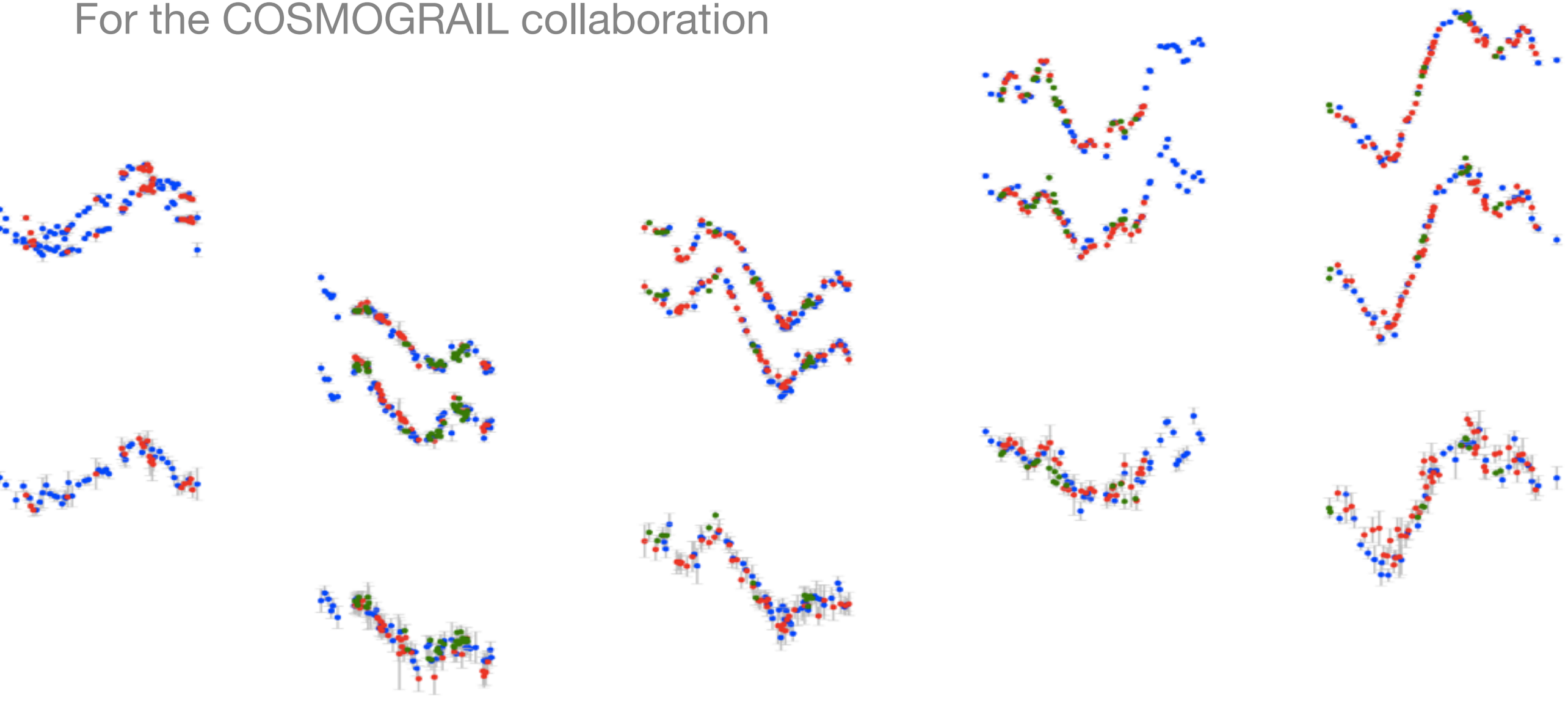
COSMOGRAIL: present and future

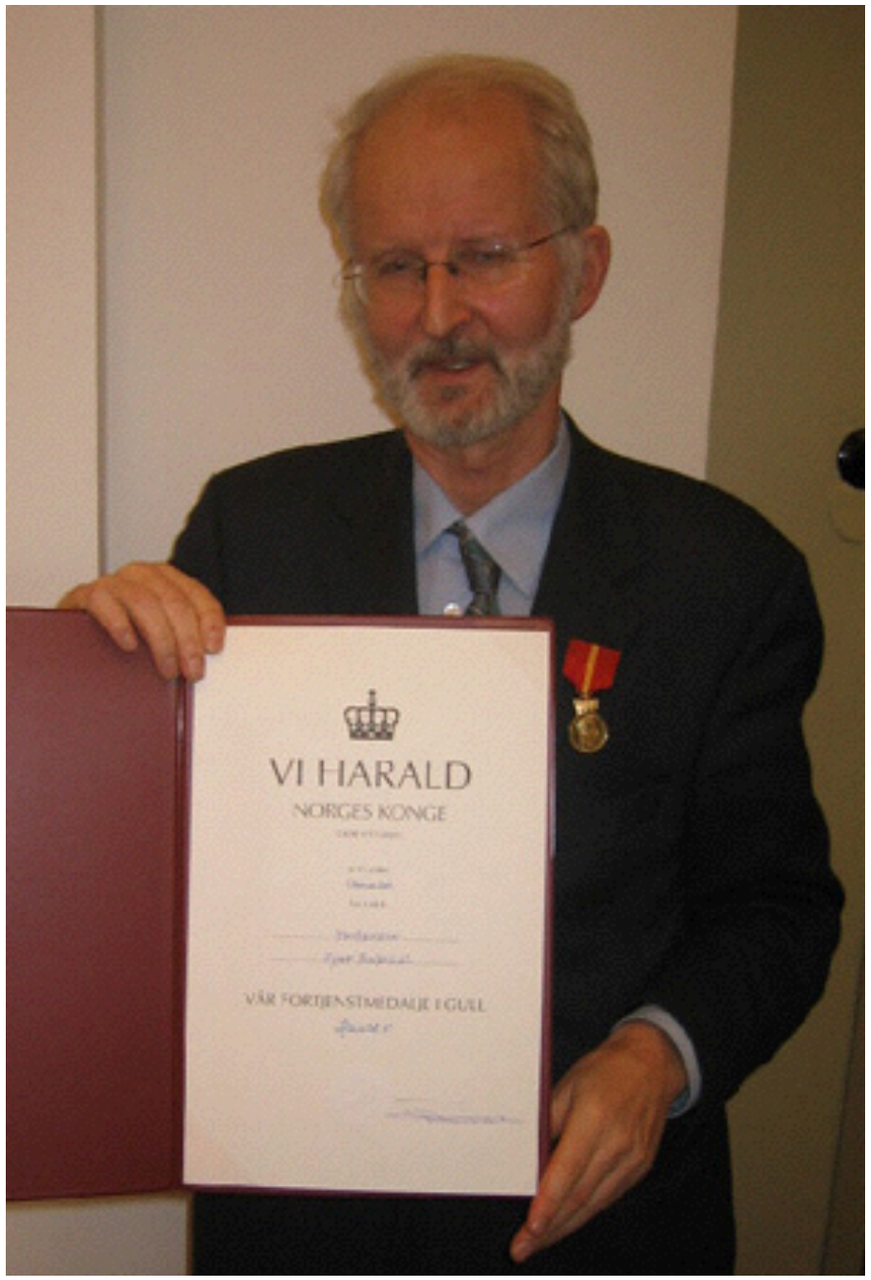
F. Courbin, G. Meylan, V. Bonvin, M Tewes, D. Sluse, D. Paraficz ...
For the COSMOGRAIL collaboration

