Detecting the missing population of dual/lensed- AGNs at sub-arcsec separations with ESA and ESO instrumentation

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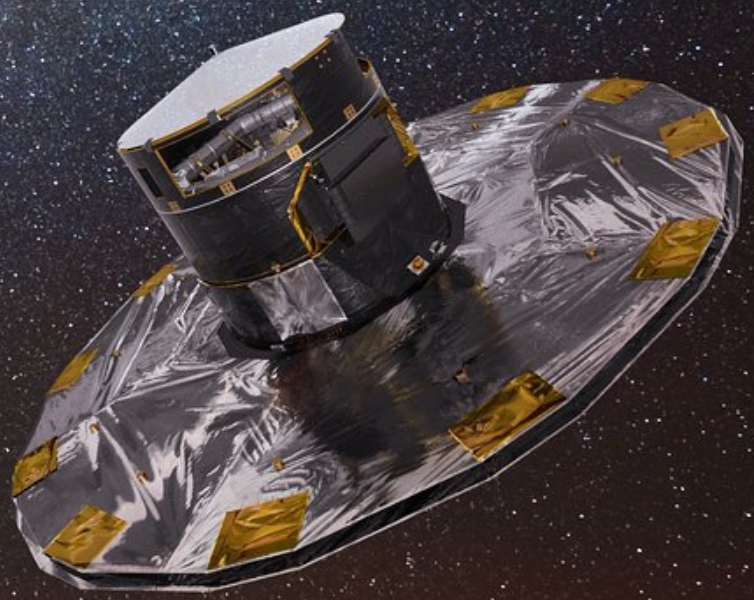
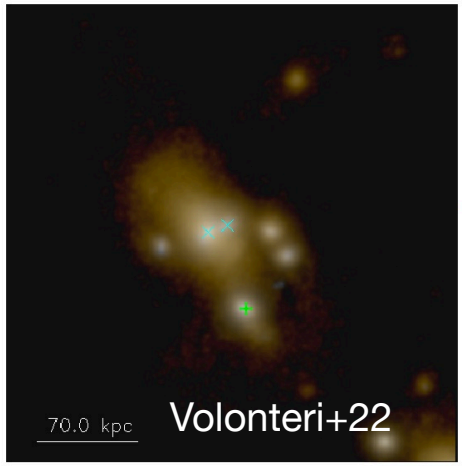
E. Pancino, A. Amirnezam, F. Belfiore, V. Braito, S. Carniani, C. Cicone, A. Ciurlo, G. Cresci, A. De Rosa, E. Lusso, A. Marasco, C. Marconcini, A. Marconi, I. Motoya Arroyave, E. Nardini, E. Pinna, M. Polletta, P. Rosati, Rubinur K., P. Saracco, M. Scialpi, P. Severgnini, M. Scialpi, M. Volonteri, G. Venturi, C. Vignali, G. Tozzi, S. Yeh

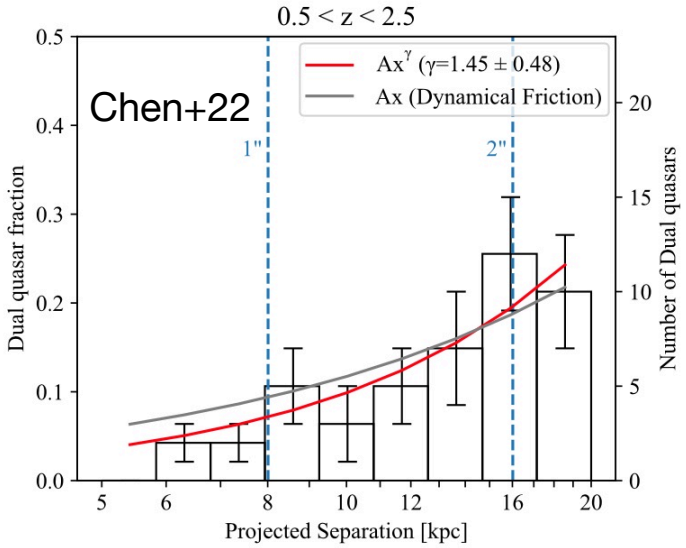


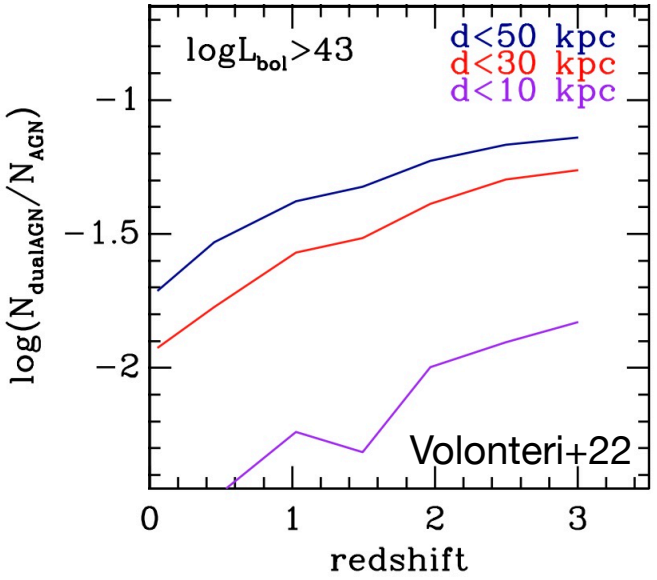
Hierarchical merging

Tremmel et al, 2018

Widespread population of Multiple SMBHs in the same host galaxy







Long timescales, ~kpc separations

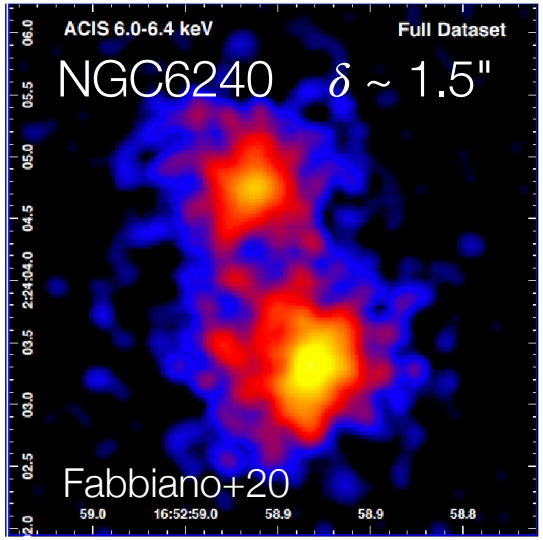
Large fraction to produce **dual AGNs**

Importance:

