Transient Detection using Convolutional Neural Networks

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Millennium Institute of Astrophysics (MAS)

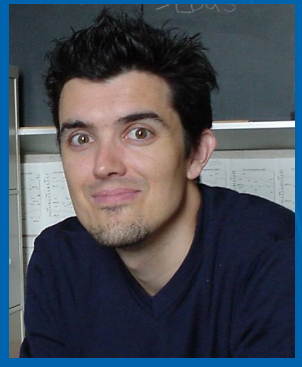
Started in January 2014

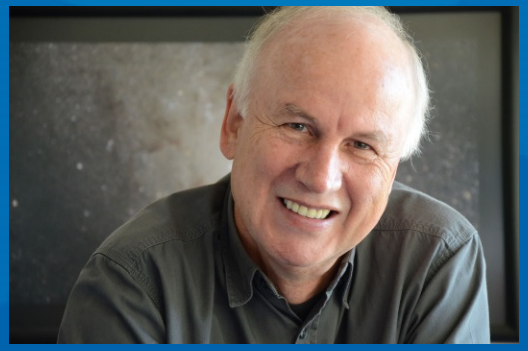



Passion for the exploration of the natural world







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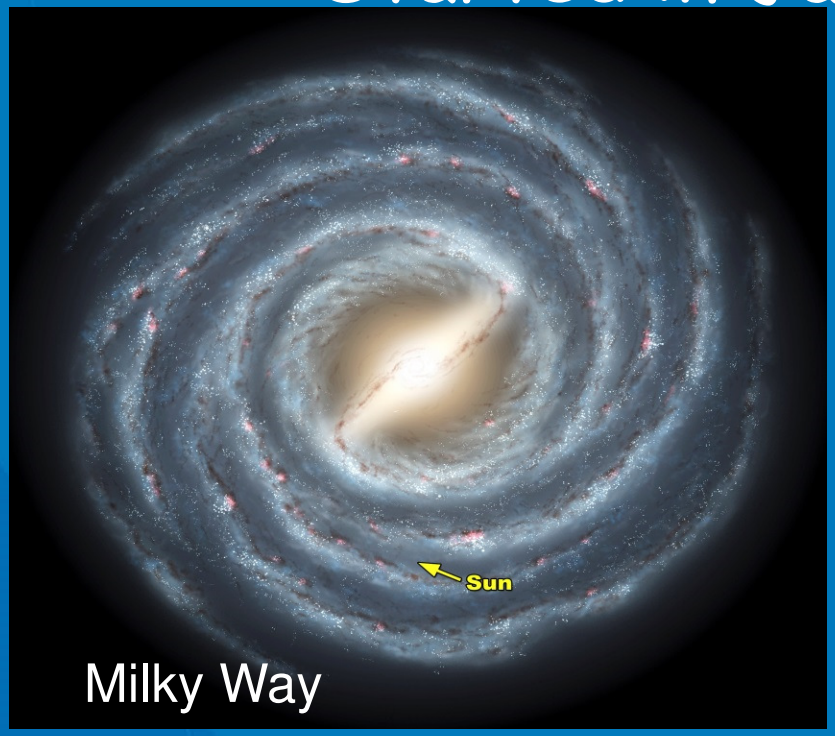
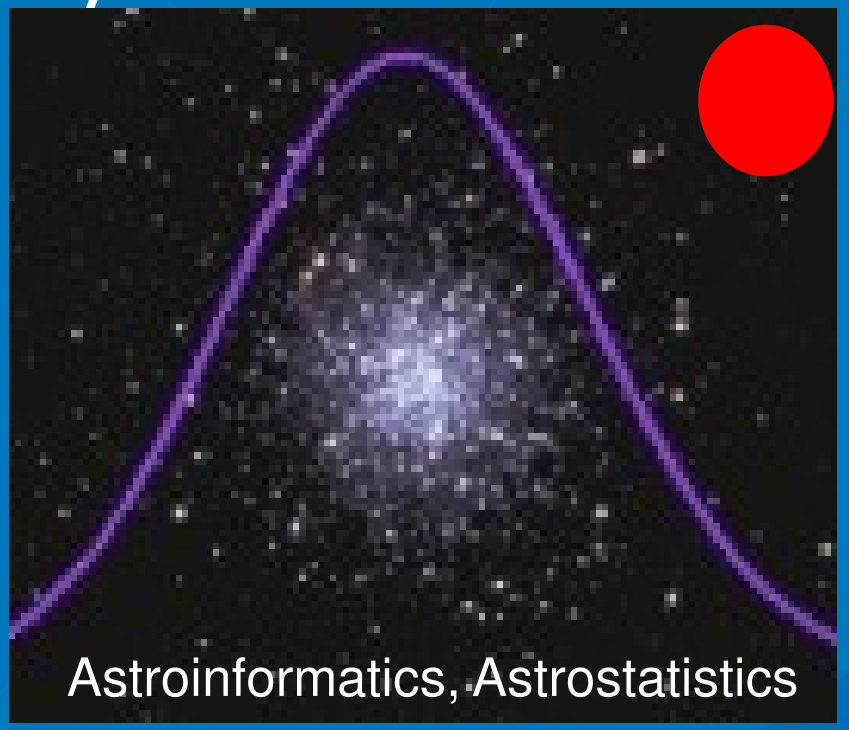
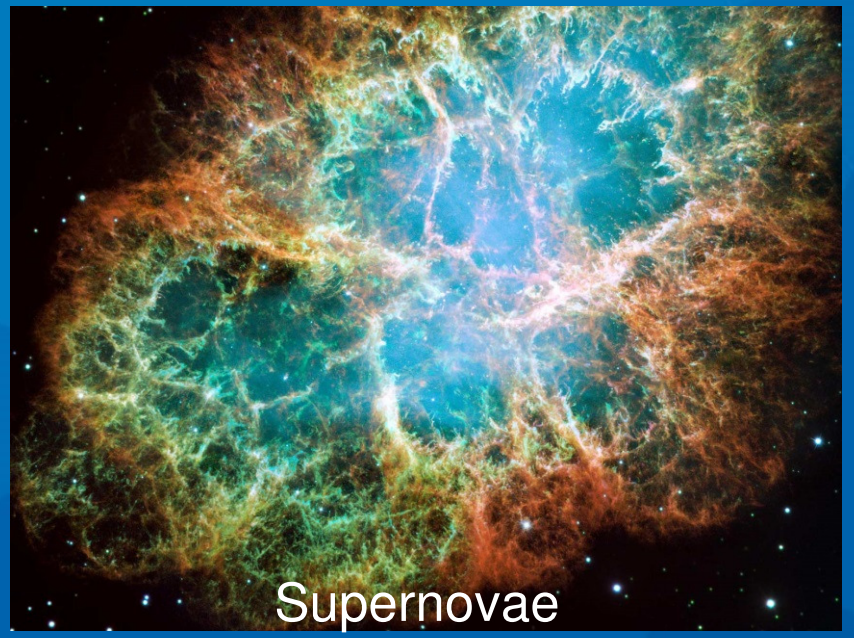