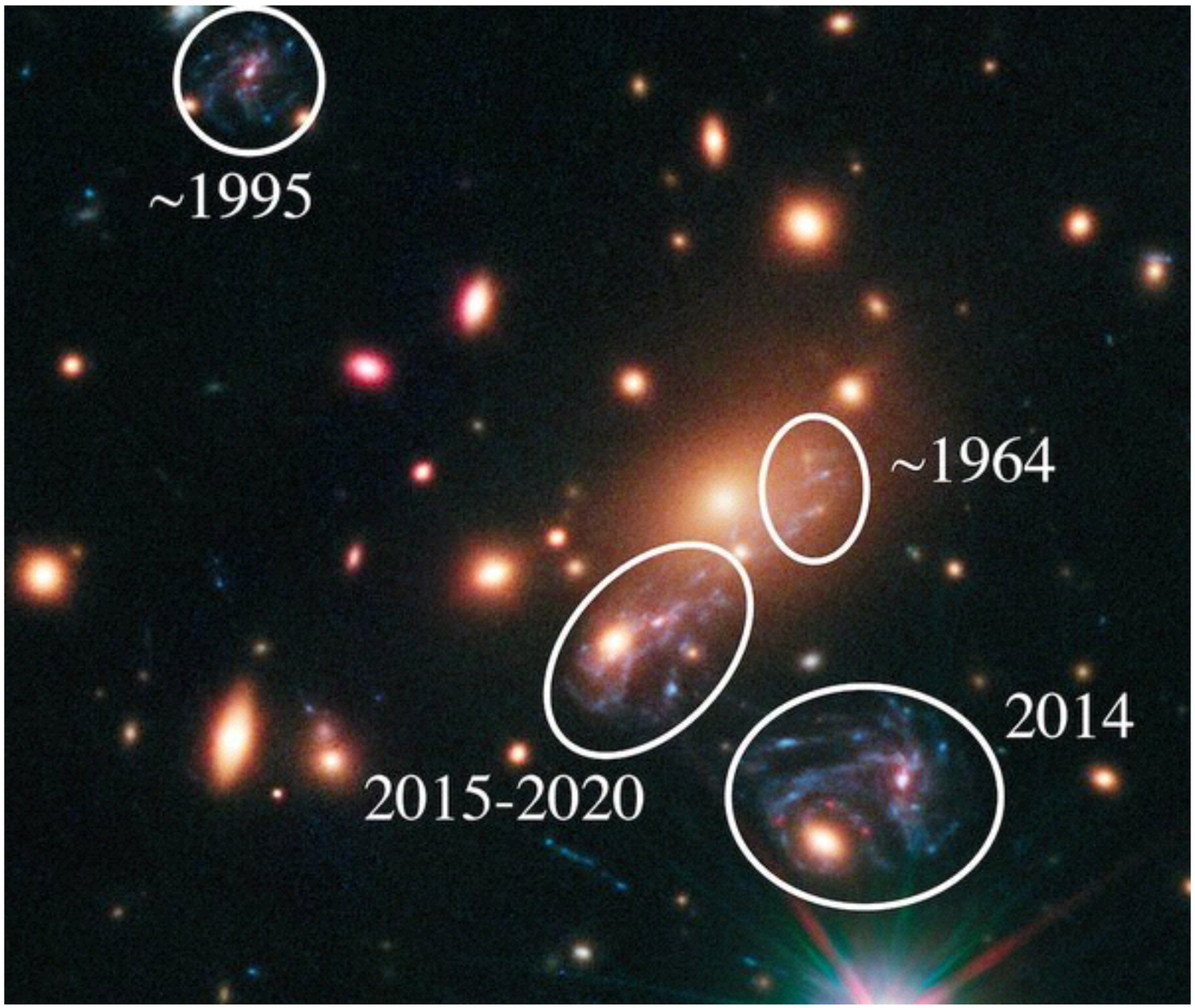


ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Laboratoire d'astrophysique http://lastro.epfl.ch
Ecole Polytechnique Fédérale de Lausanne (EPFL)

Quasar Time Delay Meeting
EPFL, April 2015

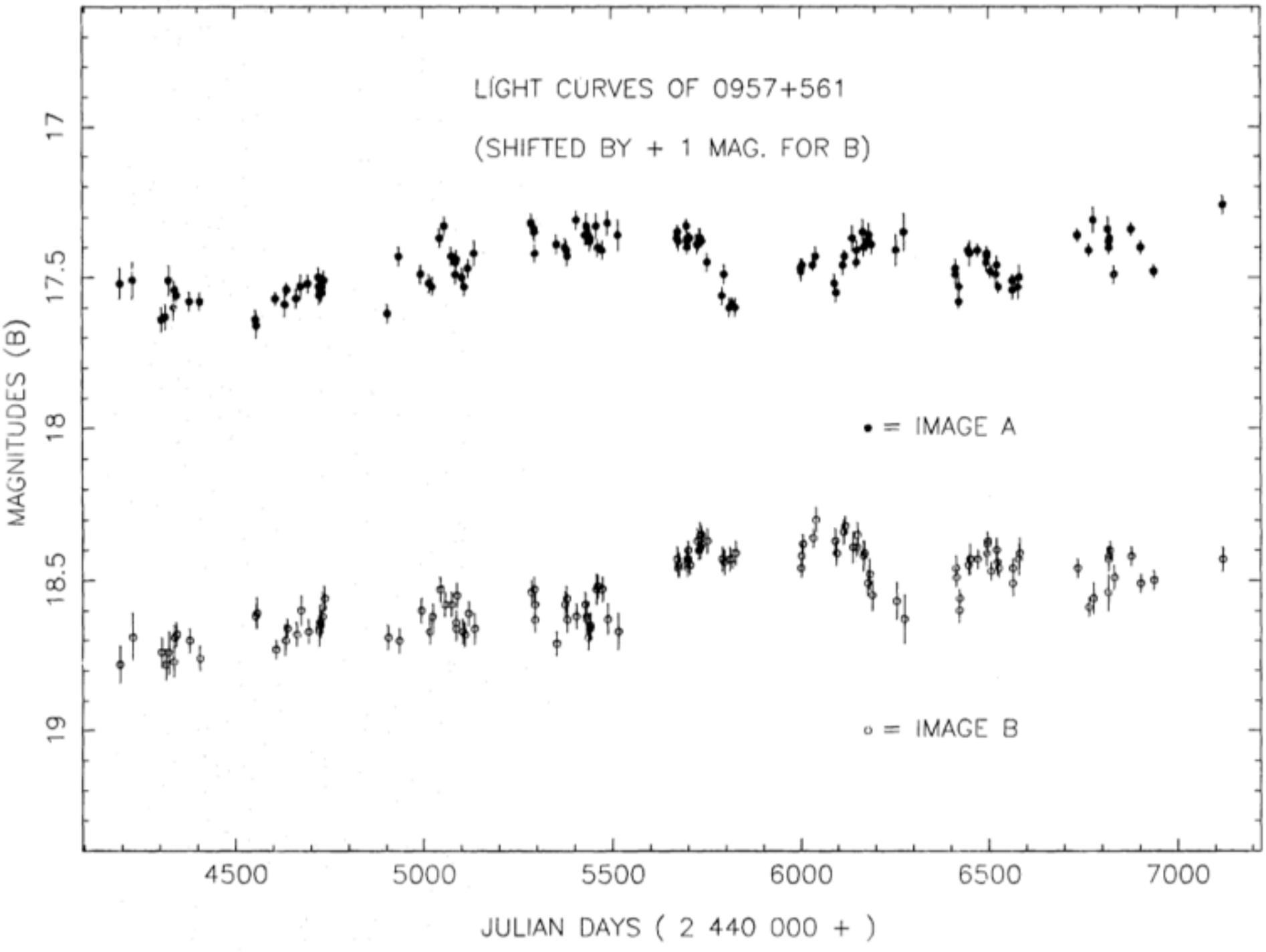
Thanks Sjur !





