Strong Lensing Legacy Survey

Automated search for strong lenses in CFHTLS data

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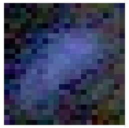
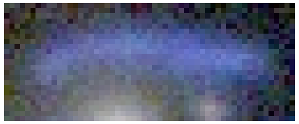
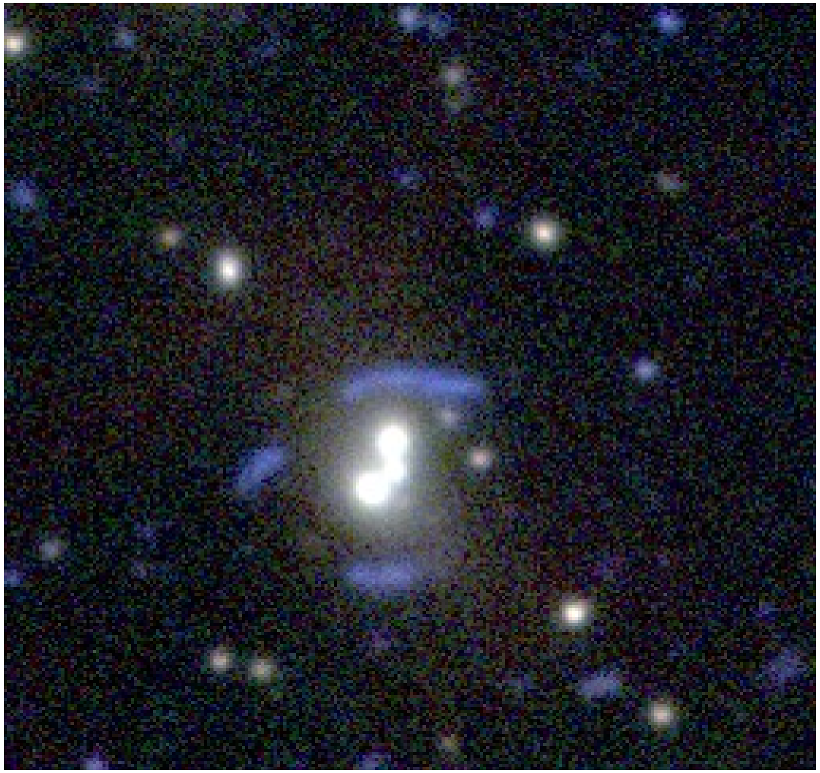
Abell 2218
HST

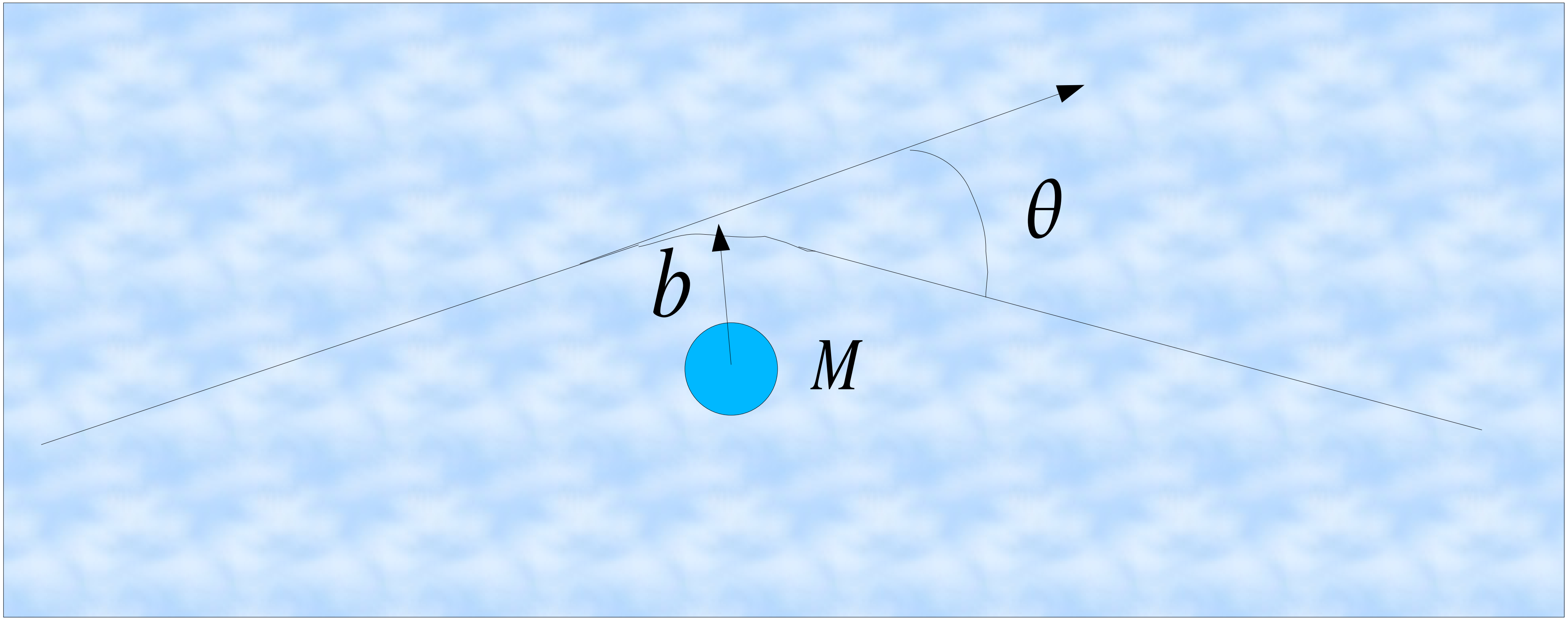
How to find highly distorded (arc-like) images, using automated softwares ?