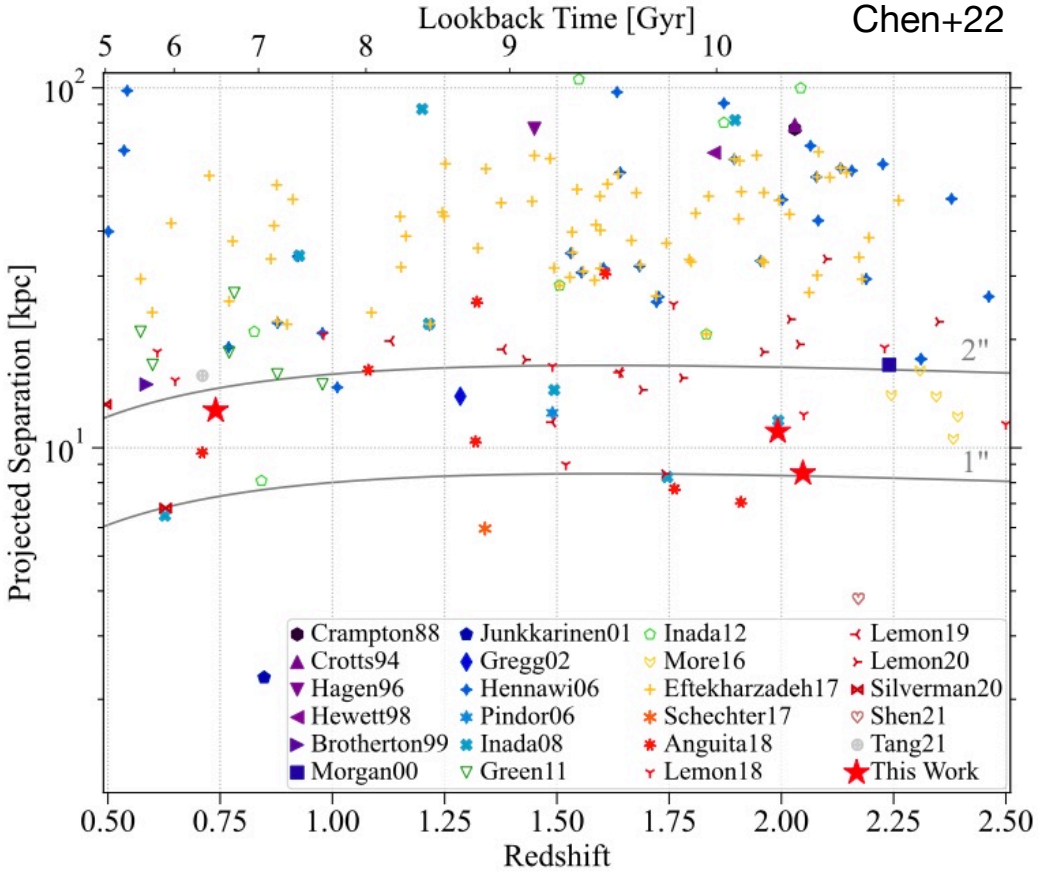
1. key prediction of the model, untested
2. test the details of the models: separations, mass ratios, luminosities, z evol. ....
3. study the processes driving to the final merger
4. parent population of the GW-emitting systems

Current status of observations

- A few systems in the local universe
- Distant (z>0.5) systems at large separations
- Only 4 confirmed systems at z>1 and δ < 8 kpc

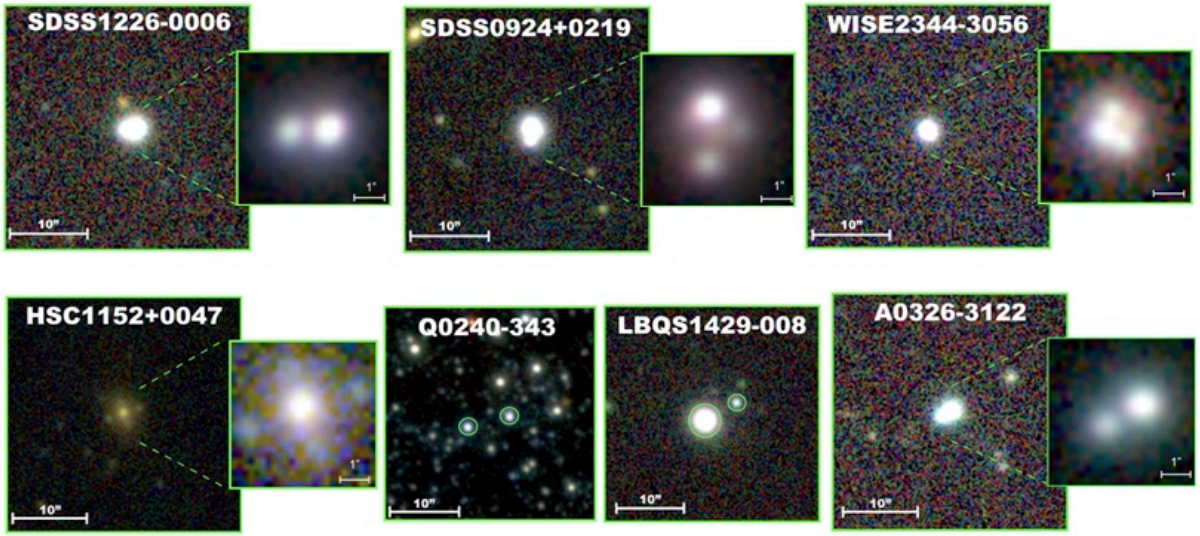


Chen+22

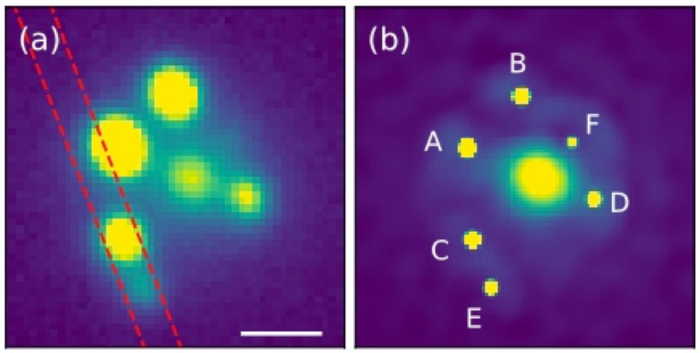


Lensed AGNs

Spiniello+18



Lemon+22



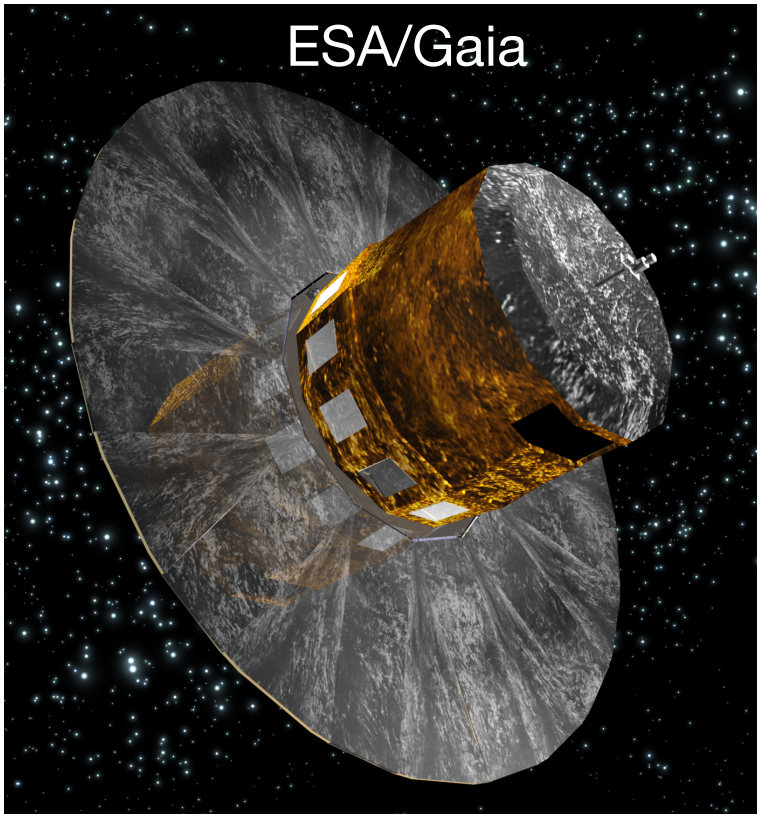
- very rare: f ~10^{-4}
- cosmological parameters through variability
- dark-matter substructures
- host galaxies
- inner structure of the AGN through microlensing
- lensing galaxy

