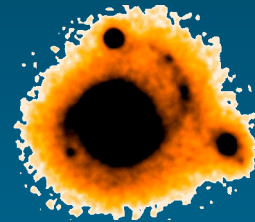


# Case Studies of Quasar Host Galaxies



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Julia Scharwächter

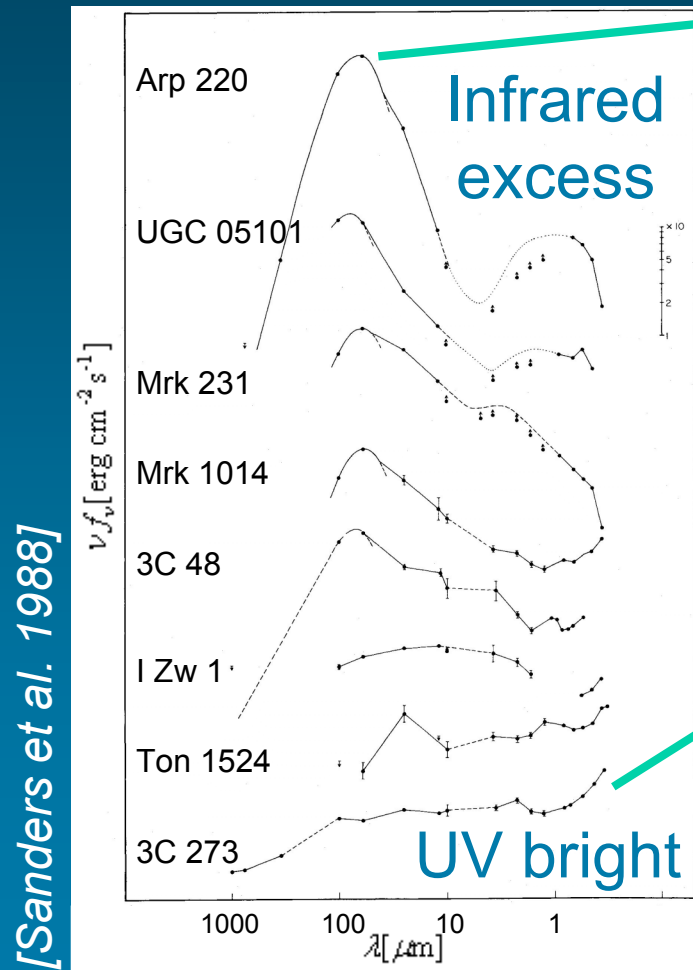
- Ph.D. at University of Cologne (Germany)
- Fellow in Chile since May 2005 (La Silla, NTT)

# Guideline

- Motivation
  - Hypothesis of a **ULIRG-to-QSO** evolution
- Part 1:
  - Multi-wavelength study of **I Zw 1**  
*[A. Eckart, E. Schinnerer, J. G. Staguhn, I. Saviane, J. Zuther, S. Pfalzner]*
- Part 2:
  - First glance at **SDSS J114203.40+005135.8**  
*[V. D. Ivanov, L. E. Tacconi-Garman, J. Kotilainen, J. Reunanen, J. Zuther, A. Eckart, R. Schödel]*

