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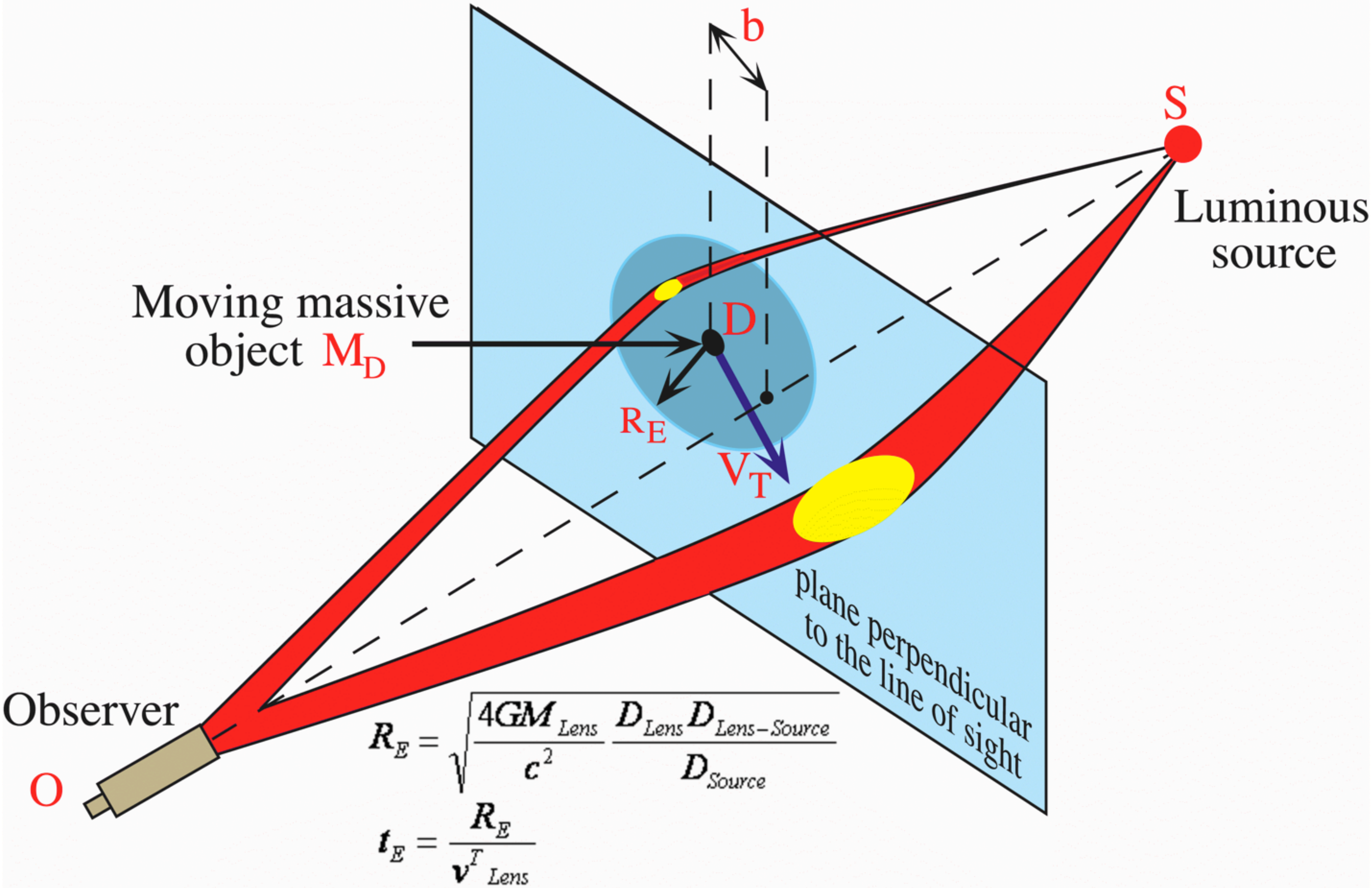
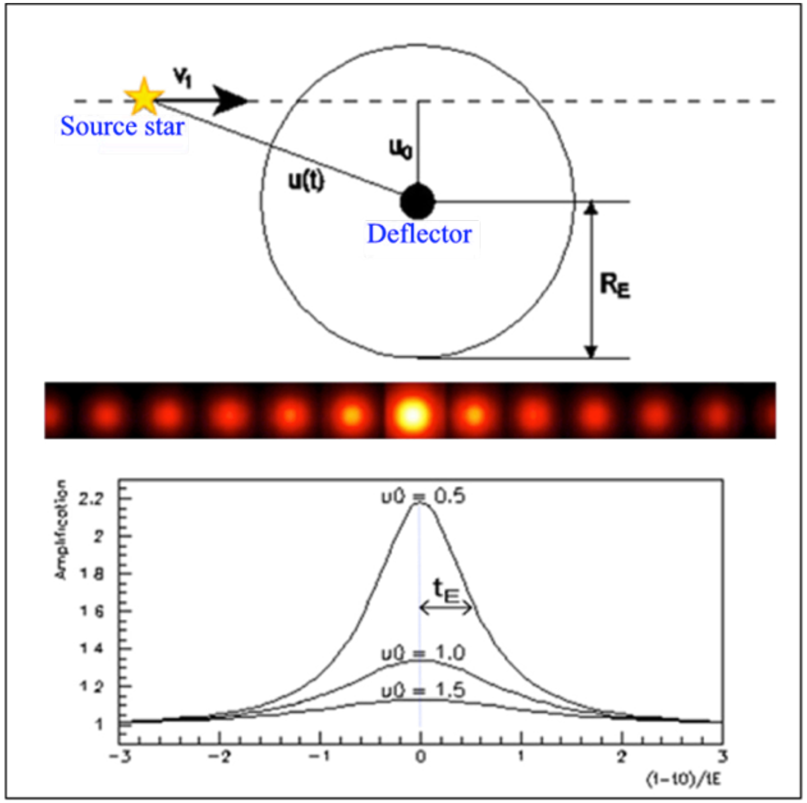
Baryonic hidden matter: search for Microlensing and interstellar scintillation with LSST



GRAVITATIONAL MICROLENSING EFFECT

Description of a microlensing event



Light curve characteristic:

- Symmetric
- Achromatic
- Unique (~1 evt / 10^6★)

