Proper Motion

An X-Ray Frontier
for ***Chandra***
and ***X-Ray Surveyor***

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and ***X-Ray Surveyor***

Rosanne Di Stefano, Vinay Kashyap, Sebastien Lepine, Frank Primini

Proper Motion

- Why is it important?

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- Potential contributions of ***Chandra*** and ***X-Ray Surveyor***

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- Why is it important?
- Potential contributions of ***Chandra*** and ***X-Ray Surveyor***
- Proof of concept

Neutron Stars

Neutron Stars	
In the Milky Way	10^8 - 10^9
Within a kiloparsec	10^6 - 10^7
Within 100 pc	10^4 - 10^5
Found:	About 2500 known (ATNF); < 10 within 100 pc

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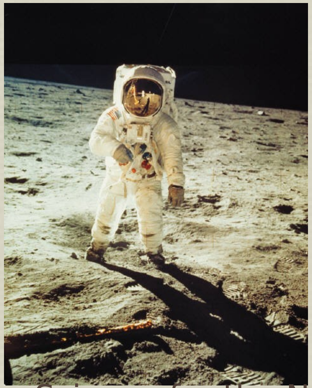

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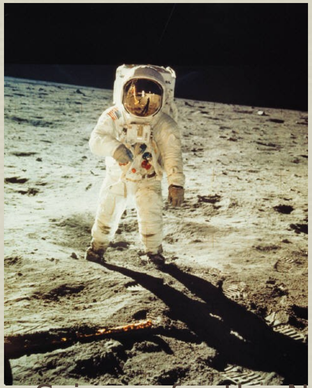
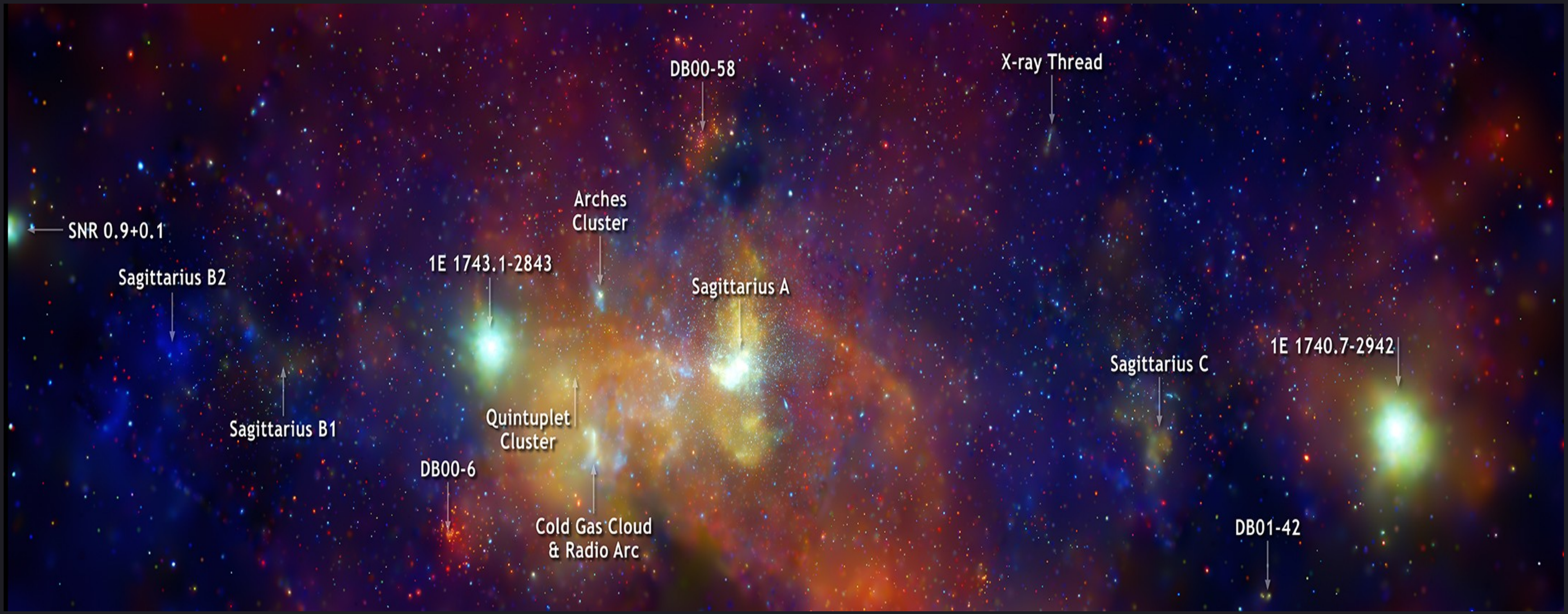


Where are they?

Orion

A neutron star moving at 100 km/s travels 0.2 arcsec/yr at 100 pc.

0.3 arcsec at 8 kpc is 2400 AU, the distance a star can move in 20 years at 570 km/s



Proper Motion of X-Ray Sources: What is it good for?

- To discover **nearby** objects and **fast** objects that are dim at other wavelengths. In particular ***neutron stars and black holes***.
- To study the ***dynamics*** of X-ray sources in nearby clusters.
- To identify microlensing events caused by lenses that are nearby compact objects. Important for ***direct mass measurement***.

