Chasing off-center Active Galatic Nuclei with Gaia

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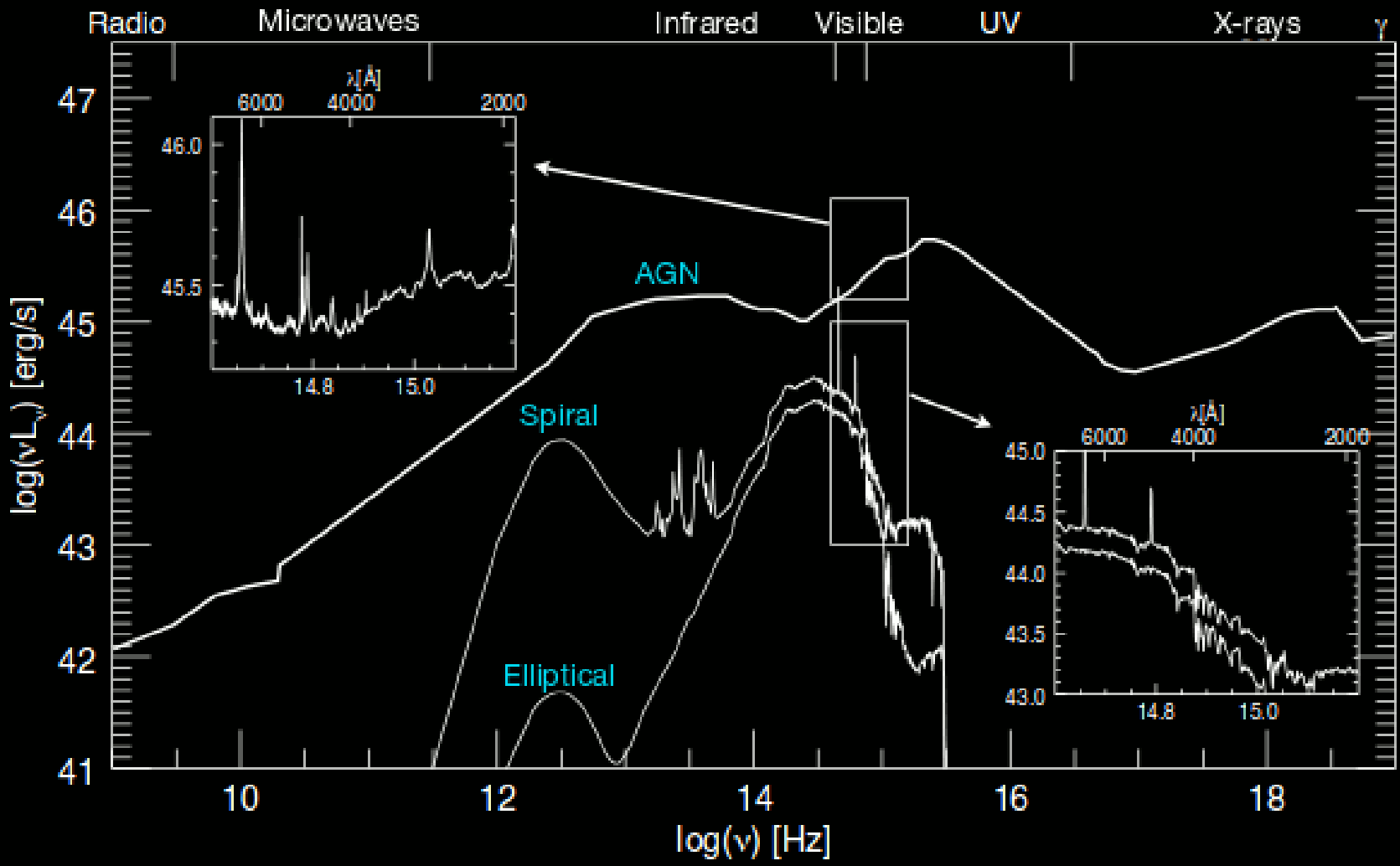
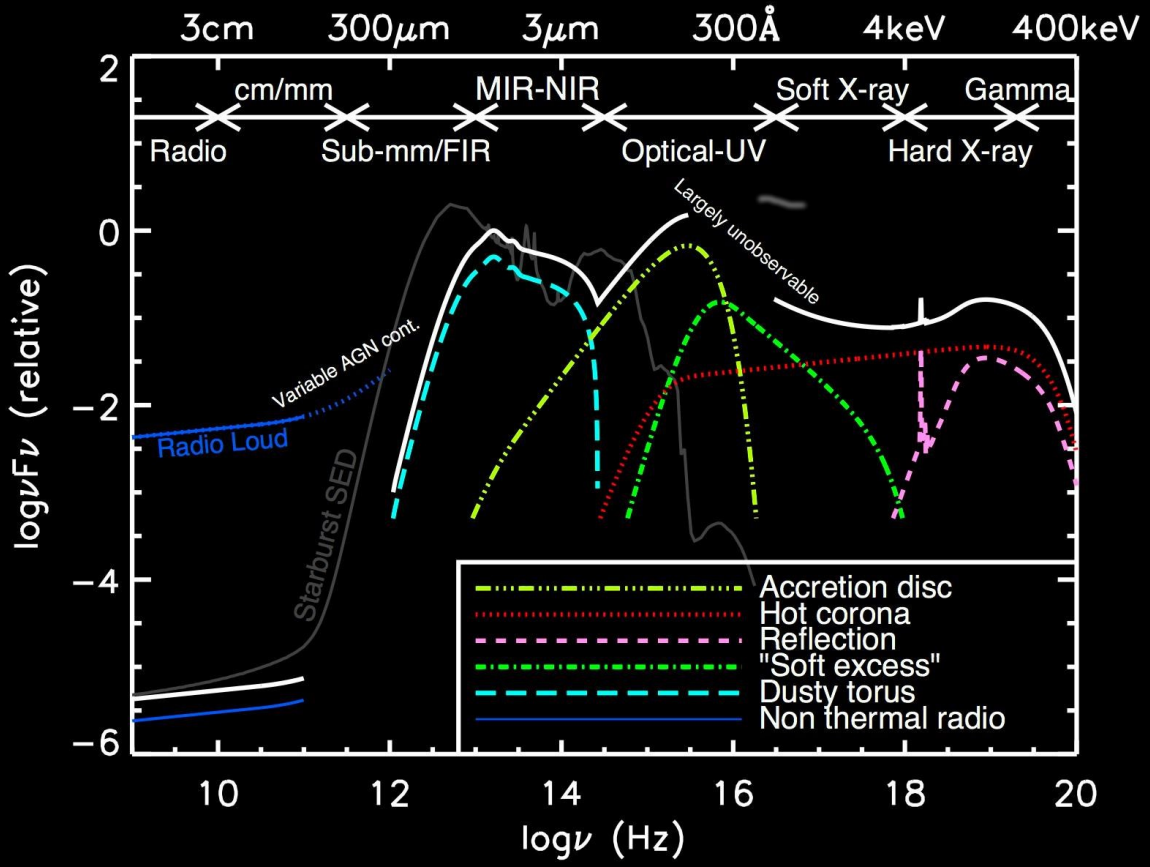
+ Ian Browne, Simon Garrington – Jodrell Bank Obs, Manchester

