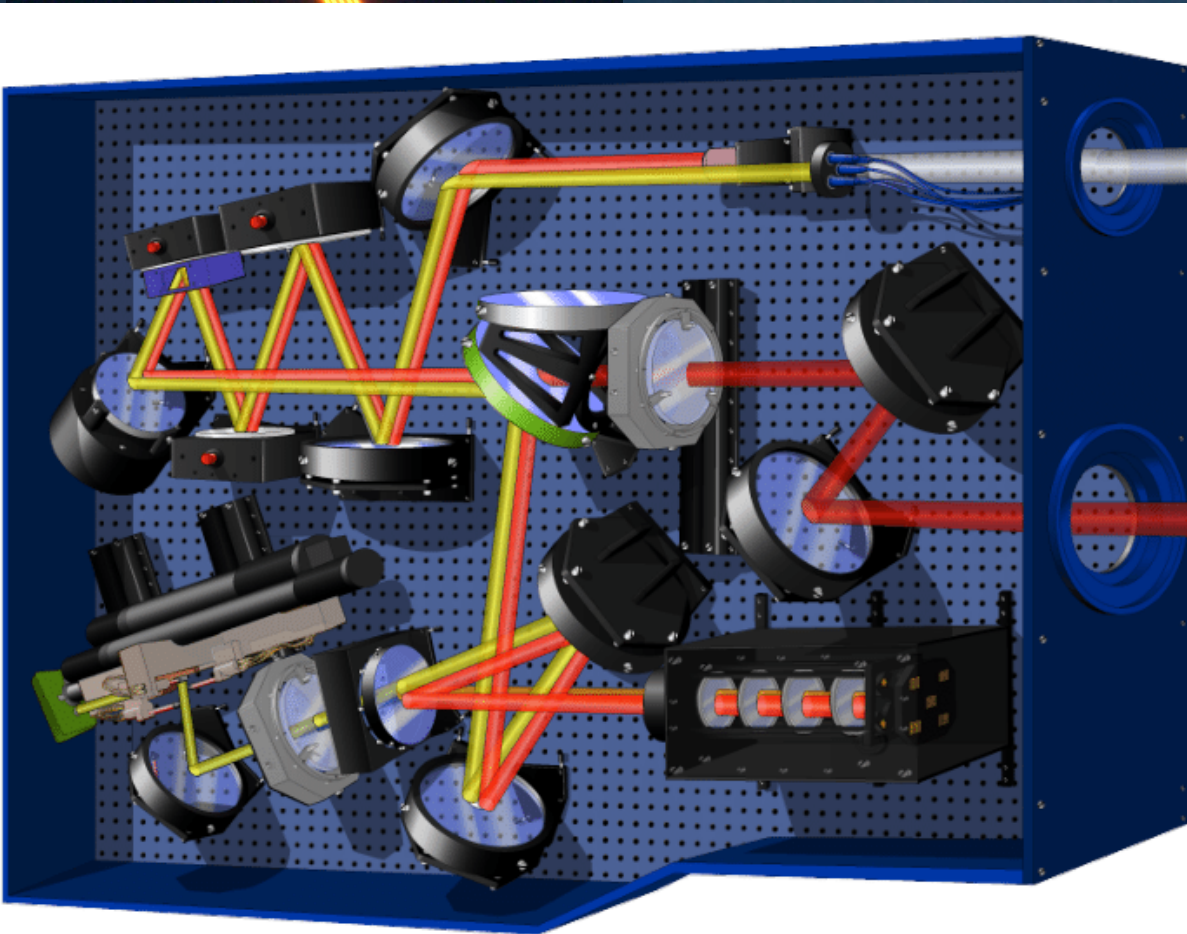
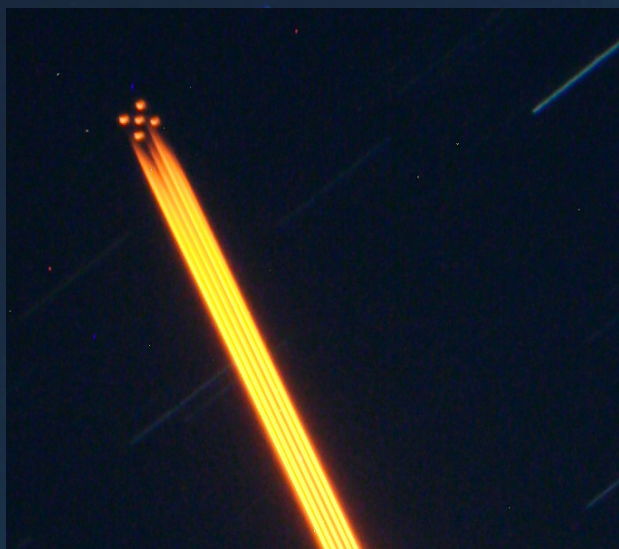


# NGS2: GeMS' new NGS WFS

Gaetano Sivo, Francois Rigaut, Benoit Neichel,  
Eduardo Marin, Marcos van Dam, Ian Price, Ignacio  
Arriagada, Rene Rutten, Celine d'Orgeville, Rodrigo  
Carrasco, Brian Chinn, Mariah Birchard, Cristian  
Moreno, Natalie Provost, Francis Bennet, Nick Herralld

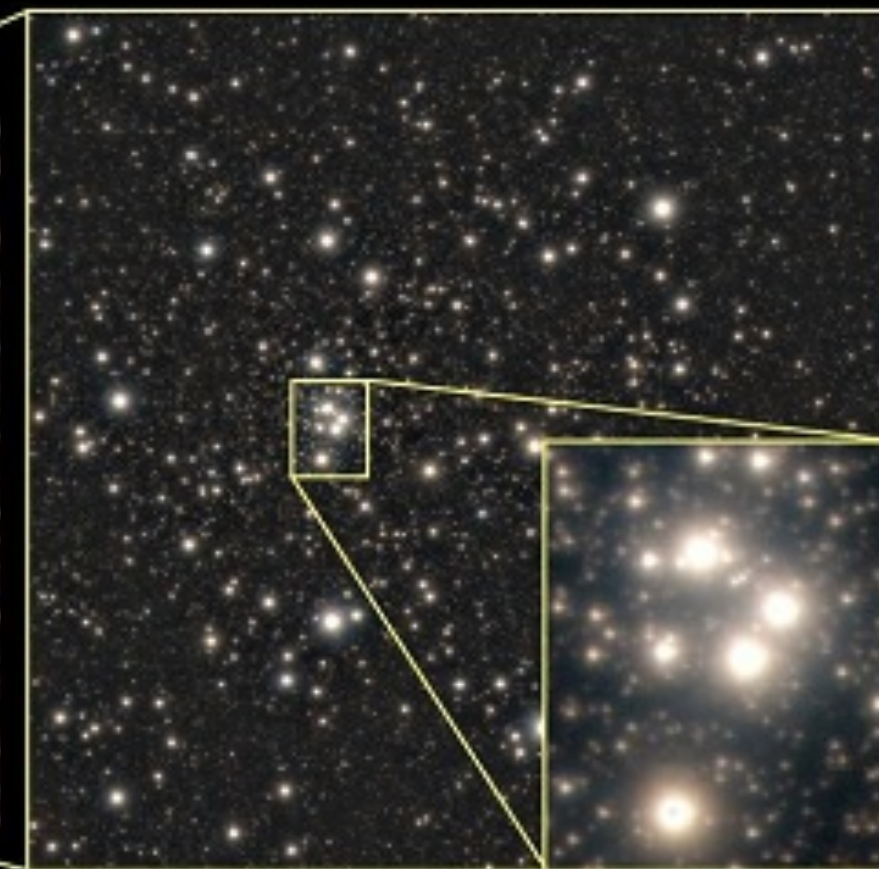
# What is GeMS ?



## HP 1 - A Fossil Relic in the Galactic Bulge



VVW - VISTA (4m)  
FWHM~0.8",  $K_{\text{lim}} \sim 17$



GSAOI+GeMS - Gemini-South (8m)  
FWHM~0.1",  $K_{\text{lim}} \sim 20$

# Outlines

- Previous NGS module
  - design
  - limitations
- NGS2
  - design
  - benefits
- NGS2 preliminary on-sky performance