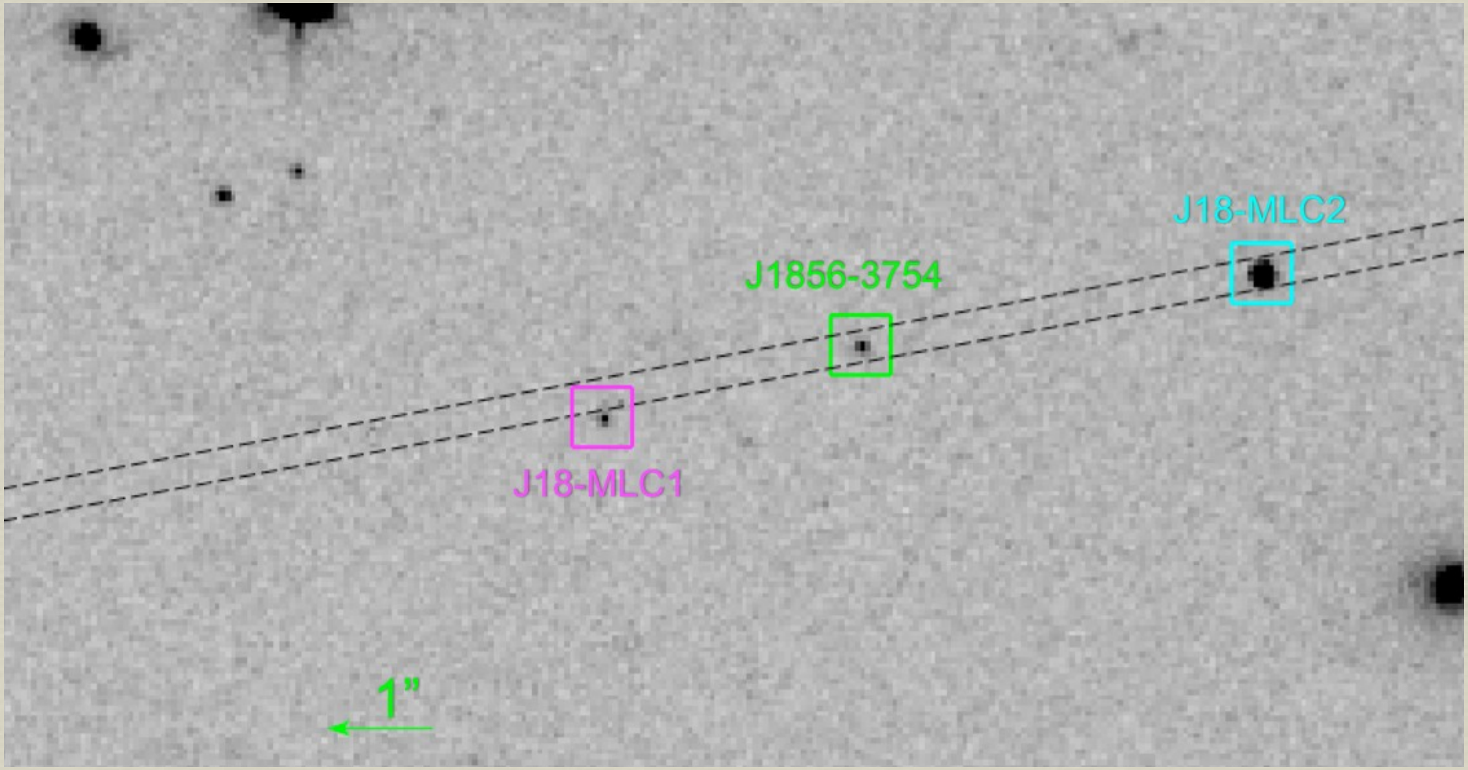
X-Ray detection of NSs

- Hot neutron star: L can be larger or smaller, depending on temperature. (50 eV to 125 eV). At the upper end of the temperature range, NSs are readily detected by Chandra.
- Accreting NSs appear to be inefficient X-ray emitters. Accretion at 10^{-14} $M_{\odot}$ per year yields about $6\ \varepsilon\ 10^{31}$ erg/s.

X-Ray detection of NSs

- We can search for young neutron stars near star forming regions or open clusters.
- We can search for NSs accreting even at low rates from a wide. (Even in systems where an X-ray binary may not form for many years.)
- In either case, proper motion may provide the key to detection.