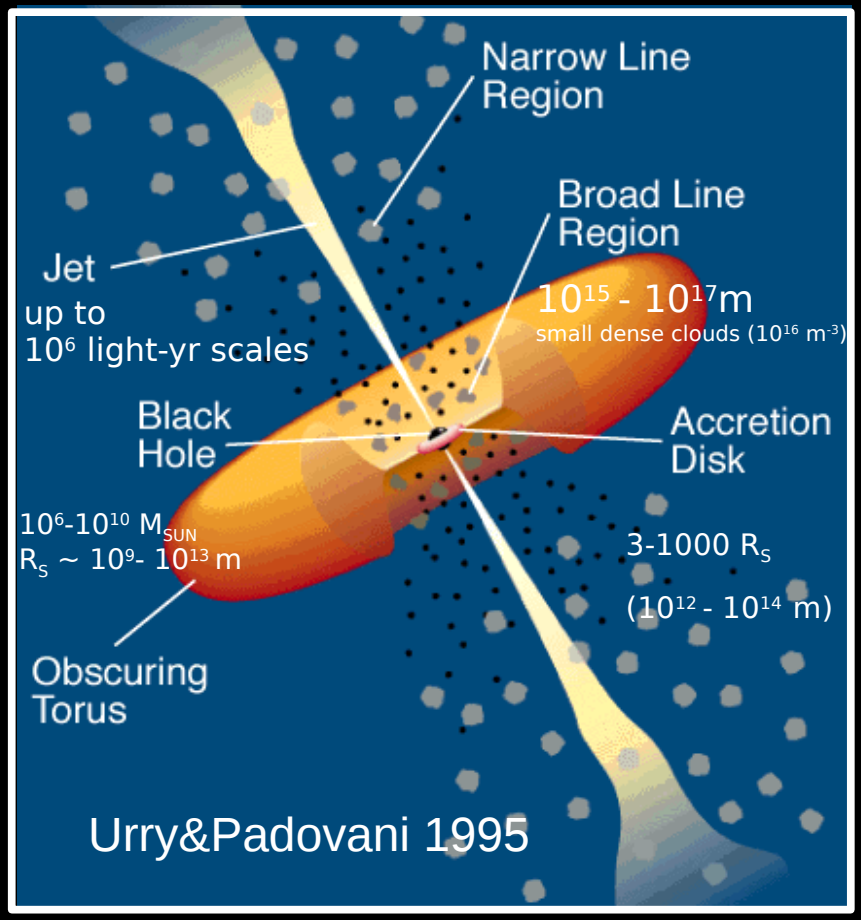


adapted from Marconi 2013

agn observations

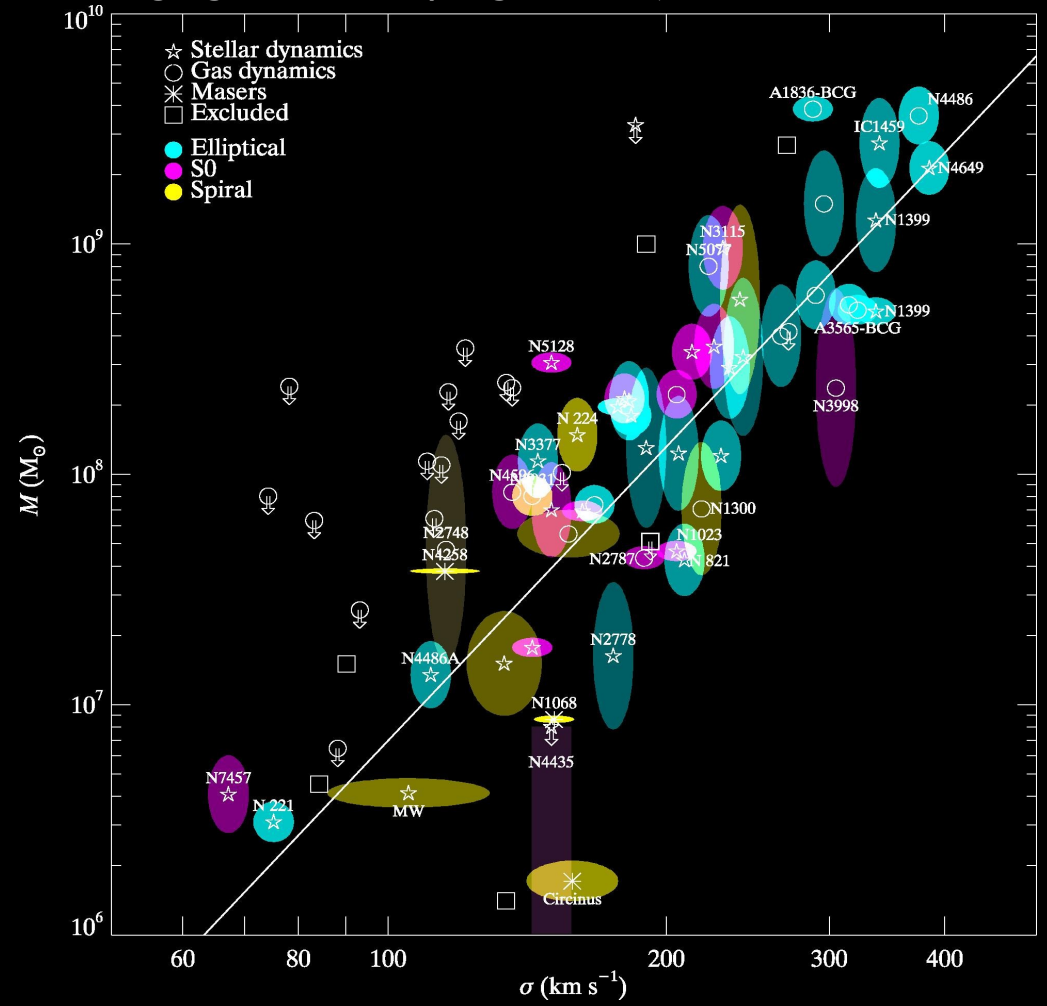


agn paradigm



coevolution of agn and host galaxies

big fraction of galaxies in the local Universe contain SMBH in their centres (Magorrian+ 1998)
there is a good correlation between the velocity dispersion of the galaxy and the mass of the SMBH (Ferrarese & Merritt 2000, Gebhardt+ 2000), which may be a consequence of both having grown through hierarchical merging of smaller progenitors (Haehnelt & Kauffmann 2000).

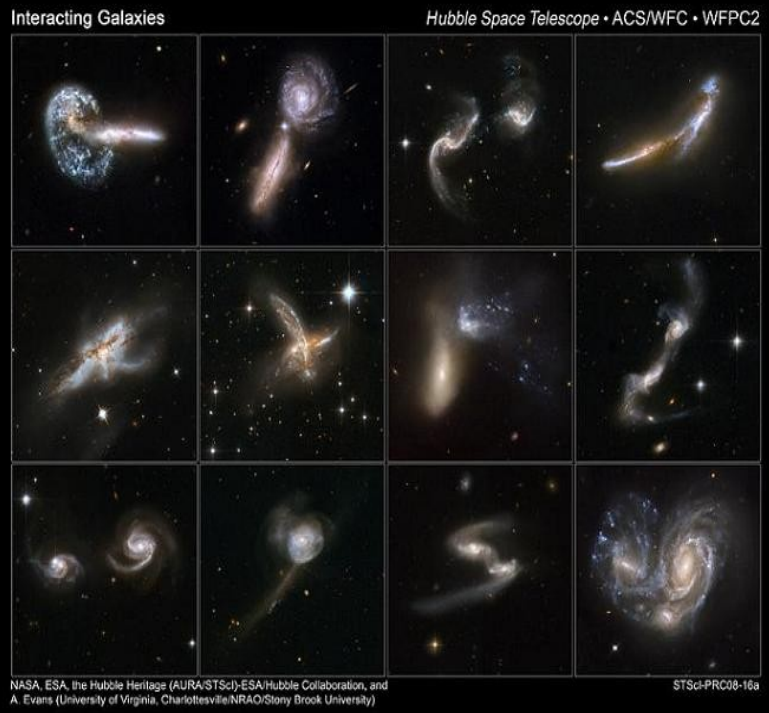


M-σ relation for galaxies with dynamical measurements

Gültekin + 2009

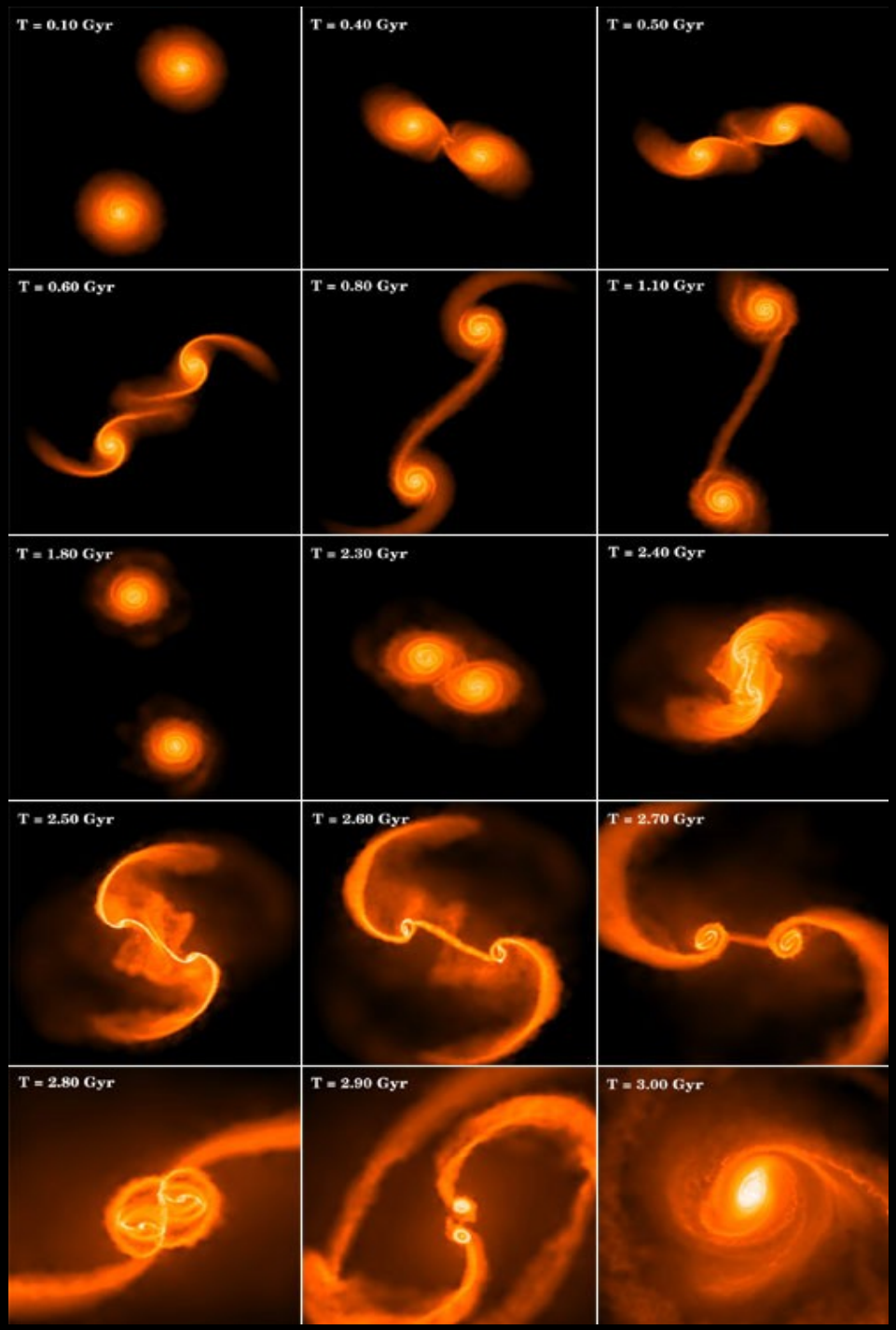
coevolution of agn and galaxies

merging is common in galaxy formation



if both have SMBH → Binary SMBH

(Belgeman+ 1980, Quinlan+ 1996, Volonteri+ 2003, Mayer+ 2007; Tanaka & Haiman 2000, Kulkarni & Loeb 2012, Kulier+ 2013)



Mayer + 2007

dynamical friction shrinks the binary orbit to the central pc scale (~10^8 yr)

system stalls (t?)

eventually coalesces

anisotropic emission of grav. waves kicks SMBH
→ a gravitational wave rocket effect!

single SMBH recoils

kick V ~500kms^{-1} →
oscillates in turn of the initial position , offset hundreds of pc, t~10^7 yrs

Komossa&Merritt 2008

but very few binary systems/kicked systems have been detected !!

→ eg CLASS sample: 16000 VLA maps, 23 lenses but no binaries (Browne + 2003)

→ different methods, mostly based in electromagnetic signatures, as for example double-peaked broad emission lines, kinematics of VLBI components in radio jets, flaring accreting disks, disrupted flares from stars around recoiling SMBH, etc (for a review see Komossa 2012).

