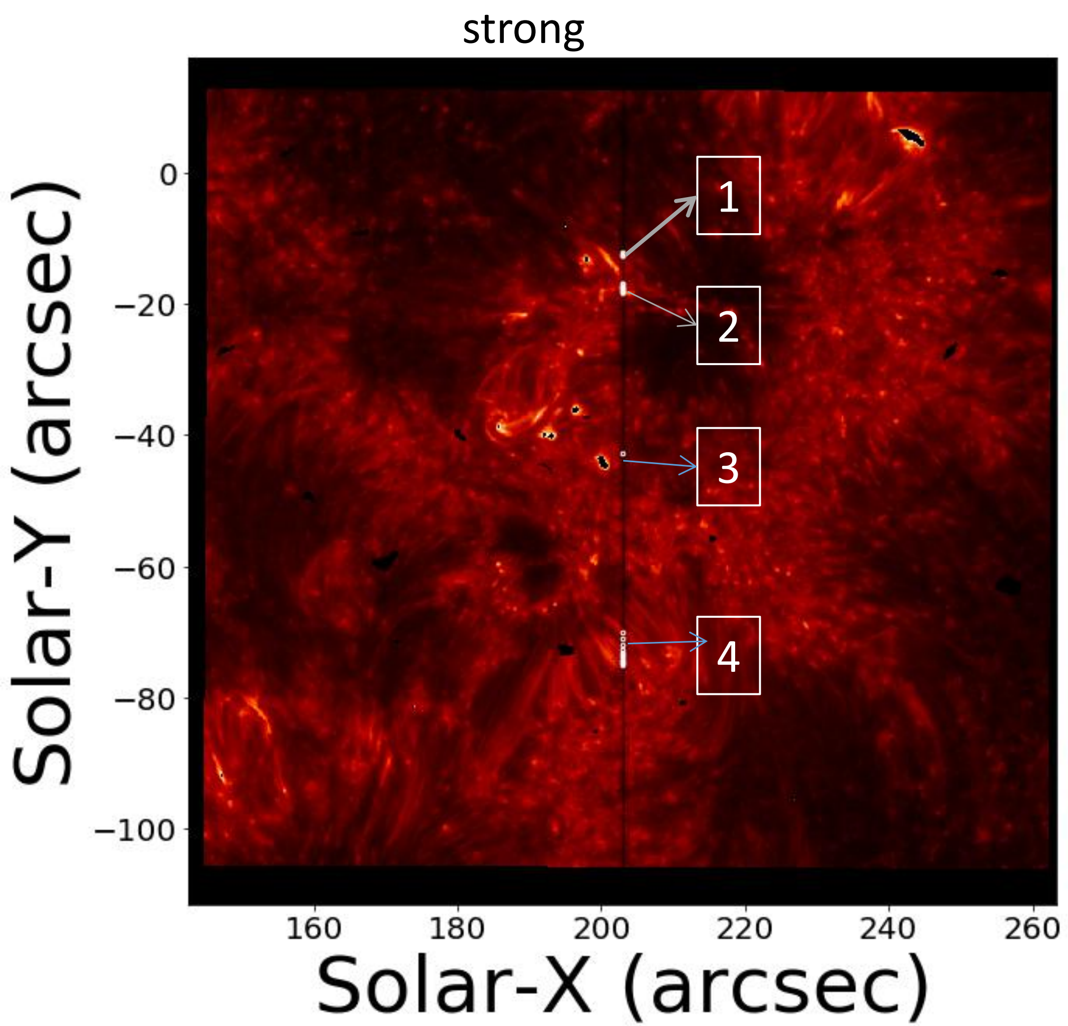
Fe II absorption

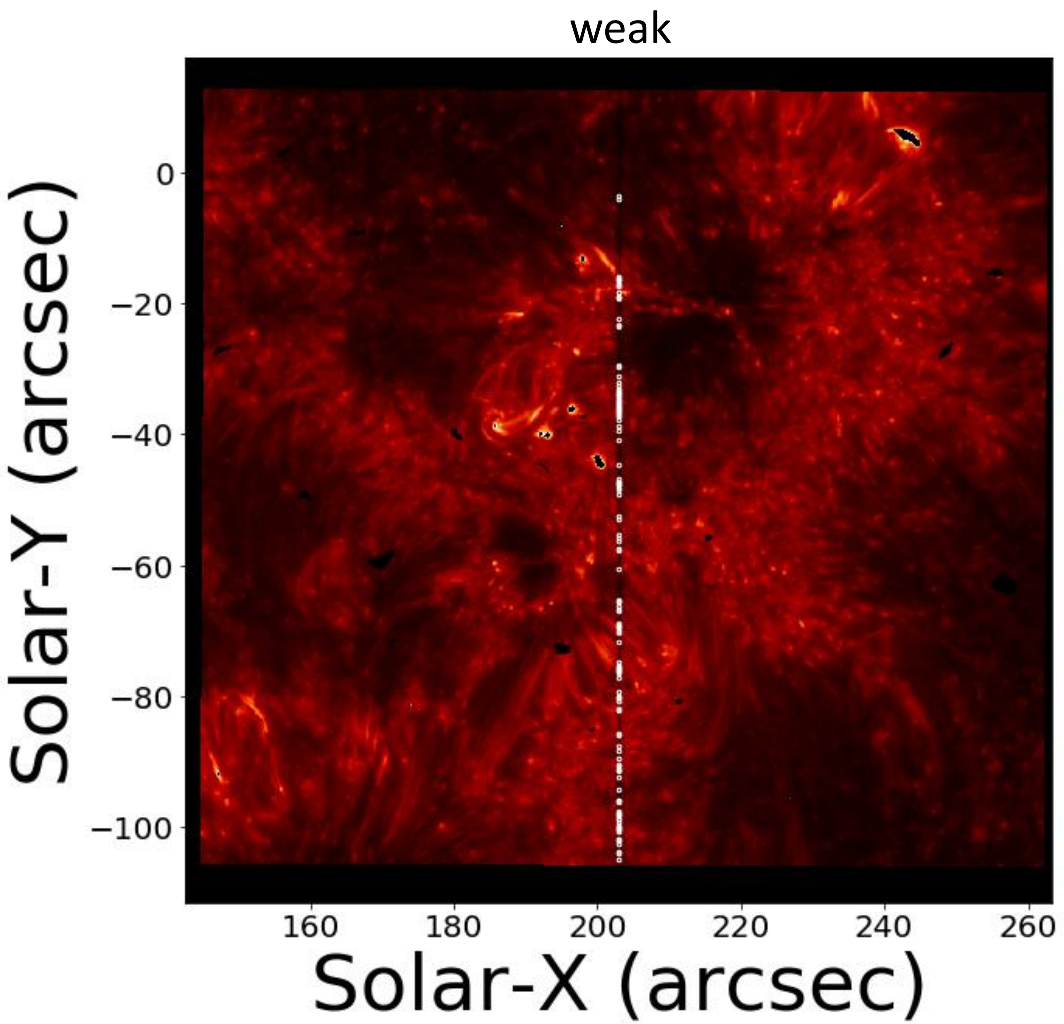


C II response

Yellow line is the time-averaged C II profile for each pixel.