An example: RX J1856-3754



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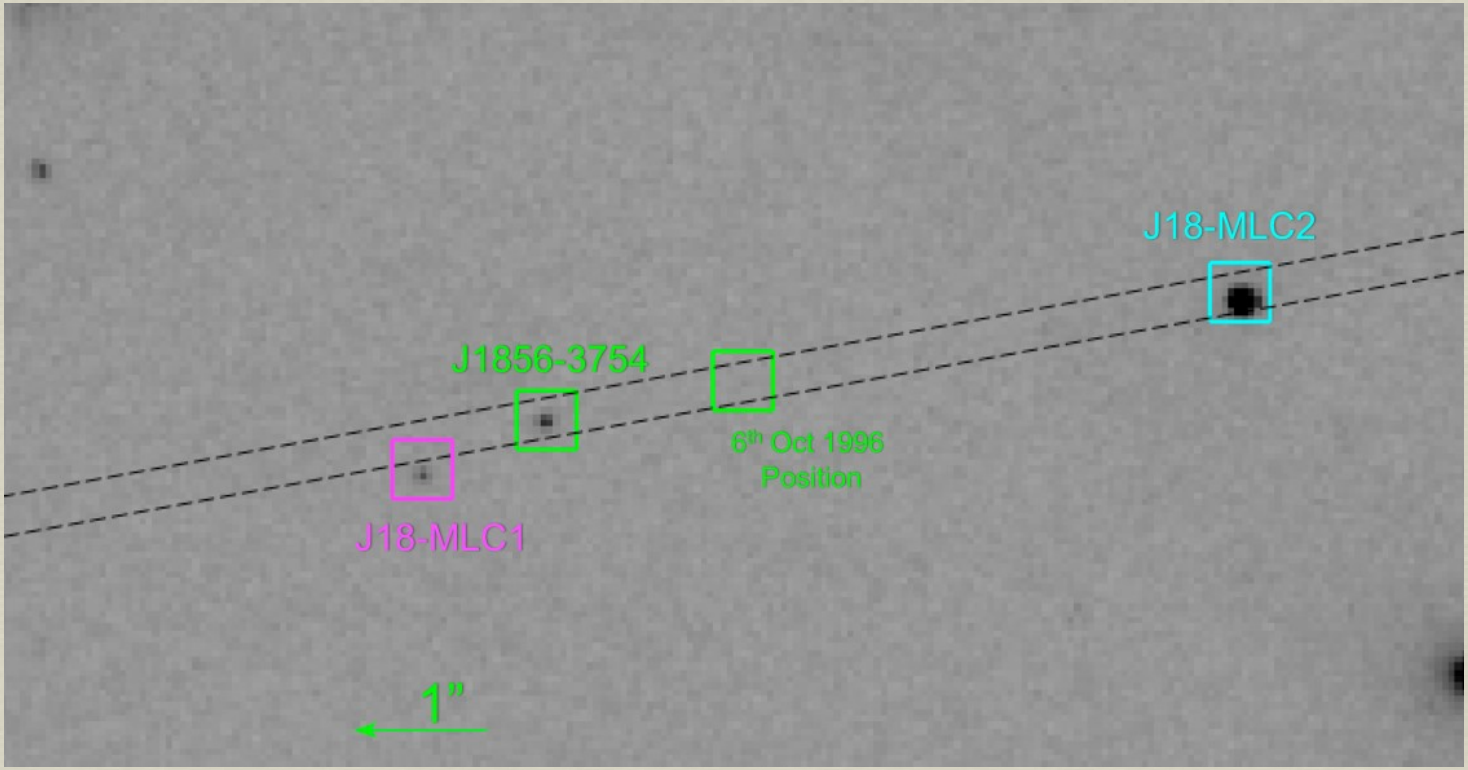
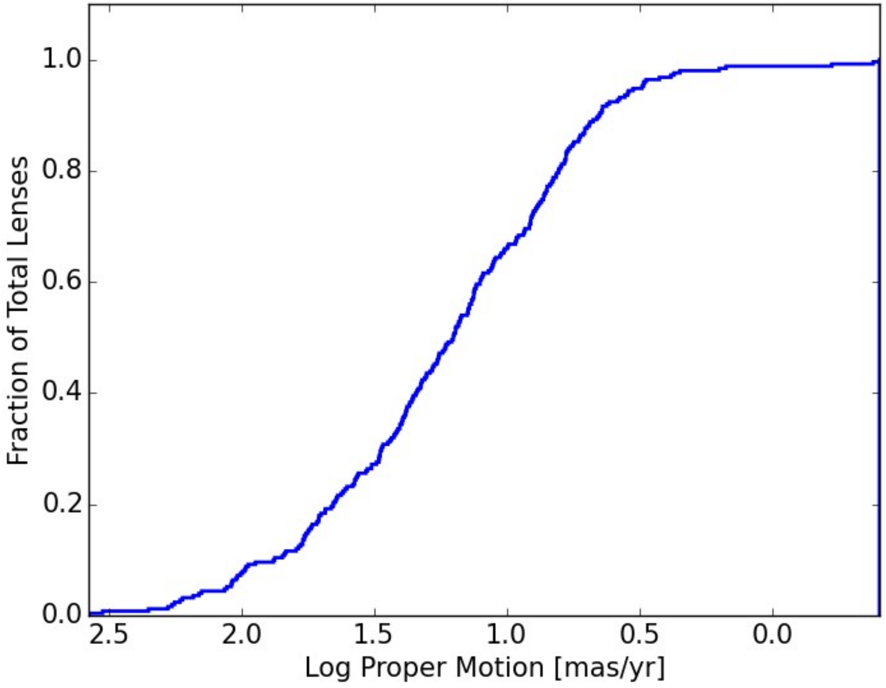


