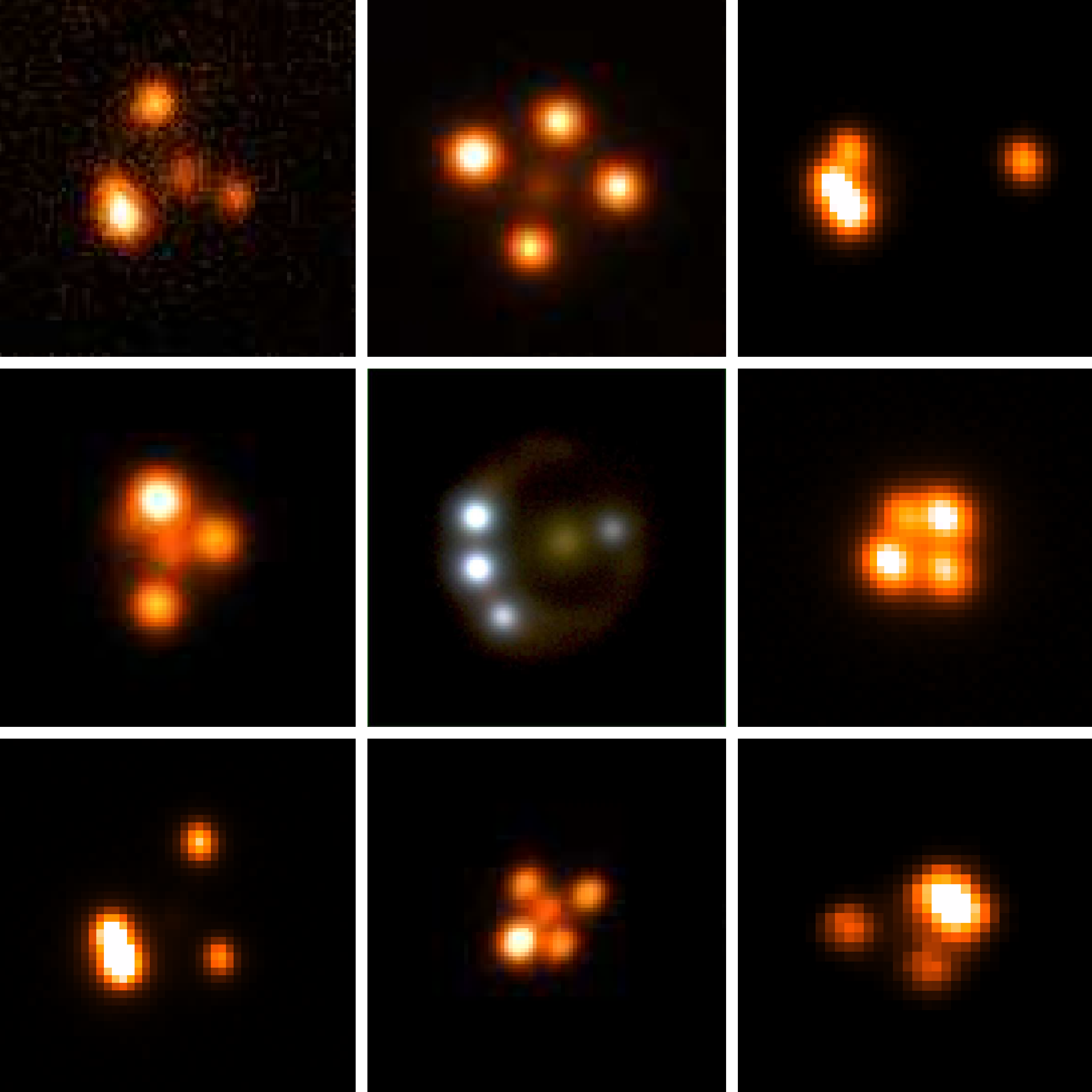
The dark matter content of elliptical galaxies measured from the static gravitational micro-lensing of multiply imaged quasars

The stellar mass content of elliptical galaxies measured from the static gravitational micro-lensing of multiply imaged quasars



$$\begin{pmatrix}\text{time}\\\text{delay}\end{pmatrix}=\begin{pmatrix}\text{geometric}\\\text{delay}\end{pmatrix}+\begin{pmatrix}\text{gravitational}\\\text{delay}\end{pmatrix}$$

effective 2-D potential:

