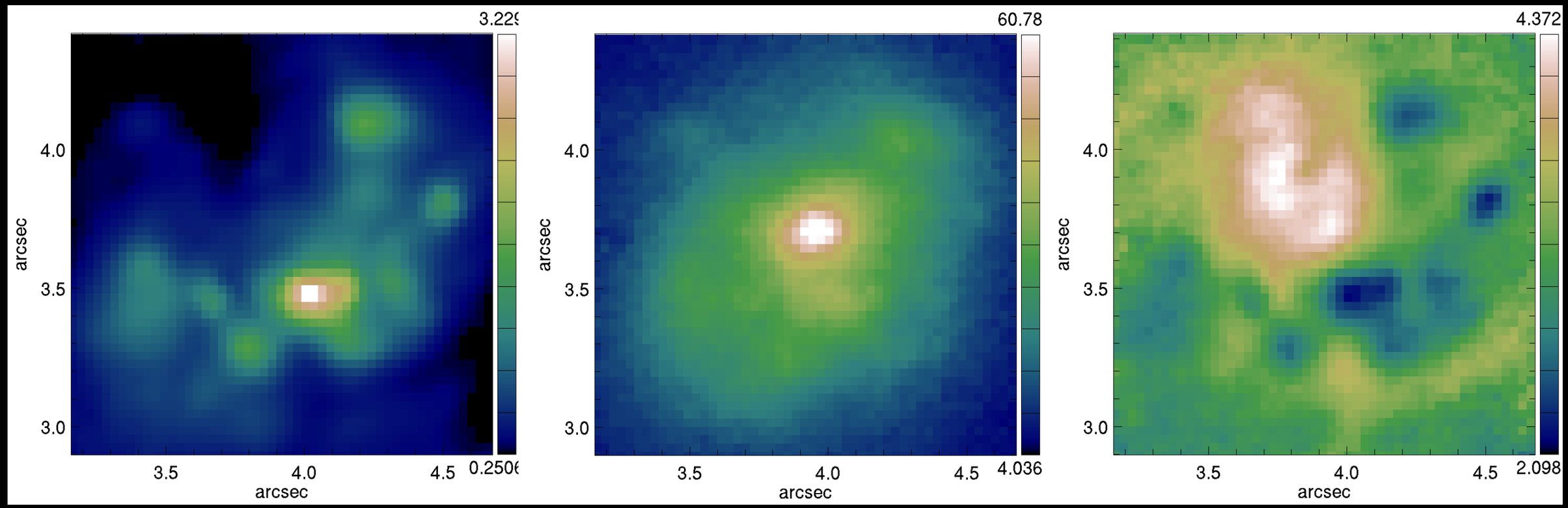
First demo science with MOAO

observations of distant merging galaxies with CANARY



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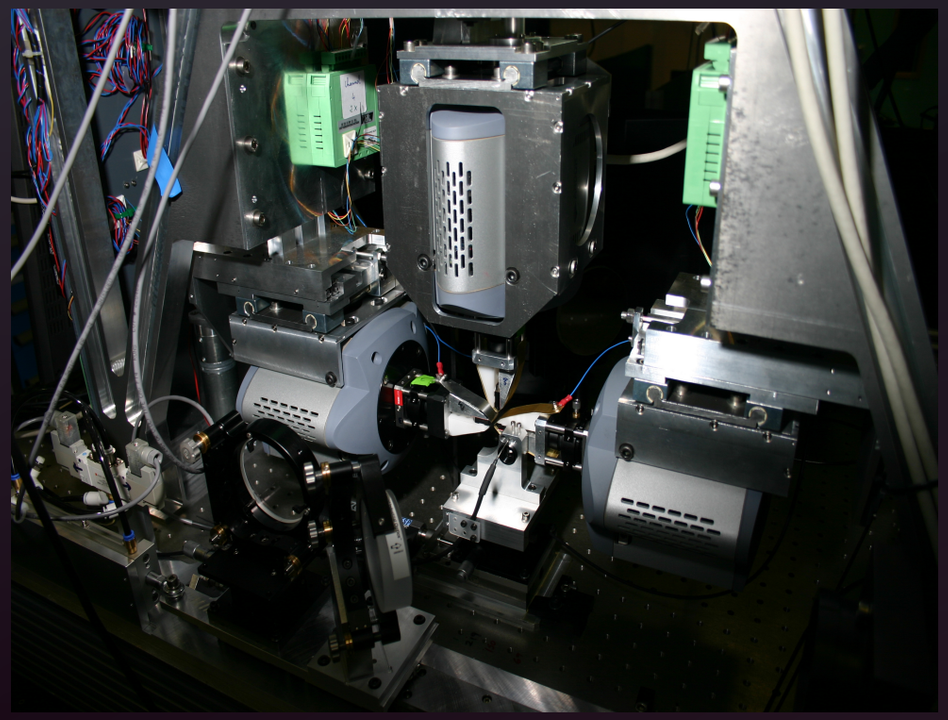
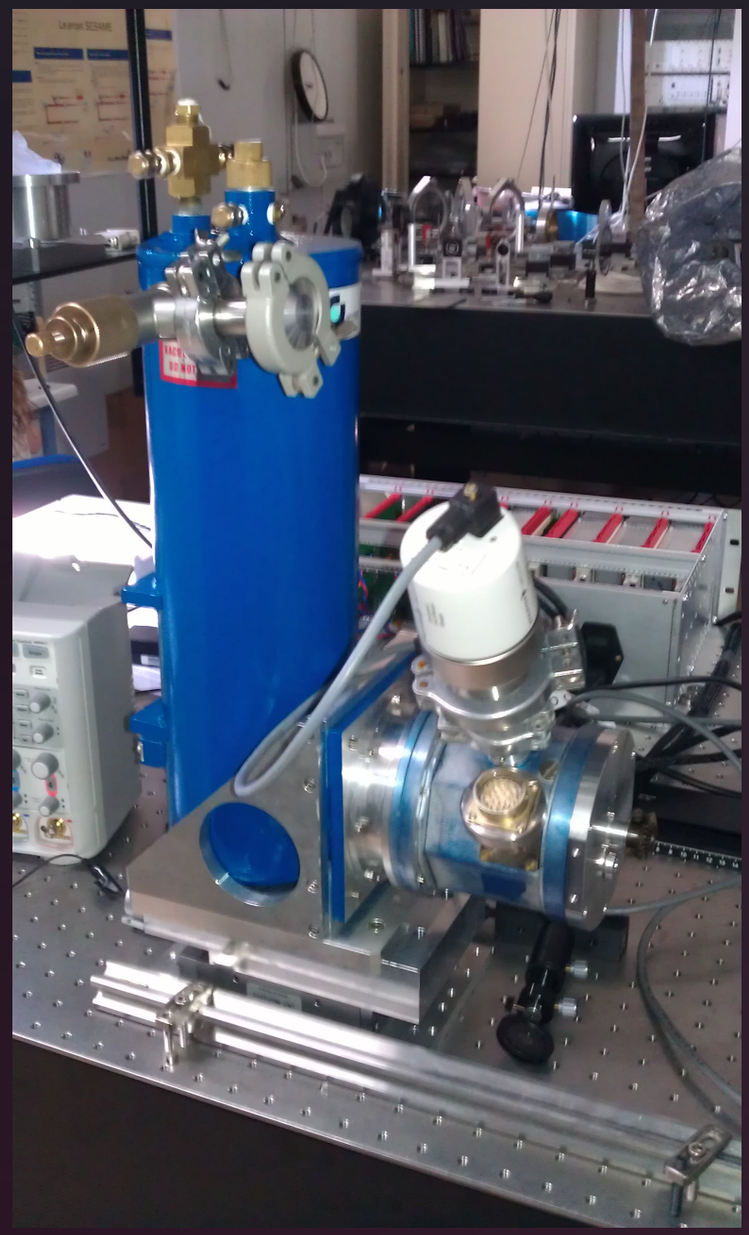
- The CANARY demonstrator
- CAMICAz : the near-IR camera for CANARY
- The science mode of CANARY
- Observing distant galaxies
- Analysis of MOAO performance for extragalactic science
- Preliminary science results
- Conclusion and perspectives

This work was supported by grants from Région Ile-de-France

The CANARY demonstrator

- On-sky MOAO demonstrator @WHT
  - Collaboration between University of Durham (UK) and LESIA
  - 2010-2011, Phase A : NGS tomography