Distribution of proper motions

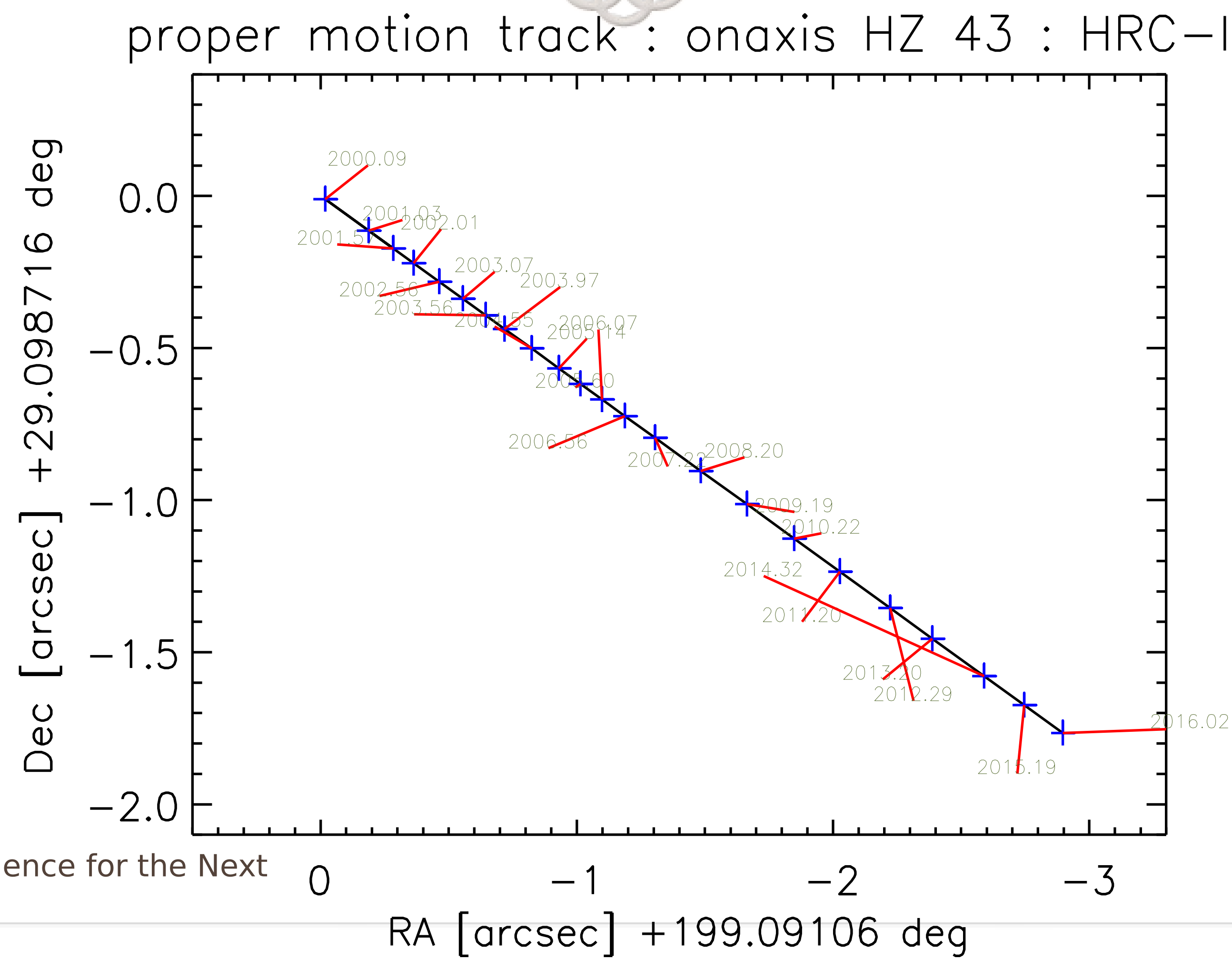


Harding et al. 2016

Our goal is to automatically detect the motion of XRSs

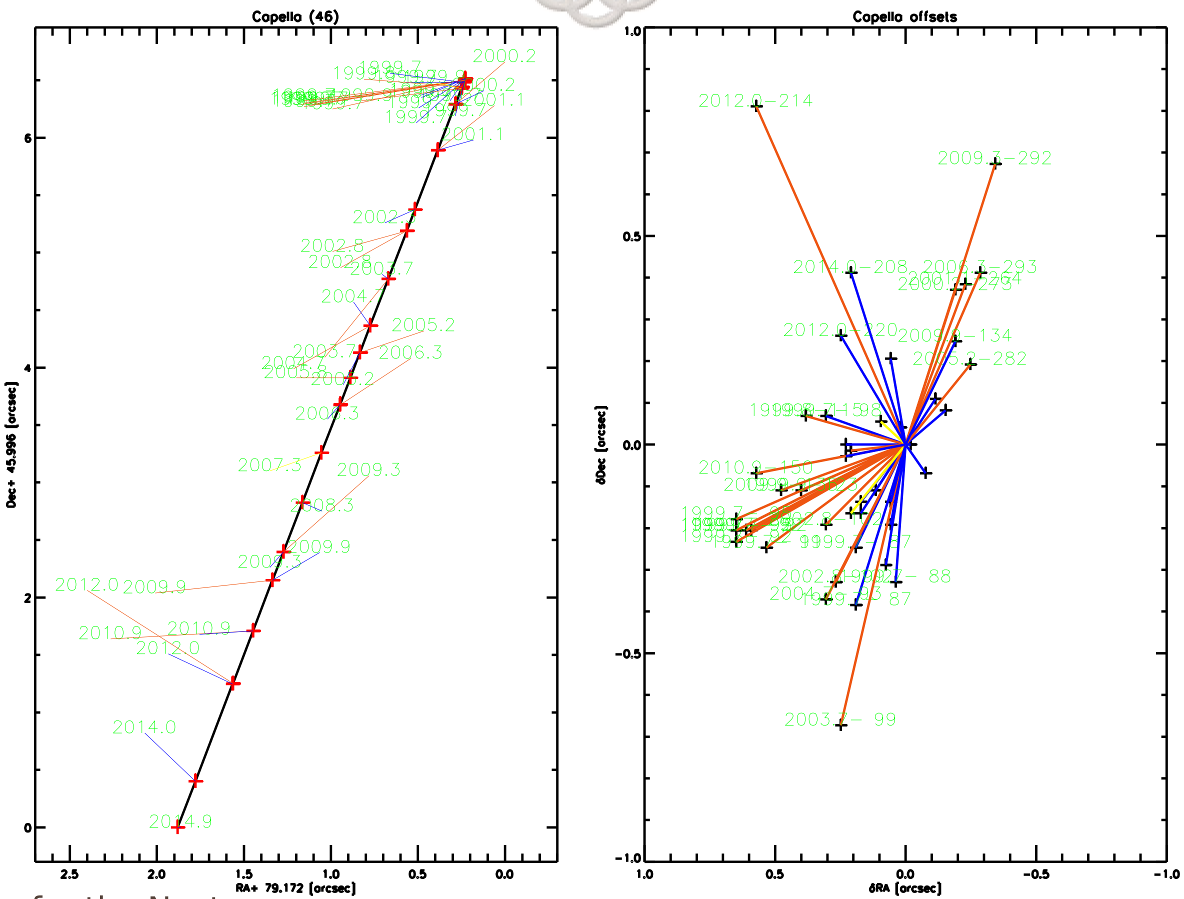
- We would like to ***discover*** the motion of XRSs.
- We start with the ***Chandra Source Catalog. (Evans et al. 2010)***
- We develop methods that can be implemented algorithmically.
- Then test them using Sepastien Lepine's "SUPERBLINK" catalog.

