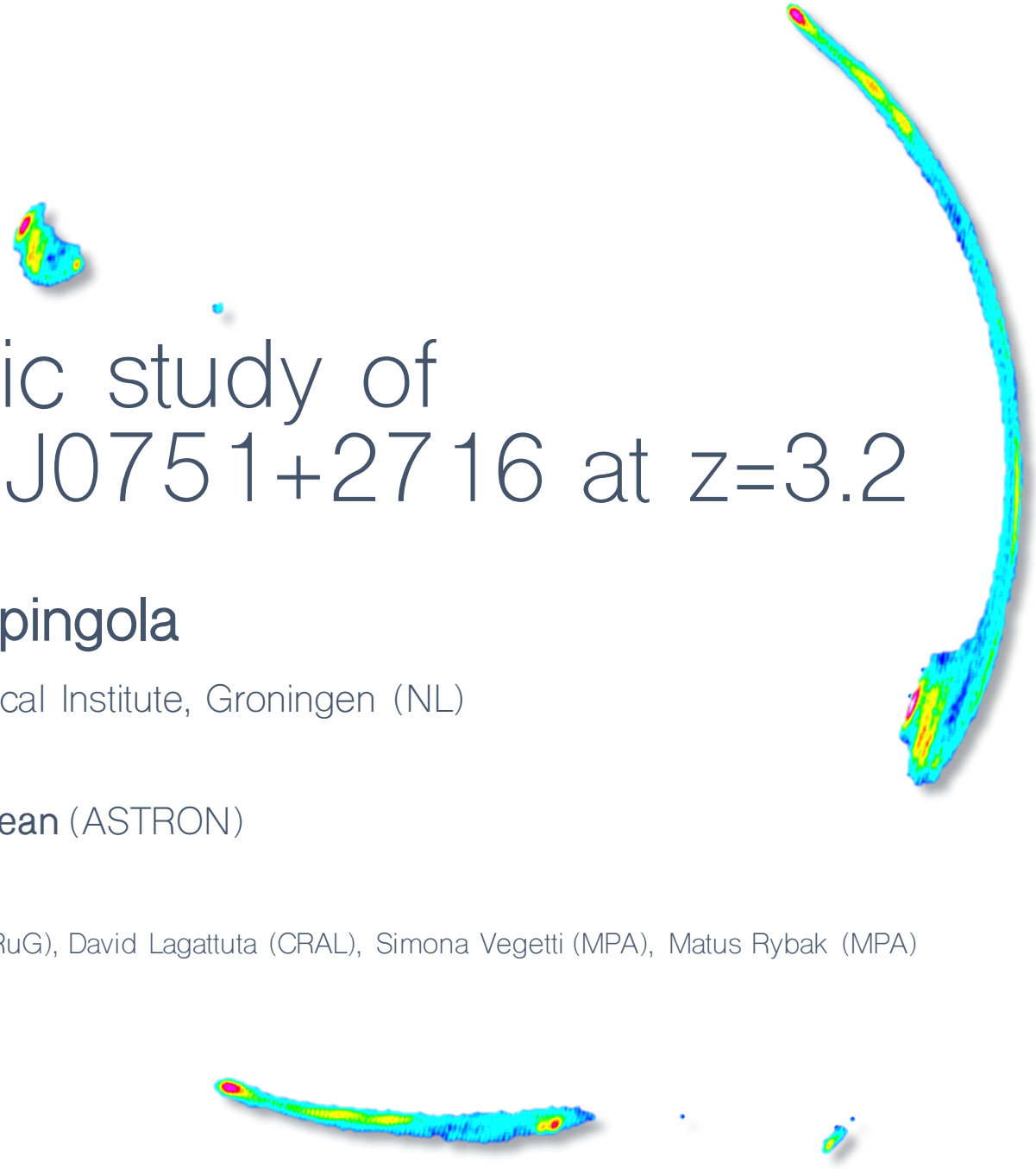


A panchromatic study of the gravitational lens MG J0751+2716 at z=3.2

Cristiana Spingola

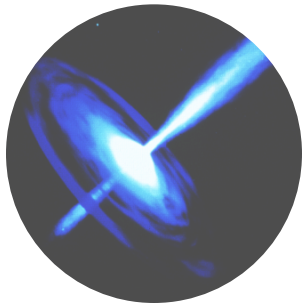
PhD student – Kapteyn Astronomical Institute, Groningen (NL)

Supervisor: **John McKean** (ASTRON)

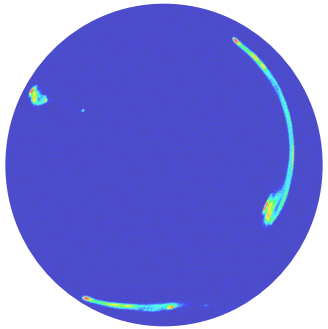
SHARP collaboration: Matt Auger (IoA), Chris Fassnacht (UC Davis), Leon Koopmans (RuG), David Lagattuta (CRAL), Simona Vegetti (MPA), Matus Rybak (MPA)

13TH European VLBI Network Symposium & Users Meeting

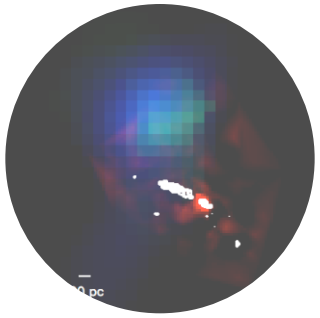
Outline



Introduction
The connection between AGN and star-forming episodes



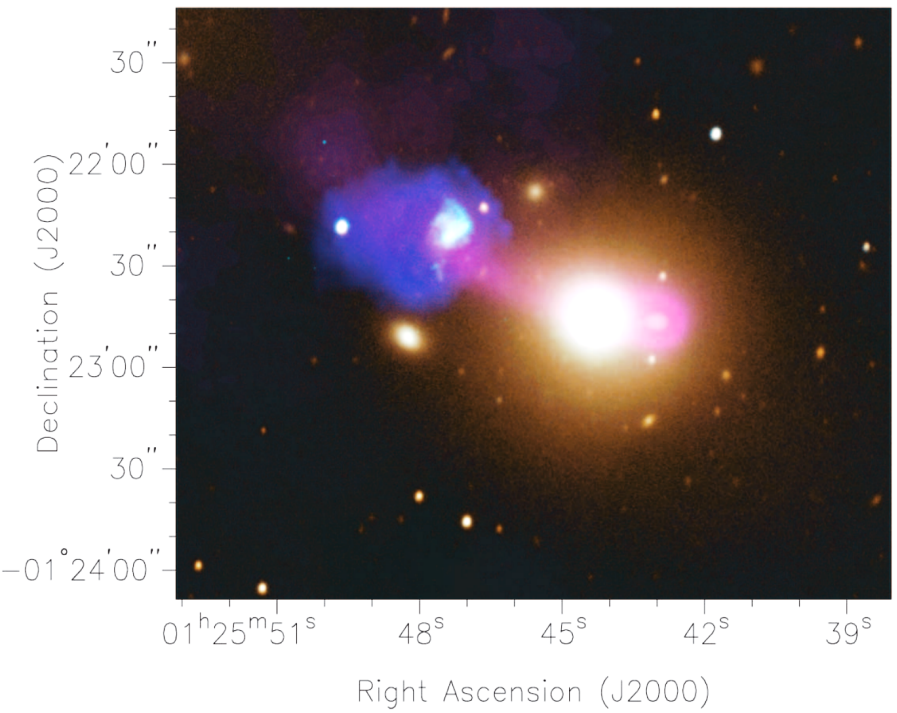
The role of **gravitational lensing** and the **multi-wavelength** approach



The multi-wavelength analysis of the lensed source **MG J0751+2716**
Results and future work

Jet-induced star-formation

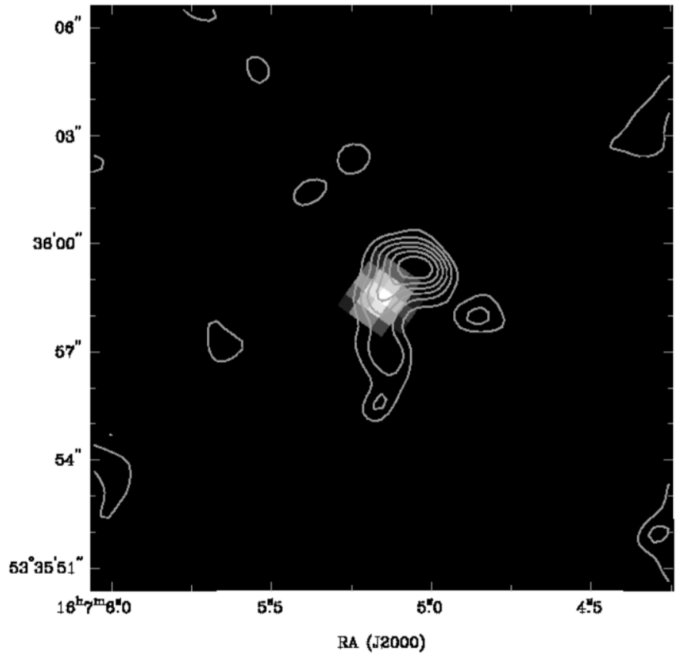
Low redshift



"Minkowski's object"
Purple: radio continuum 1.4 GHz
Dark blue: HI
Light blue: Hα

[Croft et al. 2006]

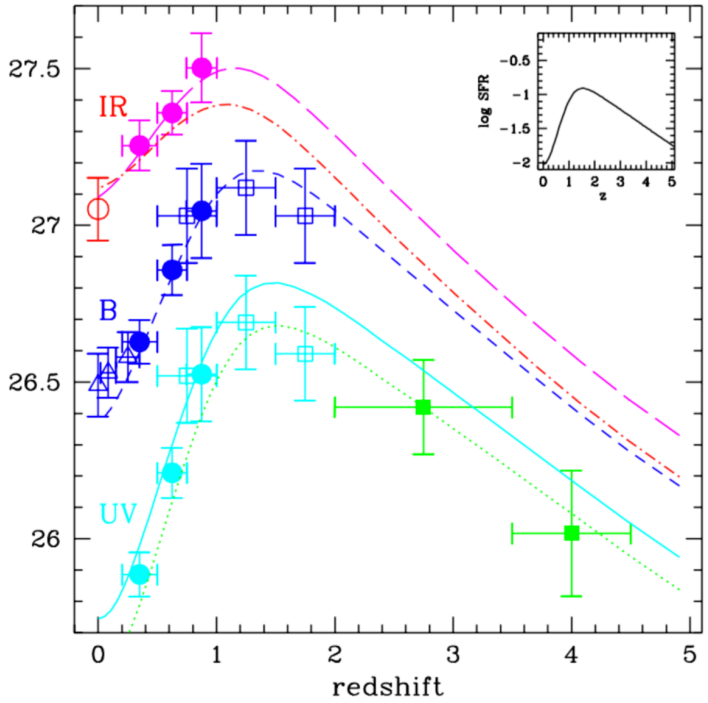
High redshift



SDSS 160705+533558 z=3.65
Greyscale = radio core
Contours = molecular gas (CO)