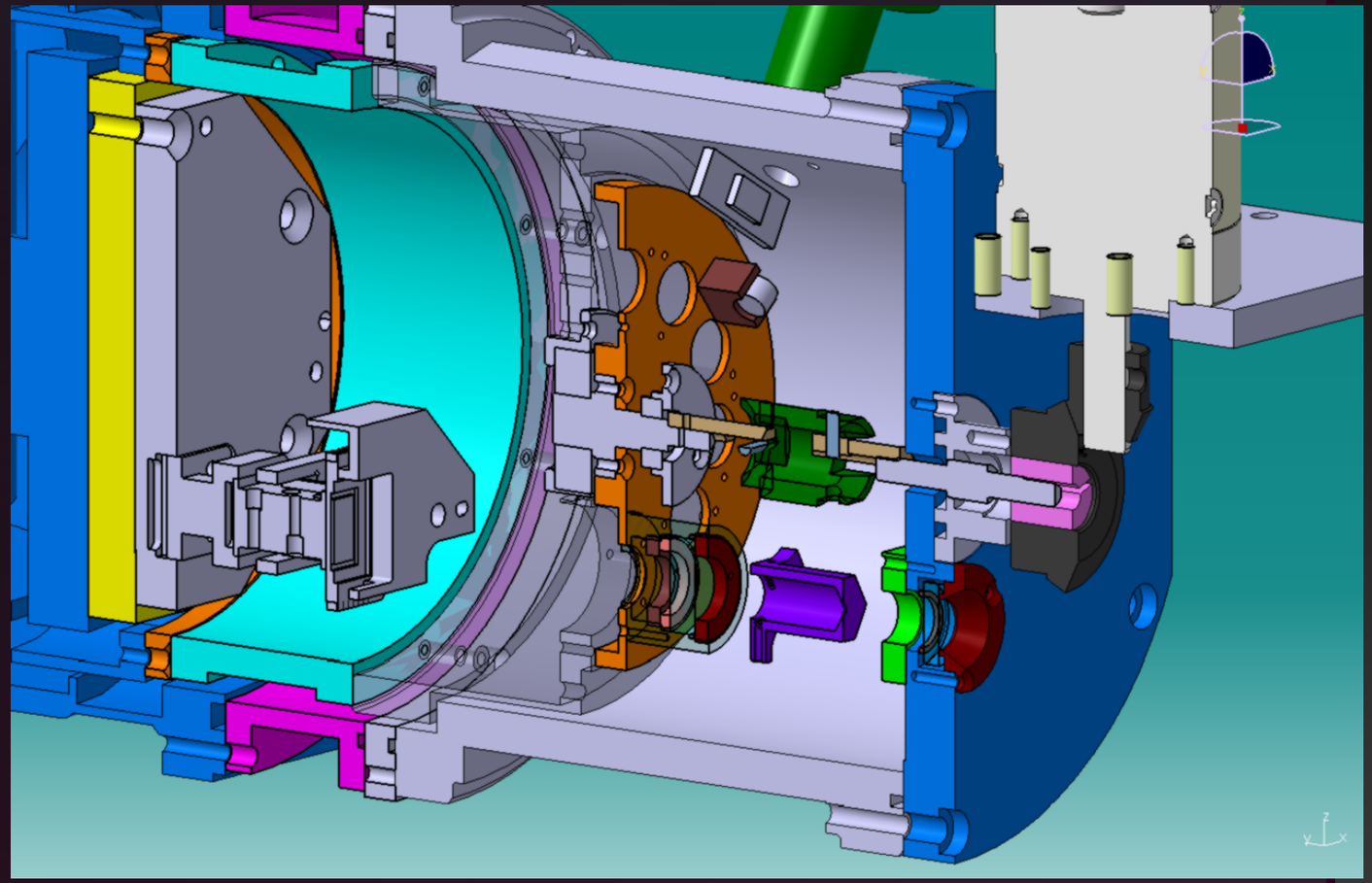


2012-2013, Phase B : mixed LGS + NGS tomography and new near-IR camera : CAMICAz

- 2014-2015, Phase C : ELT configuration and LTAO (first on-sky run in few weeks !)

CAMICAz

- Near-IR NICMOS-based camera with dedicated cryo-cooled opto-mechanics
  - 256x256 NICMOS detector (acquired in 1991 for the now decommisioned DENIS survey)
  - Cold stop, pupil imaging lens and filter wheel
  - High performance watercooled readout electronics (< 30e- read noise)
  - 30mas pixels, J, H and K broad band filters
  - **2014 : filter wheel upgraded to 10 filter positions including narrow band filters. Funding from Région Île-de-France**



CAMICAz

- Near-IR NICMOS-based car
  mechanics
  - 256x256 NICMOS detector (acquir
    survey)
  - Cold stop, pupil imaging lens and f
  - High performance watercooled readout electronics (< 30e- read noise)
  - 30mas pixels, J, H and K broad band filters
  - **2014 : filter wheel upgraded to 10 filter positions including narrow band filters. Funding from Région Île-de-France**

Science mode of CANARY

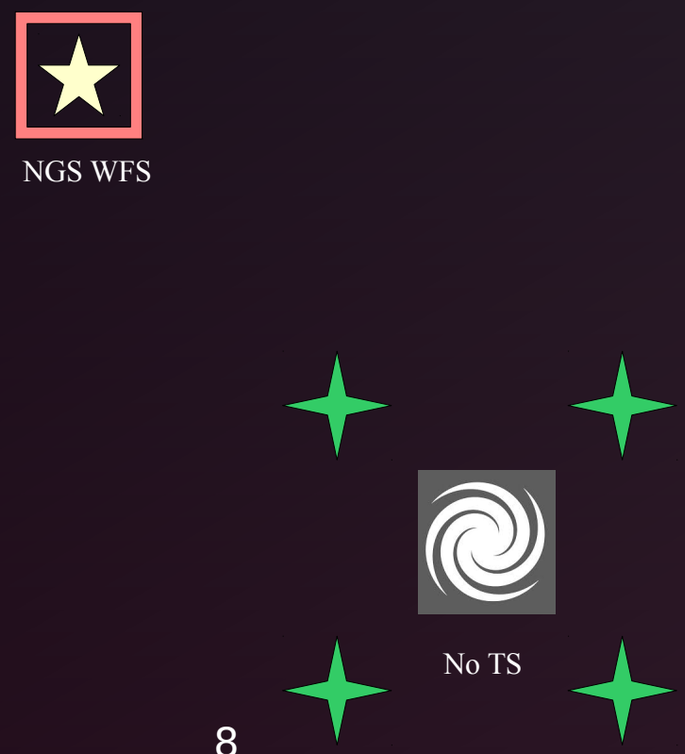
- CANARY : technology demonstrator
  - Not designed to do science observations : CANARY is not a real science facility @ WHT
  - On axis beam shared by near-IR camera and truth sensor (TS) : in science mode on faint targets, TS is useless
  - Near-IR camera FoV diameter : 8"
  - Target acquisition using low sensitivity visible camera (being upgraded) : pointing can be difficult on very faint target
  - Science FoV on-sky P.A. not known precisely (lacking some interaction with the telescope infrastructure)
  - Observing block :
    - Small jitters : no need to interrupt the MOAO loop, modify reference slopes
    - Large offsets : need to interrupt the loop and offset the telescope manually

Science mode of CANARY

- Main concern : pseudo-static aberrations
  - Static compensation based on a combination of offsets on the DM and reference slopes on the off-axis WFS
  - Cannot be measured directly in MOAO systems without TS
  - We propose a two steps approach : determine the static component on the TS for the observing configuration using the LGS WFS measured static and the NGS in two configurations

Science mode of CANARY

- Main concern : pseudo-static aberrations
  - Observing configuration : 4 LGS WFS + 1 NGS WFS (tip-tilt +)
  - Measure static term on LGS => LGS1 and on the NGS : NGS1