Point-lens, point-source, rectilinear relative motion

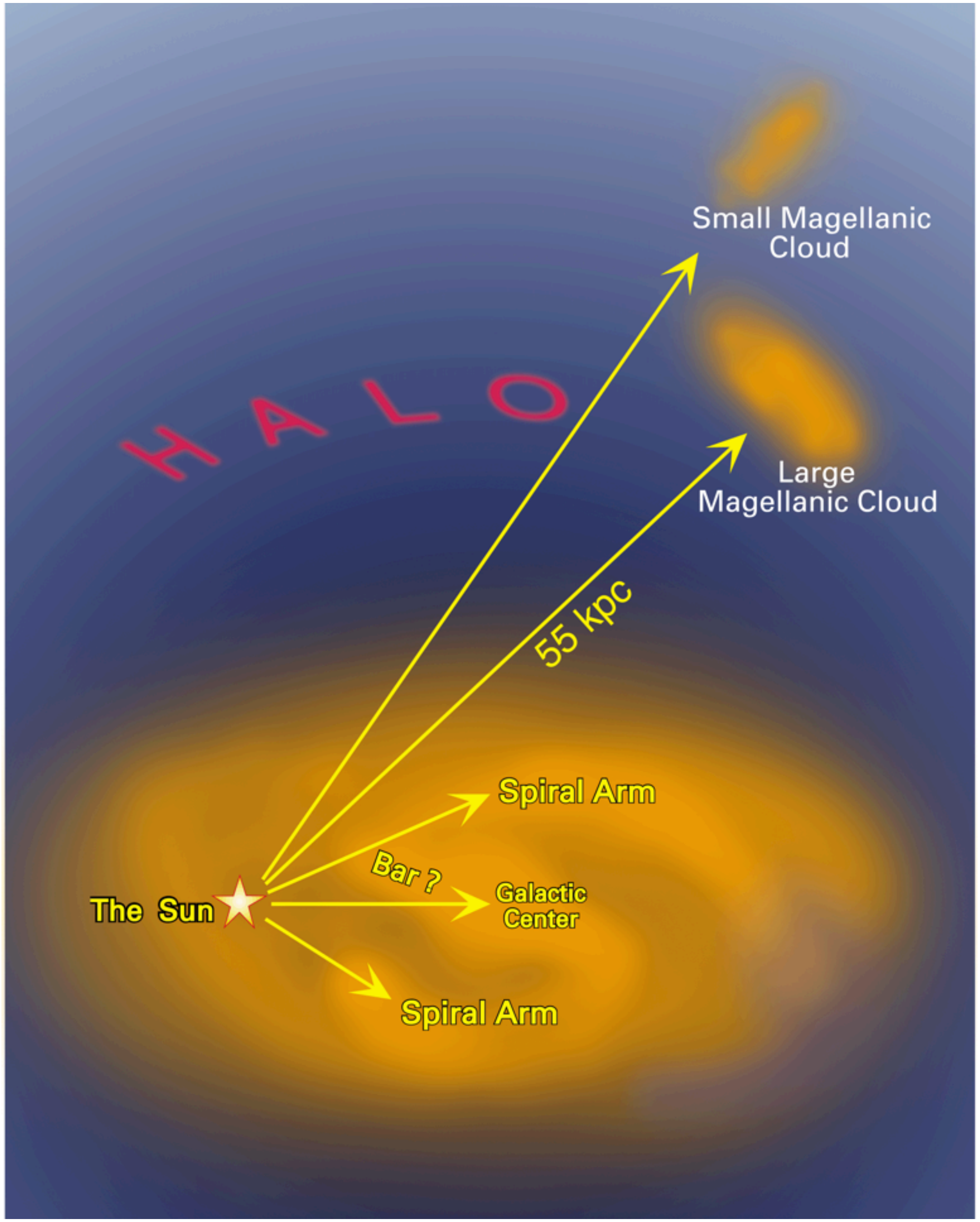
The optical depth τ :