[Clements et al. 2009]

Cosmic Star-Formation History

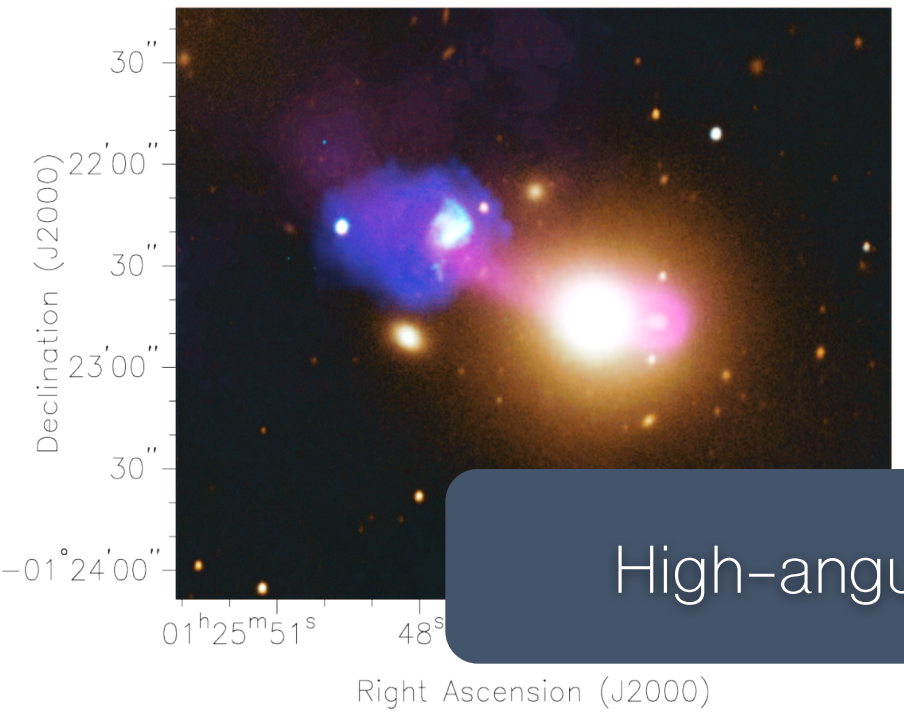


The star-formation rate density peaks at z~2
[Madau & Dickinson 2014]

The density of luminous quasars peaks at z~2
[i.e. Schmidt at al. 1995, Fan 2006]

Jet-induced star-formation

Low redshift



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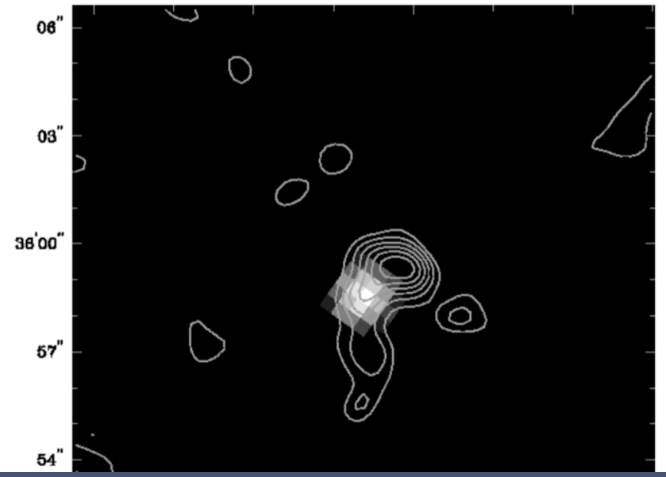

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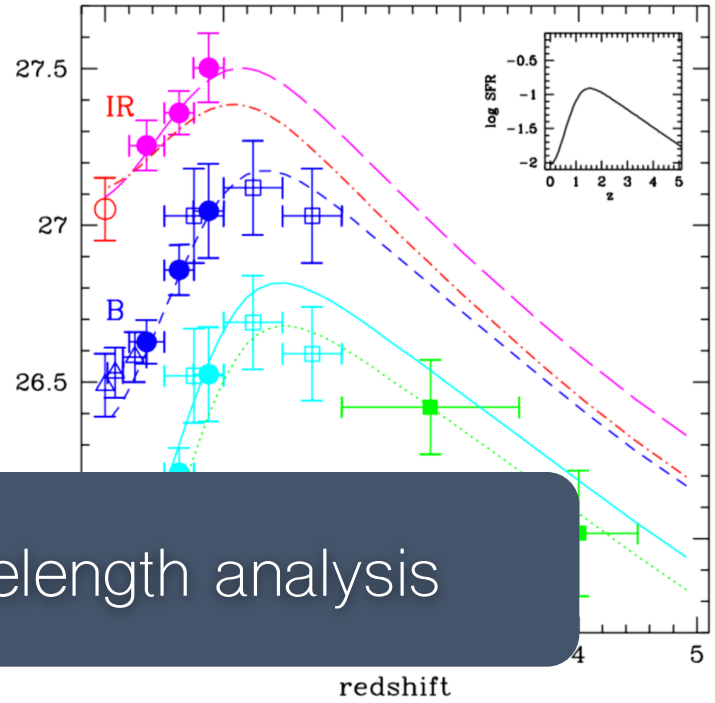

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[i.e. Schmidt at al. 1995, Fan 2006]

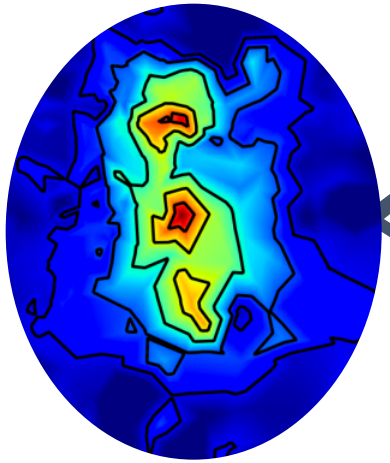
High-angular resolution + multi-wavelength analysis

The role of Gravitational Lensing

Distorted observed image of the background source

Lensing galaxy

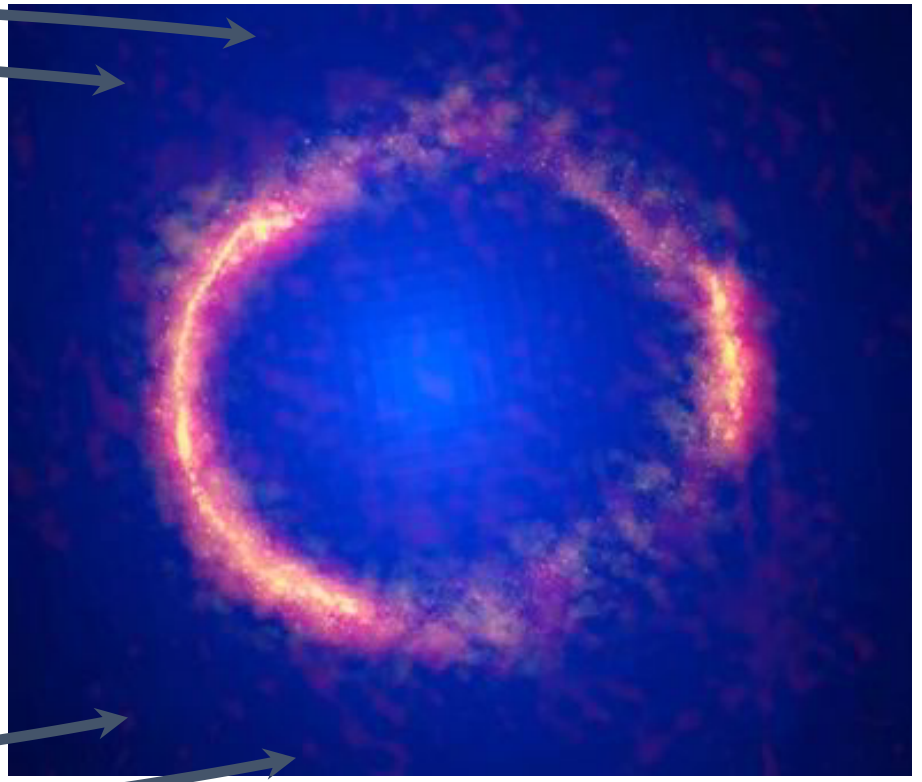
Background source



Pixellated reconstruciton of ALMA observations of SDP.81 (z=3.042)

[Rybak et al. 2015a]

Distorted light-rays



SDP.81
ALMA/ Hubble composite image

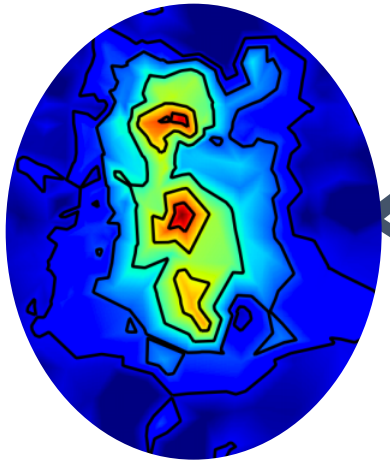
Orange = Dust
Red = Molecular Gas

The role of Gravitational Lensing

Distorted observed image of the background source

Lensing galaxy

Background source



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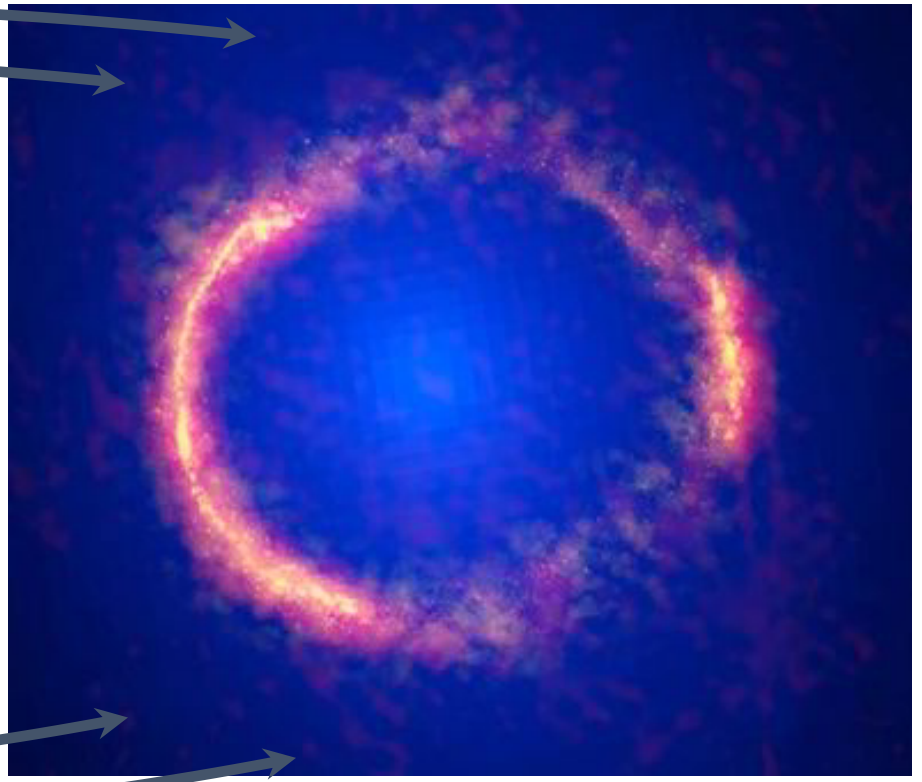