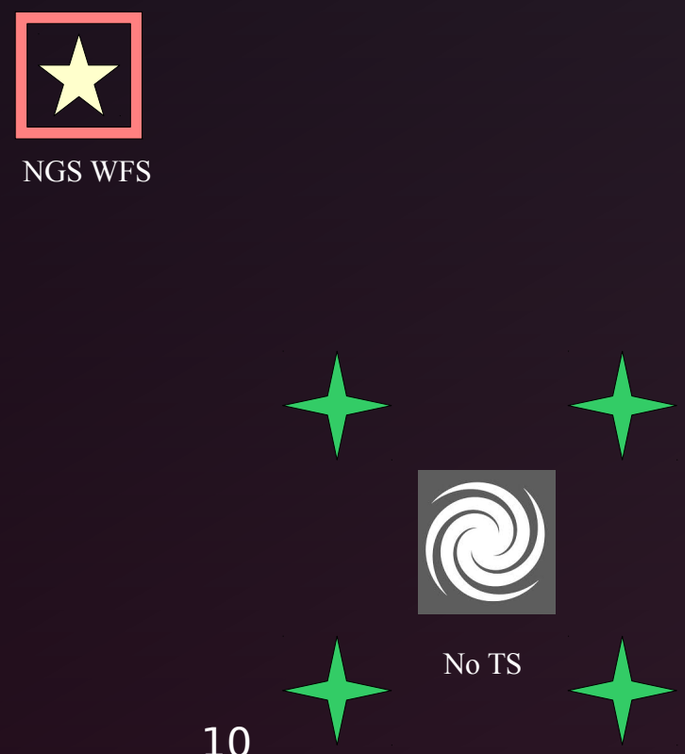


Science mode of CANARY

- Main concern : pseudo-static aberrations
  - Additional configuration : measure LGS2 and offsets to the DM from the TS measurements (TS2)

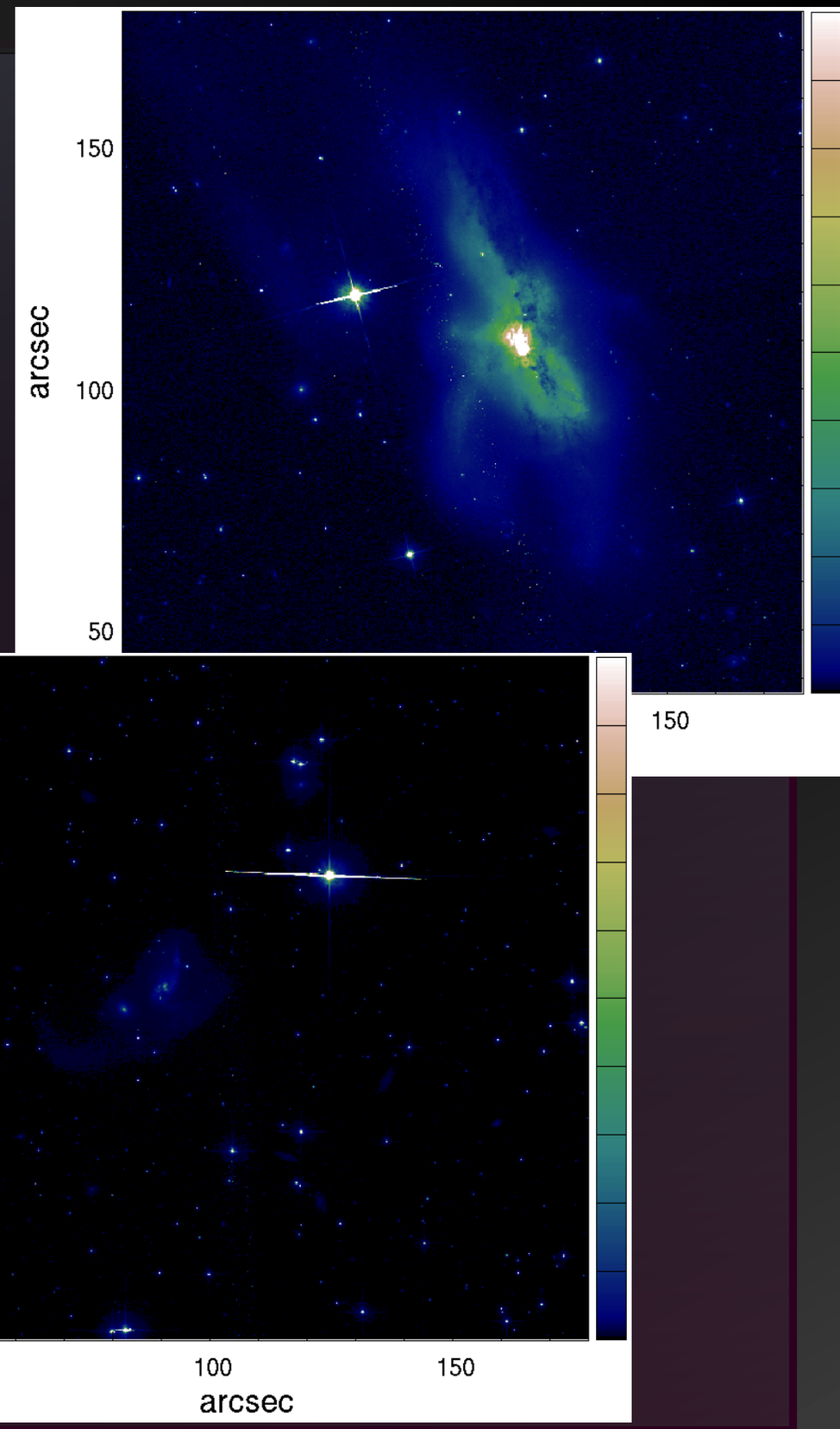
Science mode of CANARY

- Main concern : pseudo-static aberrations
  - Back to observing conditions
  - We determine the reference slopes for the NGS WFS as :
    NGS2 = NGS1 + (LGS2-LGS1)
  - Apply offsets on the DM from TS2
  - Start observing sequence

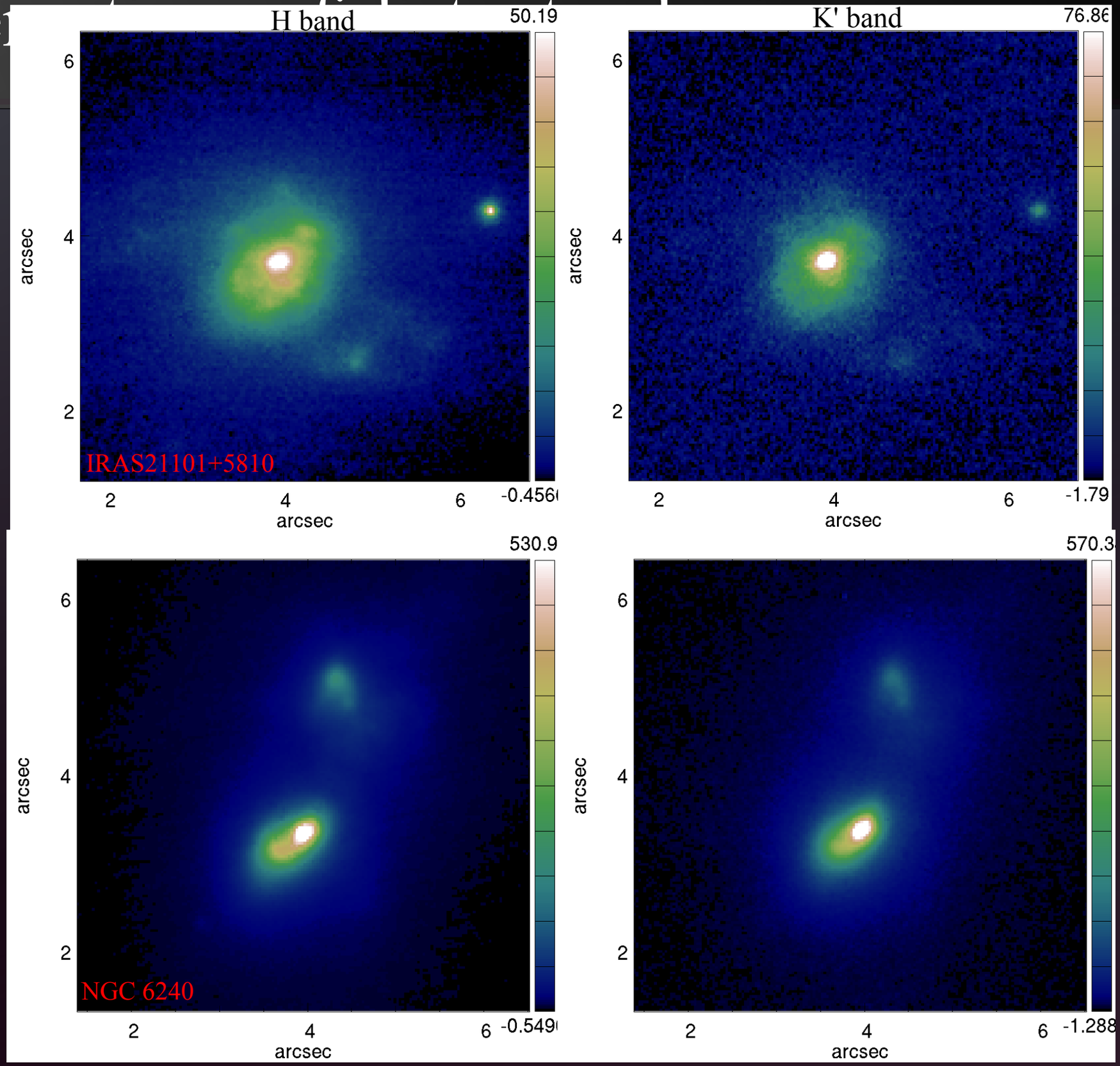


Observations of distant galaxies

- 2 merging systems from thez GOALS survey were observed in July 2013 @ broad H and K'
- NGC 6240 : z=0.0245
  Indiv. exposures of 20s
  total : 2000s per band
  NGS @ 35" off-axis
- IRAS21101+5810 : z=0.039
  Indiv. exposures of 40s
  total > 1h per band
  NGS @ 50" off-axis