Milky Way

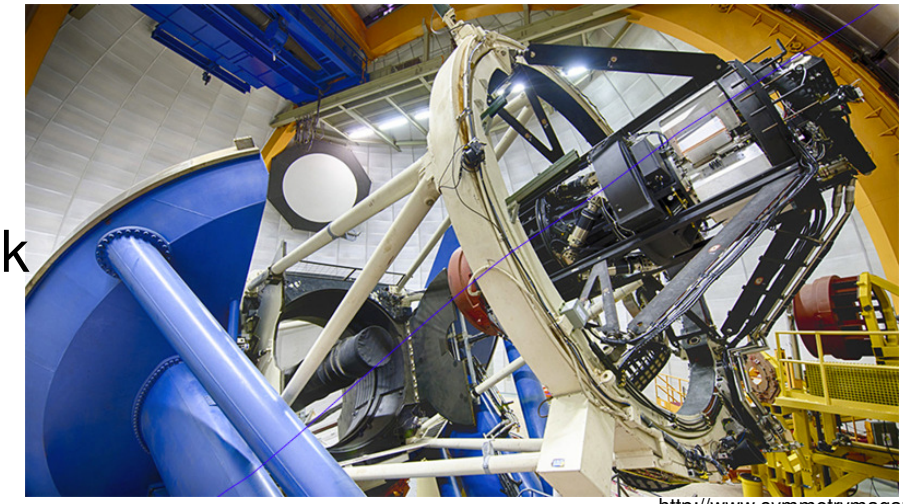

Astroinformatics, Astrostatistics


Exoplanets, Transients


Supernovae

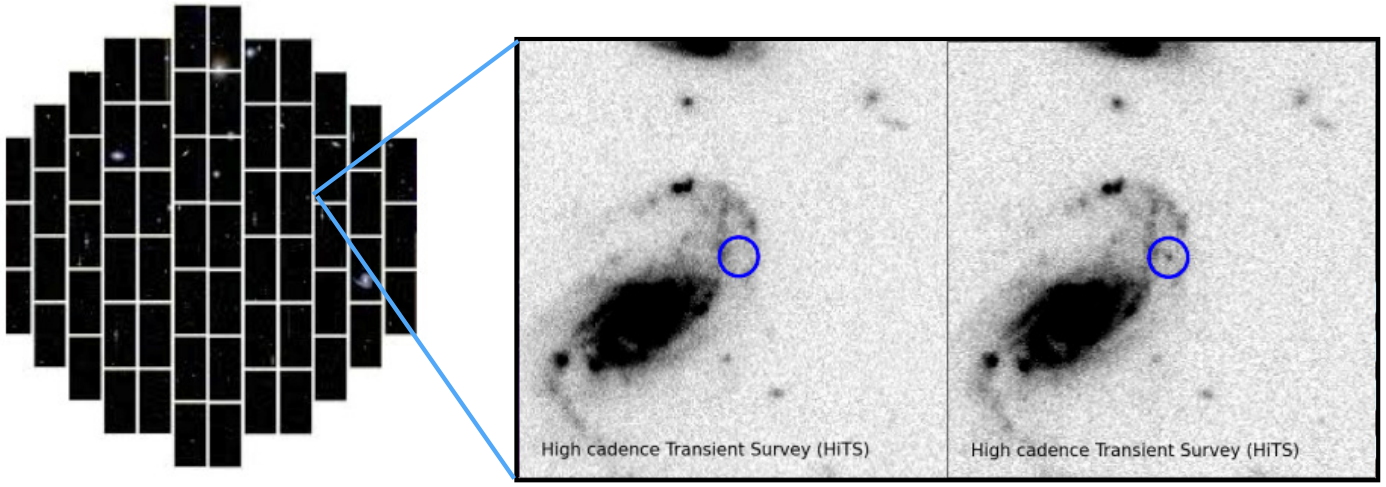
HiTS: High cadence Transient Survey (F.Förster et al.)