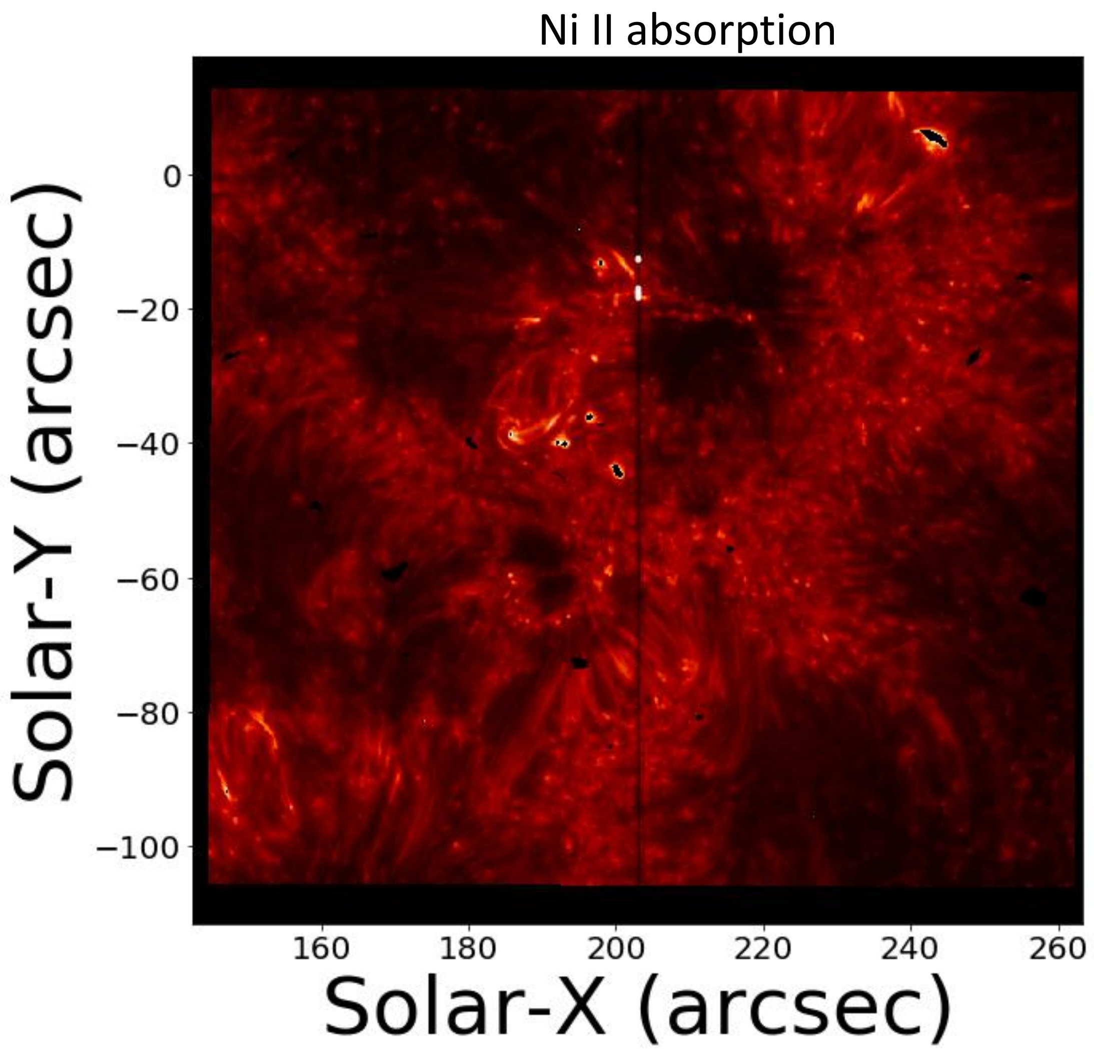
Locations of strong events versus weak events