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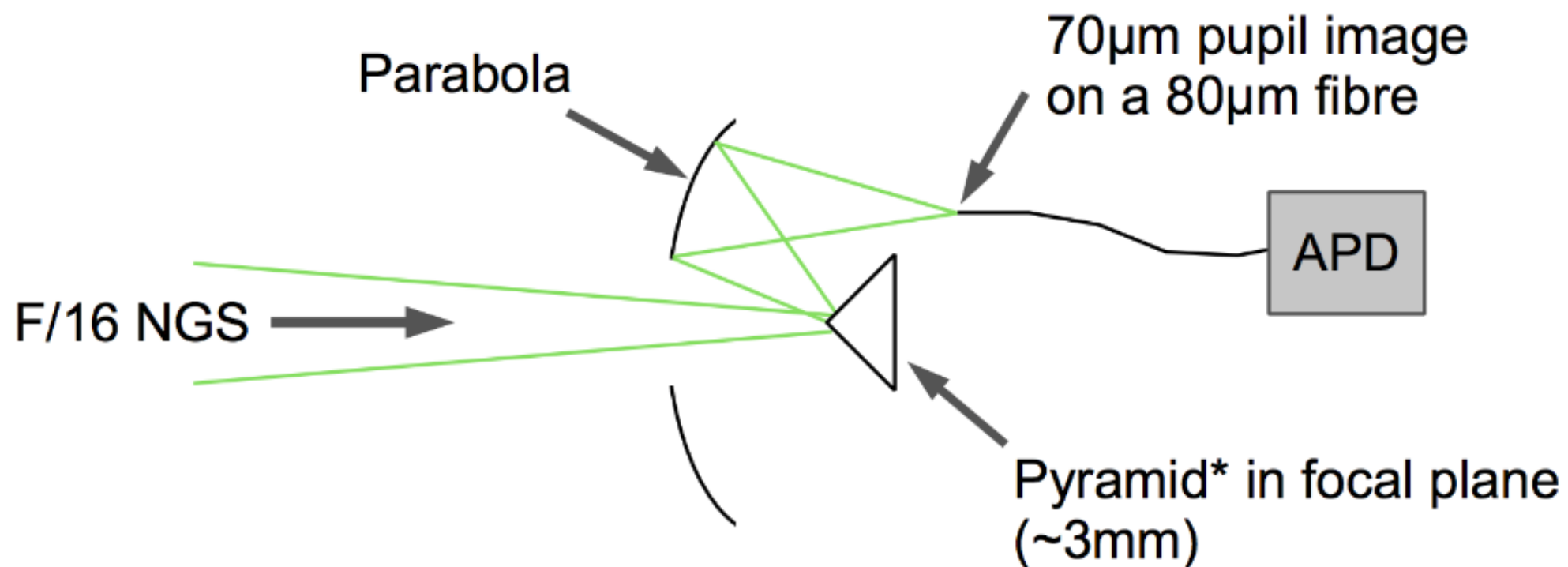
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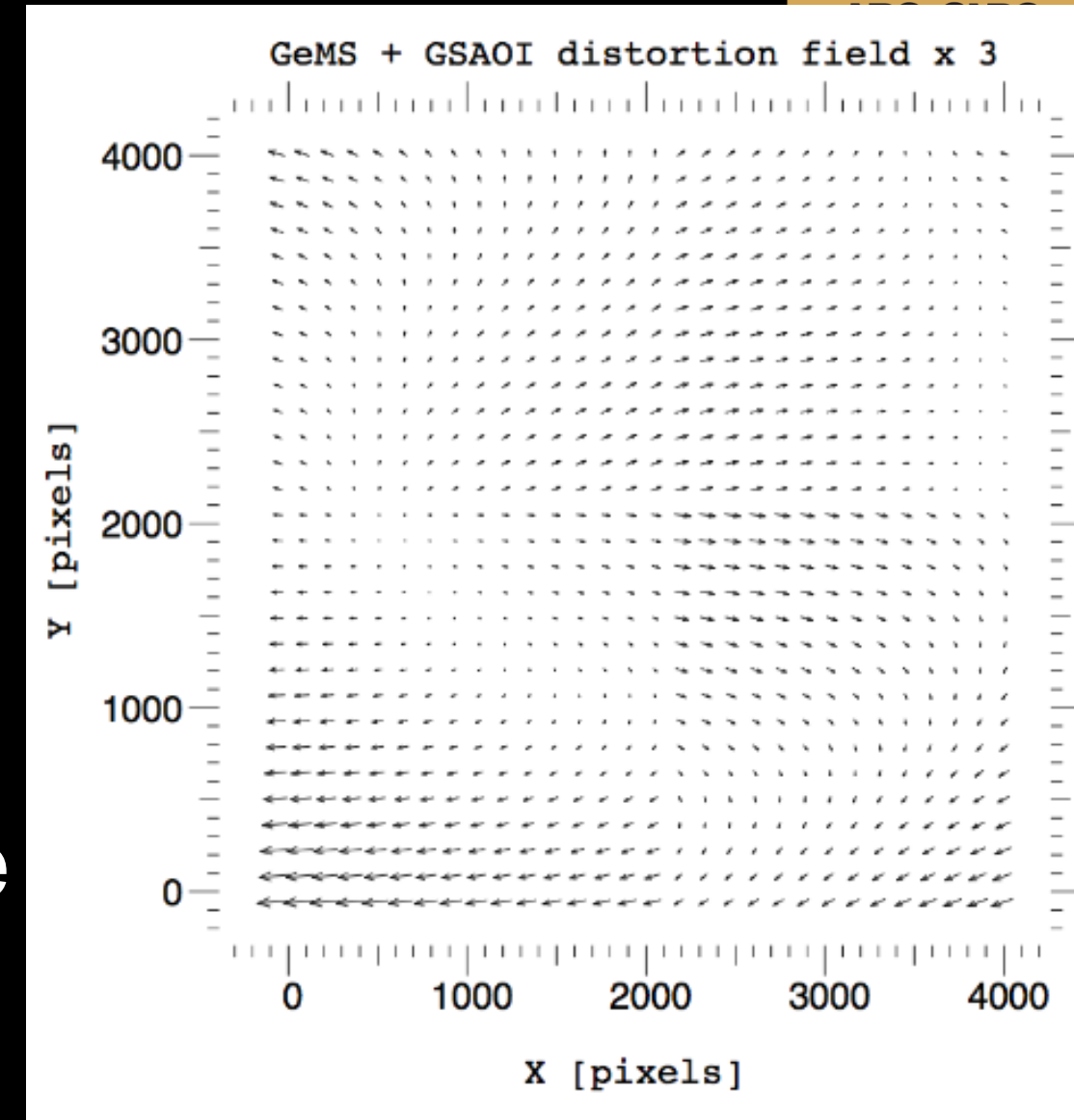
# GeMS NGS1 WFS



- Tiny, difficult to align fibre feed
- 4% optical throughput!
- Several attempts to fix but little improvement.

# NGS1 WFS issues

- Impact Guide Star acquisition
  - Linear model
  - No distortion model
- Asterism distorted as it offsets
  - induce plate scale + rotation in science exposure
  - Guide star end up outside the probe



# NGS1 WFS display

AOM | RTC | SFS | BTO | Health | Utilities

ScanTool

**Spiral**

Controller: aom NGS-3

Center (x,y): 0.0 0.0    Grab Current    Grab Display

Step sz.: 0.5     ccw / cw

Grid elts.: 11     spiral / square

▶ **Hand Paddle**

**Display**

2D interpolation: nearest

2D color map: gist\_earth

cmin 0.0     cmax 0.0

Collector: rtc APDs

Display: ngs3

checker     scan path

scan dmd     scan pos

**Progress**

Position

68 scan points

◀▶

◀▶

Save to file | Log entry:



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# NGS1 WFS display

**ScanTool**

**Spiral**

Controller: aom NGS-3

Center (x,y): 27.65 10.61 Grab Current Grab Display

Step sz.: 0.5  ccw / cw

Grid elts.: 11  spiral / square

**Hand Paddle**

**Display**

2D interpolation: nearest

2D color map: gist\_earth

cmin 3398.62329  cmax 185098.587

Collector: rtc APDs

Display: ngs3

checker  scan path

scan dmd  scan pos

**Progress**

Position

scan\_one\_step 64 @ 25.824430 12.576371

◀ ◻ ▶

◀ ▶

Save to file | Log entry:



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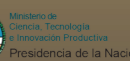
# NGS1 limitation

- Blind acquisition into tiny APD device
- Very low throughput (4%)
- Sky coverage very limited
  - V-band 15.5 under GREAT conditions
- Distortions unmapped



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# NGS2 requirements

- TT sensing on up to 3 NGSs
- Use a focal plane array
- Frame rate up to 800 Hz
- No vignetting
- $R_{lim} = 17$  with noise better than 35mas
- Focus adjustment to minimize spot size
- No heat nor light input in canopus
- As simple as possible to integrate in GeMS

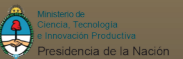


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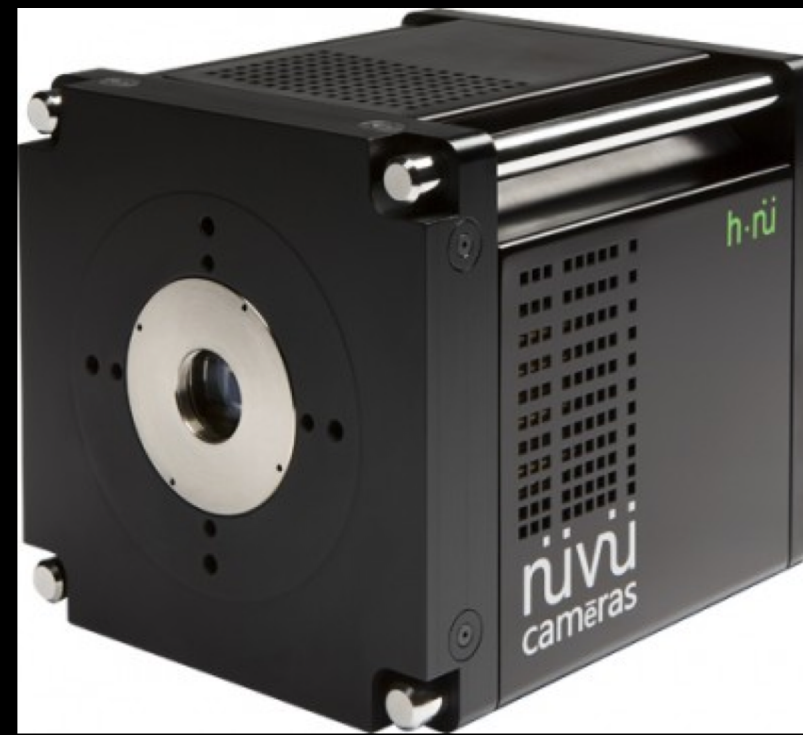