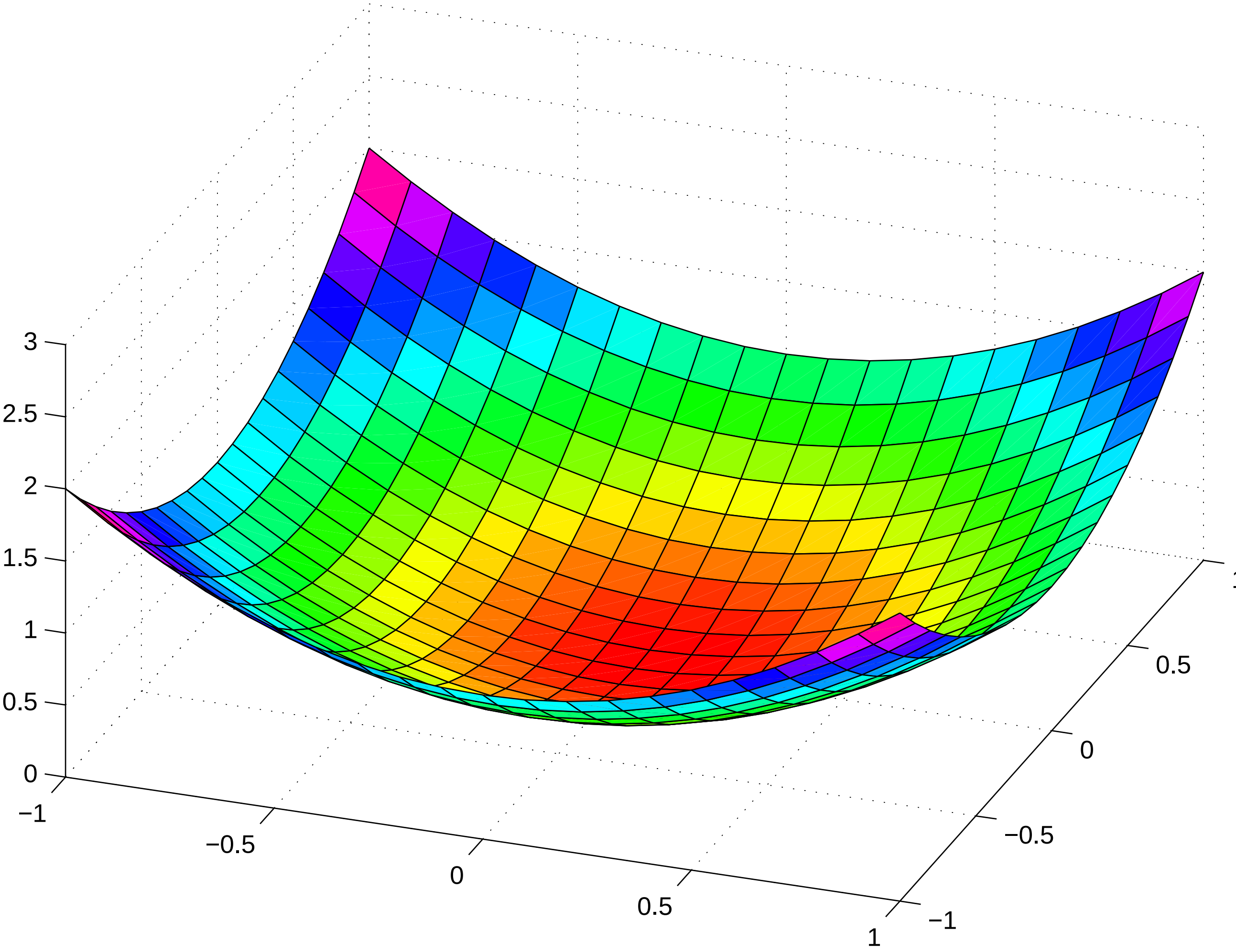
$$\psi_{2D} = \frac{D_{LS}}{D_S} \int_{observer}^{source} \frac{2\Phi_{3D}}{c^2} \frac{d\ell}{D_L}$$