Scientific Objective:
Find evidence of Shock Breakout



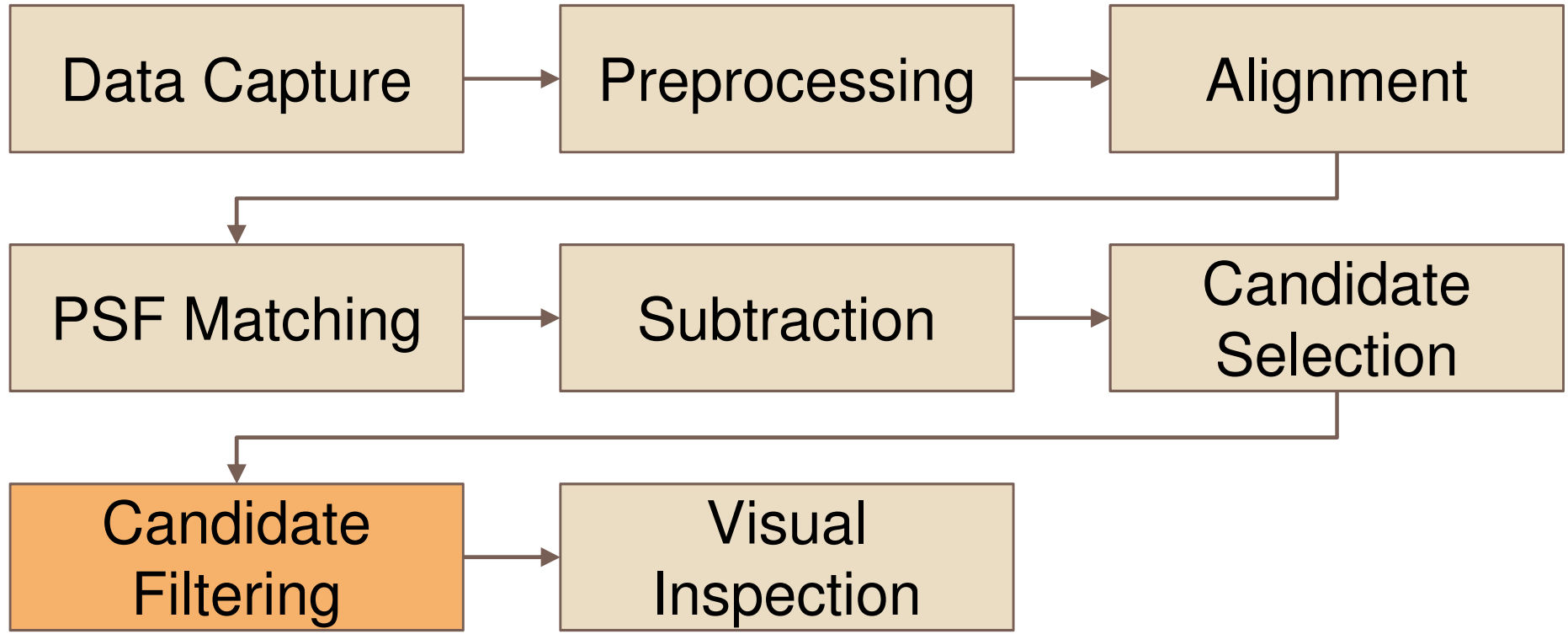
http://www.symmetrymagazine.org/

Dark Energy Camera
(DECAM)
at Cerro Tololo, Chile
512 Mpixels
64 CCDs



1 HiTS field = 64 CCD arrays ~512 Megapixels per field and epoch

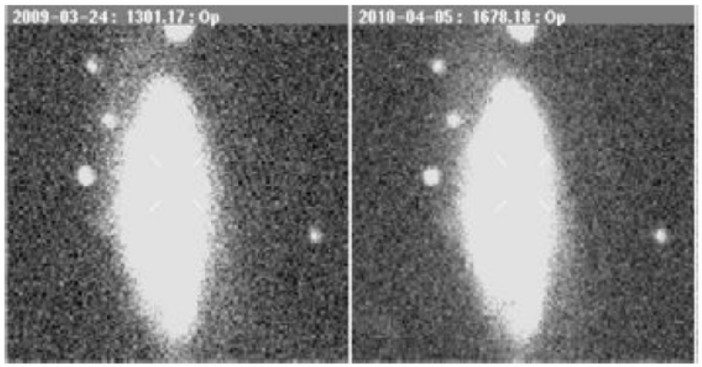
HiTS Image Reduction Pipeline

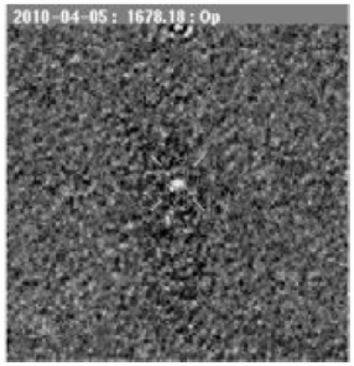


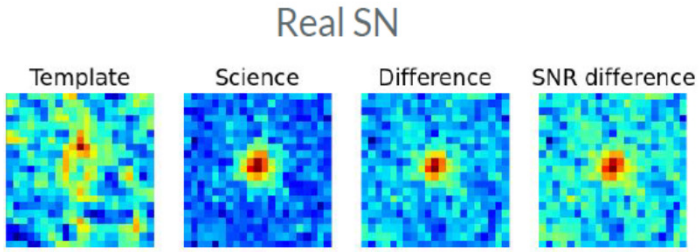
- At this point, candidates are dominated by artifacts 1:10K