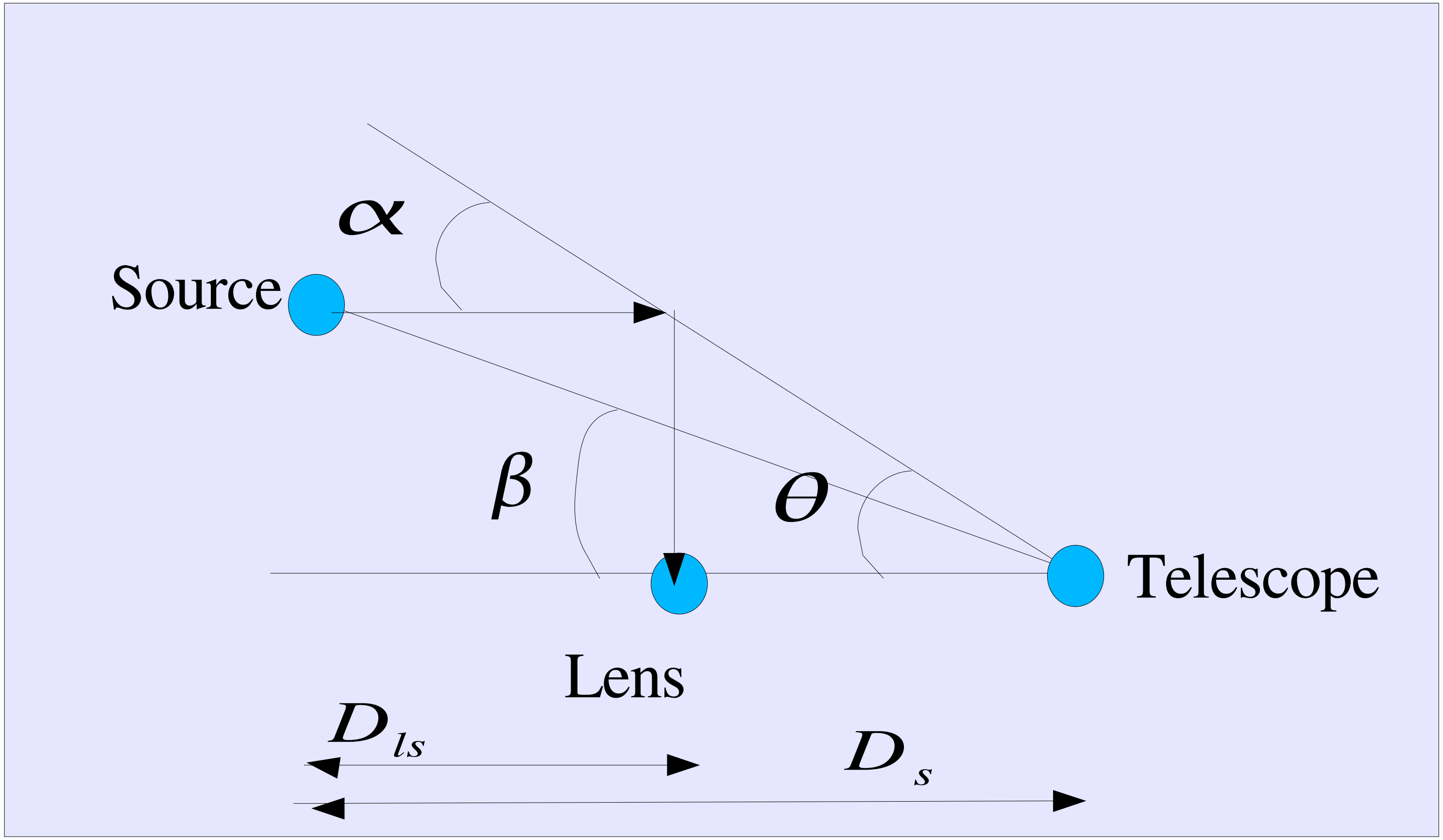
Deflection par une masse



Relativite Generale au 1er Ordre

$$\theta = \frac{GM}{b}$$

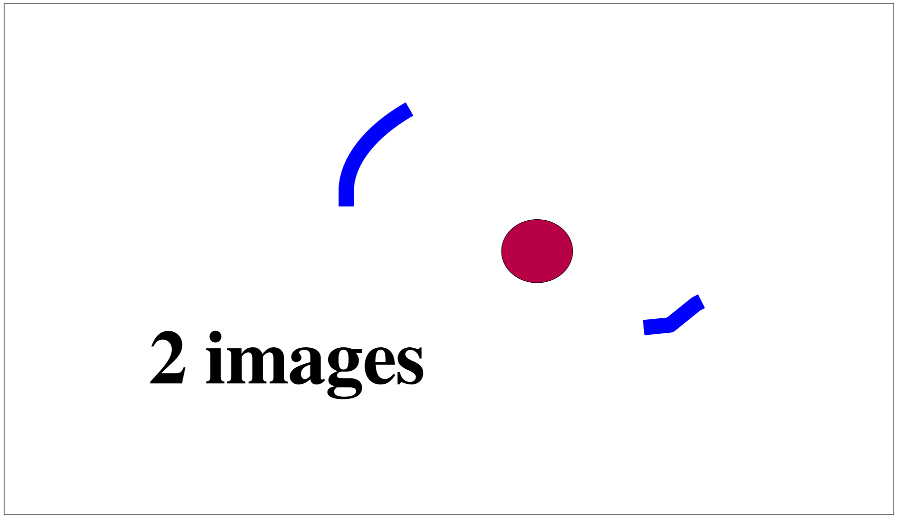
Geometry of gravitational lensing