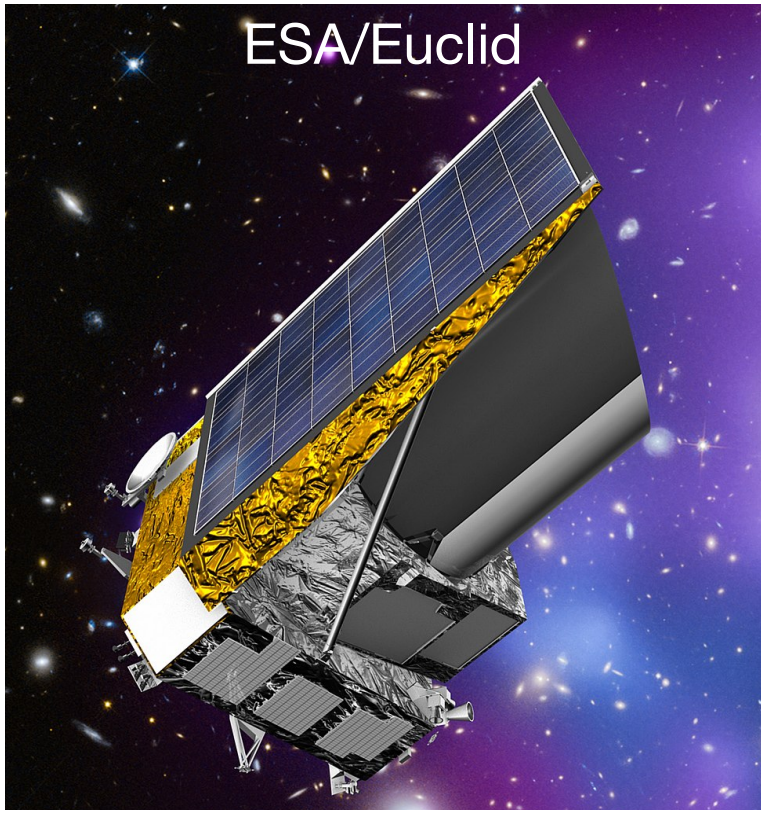
e.g. Treu & Ellis 2015

Detection

Rare objects → all (extragalactic) sky

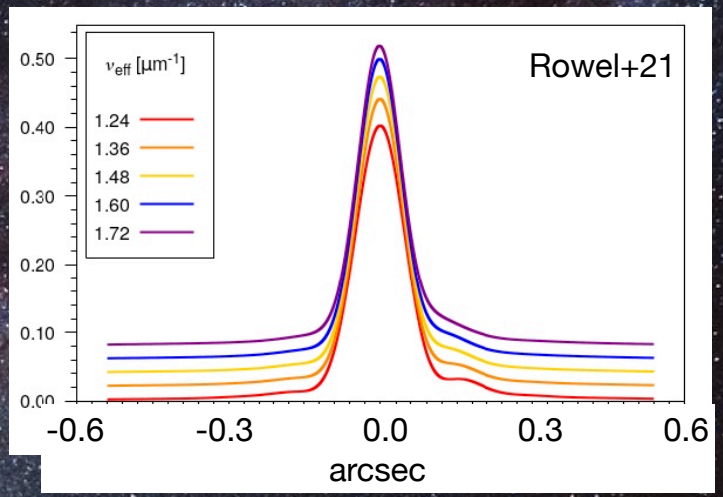
Compact → sub-arcsec resolution

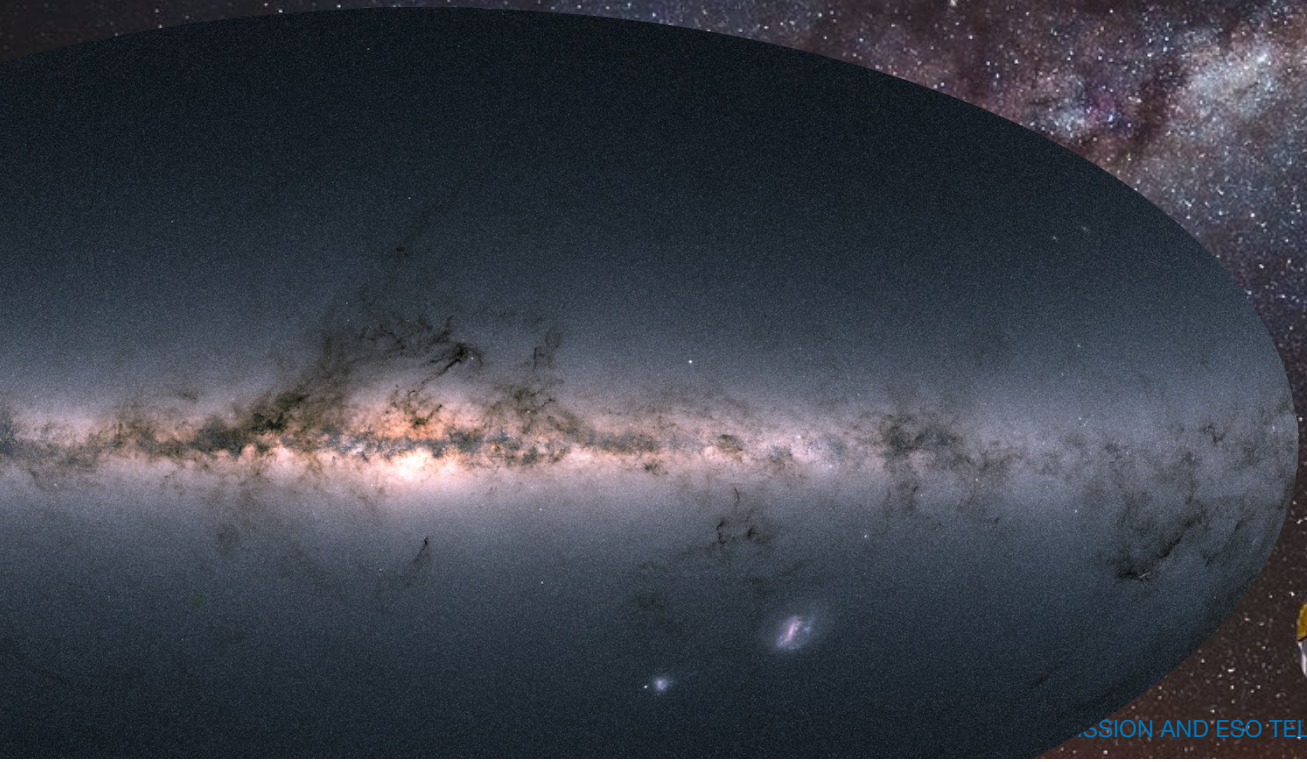


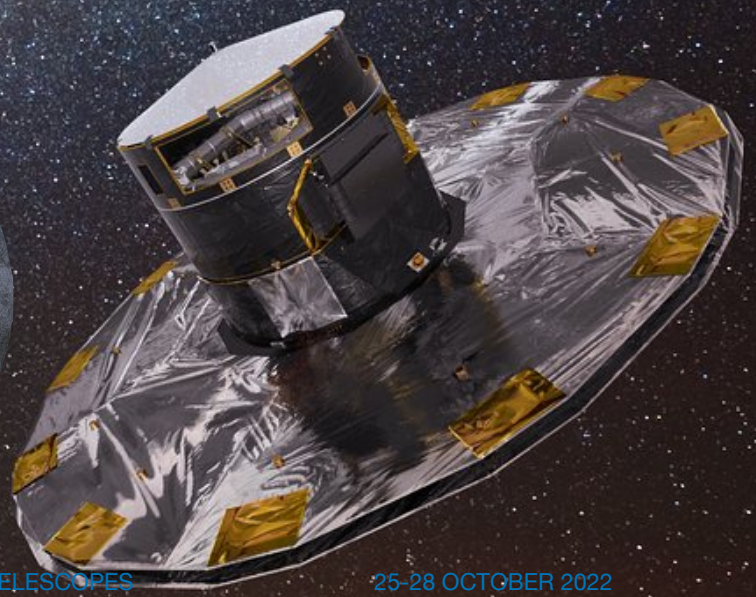


Looking for dual/lensed AGNS with Gaia

- All-sky survey
- PSF ~ 0.11"
- G ≲ 20.5





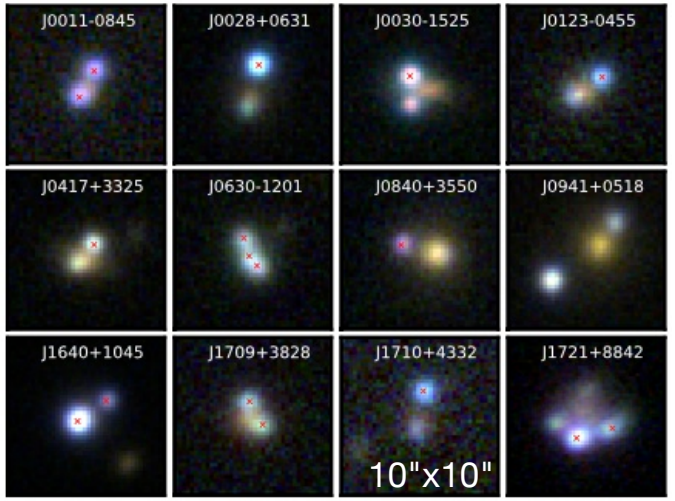


Previous Gaia-based techniques

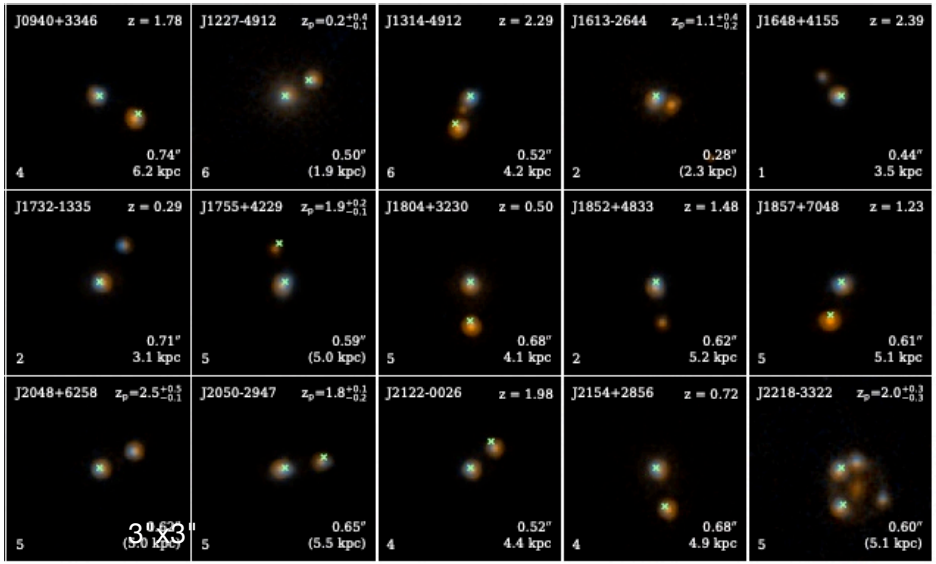
