STAR
Space sciences, Technologies and Astrophysics Research

LIÈGE université

Strong lensing studies with the 3.6-m Devasthal Optical Telescope: opportunities and challenges

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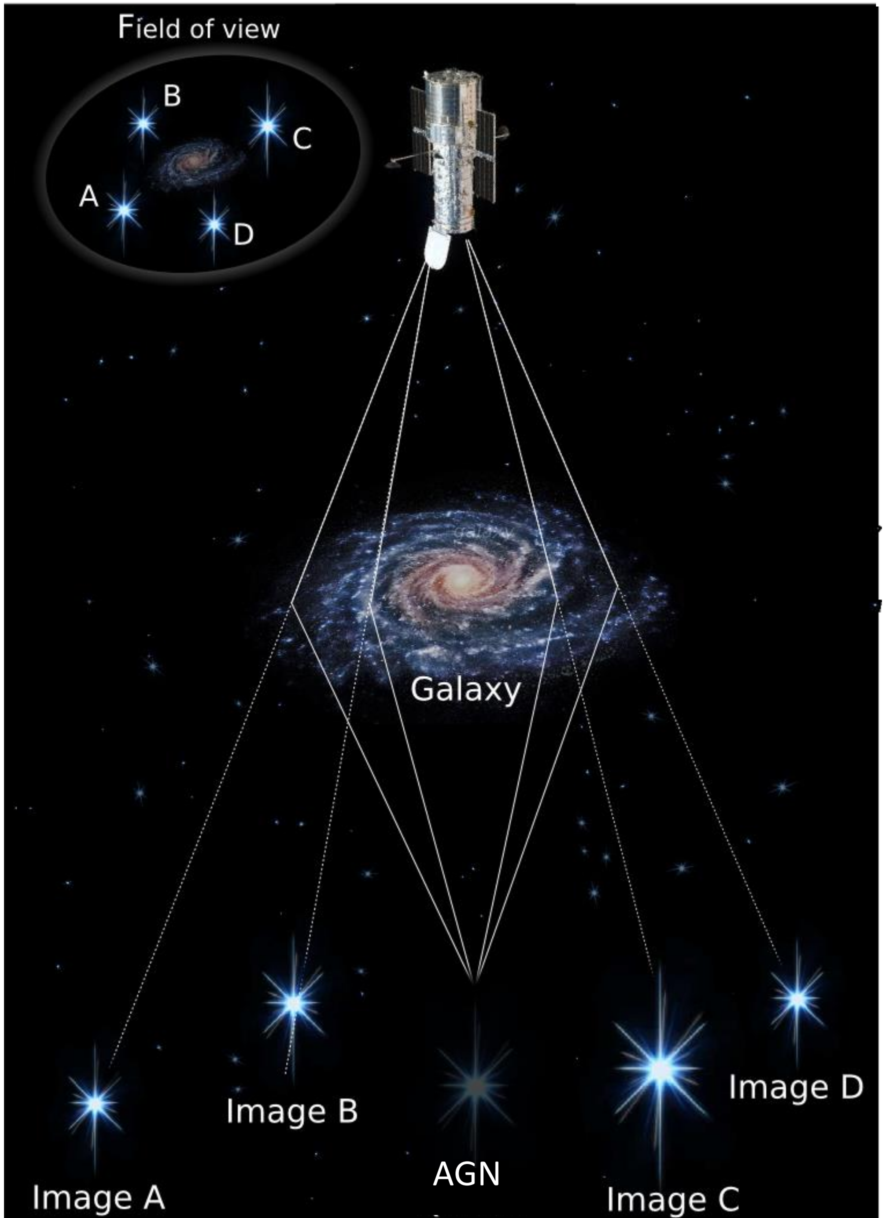
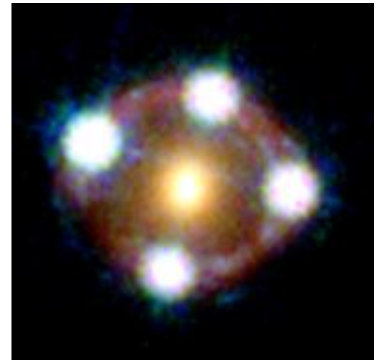
European Commission

European Research Council
Established by the European Commission

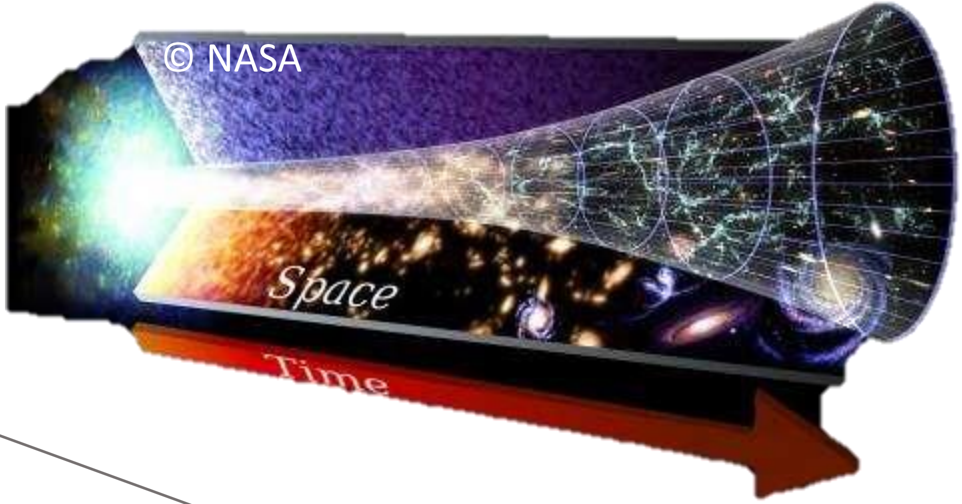
2nd BINA meeting, Brussels, Oct. 11th 2018

Strong gravitational lensing





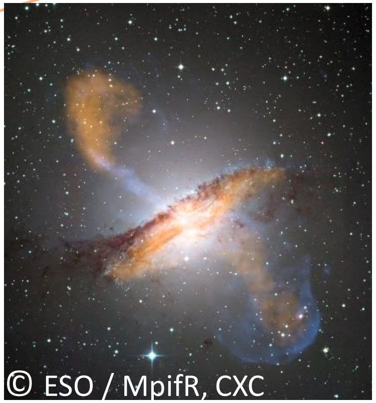
Strong gravitational lensing applications