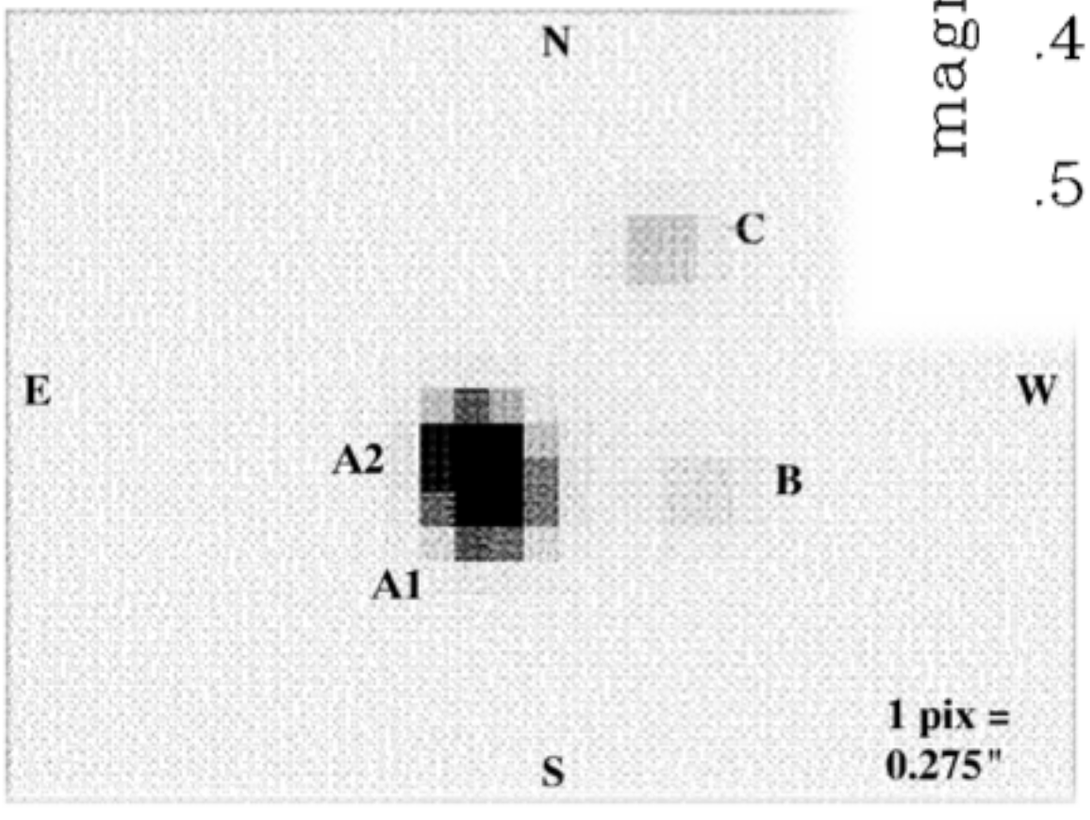
(Kelly et al. 2015, Science, 347, 1459)

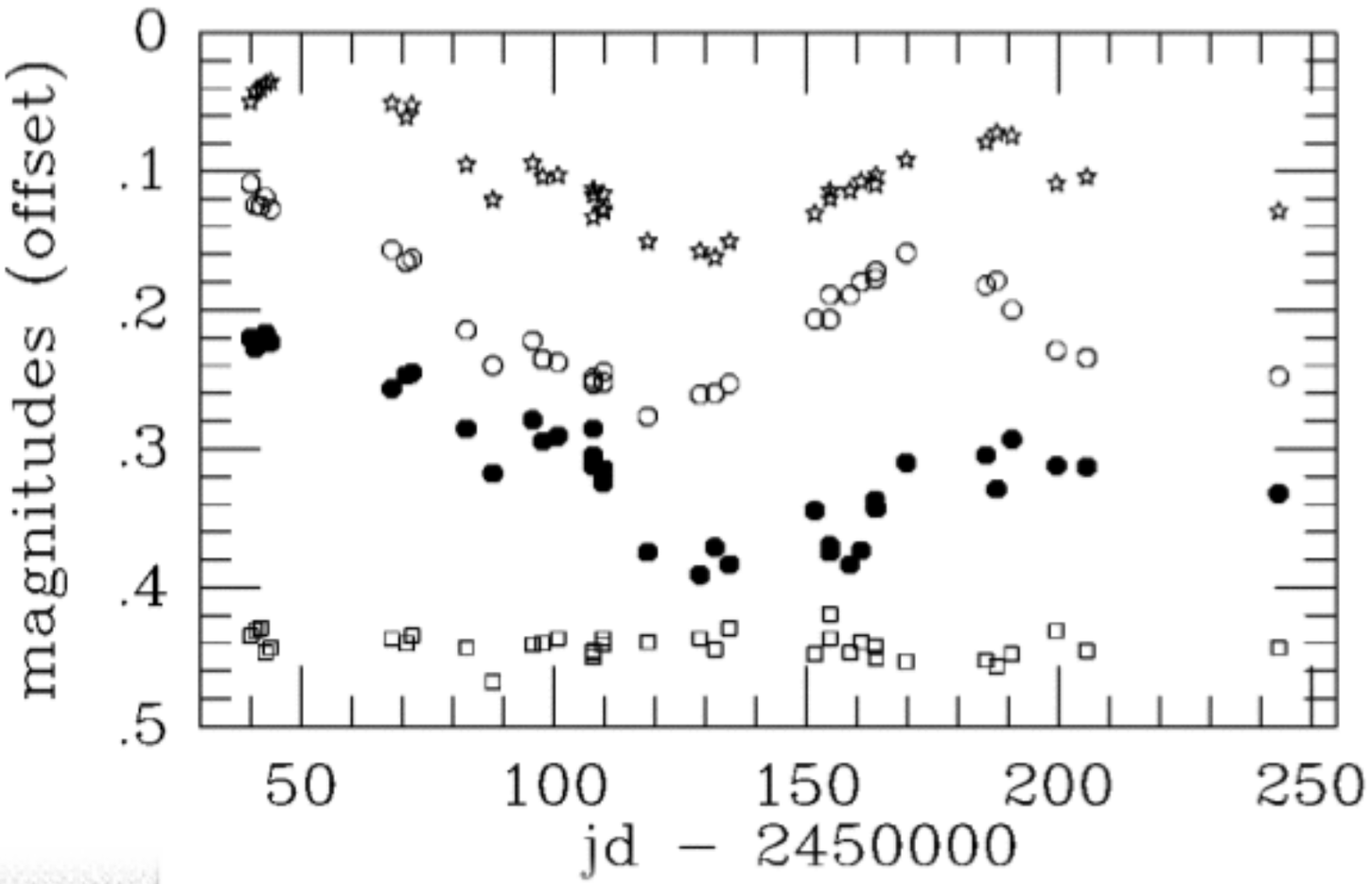
First measurements of time delays (1989-1997)



(Vanderriest et al. 1989, A&A, 215, 1)

PG 1115+080





(Schechter et al. 1997, ApJ, 475, L85; see also Barakana 1997, ApJ, 489, 21)