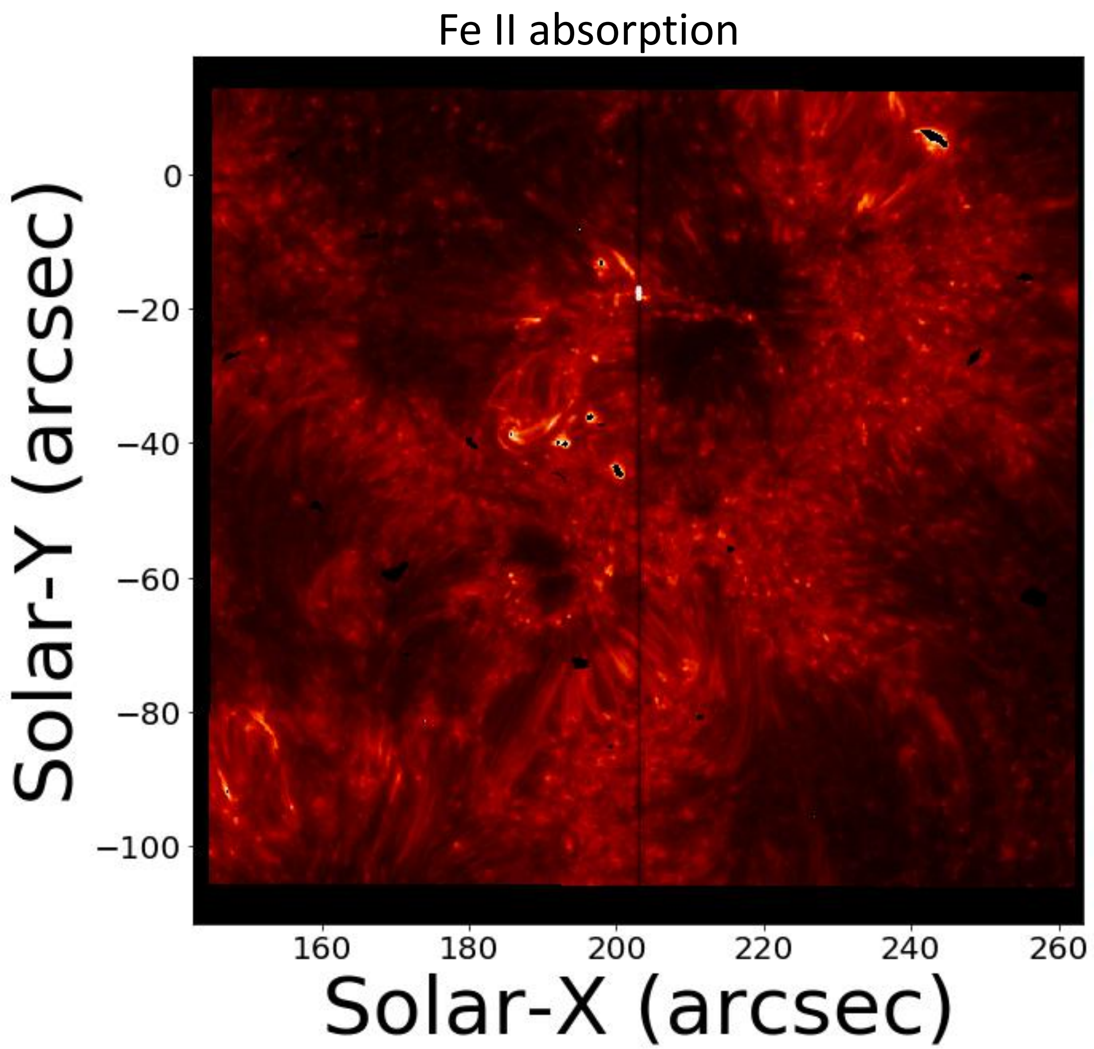




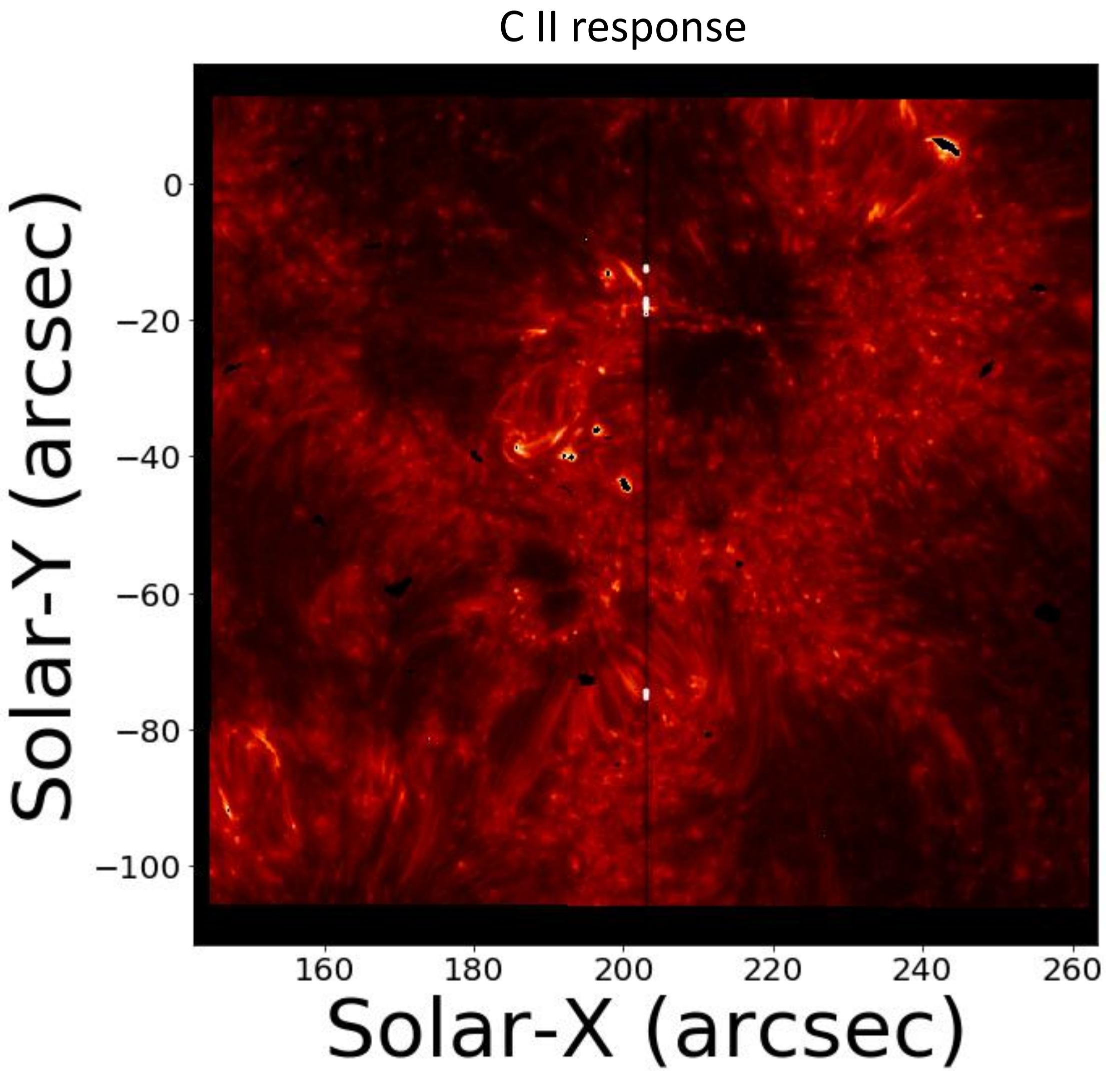
Strong events occur recurrently over four locations, each event last 30~90 seconds.