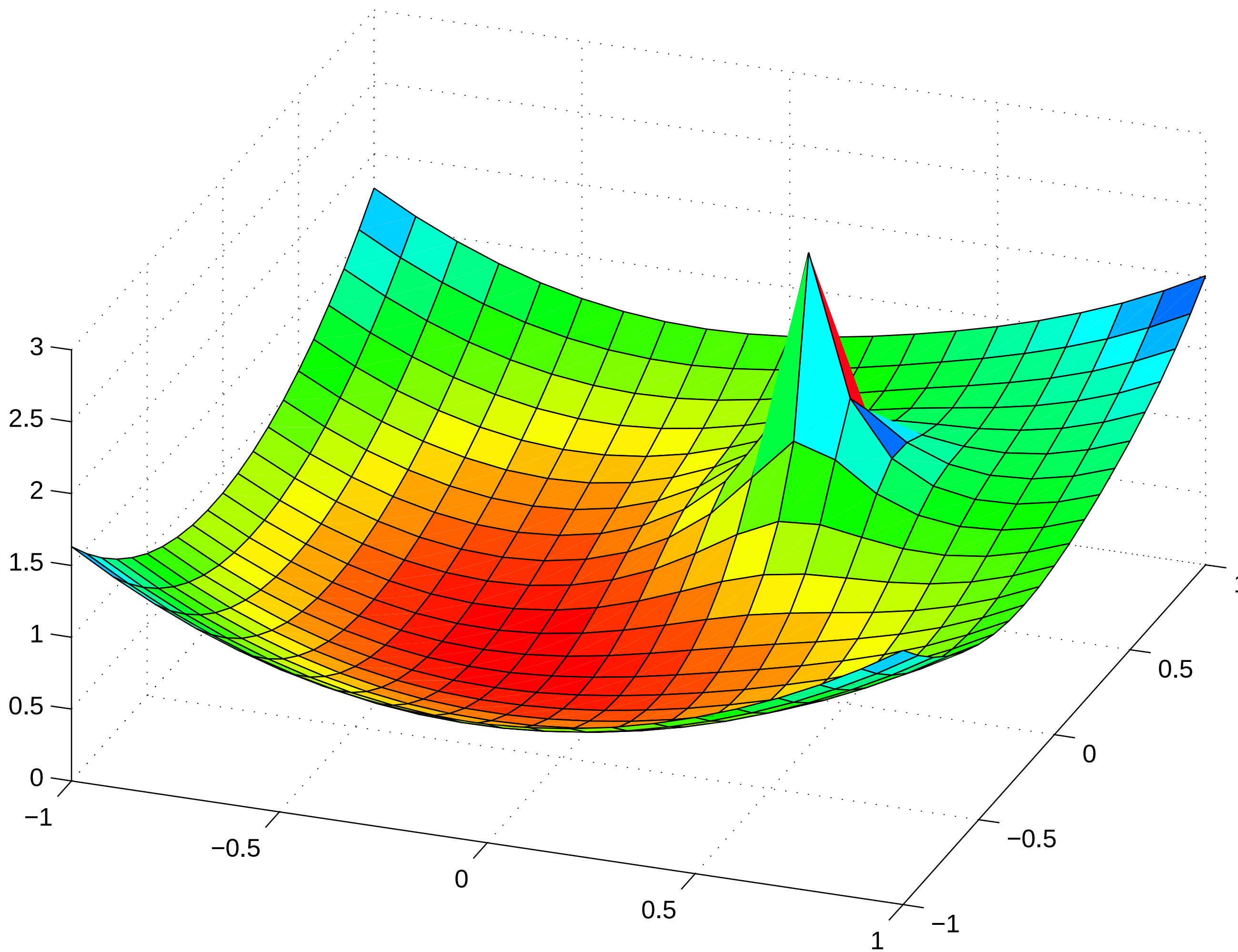
Delay: 0^{th} derivative

$$\tau = \frac{1+z_L}{H_0}\frac{d_L d_S}{d_{LS}}\left[\frac{1}{2}(\vec{\theta}-\vec{\beta})^2 - \psi_{2D}(\vec{\theta})\right]$$

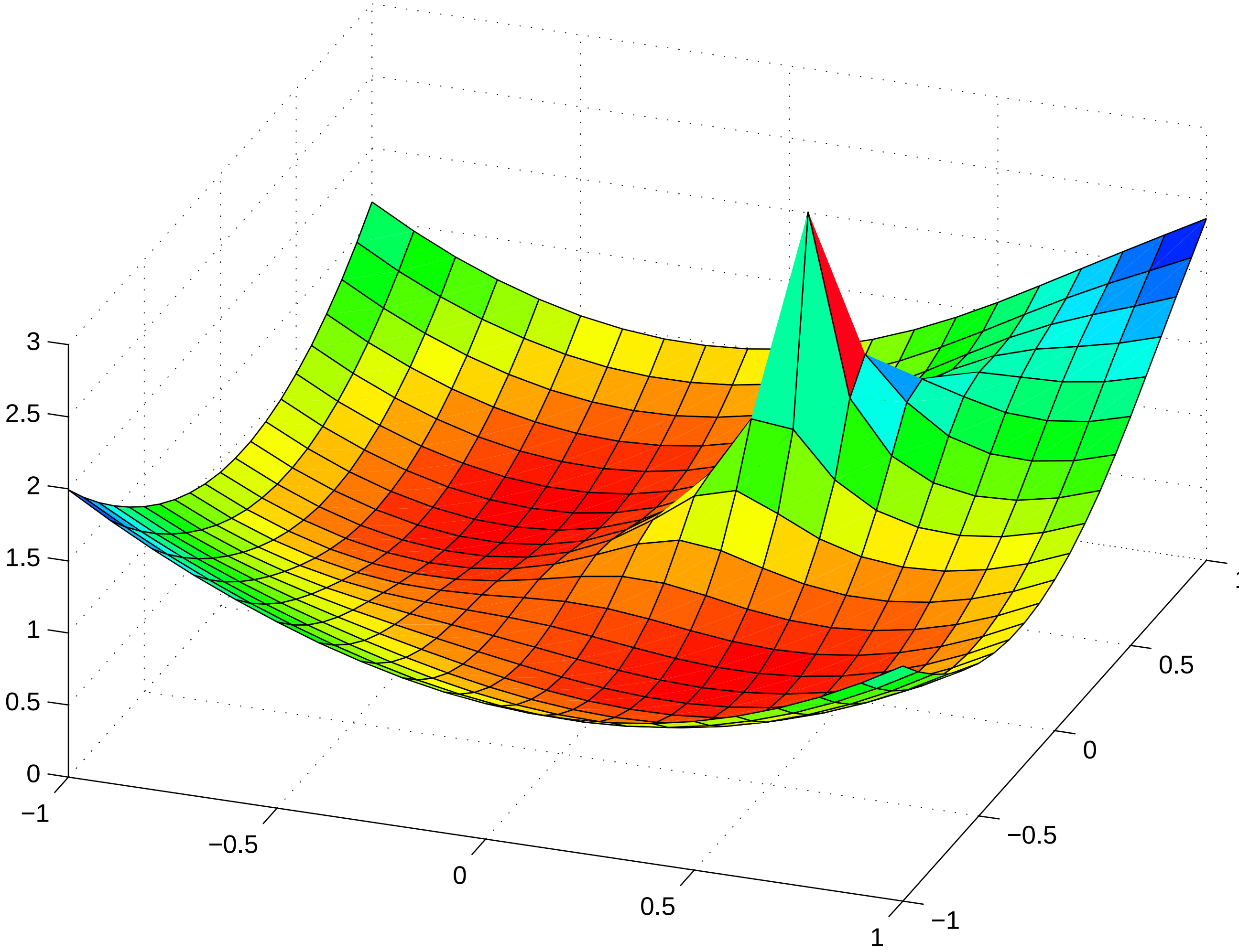
$$\vec{\theta} = \vec{\theta}_A, \vec{\theta}_B, \vec{\theta}_C, \vec{\theta}_D, ...$$