PG 1115+080

- PG1115+080: first long, well sampled light curve of a lensed quasar in the **optical** (Schechter et al. 1997, ApJ, 475, L85)

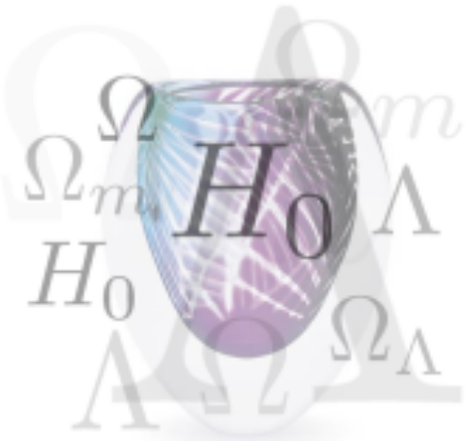
- B1608+656: **VLA** radio monitoring with no contamination by microlensing (Fassnacht et al. 2002, ApJ, 581, 823)

- Series of optical time delays by Burud et al. (2002, A&A, 391, 481; 2002, A&A 383, 71), Hjorth et al. (2002, ApJ, 572, L11) using optical data from the **Nordic Optical Telescope and from ESO.**

- Time delays from optical light curves with small telescopes become available around 2000-2005, **demonstrating the feasibility**, but

    - The accuracy of the delays remains low (10% or worse)

    - Lens models are underconstrained (including line-of-sight contribution)



COSMOGrail

Cosmological **Mo**nitoring of **Gra**v**i**tational **L**enses

... to measure "time delays", to constrain H_0, to learn about DE

EPFL: **G. Meylan, F. Courbin**, V. Bonvin, D. Paraficz

IIA Bangalore: T. Prabhu, C.S. Stalin, R. Kumar

Univ. Bonn: M. Tewes

Univ. Liège: P. Magain, D. Sluse

UzAS Tashkent: I. Asfandiyarov

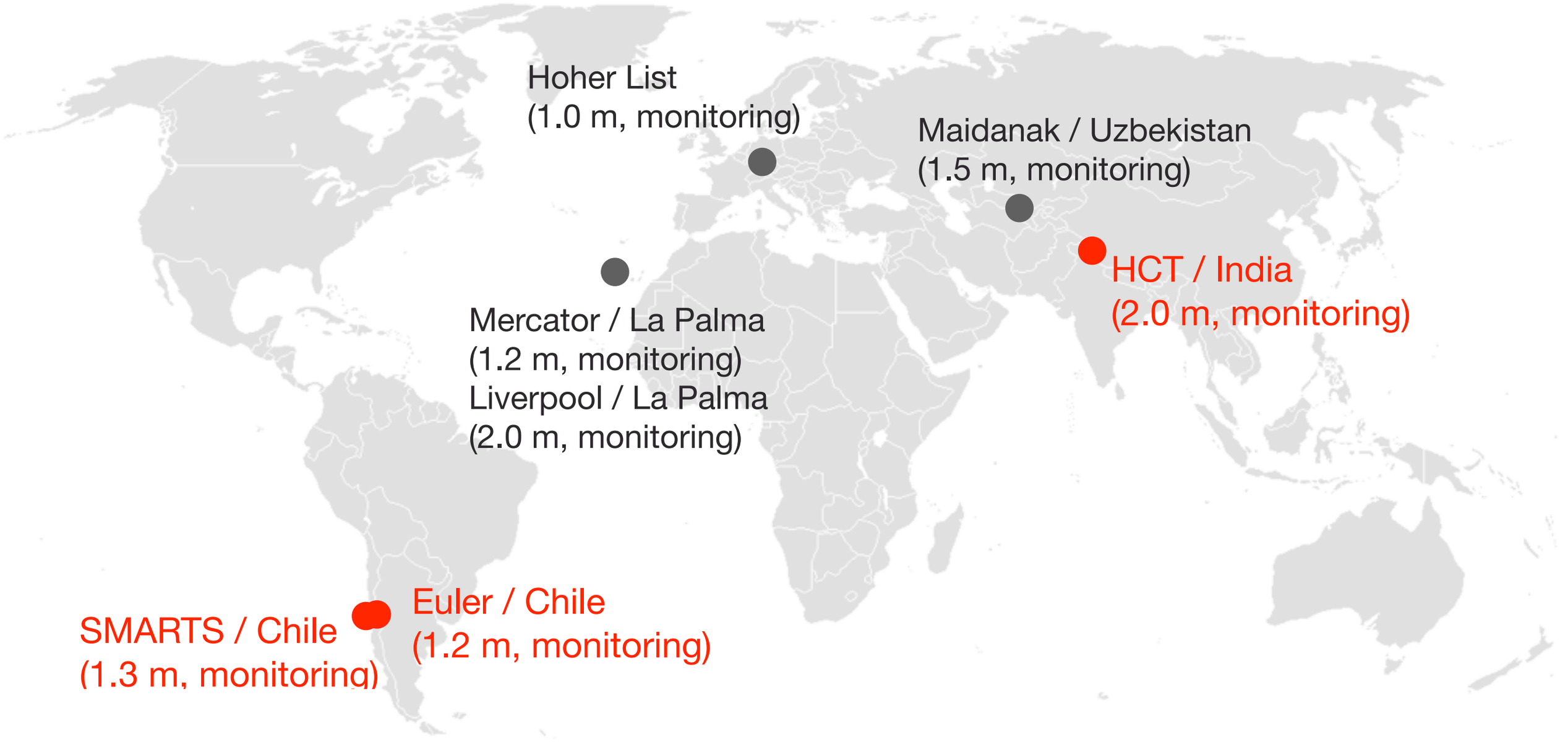
Univ. Zürich: P. Saha, J. Coles

Univ. Nottingham: S. Dye

Now also in close collaboration (monitoring, microlensing) with:
C. Kochanek, A. Mosquera (Ohio), C. Morgan, C. MacLeod, L. Hainline (USNA)

And the lens modeling & cosmography experts :
S. Suyu (ASIAA), T. Treu, M. Auger, P. Marshall, S. Hilbert, C. Fassnacht, R. Blandford, T. Collett

COSMOGRAIL monitoring telescopes



Main teams doing lens monitoring joined forces in 2010 :

1) EPFL-led COSMOGRAIL team (started in 2004) : Lead time delay work
2) Group of C. S. Kochanek (Ohio), using SMARTS 1.3-m : Lead microlensing work

Measurements of time delays (2005+)

- Dedicated (optical) monitoring program to measure many lensed quasars over a decade or more
- Small telescopes are used, but with high temporal sampling
- Deconvolution technique to sharpen the images

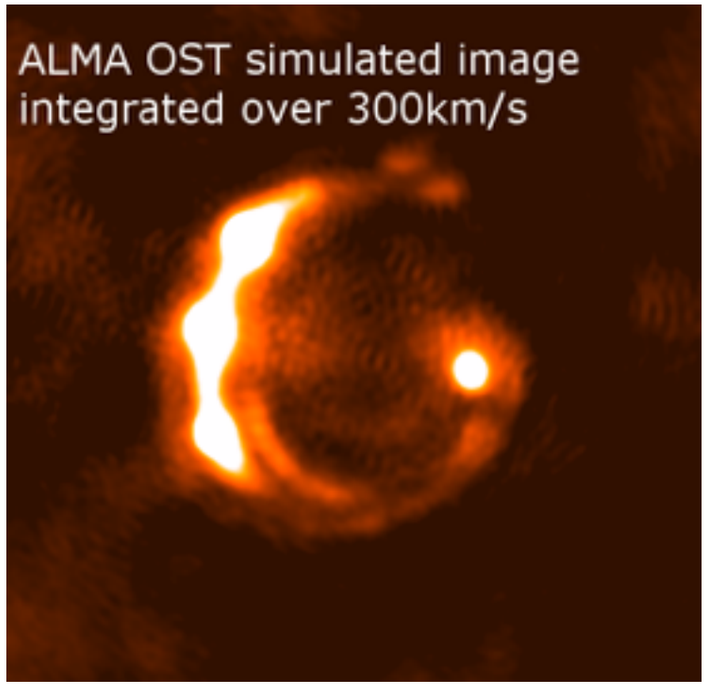
Euler Telescope, La Silla, Chile (1.2m)