1. "Multiplicity": Multiple Gaia sources associated to a single (ground-based) AGN
   - δ ~ 0.5" - 3"

2. "Varstrometry" : extra astrometric jitter, apparent proper motions, apparent parallaxes due to variability of an unresolved pair
   - high variability required
   - lower efficiency

Lemon+18

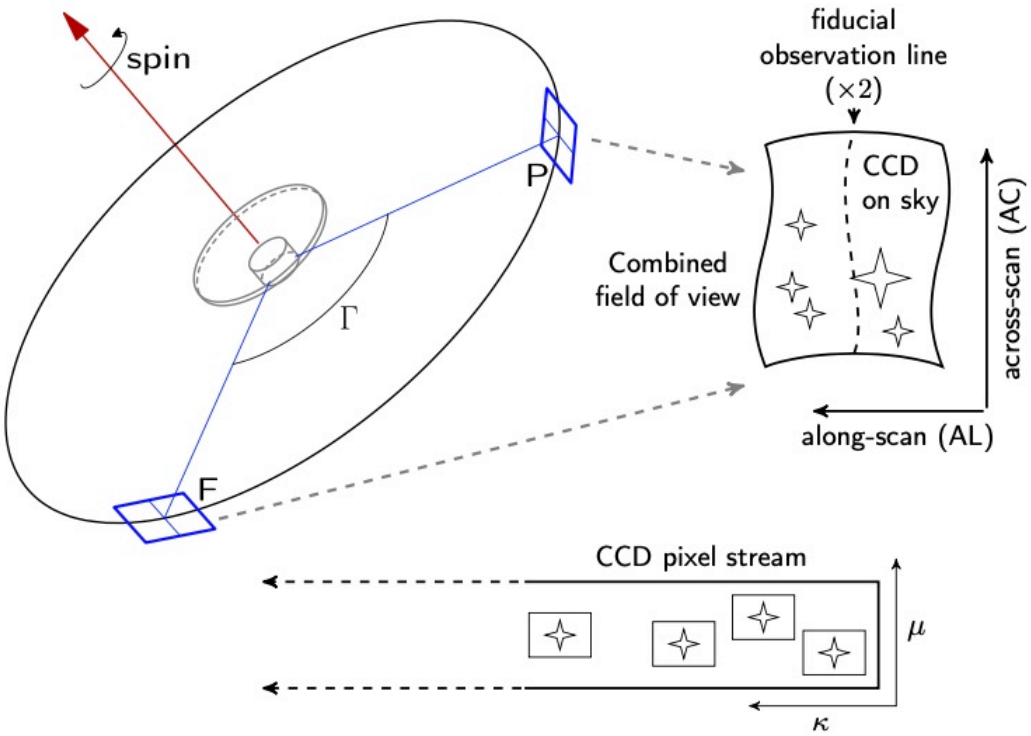


Chen+21



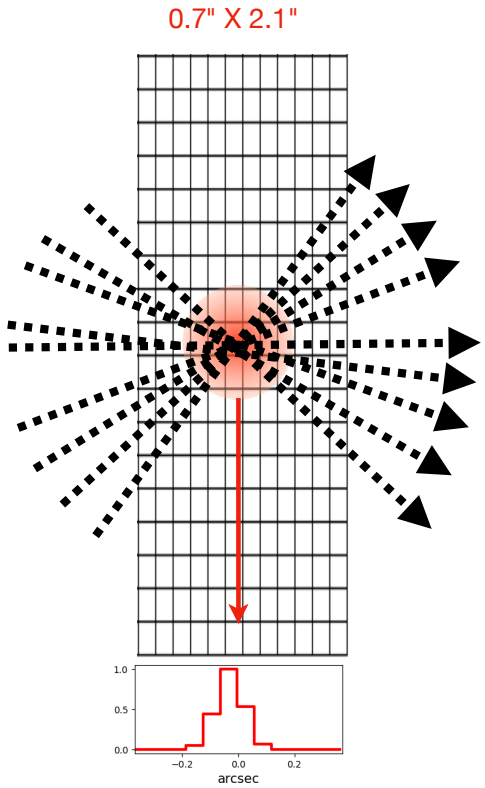
Lemon+17,18, Agnello+18, Shen+19, Hwang+20, Shen+21, Chen+22