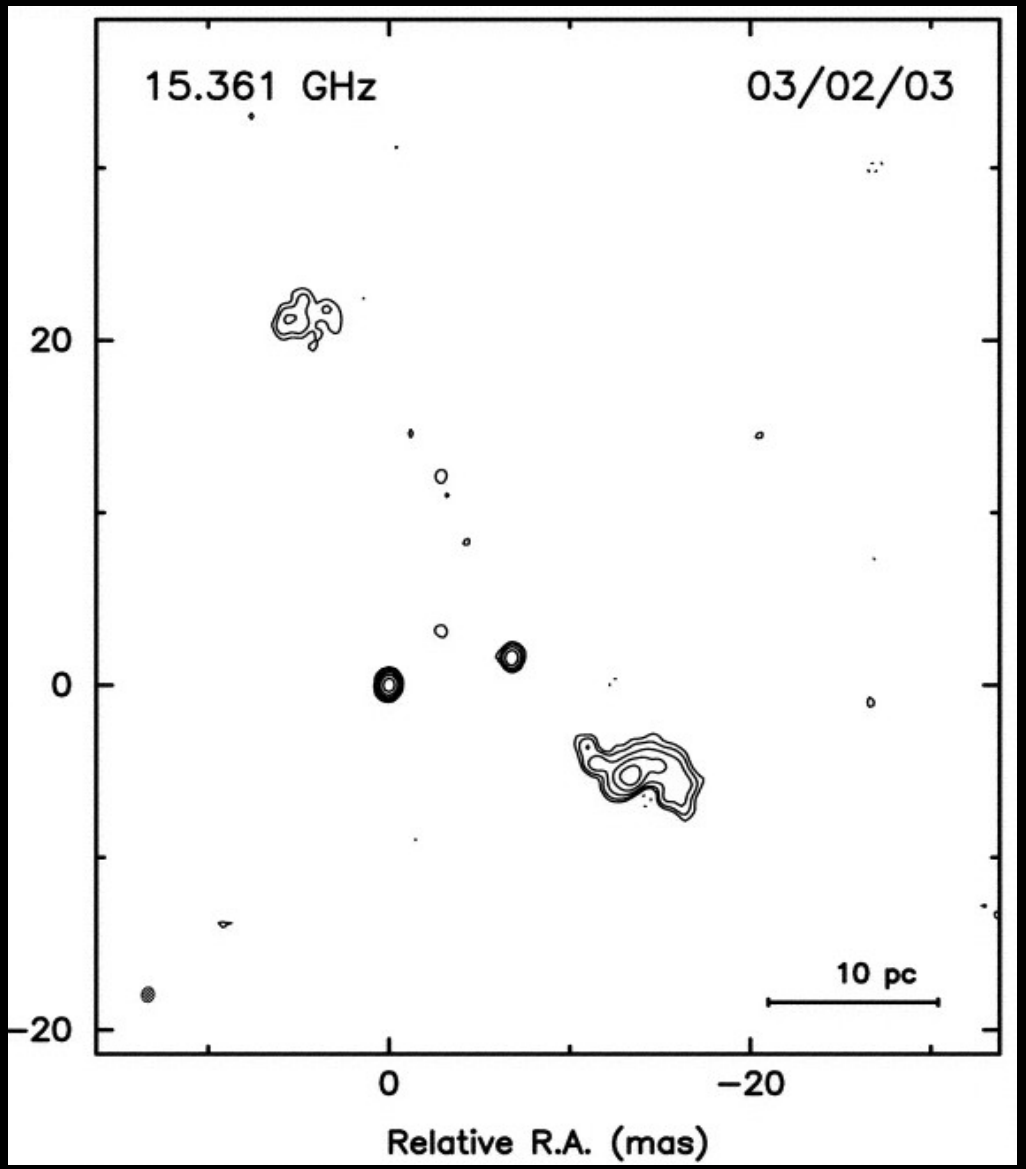
Binary SMBH

0402+379
separation 7.3 pc

Rodriguez + 2006

Maness + 2004

Burke-Spolaor + 2010
2000 VLBI maps:
only re-discovered 0402+379

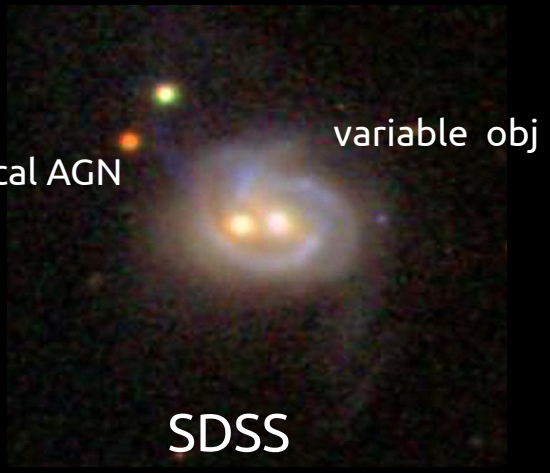


Binary SMBH

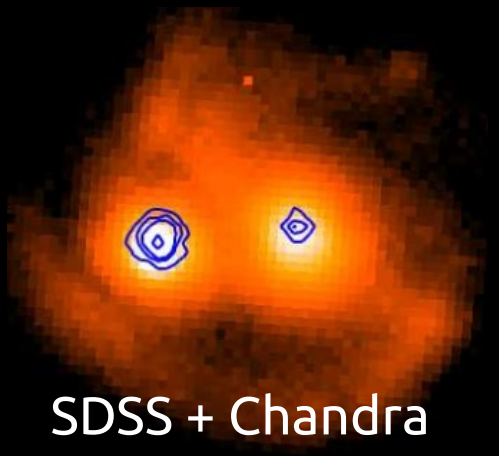
Mrk 739

separation 3.4 kpc
5.8''

Koss + 2011



SDSS

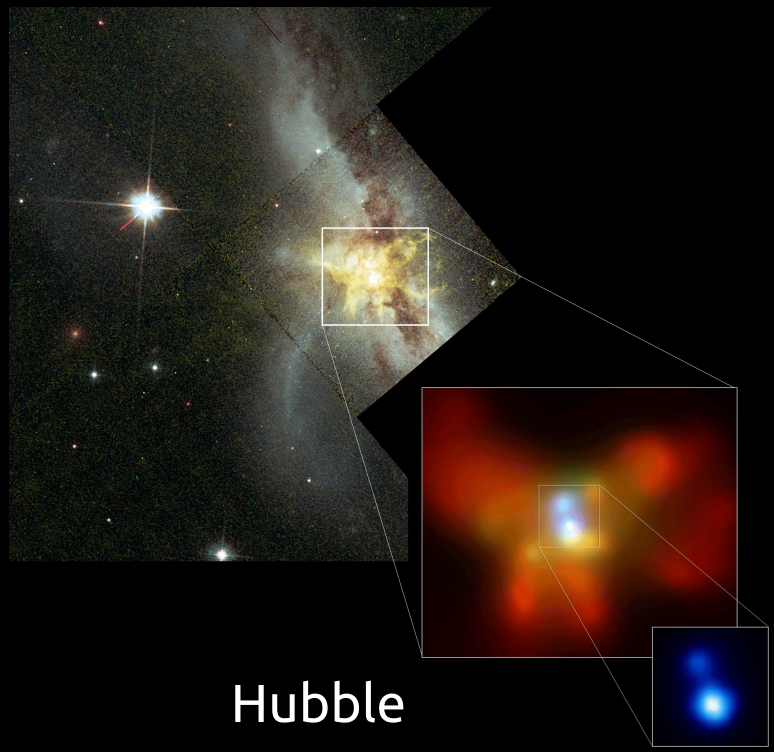


SDSS + Chandra

NGC 6240

separation 0.7 pc
1.8''

Komossa + 2003



Hubble

Chandra

Kicked SMBH?

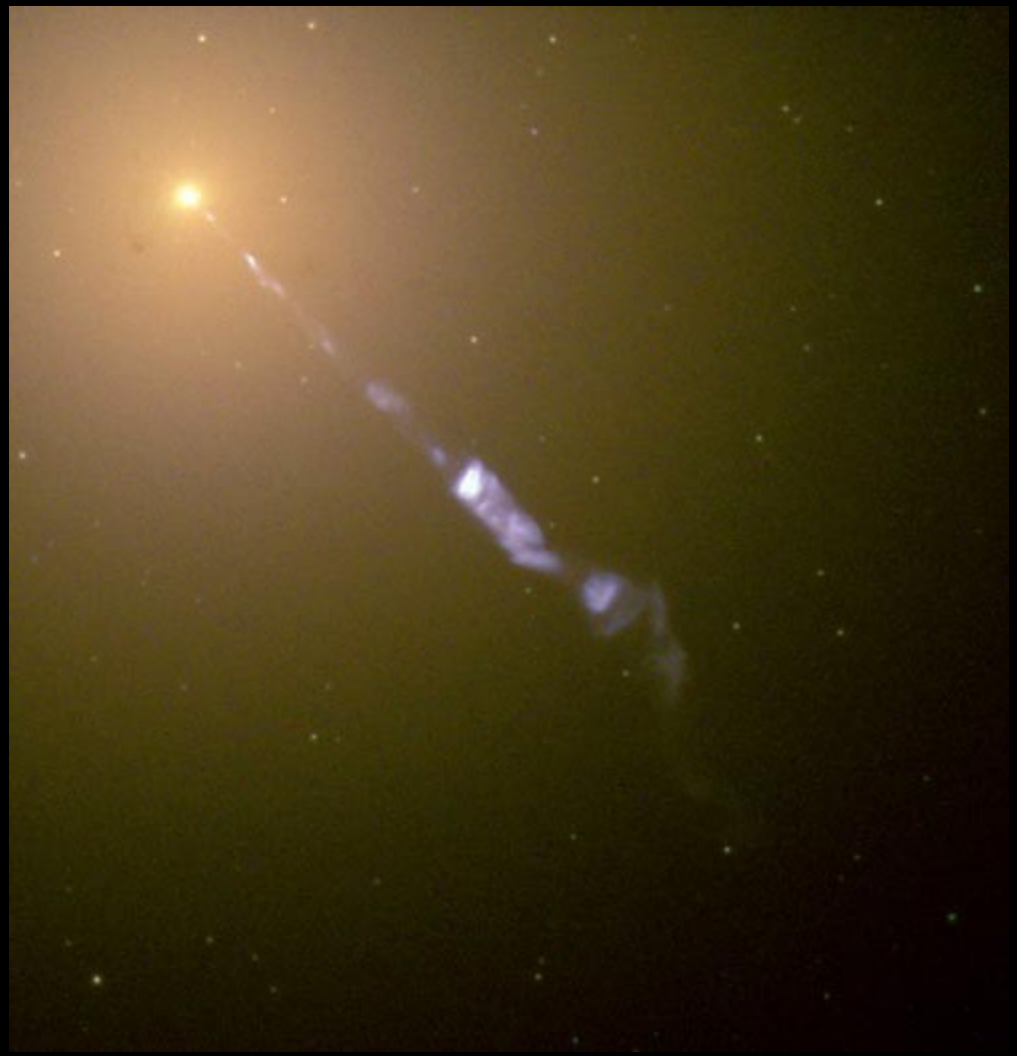
M 87

Offset between nuclear point source [AGN] and the photocenter [galactic centre through isophotal fitting]

0.1” == 6.8 pc

Batcheldor + 2010

Lena + 2014



→ by identifying these systems and determine the SMBH displacements,
distribution of kick velocities, properties of the recoiling SMBH may be
constrained paramount information for the evolution models

a n e w a p p r o a c h

Directly pinpointing “offset” systems: galaxies whose photocentre in the optical band differs from the radio position of the active SMBH (AGN)

needs excellent astrometry accuracy → Gaia and e-MERLIN (SKA pathfinder)

The novelty and success of the project is fairly dependent on the selection of the objects

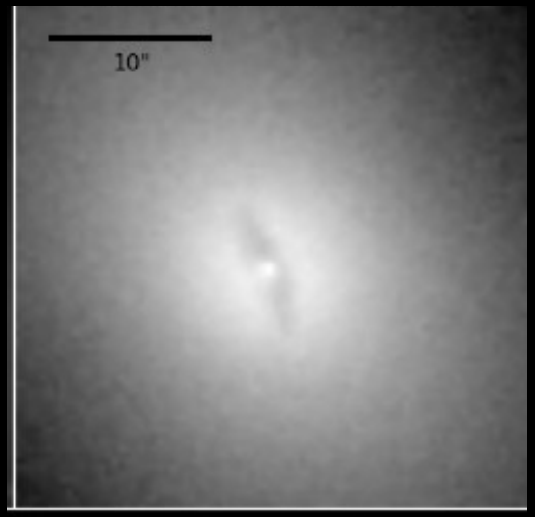
Pilot Project

a small sample of 28 galaxies, for which e-MERLIN observations were awarded as a pilot study (Garrington+).