- ML to find the needles in the haystack

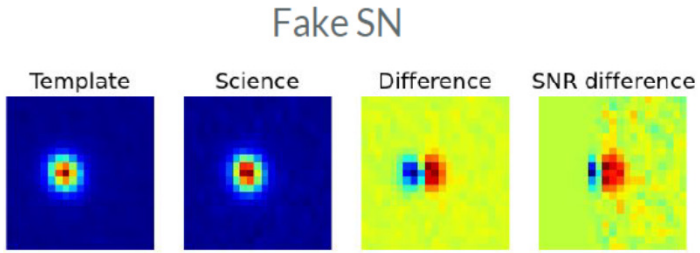
Image Differencing

Problem description



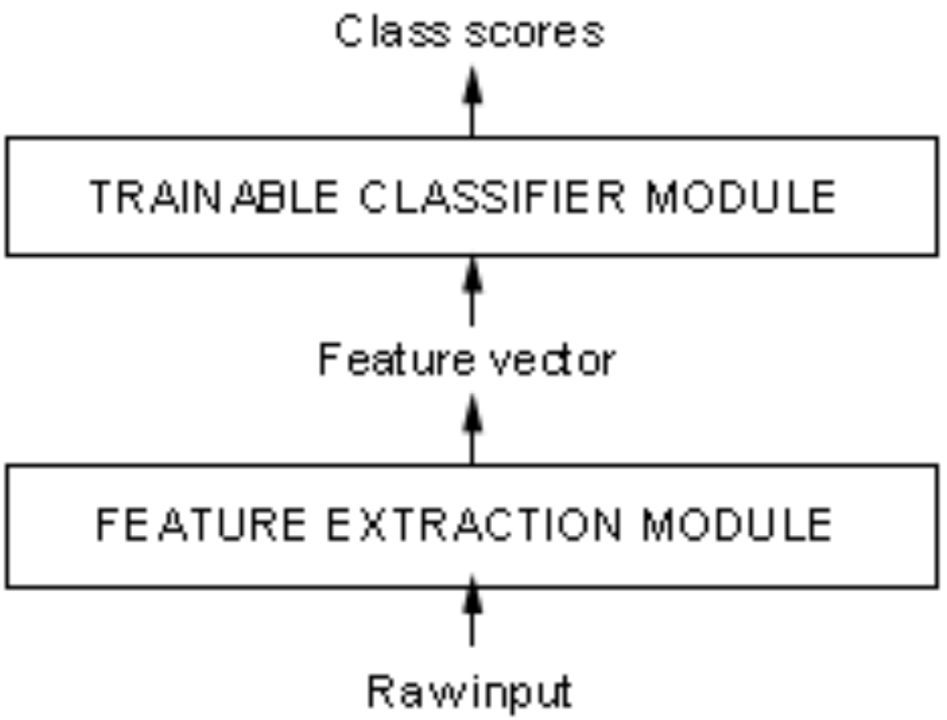






- Example of template (reference), science (current image), difference image, SNR difference image
- Image stamps of 21x21 pixels

Traditional Pattern Recognition Model



Random Forest classifier

Feature engineering:
56 handmade features

Inspired in Movie “Inception”