SDP.81
ALMA/ Hubble composite image

nge = Dust
Molecular Gas

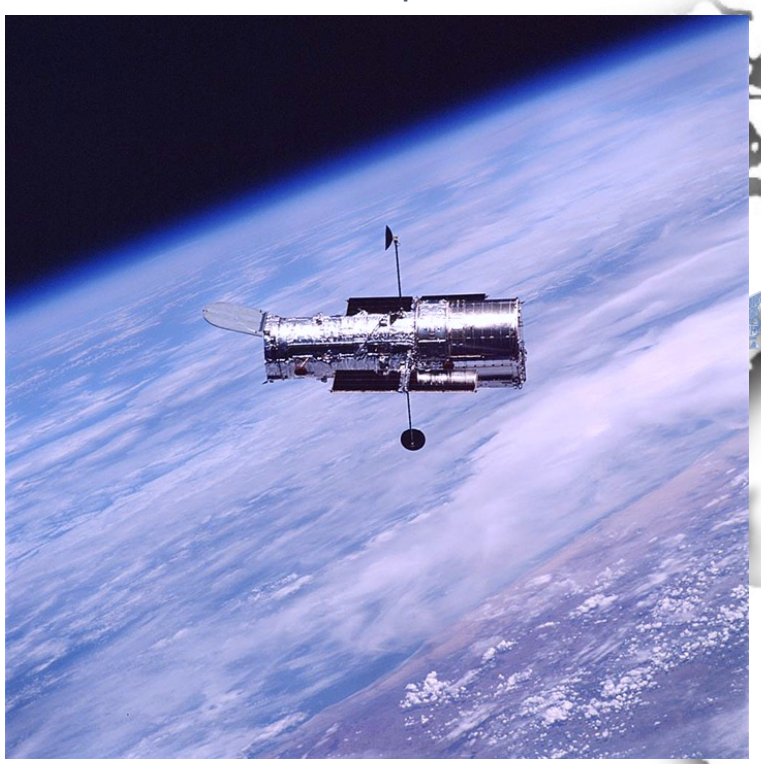
The background source is enlarged and magnified

Multi-wavelength high-resolution study

Radio wavelengths –
Very Long Baseline Interferometry
1-10 mas resolution
(at z=3.2 → **~80 pc resolution**)

Multi-wavelength high-resolution study

Optical Band – Hubble Space Telescope
100-150 mas resolution
(at z=3.2 → **~800 pc resolution**)



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Multi-wavelength high-resolution study

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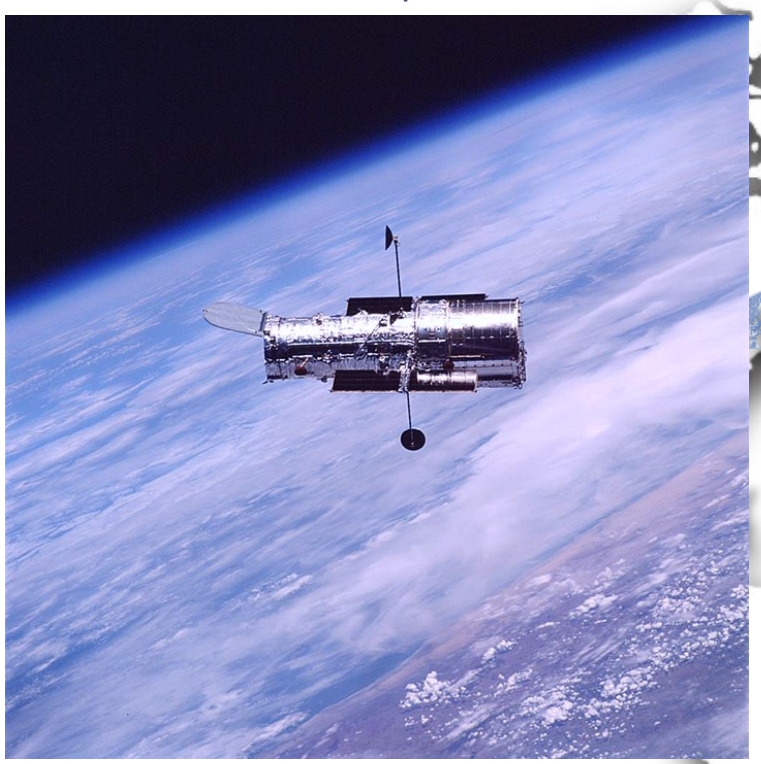
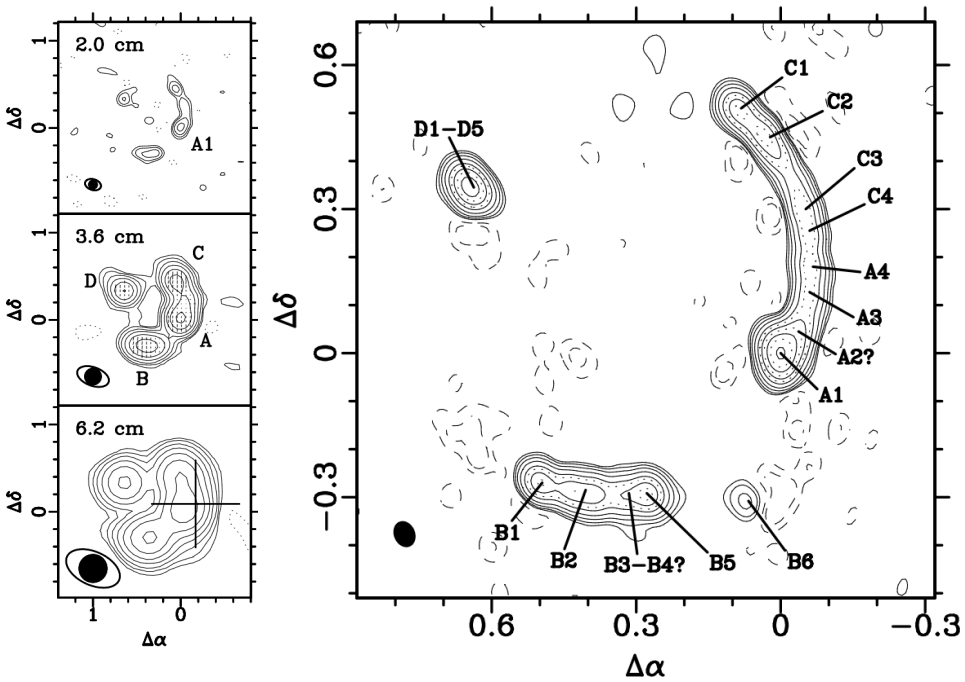


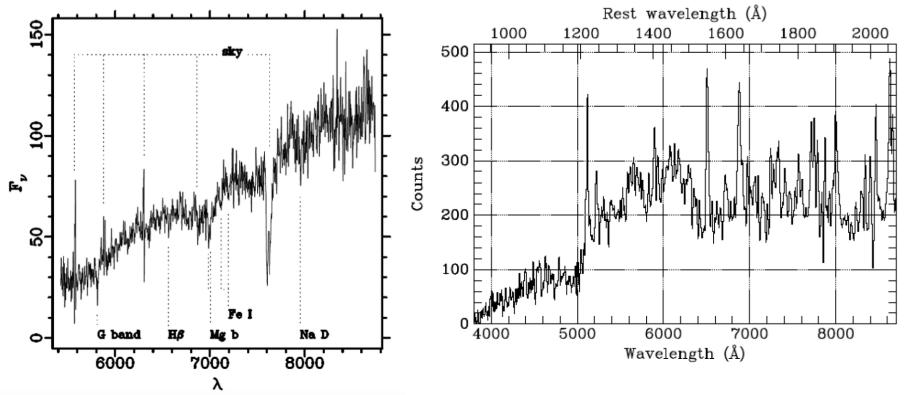
Infrared Band– Keck AO
~65 mas resolution
(at z=3.2 → **~500 pc resolution**)

Radio wavelengths –
Very Long Baseline Interferometry
1-10 mas resolution
(at z=3.2 → **~80 pc resolution**)

The gravitationally lensed source MG J0751+2716

VLA (left) & MERLIN 5 GHz (right) [Lehár et al. 1997]