Expansion rate of the Universe: H_0

GL are astrophysical laboratories

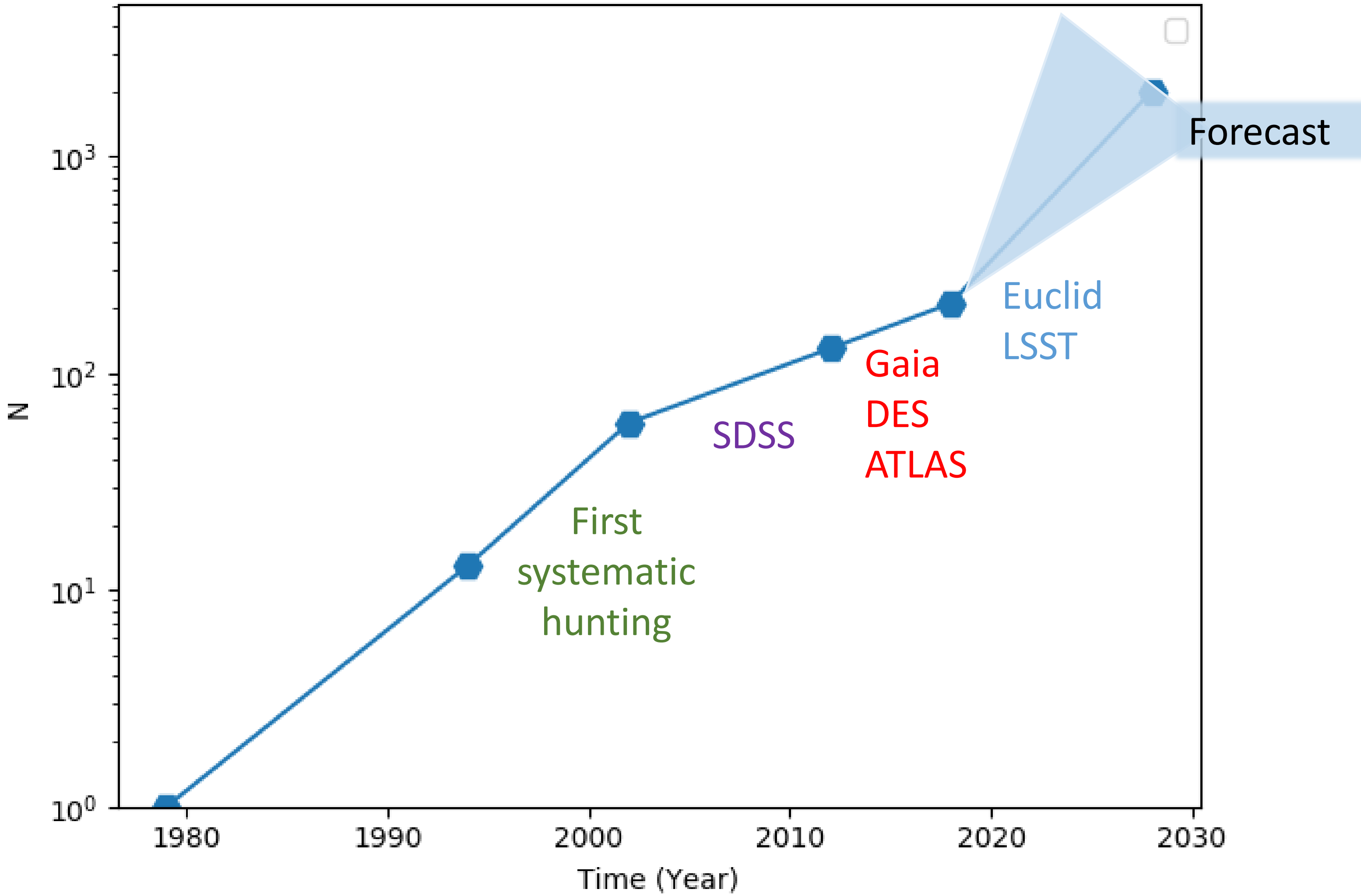
Dark matter in galaxies



Active Galactic Nuclei (AGN)