# Evolutionary Hypothesis

- Spectral energy distributions



Ultra-luminous infrared galaxies (ULIRGs)  
Starburst and obscured AGN

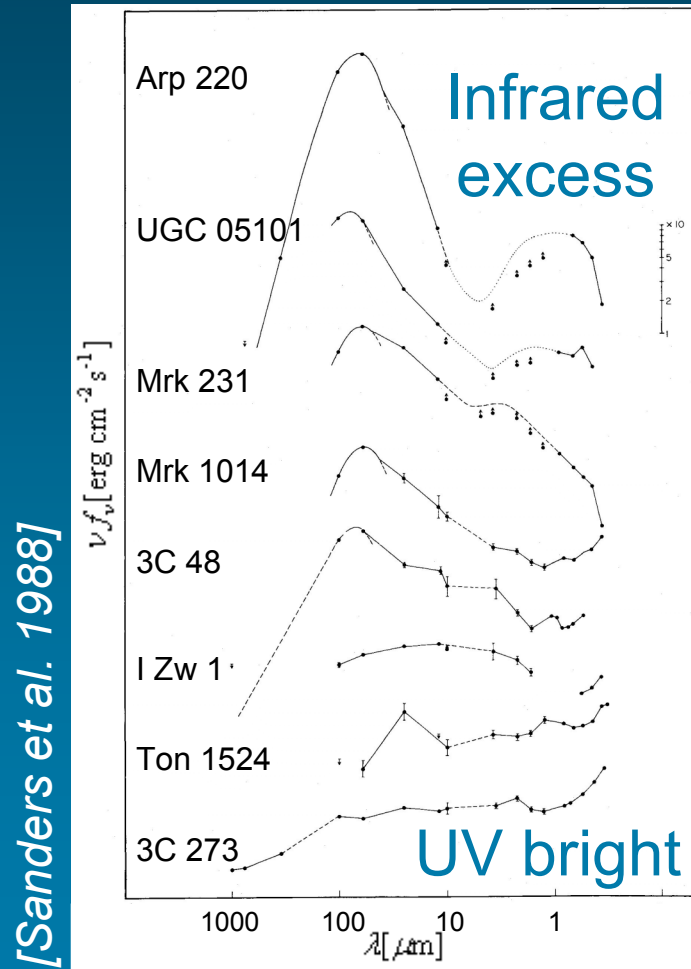
Smooth transition reflects evolutionary sequence

Quasi-stellar objects (QSOs)  
Clear line-of-sight towards AGN

# Physical Scenario

Motivation

- Sanders et al. 1988:



Galaxy merger causes  
gas inflow

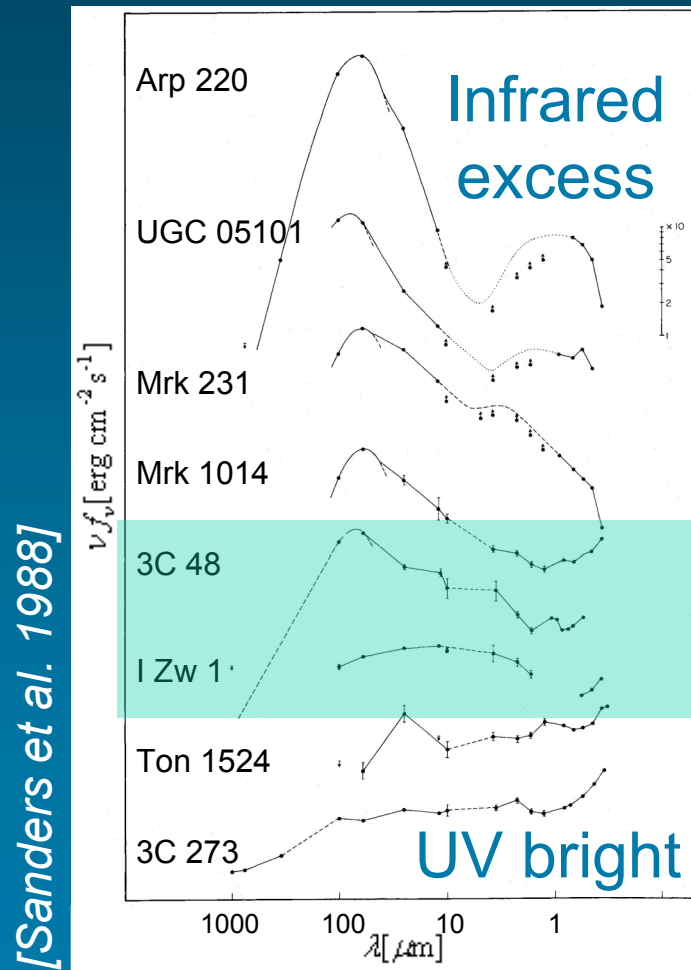
Starburst activity and  
dust-enshrouded AGN