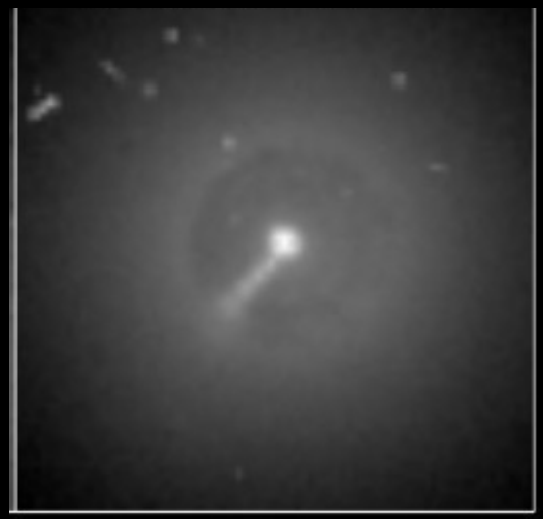
MSc thesis of Ana Afonso, made a detailed study of the morphology of the galaxies, and simulated profiles with the GIBIS (*Gaia* Instrument and Basic Image Simulator) to check for Gaia dectatibility.

avoid non smooth/relaxed optical counterparts

inner disks



optical jets



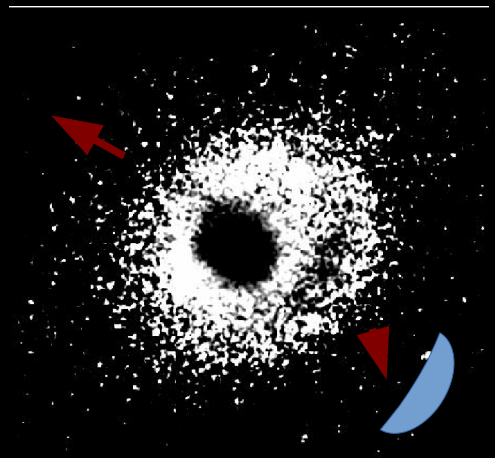
dusty regions

Afonso, 2014

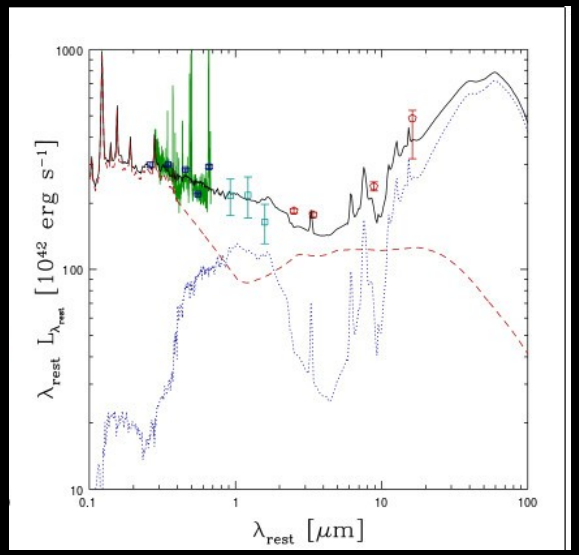
avoid non smooth/relaxed optical counterparts

SF components

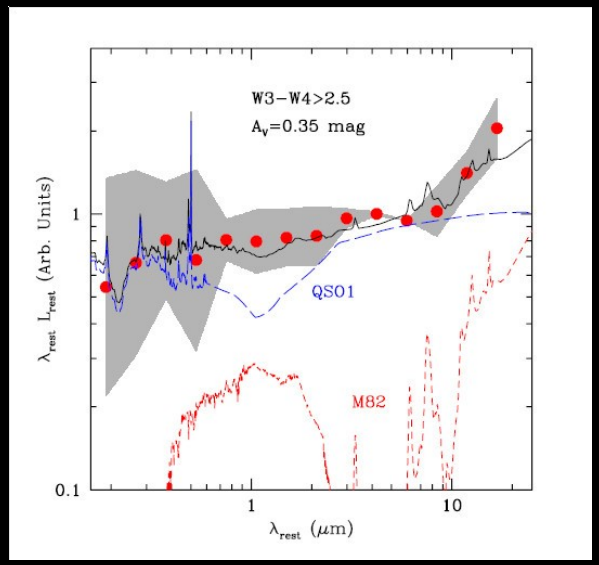
Core-jet and/or accretion disk + Star burst?