**KARI** 한국천문연구원  
Korea Astronomy & Space Science Institute

# NGS2 NuVu

## Camera spec

- 512x512 pixels
- 16um pixels
- EM gain up to 5000
- Low CIC 0.00058e-/px/fr
- RON ~300/EMgain
- Multi ROI capability
- **pixel scale 263mas**



# NGS2 Solution

- Focal plane sensor: Re-image system
  - Throughput exceed 75%
  - Solves limiting magnitude (sky coverage)
- Access to full field
  - FF imaging during acquisition simplifies ops
  - Field distortions can be mapped and include in window position model
- No moving mechanism across the field

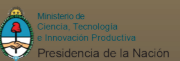


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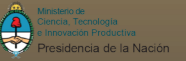


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```

[mcao@cpomca01 wfCorrector]$ ls -ltr ngs cmat 101019 231131.mat
-rw-rw-r-- 1 software software 20847 Oct 10 23:11 ngs cmat 101019 231131.mat
[mcao@cpomca01 wfCorrector]$ ls -ltr ngs cmat 111019 *
-rw-rw-r-- 1 software software 20847 Oct 11 01:36 ngs cmat 111019 013630.mat
[mcao@cpomca01 wfCorrector]$ ls -ltr ngs cmat 111019 *
-rw-rw-r-- 1 software software 20847 Oct 11 01:36 ngs cmat 111019 013630.mat
[mcao@cpomca01 wfCorrector]$ ls -ltr ngs cmat 111019 *
-rw-rw-r-- 1 software software 20847 Oct 11 01:36 ngs cmat 111019 013630.mat
[mcao@cpomca01 wfCorrector]$
Broadcast message from root (pts/10) (Fri Oct 11 03:31:34 2019):
The system is going down for reboot NOW!
Connection to cpomca01 closed by remote host.