HZ 43



proper motion track : onaxis HZ 43 : HRC−I
Dec [arcsec] +29.098716 deg
RA [arcsec] +199.09106 deg
0.0
−0.5
−1.0
−1.5
−2.0
0
−1
−2
−3
2000.09
2002.01
2002.56
2003.07
2003.97
2003.56
2006.07
2006.56
2008.20
2009.19
2010.22
2014.32
2011.20
2012.29
2016.02

Capella



Capella (46)
Dec+ 45.996 [arcsec]
RA+ 79.172 [arcsec]
Capella offsets
δDec [arcsec]
δRA [arcsec]

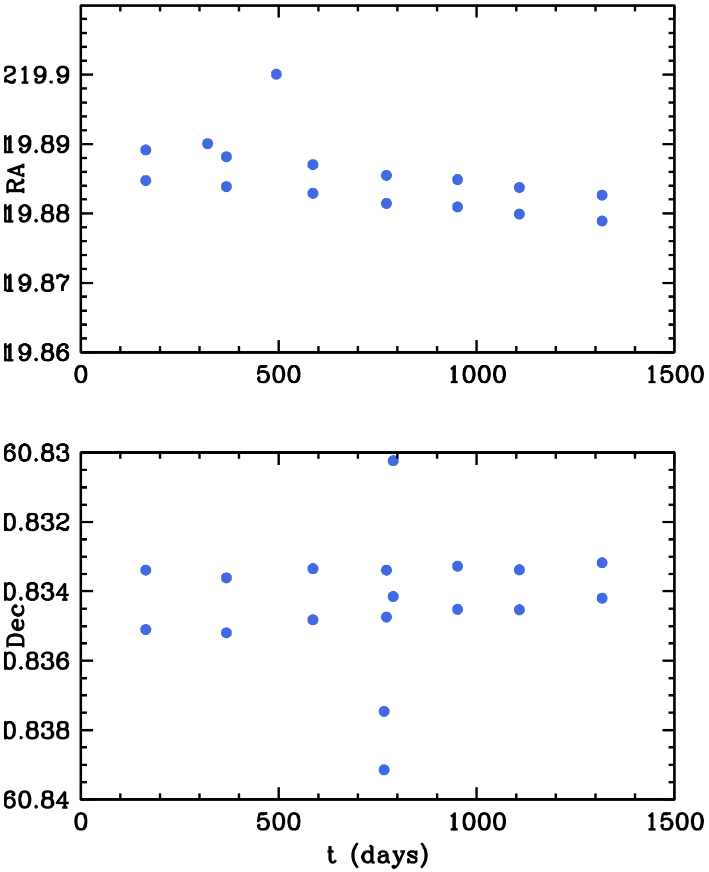
Trial Method

- A single star may not have been given a single ID number if it moved too much between observations.
- We examine each ID’ed source.
- If it was observed and given the same ID several times, we use the apparent changes in position over time to place an upper limit on the proper motion.
- During observations when it is absent, we test whether any other stars may actually be the one that is “missing”.

We rediscovered some proper motion.

- Alpha Centauri, VB 10, Capella and others.

Chandra's view of Alpha Centauri



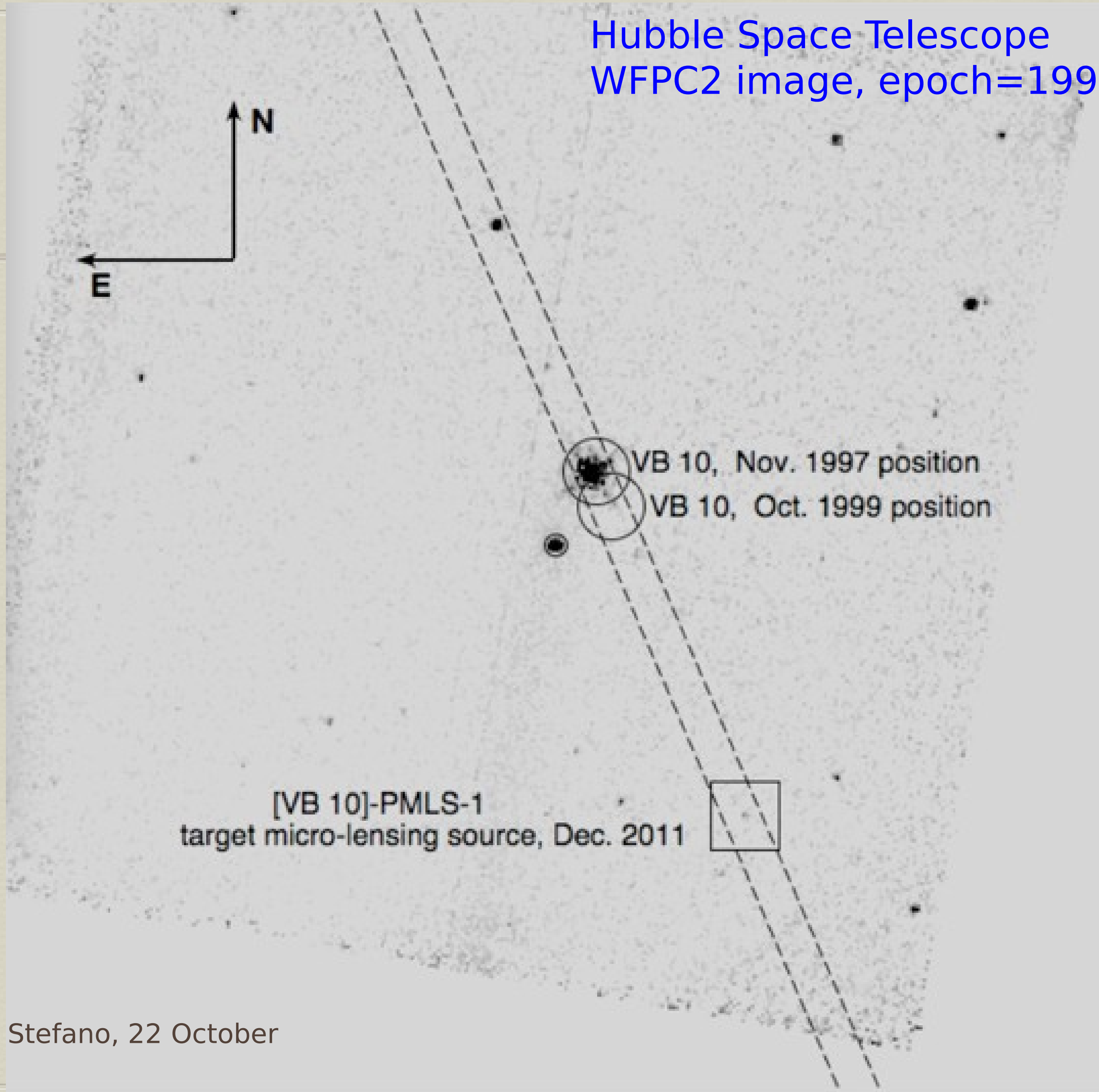
We rediscovered some proper motion.