AGN blown free of  
dust envelope

# ULIRG to QSO Evolution?

Motivation

- Transition objects



Pick “transition objects”  
and study them in detail

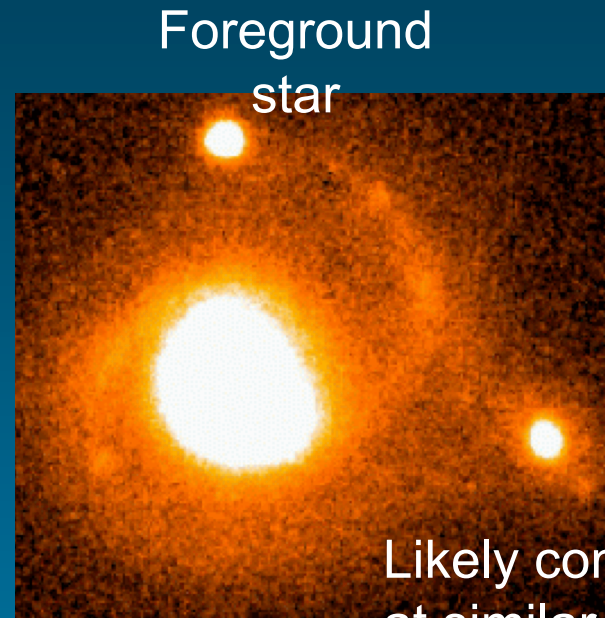
- Signs for Mergers?
- Starburst properties?
- Gas as fuel for AGN?

# I Zw 1

I Zw 1

## In a nutshell

- One of the closest QSOs ( $z=0.06$ ) and possible counterpart of high- $z$  QSOs
- Prototype narrow-line Seyfert 1
- Direct spectroscopic evidence for nuclear starburst  
*[Schinnerer et al. 1998]*



Likely companion at similar redshift as I Zw 1 *[Canalizo & Stockton 2001]*

NIR images and spectra (ISAAC)  
mm observations (BIMA, PdBI)

# Nuclear Spectrum

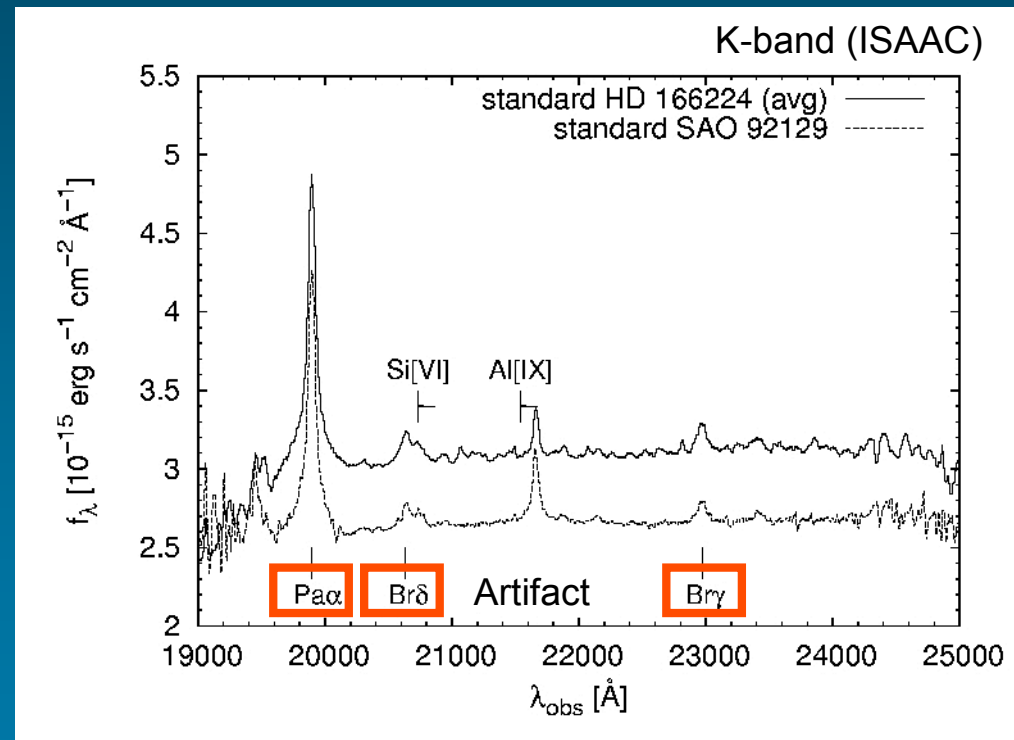
I Zw 1

## Narrow-line Seyfert 1

- Small black hole mass and high accretion rate  
*[e.g. Mathur 2000]*

QSO in the formation?