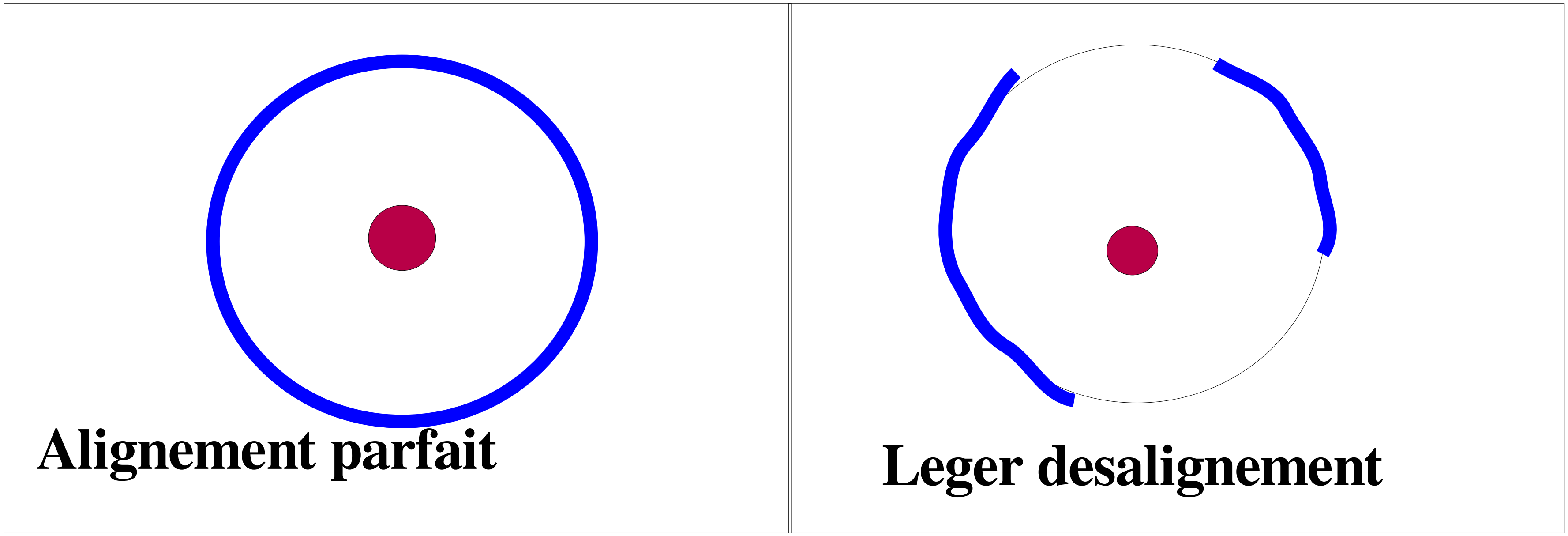


$$\beta = \theta - \frac{D_{ls}}{D_s}\alpha$$

Lens equation

Lentille ponctuelle





Spatially extended lens

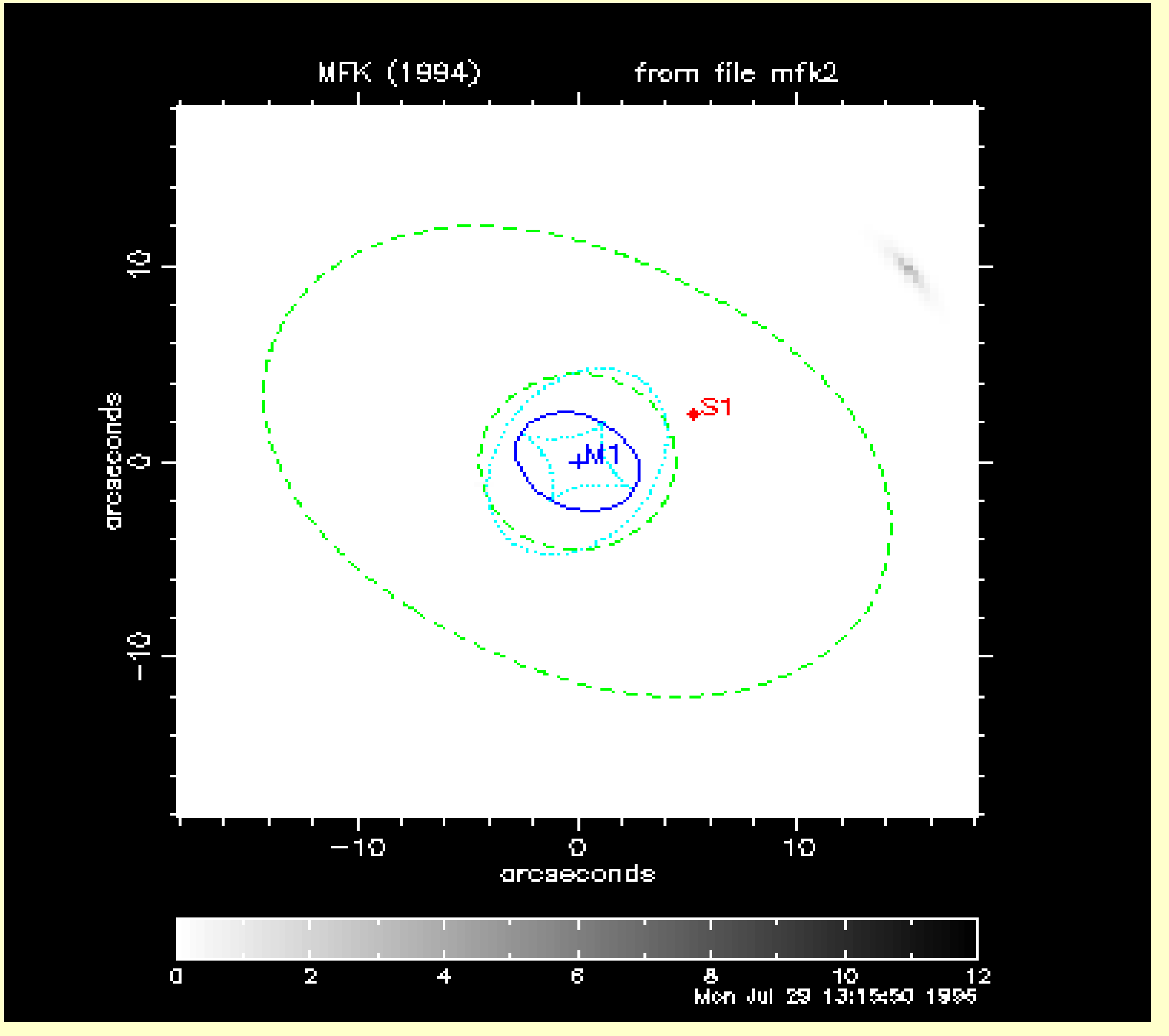
$$\beta = \theta - \frac{D_{ls}}{D_s} \alpha$$