probability for a star to be behind an Einstein disk

Disk surface α R_E^2 α M_{lens}

$\Rightarrow \tau \,\alpha \sum M_{lens}$

α total mass of the probed structure

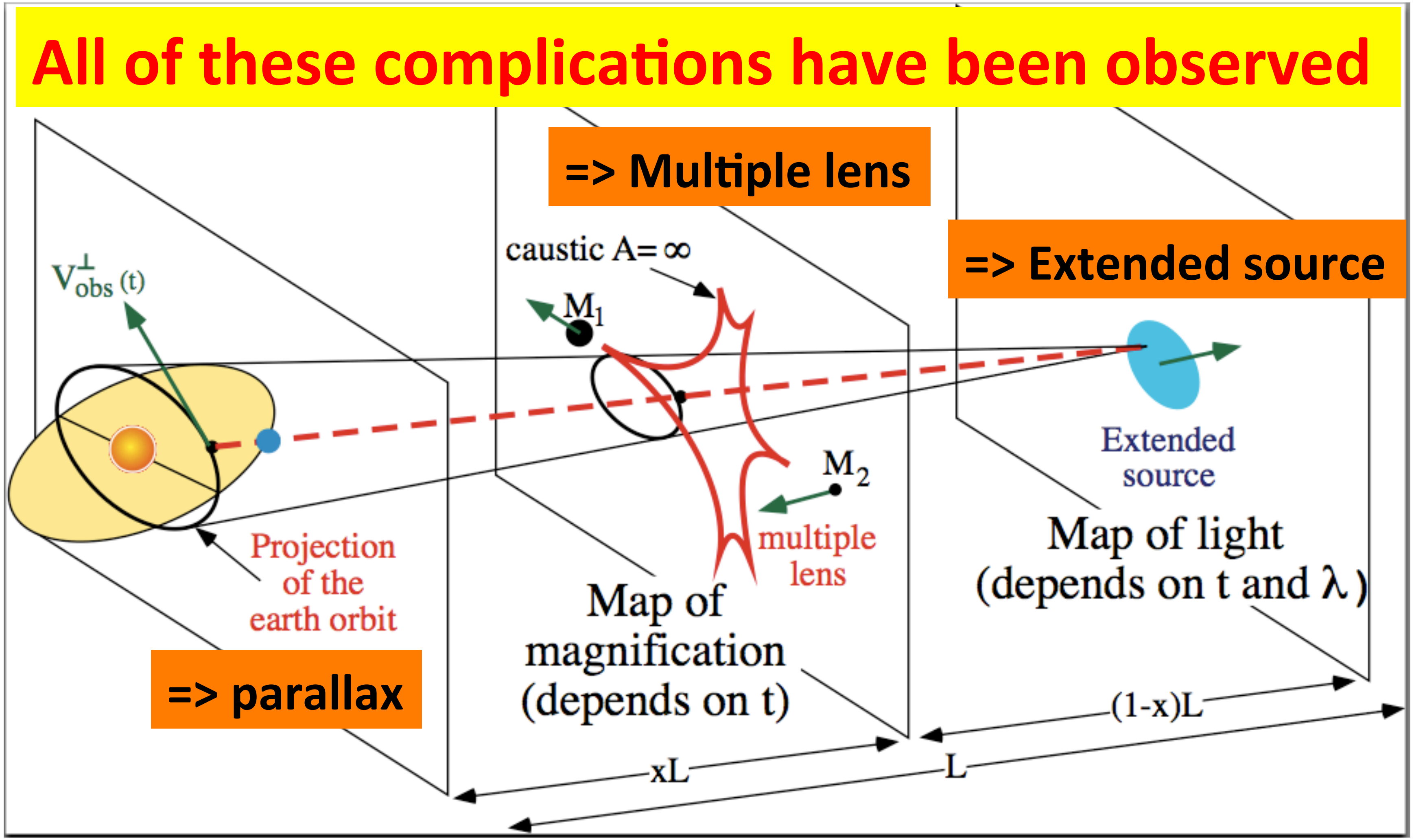


Main targets

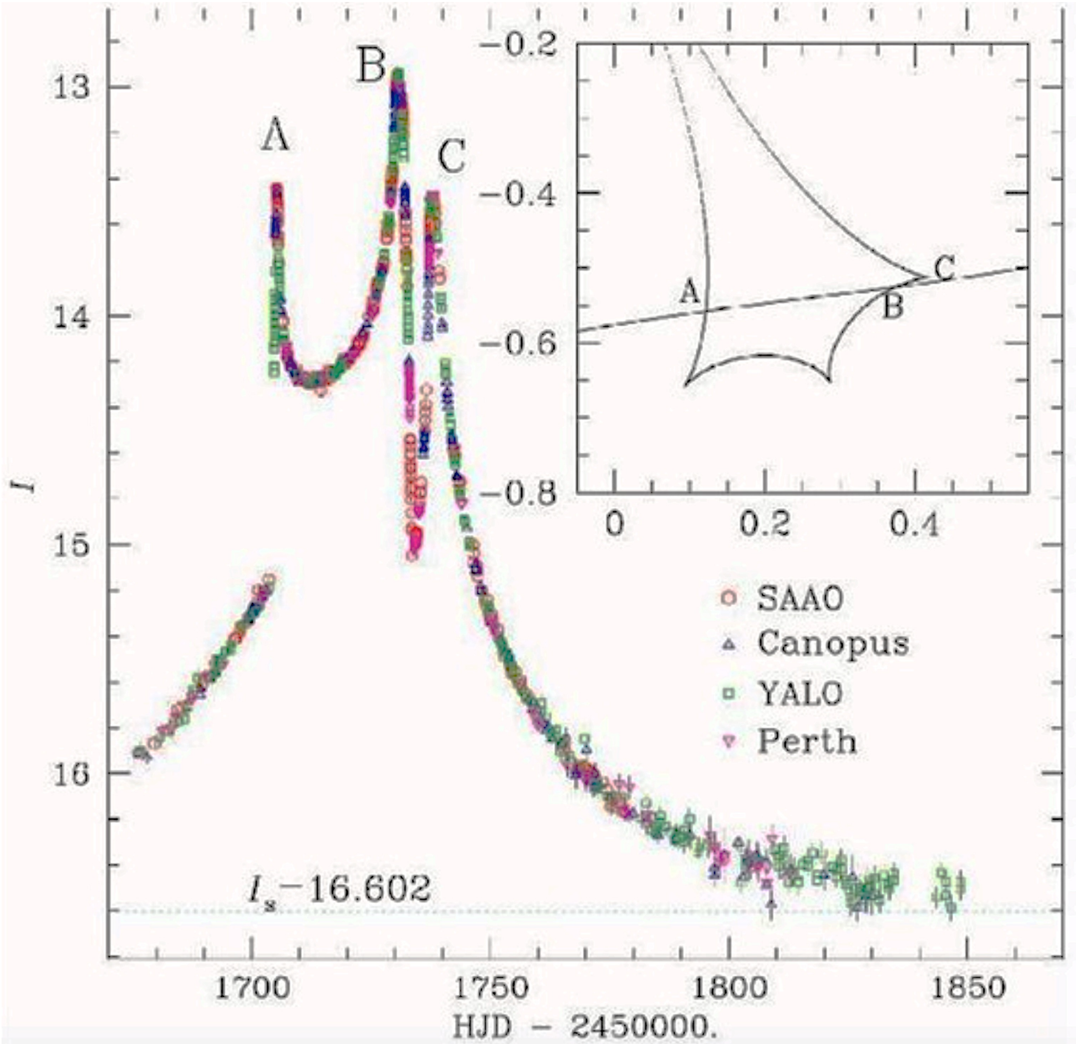
monitored since 1990's

- **Magellanic Clouds** => probe hidden matter in **halo** **($\tau \sim 5.10^{-7}$)**
- **Galactic center** => probe ordinary stars as lenses in **disk/bulge ($\tau \sim 2.10^{-6}$)**
- **Spiral arms**
  => probe ordinary stars in **disk, bar** + hidden matter in **thick disc ($\tau \sim 5.10^{-7}$)**
- **M31**