*[Schinnerer et al. 1998, Scharwächter et al. 2007]*



# Nuclear Spectrum

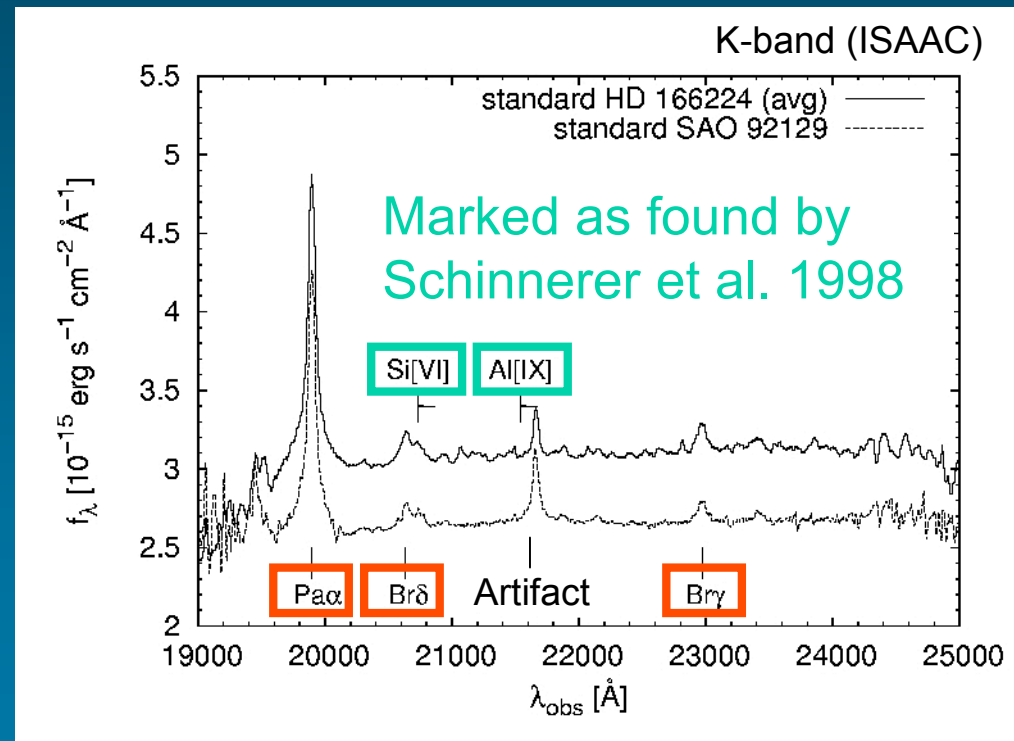
I Zw 1

[Schinnerer et al. 1998, Scharwächter et al. 2007]

## Possible nuclear outflow:

- Blueshifted high-excitation lines ([SiVI] by  $\sim 1460$  km/s wrt to I Zw 1)

Young QSO stage?