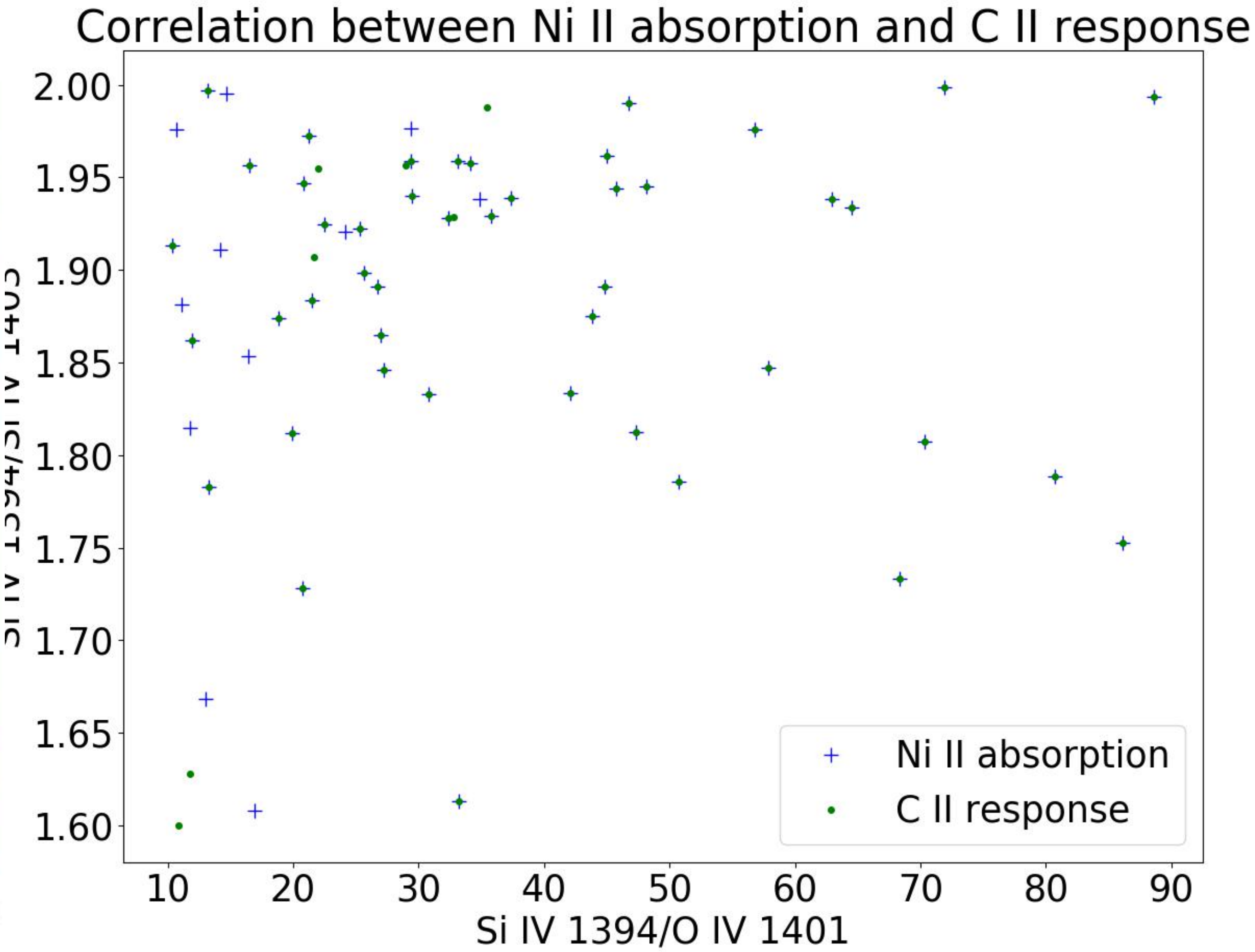
Locations of events with Ni II and Fe II absorption