Lens equation

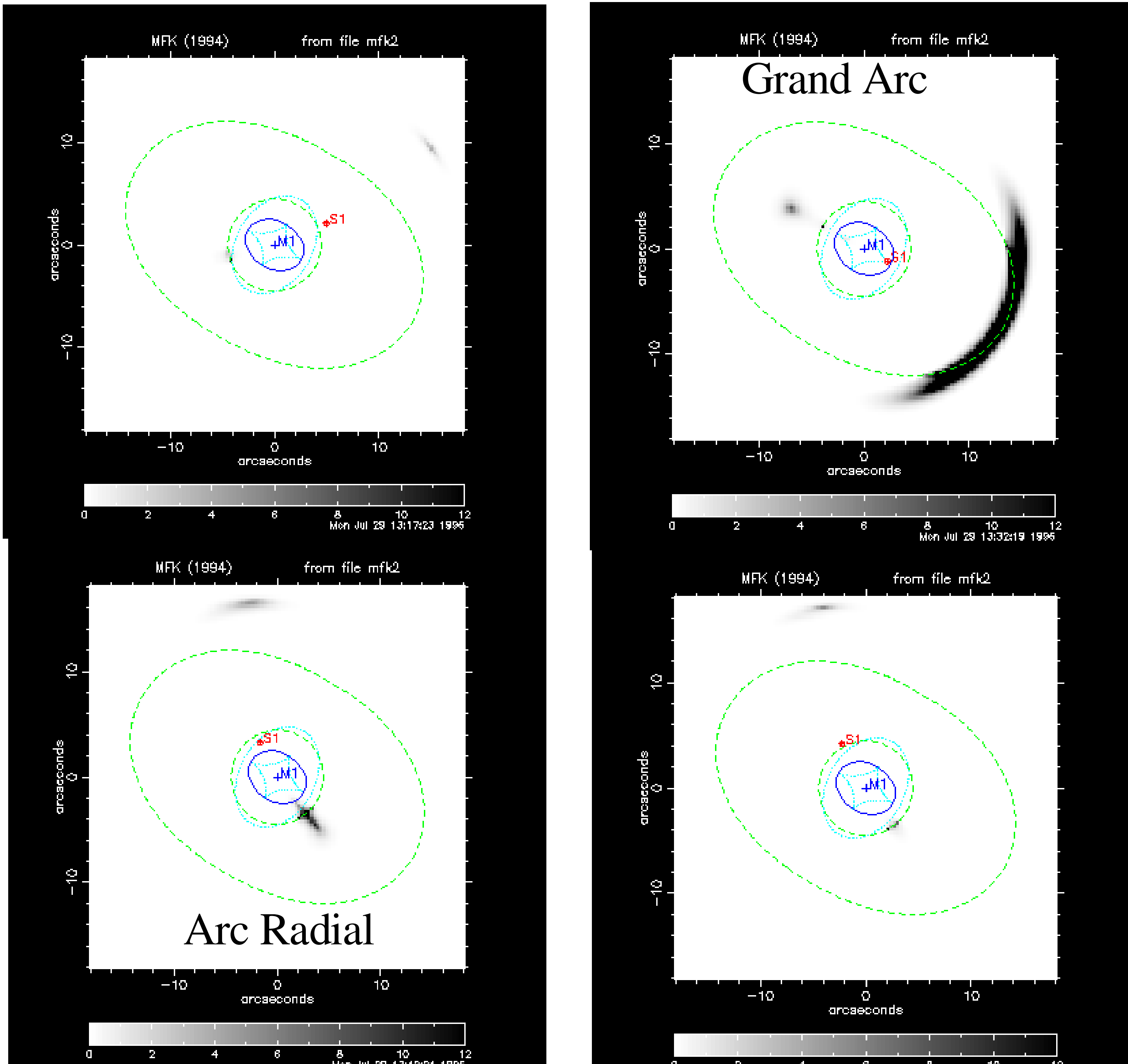
$$\Delta \phi = 2 \rho$$

$$\alpha = \nabla \phi$$

Elliptical lens with isothermal profile



Peter Newbury 1997

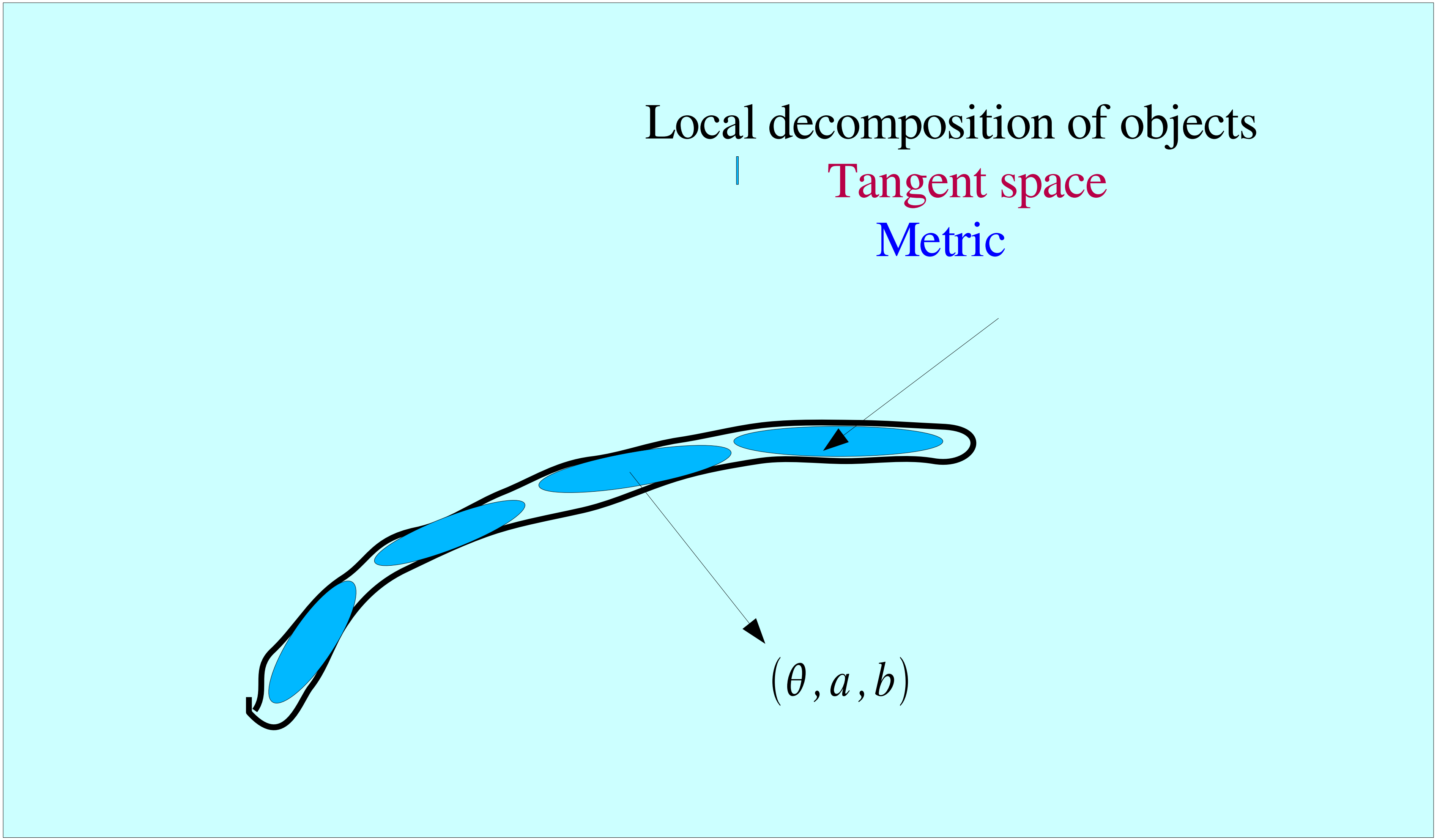

MFK (1994)
from file mfk2
Grand Arc
Arc Radial
S1
M1
arcseconds
Mon Jul 29 13:17:23 1996
Mon Jul 29 13:32:19 1996

Finding arcs or arclets in wide field CFHTLS images

Most of the time

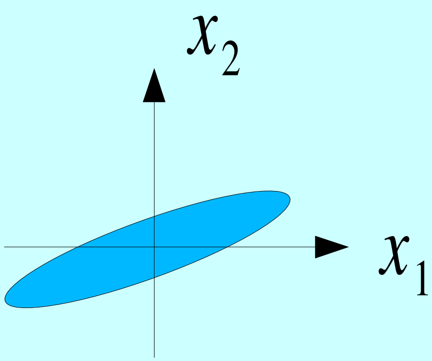
somewhat unusual

Modeling arcs



local elongation and orientation at each point of the image

Estimating local geometry



2nd order Moments $\sigma_{ij} = \int I(x_1, x_2)\, x_i\, x_j\, dx_1\, dx_2$

Rotation, in proper axis: $\sigma_{12} = 0$

Local elongation, ratio of 2nd order moments: $\frac{\hat{\sigma}_{11}}{\hat{\sigma}_{22}}$