Gaia observing strategy



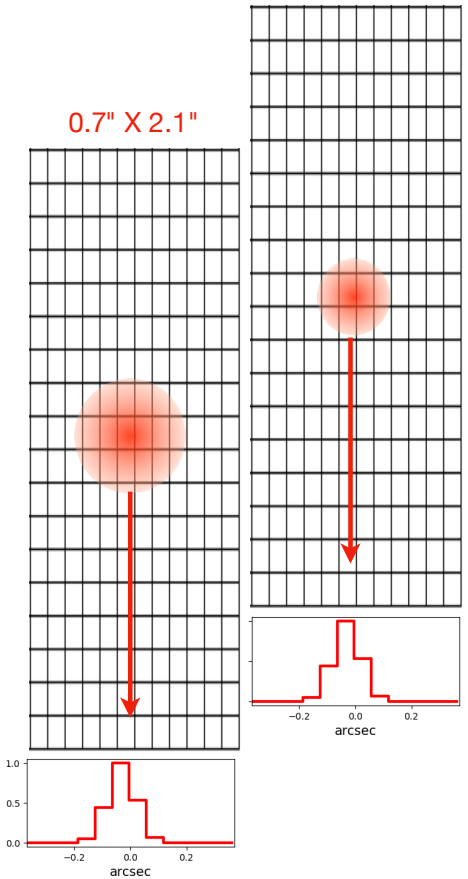
Brown 2021

- G = 16-20:
  no images
  1D light profile
- large photometric window
- Multiple scans different directions



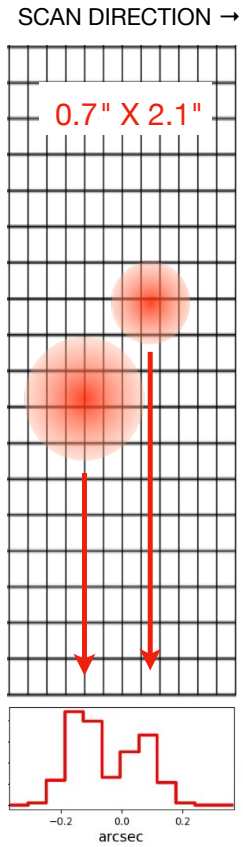
Resolving near-by sources

"Distant" sources (δ~0.7")



Two entries in the catalog: "*Separated*"

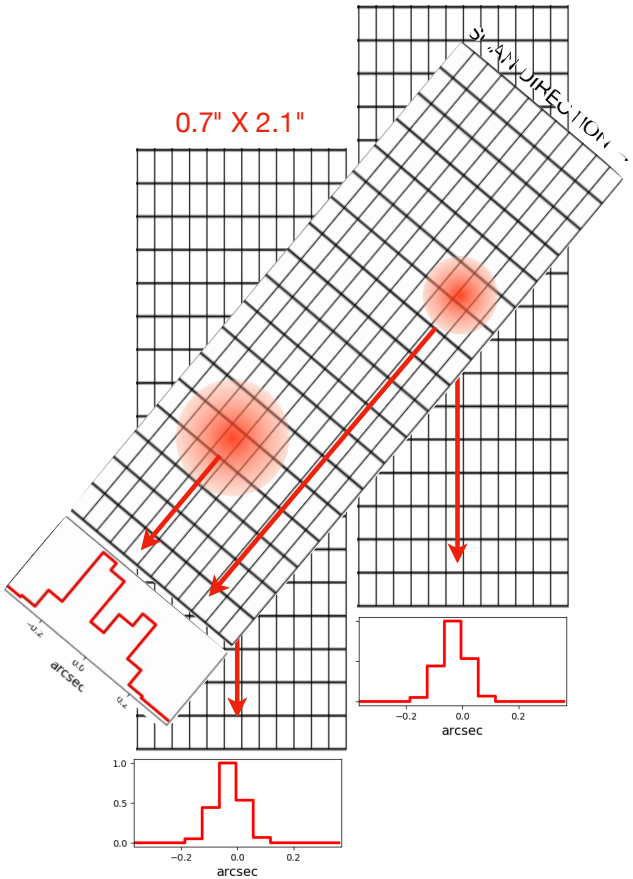
Nearby sources (δ~0.2")



"*Unseparated*"

Resolving near-by sources

"Distant" sources (δ~0.7")

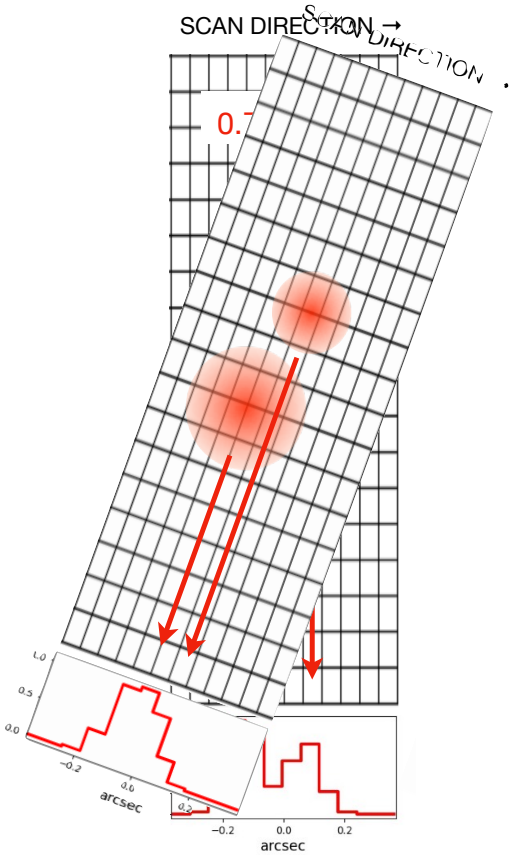


Two entries in the catalog: "*Separated*"

Gaia Multi Peak (**GMP**) technique

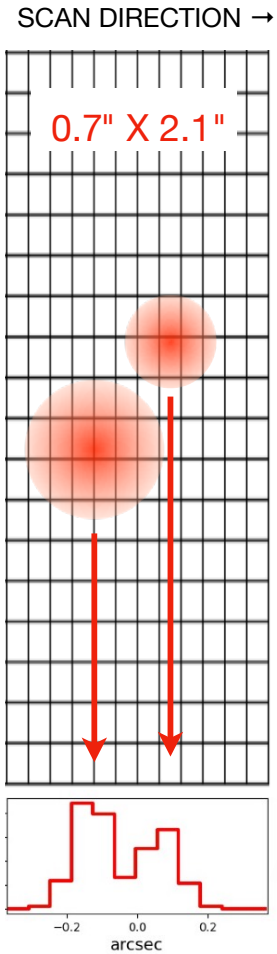
more than 8% of multiple peaks

Nearby sources (δ~0.2")