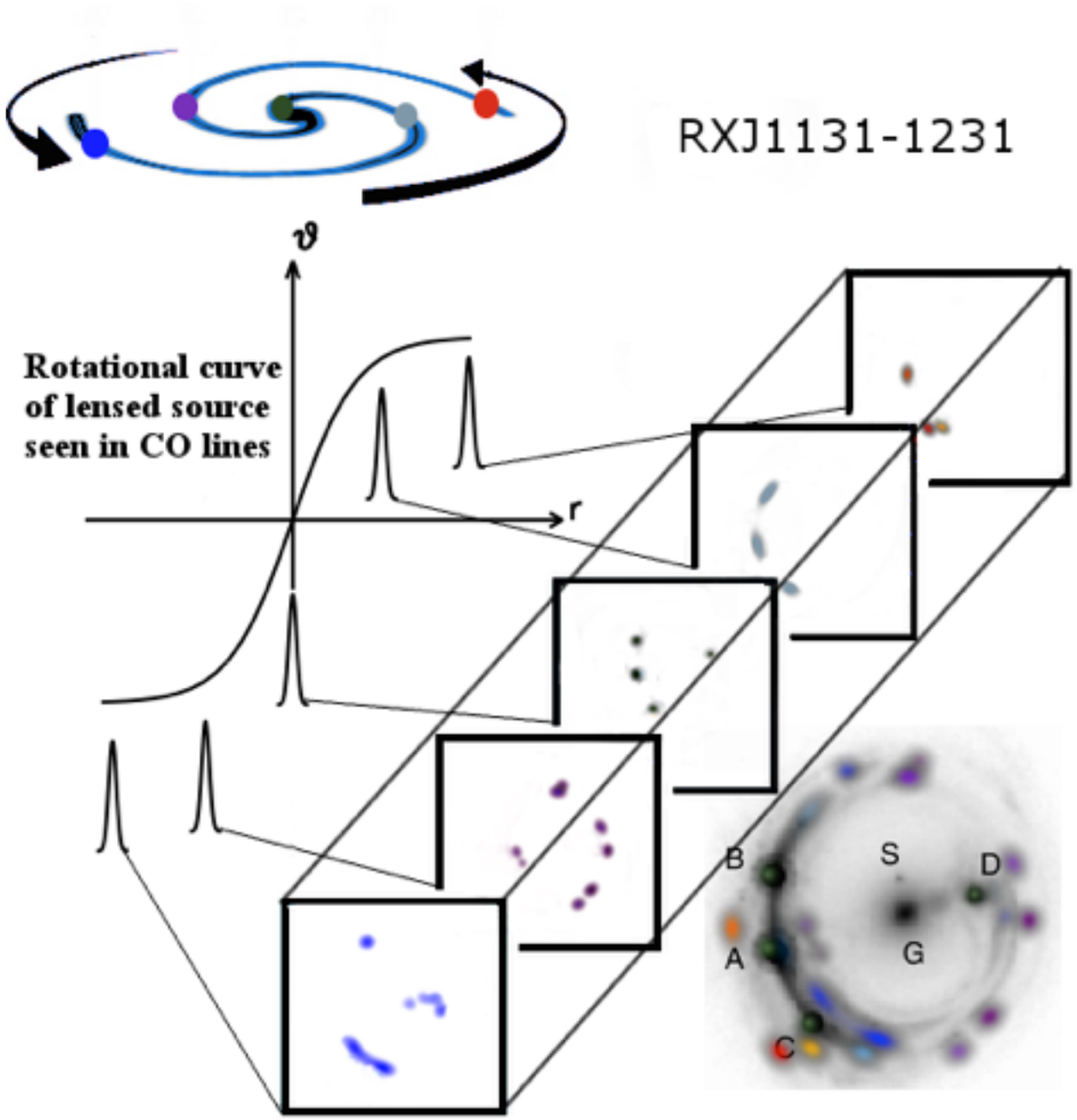
Himalayan Chandra Telescope, India (2m)

Mercator Telescope, La Palma, Spain (1.2m)

Maidanak observatory, Uzbekistan (1.5m)

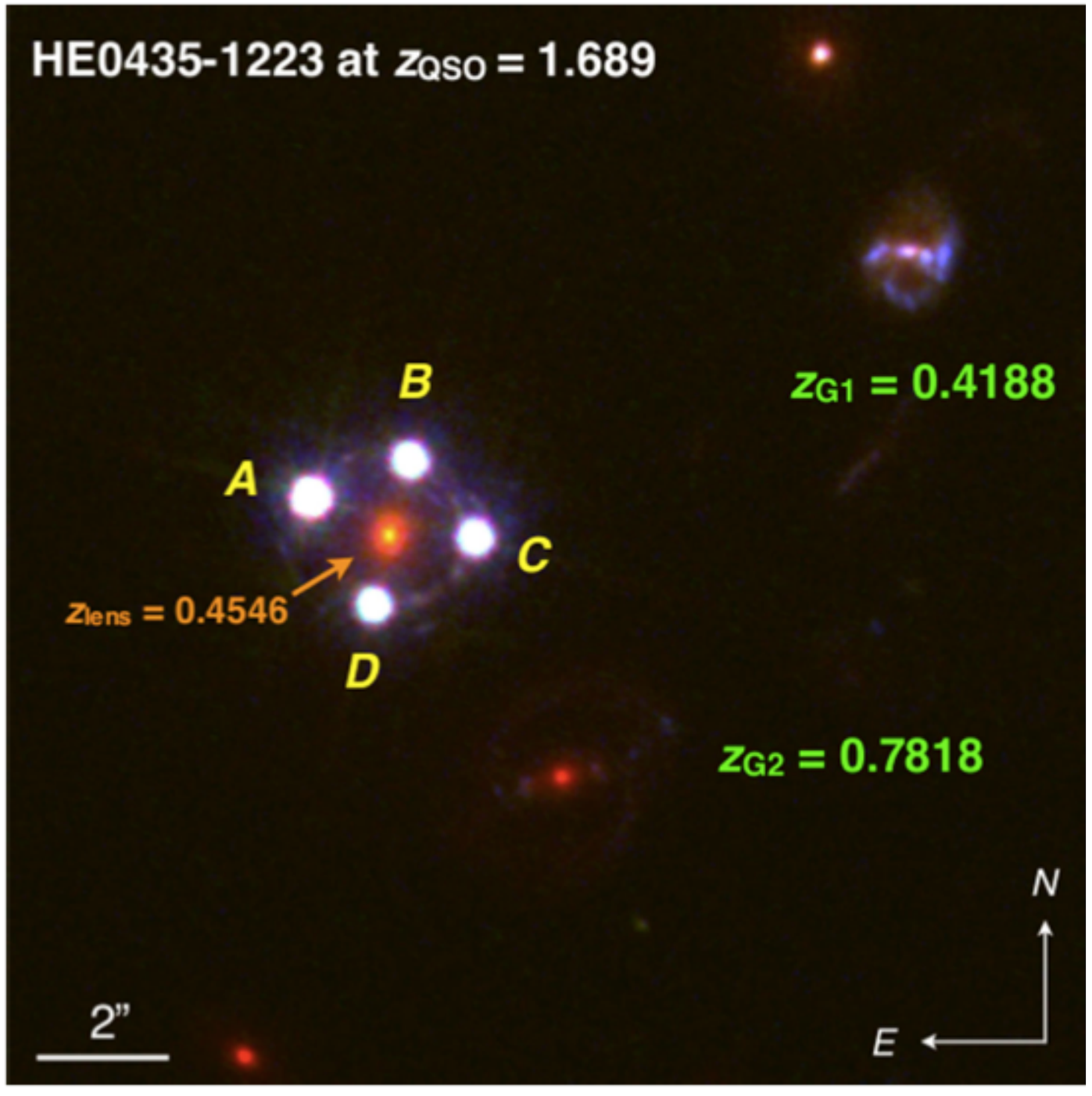
Further Constraints with **ALMA** and **MUSE** and the **NTT**