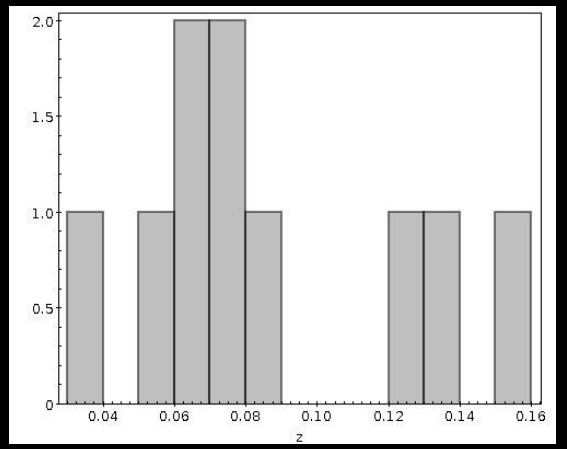
Antón, Browne & Marchã, 2008

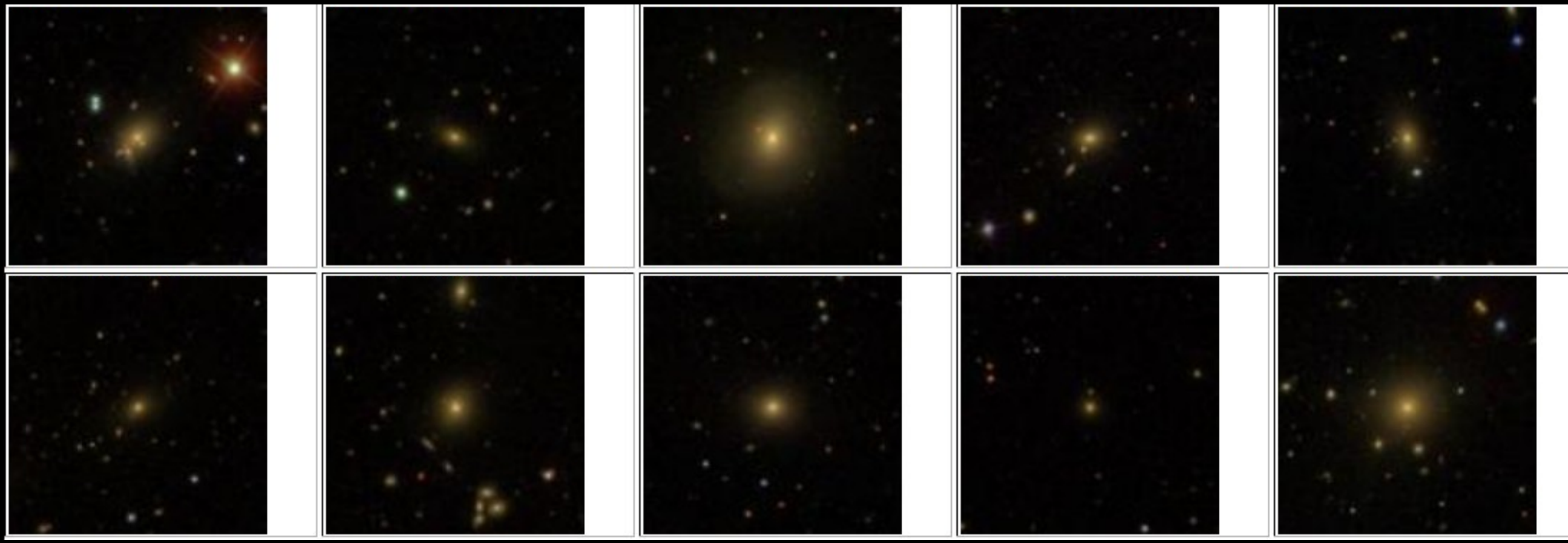


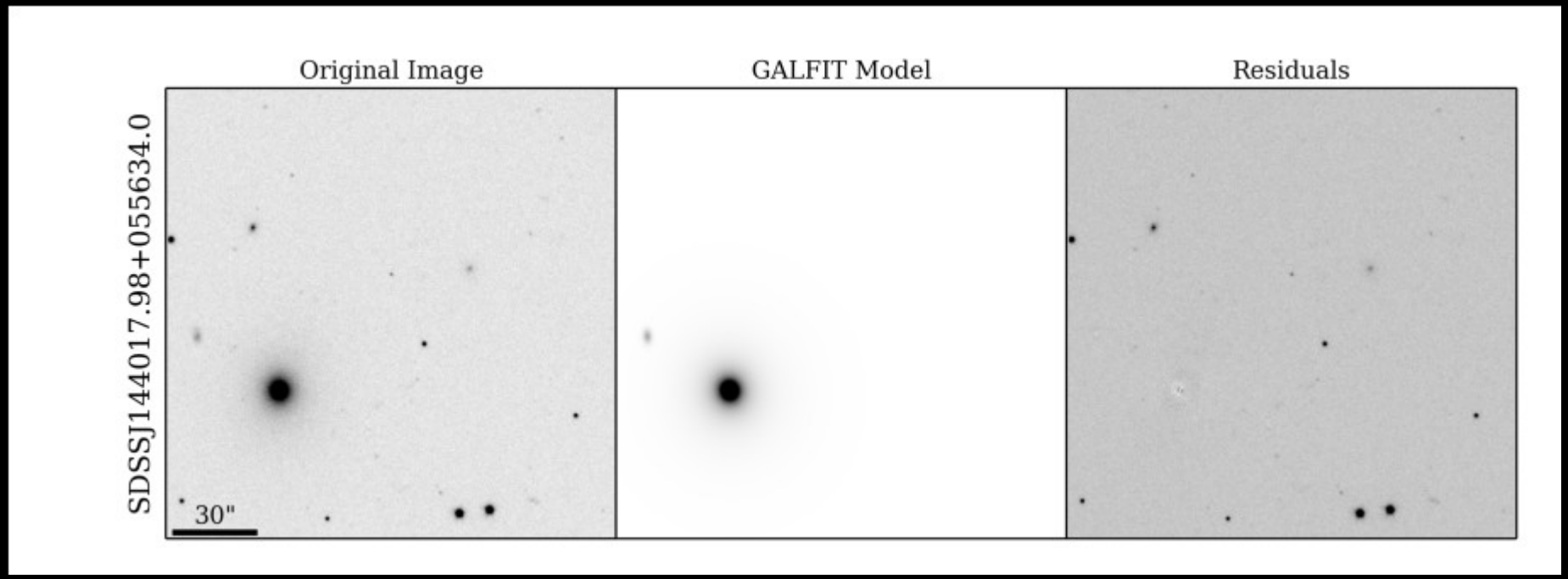
Caccianiga, Anton+ 2014

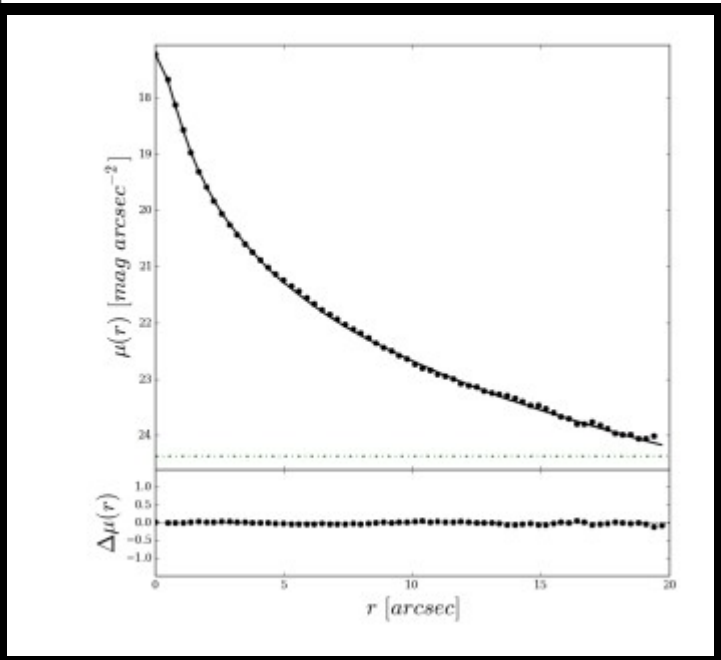


Caccianiga, Anton+ 2015


2.0
1.5
1.0
0.5
0
0.04
0.06
0.08
0.10
0.12
0.14
0.16
z




Original Image
GALFIT Model
Residuals
SDSSJ144017.98+055634.0
30"


$\mu(r)$ [$mag\ arcsec^{-2}$]
$\Delta\mu(r)$
r [$arcsec$]