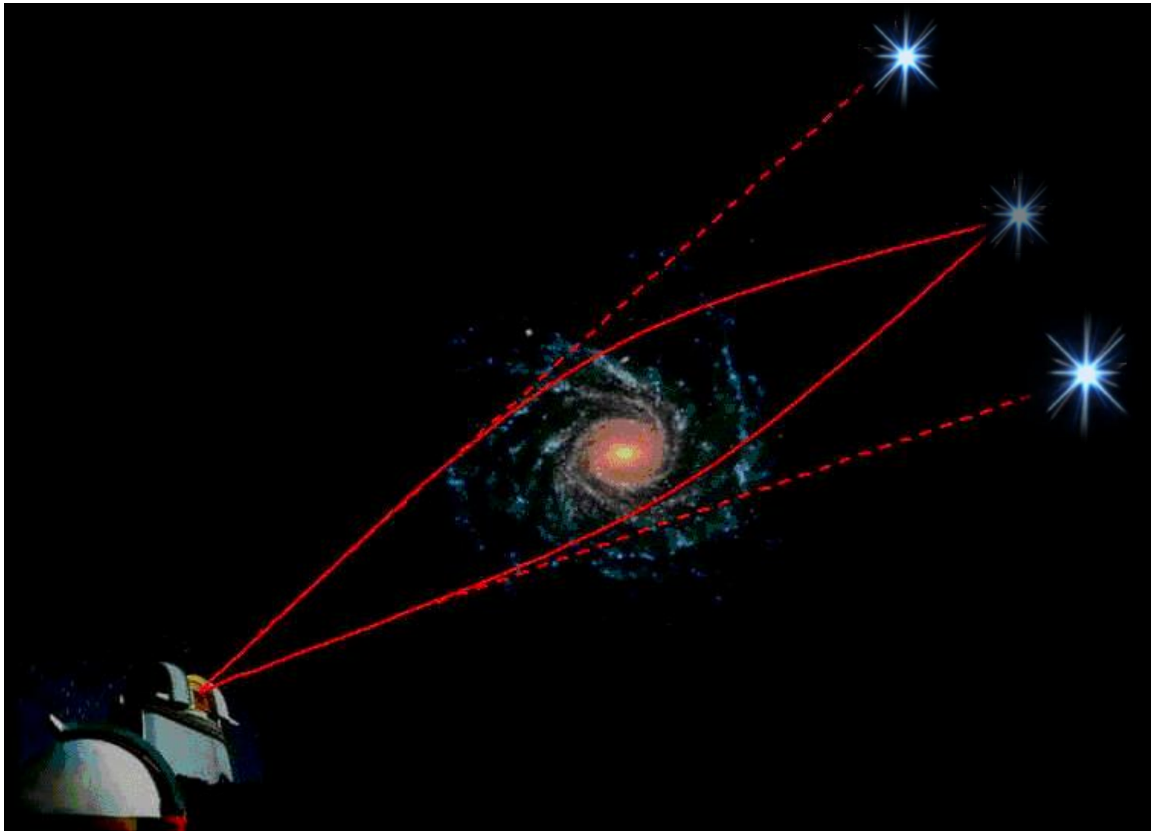
A new era for strong lensing studies

Rapid Increase of the number of known strongly lensed quasars/AGNs



Potential scientific opportunities with BINA telescopes

Expansion rate of the Universe: H_0



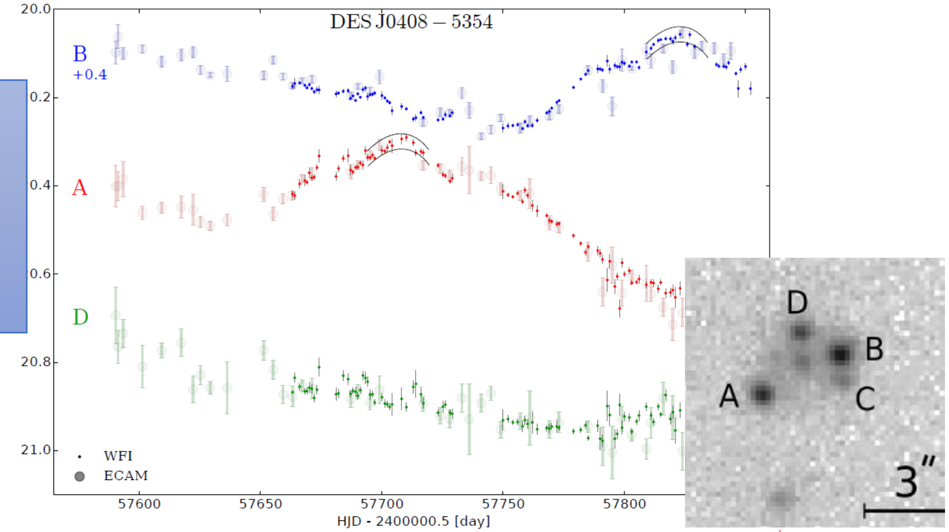
z_L ≡ lens redshift

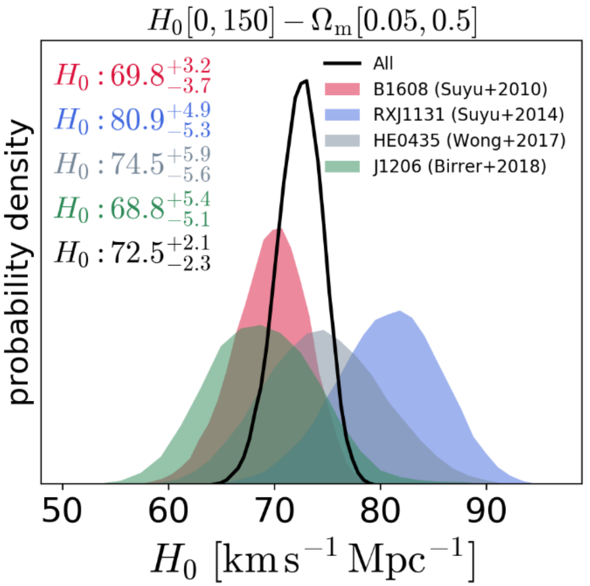
$$\Delta t = \frac{1+z_L}{c}\underbrace{\frac{D_L\,D_S}{D_{LS}}}_{\propto 1/H_0} \cdot f\,(\text{geometry, mass distribution})$$

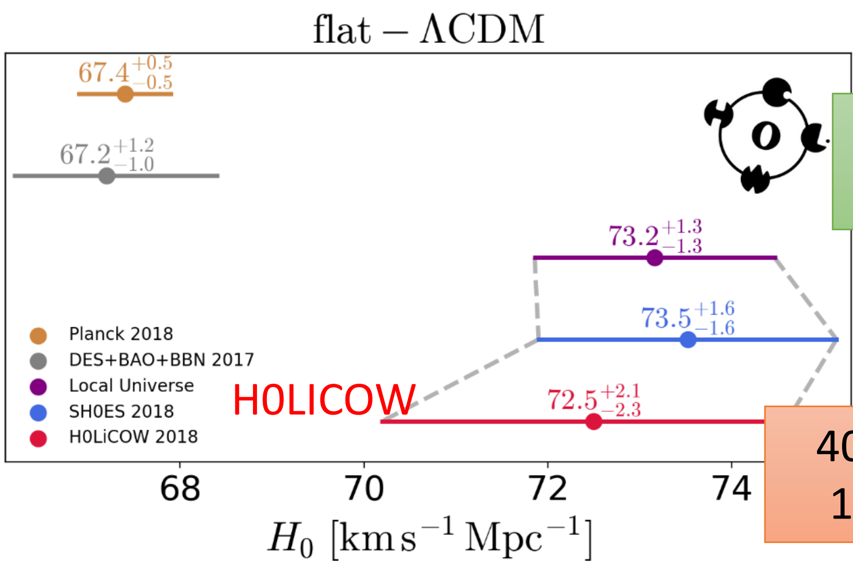
Expansion rate of the Universe: H_0

Requirements for Δt measurement ($\sigma_{\Delta t}$ <3%)