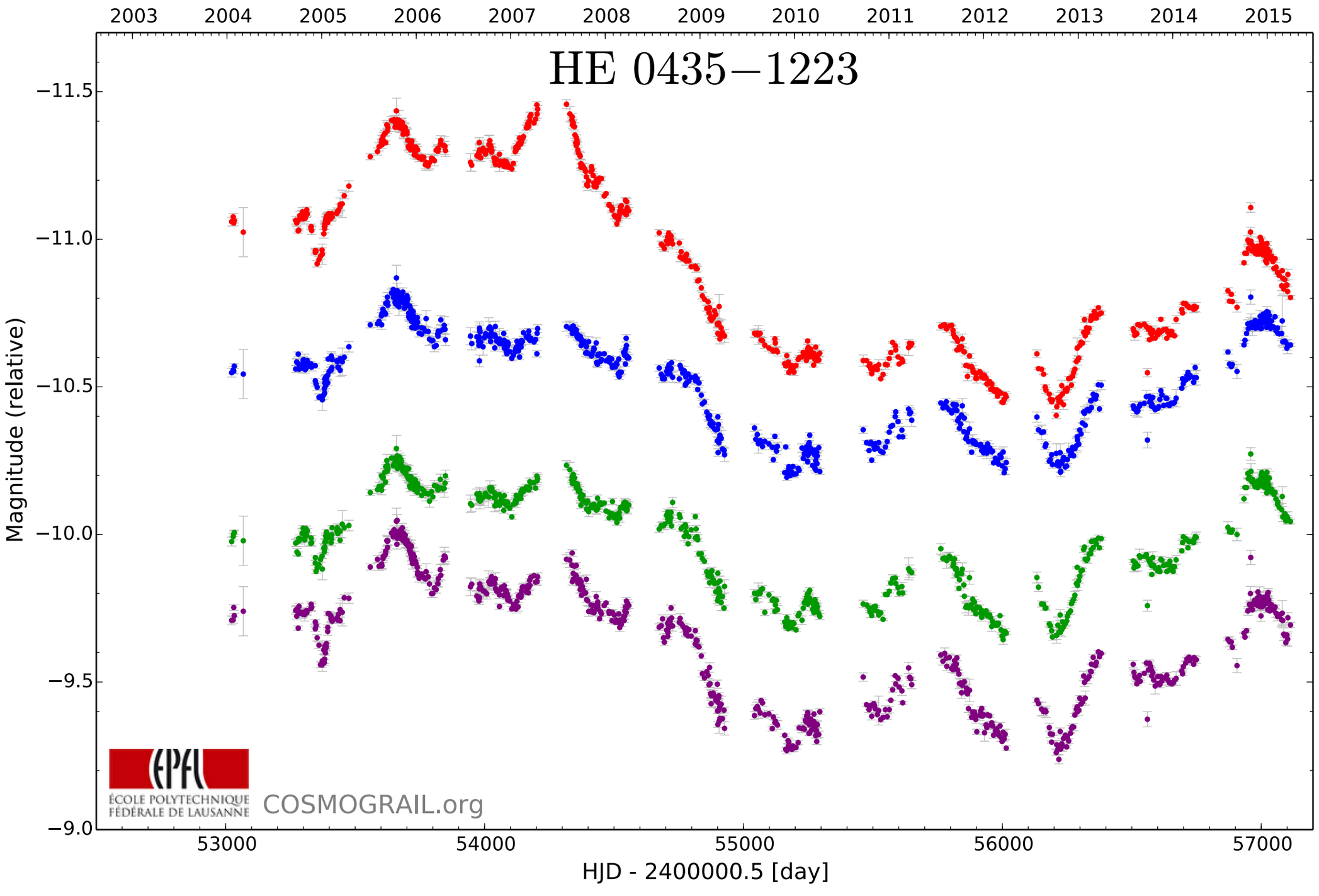
- **ALMA:** velocity field of the **source** and no contamination by the lensing galaxy
- **MUSE (AO):** velocity of the source (OIII) and lens (Ca, NaI)
- **MUSE (no AO):** line-of-sight on 1’ scale
- **NTT:** time delays and their ratios to 1%
- Also with help from **weak lensing (e.g. Subaru)**

HE 0435-1223: next COSMOGRAIL high-quality target



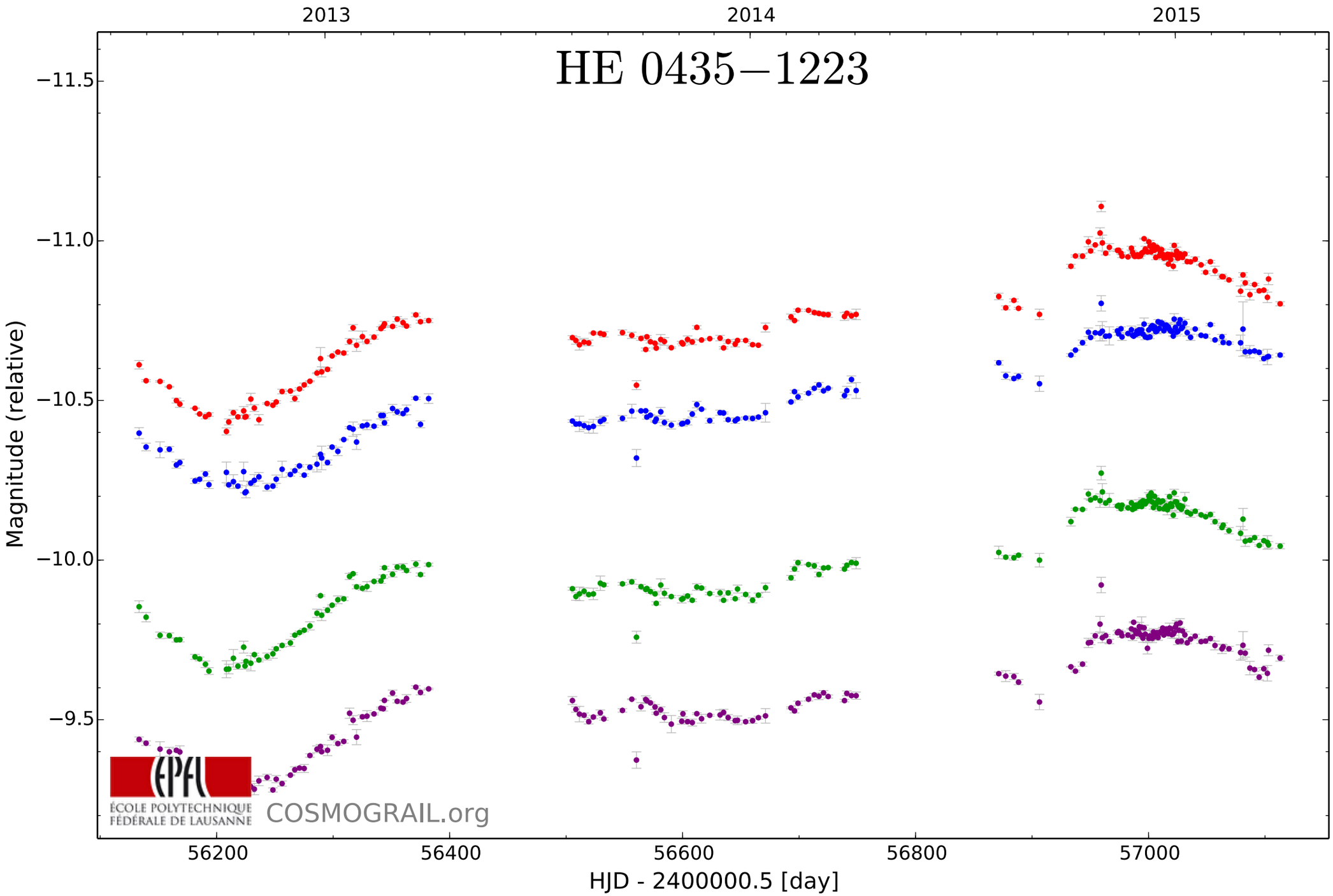
From Hsiao-Wen et al. (2013, MNRAS, 438, 1435)