e-MERLIN/VLBI facility

SKA pathfinder

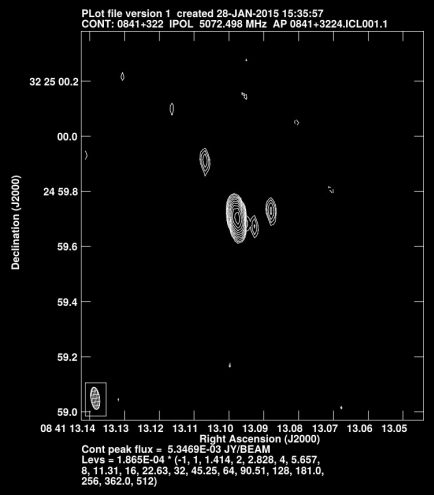
array of 7 antennas

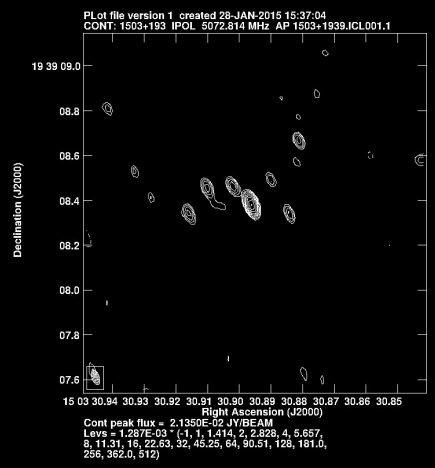
Bands: 1.3-1.8 GHz
4-8 GHz
22-24 GHz

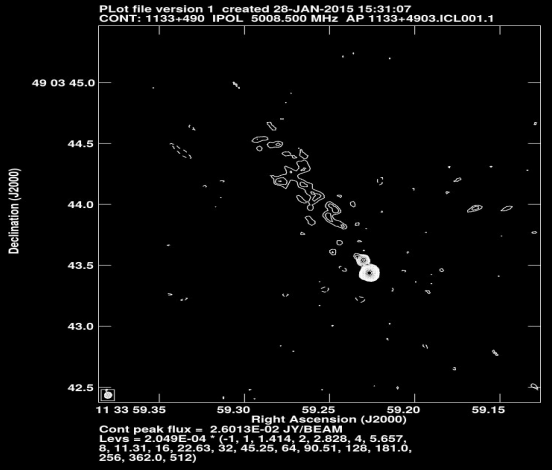
Resolution: 10-150 mas

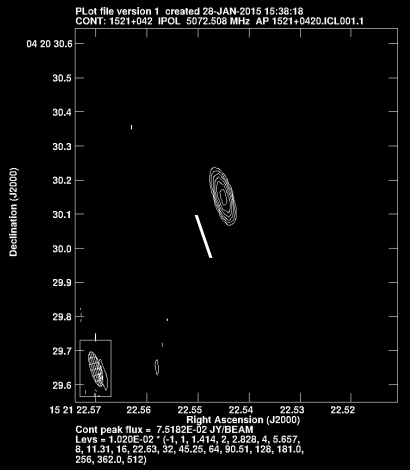
Sensitivity: 1 microJy

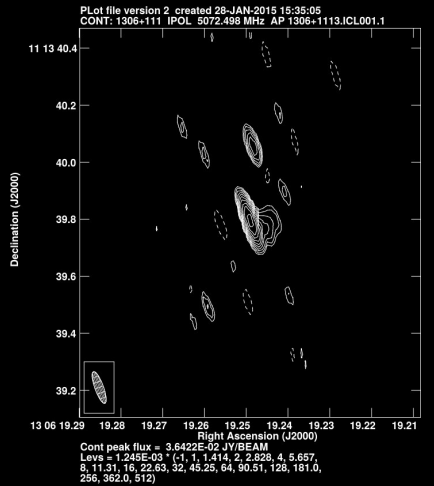
Astrometry, Polarimetry

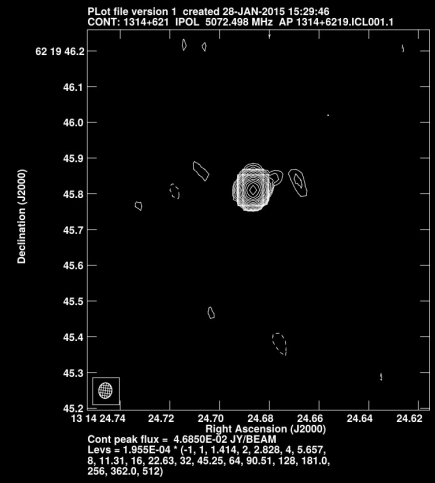


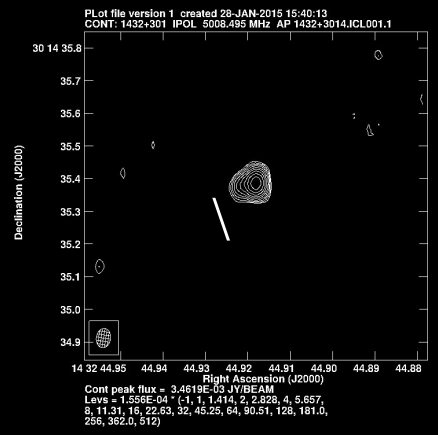


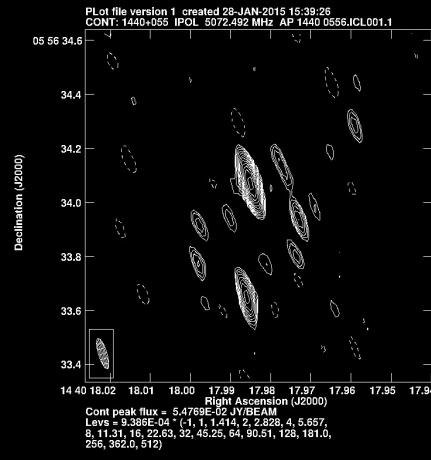






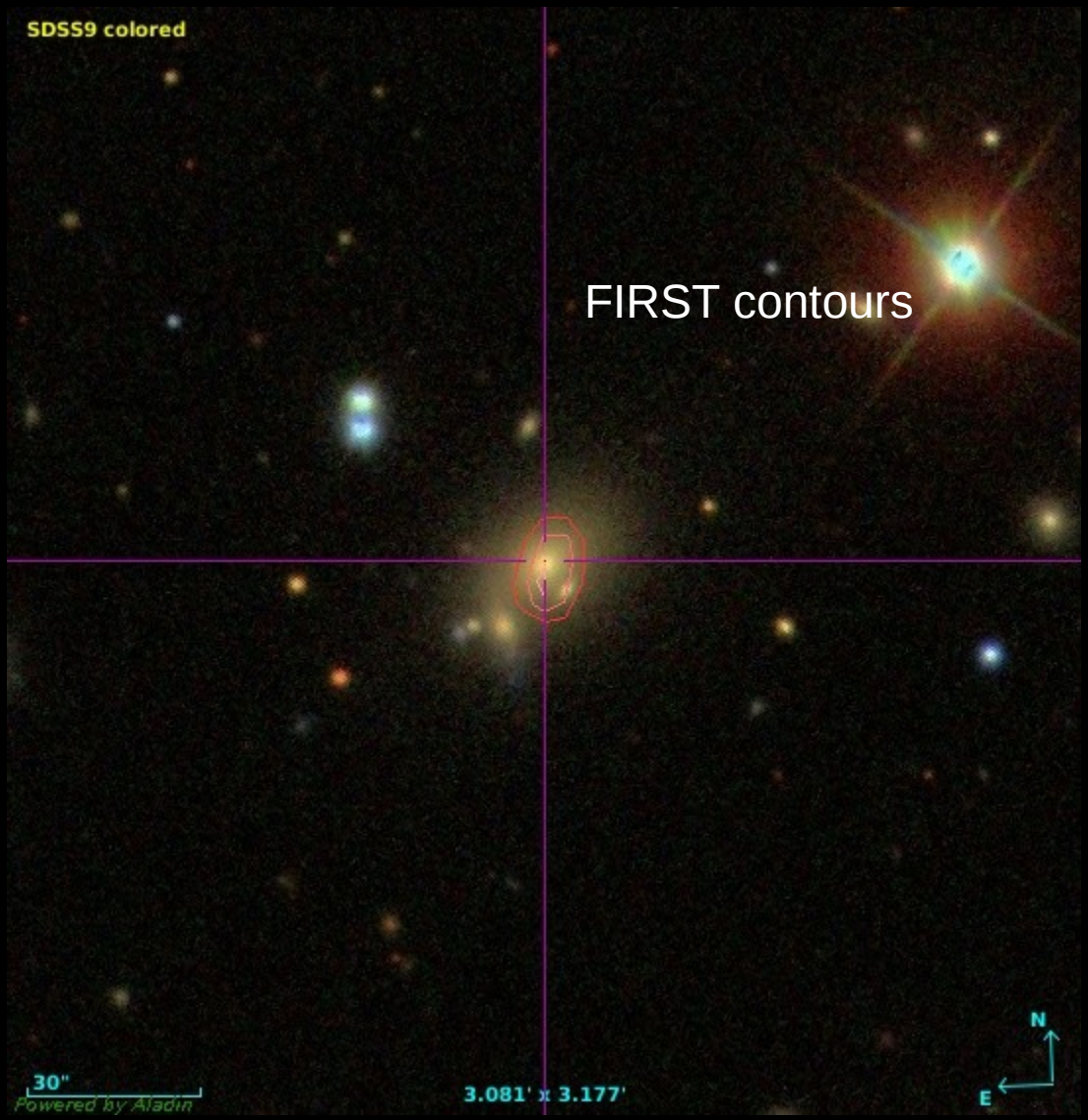




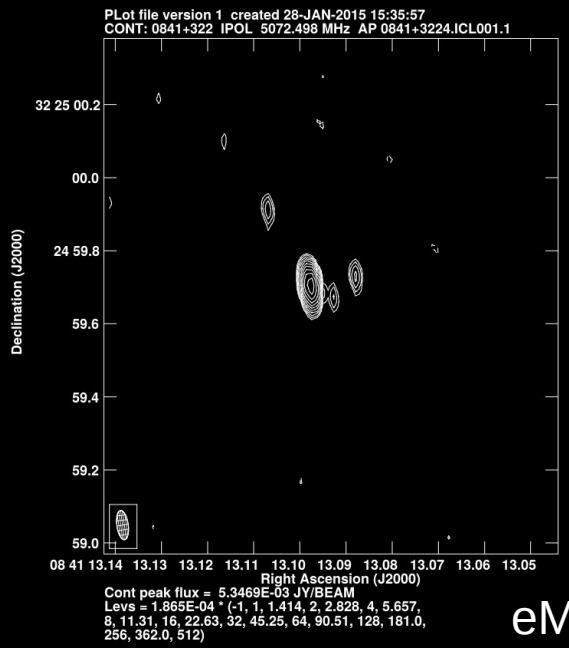


e-MERLIN 5 GHz observations

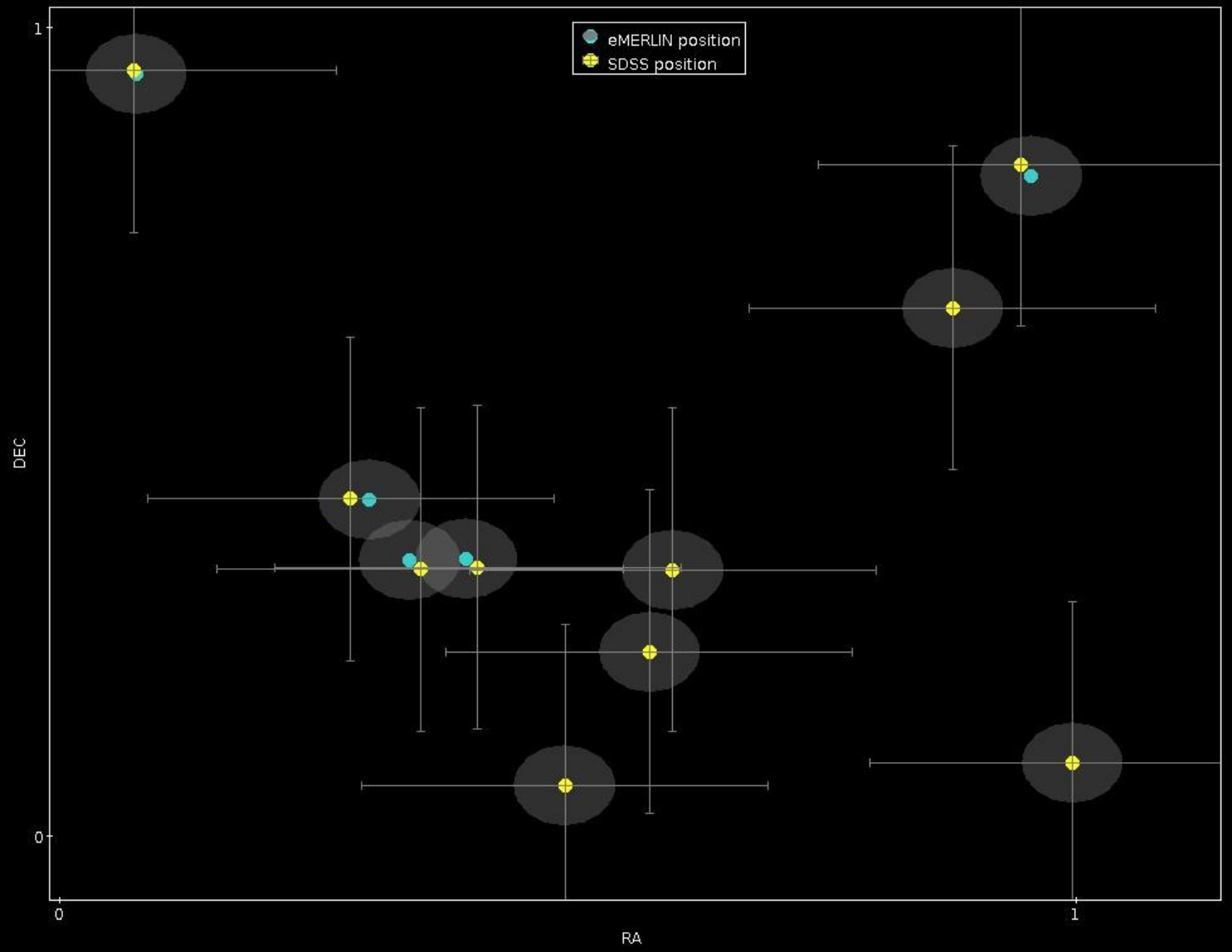
Anton, Browne & Garrington in prep



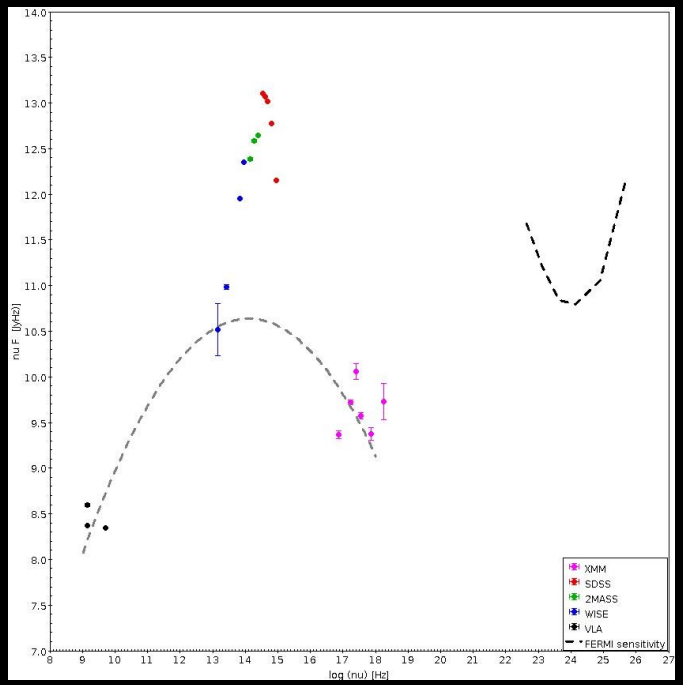
FIRST +