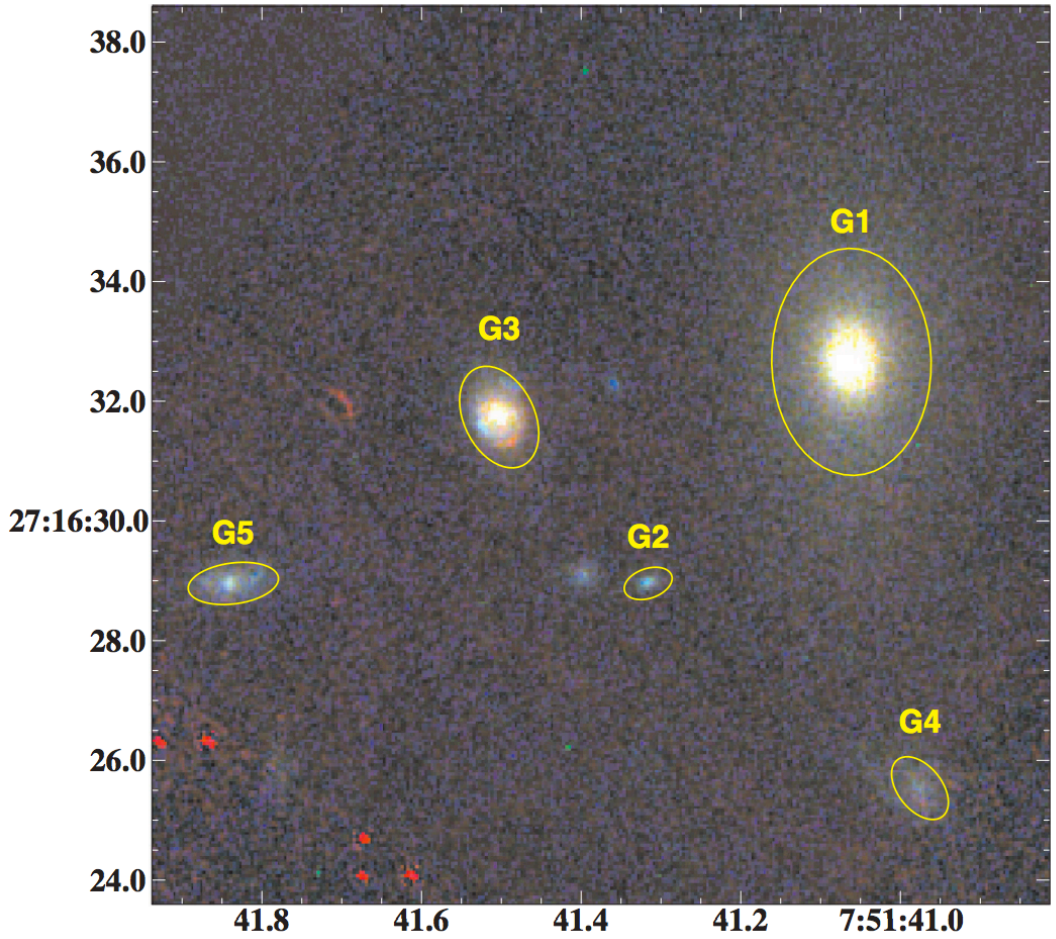




[Tonry & Kochanek 1998]

z_{source}= 3.2
z_{lens} = 0.35

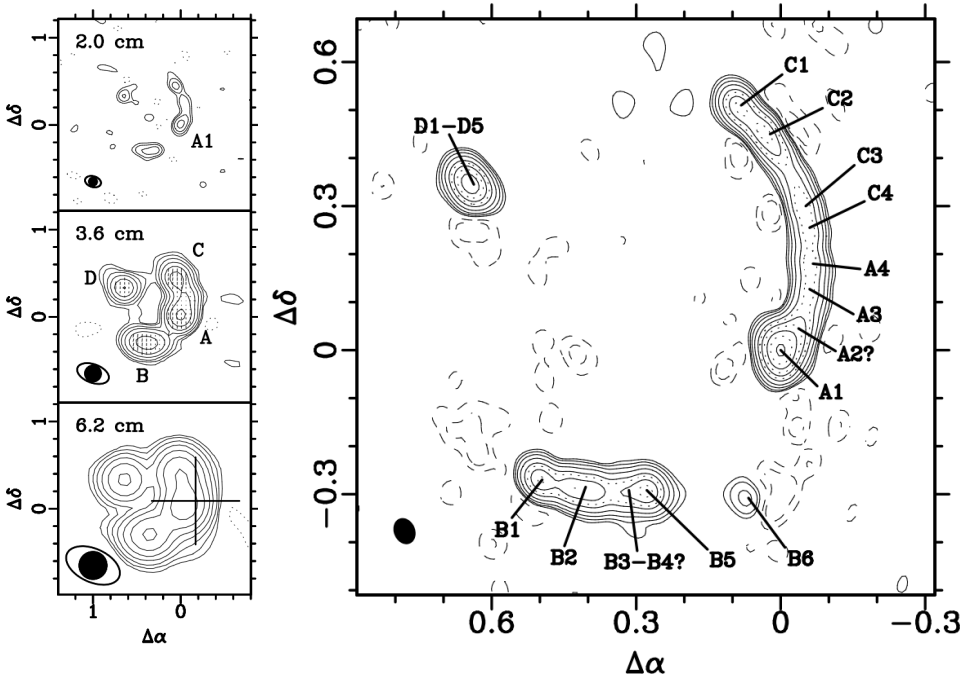
Narrow Line Quasar

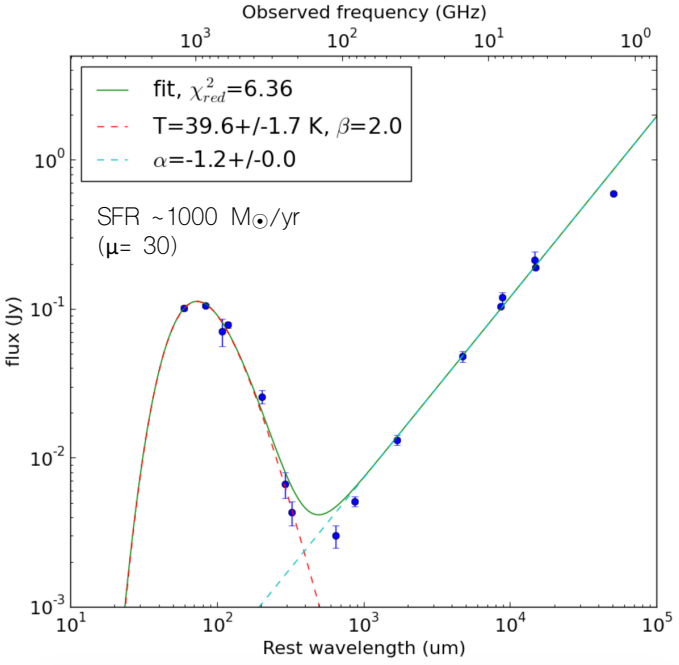


HST WFPC2 (F555W and F814W) and NICMOS (F160W)
[Alloin et al. 2007]

The gravitationally lensed source MG J0751+2716

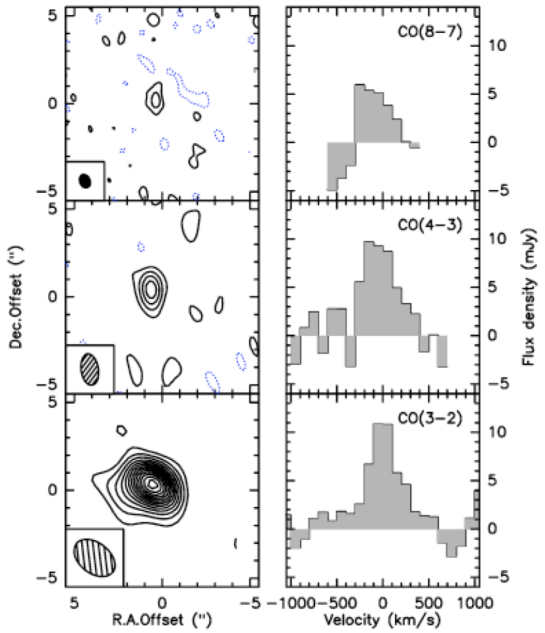
VLA (left) & MERLIN 5 GHz (right) [Lehár et al. 1997]





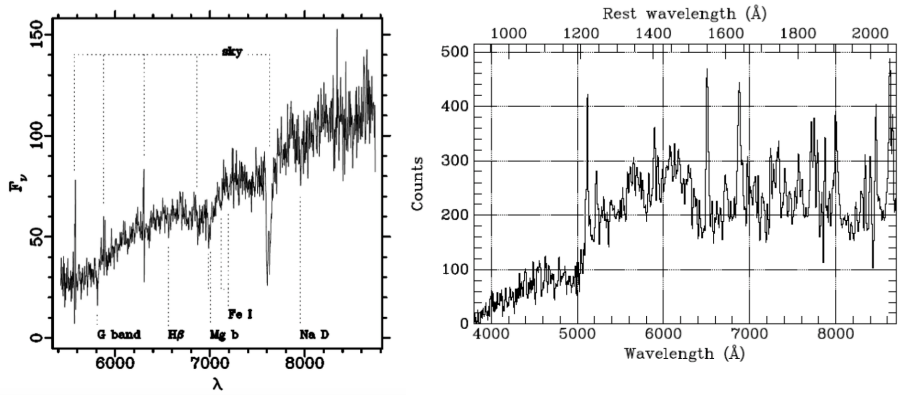
Spectral Energy Distribution

Data from Herschel, Scuba, Mambo, PdB, VLA
Steep spectrum radio source (α= -1.2)
[McKean et al. in prep]



Molecular gas – CO

IRAM Plateau de Bure
[Alloin et al. 2007]



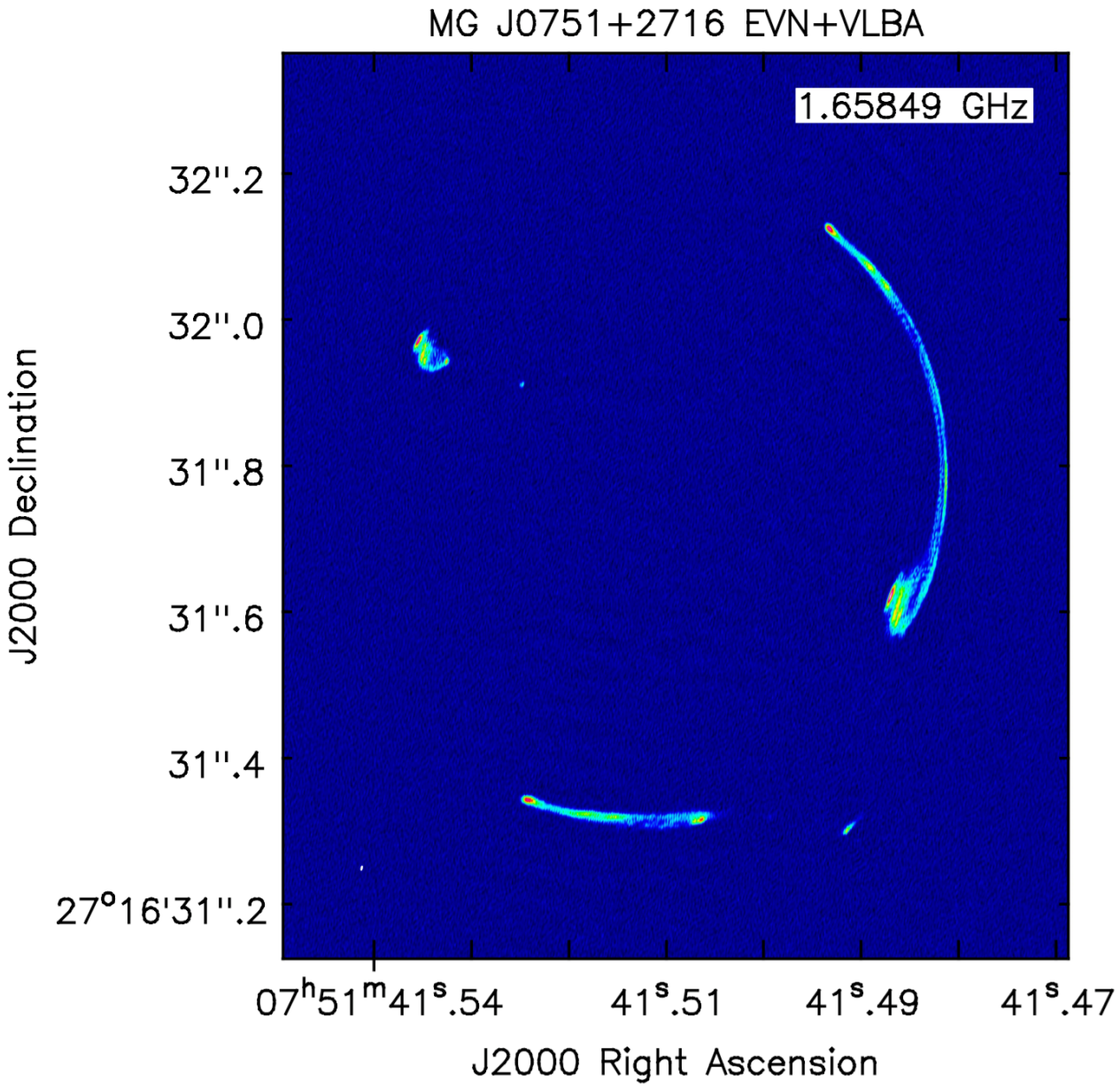
[Tonry & Kochanek 1998]