Connection to cpomca01 closed.
[telops@cpotelops-l04 ~]$ ssh -Y mcao@portdev01
mcao@portdev01 ~$ password:
Last login: Fri Oct 11 03:09:44 2019 from 172.17.77.192
[mcao@portdev01 ~]$ vi /gnsssoft/opt/mcao-ftc10c/incboot/locrtc/st.cmd
[mcao@portdev01 ~]$ /gnsssoft/opt/mcao-ftc10c/incboot/locrtc/st.cmd

```

**Adaptive Optics Module Components Controller**

Health: OK | AOM in Position Status: OK

WFS Control:  $X=0.00$ ,  $Y=0.00$

DMs commands:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 1:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 2:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 3:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 4:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 5:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 6:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 7:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 8:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 9:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 10:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 11:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 12:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 13:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 14:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 15:  $X=0.00$ ,  $Y=0.00$

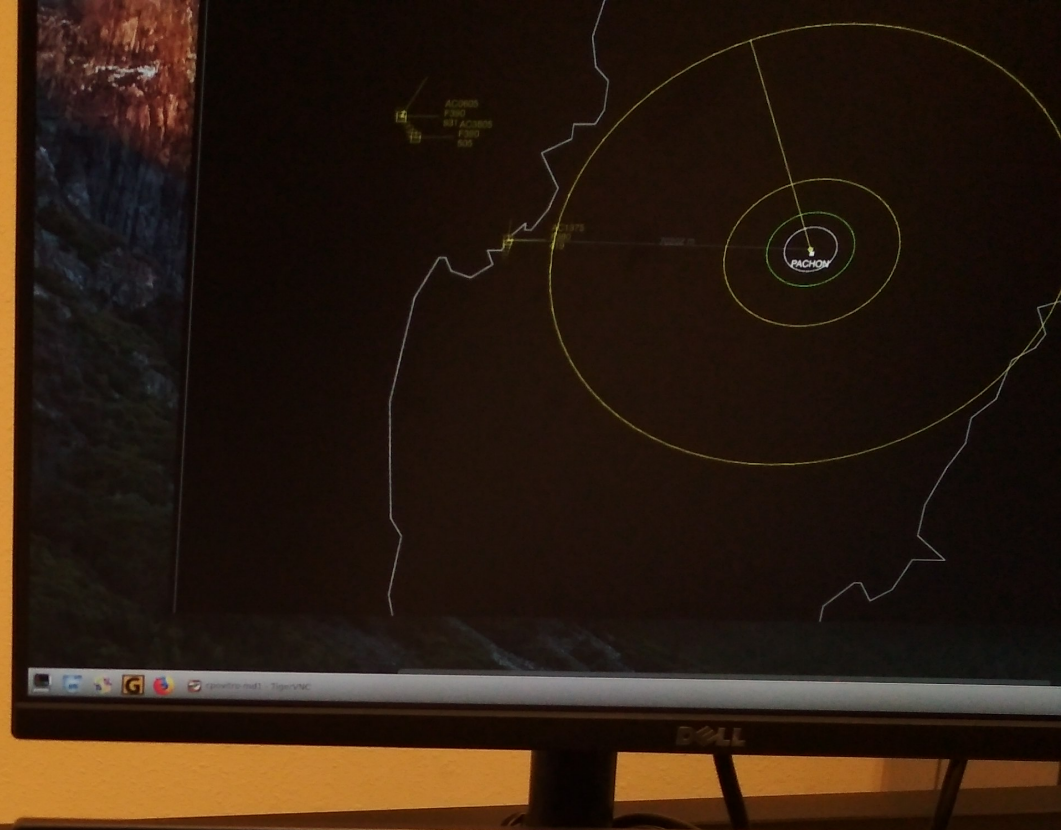