Units: (angle)$^2/H_0$

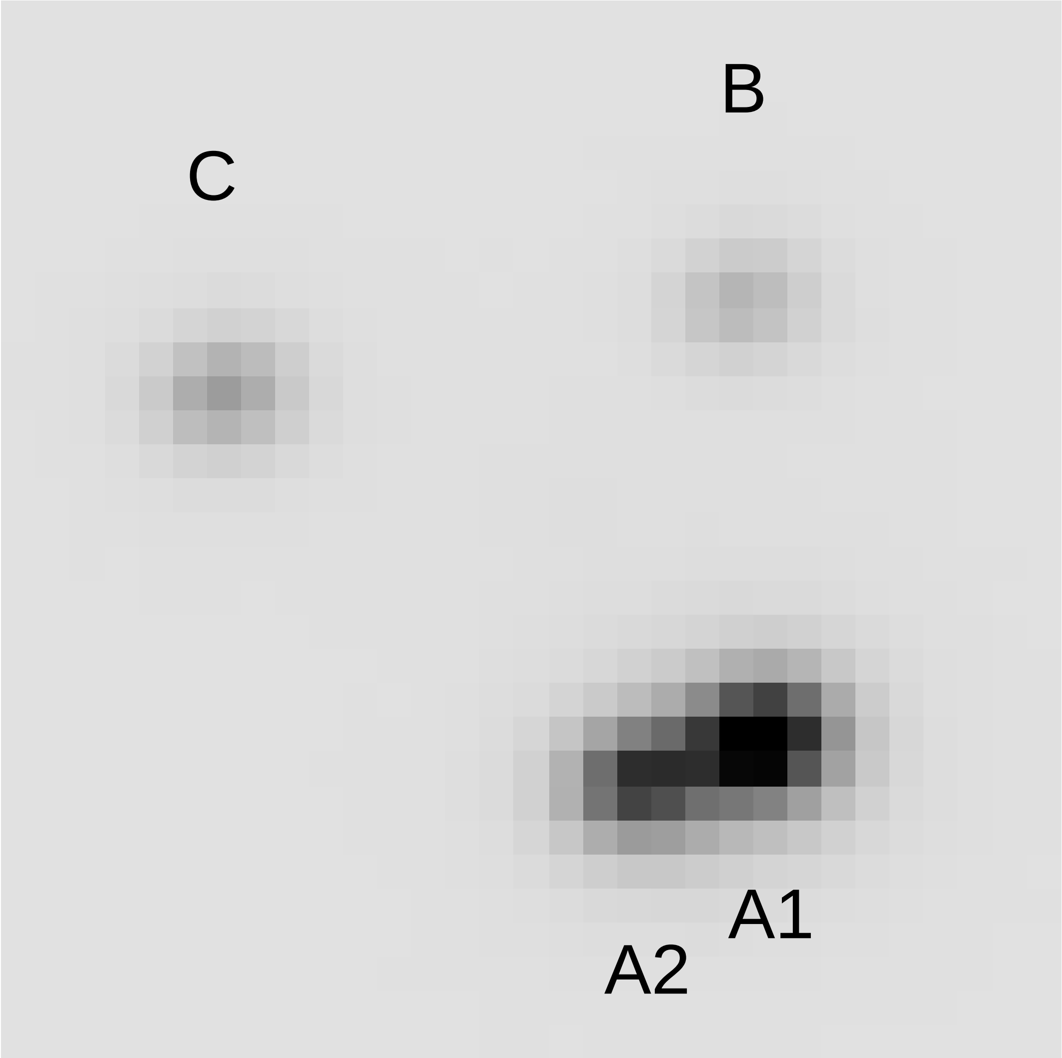

3
2.5
2
1.5
1
0.5
0
−1
−0.5
0
0.5
1
−1
−0.5
0
0.5



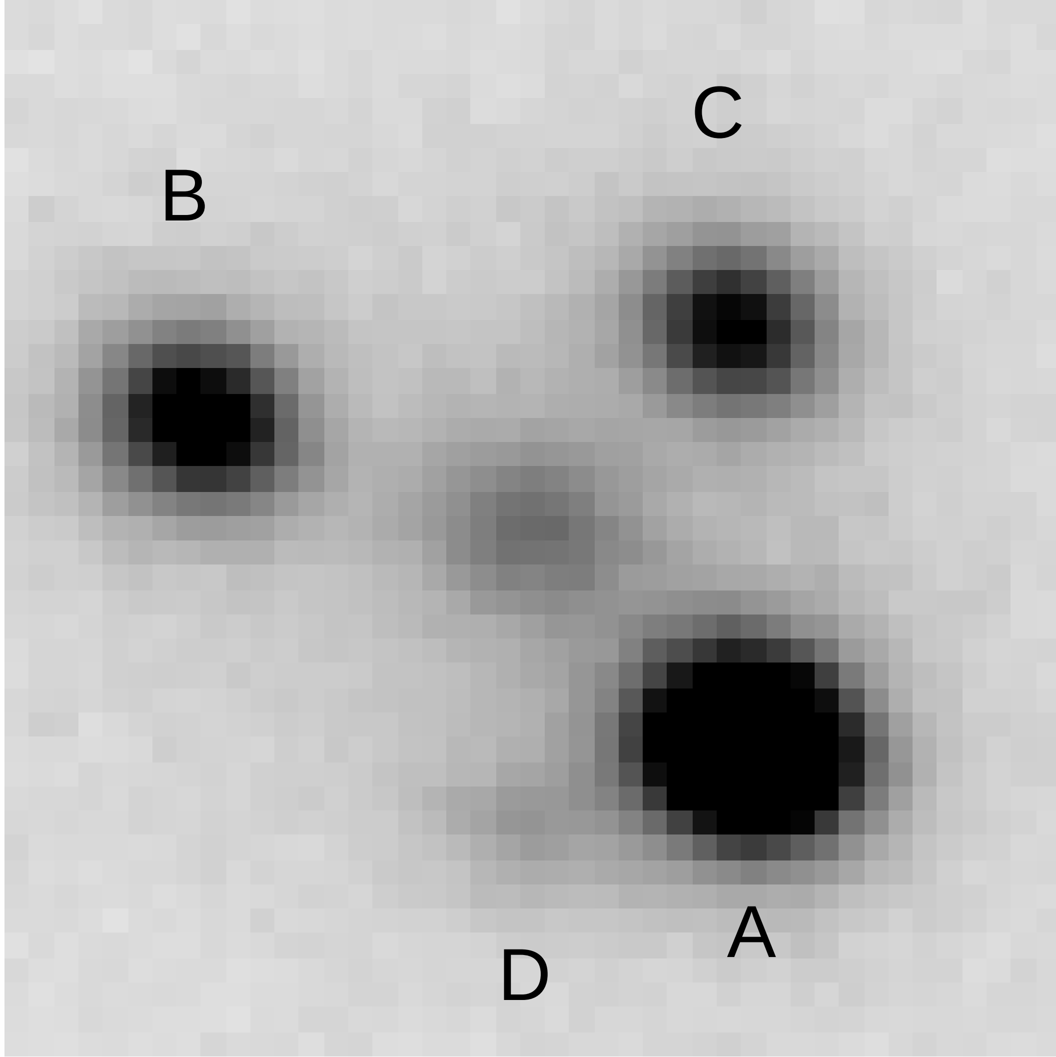