Parameters of local geometry

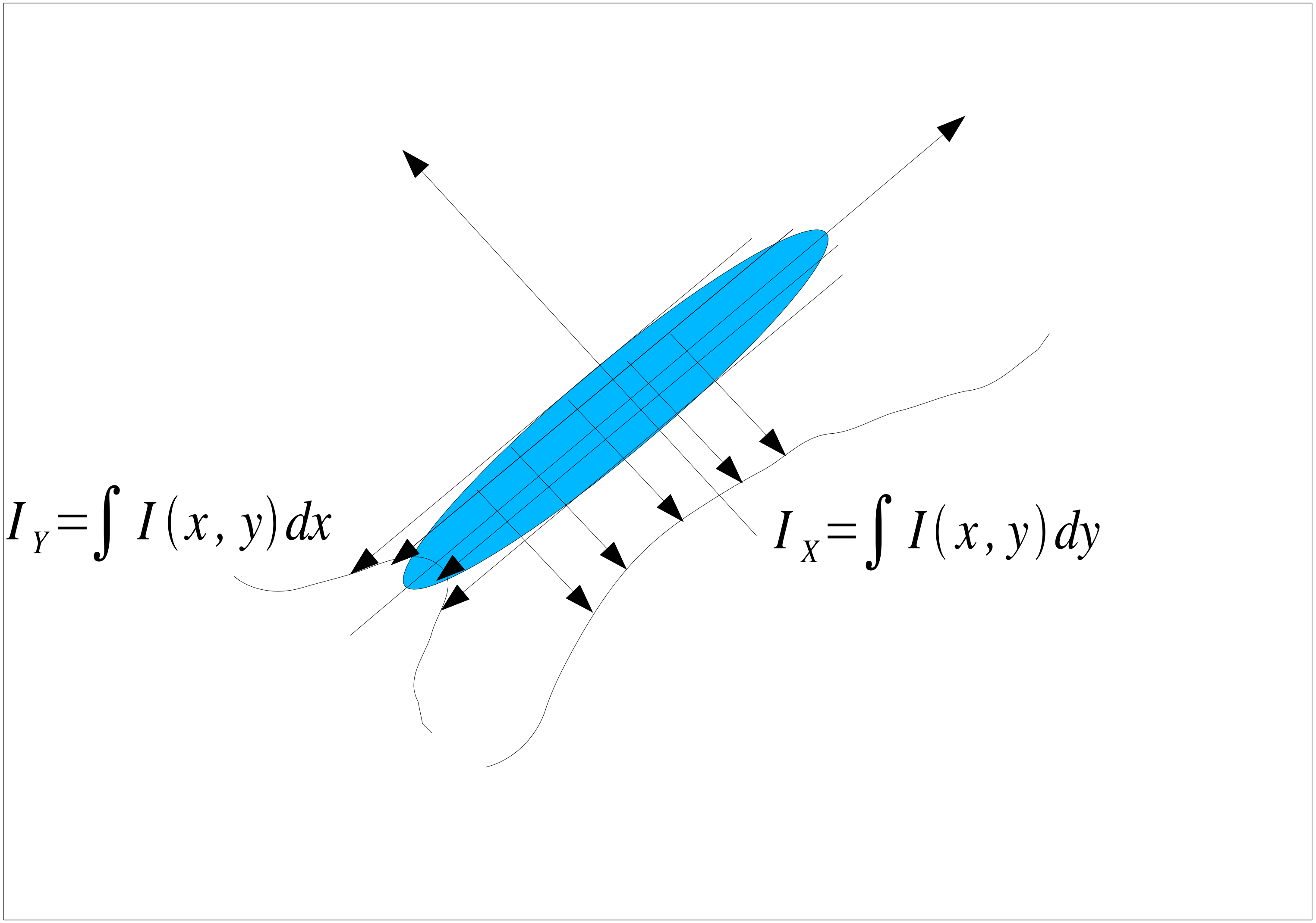
Estimation of θ not very noisy using 2nd order moment

Variance on θ proportional to noise variance

$$\sigma_\theta \simeq \frac{1}{4}\frac{S}{N} \simeq 1^\circ \; for \; \frac{S}{N} = 10$$

Elongation a:/b --> divergent, very sensitive to noise
and to details of the local distribution

Estimating local elongation



Marginal Distributions projected along axis

Elongation estimator

$$Q(x_0, y_0) = \frac{1}{2M} \frac{I_Y(x_0)}{SUP.[I_X(x_0+x)]_{[-M<x<M]}}$$

$$Decomposable\ \ locally\ I(x+x_0, y+y_0) = f(x)\,g(y)$$

$$Q(x_0, y_0) \le \frac{g(0)}{\int g(y)\,dy} \qquad g(y) = \alpha\, G\left(\frac{y}{b}\right) \qquad Q(x_0, y_0) \le \frac{G(0)}{b}$$

Bounded estimator, maximal for small b (PSF size)

Equal to sup bound if distribution is flat along main axis ~ Arc

Other propriety of the estimator

Homothetic profiles: $f(x)=\alpha F(\frac{x}{a})$; $g(x)=\beta G(\frac{x}{b})$

$$(a,b)\ll M \;,\; Q(x_{0,}y_0)=\frac{G(0)}{2M}\frac{a}{b}$$

$a\gg M \;,\; Q(x_{0,}y_0)\rightarrow\frac{G(0)}{b}$ Saturation value

Noise on estimation of local elongation

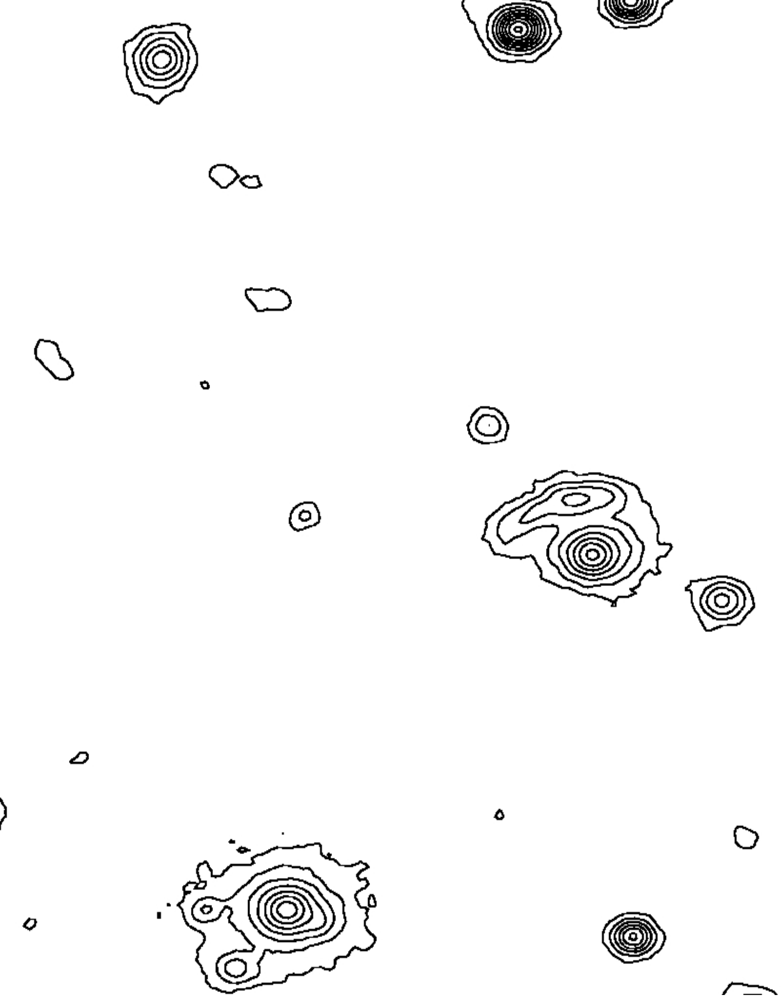
Truncated expansion of Q(x,y) for small errors
Combination of errors for the 2 marginale distribution
using an order statistics