eMERLIN contours

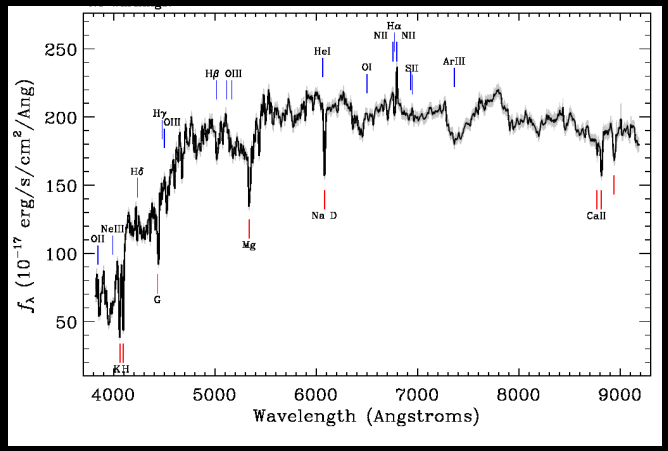


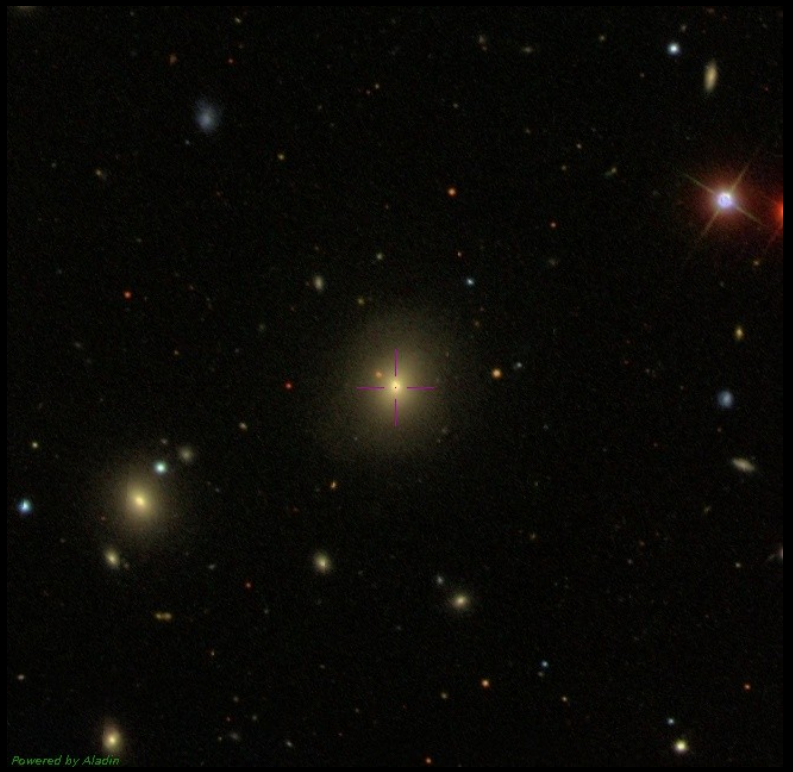
eMERLIN


eMERLIN position
SDSS position
1
0
DEC
0
1
RA

231 pc “displaced” candidate

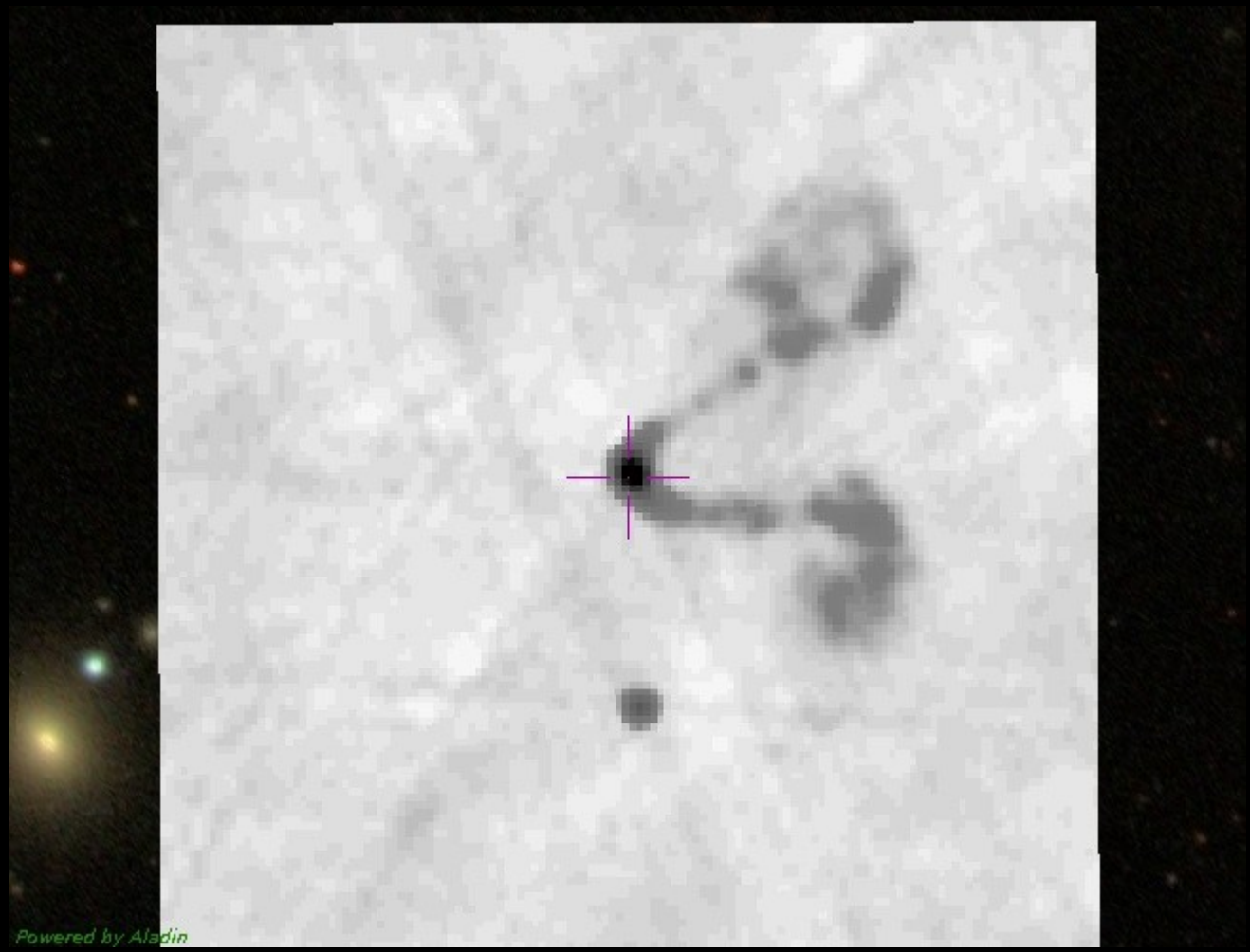




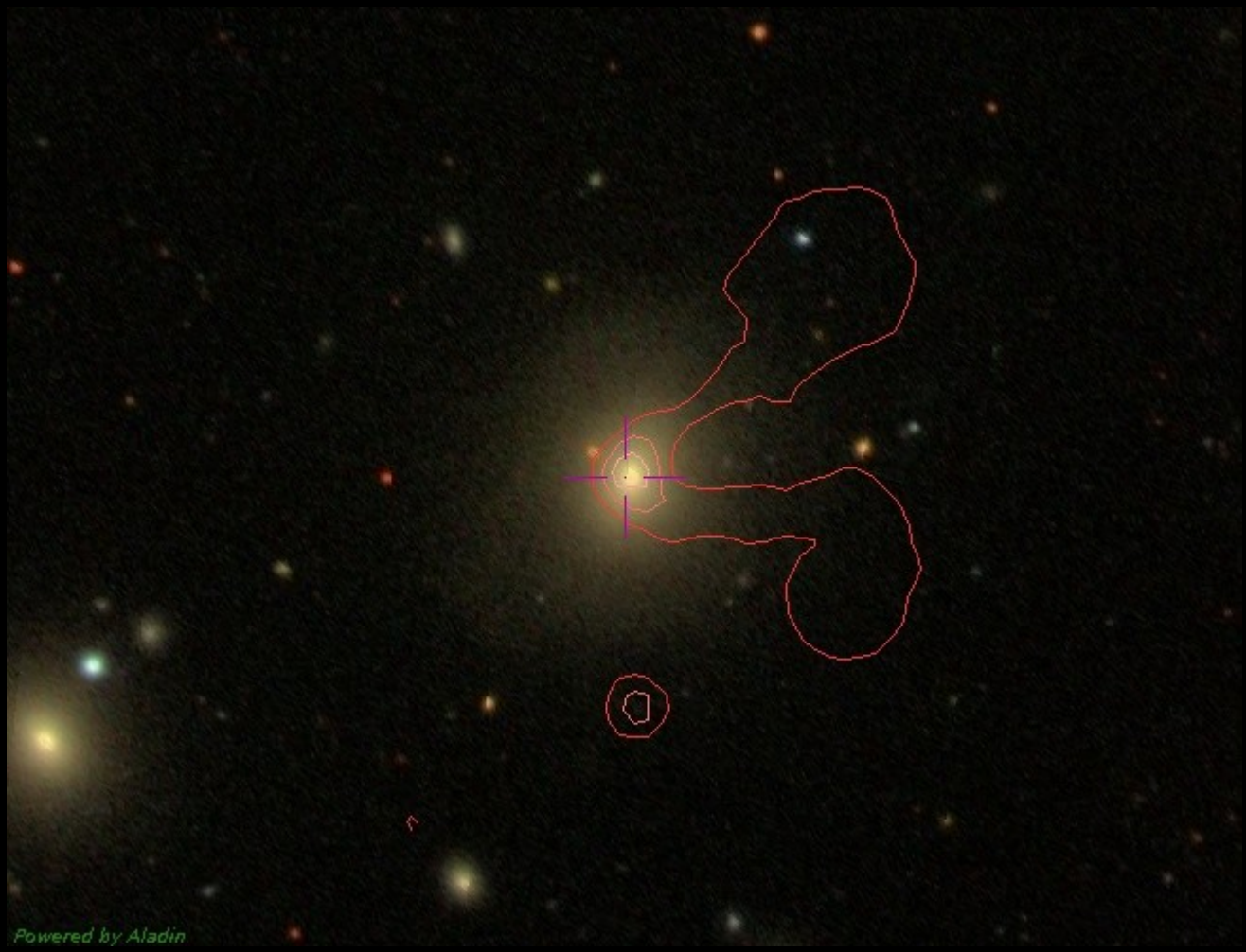


231 pc “displaced” candidate

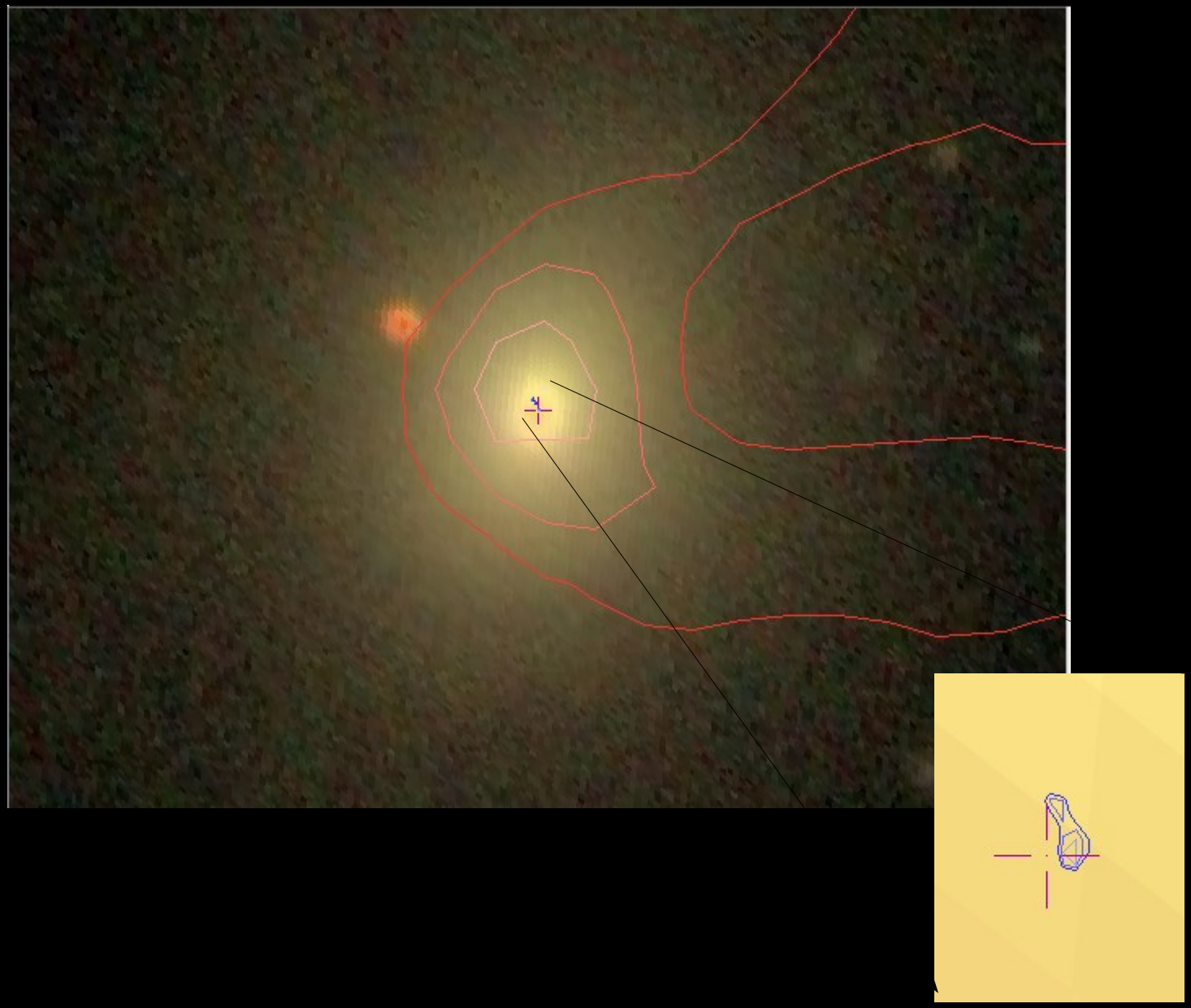
FIRST 1.4 GHz map
peak 118mJy/beam



231 pc “displaced” candidate

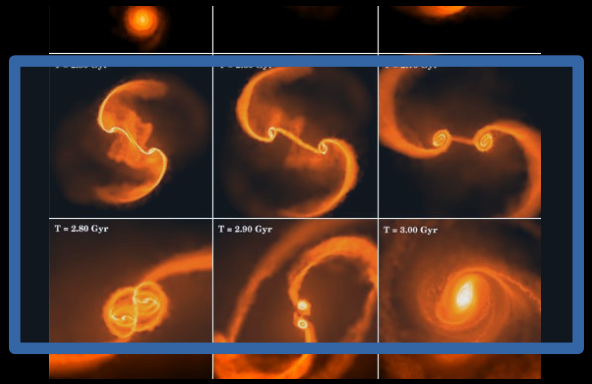


231 pc “displaced” candidate



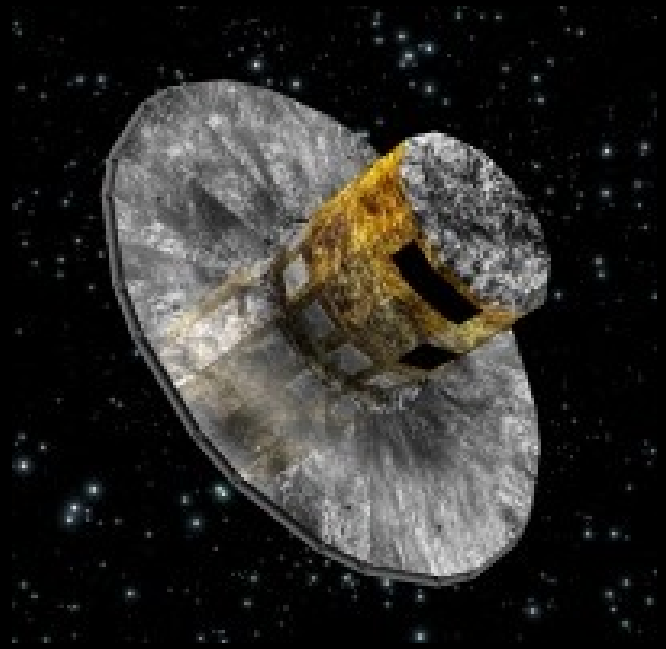
astrometry & AGNs in the Gaia – e-MERLIN – SKA era

low z



Any offset SMBH system?

maybe 50 systems / 10 000 candidates



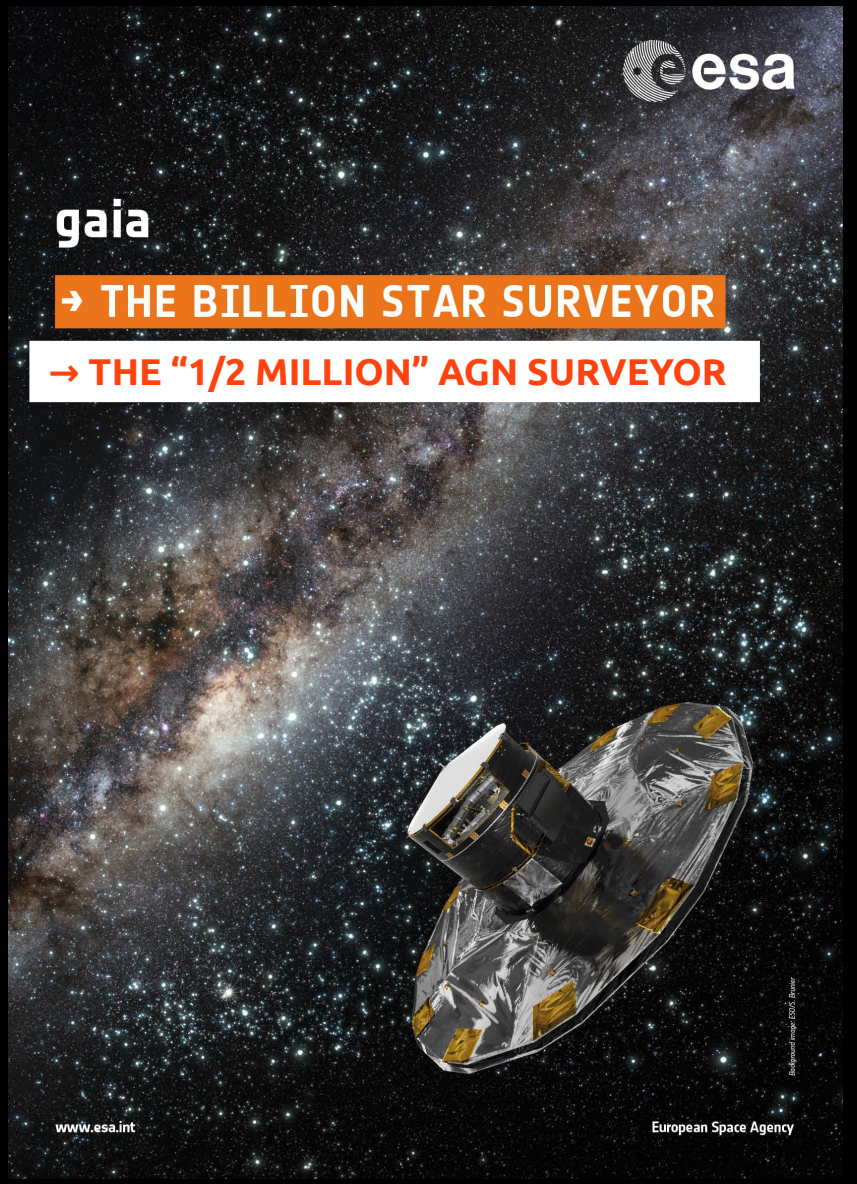
gaia mission 2013-2019

first data release 2016