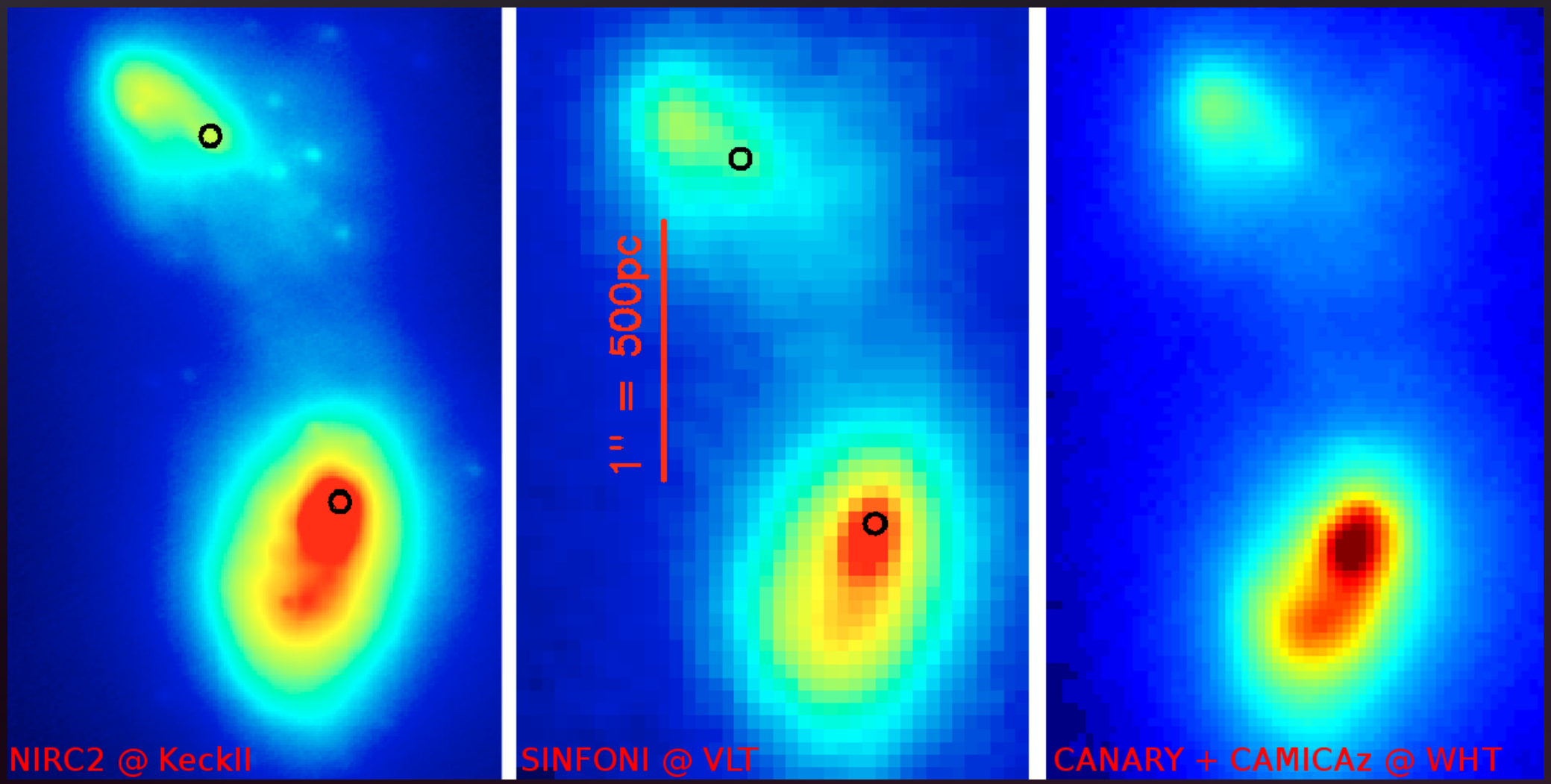


Obser


H band
50.19
-0.456
IRAS21101+5810
K' band
76.86
-1.79
530.9
-0.549
NGC 6240
570.3
-1.288
arcsec
2
4
6

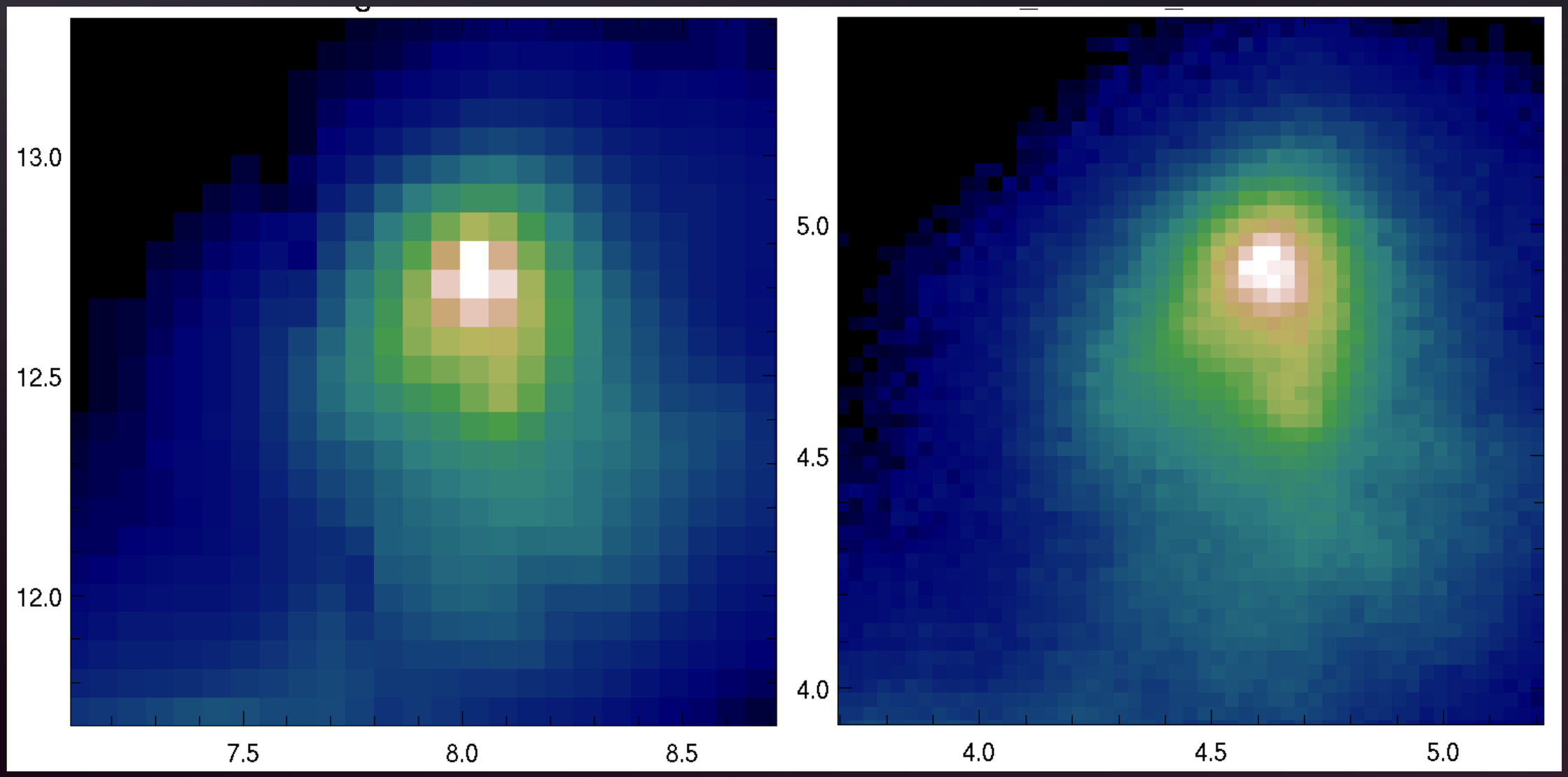
MOAO performance

- Comparing CANARY data to archive data
- NGC 6240 : already observed with LGS AO (e.g. Pollack et al. with KeckII LGS AO or Engel et al. with VLT SINFONI)