z_{source}= 3.2
z_{lens} = 0.35

Narrow Line Quasar

Synchrotron emission from 20 cm to 3 mm
Dip from 2 mm to 1 mm
Steep rise due to **heated dust emission** from 1mm

The panchromatic study of MG J0751+2716 – **RADIO**

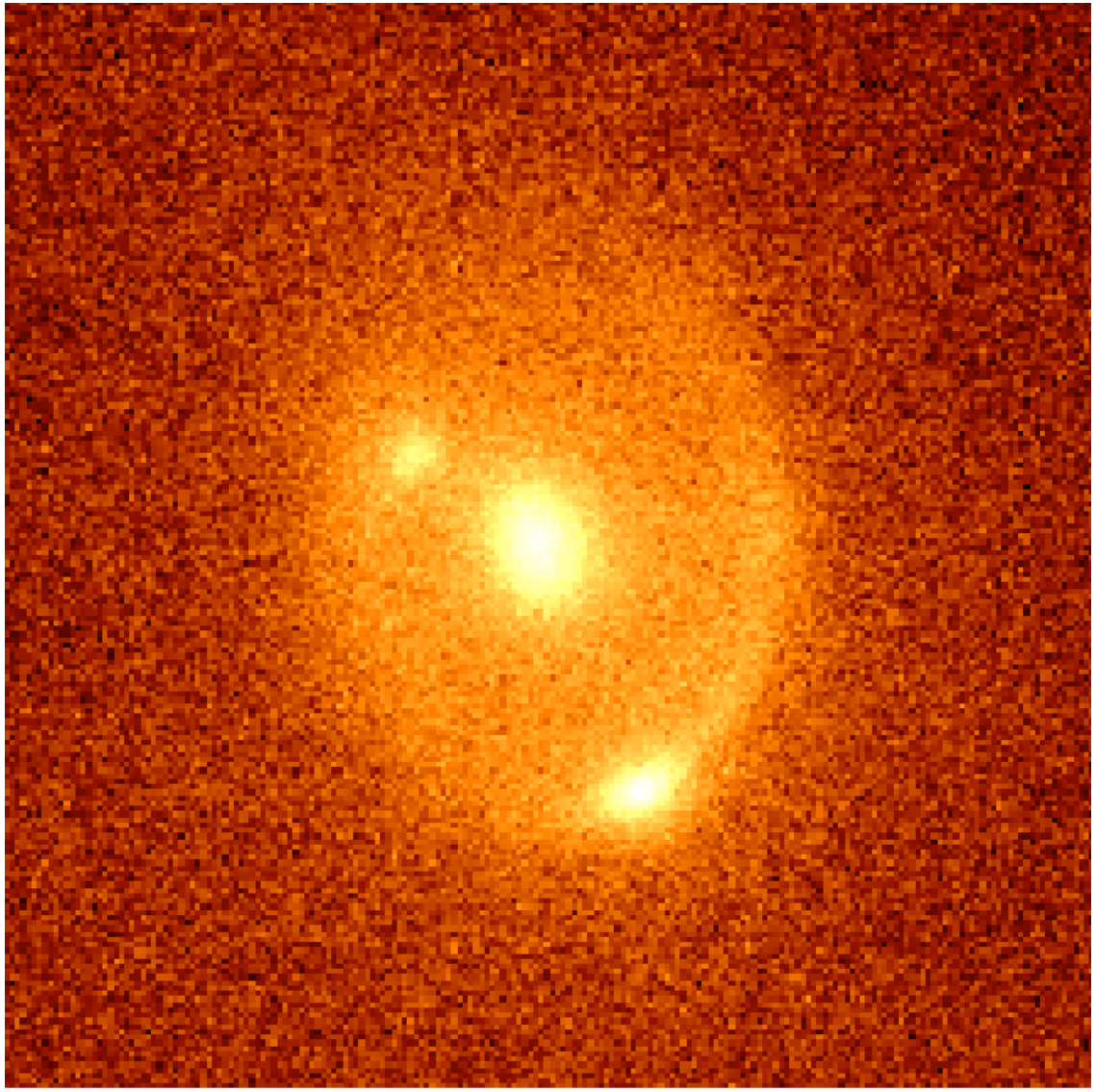


Global-VLBI 18 cm
25 antennas
GM070 PI: McKean

AGN component

Beam: 2 mas x 7 mas
$S_{1.7GHz}$~400 mJy
rms = 18 μJy beam^{-1}

The panchromatic study of MG J0751+2716 – **IR and Optical**



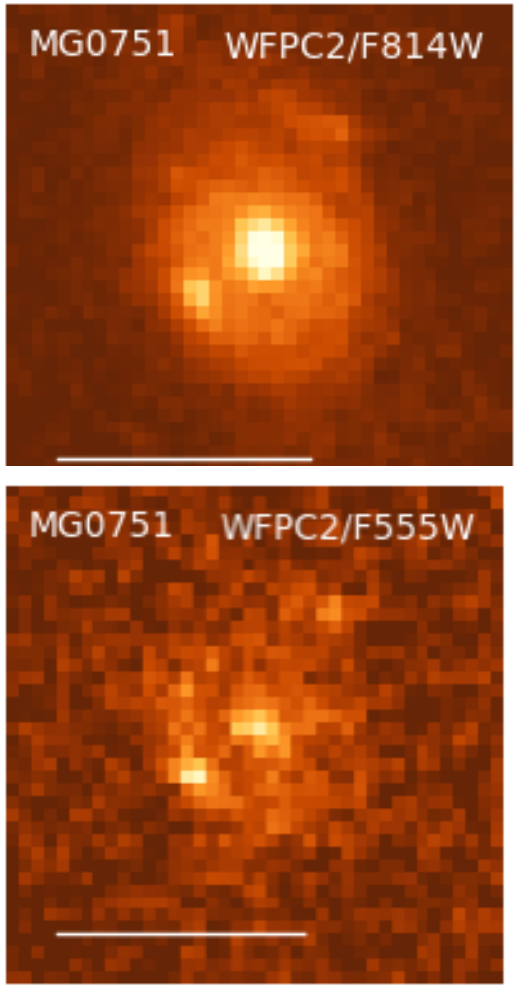
KECK AO
Nirc2 KP - 2.2 μm

Host Galaxy

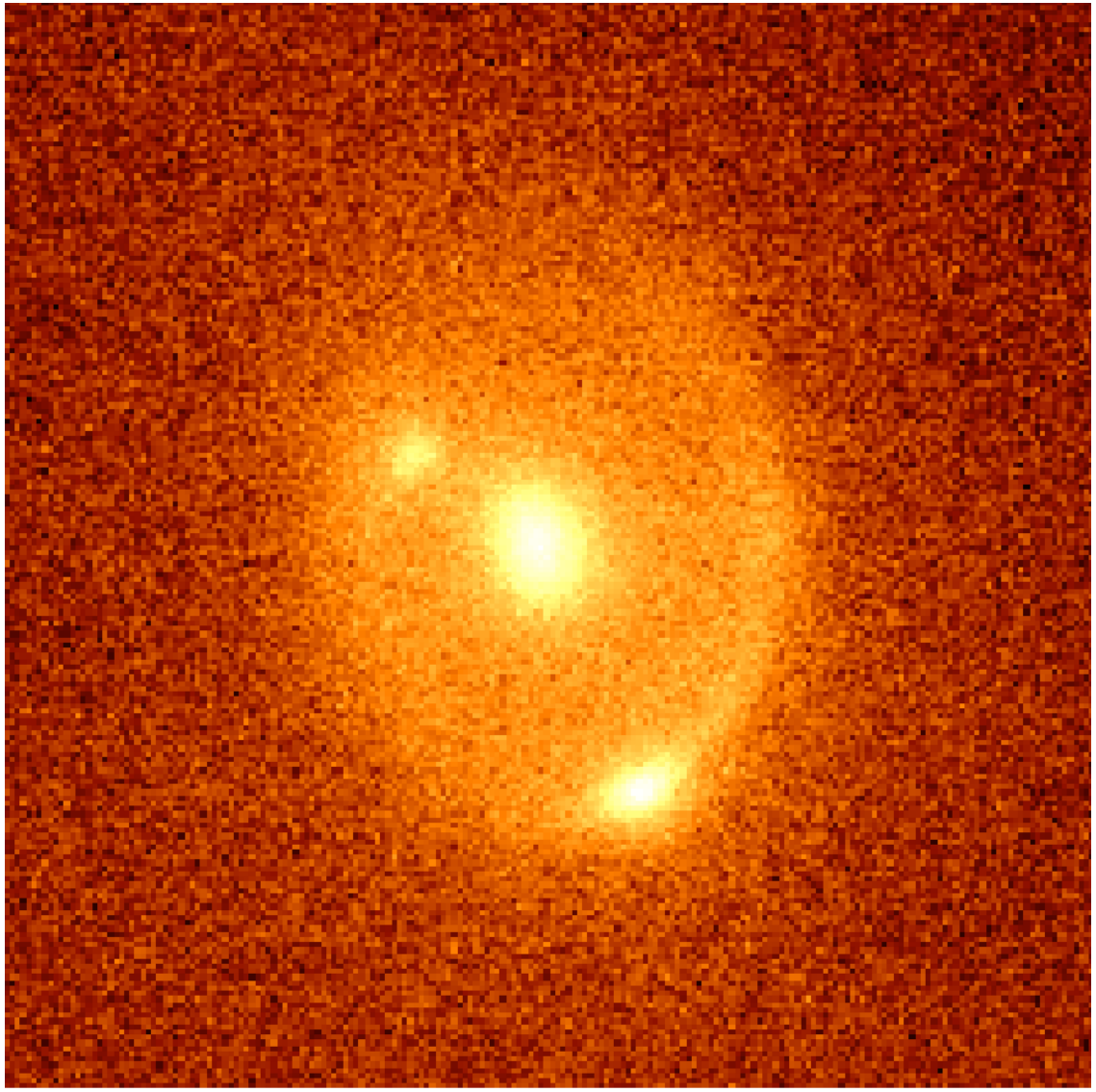
10 mas/pixel

The panchromatic study of MG J0751+2716 – **IR and Optical**

Hubble Space Telescope



[Fassnacht et al. in prep.]



