Lucky Imaging

on Deep Sky Objects

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Today

We will see...

how to apply Lucky Imaging, a consolidated technique used in planetary imaging, to Deep Sky Objects.

We will not see...

beautiful pictures, instead just some experimentation results.

Main Topics

Imaging DSO ► *Traditional techniques*

Turbulence and Seeing ► *problems to face*

Deconvolution & Adaptive Optics ► *one solution*

Lucky Imaging ► *another possible solution*

EMCCD Cameras ► *new cameras*

DSO Lucky Imaging with EMCCD ► *new pipeline*

Imaging Deep Sky Objects

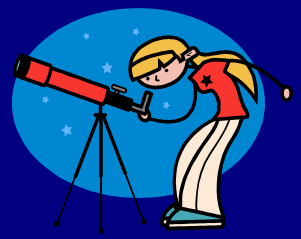
DSO are usually very faint objects

They require long integration time

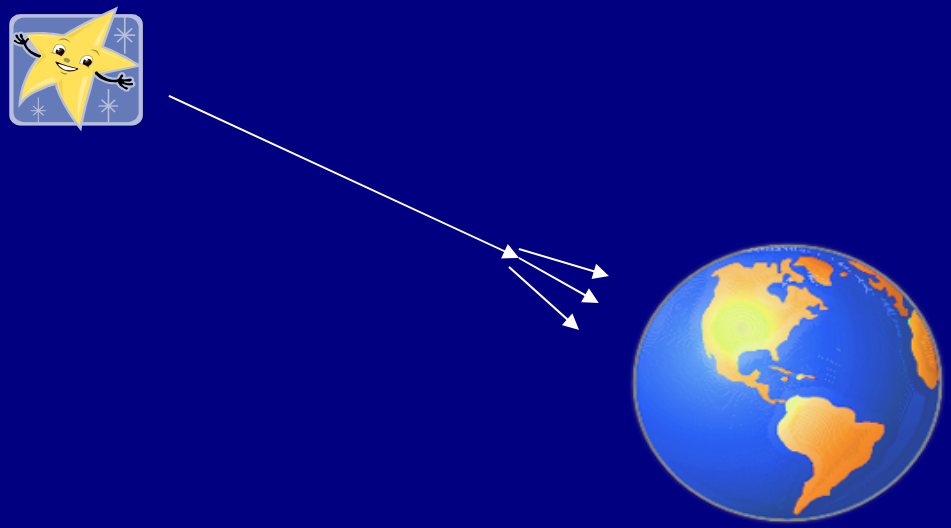
Multiple imaging parameters must be taken into account *(guiding, flextures, focusing, etc.)*

Small and Medium Focal Lenghts are mostly used

Turbulence and Seeing *[1/2]*



Twinkle twinkle little star...



Turbulence and Seeing *[2/2]*

Turbulence model is quite complex

Metric is tipically based on Isoplanatic Patches

Turbulence distortion is almost proportional to telescope aperture

Turbulence moves targets in 3 directions (X-Y-Z)

Deconvolution – *Blur Model*

A distorted image (I_d) could be described as:

$$I_d = O_d * I_o + N$$

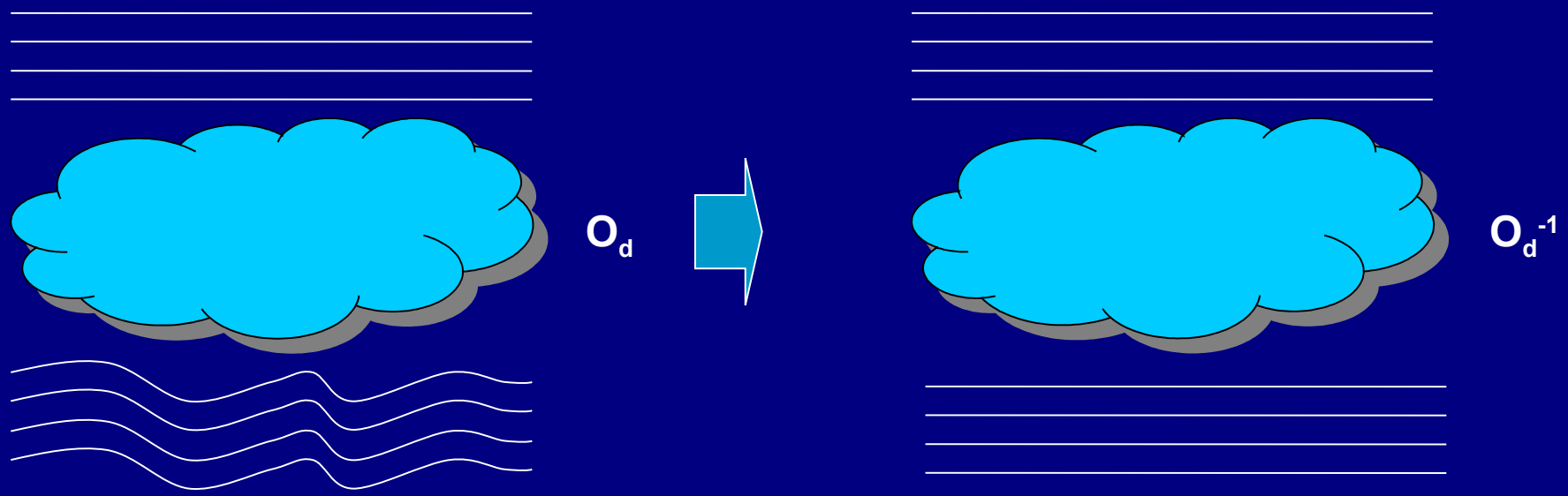
where N is the noise introduced by the Image sampling, O_d the distortion operator, I_o the original source signal.