Raw NGS-WFS 16:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 17:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 18:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 19:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 20:  $X=0.00$ ,  $Y=0.00$



**MCAO Remote Real Time Display**

Tasks and Offloads:

Task	A	S	Perf.	Message
LGS LOOP	START	<input type="checkbox"/>	DISABLED	Not enough LGS counts (0)
T.T. LOOP	START	<input type="checkbox"/>	DISABLED	
T.A. LOOP	START	<input type="checkbox"/>	DISABLED	
FLEX. LOOP	START	<input type="checkbox"/>	DISABLED	
CMAT OFFIM.	START	<input type="checkbox"/>	DISABLED	
LGS CENT. GAINS	START	<input type="checkbox"/>	DISABLED	
DM0 > M1	ABORT	<input type="checkbox"/>	INPROGRESS	
TT > M2	START	<input type="checkbox"/>	DISABLED	
LGSWFS > FSA	STOP	<input checked="" type="checkbox"/>	GOOD	
WFS > LGSWFS	START	<input type="checkbox"/>	DISABLED	Integ=0.0 Ref=-10.6 Off=-3.5 Em=13.5
NGS > CRCS	START	<input type="checkbox"/>	DISABLED	
FSA > KM	STOP	<input checked="" type="checkbox"/>	GOOD	FSA offload: Setting KM to 0.254239
LGS Stoppers	STOP	<input checked="" type="checkbox"/>	UNKNOWN	

Focus control: Focus offset: 3.500 | Focus reference: 0.000 | DM:60C | Reset Focus integrator: 0.0

Raw NGS-WFS 1:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 2:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 3:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 4:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 5:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 6:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 7:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 8:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 9:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 10:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 11:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 12:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 13:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 14:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 15:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 16:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 17:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 18:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 19:  $X=0.00$ ,  $Y=0.00$

Raw NGS-WFS 20:  $X=0.00$ ,  $Y=0.00$



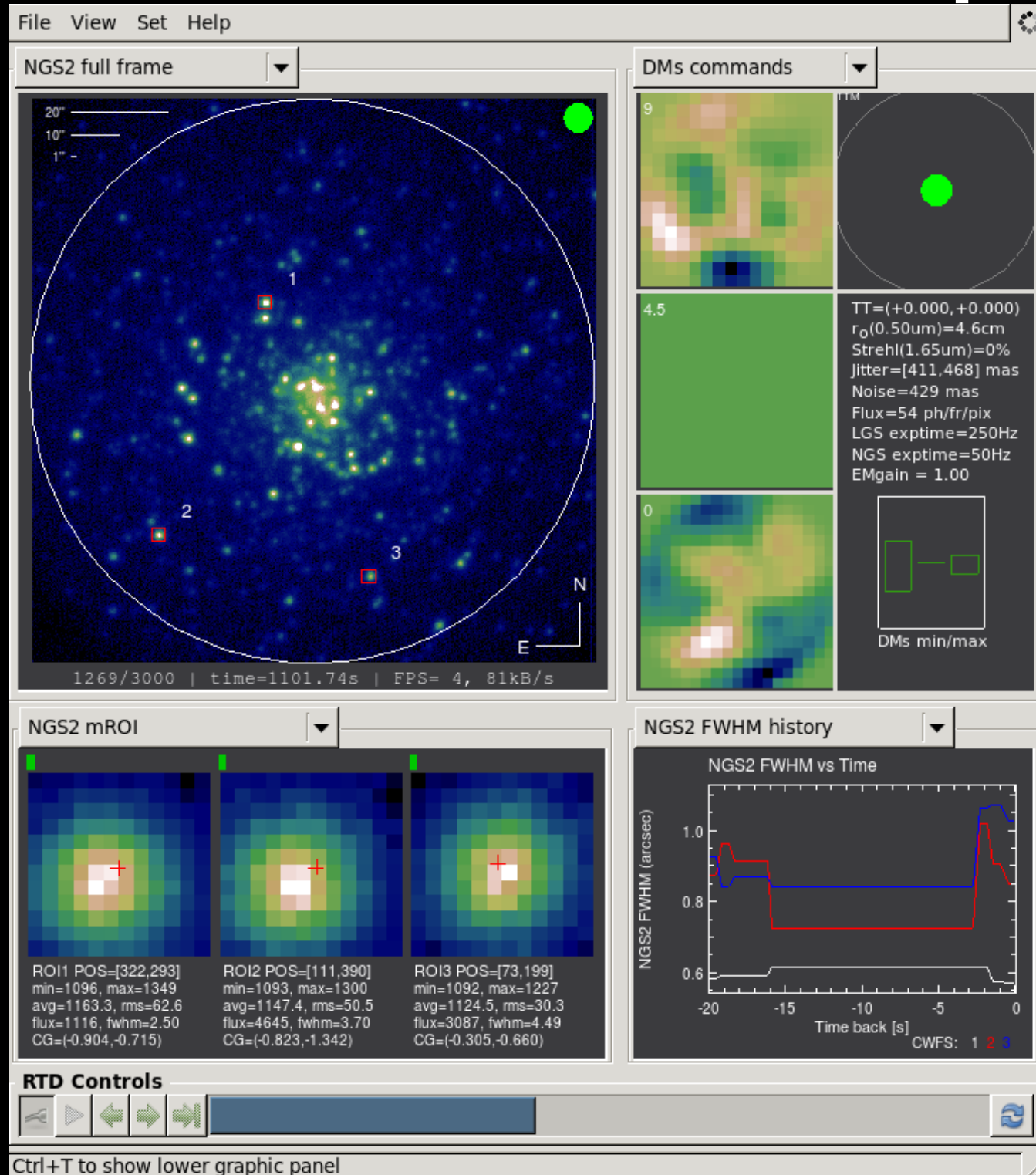
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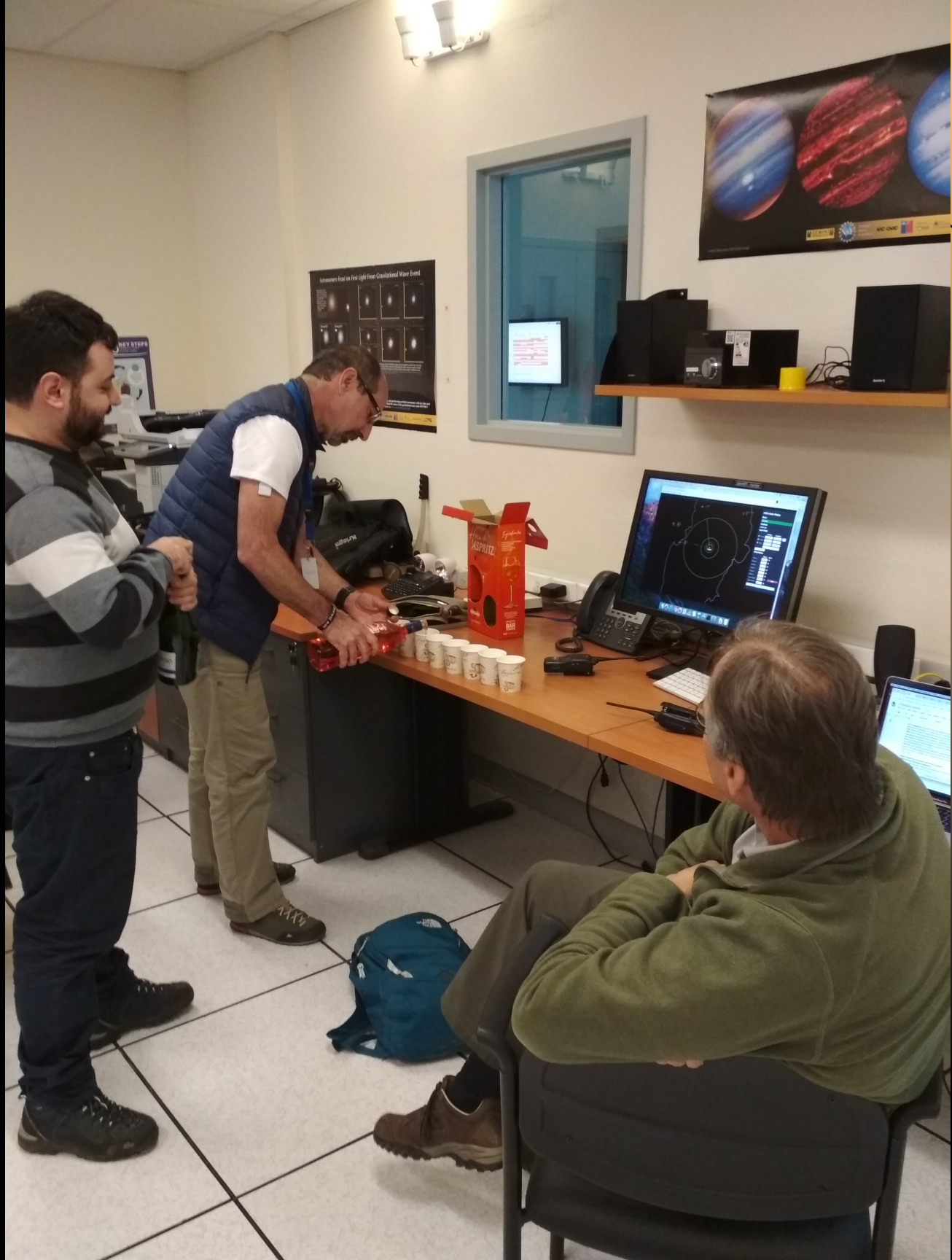


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# GeMS NGS2 display



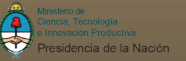


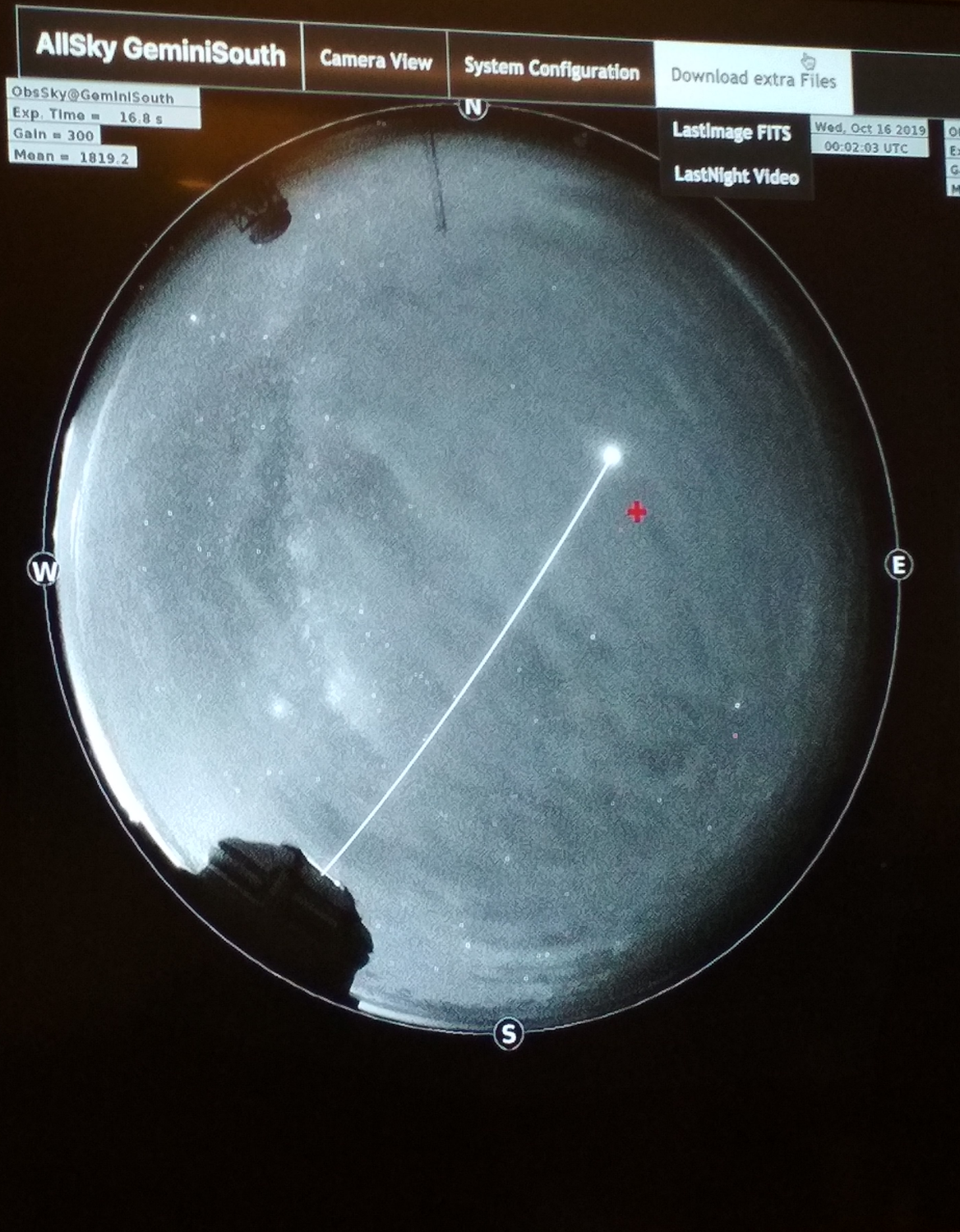
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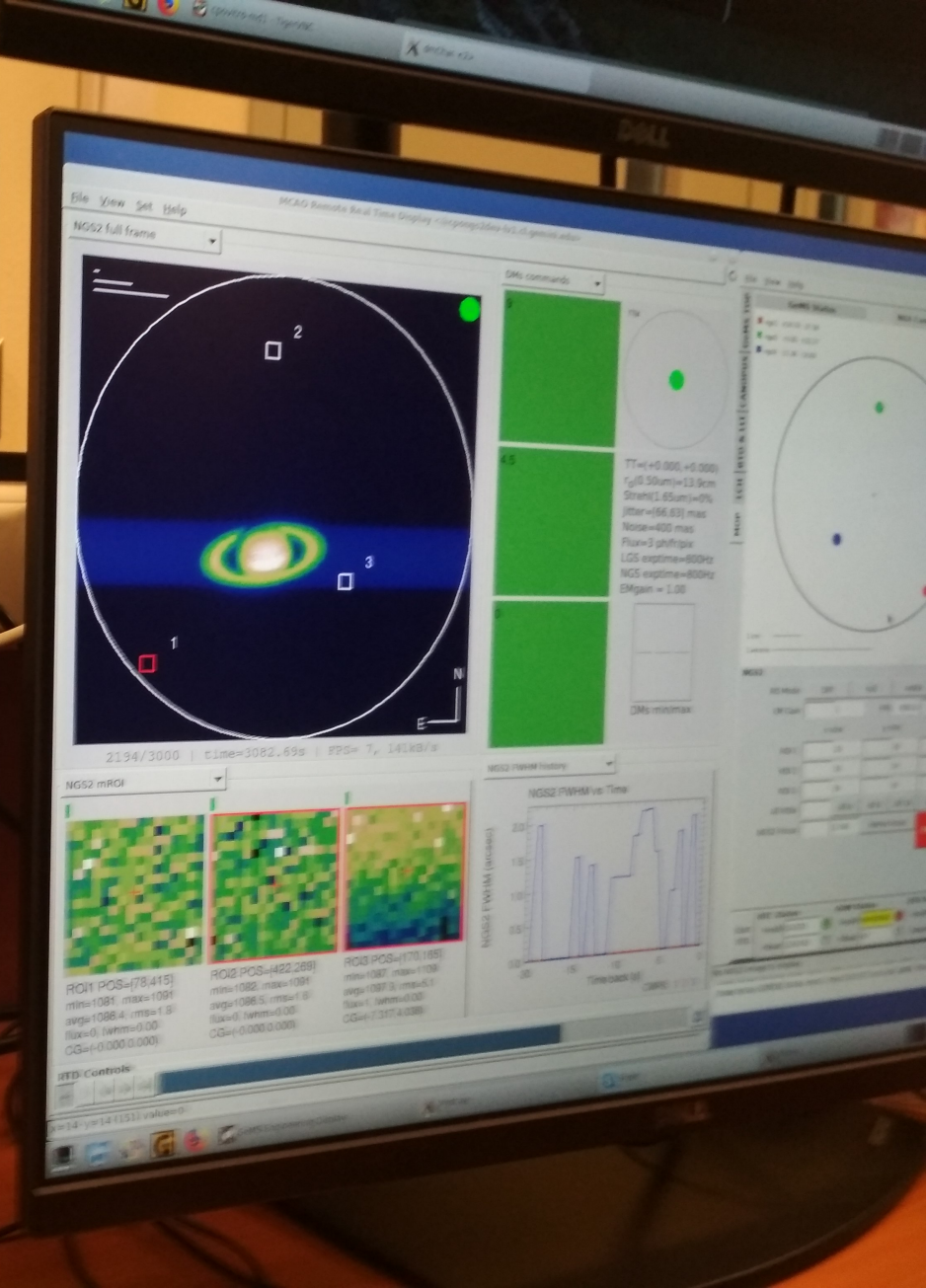
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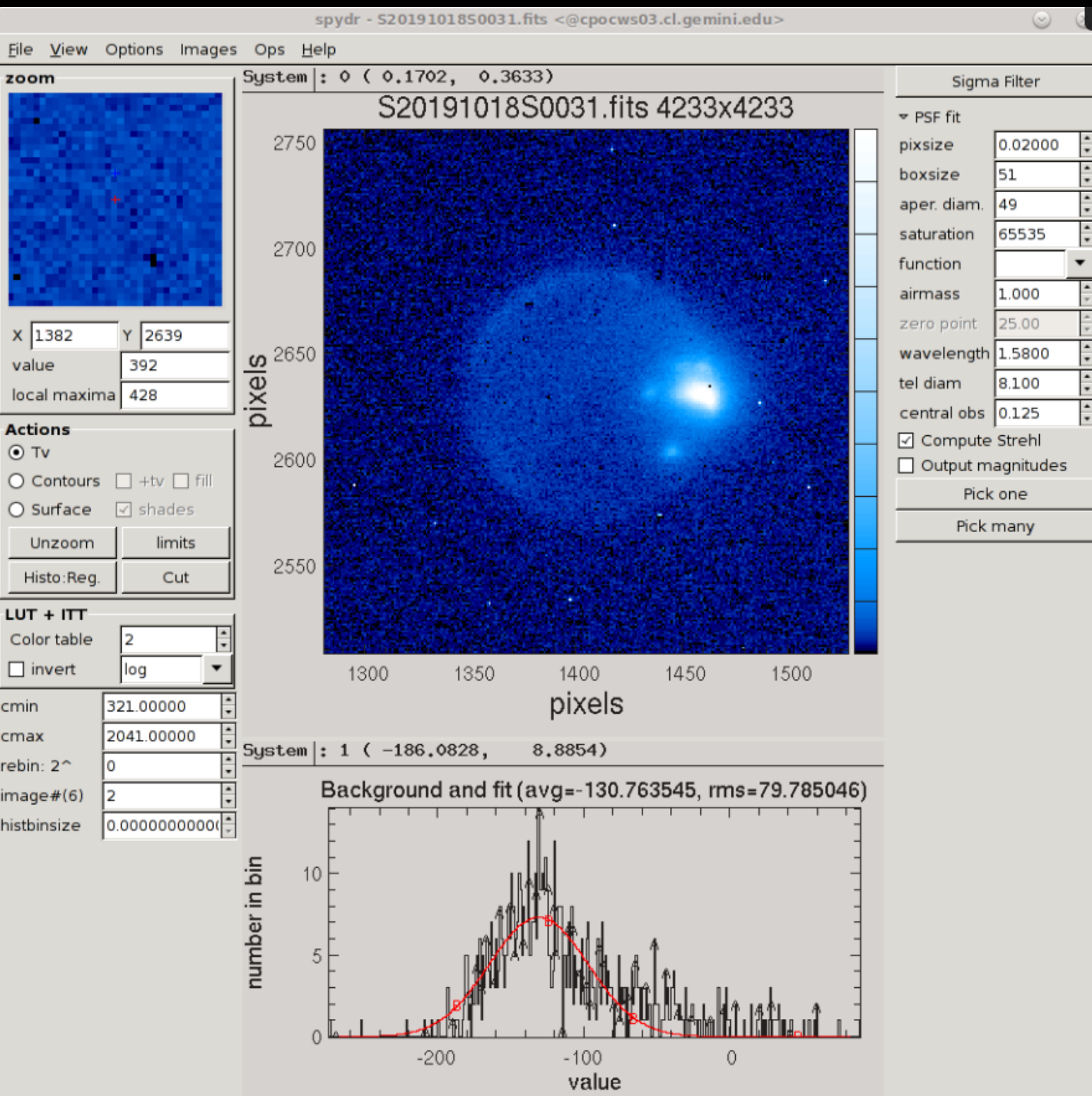
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**NRC-CMRC**





# Non-sidereal observations



Neptune observation  
Guiding on Triton

# Non-sidereal observations

WFS pixels