KECK AO
Nirc2 KP – 2.2 μm

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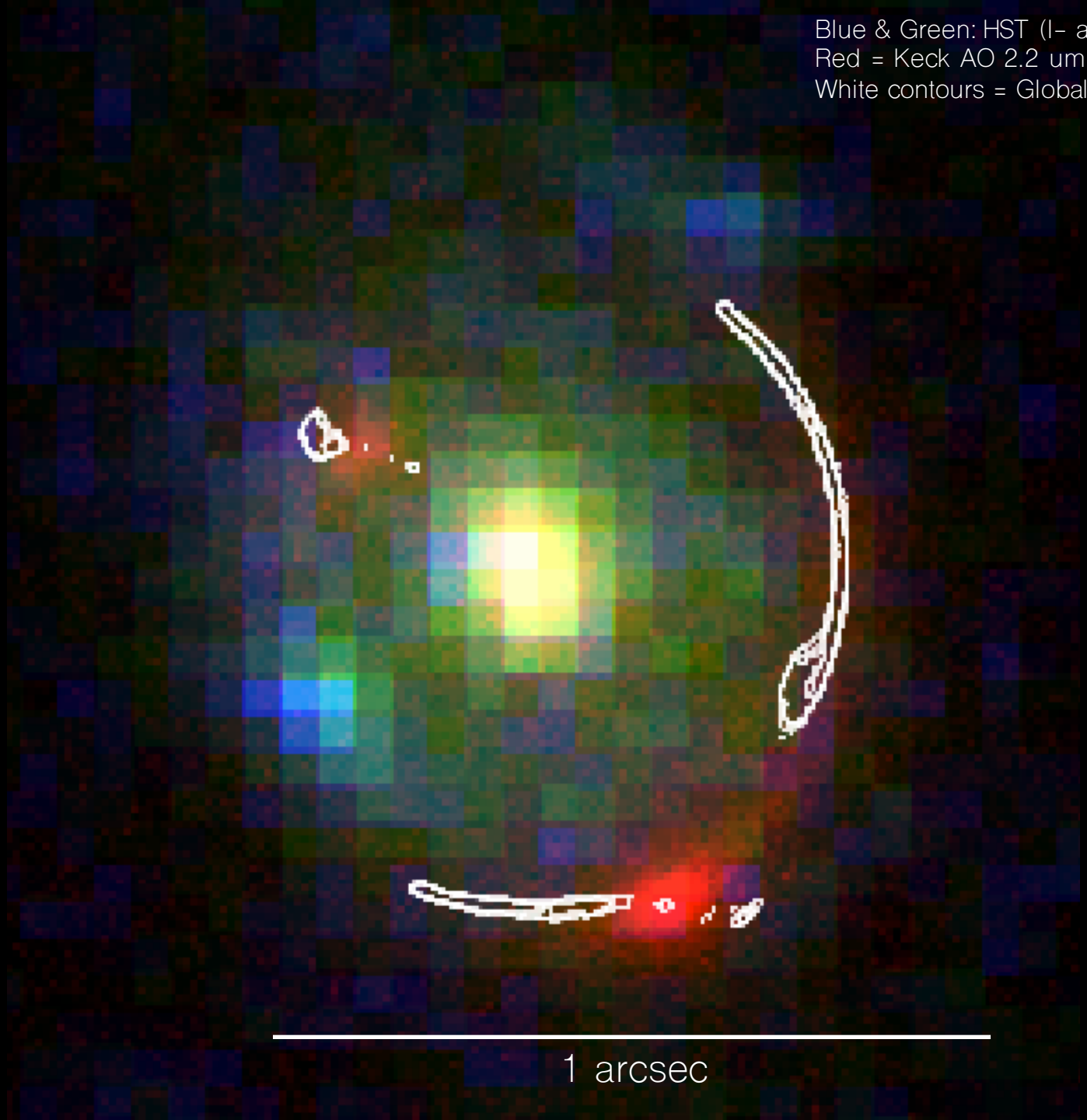
10 mas/pixel

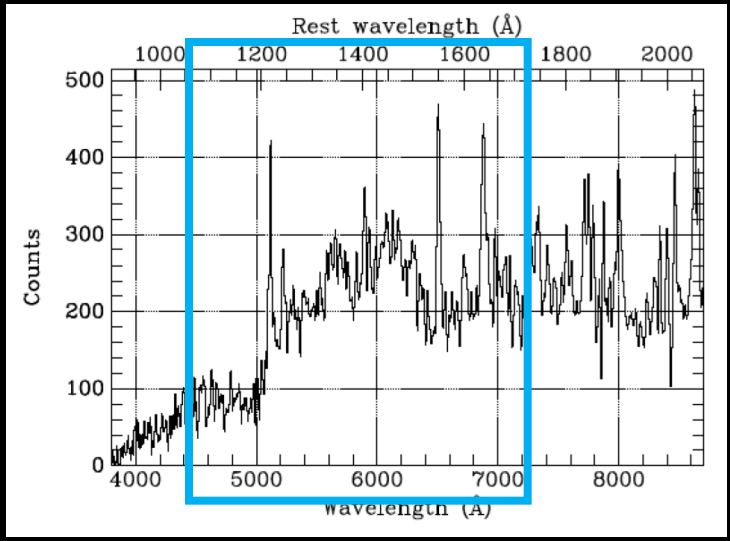
Lens Plane


Blue & Green: HST (I- and V- bands)
Red = Keck AO 2.2 um
White contours = Global-VLBI 1.7 GHz
1 arcsec

Lens Plane

New blue component from HST imaging

The images are separated by ~0.8"→ similar redshift of J0751+2716



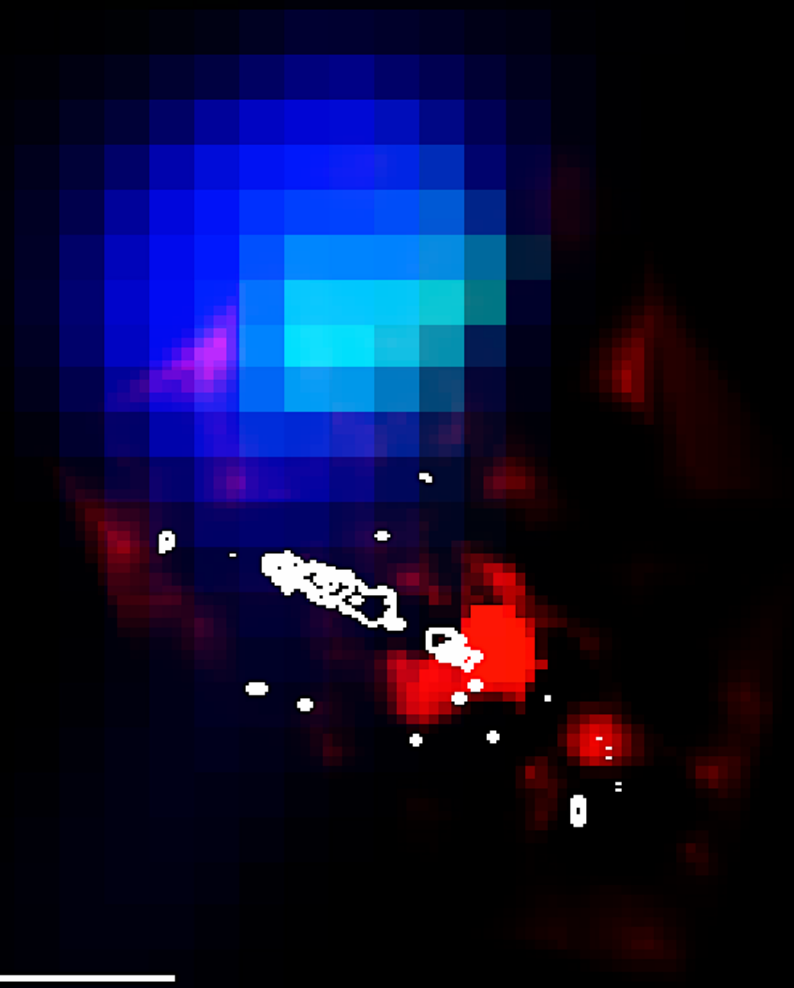
Lyα emission in V-band
(indicated by the blue box)

LRIS spectrum [Tonry & Kochanek 1998]

Blue & Green: HST (I- and V- bands)
Red = Keck AO 2.2 um
White contours = Global-VLBI 1.7 GHz

1 arcsec

Source Plane



Blue & Green: HST (I- and V- bands)
Red = Keck AO 2.2 um
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Lens Modelling

- The source-plane grid is constructed using a Delaunay tessellation (highly magnified regions are sampled more densely than those with lower magnification).
- The modelling optimises the Bayesian evidence (a measure of the probability of the data given a specific model).
- Lensing potential: elliptical power-law mass distribution with an external shear.