- 2-4m class telescope
- 2 seasons w. 1 mmag accuracy
- Daily cadence





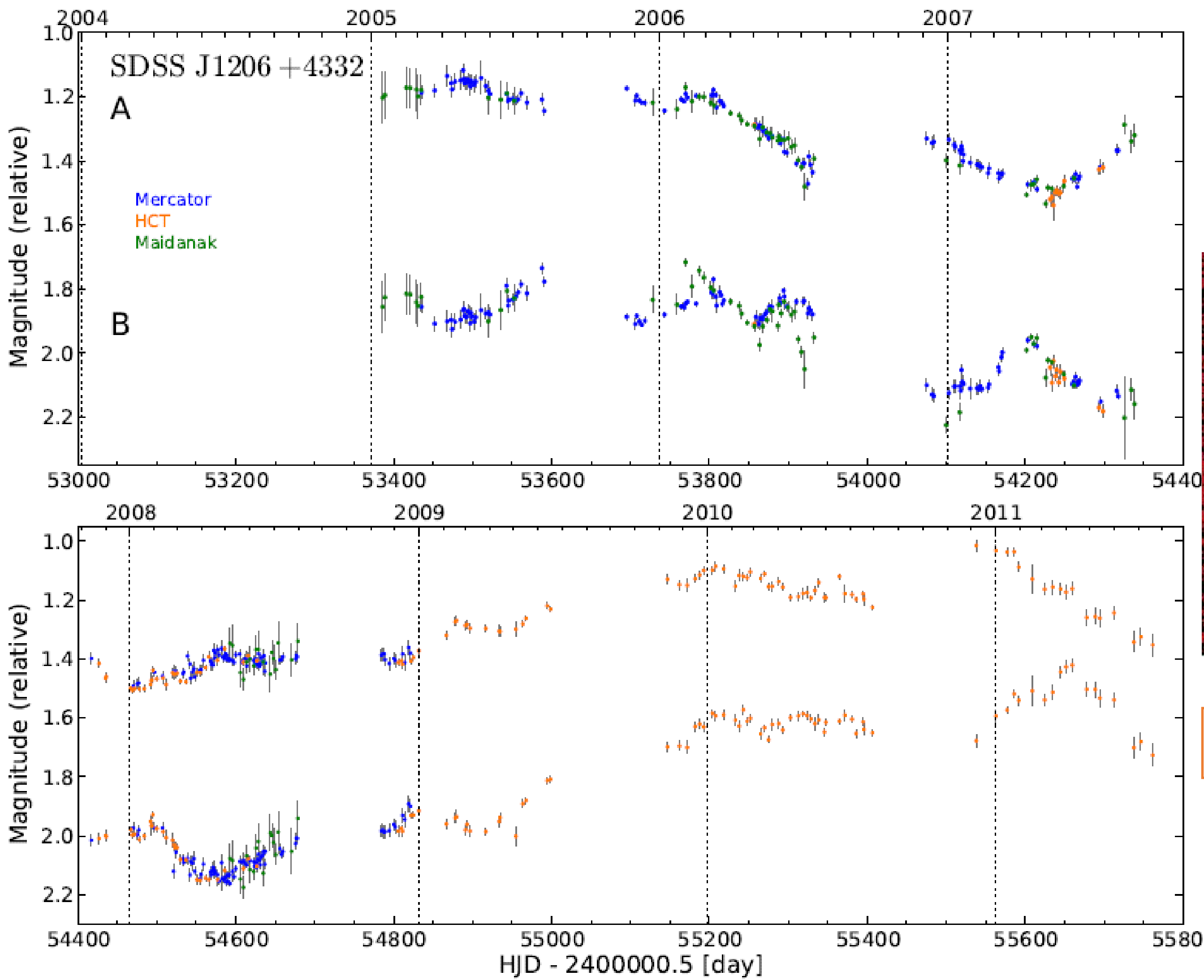


TODAY
3% accuracy on H_0

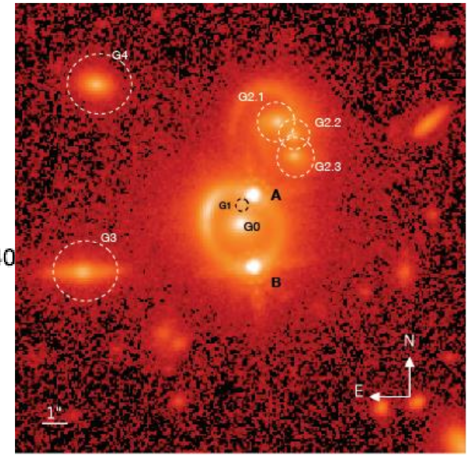
40 systems to reach
1% accuracy on H_0

Bonvin+ 2017, Sluse+2017, Courbin+2018, Birrer+2018

Expansion rate of the Universe: H_0



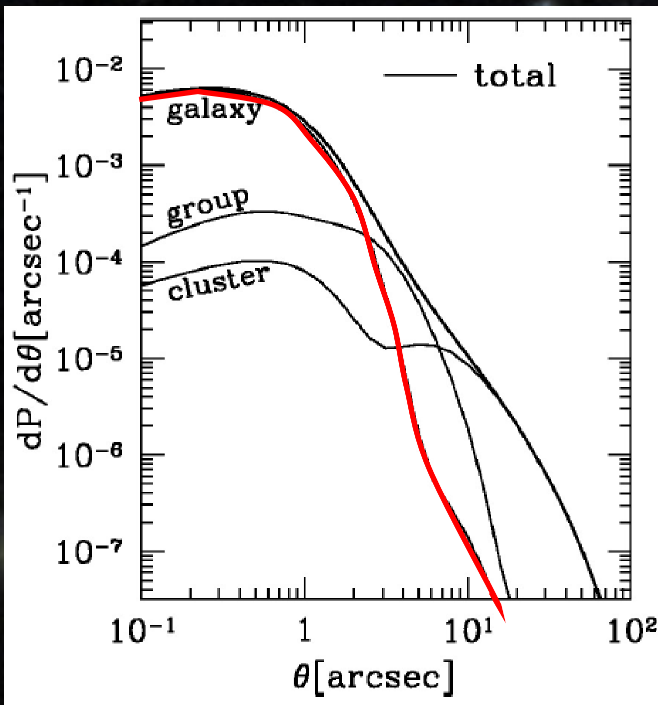
Time delay of J1206+4332 (last published H0LICOW lens)

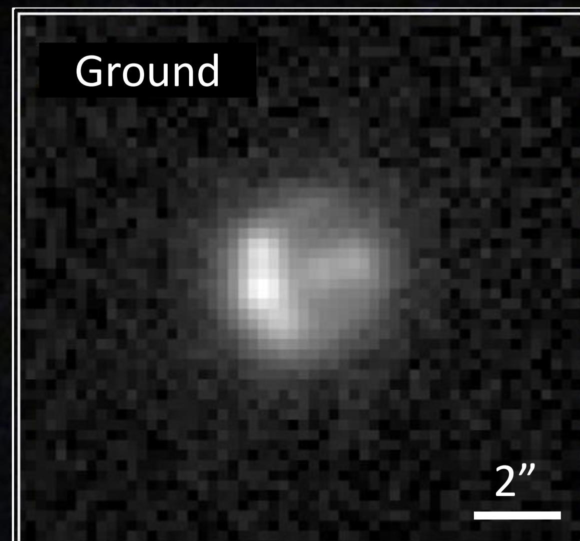


$\Delta t = 111.8^{+2.4}_{-2.8}$ days

Eulaers+ 2013, Birrer+ 2018

Challenge: Compact objects





$\Delta\theta < 2''$ for most systems:

=> Need sampling ≤ 0.35”/pixel (0.2”/pixel is ideal)

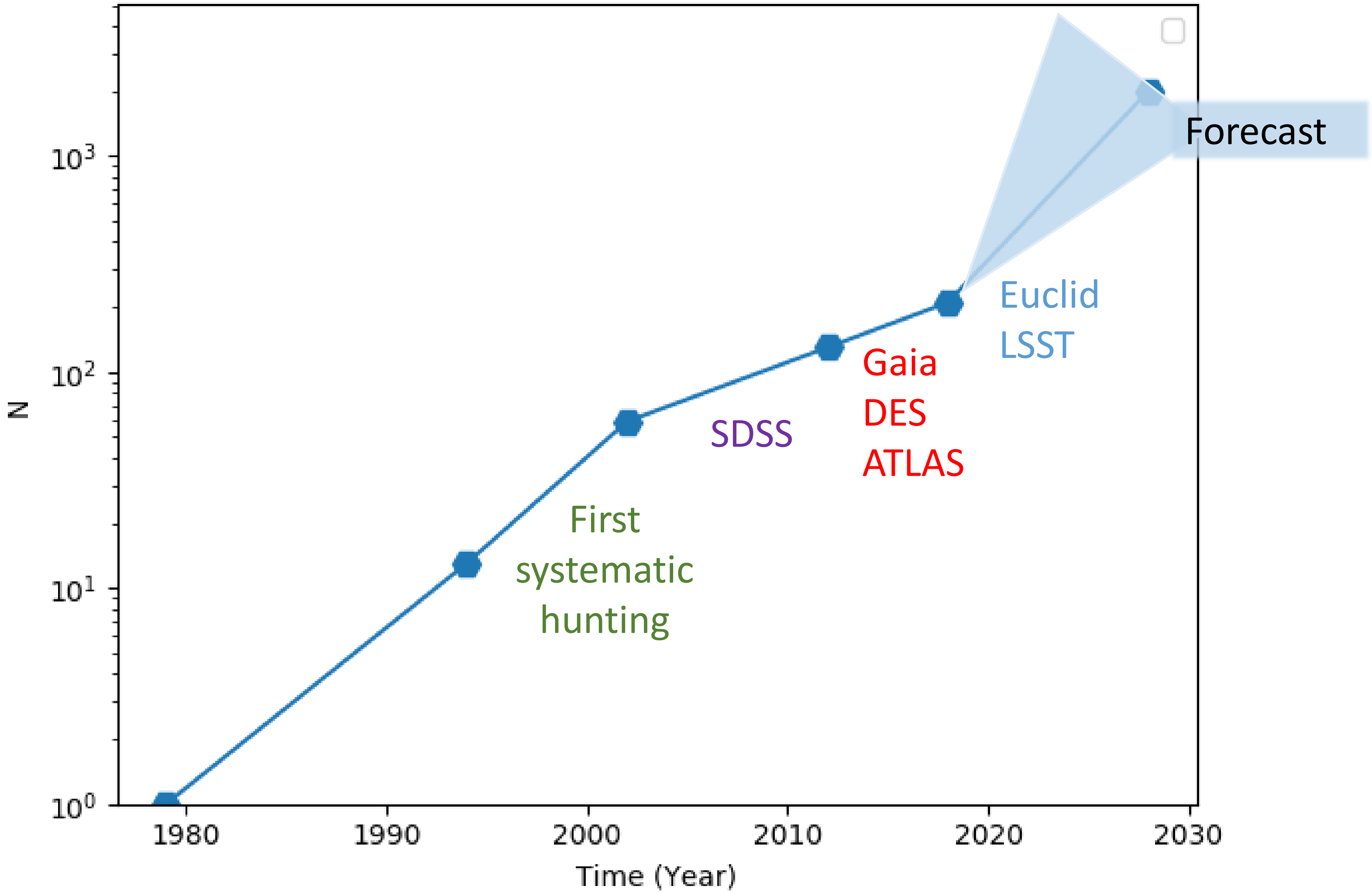
Typical photometric accuracy for R = 18.5 mag and seeing 1” :