2698/3000 | time=16029.35s | FPS=11, 222kB/s

DMs commands

TT=(-0.049,+0.020)  
r<sub>0</sub>(0.50um)=5.9cm  
Strehl(1.65um)=0%  
Jitter=[352,683] mas  
Noise=309 mas  
Flux=38 ph/fr/pix  
LGS exptime=225Hz  
NGS exptime=225Hz  
EMgain = 1.00

Engineering | Calibrations | Smart Tools | Display

**Tasks and Offloads**

Task	A	S	Perf.	Message
LGS LOOP	STOP	<input type="checkbox"/>	OPTIMAL	15 eq. modes corrected
T.T. LOOP	STOP	<input type="checkbox"/>	GOOD	residual 27 mas
T.A. LOOP	START	<input type="checkbox"/>	DISABLED	
FLEX. LOOP	START	<input type="checkbox"/>	DISABLED	
CMAT OPTIM.	STOP	<input checked="" type="checkbox"/>	UNKNOWN	New CMAT computed for zen=47.7
LGS CENT. GAINS	STOP	<input checked="" type="checkbox"/>	UNKNOWN	
DM0 > M1	STOP	<input checked="" type="checkbox"/>	UNKNOWN	
TT > M2	STOP	<input checked="" type="checkbox"/>	UNKNOWN	
LGSWFS > FSA	STOP	<input type="checkbox"/>	GOOD	
SFS > LGSWFS	STOP	<input type="checkbox"/>	UNKNOWN	Integ=-11.0 Ref=9.5 Off=0.0 Err=-6.0
NGS > CRCS	START	<input type="checkbox"/>	DISABLED	
FSA > KM	STOP	<input type="checkbox"/>	GOOD	FSA offload: Setting KM to -0.160469
LGS Steppers	STOP	<input type="checkbox"/>	UNKNOWN	Sending LGS stepper to 122.41 km

**Focus control**

Focus offset: 0.000 | 0.000C | Focus reference: 9.500 | 9.500C | Reset Focus integrator | rg + off + integ. with integ =

lgs wfs offsets: Read npc\_a\_zen46.mat -> internal (current\_offsets)

56054	46779	56054	46779
61805	48655	61805	48655