[Koopmans 2005, Vegetti & Koopmans 2009]

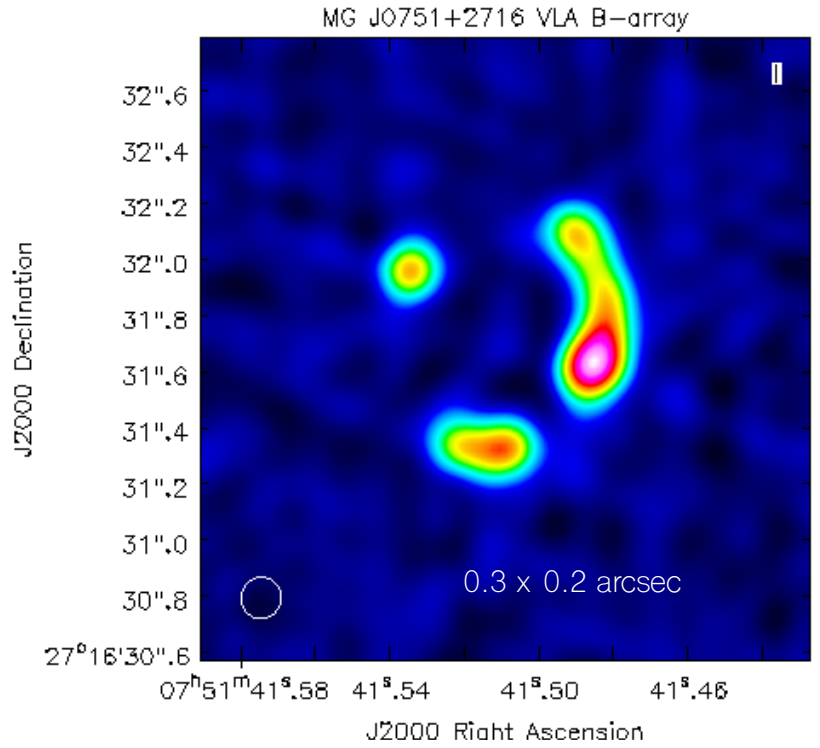
The lens modelling of the radio data has been performed in the **visibility plane**.

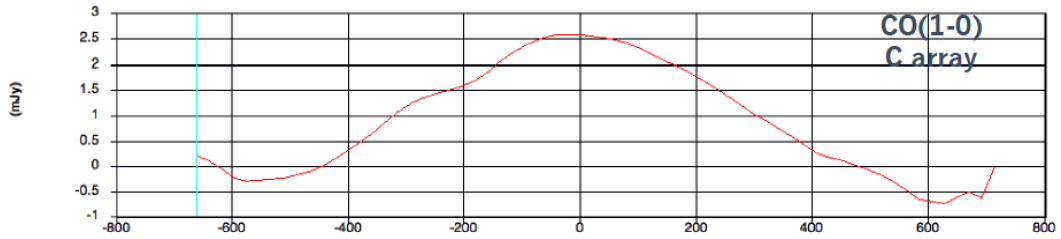
[Rybak et al. 2015, Vegetti et al. in prep.]

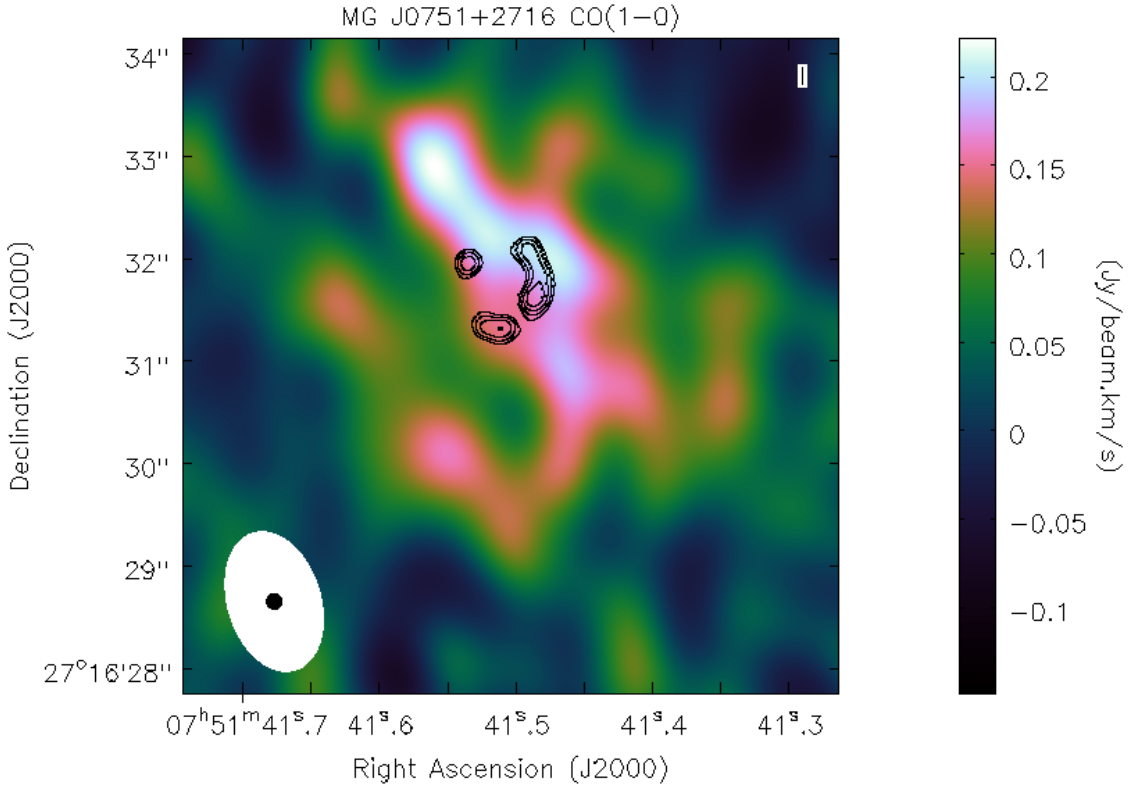
The panchromatic study of MG J0751+2716
Molecular Gas / CO

Preliminary JVLA CO(1-0)

Continuum @ 27 GHz

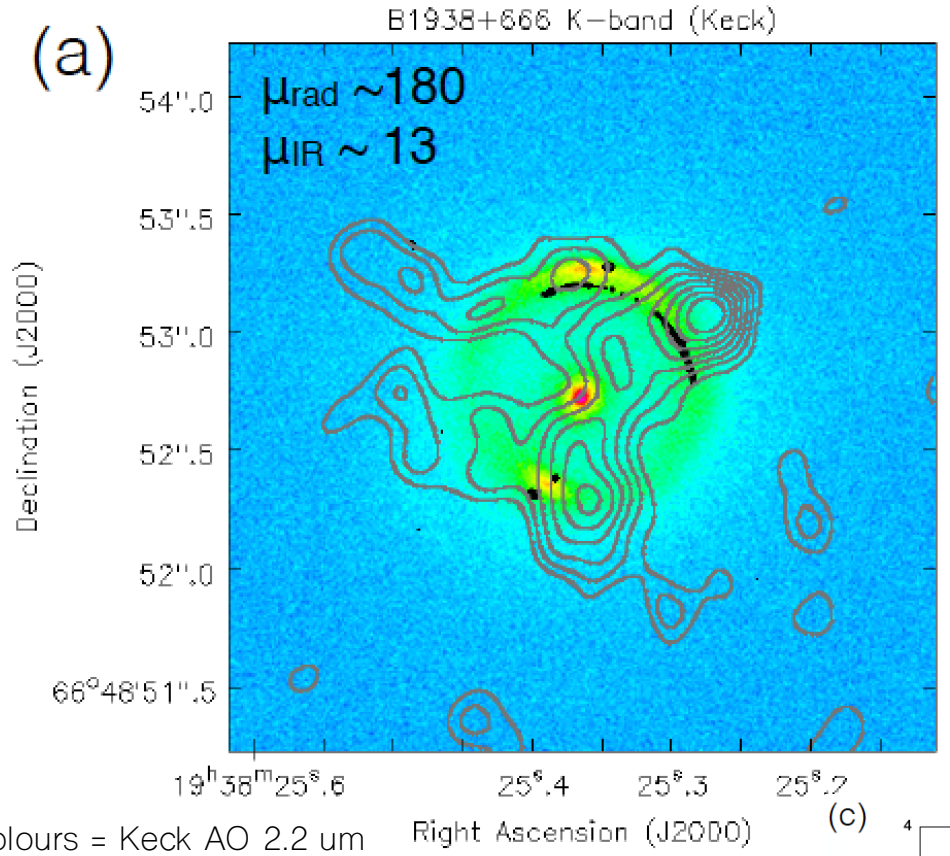


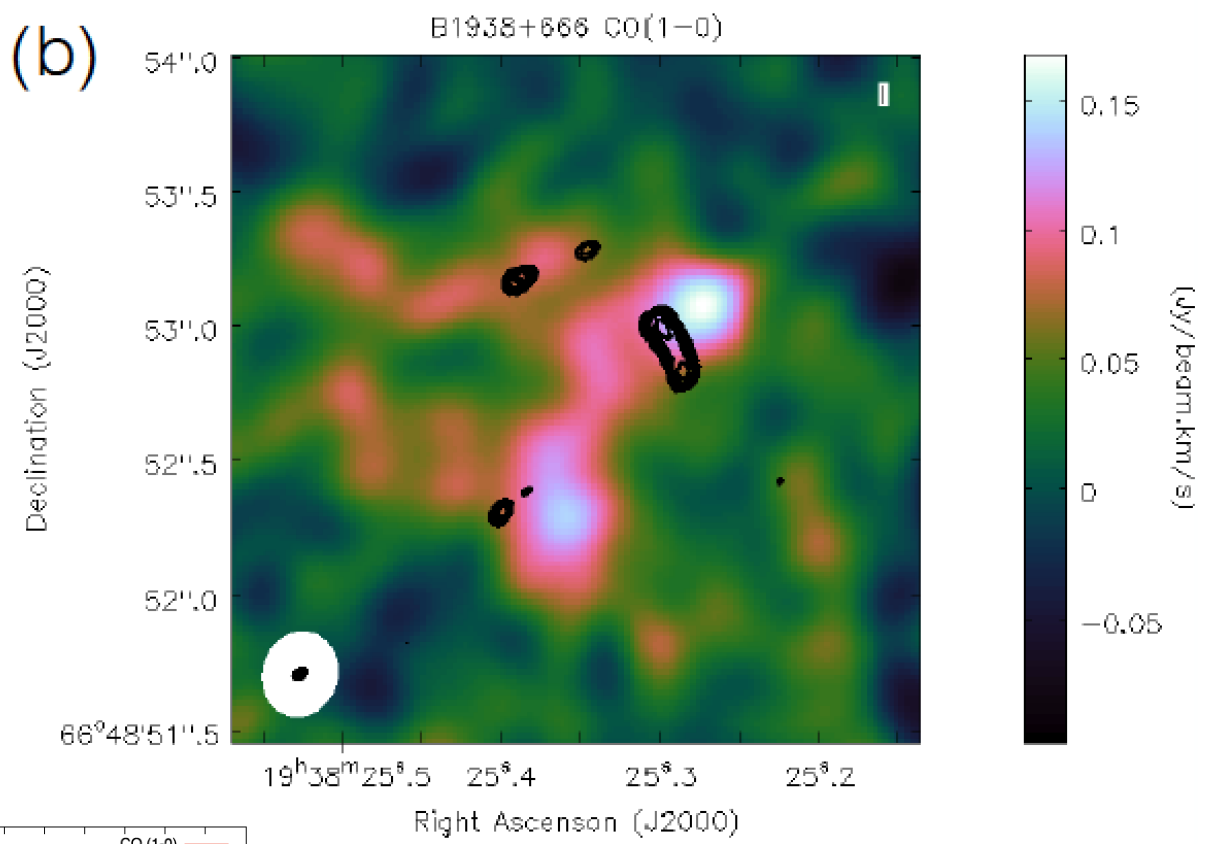




Moment 0 map
(integrated intensity line emission)