Beyond the simple approximations



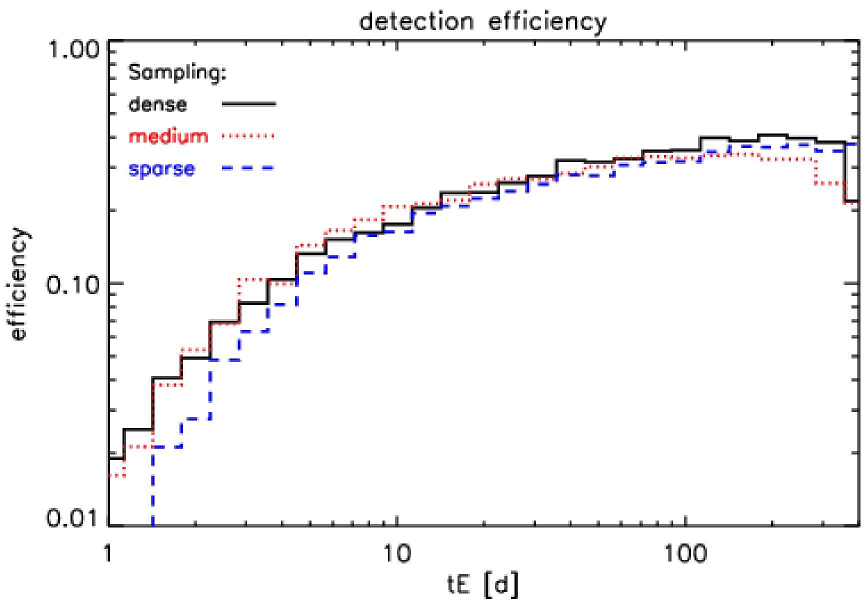
Microlens alert EROS 2000-BLG-5

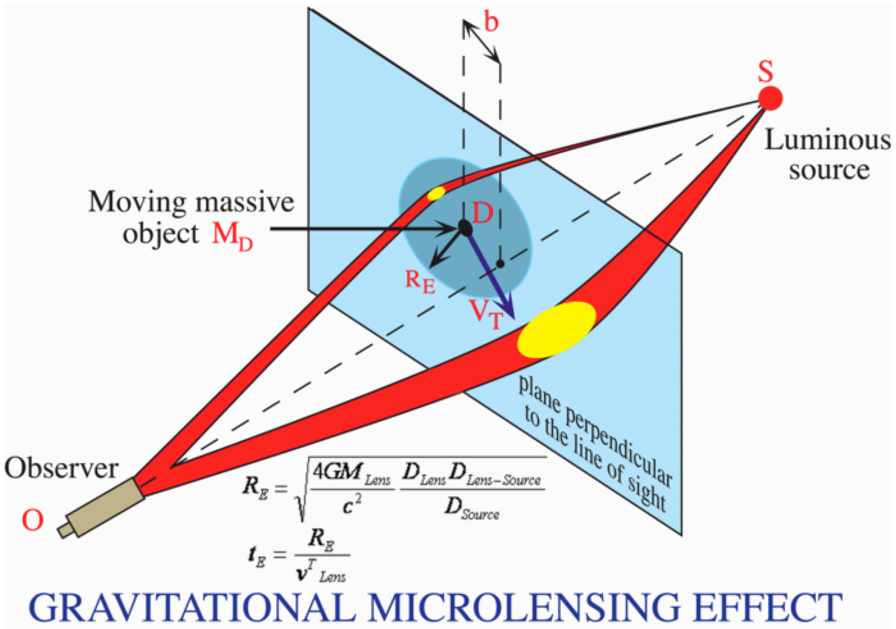


- **Binary lens** effect on a giant star from the Galactic Center
- Discovered by **EROS alert system**
- Photometric follow-up by PLANET, MPS, EROS coll.

  => exceptional time sampling
- Resolve source surface (photo and spectro)

Microlensing expectations



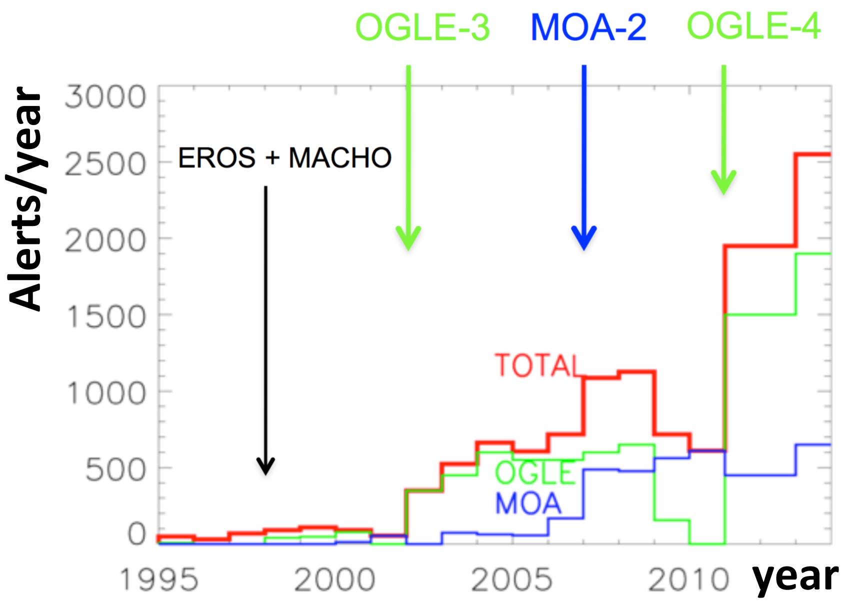


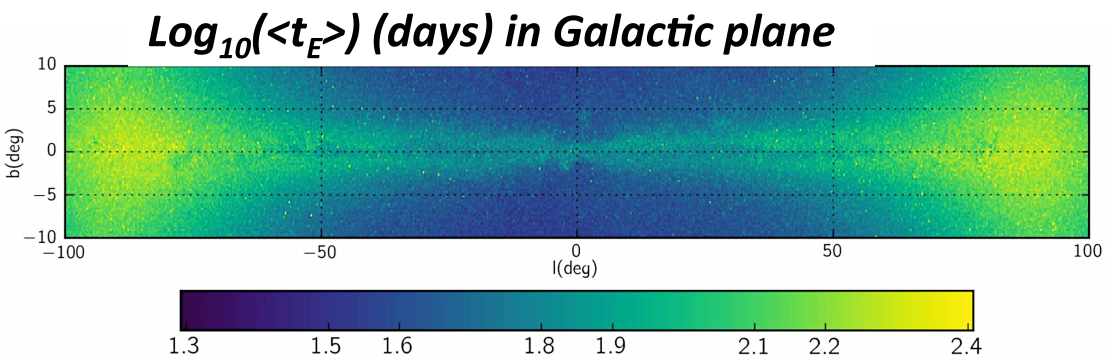
- O(10^8 stars) monitored
- with Δm < 5mmag
- Towards Milky-Way
- Towards LMC/SMC
- On average every 4th night during 10 years

Table 8.4: **Nearby Microlens Event Rates**

	Past	**Present**	**LSST ?**	
	per decade	per decade	per decade	per decade
Lens type	per deg^2	per deg^2	per deg^2	**over 150** deg^2
M dwarfs	2.2	46	920	1.4×10^5
L dwarfs	0.051	1.1	22	3200
T dwarfs	0.36	7.6	150	2.3×10^4
WDs	0.4	8.6	170	2.6×10^4
NSs	0.3	6.1	122	1.8×10^4
BHs	0.018	0.38	7.7	1200

LSST Microlensing perspectives





- **Search for Galactic black holes (M > 10 Msol): long events (years)**
  - Hidden baryonic matter in Milky-way
  - Estimate GW rate
- **High statistics (10 000's of events)**

  -> **map the Milky-way**

  - optical depth τ

  - duration distrib. moments $<t_E>$ and $\sigma(t_E)$

(Note that detection of all durations should be optimised through varying time sampling)