- 10 mmag for 5x360s on 1.2 m telescope
- 1 mmag for 4 x 320s on 2.2 m telescope

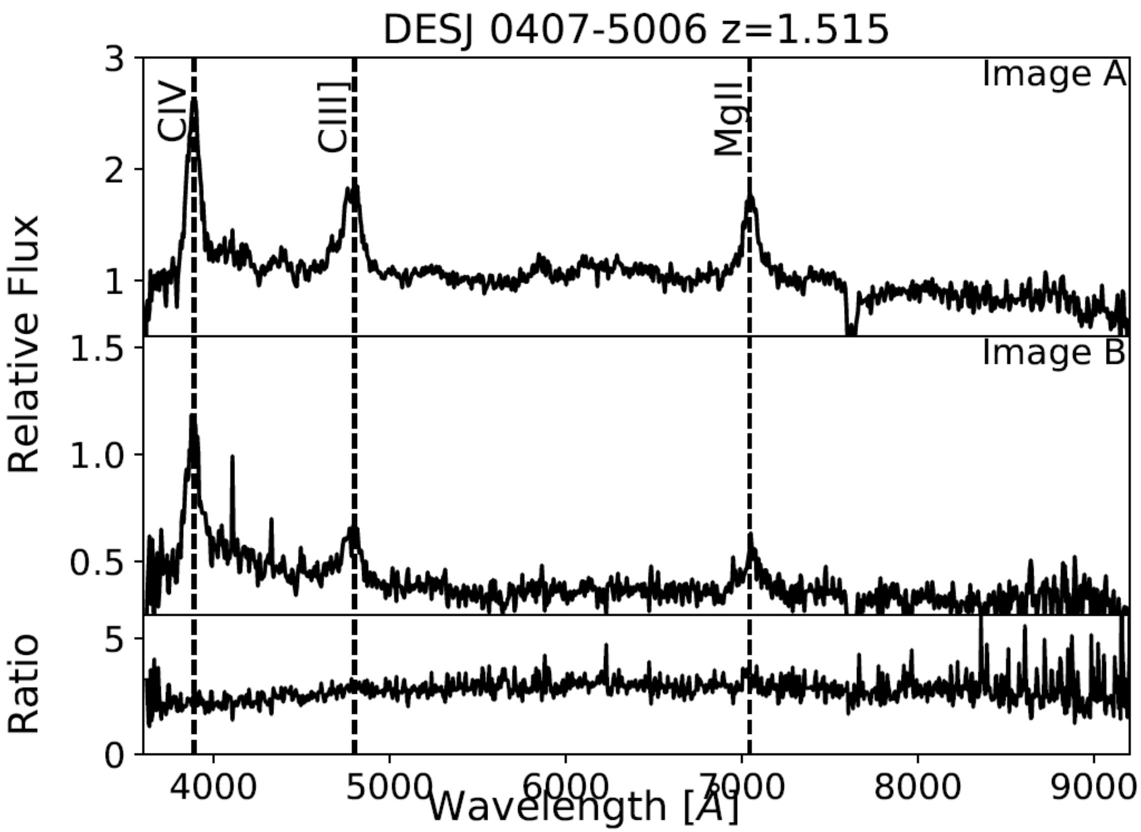
Oguri 2006, Tewes+2013, Magain-Courbin-Sohy (MCS deconvolution; 1998)

Confirming lensed quasar candidates

Rapid Increase of the number of known strongly lensed quasars/AGNs



Confirming lensed quasar candidates

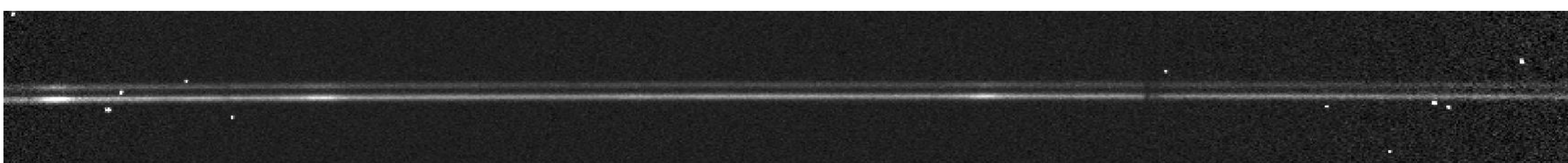


Example of confirmation w. 3.6m telescope (EFOSC at NTT)