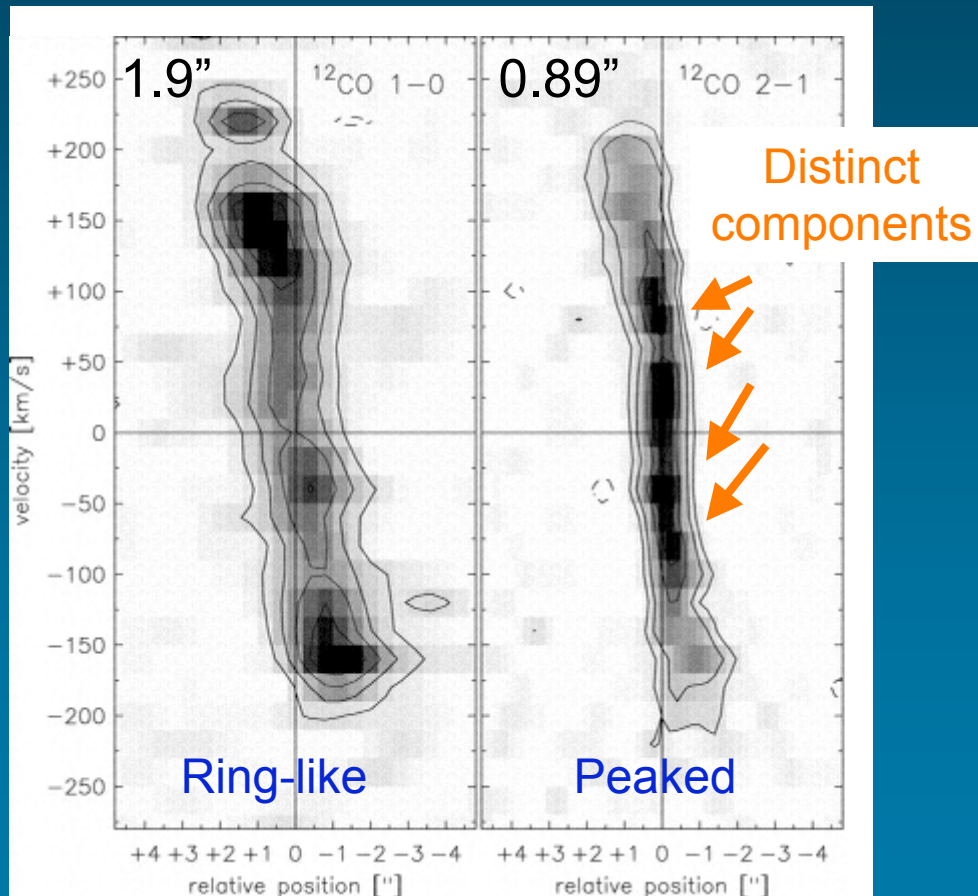




# mm Observations

I Zw 1

Plateau de Bure [Staguhn et al. 2004]



Position-velocity diagrams

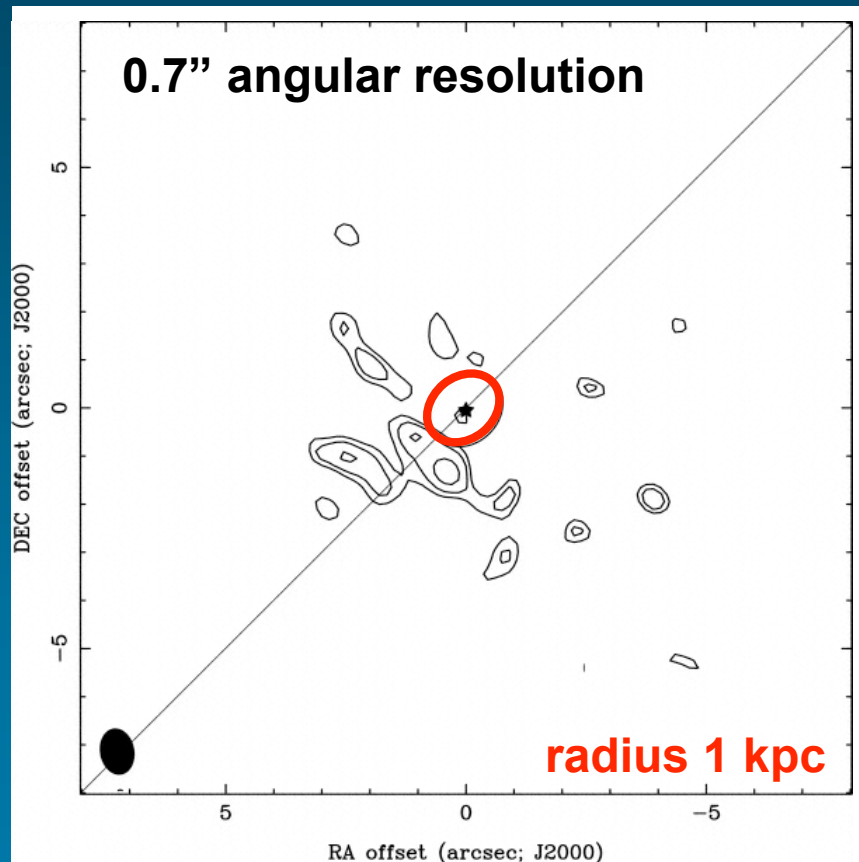
- Disk: Cold and/or sub-thermally excited gas
- Nucleus: Warm optically thick gas with distinct components

Excitation by starburst  
not by AGN

# mm Observations

I Zw 1

$^{12}\text{CO}(1-0)$  map (BIMA)



[Staguhn et al. 2004]