NGS2 mROI

ROI1 POS=[198,237] min=1550, max=11098 avg=2136.0, rms=1368.6 flux=261755, fwhm=5.34 CG=(0.037,0.053)  
 ROI2 POS=[32,361] min=1354, max=1558 avg=1462.3, rms=38.1 flux=2, fwhm=0.00 CG=(-11.816,-8.964)  
 ROI3 POS=[114,139] min=1418, max=1680 avg=1538.8, rms=37.4 flux=7, fwhm=0.00 CG=(-8.176,-9.986)

NGS2 FWHM history

NGS2 FWHM (arcsec)

Time back [s]

CWFS: 1 2 3

RTD Controls

Perf met

Guiding on Vesta

# NGS2 observation: Science performance



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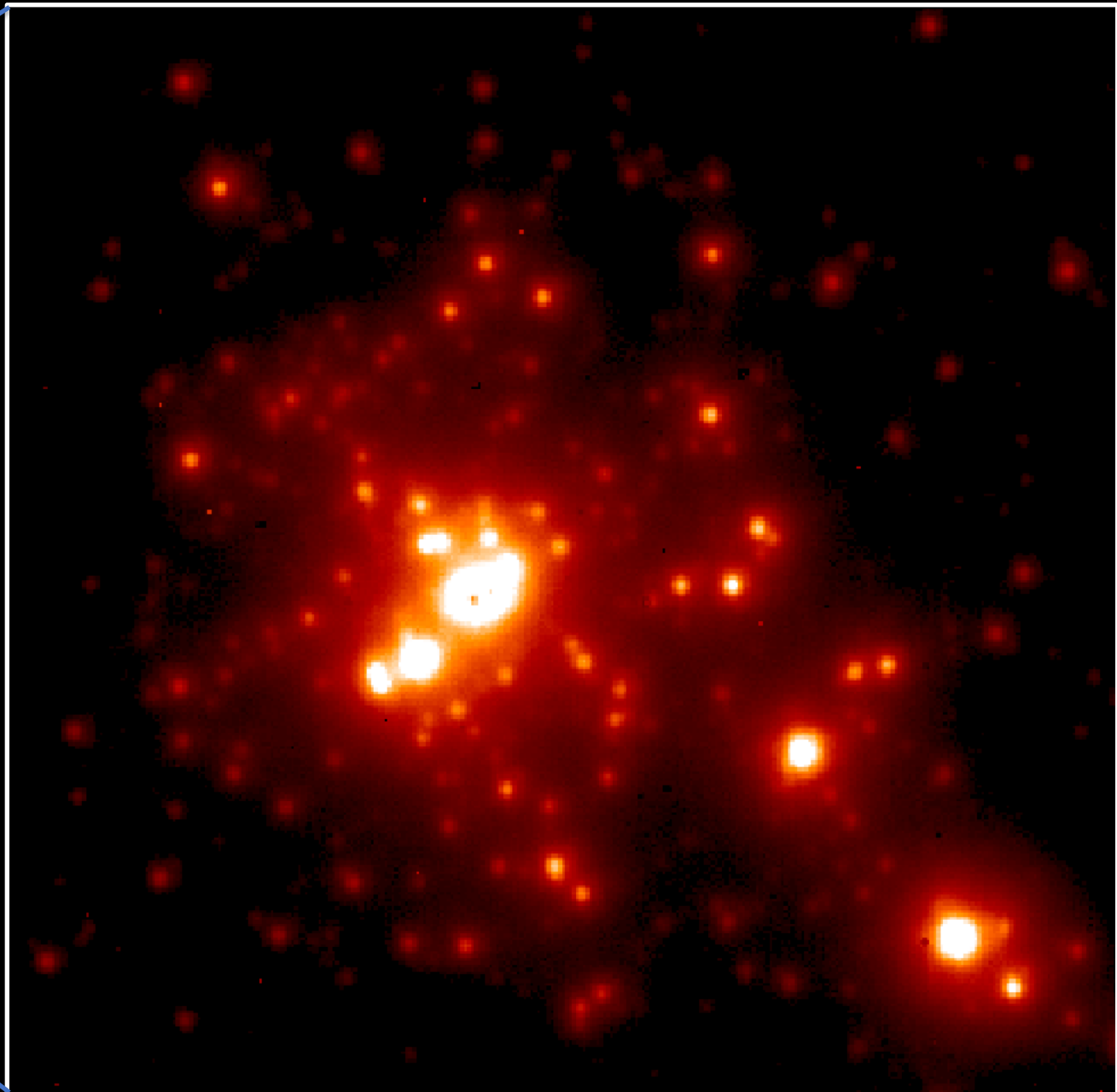
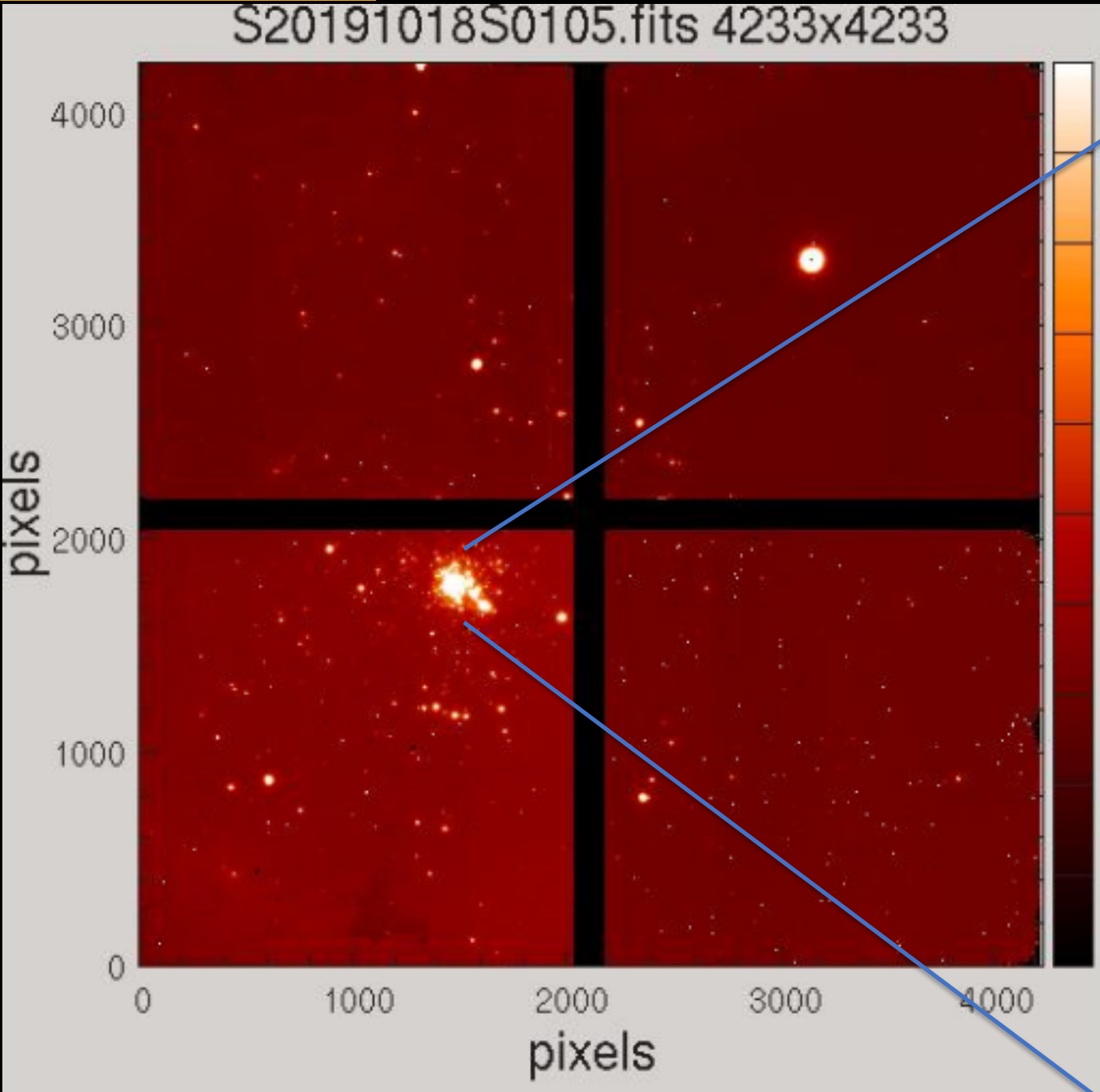
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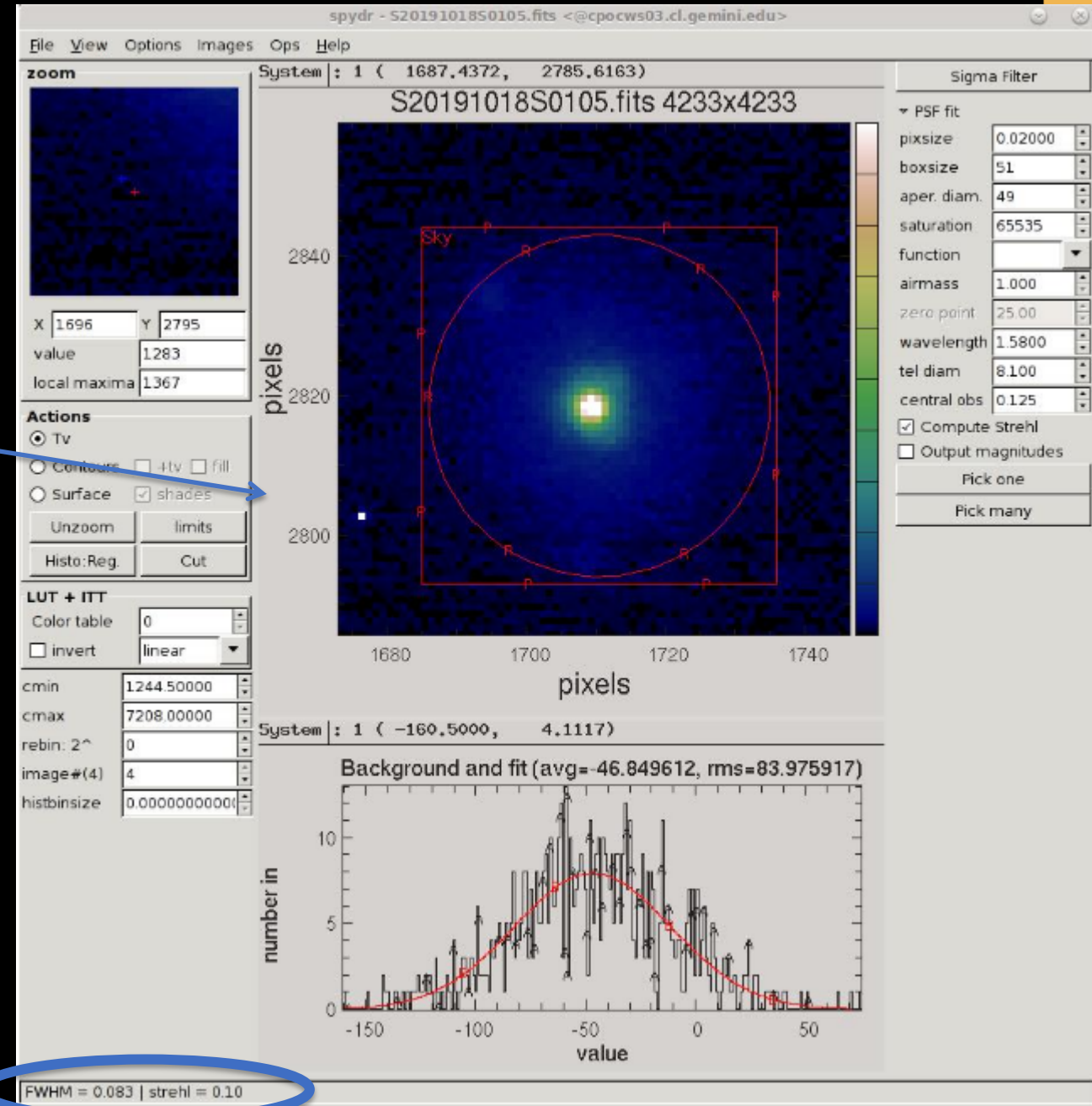
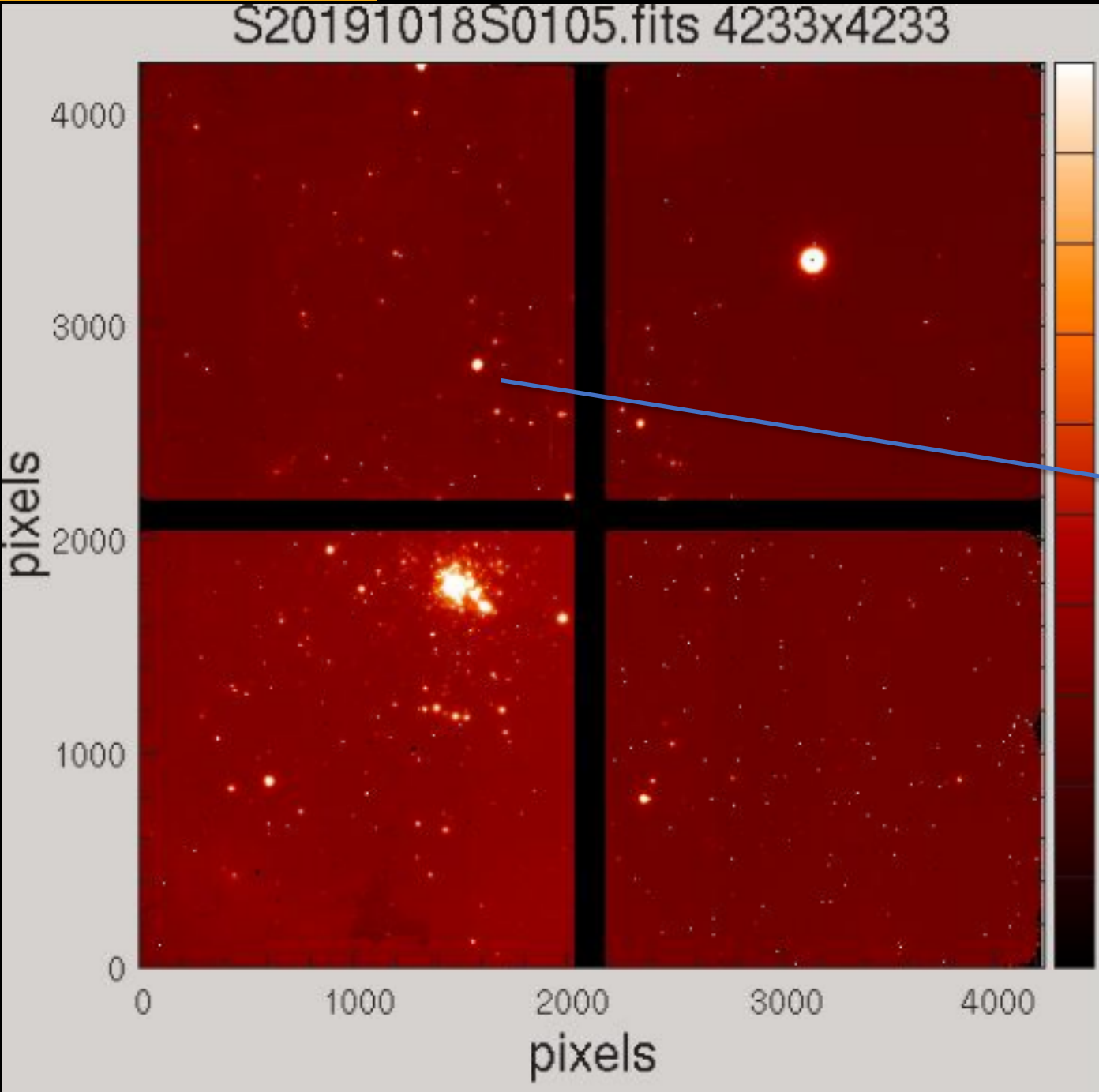
Presidencia de la Nación



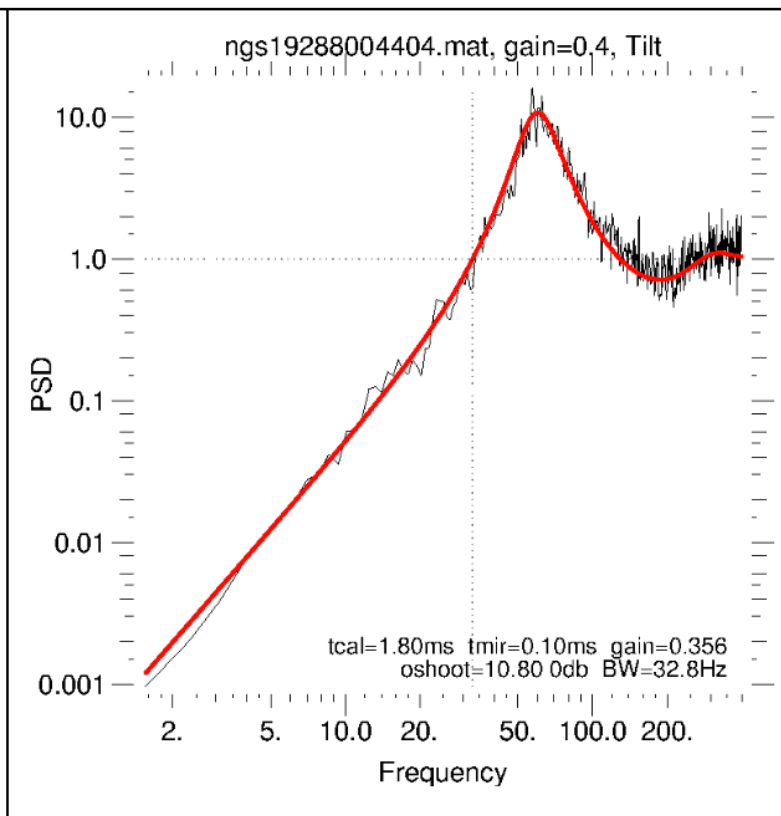
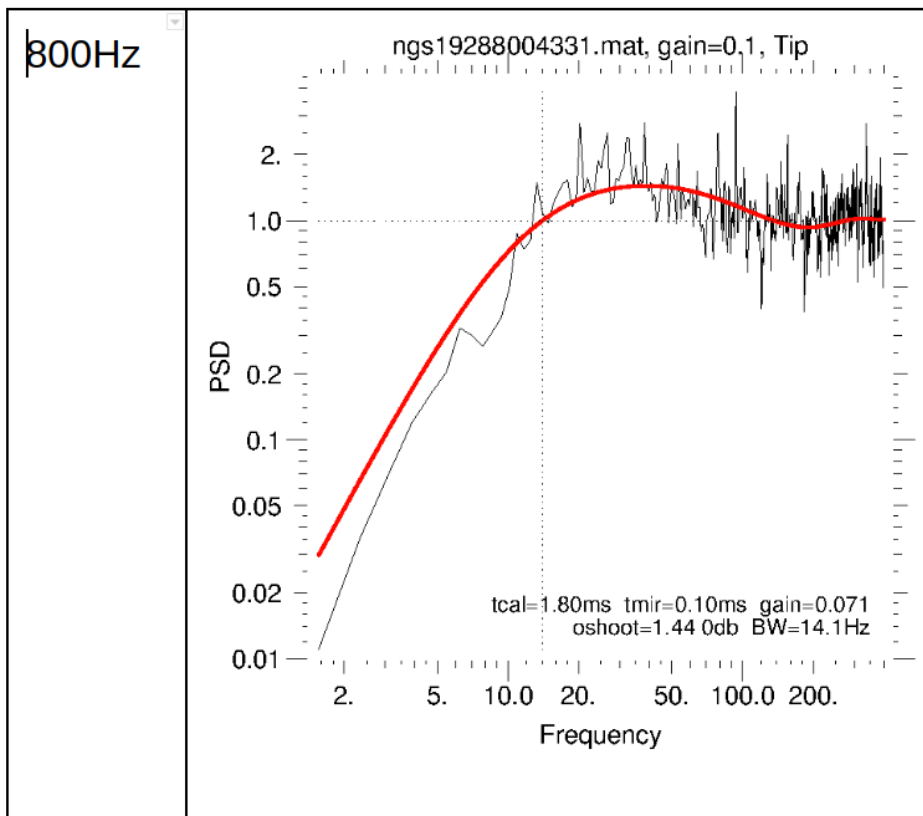
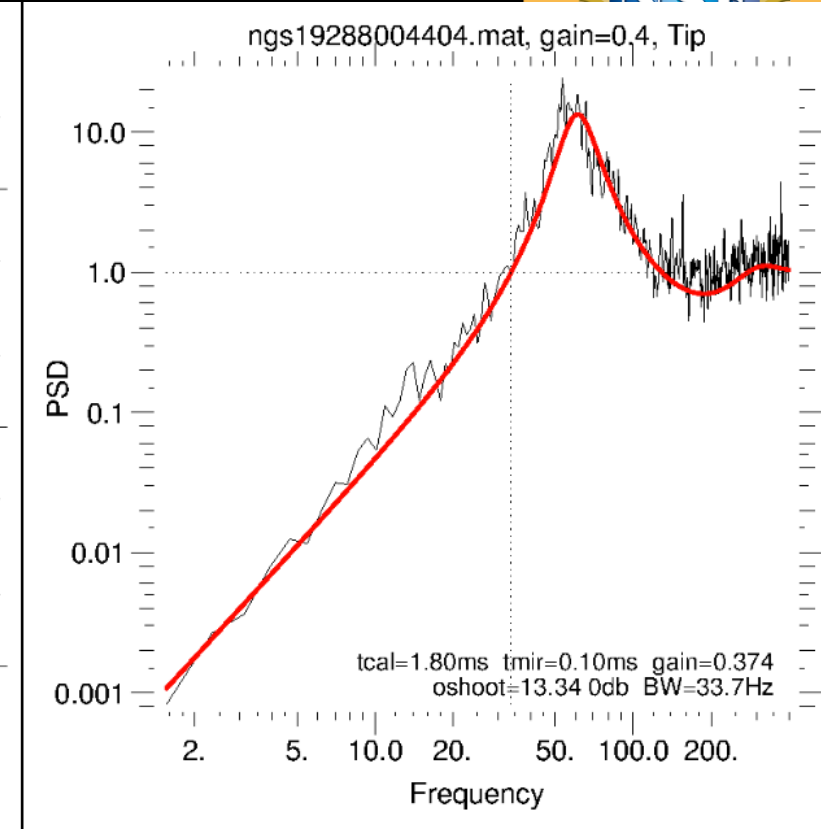
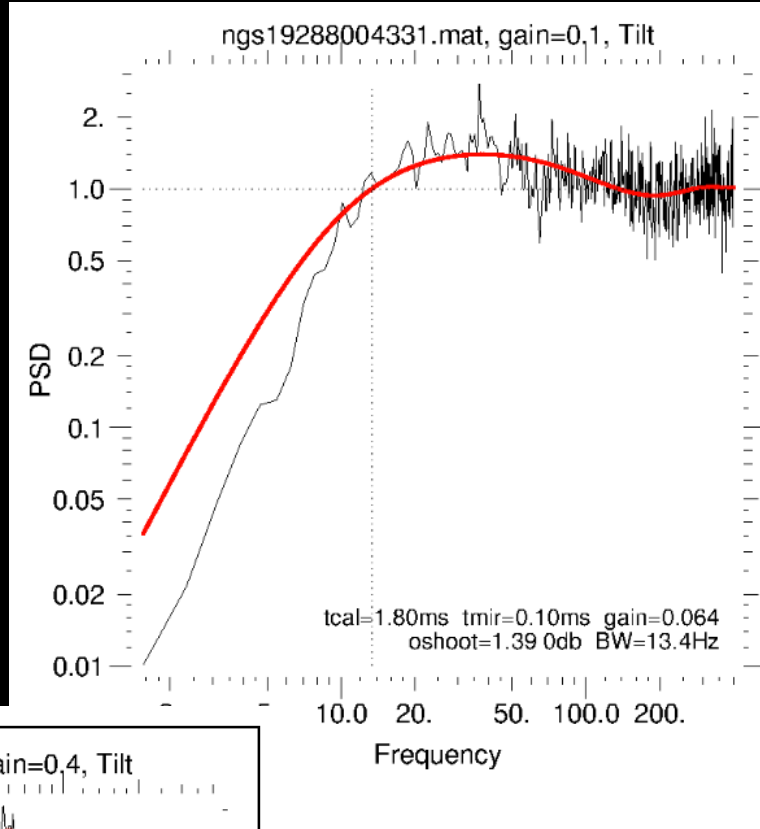
KARI 한국천문연구원  
Korea Astronomy & Space Science Institute



# NGS2 observation: Science performance



# NGS2 bandwidth



# Conclusion

- **NGS Works !**
  - Being able to get 30mas TT on  $R=17.5$
  - Even close loop on  $R=18.2$  !
  - Major upgrade for GeMS Sky Coverage !
- **Ultra-fast acquisition**
  - Full Field imaging during acquisition simplifies ops
  - Field distortions can be mapped and include in window position model
- **No moving mechanism across the field**



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