$$\frac{Q}{N_Q} \simeq 0.45 \frac{S}{N}$$

For $\frac{S}{N} = 10$ noise is only ~ 20% of signal

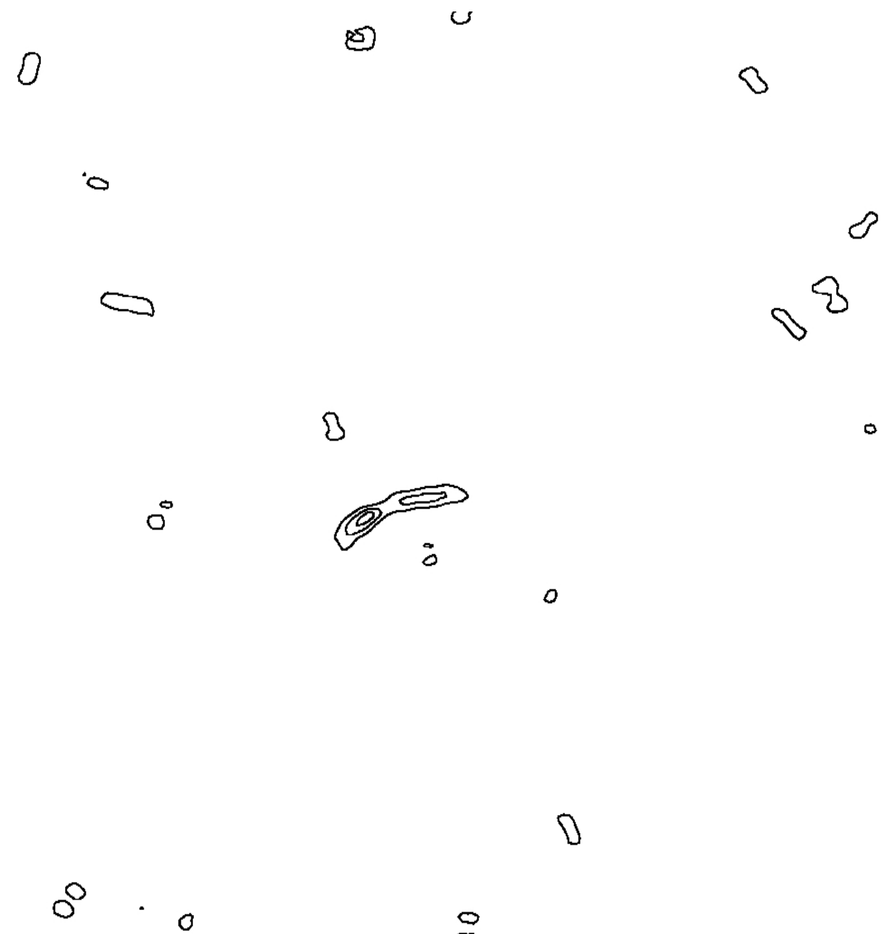
Dynamic on Q(x,y) ~ factor 3, noise is not an issue