-> Associated science

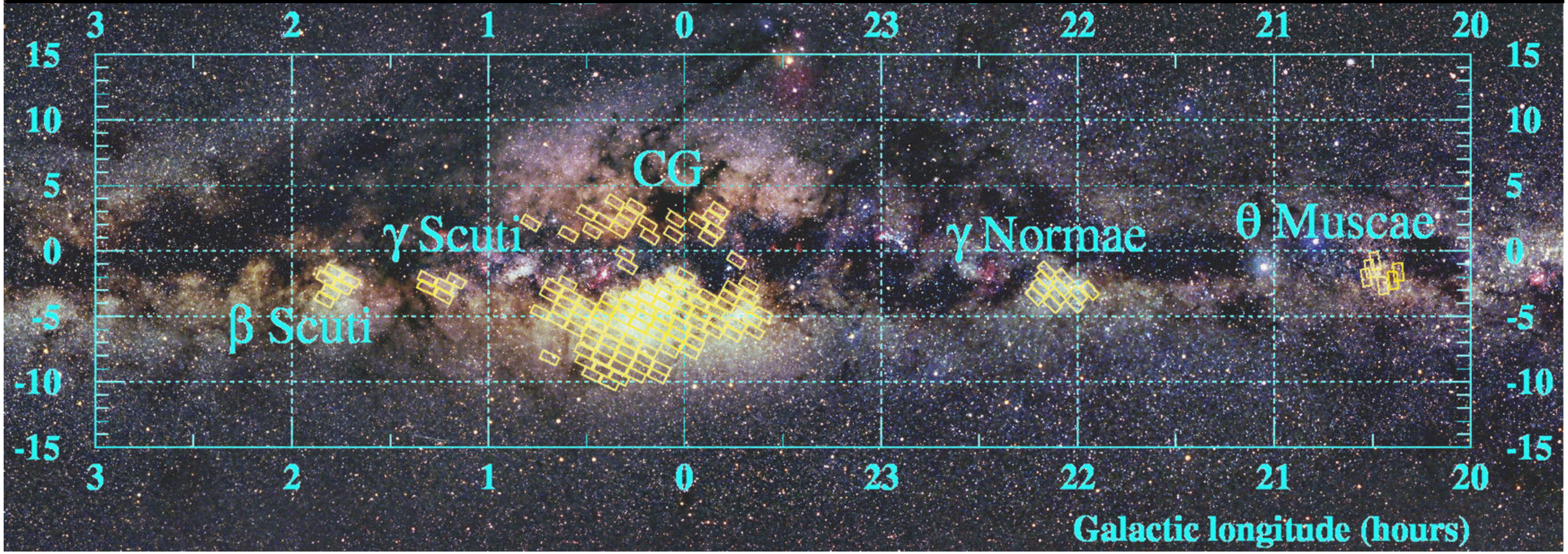
- Milky-way kinematical structure
- Lens IMF
- Thick disk contraints, hidden baryonic mass

Detection of special events (caustic…)

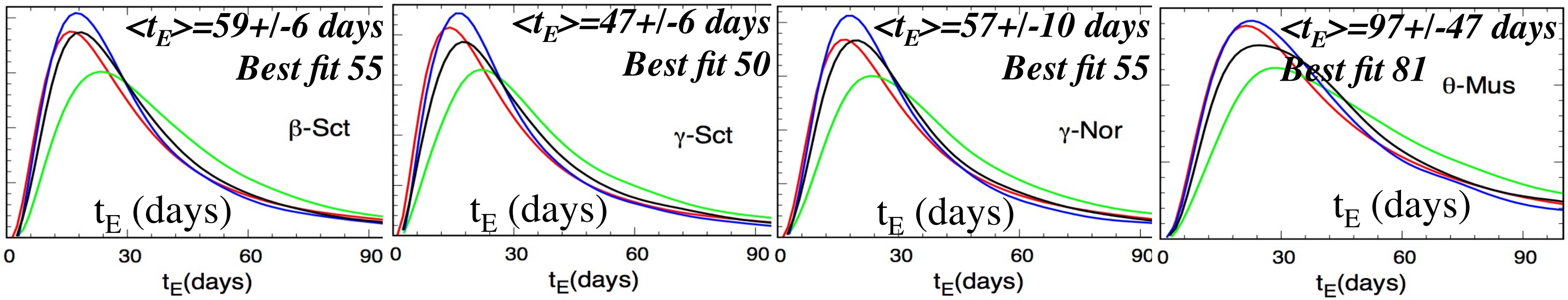
-> coupling with follow-up through **early alert system**