$\Delta\theta = 1.7''$
R = 18.07 – 19.36

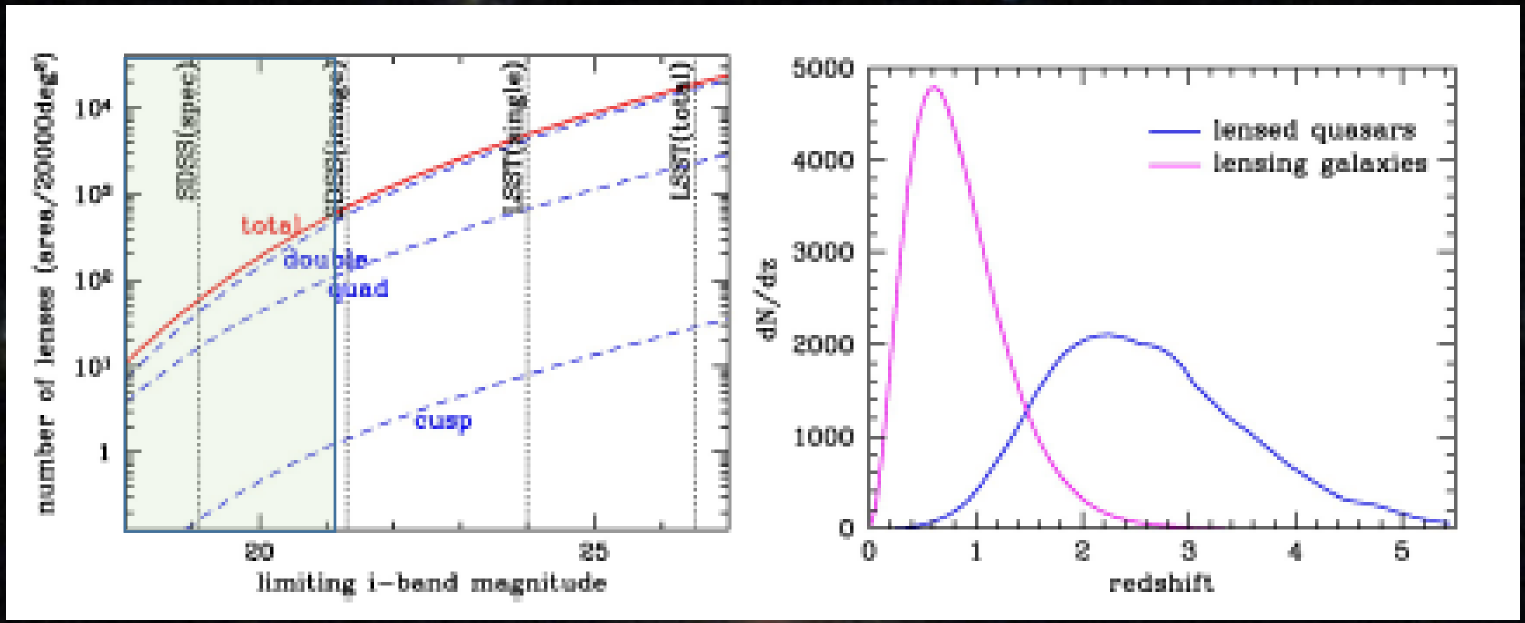
Exp. Time: 600s

Deconvolution could be needed but it requires a PSF spectrum



Anguita+ 2018

Confirming lensed quasar candidates



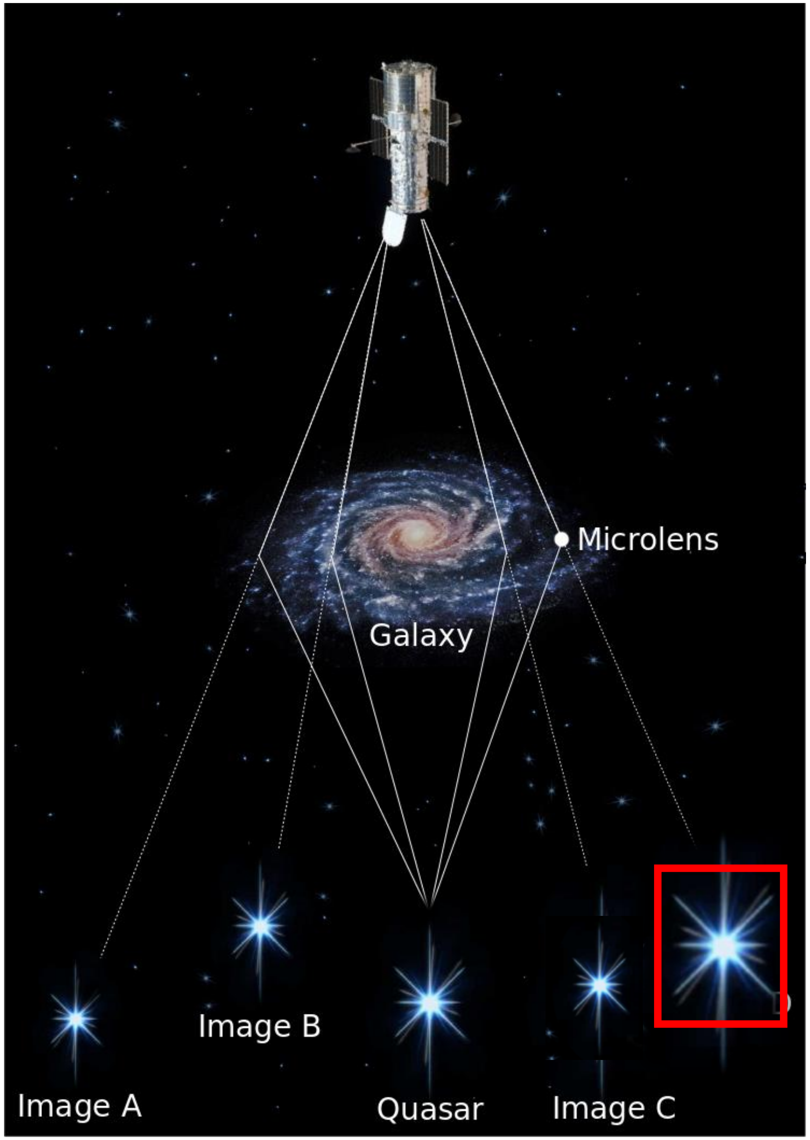
100 – 500 lensed quasars that could be confirmed *spectroscopically* w. DOT (i.e. down to I ≅ 21. mag)

Requirements :

- Spatial resolution of ≤ 0.35”/pixel
- Good seeing (1” or up to 1.4” for largest separation)
- Large spectral coverage (4000-9000+ Å).
- Resolving power R ≥ 200
- MXU / MOS (Multi-object Spectroscopy) or IFS (Integral Field Spectroscopy)