Illustration with CFHTLS wide image



CFHTLS image

Calculation of local estimator
at each point



Small arcs – observational limits

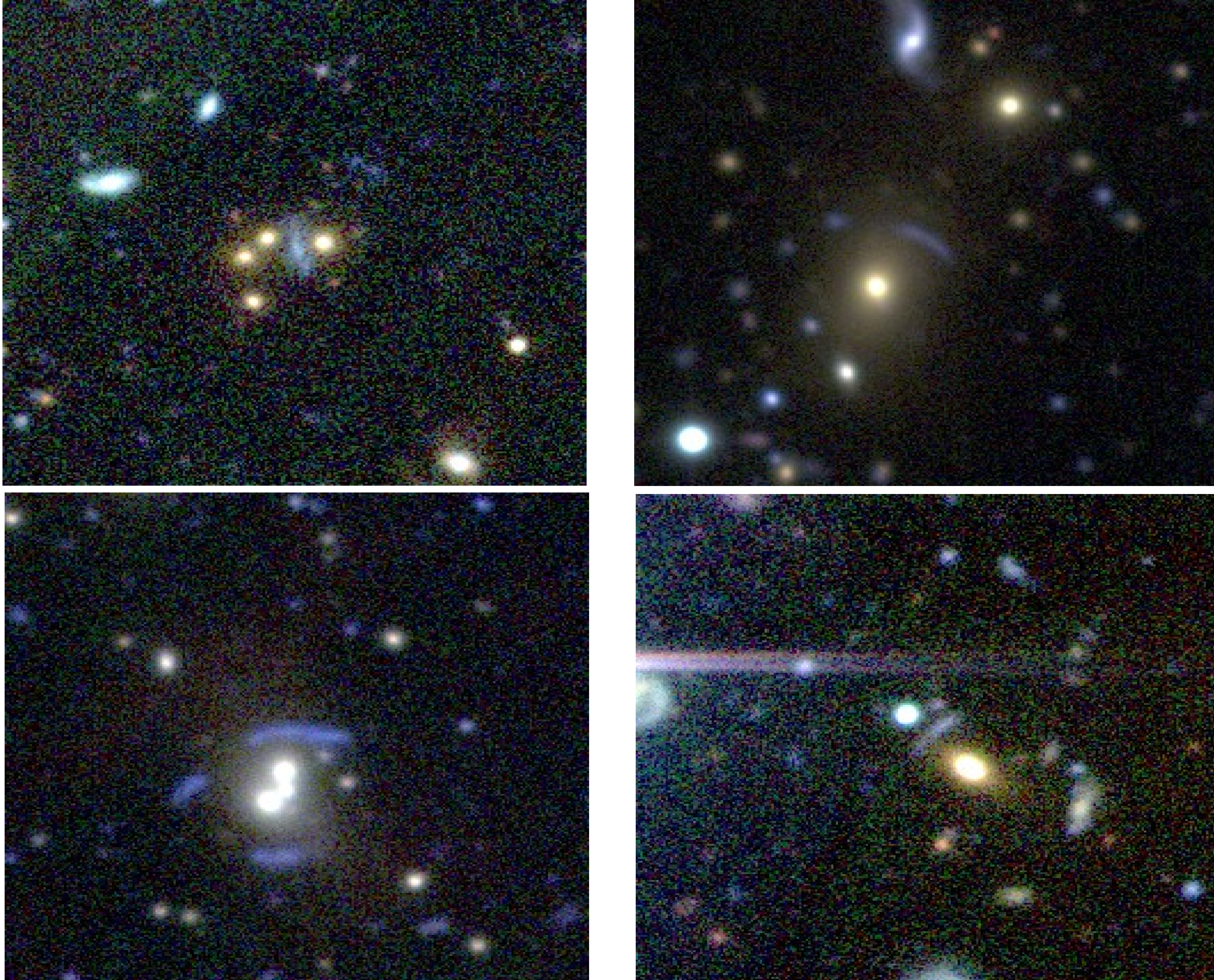
Galaxy groups

Typically a few tens of galaxies

Mass ~ 10^{13} Solar mass

Velocity dispersion inside group
a few hundreds km/s

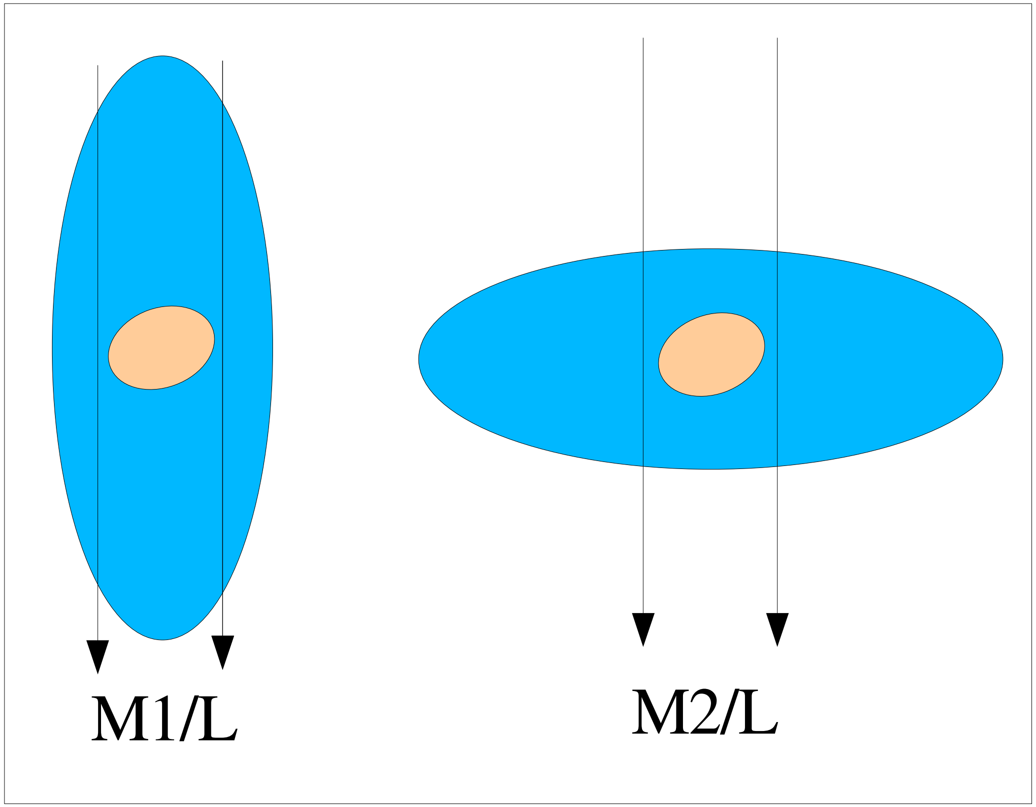
Lensing du to galaxy groups, separations
of a few arc seconds



Arcs appears near critical radius
size of system is close to Einstein radius
-----> Estimation of Einstein radius
-----> Mass of deflector

Ellipticity of halos

M1/L > M2/L



Effect of sub-structures, small perturbations of caustics --> arc shape modified col dark matter granularity, visible in arcs ?

Uneasy to disentangle from intrisic source granularity

Future

Data acquisition & data reduction

Spectro & redshifts: ESO Proposals, Gemini

Automated search in new CFTHLS releases

Comparison of the observational search with cosmological models – Ray tracing in numerical simulations, reconstruction of arcs, computation of arcs properties & estimation of detection efficiency on numerical simulations