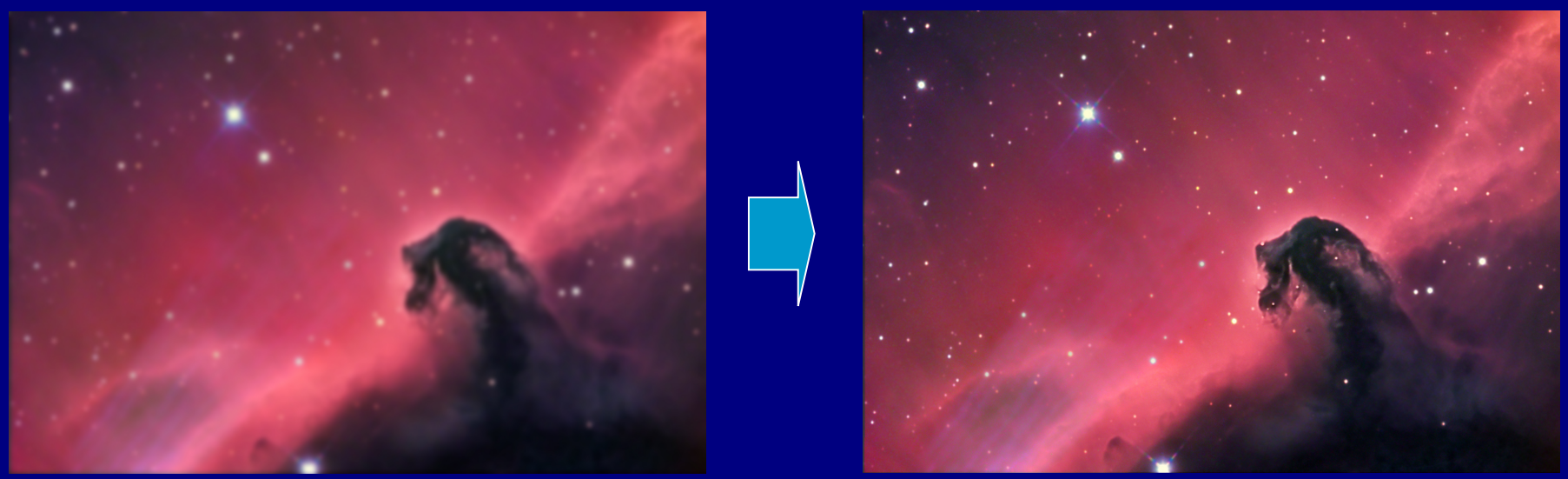
Finding the Inverse Operator

$$I_d - N = O_d * I_o$$

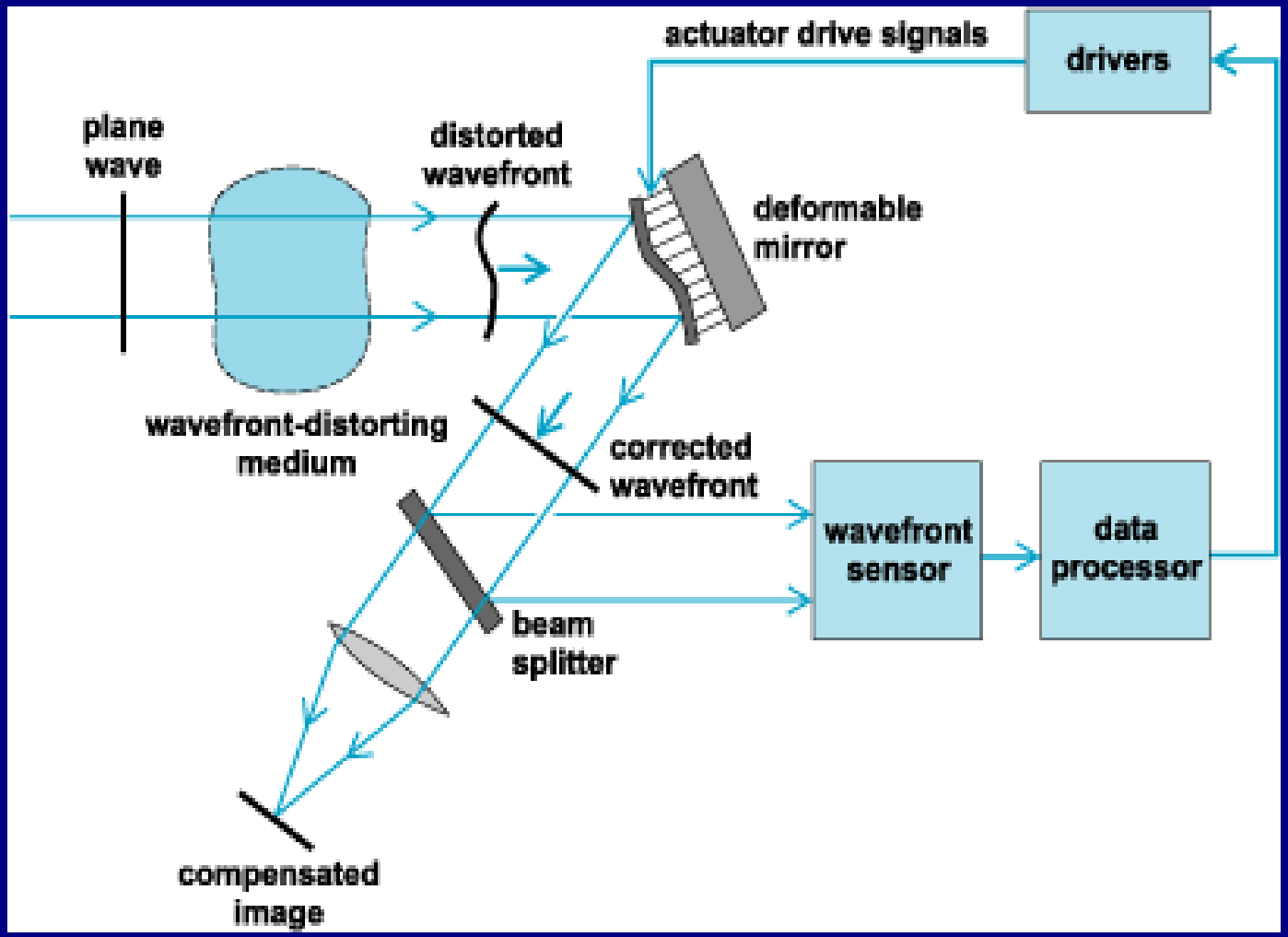
$$\mathbf{I_o = O_d^{-1} * (I_d - N)}$$

Deconvolution - *Finding the right operator*





Adaptive Optics *[1/2]*



Adaptive Optics Schematics *(source answers.com)*

Adaptive Optics *[2/2]*

Tip Tilt (X-Y) AO are available to amateurs:

- High freqs (30Hz) need a bright reference star
- Cannot overcome the focus (Z) components

Regarding professionals, only few observatories have an Adaptive Optics System (X-Y-Z) with LGS (Laser Guide Star) that permits to reach (500-1000 Hz) very fast updates.

Lucky Imaging

Lucky Imaging is a commonly used technique by amateurs for planetary pictures.

- High frequencies sampling (30-60 Hz)
- Selection of best frames (around 10%)

Lucky Imaging – *Pros vs Cons*

Pros

- Overcome major turbulence effects
- Quite indipendent from tracking issues

Cons

- Needs a very bright source
- Could be field limited, usually by the Isoplanatic Patch size