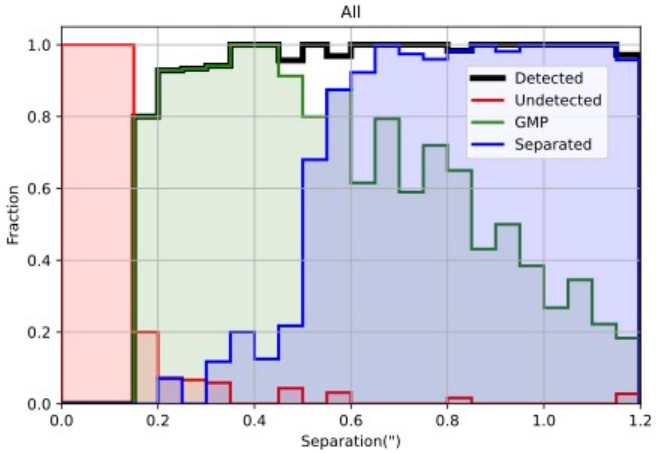


"*Unseparated*"

Fully exploiting Gaia spatial resolution

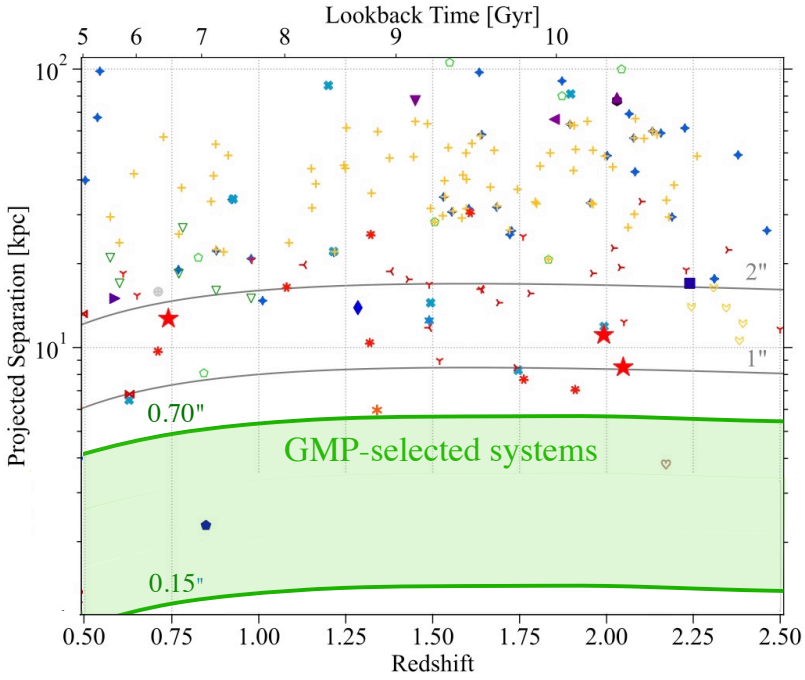


stellar pairs in dense stellar fields observed with HST



0.15" < sep <0.7"
for unseparated sources

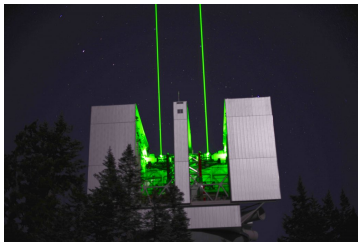
Spectroscopic QSOs
~250 targets,
~0.1-0.2% of the population

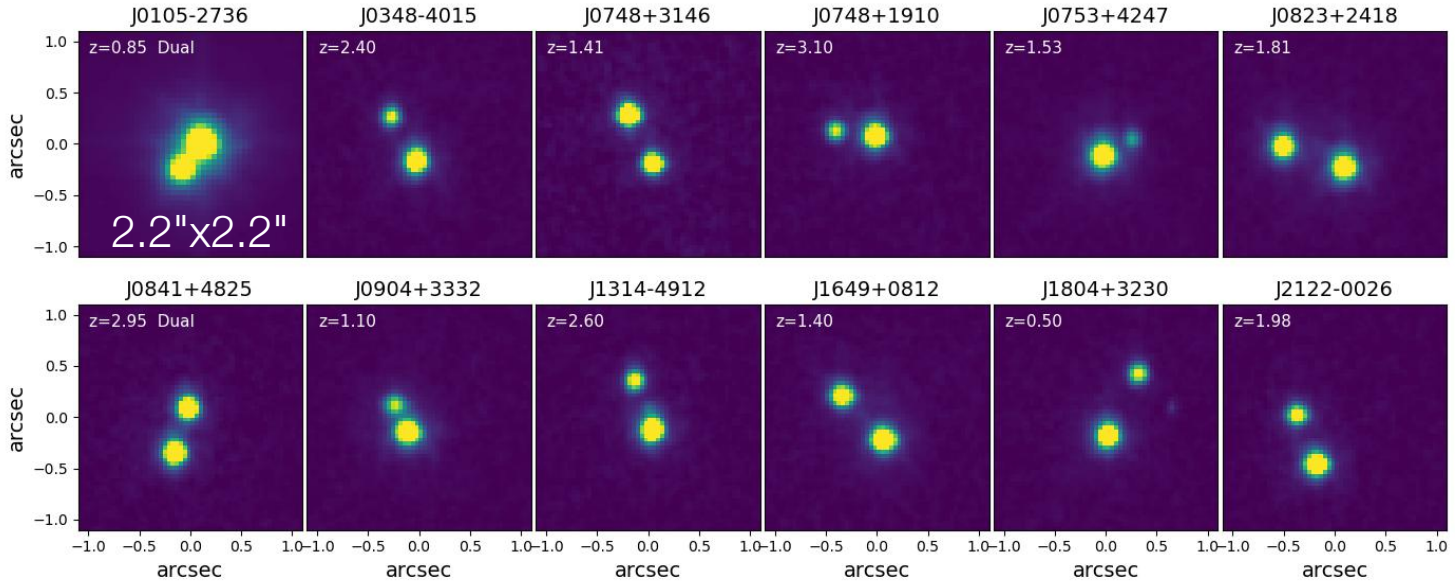


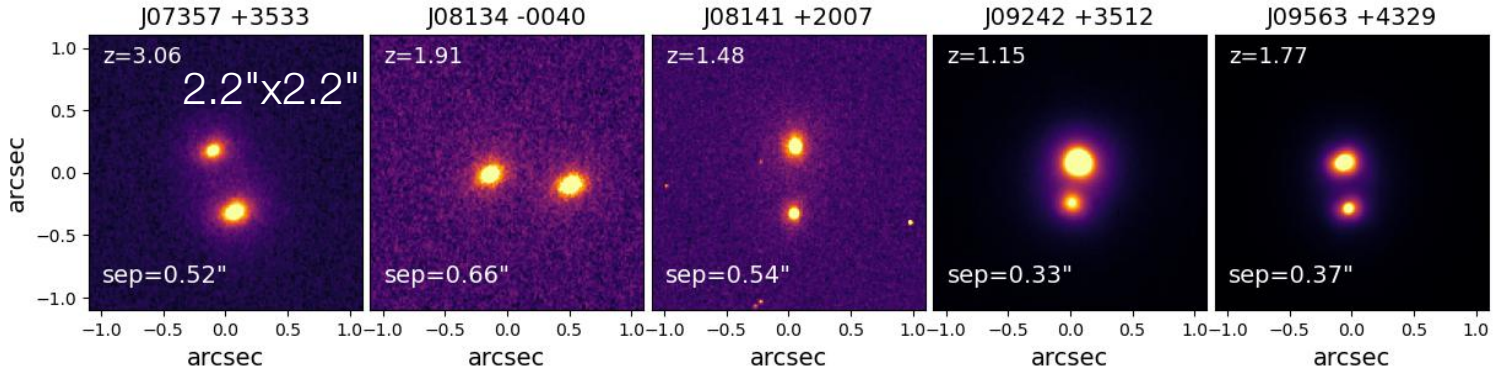
High-resolution imaging

HST: 26 archival images

LBT: 5 dedicated obs.