- Alpha Centauri, VB 10, Capella and others.
- Many other matches (about 70 in all).
- Not all are reliable. We are identifying those that are not.
- Many in dense fields signify variability, but some need to be checked.

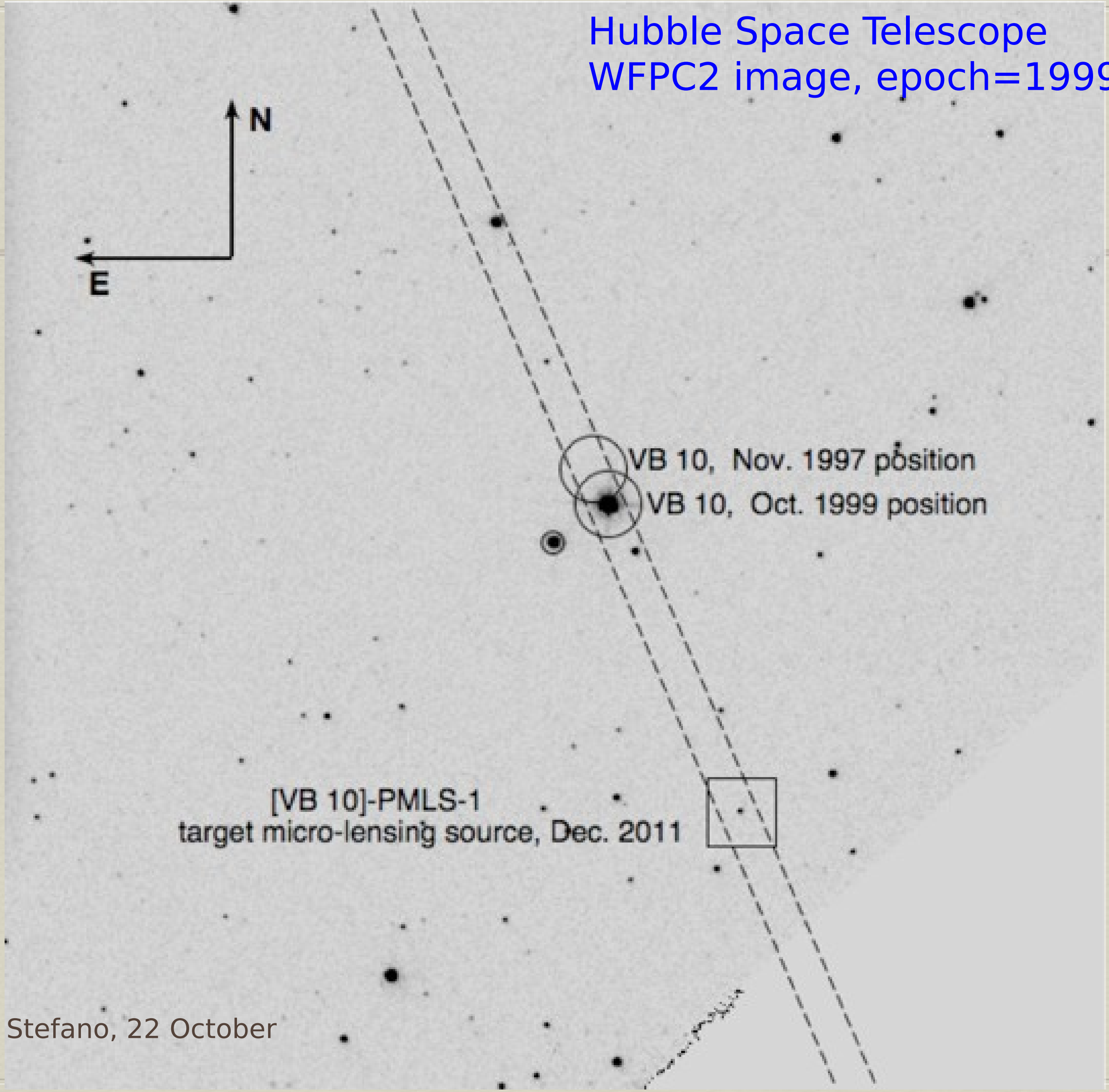
RD et al 2016

VB 10

Another fast-moving ***Chandra-proper-motion-detected*** star happens to have had a possible connection to gravitational lensing.


Hubble Space Telescope
WFPC2 image, epoch=1997
N
E
VB 10, Nov. 1997 position
VB 10, Oct. 1999 position
[VB 10]-PMLS-1
target micro-lensing source, Dec. 2011