HE 0435-1223: next COSMOGRAIL high-quality target



Bonvin et al. 2015

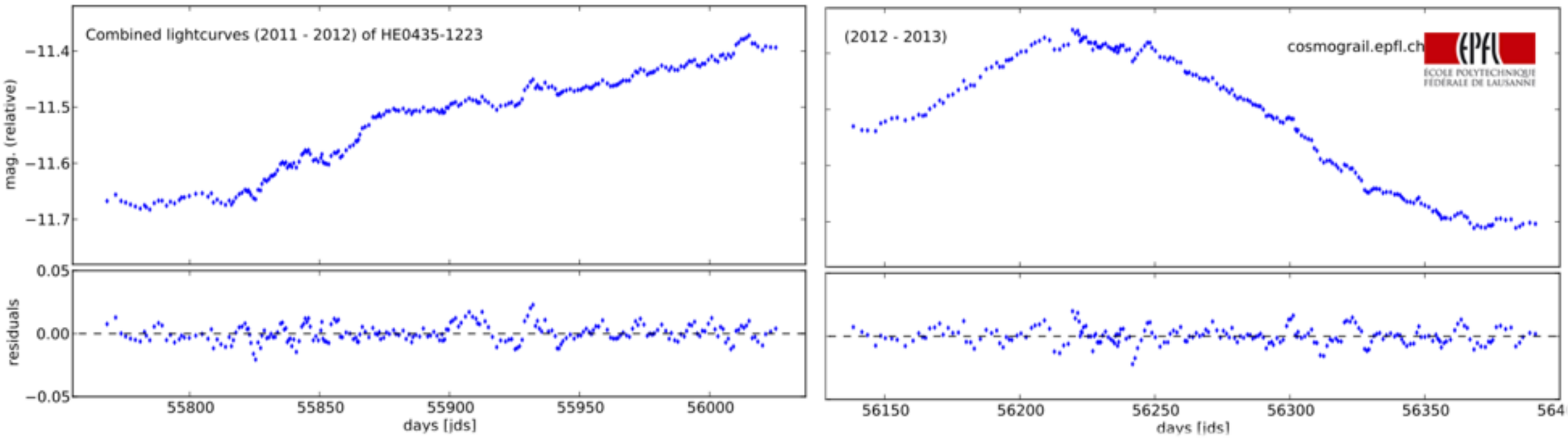
HE 0435-1223: next COSMOGRAIL high-quality target



Bonvin et al. 2015

Future: high cadence monitoring at high SNR (>1000)

«Stacked» COSMOGRAIL data for HE 0435-1223



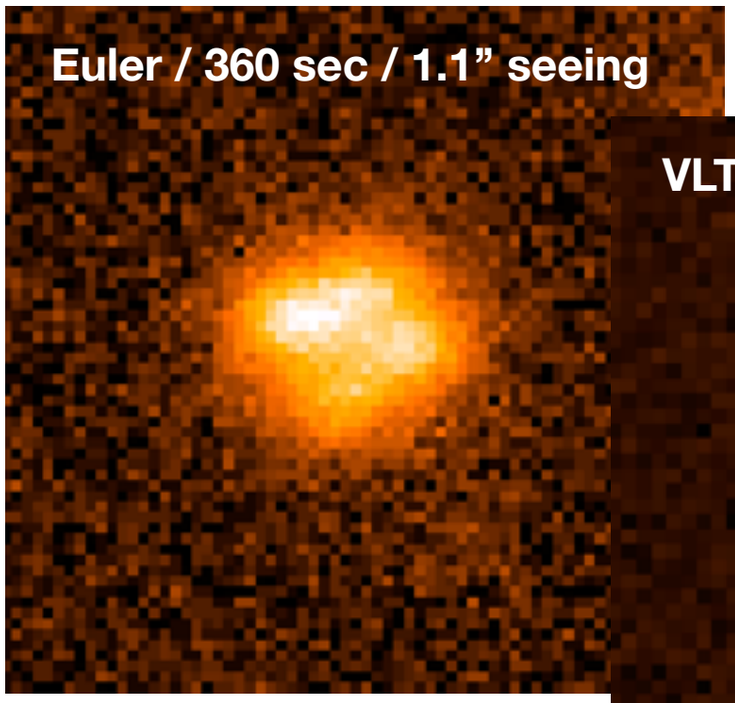
Use small (mmag) variations, shorter than microlensing

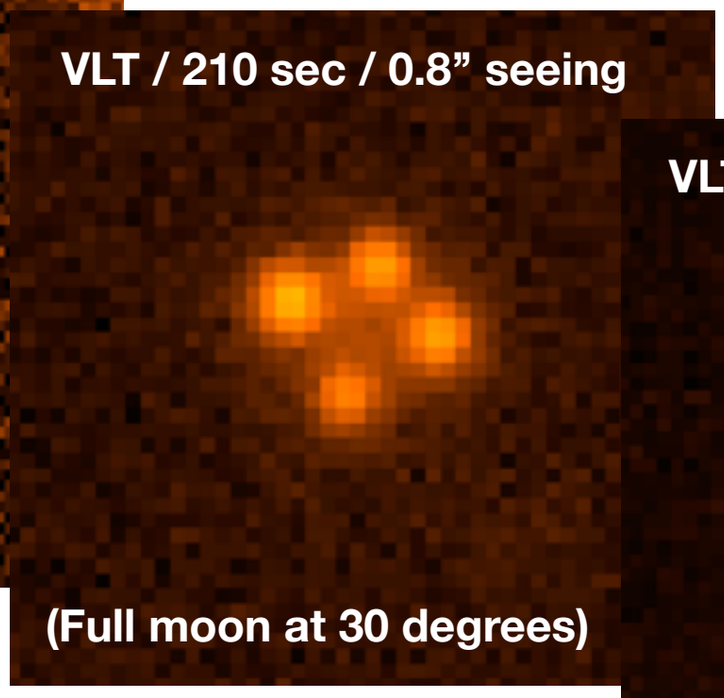
Go to larger telescopes WITH flexible scheduling capability.