Locations of events with C II response





Conclusion

- We present a method to study a massive amount of spectroscopic data efficiently.
- Judging from spectroscopic diagnostics (C II response, Ni II absorption, Fe II absorption etc.), explosive events occur under different plasma environments.

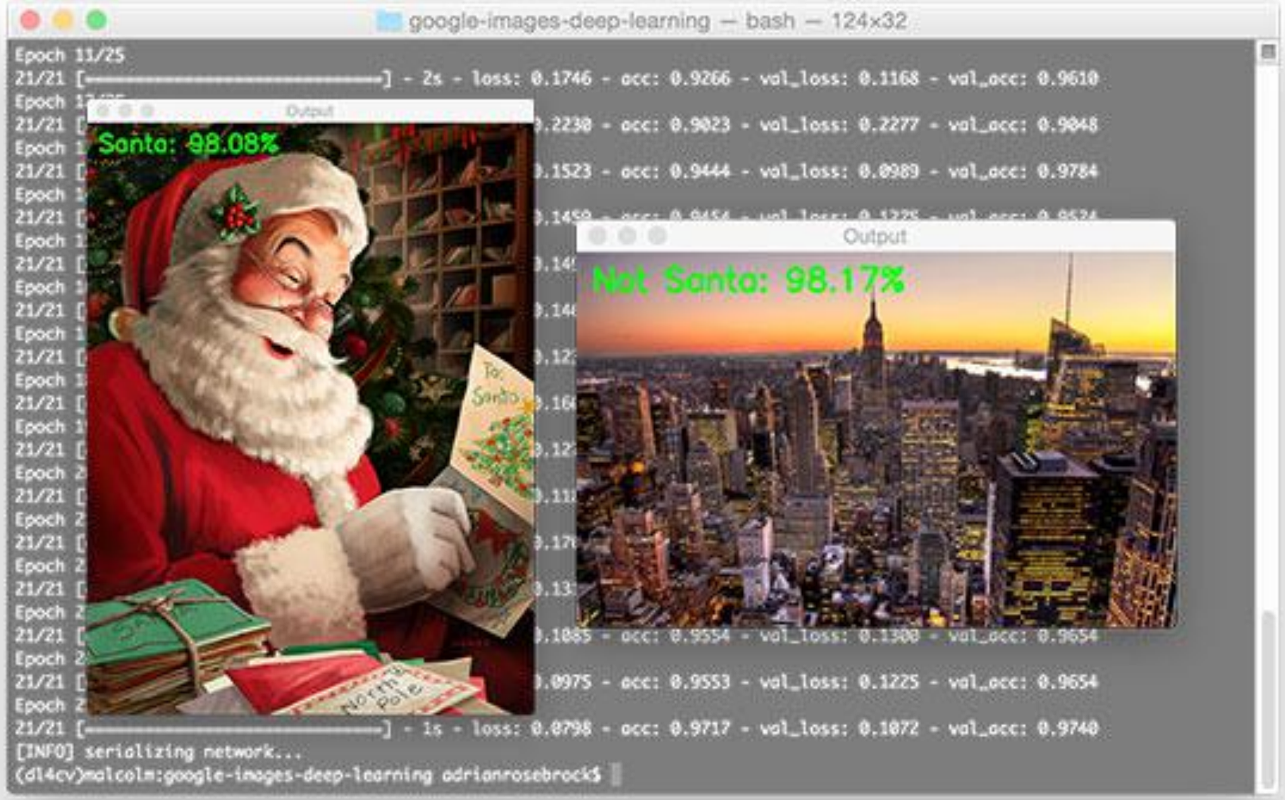
- Ongoing work:

  ---Include Mg II h&k, triplet response

  ---Scan all 264 sit-and-stare datasets

Thank you for your attention!