LSST Science book

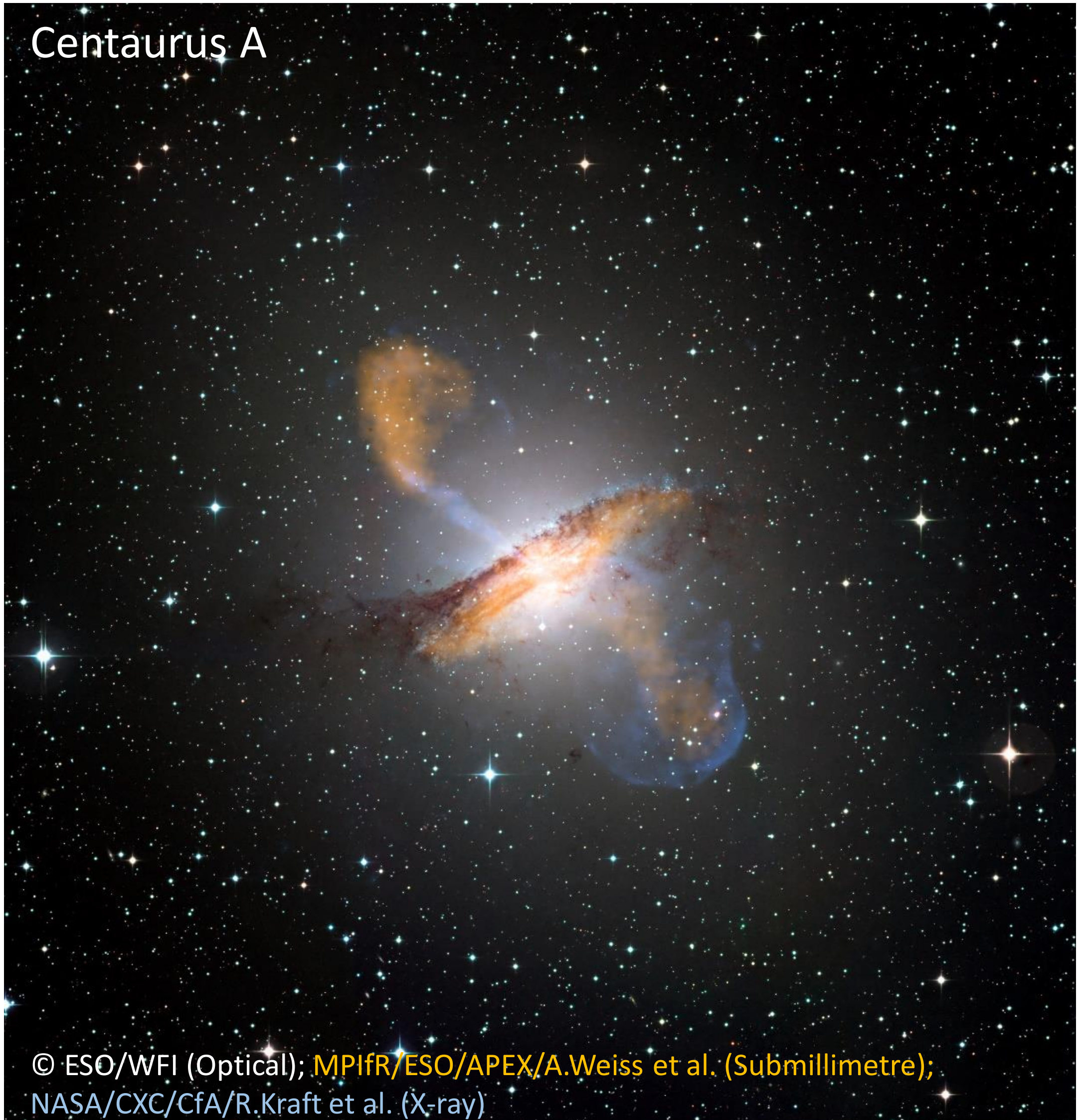
Scanning AGN with microlensing



Micro-lenses = stars in the lensing galaxy

Magnification depends on the source size

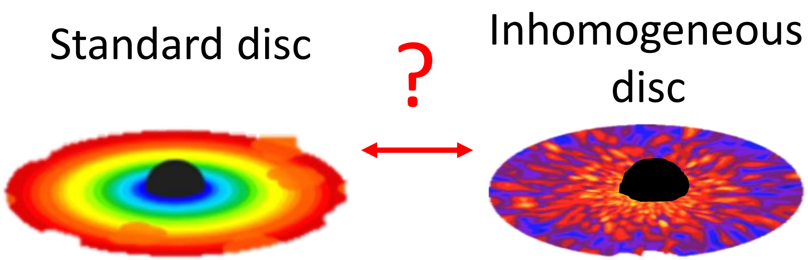
Scanning AGN with microlensing



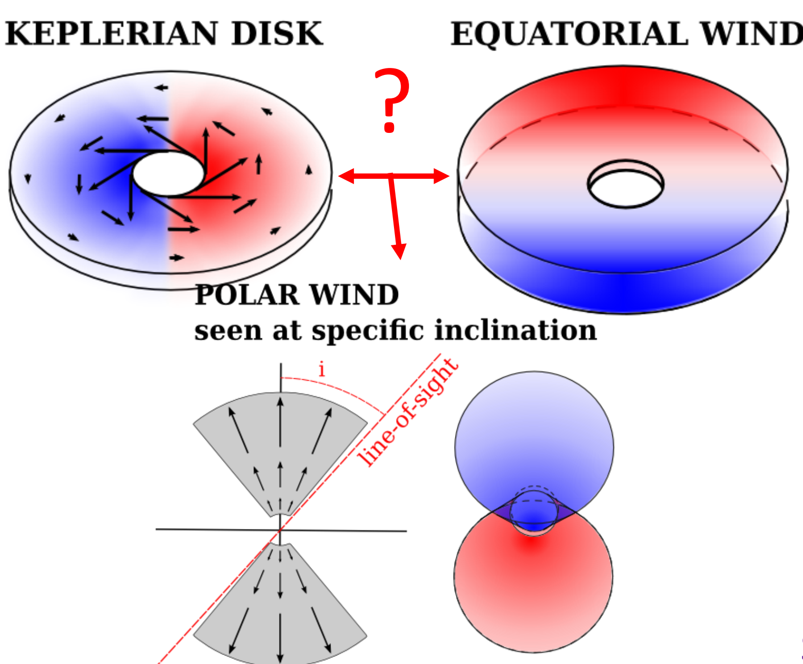
- Visible signature of an accreting supermassive black-hole located in the central regions of galaxies (a few light-days). They remain *spatially unresolved* with our telescopes.
- Key role in galaxy evolution through *feedback* processes: impacts both the star formation and inner mass distribution of galaxies
- Probe of the evolution of supermassive black holes

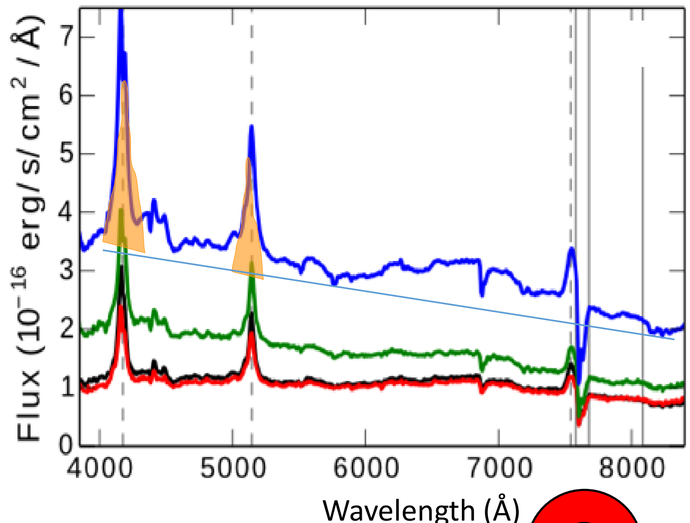
Scanning AGN with microlensing

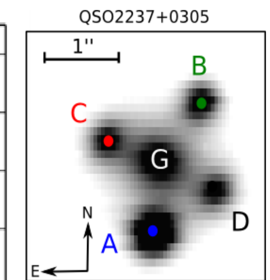
Accretion disc (AD)

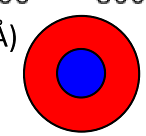


Broad line region (BLR)









$ML_{blue} > ML_{red}$

Specific requirements:

- Resolving power R ≥ 300
- Accurate de-blending (MOS-MXU / IFS)
- Multi-epochs over years
- SNR > 10/pixel for emission lines

Sluse+2011, Sluse+2015, Braibant+ 2016, 2017

Conclusions

Main scientific opportunities:

- Identification of new systems among hundreds accessible with 4m-class
- Time-delay measurements for cosmology (ILMT, DOT, 2-m class, …)
- Scan of AGN structure with microlensing

Main requirements:

- High spatial resolution (< 0.35”/pix) and seeing typically < 1.5” (+ asset of advanced deconvolution and potential AO system –Orban de Xivry talk-) ☑
- Low to medium spectral resolution (R ≥ 300) and large wavelength coverage ☑
- Ability to perform monitoring over multiple years ??

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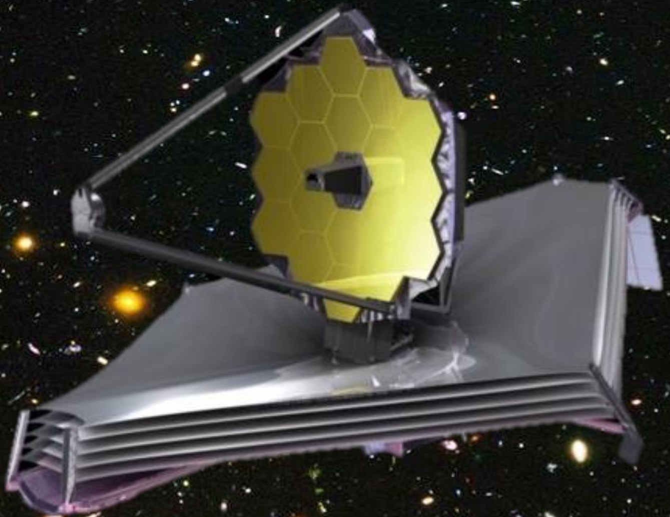
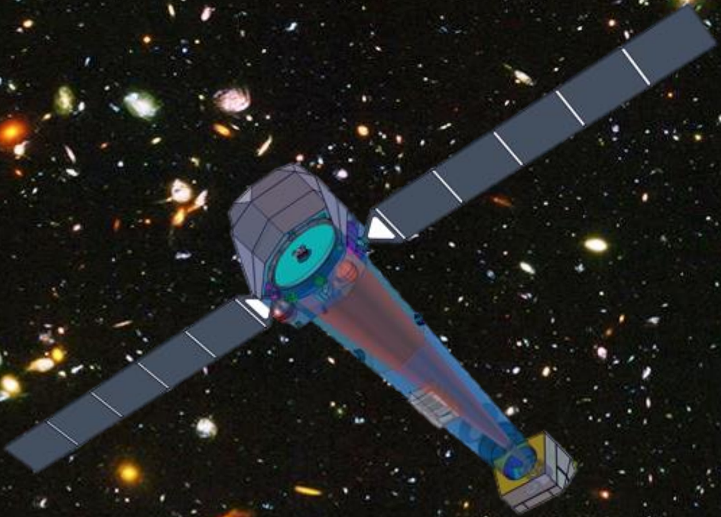
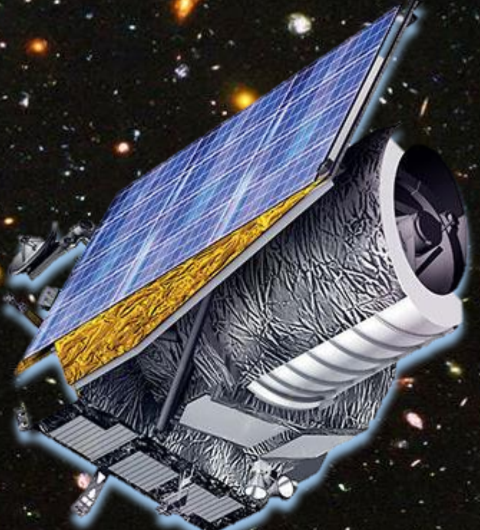
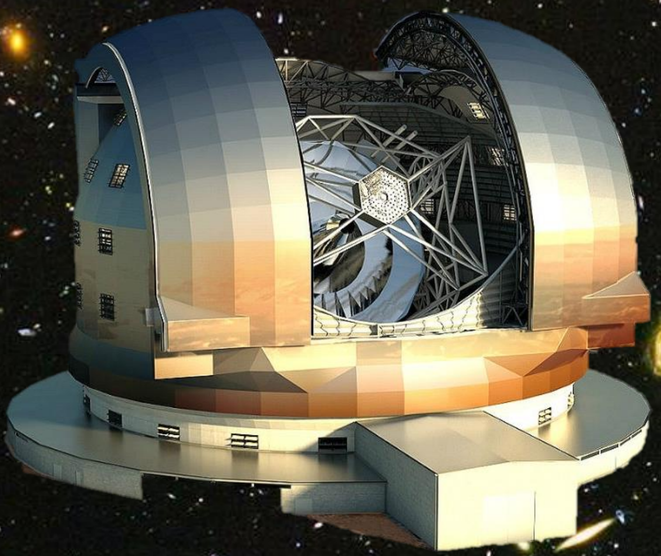