EMCCD Camera *[1/3]*

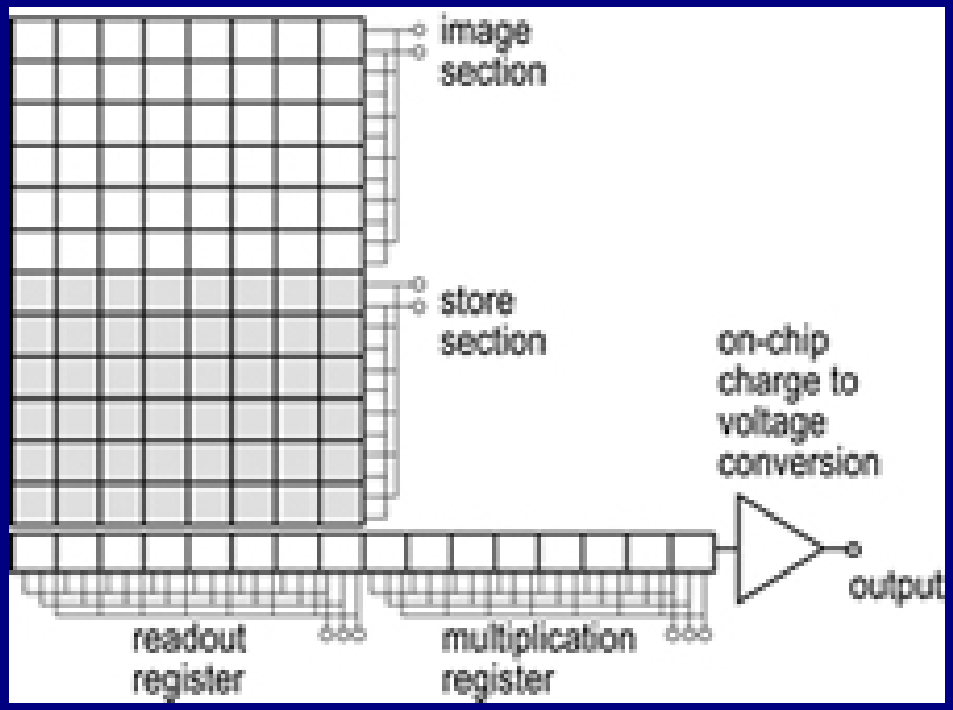
EMCCD = Electron Multiplied CCD

Multiplication Stage inside the CCD

CCD_Gain_100X = 100*CCD_Signal + 100*CCD_Noise

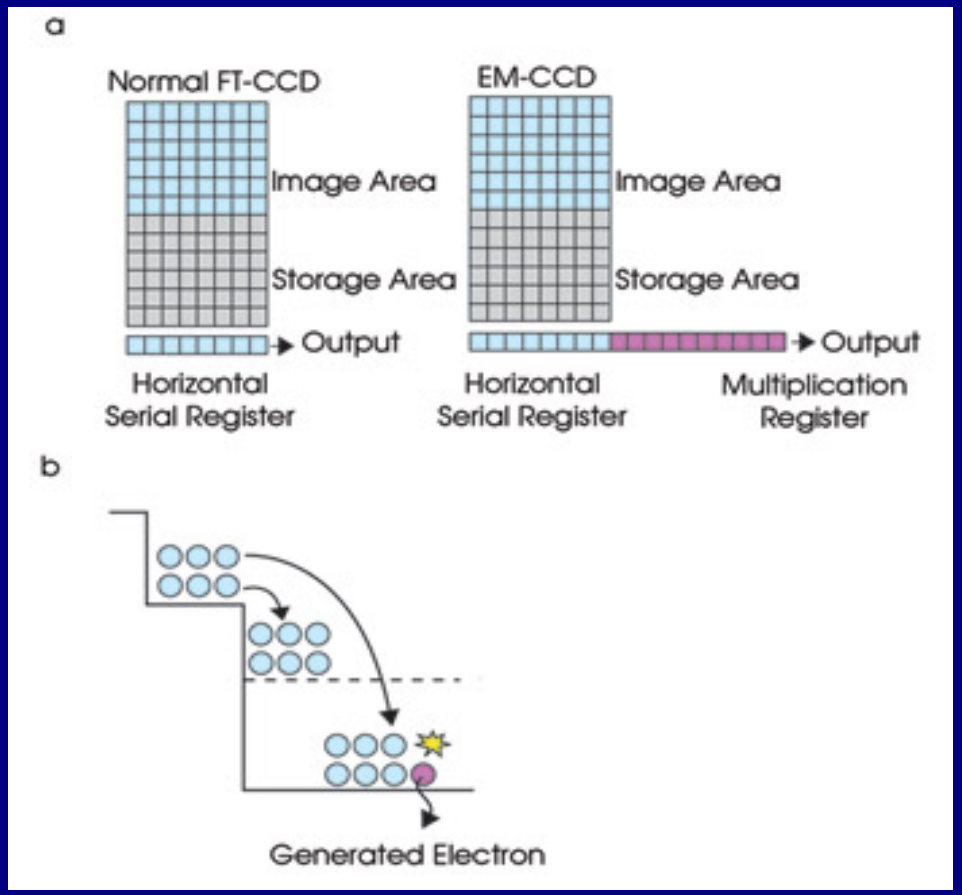
EMCCD_Gain_100X = 100*EMCCD_Signal + EMCCD_Noise

EMCCD Camera *[2/3]*



EMCCD Workflow *(source andor.com)*

EMCCD Camera *[3/3]*



EMCCD Impact Ionization *(source photonics.com)*

DSO Lucky Imaging with EMCCD *[1/10]*

<u>Main goals</u>

Sampling pictures on some DSO

Use of Long Focal Lenghts (around 8 mt)