measure the positions of ~1 billion objects with an accuracy down to 20 μas

perform spectral and photometric measurements

derive space velocities using the stellar distances and motions



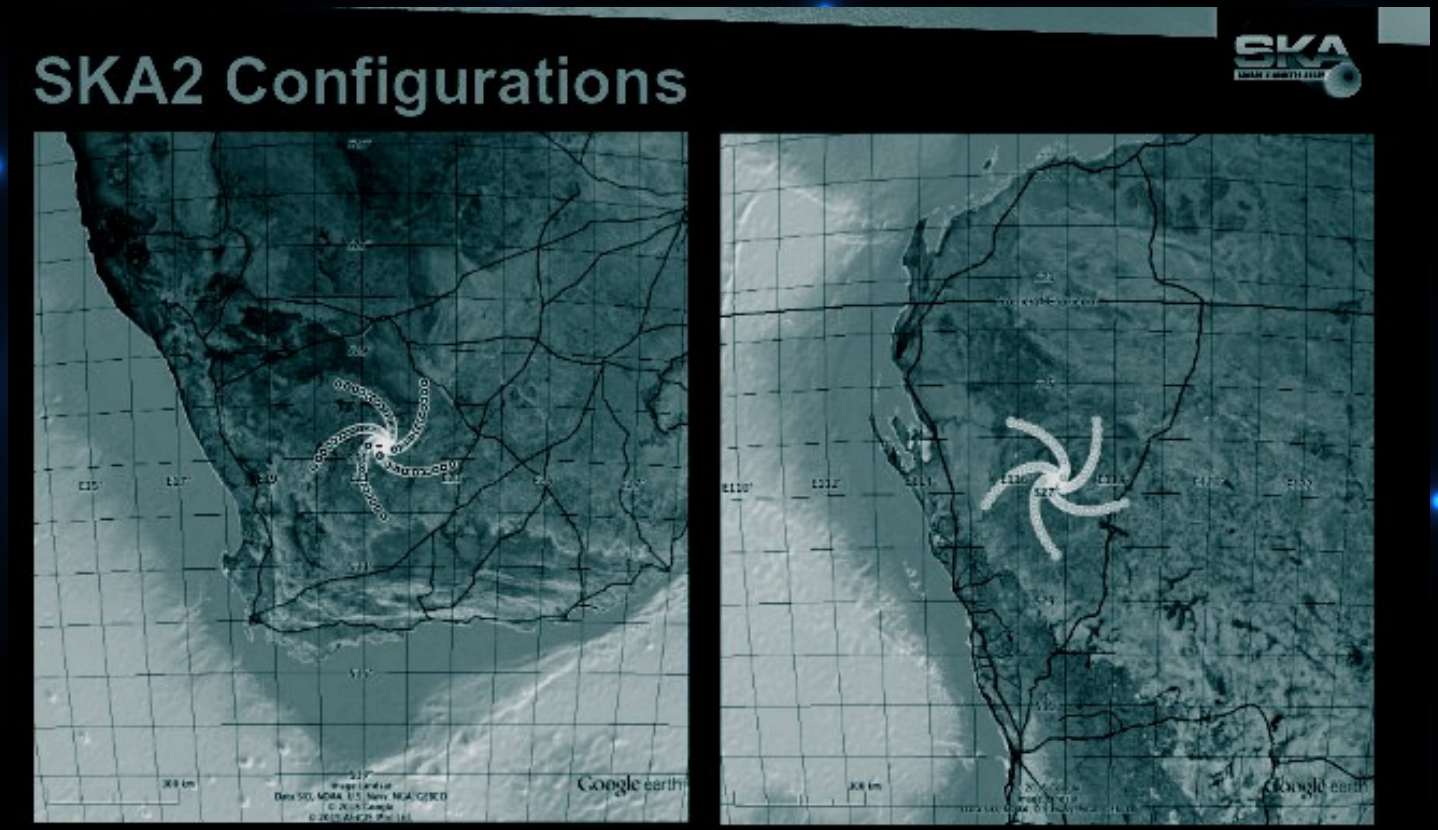
magnitude limit 20 mag

# objects		
Stars	26 million	to V=15
	250 million	to V=18
	1000 million	to V=20
AGNs	500 000	
Galaxies	1 000 000	
Accuracy	5-14 micro-arcsec	V= 6-12 mag
	25 microarcsec	at V=15
	540 microarcsec	at V=20
Photometry	low-res spectra	to V=20

Gaia will provide for the first time a unique combination of **microarcsec** astrometric accuracy and multi-epoch (~70x) optical photometry in an all-sky flux limited survey

Square Kilometer Array - SKA

largest telescope ever built



adapted from Braun 2015

thank you