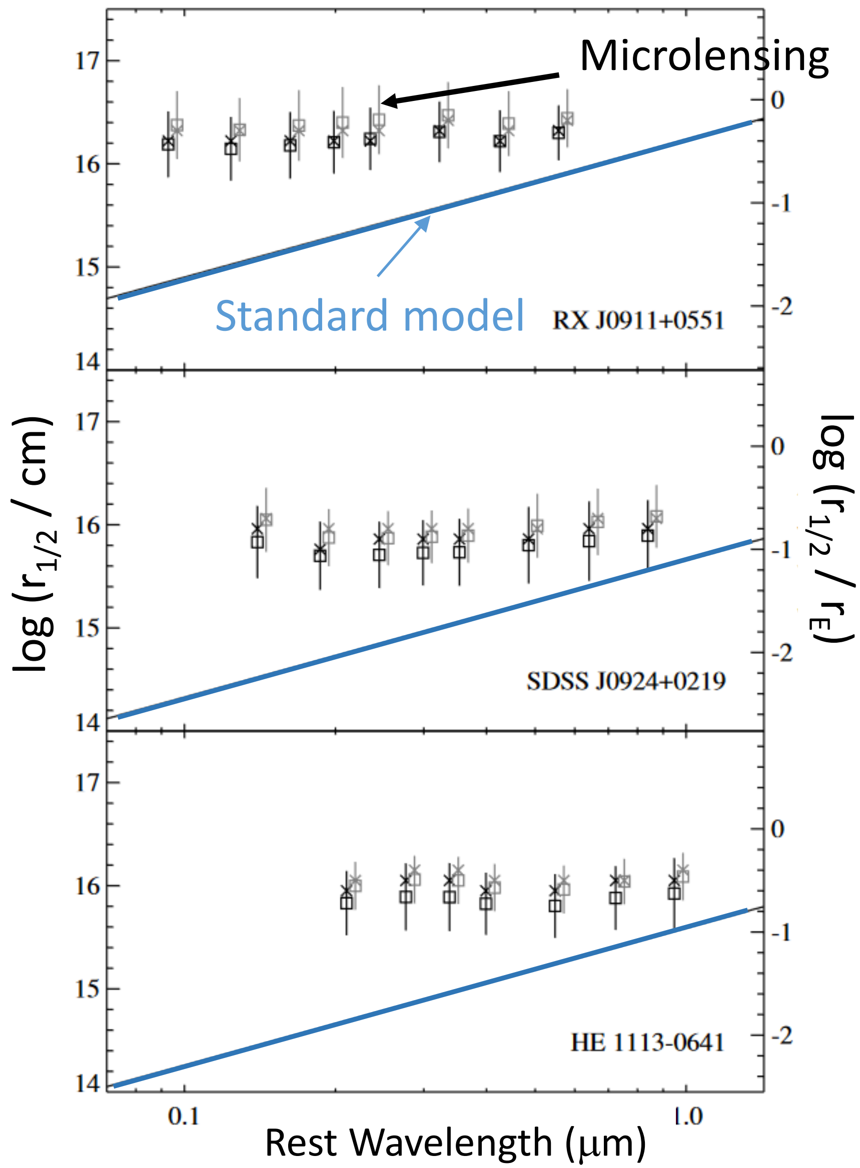


Supplementary slides



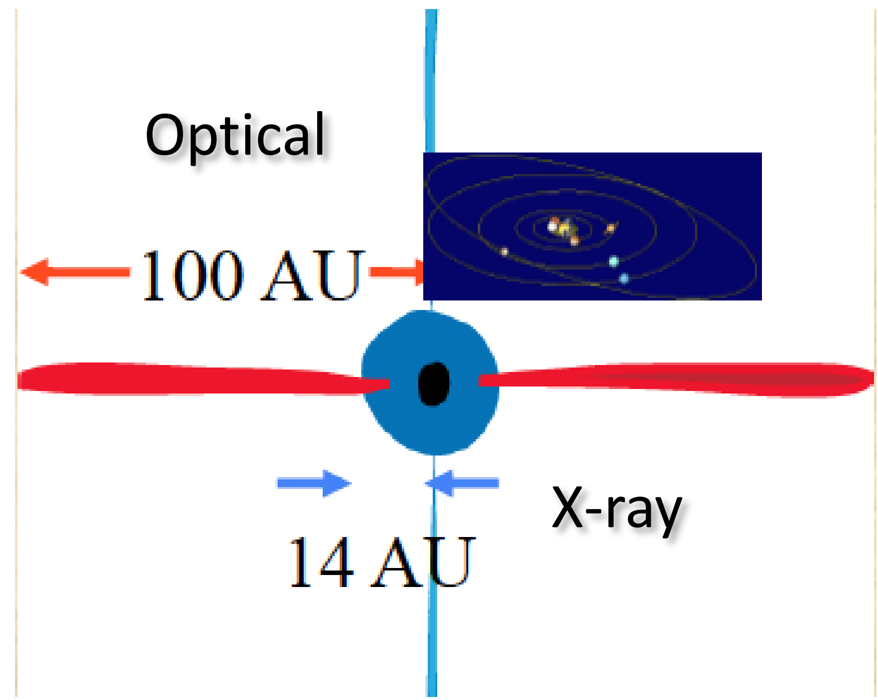


Scanning AGN with microlensing



Microlensing measures $r_{1/2}(\lambda)$:

- Multi-color imaging (1 / multi-epochs)
- Spectroscopy (1 / multi-epochs)



Eigenbrod+ 2008, Morgan+ 2010, Blackburne+ 2011