- Binarity, planetary systems

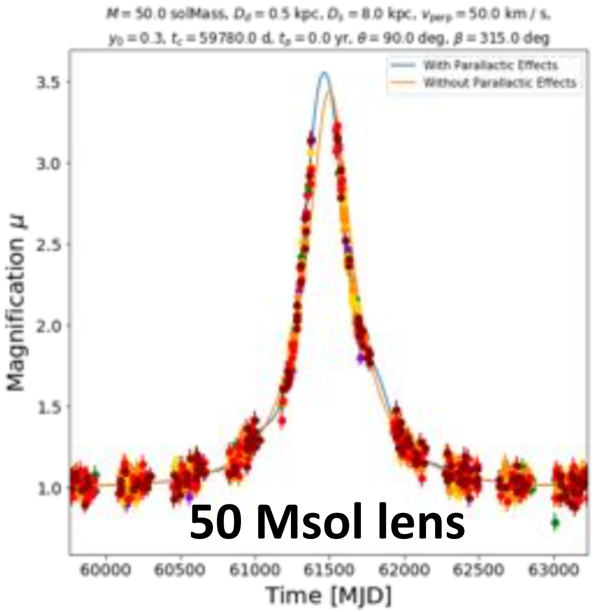
Mapping the Milky way: spiral arms

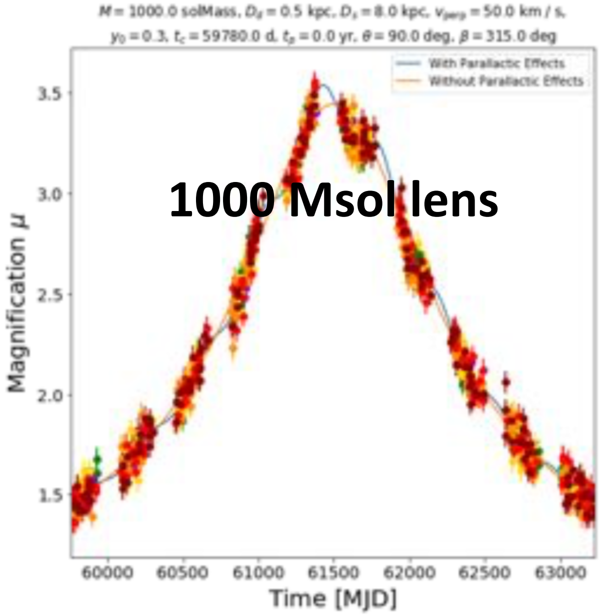


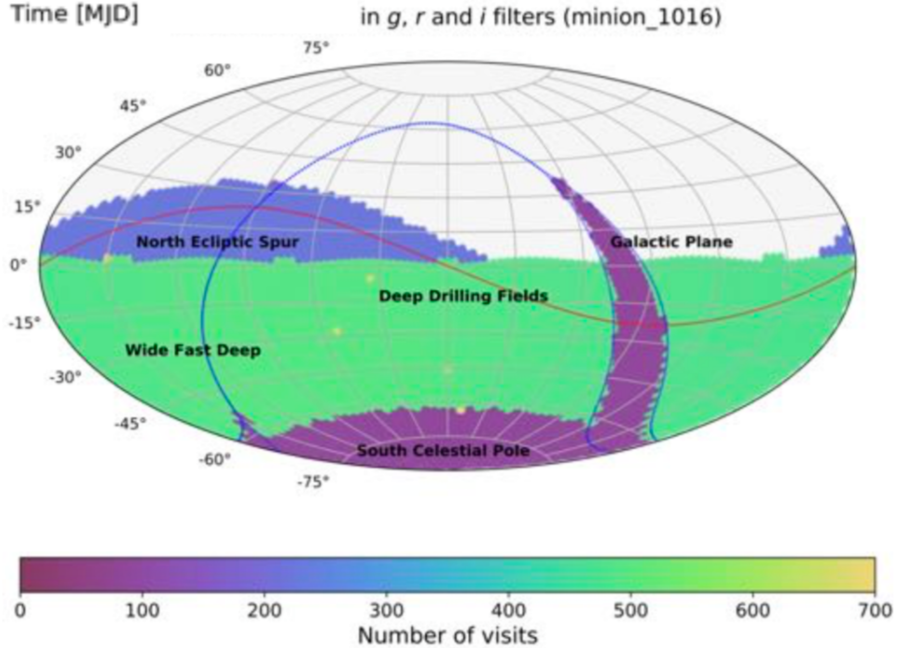
$\tau_{measured}$ =	$0.30^{+.23}_{-.20}$	$0.72^{+.41}_{-.28}$	$0.49^{+.21}_{-.18}$	$0.67^{+.63}_{-.52}$
$\tau_{simple\ mod.}$ =	0.45	0.43	0.38	0.23
$\tau_{Besançon}$ =	0.40	0.44	0.34	0.22