10’’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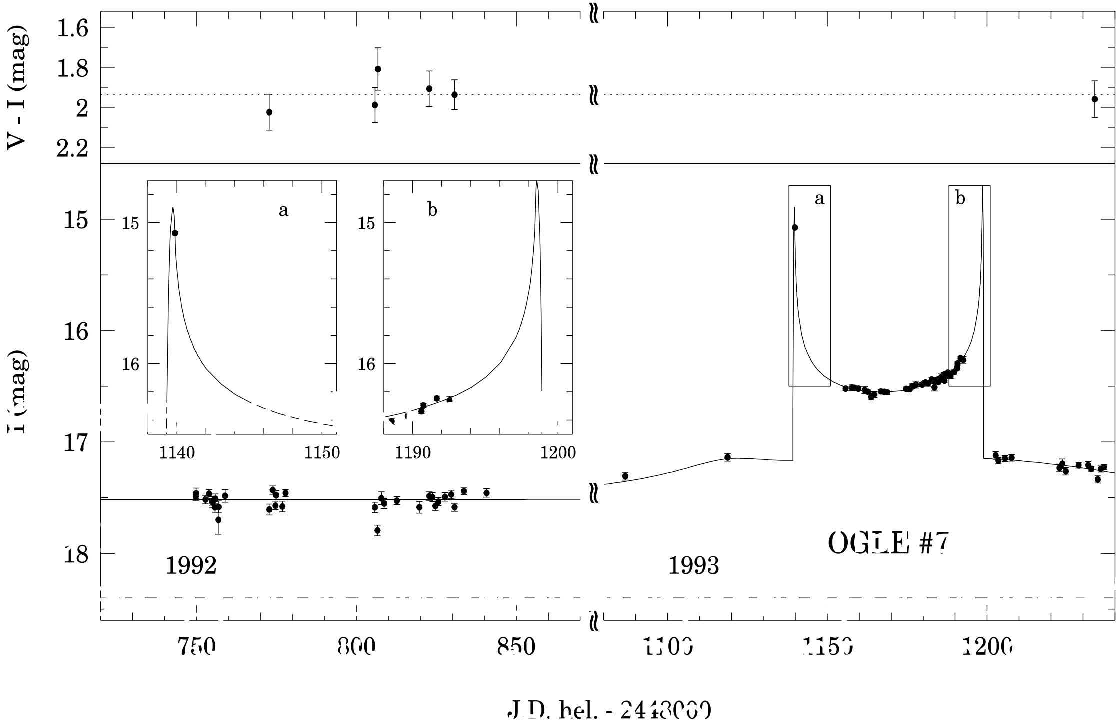
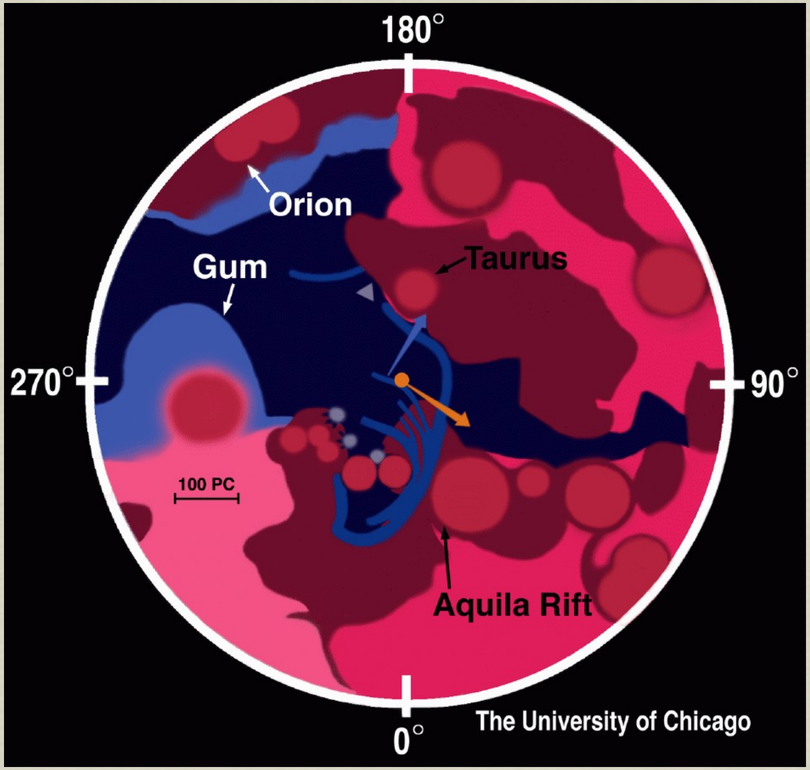
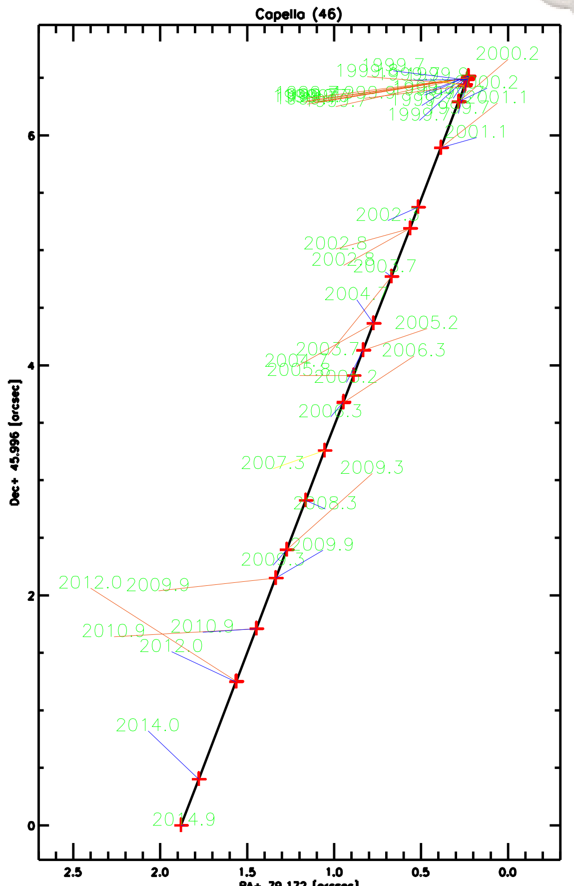

V - I (mag)
1.6
1.8
2
2.2
I (mag)
15
16
17
18
a
b
1140
1150
1190
1200
1992
1993
OGLE #7
750
800
850
1100
1150
1200
J.D. hel. - 2448000

We may have **discovered** some XRSs not previously known to be moving.