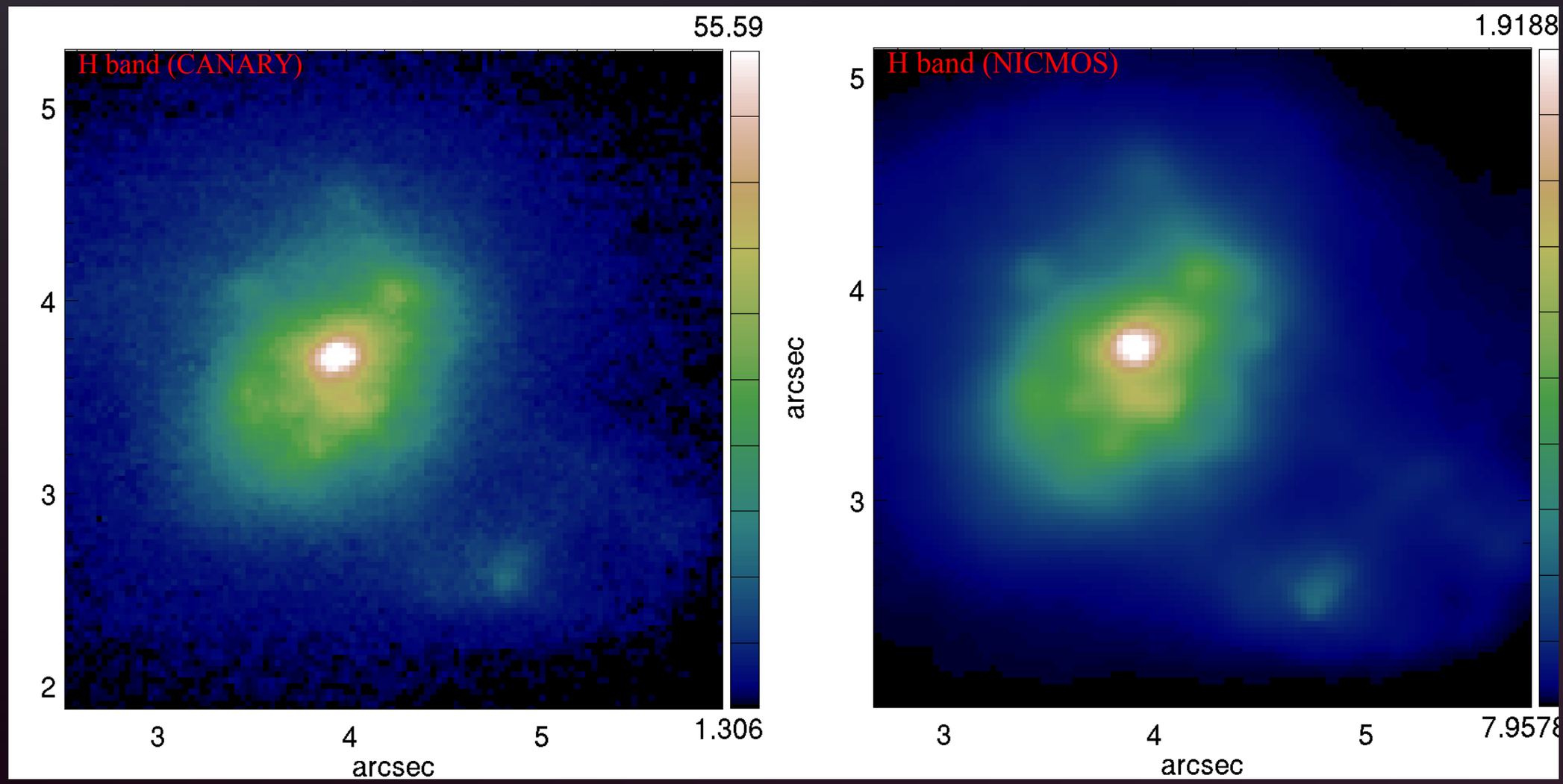
MOAO performance

- Comparing CANARY data to archive data
- NGC 6240 @ H : data from HST archive



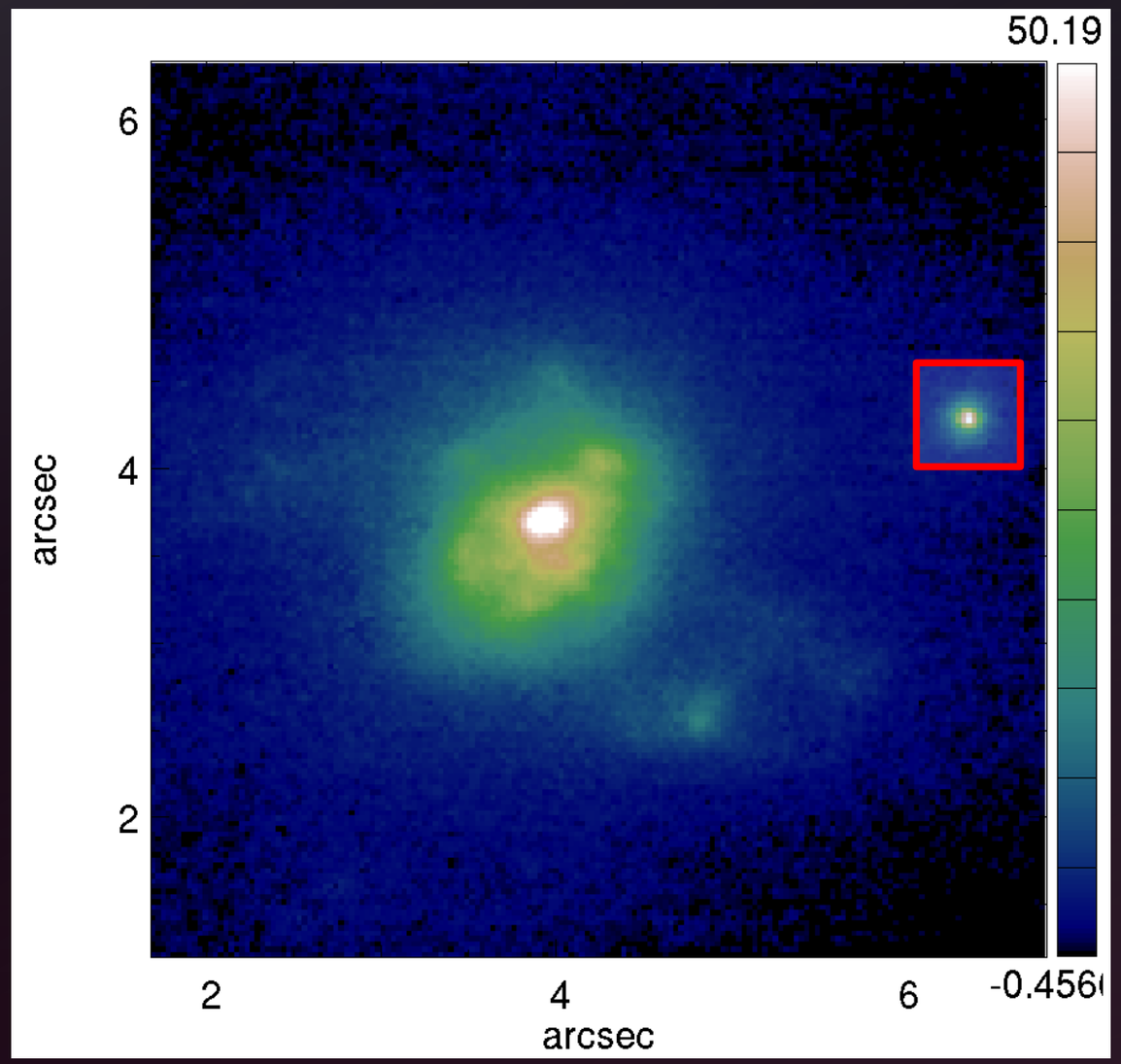
MOAO performance

- Comparing CANARY data to archive data
- IRAS21101+5810 : observed with HST



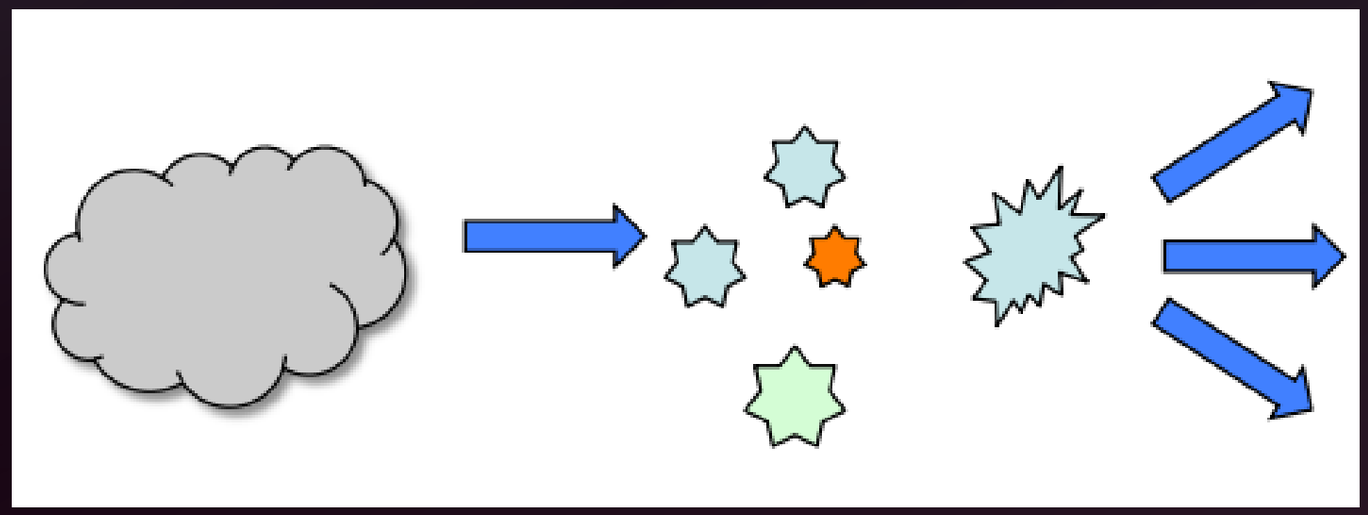
MOAO performance

- Field star on IRAS21101+5810 : monitor image quality during a long (>1h) exposure
  - FWHM varies from 0.12" to 0.18" (diffraction on WHT @ H : 0.08")



Preliminary science analysis

- Super Star Clusters : extreme star formation
  - Plays a major rôle in galaxy structural and chemical evolution
  - Massive conversion of gas into stars, heavy elements production
  - Distribution in the ISM through post-AGB and SNe
  - Power injection in the galactic medium and interaction with central black hole (feeding, feed-back)