3
2.5
2
1.5
1
0.5
0
−1
−0.5
0
0.5
1
−1
−0.5
0
0.5



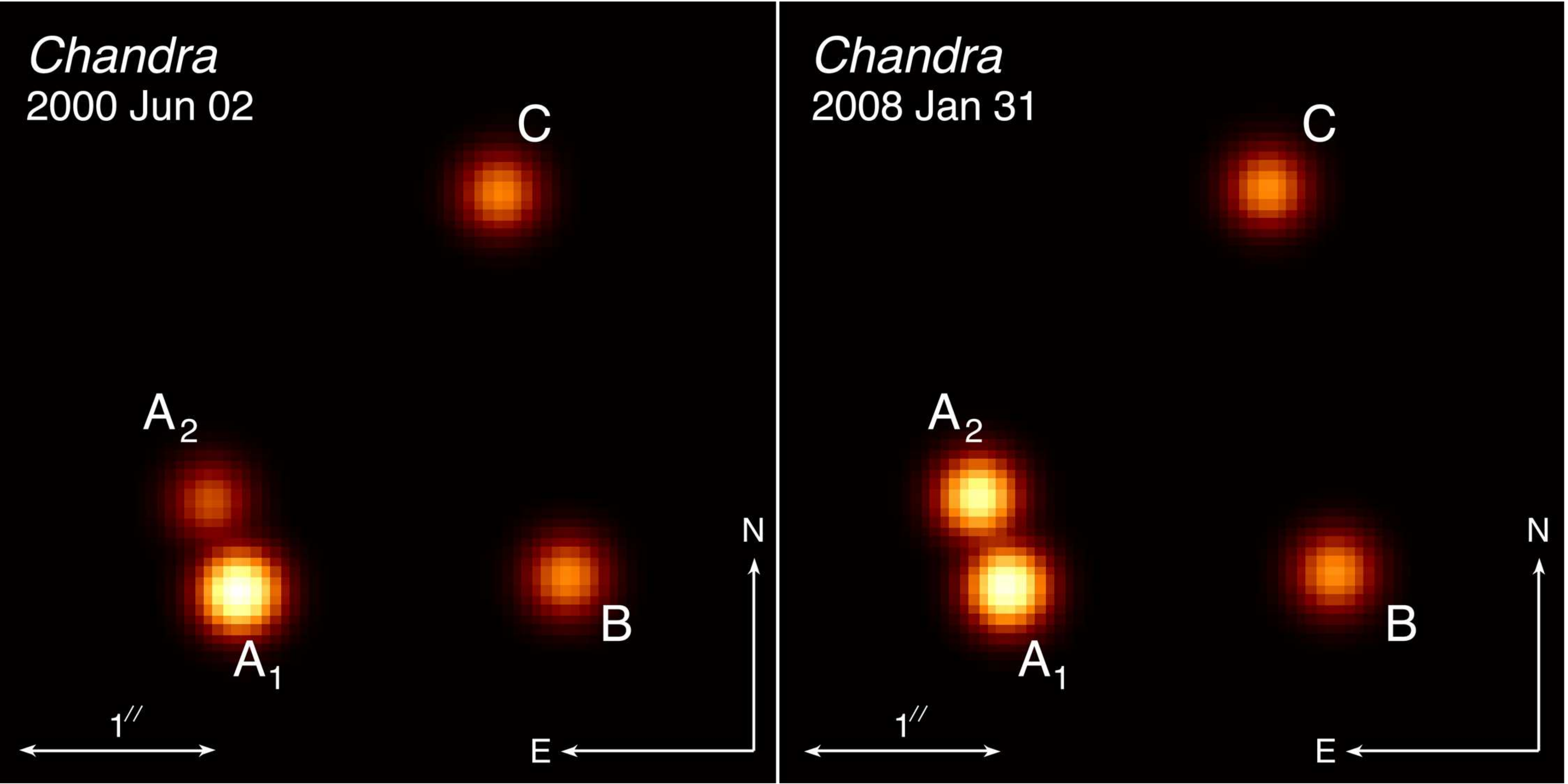
3
2.5
2
1.5
1
0.5
0
−1
−0.5
0
0.5
1
−1
−0.5
0
0.5