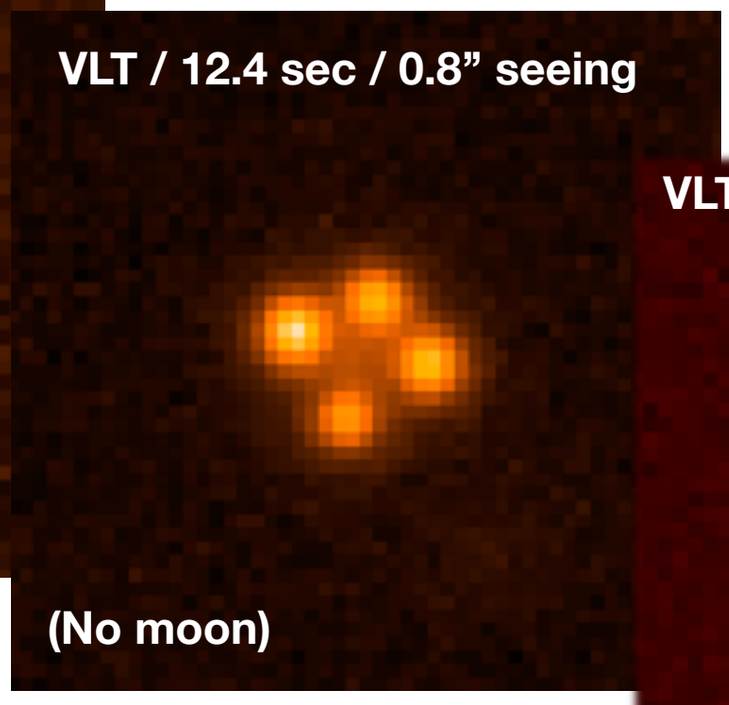
Goal: time delays to 1% or below within a few months of observations

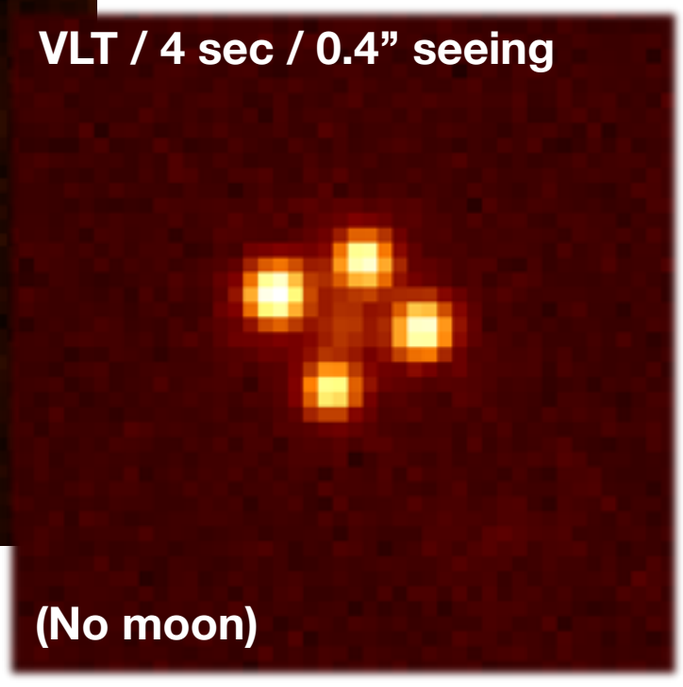
VLT monitoring of HE 0435-1223

- 1 point per day (210 sec exposure) **from Oct 2014 to April 2015**
- Simultaneous monitoring with Euler with improved cadence (1 day^{-1}) in Nov-Dec 2014
- + SMARTS (Kochanek) and LCOGT (Moustakas, Keeton)









Using the ESO 3.5m NTT at La Silla ?

- Call for ideas to use the NTT between 2015 and 2019
- We answered the call in March 2014
- **Confirming DES lenses + spectroscopy of line of sight + daily lens monitoring during 4 periods of 3 months + 10% of the time for «fillers»**
- Pre-selected in August 2014
- Submitted formal proposal to ESO OPC on Oct 1, 2014
- Draft agreement between ESO and us being prepared
- ESO STC and OPC approved the program in December 2014
- **September 2016: start of observations (and of payments !)**

Using the ESO 3.5m NTT at La Silla ?

AGREEMENT

CONCERNING THE GRANTING OF OBSERVING TIME

at the

NEW TECHNOLOGY TELESCOPE (NTT)

at the La Silla Site of the La Silla Paranal Observatory in Chile

between the

European Organisation for Astronomical Research in the Southern Hemisphere

Karl-Schwarzschild-Strasse 2

D-85748 Garching bei München, Germany

hereinafter referred to as ***ESO***

on the one hand,

and the

École polytechnique fédérale de Lausanne

Route Cantonale, 1015

Lausanne, Switzerland

hereinafter referred to as ***EPFL***

on the other hand.

ANNEX A

Standard cost rates for EPFL

1.	**Contribution to the Operations** Per executed observing night at the NTT (2015) The above nightly rates are subject to revision due to yearly cost variation indexing as approved on an annual basis by ESO internal bodies.	€ 4150
2.	**Travel, Board and Lodging Costs in Chile (Rates as of January 1, 2013)**	
	Lodging in ESO Guesthouse Santiago (breakfast included)	€ 60.00
	Main meal in ESO Guesthouse Santiago	€ 15.00
	Round trip air transfer to/from La Serena	€ 130.00
	24 hrs stay at La Silla	€ 60.00
	One – way surface transport between La Serena and La Silla	€ 25.00
	Transfer (one-way) within Santiago	€ 25.00
	The above prices for board, travel and lodging are subject to revision and are updated on a regular basis and can be found at "http://www.eso.org/sci/observing/travel/visas-instruc.html". The board, travel and lodging prices published on the ESO website shall prevail.	

Total cost: <u>1.5 Meuro</u> for 1 full year of NTT (split over 4 years)

Using the ESO 3.5m NTT at La Silla ?

	Target ($Euros/year)	Obtained	Period	
EPFL	190 000	48 000	per yr, until 2017	
UCLA	70 000	70 000	per yr starting now	
ASIAA	30 000	30 000	per yr starting now	
UC Davis	14 000	14 000	per yr starting now	
Fermilab	80 000			Currently applying for funds
OSU	max 40 000			Need to choose between SMARTS and the NTT
JPL				Currently applying for funds
Rutgers				No recent news
Cambridge	max 40 000			No recent news
Stanford	22 000			Through LSST (TBC)
Chile	up to 30 nights (?)			Will contribute with time and observers
TOTAL				
	375 000 per year needed			

+ Paul Schechter contributing to the observations

Almost 50% of the funding for the first two years is secured
Please chase more funding !

Summary

- **COSMOGRAIL** provides the best possible time delays

- **H0LiCOW**: H_0 Lenses in COSMOGRAIL Wellspring
  --> turns time delays into cosmology

- **DES (STRIDES),** KIDS, LSST will discover hundreds of new targets

We are here to:

- Share time delays and improve them
- Find new lenses in the southern sky
- Plan and share follow-up data (confirm lenses, kinematics, line-of-sight)
- Fight the MST and the SPT (toy models ? Full N-body simulations ? Both ?)
- Plan the future of time delay cosmography (NTT, LSST)
- Convince the cosmology community that time delays are useful !