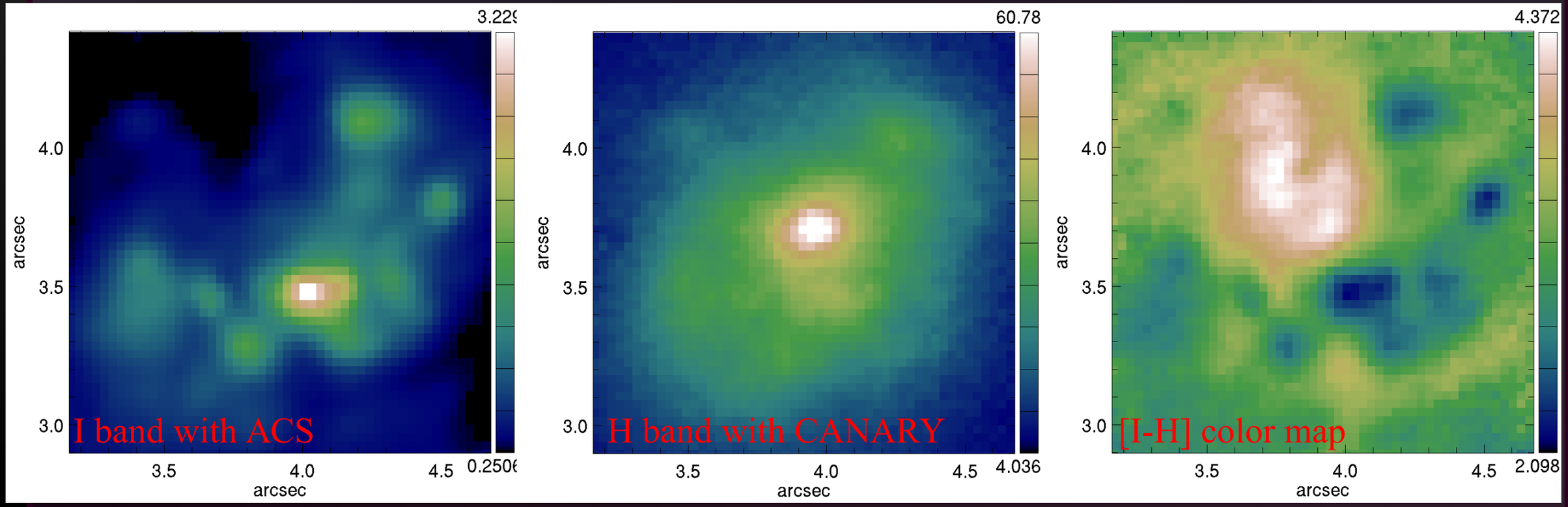
Halo, disk, bulge

Power

Heavy elements

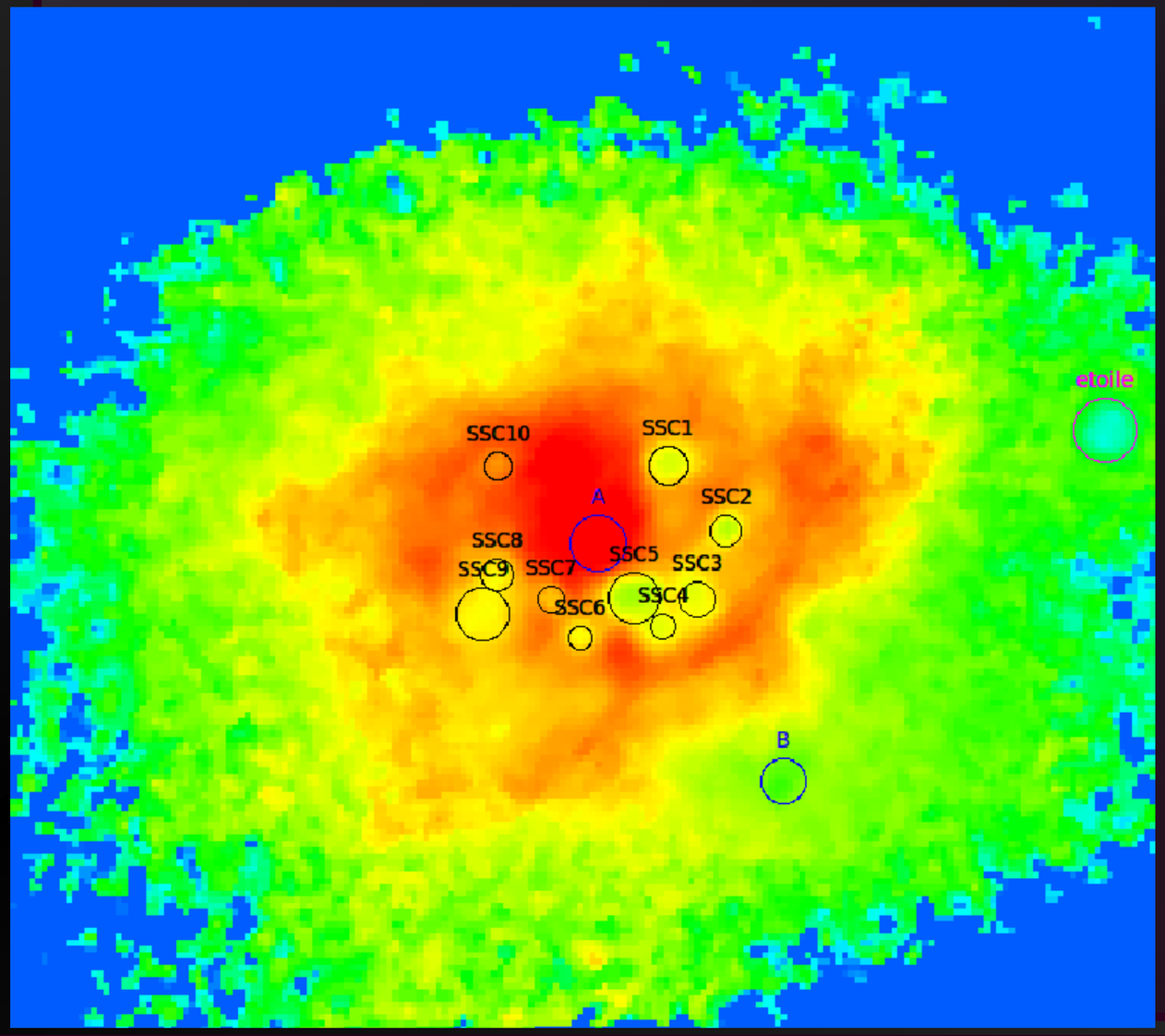
Preliminary science analysis

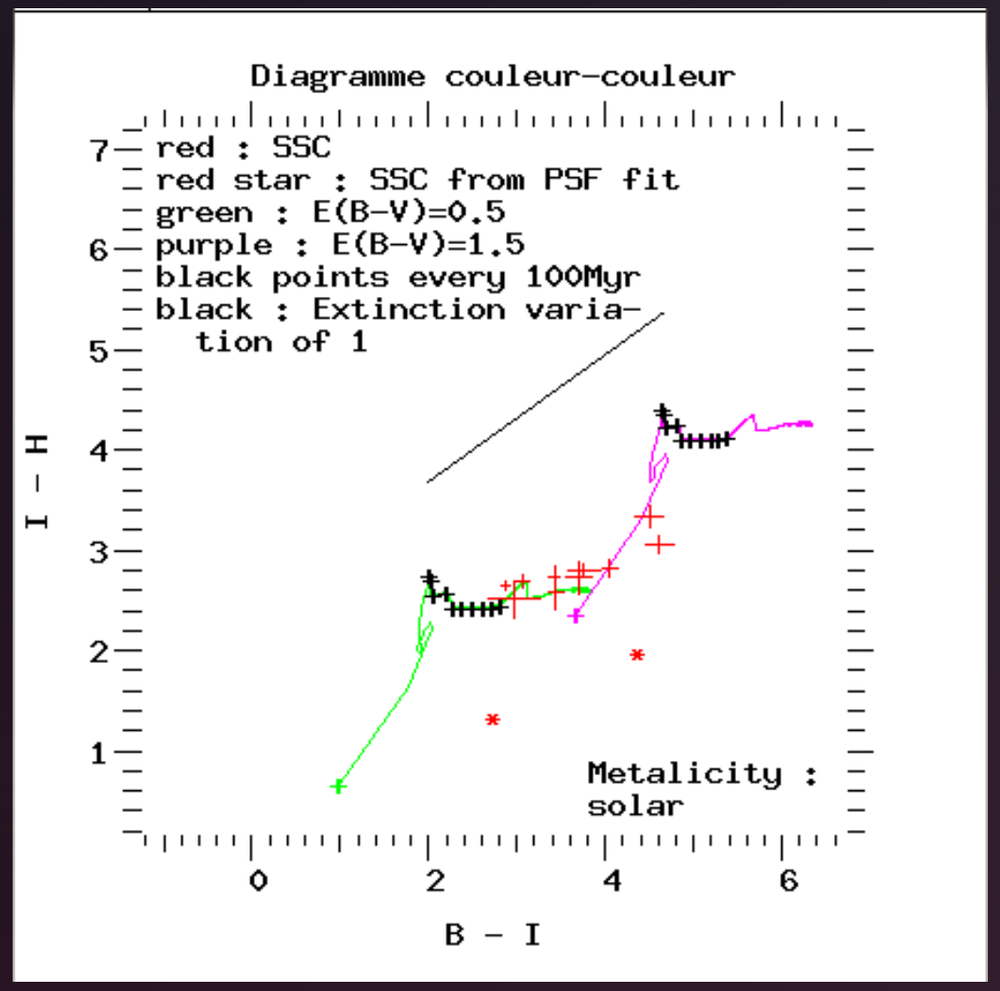
- Multi-spectral analysis : measure the SED of identified SSCs and derive age and physical properties