Guillermo Cabrera

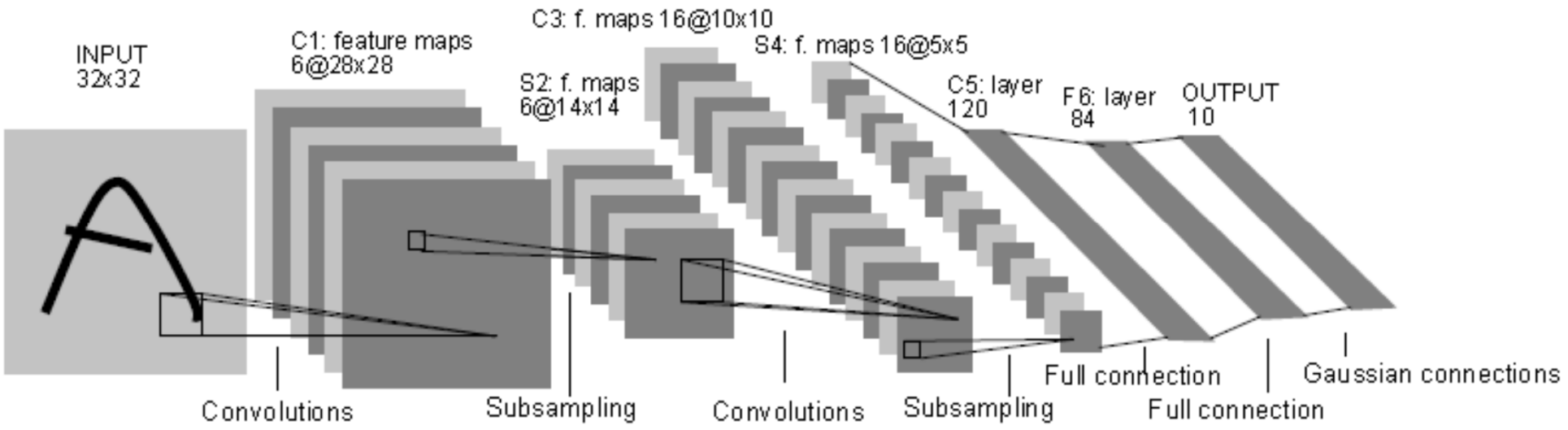
Francisco Forster

Deep Learning

- Deep Learning is achieving impressive results in data science.
- They are based on neural networks, and recent breakthroughs are due to:
  - Large datasets (e.g. millions of images)
  - Faster algorithms and machines
  - New way of dealing with overfitting
- Most common type: Convolutional Neural Nets (ConvNets)

LeNet5 (1998)
Y. LeCun et al.

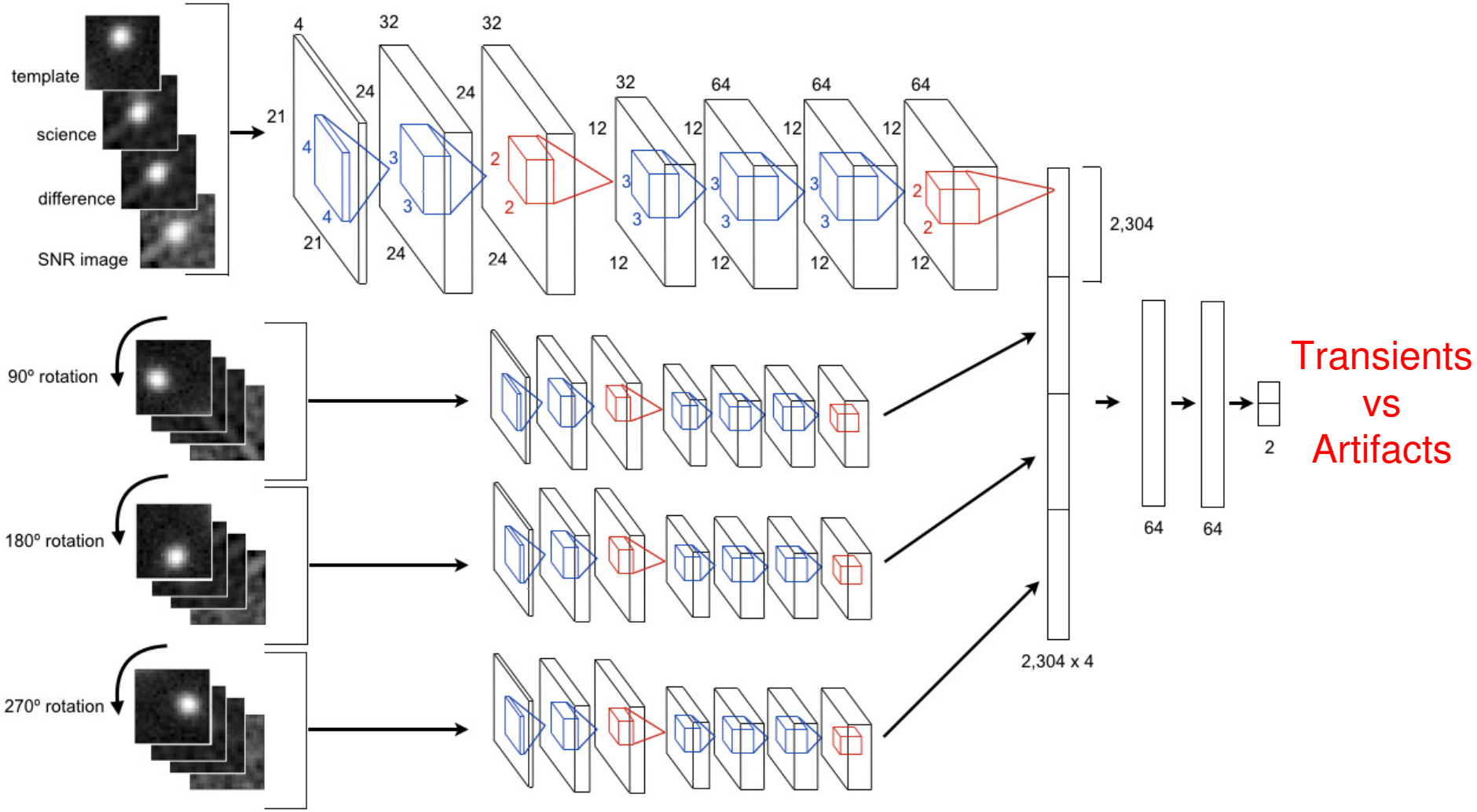
- Architecture designed to process images (handwritten digits) including invariances to traslation, scaling and distortion
- It combines convolutional and subsampling (pooling) layers