- It will take time, and possibly new observations to check them.
- In the meantime the important job is to refine this work and to think “big” in determining what new information and methods are needed. **Which new observations are needed? What new approaches?**


180°
Orion
Gum
Taurus
270°
90°
100 PC
Aquila Rift
0°
The University of Chicago

Capella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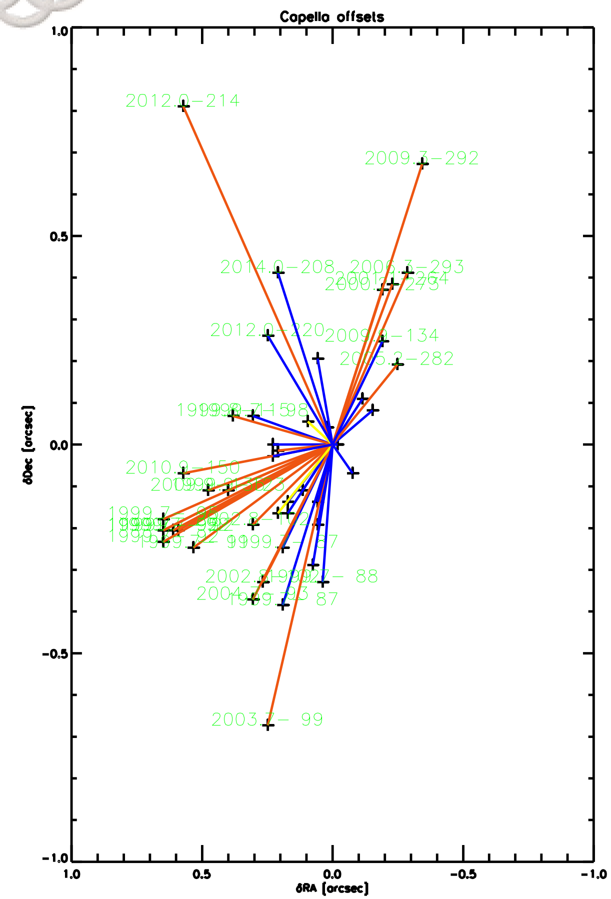
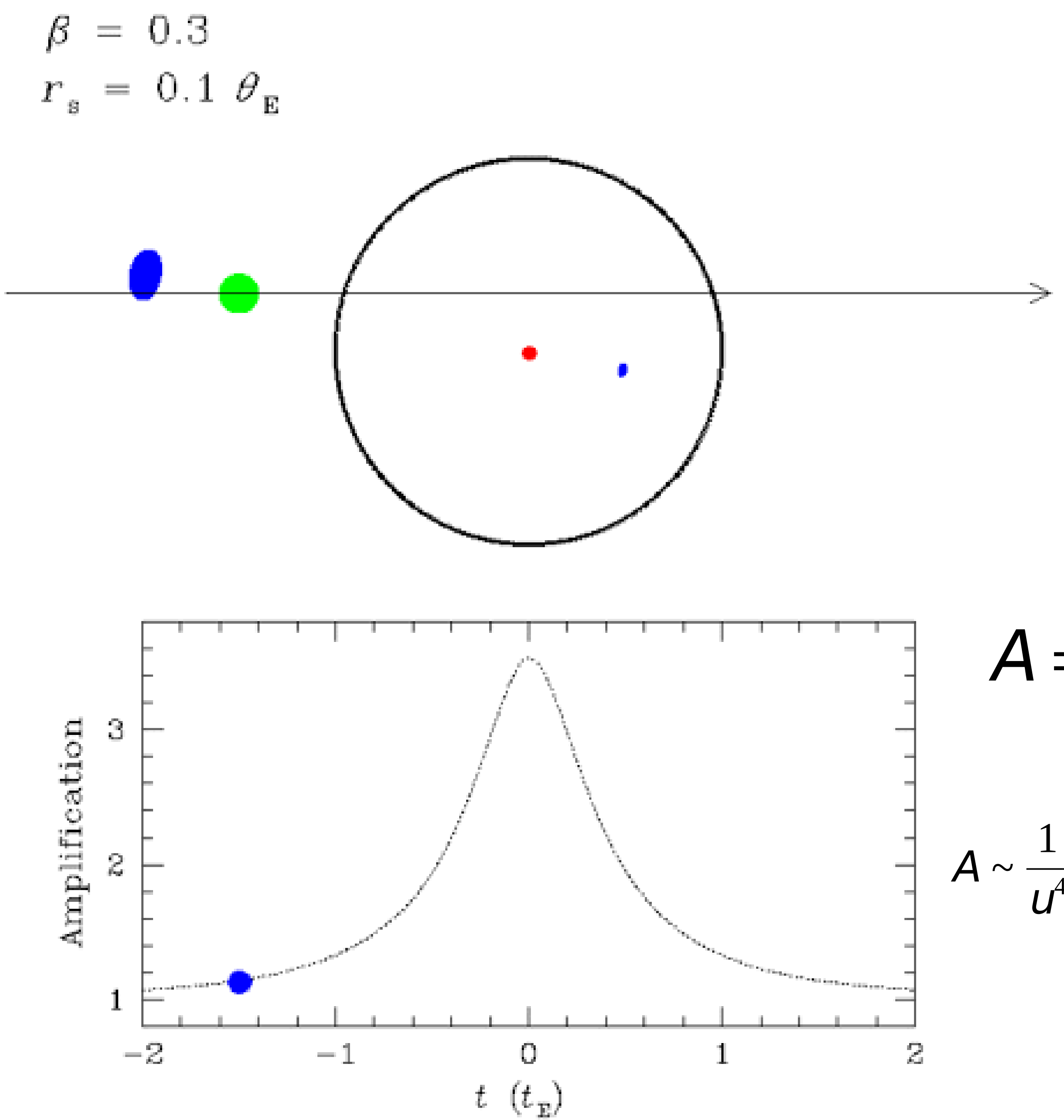

Capella offsets
δDec [arcsec]
δRA [arcsec]



$$A = A(u)$$

$$A \sim \frac{1}{u^4}; \qquad \delta \sim \frac{1}{u}$$