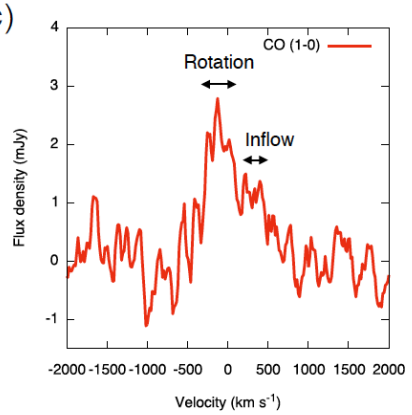
Work in progress: B1938+666

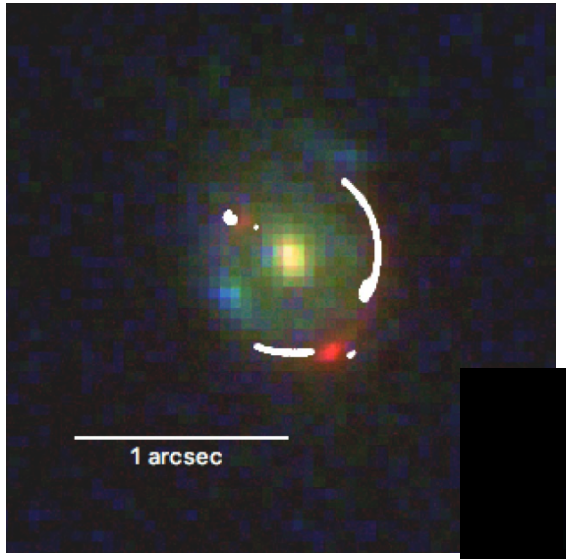


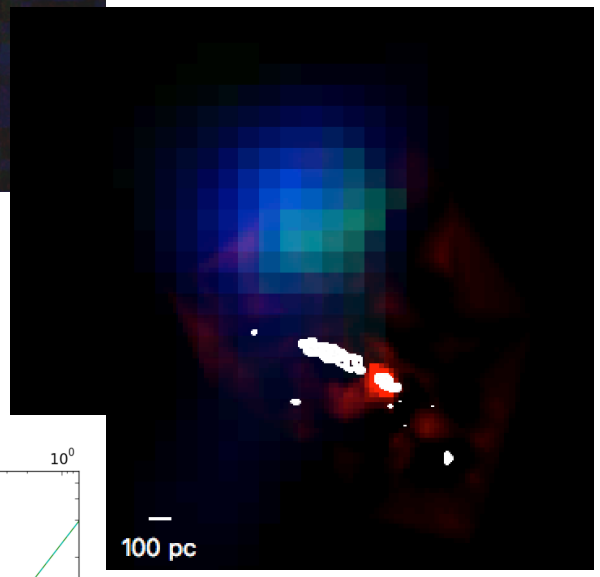


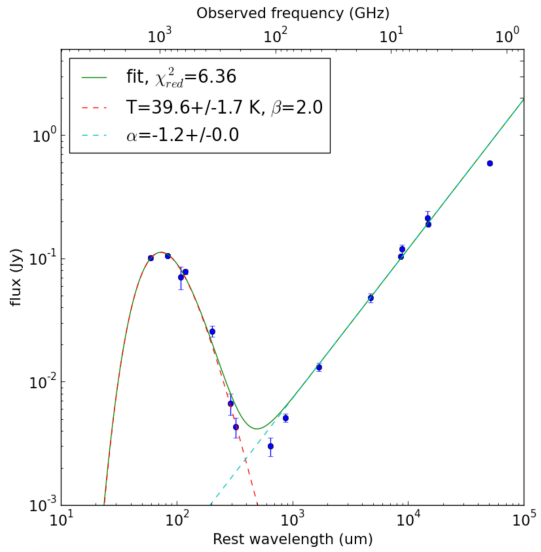
Colours = Keck AO 2.2 um
Black = gvlbi 1.7 GHz
Grey = Mom 0

(c)









Summary

- Higher-angular resolution multi-band imaging of MG J0751+2716 revealed a **new bluer component**: did we detect a z=3.2 star-forming object?
- Herschel observations find a strong dust bump, which shows that there is **ongoing star-formation** in this system, but where is the dust? Where is the molecular gas?
- Our pixellated lensing reconstruction finds that the evolved stellar population is extremely compact, while the blue component extends for few hundreds of parsecs and is offset from the radio jet: jet-induced star formation?

Next

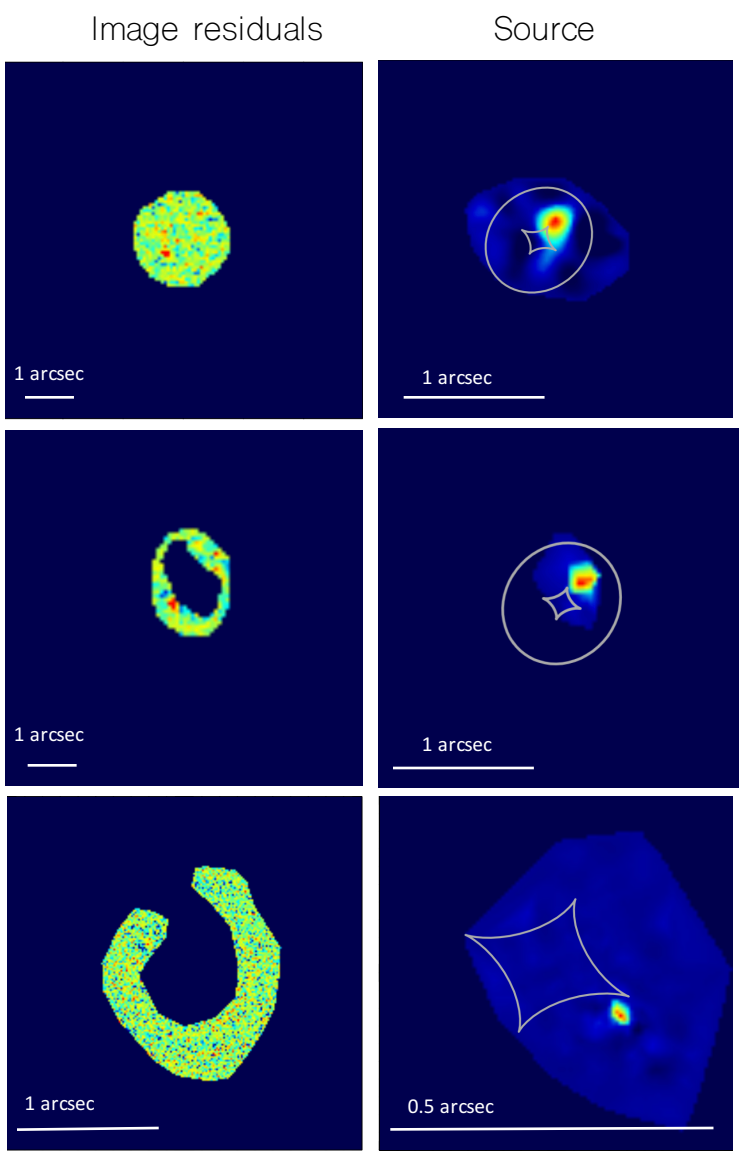
- Study the **dynamics of the gas from JVLA CO(1-0)** in order to search for outflows due to the presence of the radio-jets.
- Apply this analysis to a **sample of high-redshift lensed star-forming galaxies** (i.e. SHARP survey).

THANKS!

Спасибо!

C. Spingola – Kapteyn Astronomical Institute - spingola@astro.rug.nl

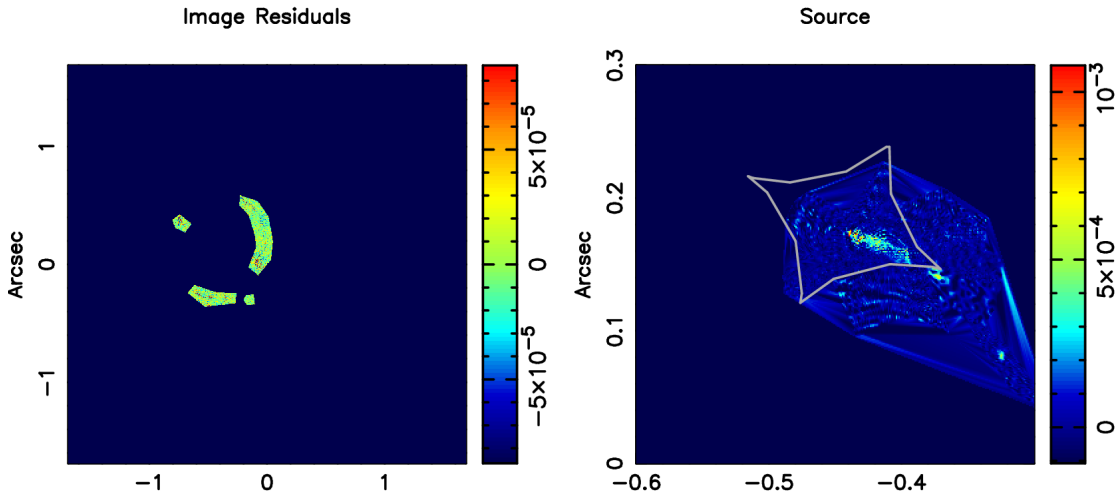
Lens Modelling of MG J0751+2716



HST F555W

HST 814W

Keck 2.2 μm



Global-VLBI 1.7 GHz – Lens modelling of the **visibilities**
(Rybak et al. submitted)