Feature Extraction

MLP Classifier

Convolutional Neural Nets Applied to HiTS



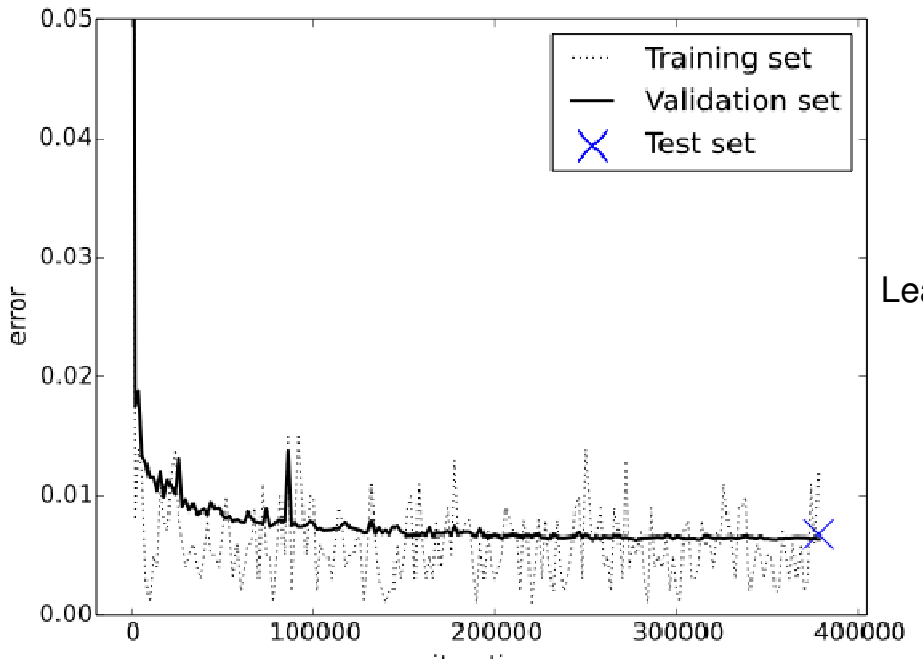
Training: Simulated and Real Data from HiTS 2013

Data:

- 802,087 non-transients (negatives) + 802,087 simulated transients (positives).
- 1,250,000 for training, 100,000 for validating, 100,000 for testing.

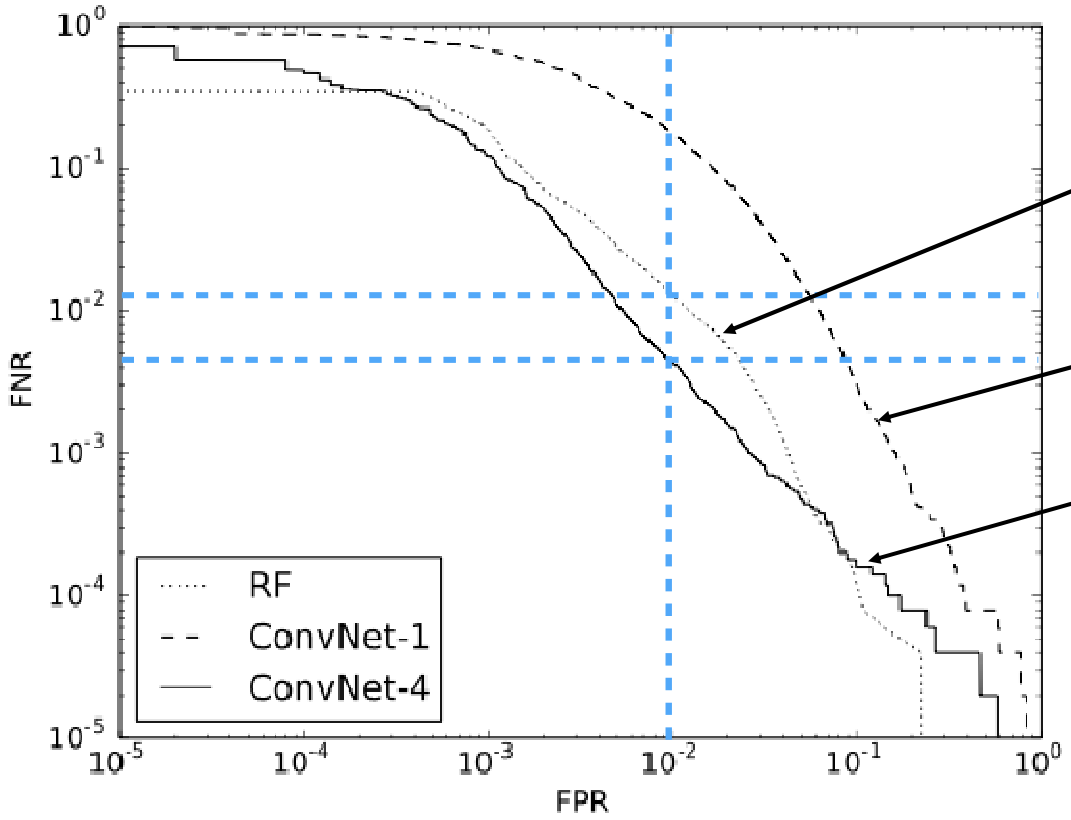
Training:

- Stochastic gradient descent (SGD) with batches of 50 examples.
- Learning rate reduced to half every 50,000 iterations
- Implemented using Theano and took approximately 37 hours to train on a NVIDIA TESLA K20 GPU.