Finding the right software pipeline

Making a comparison between CCD and EMCCD

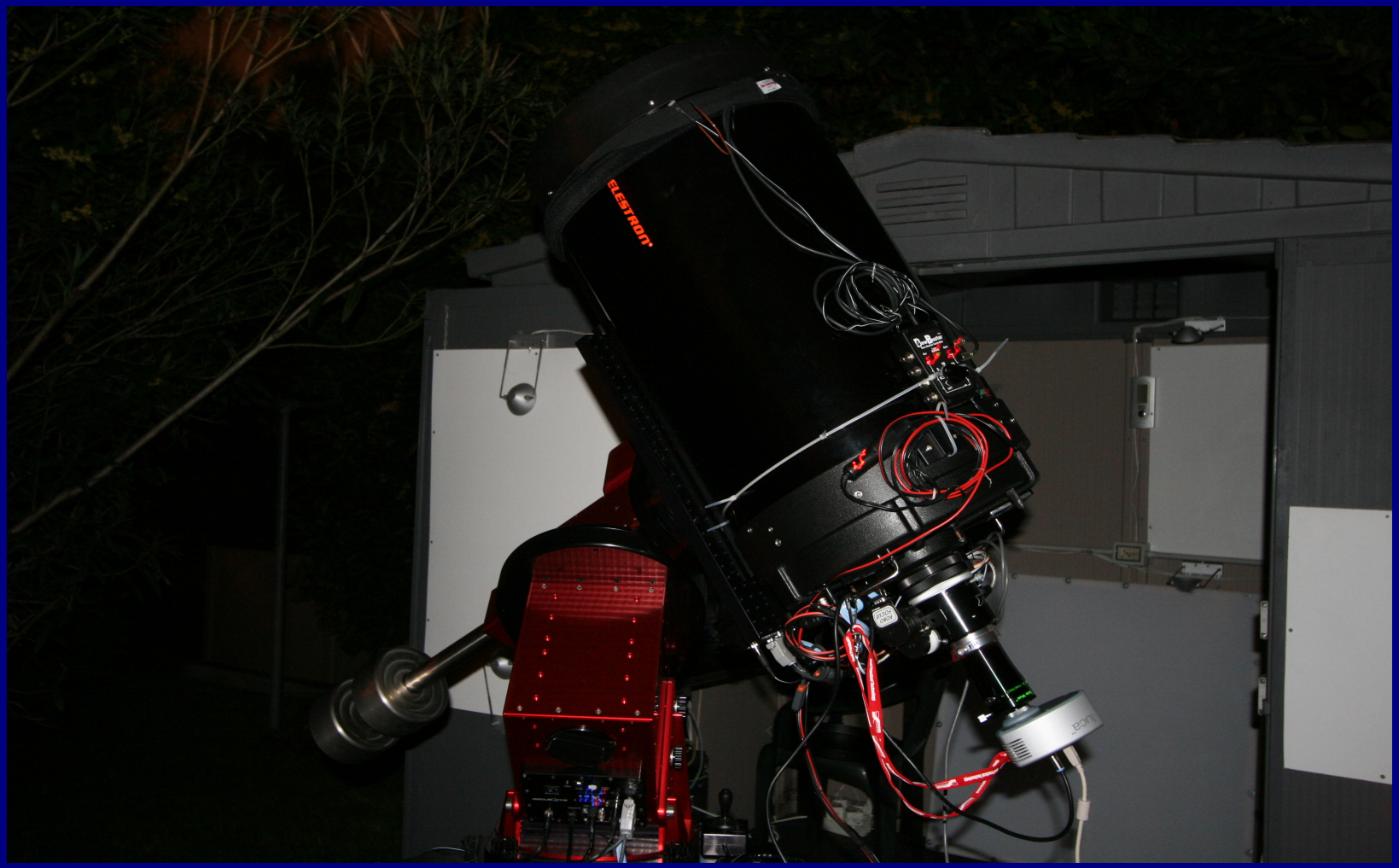
DSO Lucky Imaging with EMCCD *[2/10]*

Camera Info

Andor Luca-S

Pixel Size: 10 microns
EMCCD Array: 658x496 with ROI
A/D conversion: 14bit
Cooling: -20°C
Framerate: up to 37 fps
Connection: USB 2
QE: around 50%
EMCCD Gain: up to 1000x