Hotdog detection app



Santa monitor

Supplemental slides
Machine learning softwares

- Caffe (c), Keras, Tensorflow(python), Theano(python) etc.

- We will go with tensorflow for now, and keep an eye on developments of other softwares.

- https://www.tensorflow.org/

- If you are interested in other softwares, here is a summary: https://en.wikipedia.org/wiki/Comparison_of_deep_learning_software

Prepare data for training: annotate images

Annotation software generate *.xml files

	A	B	C	D	E	F	G	H
1	filename	width	height	class	xmin	ymin	xmax	ymax
2	101-5.png	307	607	event	81	507	241	535
3	102-5.png	307	607	event	68	502	249	538
4	103-5.png	307	607	event	85	494	240	537
5	103-5.png	307	607	event	83	564	247	600
6	104-5.png	307	607	event	83	559	235	604
7	125-3.png	307	607	event	94	412	218	463
8	130-4.png	307	607	event	69	60	252	85
9	130-5.png	307	607	event	66	49	272	88
10	162-5.png	307	607	event	87	277	235	323
11	163-5.png	307	607	event	68	281	247	327

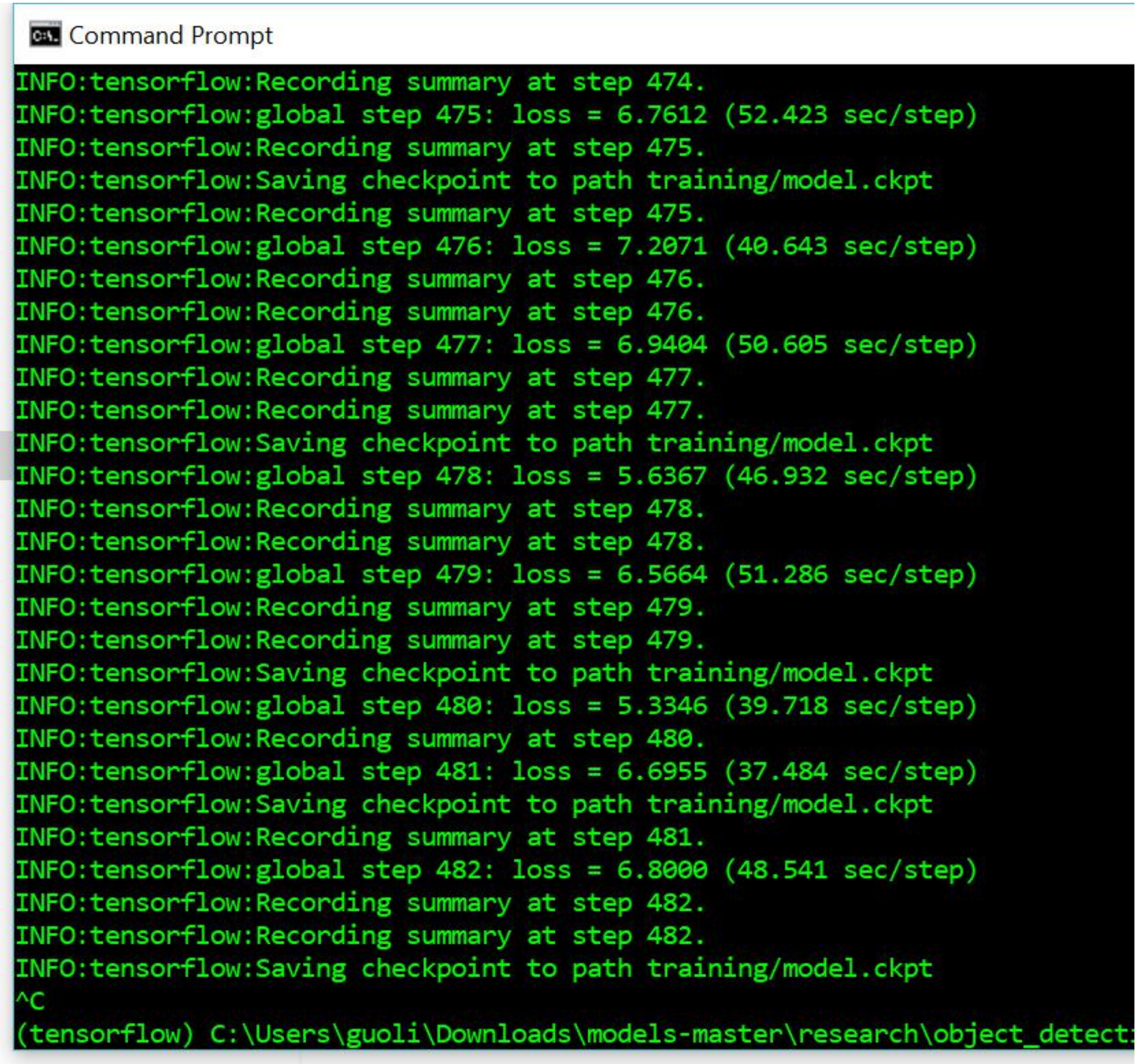
Choose a model

models available in model zoo:
https://github.com/tensorflow/models/blob/master/research/object_detection/g3doc/detection_model_zoo.md

System	VOC2007 test *mAP*	FPS (Titan X)	Number of Boxes	Input resolution
Faster R-CNN (VGG16)	73.2	7	~6000	~1000 x 600
YOLO (customized)	63.4	45	98	448 x 448
SSD300* (VGG16)	77.2	46	8732	300 x 300
SSD512* (VGG16)	**79.8**	19	24564	512 x 512

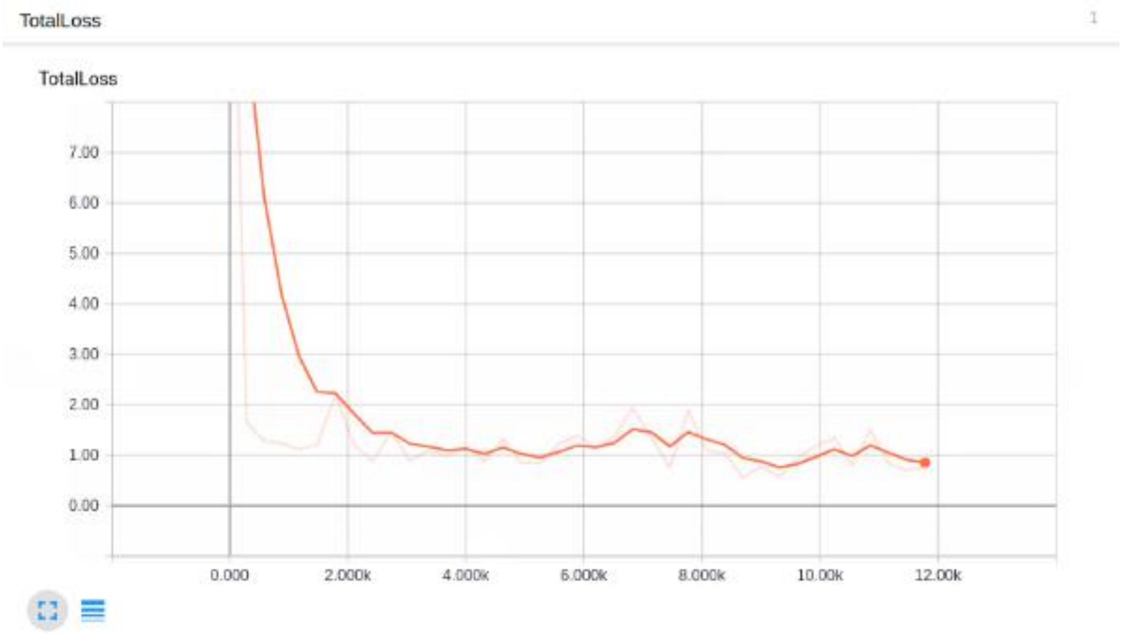
Download models and put them in the 'object_detection' directory

Start training



type 'python train.py --logtostderr --train_dir=training/ --pipeline_config_path=training/iris.config'

Automatically save training progress
Automatically restart from the latest checkpoint.



Resources

- https://pythonprogramming.net/introduction-use-tensorflow-object-detection-api-tutorial/
- https://www.youtube.com/watch?v=vT1JzLTH4G4&list=PL3FW7Lu3i5JvHM8ljYj-zLfQRF3EO8sYv