100% success rate, 0.3"<δ<0.8"

Need for resolved spectroscopy

1. AGN/AGN - Dual → different spectra
2. AGN/AGN - Lensed → very similar spectra
3. Chance AGN/star alignment: expected <30%

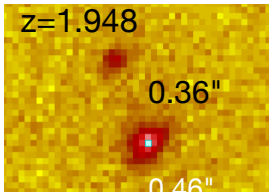
Resolved spectroscopy

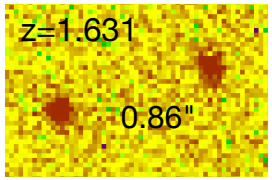
8 systems observed:

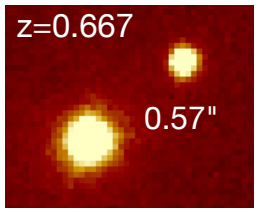
- 4 Keck/Osiris (2 half nights)
- 3 VLT/MUSE-NFM
- 1 HST/STIS (archival)

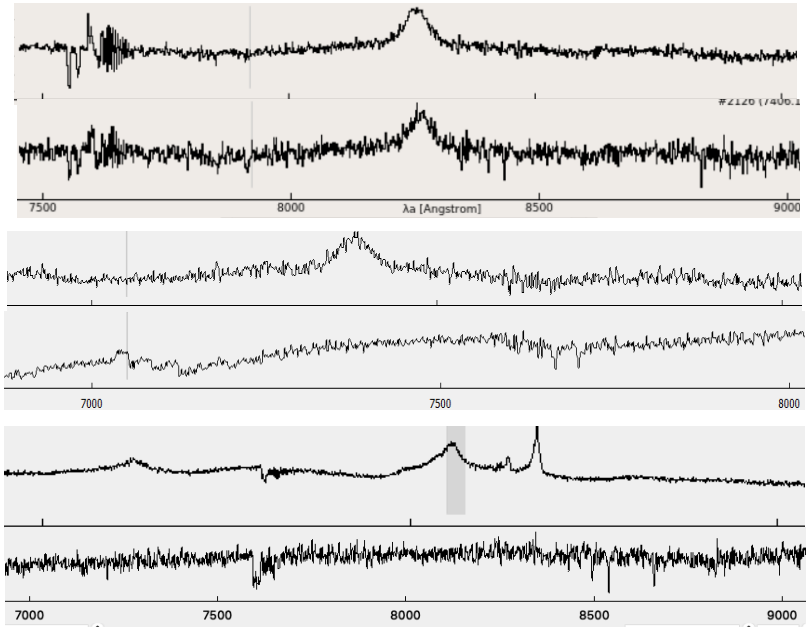
Spectroscopy with VLT/MUSE-NFM

VLT/MUSE
AO









Dual

AGN/Star

AGN/Star

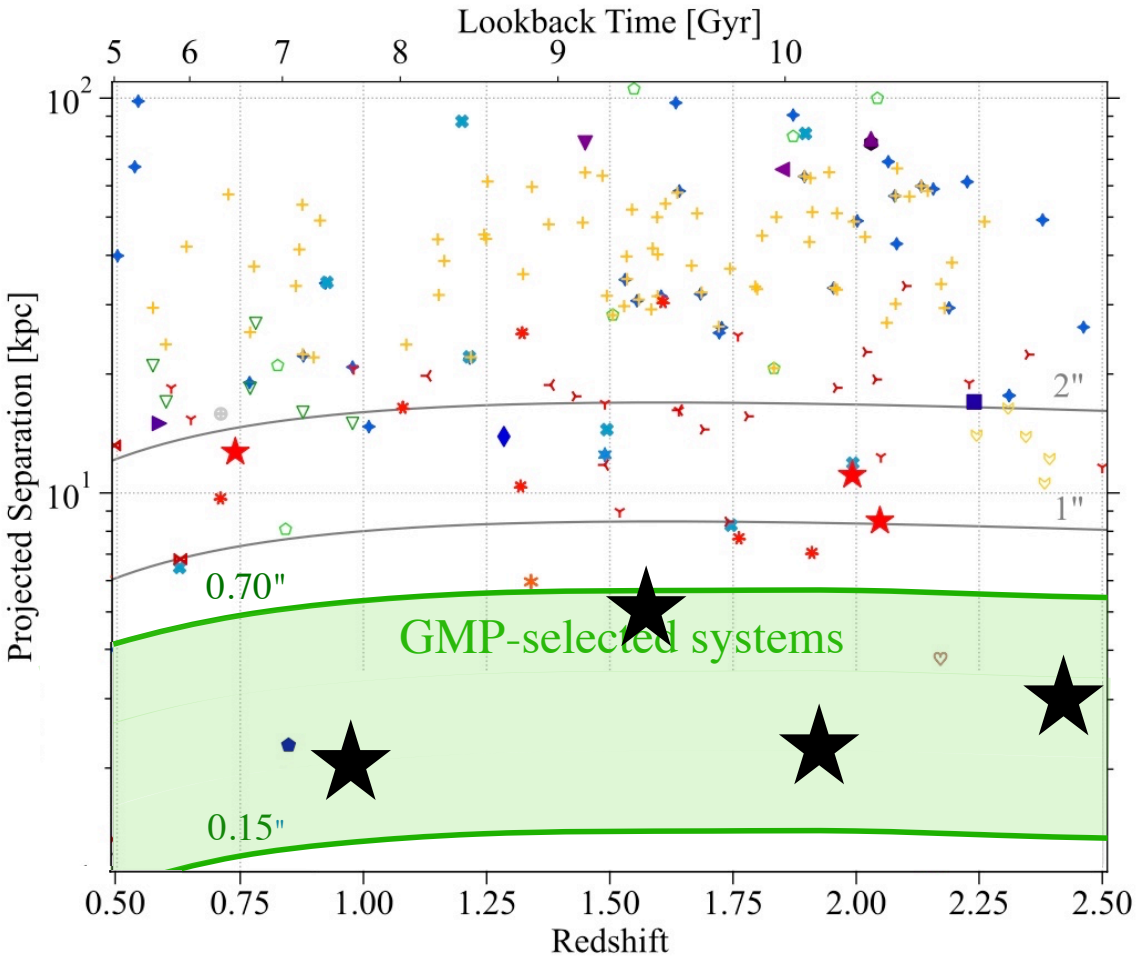
30 more systems scheduled for P110

ERIS GTO observations

- New AO imager and IFS
- Much larger sky coverage and higher AO corrections
- Last commissioning run: next week
- 115 hr of GTO ~ **130** systems