- The image quality obtained in the near-IR with CANARY allows a direct comparison with HST visible



Preliminary science analysis

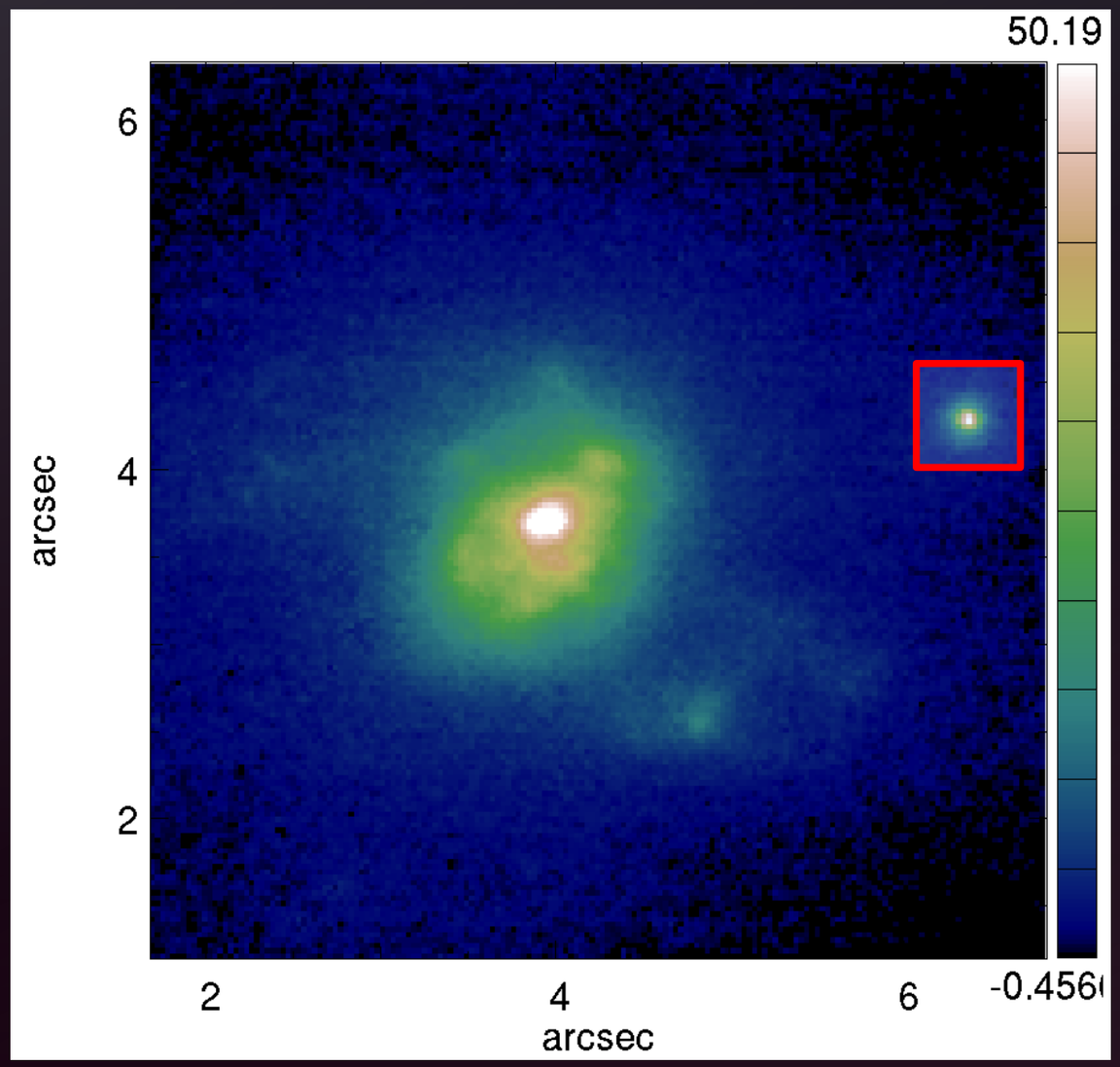
- Multi-spectral analysis : measure the SED of identified SSCs and derive age and physical properties
- Strong background in the IR : photometry with PSF fitting very difficult