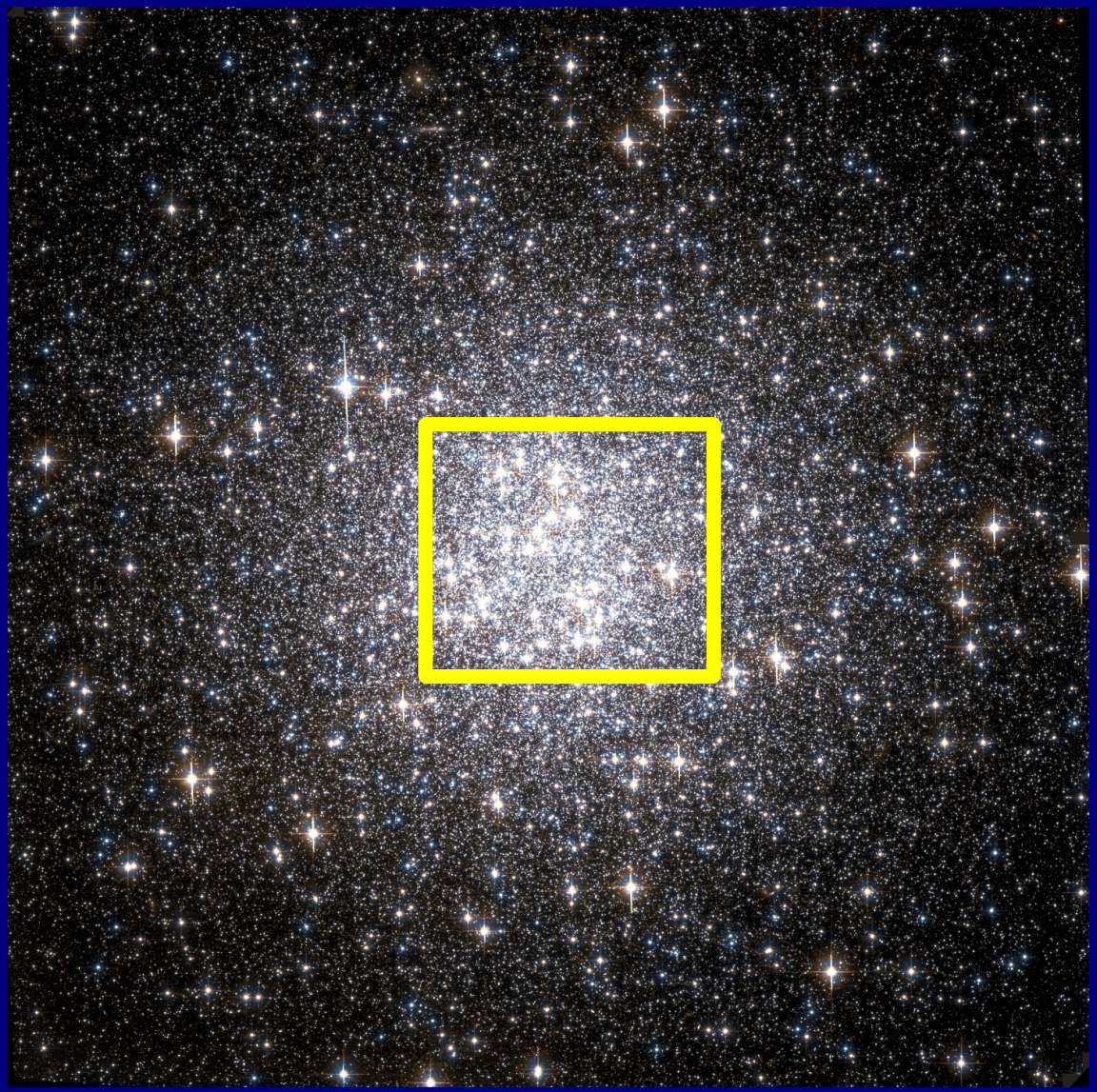
DSO Lucky Imaging with EMCCD *[3/10]*