LSST microlensing with standard sampling





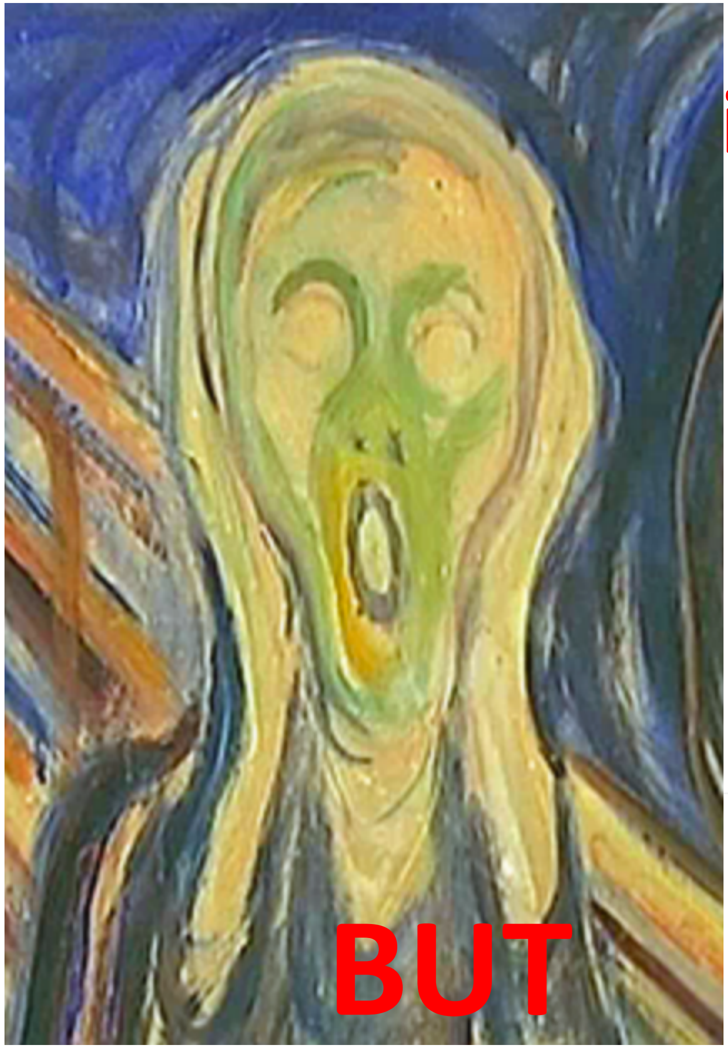


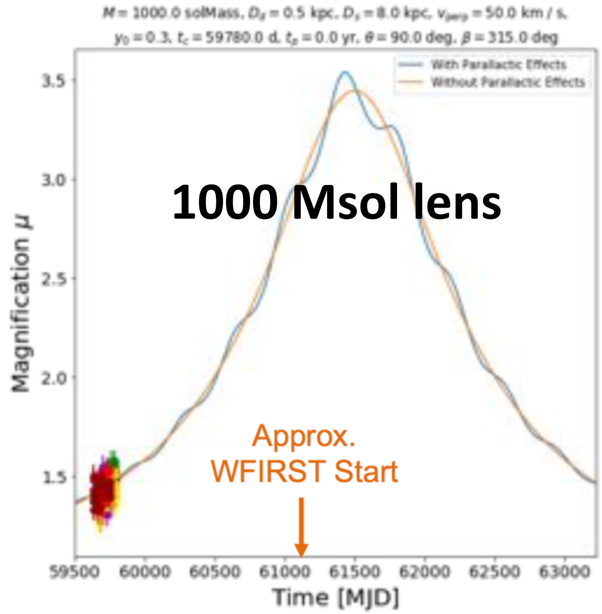
BUT

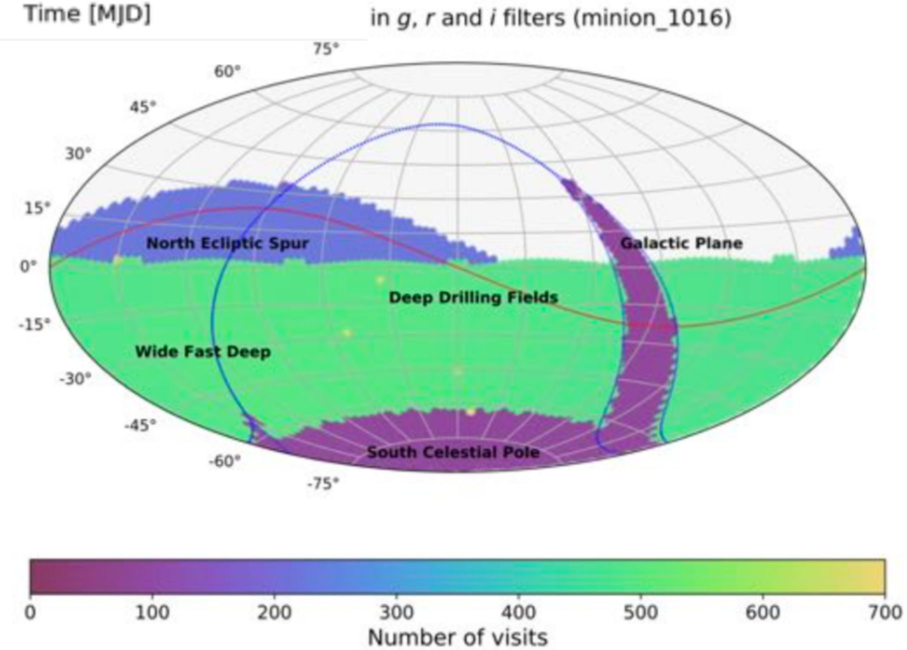
The Galactic plane and LMC/SMC **are not** in the main survey
-> All Galactic plane fields taken only 180 times.

IF all the same year -> catastrophic

ing with standard sampling







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Microlensing with LSST

- **Excellent potential BUT**

Need optimising strategy towards Galactic Plane + LMC/SMC

- Is there a good reason to have all Galactic Plane images taken in only one year?

  If not: spread over the 10 years at no cost

- **LMC (+SMC)** probably deserves **a dedicated deep field**

Major benefits of LSST

- Use astrometric info. to decrease microlensing degeneracy (D_{os})
- Excellent photometric repetability (<0.5% for g<25) allows to search for large impact parameter events and deviations from point-source point-lens rectilinear events

Synergies

- **EUCLID, WFIRST** (parallax, NIR)
- On Earth **follow-up telescopes**

The expected proper motion, parallax and accuracy for a 10-year long baseline survey.

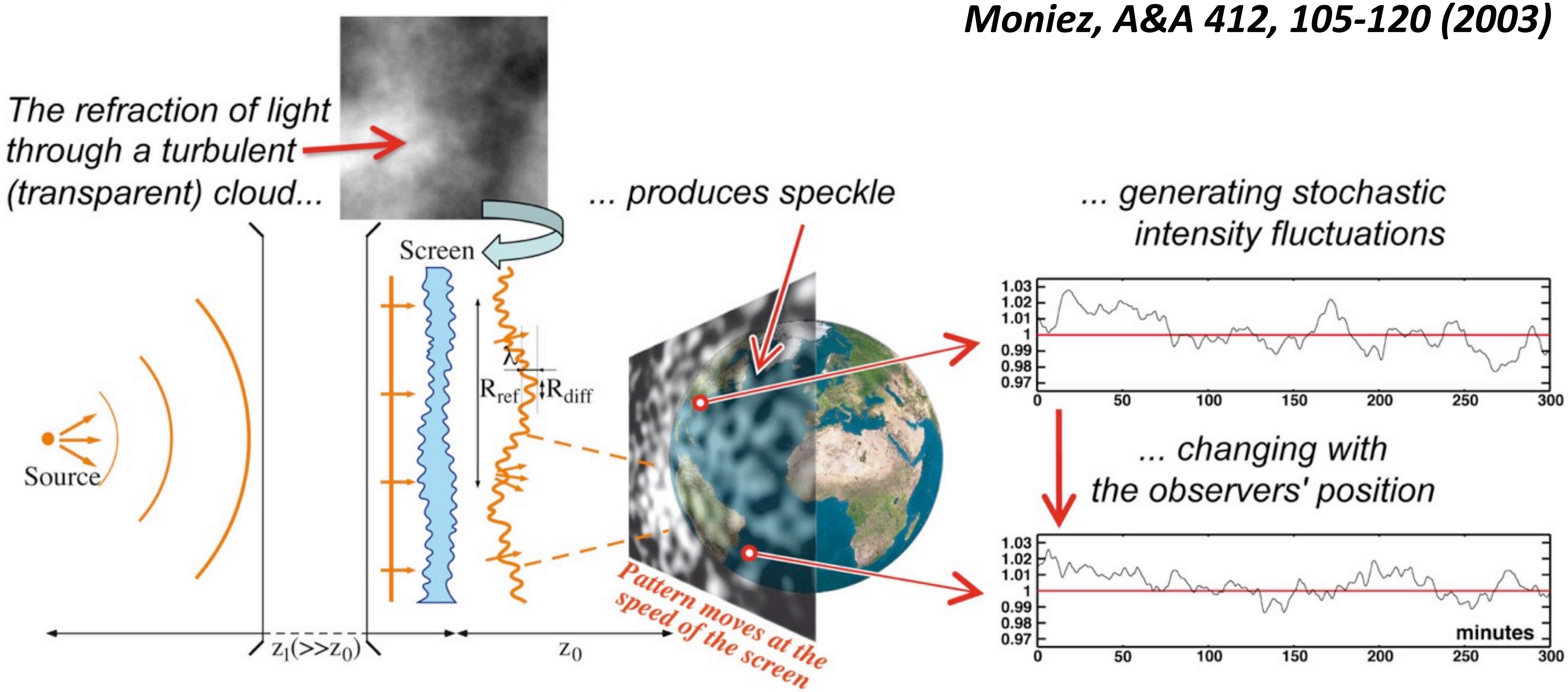
r mag	σ_{xy}^a mas	σ_π^b mas	σ_μ^c mas/yr	σ_1^d mag	σ_C^e mag
21	11	0.6	0.2	0.01	0.005
22	15	0.8	0.3	0.02	0.005
23	31	1.3	0.5	0.04	0.006
24	74	2.9	1.0	0.10	0.009

[a] Typical astrometric accuracy (rms per coordinate per visit);
[b] Parallax accuracy for 10-year long survey;
[c] Proper motion accuracy for 10-year long survey;
[d] Photometric error for a single visit (two 15-second exposures);
[e] Photometric error for coadded observations (see Table 1).