Learning Curve

Detection Error Tradeoff (DET)



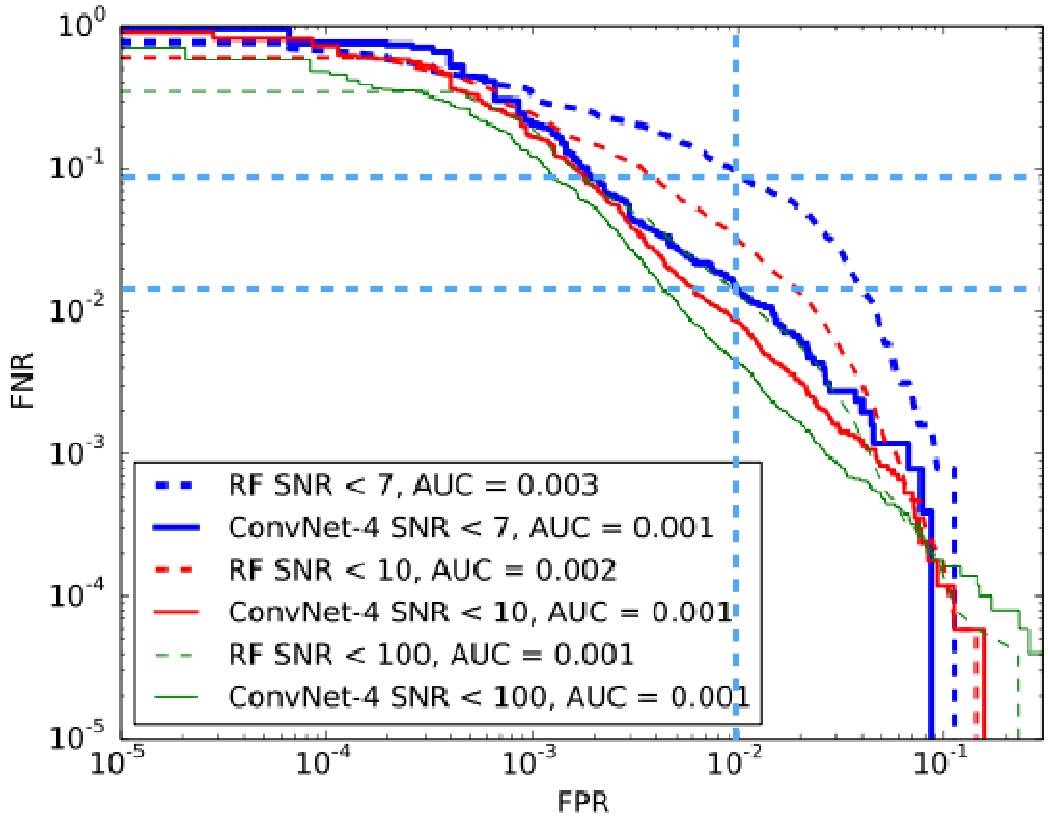
RF: random forests +feature engineering approach (56 handmade features)

ConvNet-1: only the difference image.

ConvNet-4: using all 4 images.

- Consider 100,000 candidates per night, from which around 10 are real transients, and we want to visually inspect 1,000. FPR~10^{-2}
- By using our ConvNet model we reduce the FNR from ~10^{-2} to ~3×10^{-3}

Detection Error Tradeoff (DET)



- Results for SNR < 7 are shown in blue
- FNR is reduced from ~10-1 to ~3x10-2 for very faint sources.