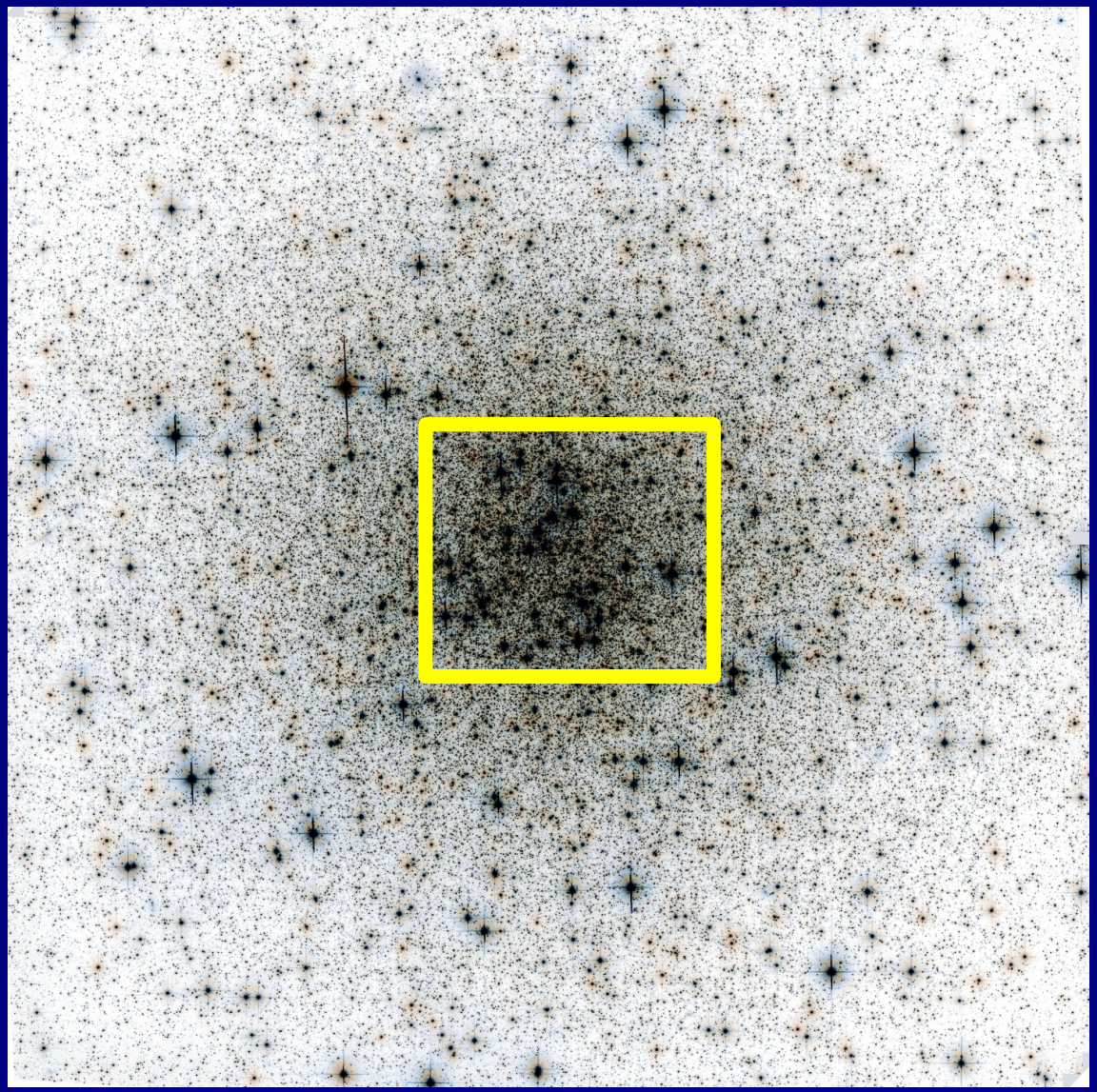
Imaging System *(Paramount ME + C14 + Andor Luca-s)*