C
B
A2
A1



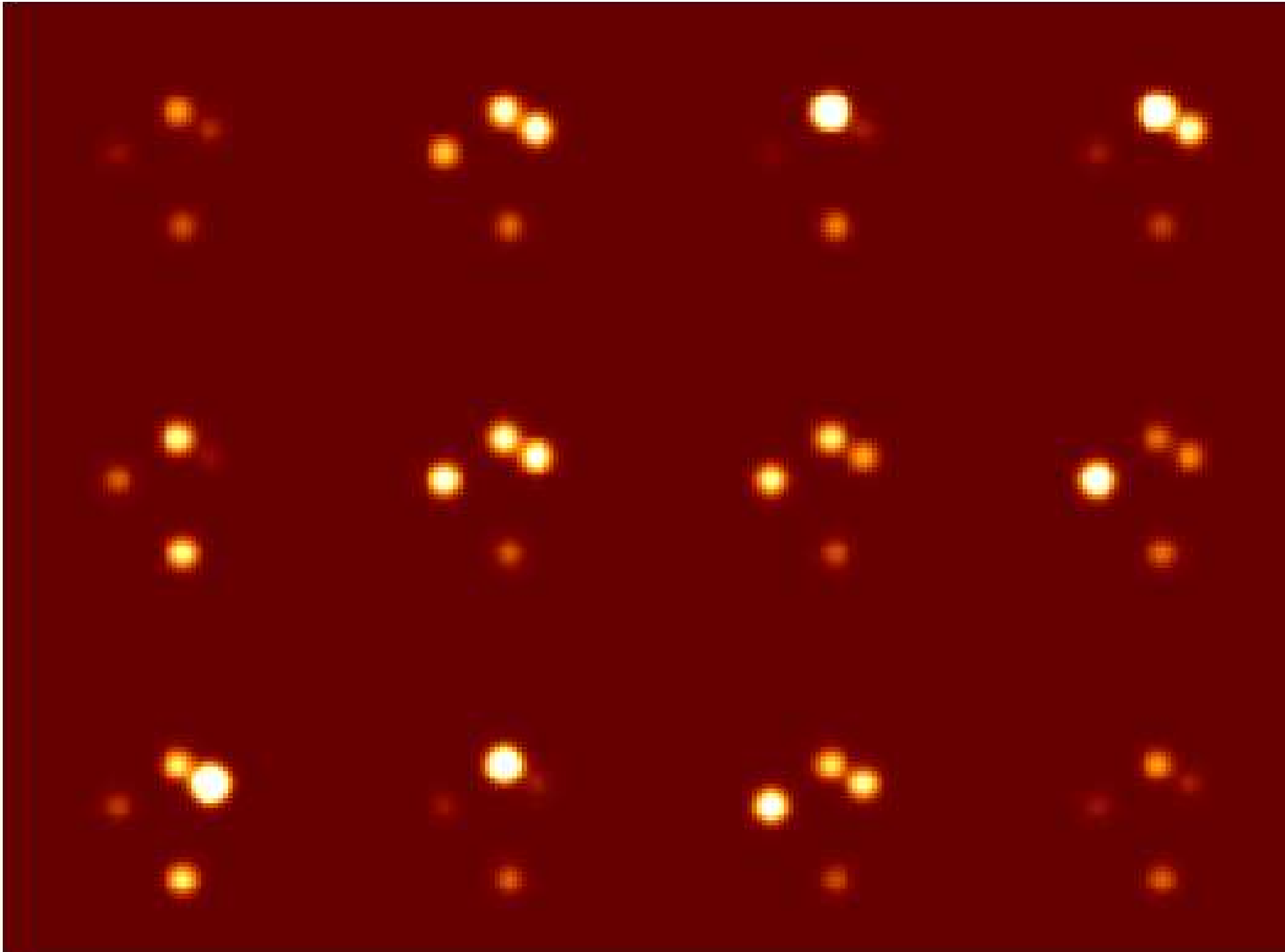
C
B
D
A

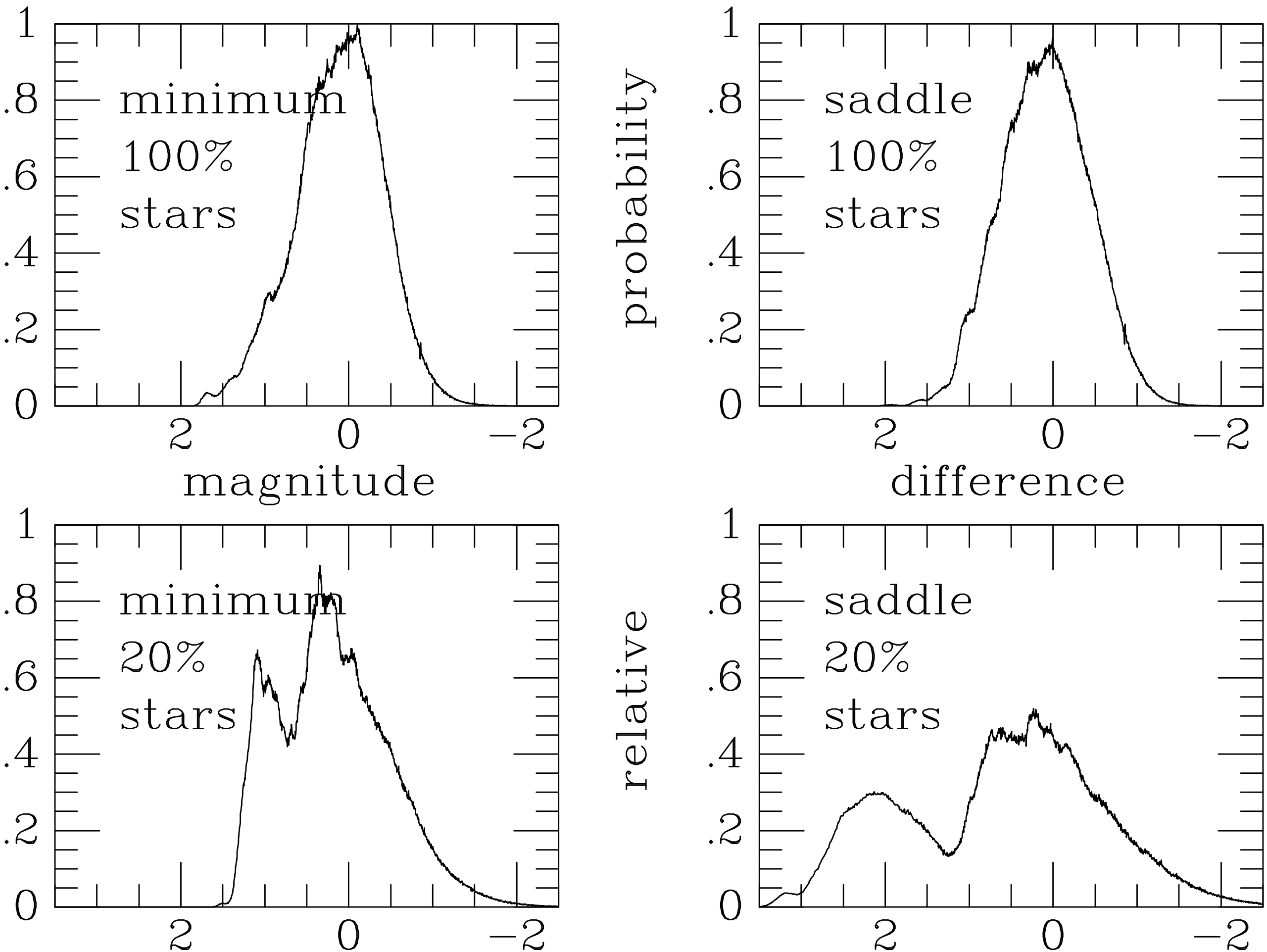


Chandra
2000 Jun 02
C
A2
A1
B
N
E
1″
Chandra
2008 Jan 31
C
A2
A1
B
N
E
1″

MICRO-LENSING AT UNIT OPTICAL DEPTH: I & II

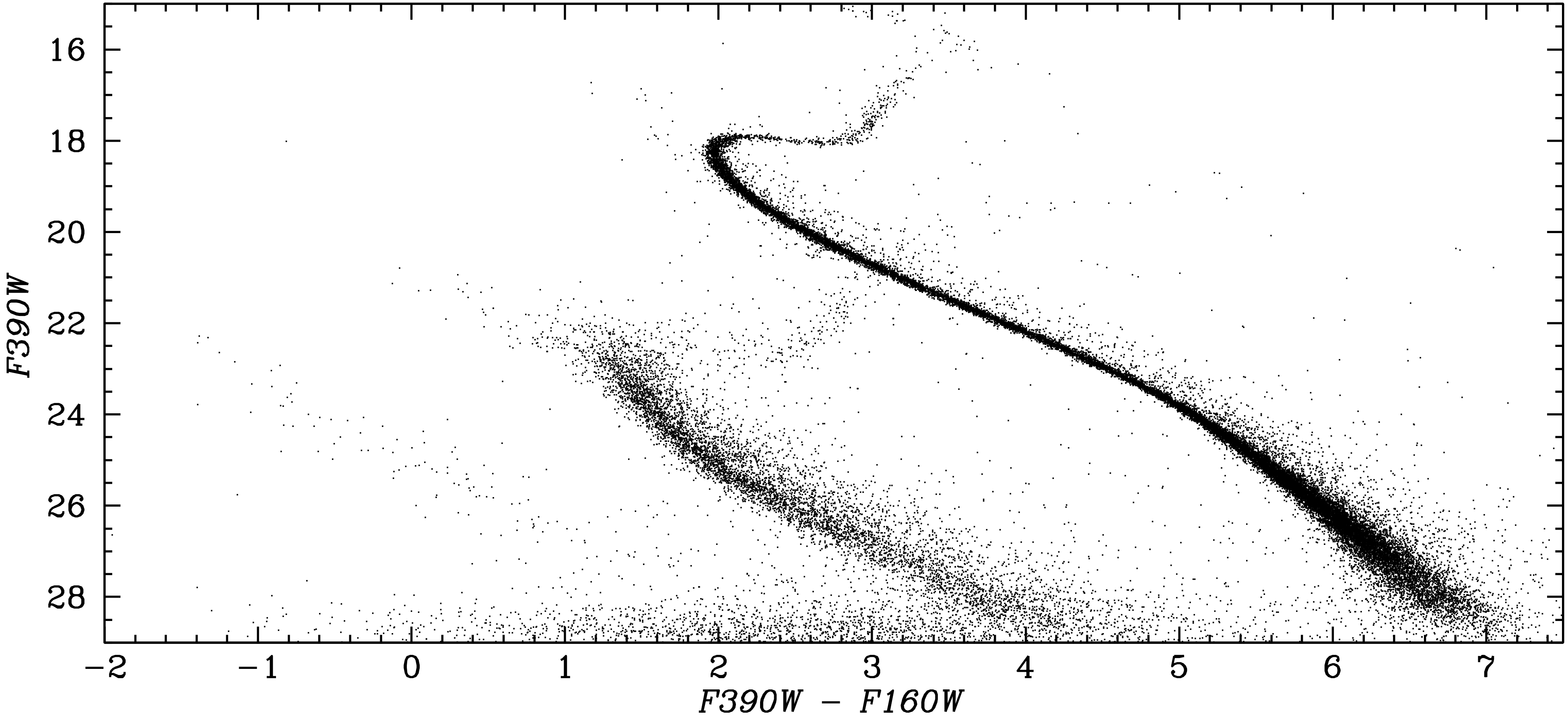
written,
directed and
produced by
Svetlin Tassev




minimum
100%
stars
saddle
100%
stars
minimum
20%
stars
saddle
20%
stars
relative probability
magnitude difference
1
.8
.6
.4
.2
0
2
0
−2

X-Ray and Optical Flux Ratio Anomalies in Quadruply Lensed Quasars. II. Mapping the Dark Matter Content in Elliptical Galaxies (2012) ApJ 744, 111

David Pooley, Saul Rappaport, Jeffrey A. Blackburne, Paul L. Schechter and Joachim Wambsganss


F390W
F390W − F160W
16
18
20
22
24
26
28
−2
−1
0
1
2
3
4
5
6
7