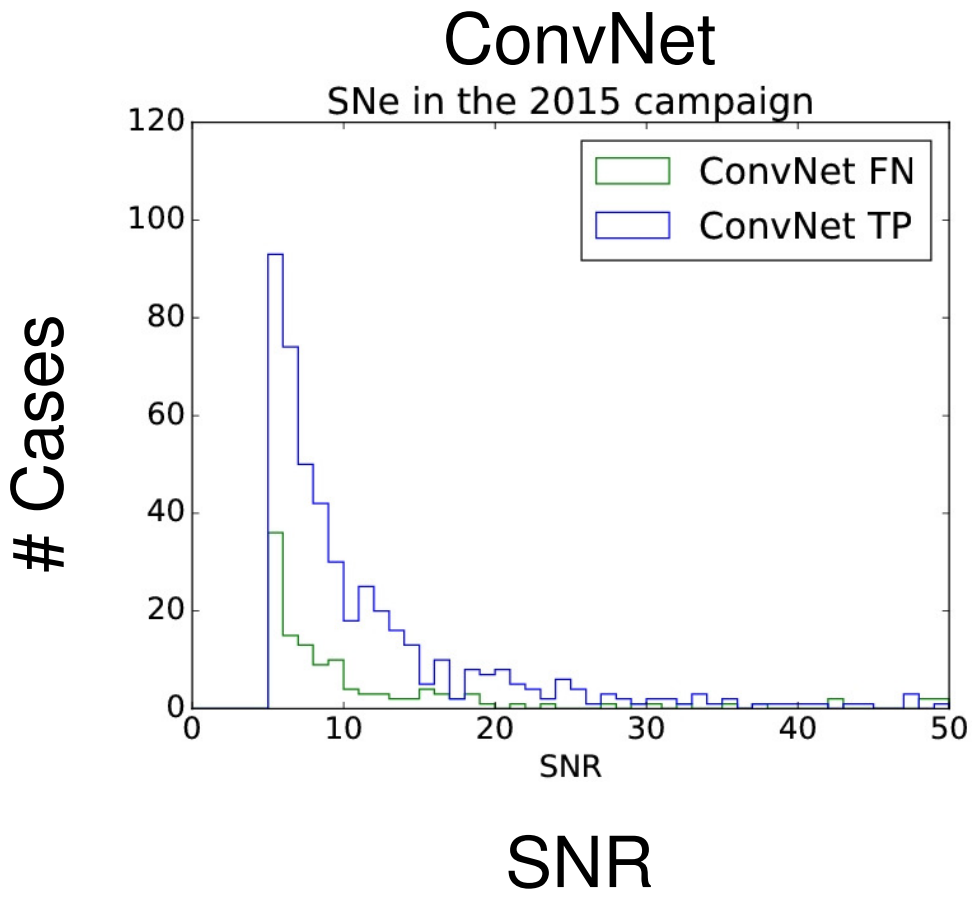
Test on 2015 HiTS Campaign (real data)

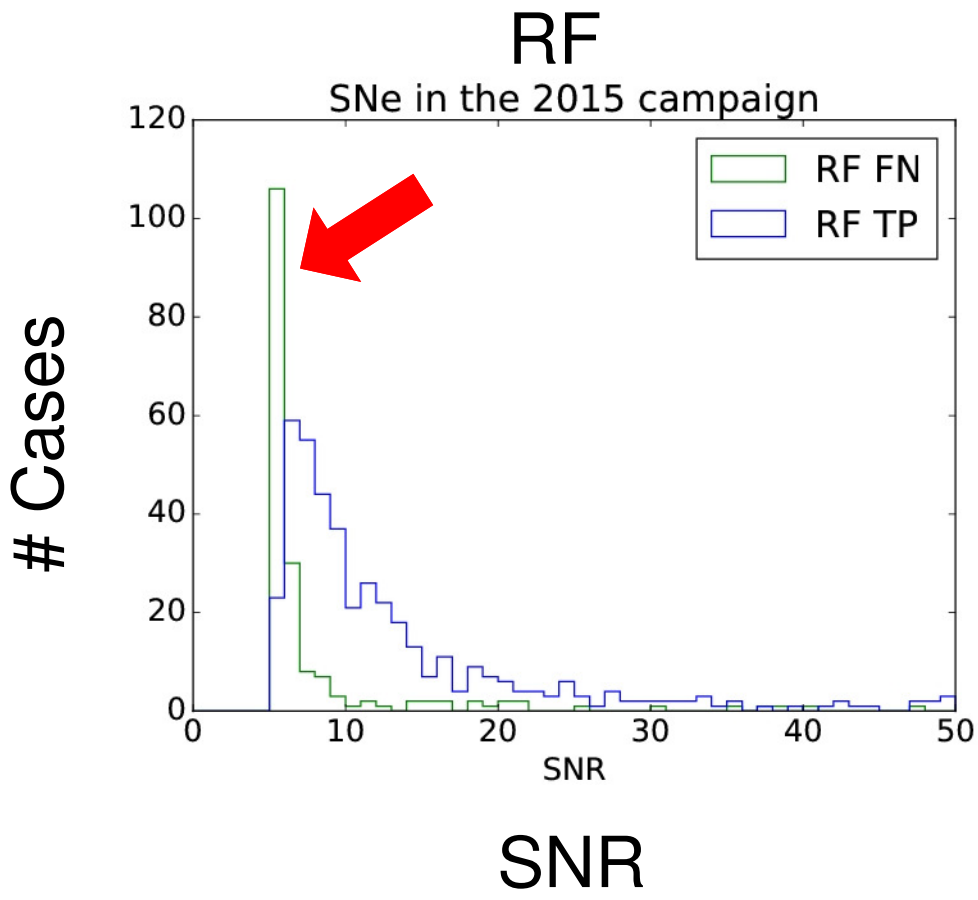
- All the difference images with SNe candidates were analyzed (Total: 628)

Method	# Correct Detections	FNR
RF	439	0.300
ConvNet	487	0.224

Comparison ConvNet vs RF

- At low SNR, ConvNets has a much lower FNR than RF





Conclusions

- The proposed convolutional neural network (ConvNet) approach is useful to detect transients (supernovae).
- Our approach outperforms a previous method based on feature engineering and a random forest (RF) classifier, particularly at low SNR.
- Both models seems to be complementary and further research is needed.

Thank you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