DSO Lucky Imaging with EMCCD *[4/10]*

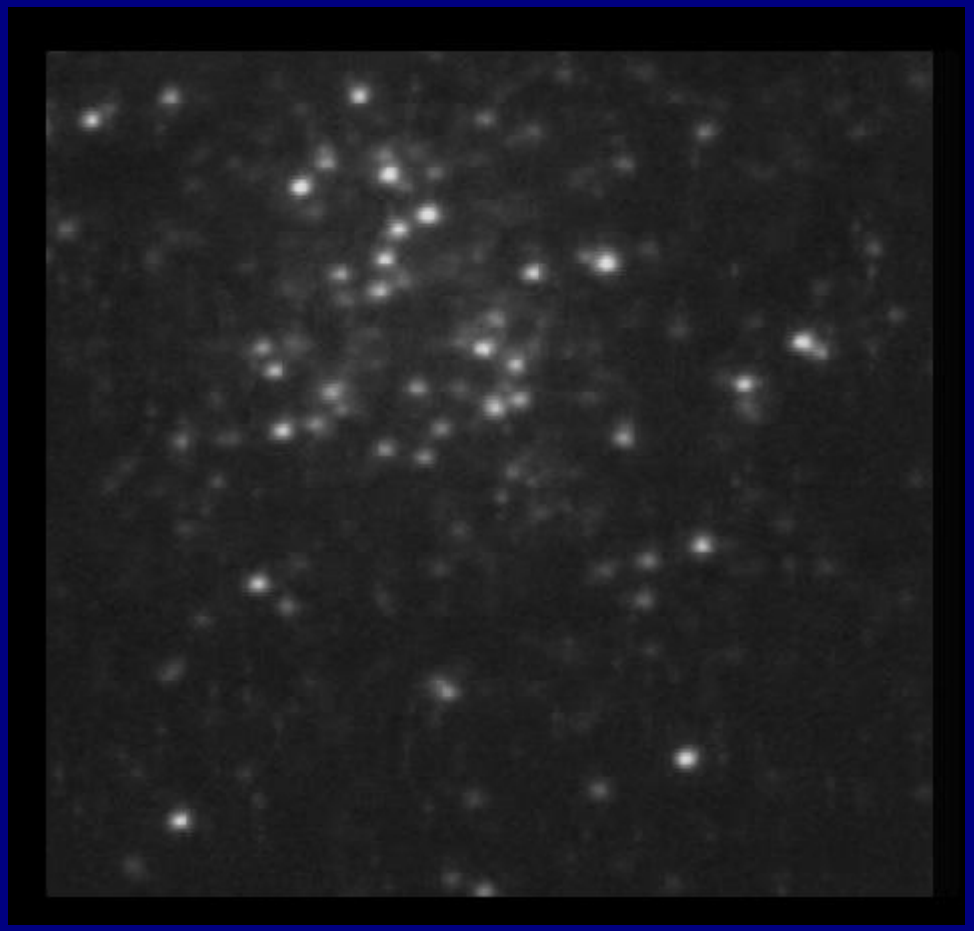
DSO Lucky Imaging with EMCCD *[5/10]*



DSO Lucky Imaging with EMCCD *[6/10]*



DSO Lucky Imaging with EMCCD *[7/10]*

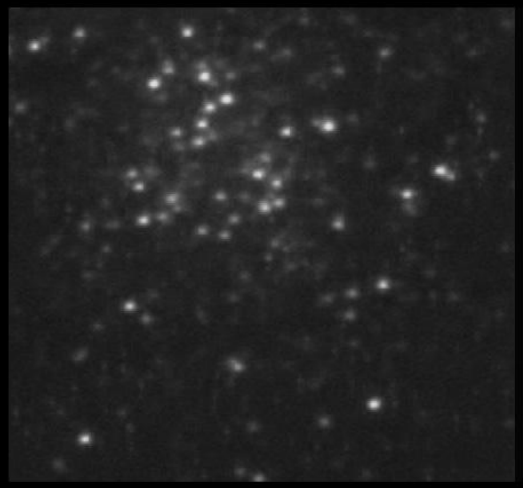


fl=7900mm f/22 800 frames @ 60ms

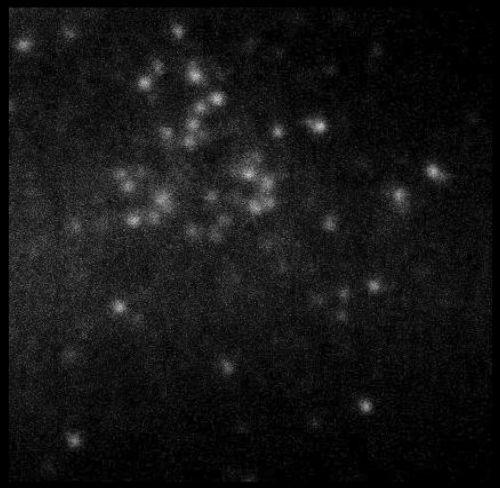
DSO Lucky Imaging with EMCCD *[8/10]*

M 53, C14 fl=7900mm f/22 Preliminary Results

Comparison between standard CCD and EMCCD



800 Frames selected from 2000
Single Frame exposure: 60ms (1/17 sec)
Total exposure: 48 sec
Andor Luca



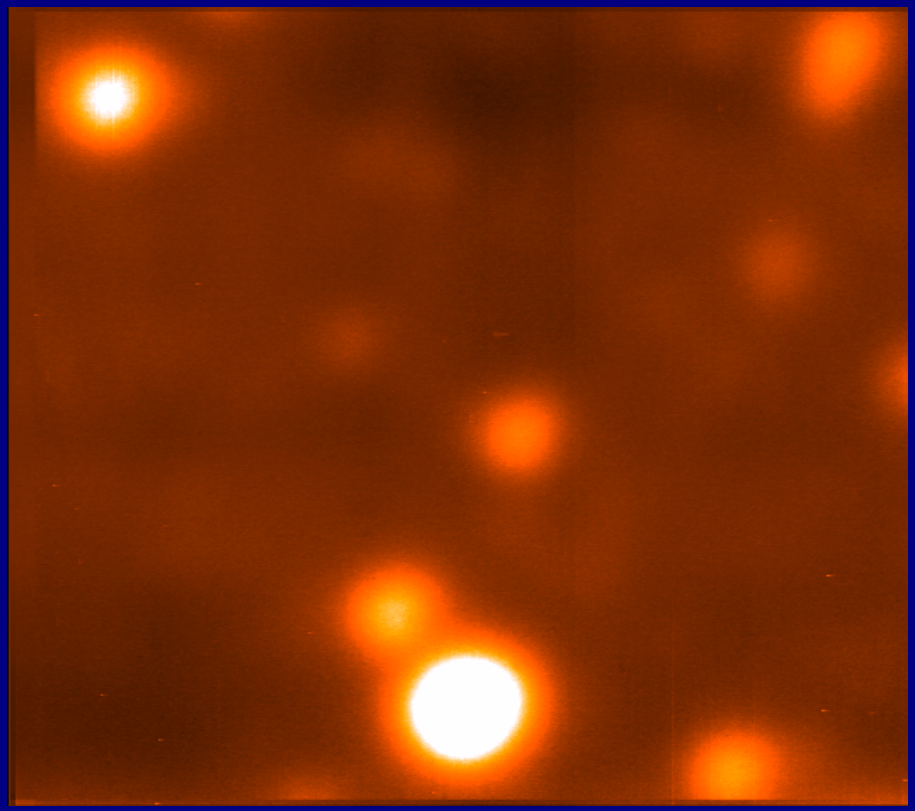
120 Frames selected from 232
Single Frame exposure: 5 sec
Total exposure: 600 sec
Standard CCD

DSO Lucky Imaging with EMCCD *[9/10]*

M53 Sampling Video

DSO Lucky Imaging with EMCCD *[10/10]*

Some results on M13 obtained using an EMCCD on the 5 meters @ Palomar Observatory *(source Univ. Of Cambridge, Lucky Imaging Group)*



Possible applications and Next Steps

Sampling fast images of Pulsar
Use of the EMCCD as guide cameras for AO

Camera cooldown up to -100°C (-80°C by TE)
Smarter software pipelines

We got Lucky !

Relocation: *Remote working, Local Telescope*

vs

Remote Imaging: *Local working, Remote Telescope*

References

LuckyCam Group:
http://www.ast.cam.ac.uk/research/lucky

Some Camera manufacturers:
www.andor.com
www.emccd.com

Thank you !