"All of our derived parameters are tied to a specific choice of IMF. Changing the IMF would scale the stellar mass estimates by a fixed factor. For example, changing from a Kroupa (2001) to a Salpeter IMF with a cutoff at $0.1M_{\odot}$ would result in a factor of 2 increase in the stellar mass."

–Kauffmann et al. 2003

fundamental plane (Djorgovski & Davis 1987)

$$\log\begin{pmatrix}\text{stellar}\\\text{surface}\\\text{brightness}\end{pmatrix} = a * \log\begin{pmatrix}\text{stellar}\\\text{velocity}\\\text{dispersion}\end{pmatrix} + b * \log\begin{pmatrix}\text{half}\\\text{light}\\\text{radius}\end{pmatrix} + c$$

stellar mass plane (Hyde & Bernardi 2009)

$$\log \begin{pmatrix} \text{stellar surface} \\ \text{mass density} \\ \text{assuming IMF} \end{pmatrix} =$$

$$a * \log \begin{pmatrix} \text{stellar} \\ \text{velocity} \\ \text{dispersion} \end{pmatrix} + b * \log \begin{pmatrix} \text{half} \\ \text{light} \\ \text{radius} \end{pmatrix} + c$$

definitions:

m_s = **source magnitude (unmagnified)**

μ_i = **macro-magnification (i^{th} image)**

$m_{o,i}$ = **observed magnitude (i^{th} image)**

$\mathcal{R}$ = **stellar mass ratio (actual/fiducial)**

$\mathcal{L}(m_s|m_{o,i};\mu_i;\mathcal{R})$ = **likelihood of** m_s

$$\mathcal{L}(m_s|m_{o,i};\mu_i;\mathcal{R}) = \mathcal{P}(m_{o,i}|m_s;\mu_i;\mathcal{R})$$

$$\mathcal{L}(m_s|\mathcal{R}) = \prod_{i=1}^{i=4} \mathcal{L}(m_s|m_{o,i};\mu_i;\mathcal{R})$$

$$\mathcal{L}(\mathcal{R}|\{m_{o,i}\};\{\mu_i\}) = \int \mathcal{L}(m_s|\mathcal{R})dm_s$$

possible sources of systematic error

1. statistical bias
2. incorrect macro-lens models
3. effective radius measurements
4. prior on unlensed x-ray flux
5. variation of stellar mass fundamental plane with redshift