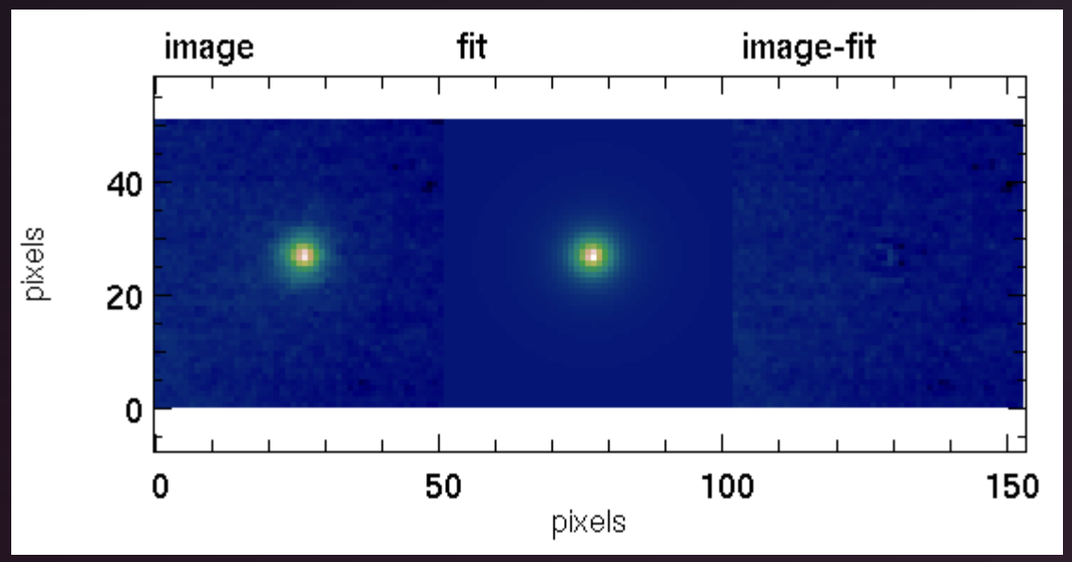




Preliminary science analysis

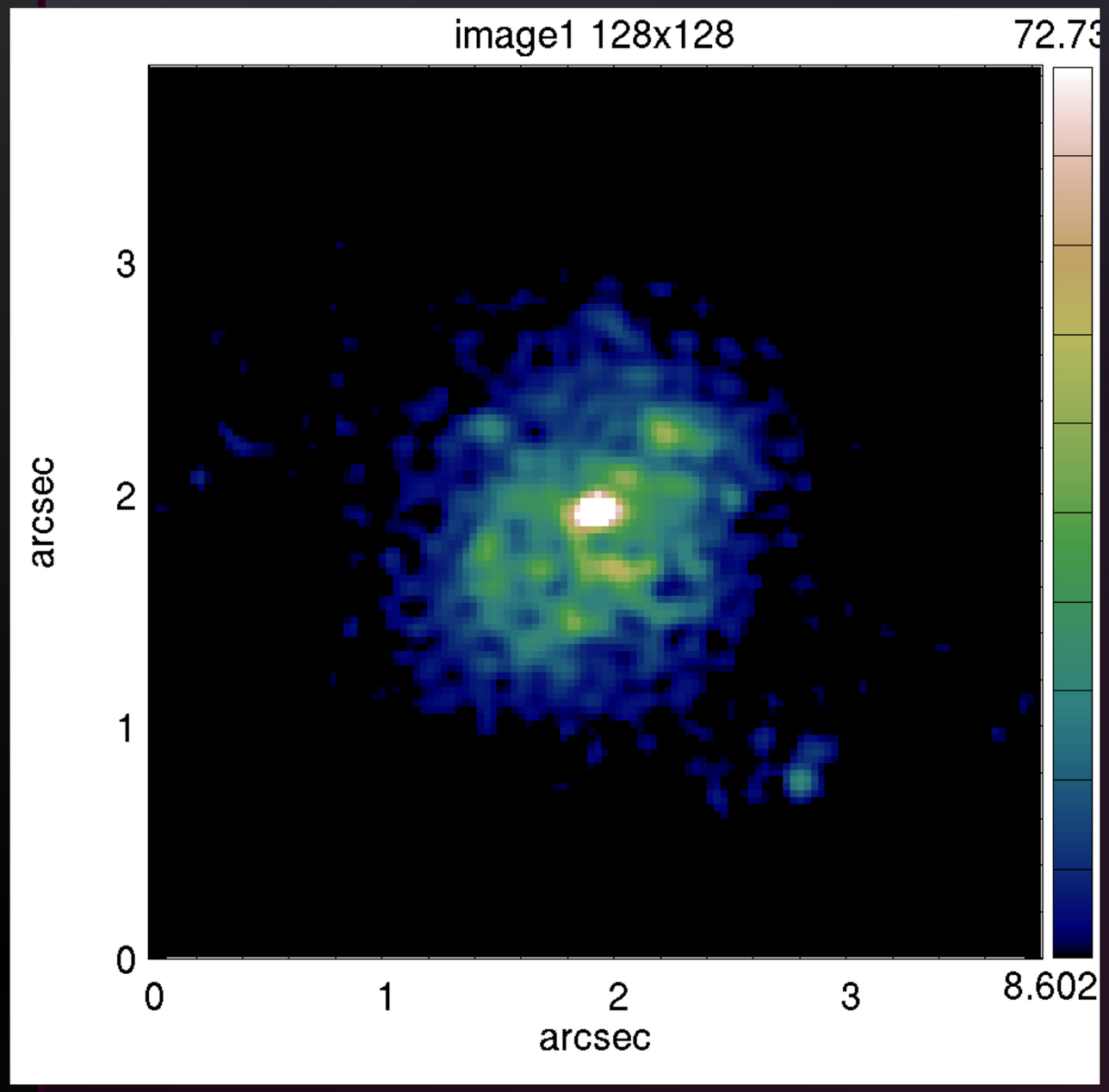
- Advanced data processing : deconvolution ?
- Using a model of the PSF measured on the image (Spydr Yorick plugin)

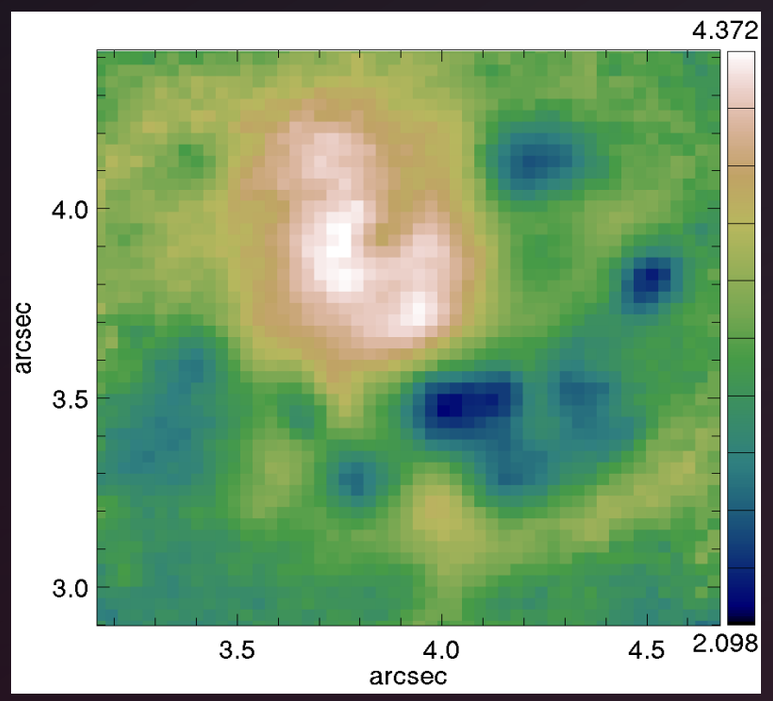




Preliminary science analysis

- Yoda deconvolution algorithm (maximum likelihood approach « à la MISTRAL » : https://github.com/dgratadour/Yoda)





Conclusions

- MOAO provides adequate performance for science
  - Image quality in the near-IR on a 4m ground based telescope comparable to HST visible
  - Stable performance over long exposures
- CANARY has limited science capabilities
  - Near-IR camera with a set of broad and narrow band filters
  - Not designed for science observations (pointing, interaction with telescope, …)
- RAVEN has spectroscopic capabilities on a 8m telescope
  - Very powerful for physical diagnostics
- CANARY science team welcomes good ideas for new programs or collaborations !

Can't wait for MOAO on the E-ELT !