- MPE - Garching
- INAF - Arcetri
- UKATC - UK
- NOVA - NL
- ETH - Zürich
- ESO

Populating the desert with GMP objects



8 observed systems:

- 4 dual AGNs
- 3 AGN/star alignments
- 1 lensed system

Future AO observations of ~200 GMP-selected systems

The role of Euclid

All (extragalactic) sky survey

High spatial resolution

Real imaging

Stable PSF

Much deeper than Gaia:
- fainter AGNs
- larger luminosity ratio

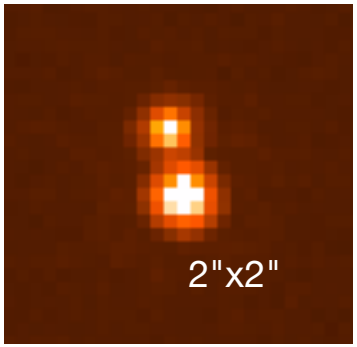
AGN pairs Euclid-VIS detection efficiency

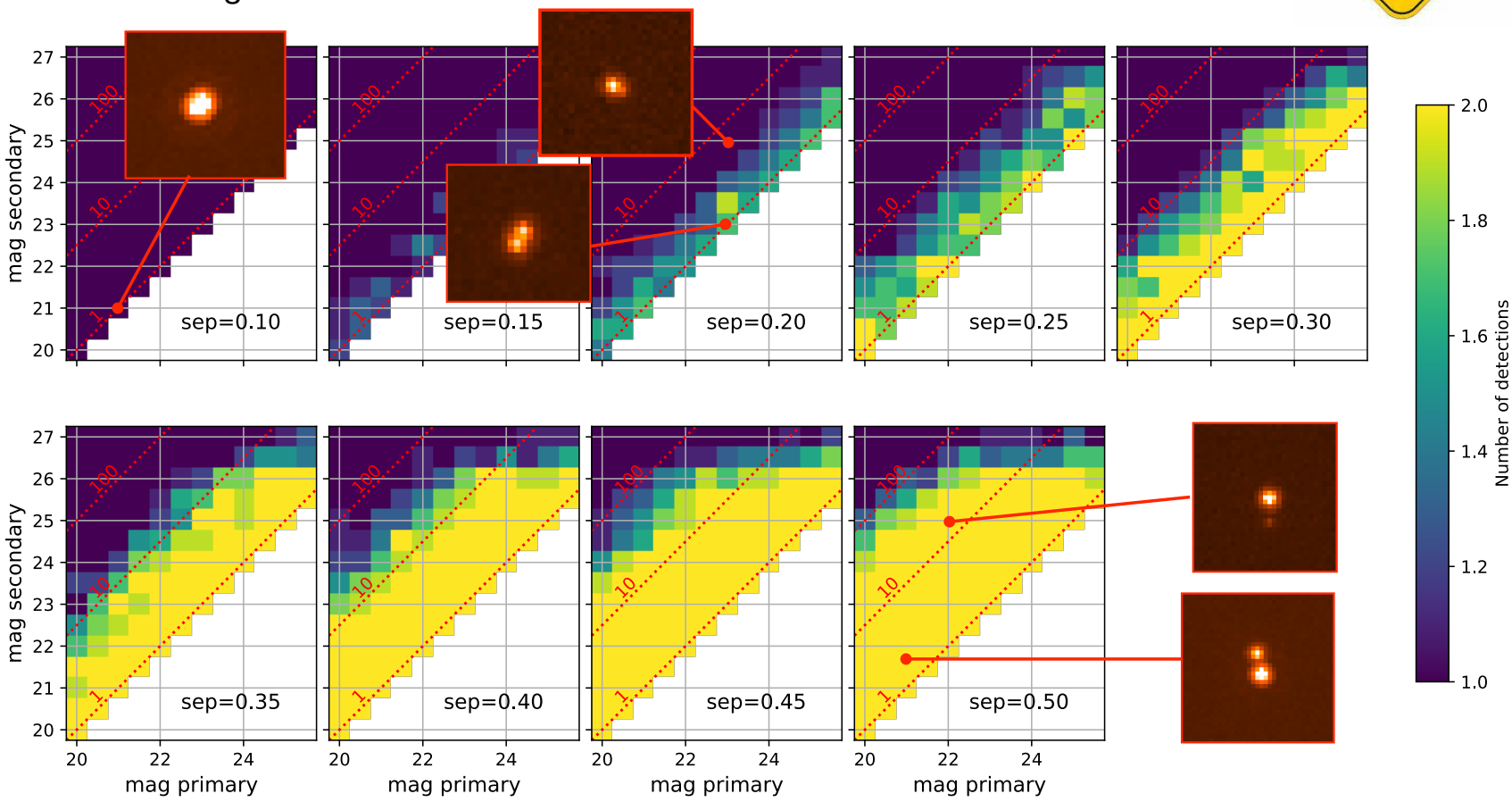
M. Meneghetti

Two point sources

Efficiency of detection as a function of:
1. primary mag
2. secondary mag
3. separation

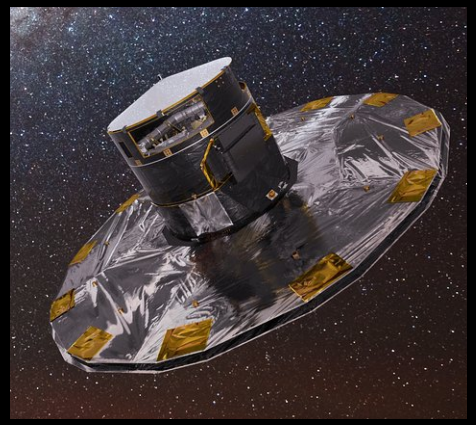
- Many realizations changing position angle
- Automatic detection





Conclusions

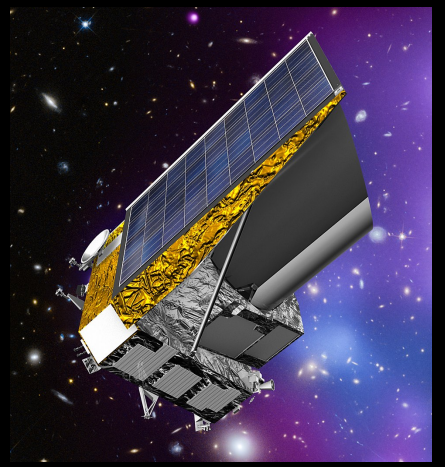
1. GMP very efficient in selecting multiple systems with Gaia with separations 0.15"<δ<0.7" (1<δ<5 kpc @ z>1) same galaxy
2. ESO AO-assisted spectroscopy of >150 targets to test the models
3. Euclid to extend towards fainter systems with larger lum ratios



nature astronomy (2022) 6, 1185 ARTICLES
https://doi.org/10.1038/s41550-022-01761-5
Check for updates

Unveiling the population of dual and lensed active galactic nuclei at sub-arcsec separations

F. Mannucci[1]✉, E. Pancino[1,2], F. Belfiore[1], C. Cicone[3], A. Ciurlo[4], G. Cresci[1], E. Lusso[1,5], A. Marasco[1], A. Marconi[1,5], E. Nardini[1], E. Pinna[1], P. Severgnini[6], P. Saracco[6], G. Tozzi[1,5,7] and S. Yeh[8]



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