Search for missing H_2 turbulent galactic gas

through scintillation detection (the OSER project)

Moniez, A&A 412, 105-120 (2003)



Light received by telescope varies with

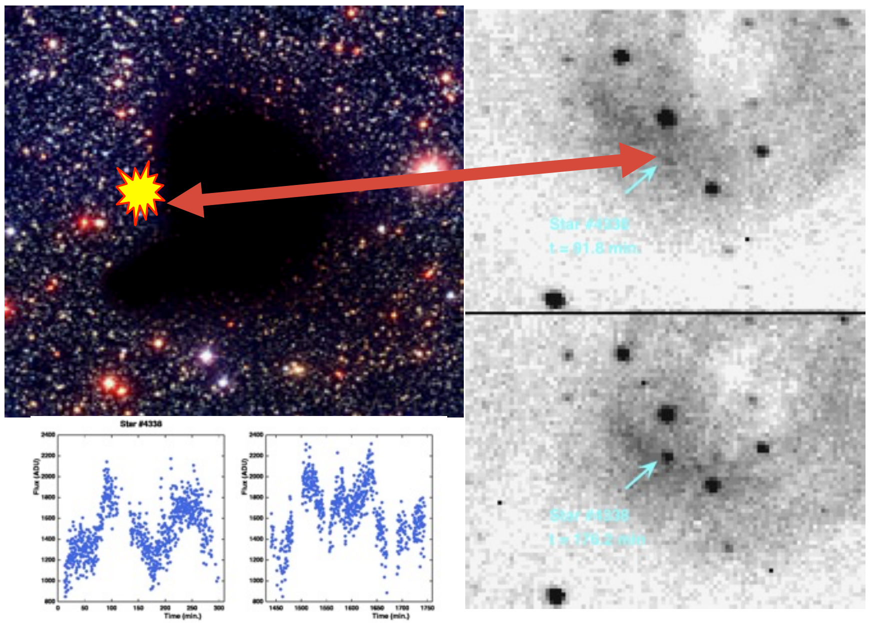
- ***timescale ~10 min*** *(due to the relative velocity of the gas)*
- ***modulation of a few %*** *(depending on distances / turbulence parameters / source extension)*

Results from feasibility studies

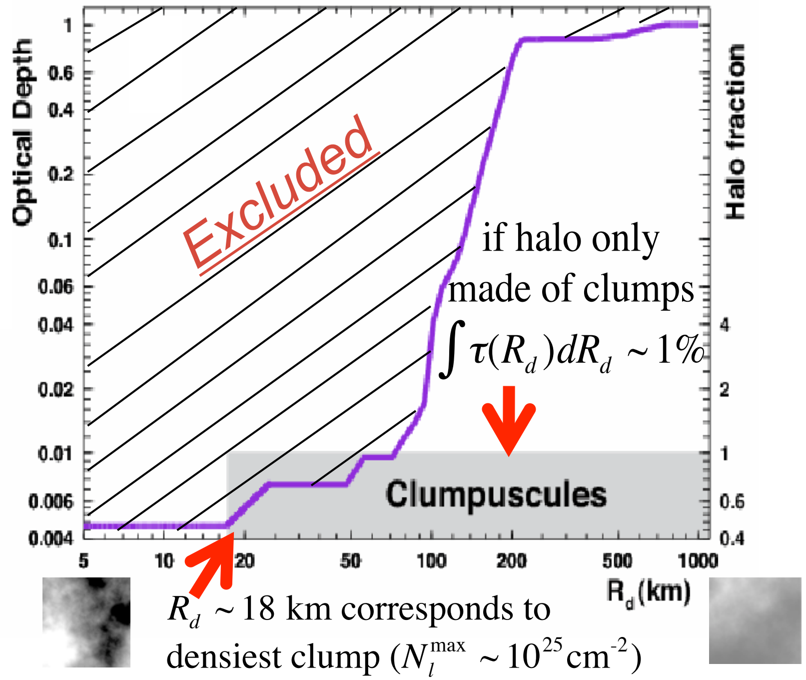
Based on

- Simulation of fractal clouds and the Fresnel diffraction involved
  -> Habibi, Moniez, Ansari, Rahvar, A&A, 552, A93 (2013)
- Test data taken with the 3.6m ESO-NTT telescope
  -> Habibi, Moniez, Ansari, Rahvar, A&A 525, A108 (2011)

A star scintillating through visible gas?



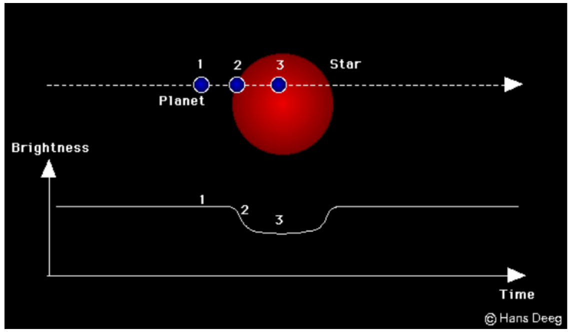
Upper limits on scintillation probability =>
constrain the turbulent gas abundance

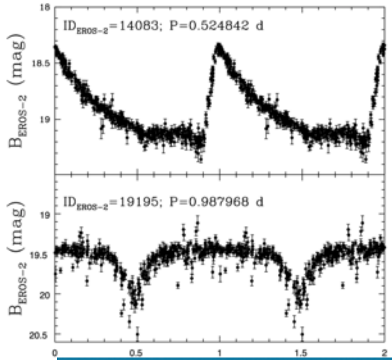


A movie dedicated to LMC

Proposed nano-survey (during commissioning?)

- Take a **~ 8 hour movie** of 15s consecutive exposures of the same LMC field in R
- O(1000) exposures
- Ideal to search for **scintillation** due to hidden gas-clouds
- **Also ideal for**
  - Planetary transits
  - Very short time-scale microlensing events due to <10^{-8} Msol objects
  - RR-Lyraes and other (very) short time-scale variables
  - Atmospheric subtle fast variation studies
- Technical bench
- Serendipity





Supplements

Potential of Milky-Way mapping

Observations (CMD, τ and t_E distributions) compared with a model taking into account

- Galactic structures –> mass, kinematics
- 3D absorption map (Marshall…)
- Local IMF of lenses

Different Distances/Masses/Velocities

- **Bulge**
- **Thin disk**
- **Thick disk (?)**
- **Bar (extension?)**
- **Halo**
- **Spiral arms**