Circum-nuclear  
molecular ring

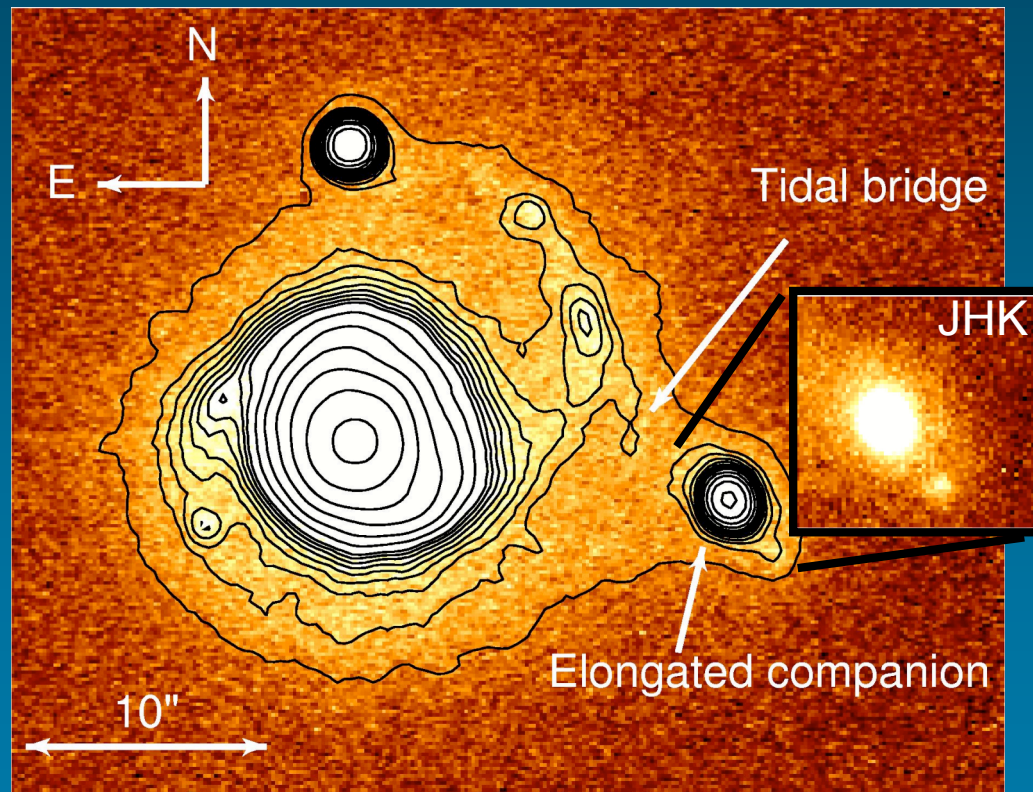
- Likely location of nuclear starburst
- Typical in barred spiral galaxies
- In un-barred spirals possibly caused by minor merger

Minor merger?

# Near-Infrared Imaging

I Zw 1

- J-band image (ISAAC)



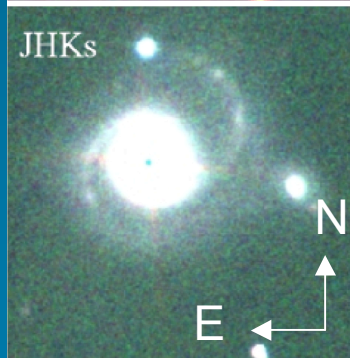
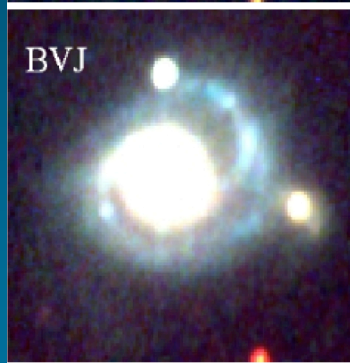
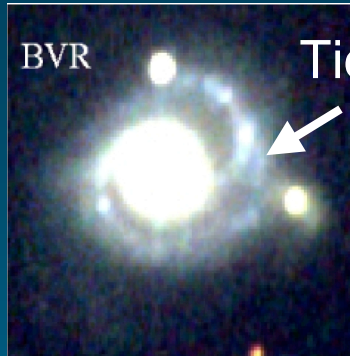
[Scharwächter et al. 2003, 2007]

## Evidence for ongoing merger

- Tidal bridge
- Elongated companion
- Apparent “tidal tail” of companion resolves into separate object

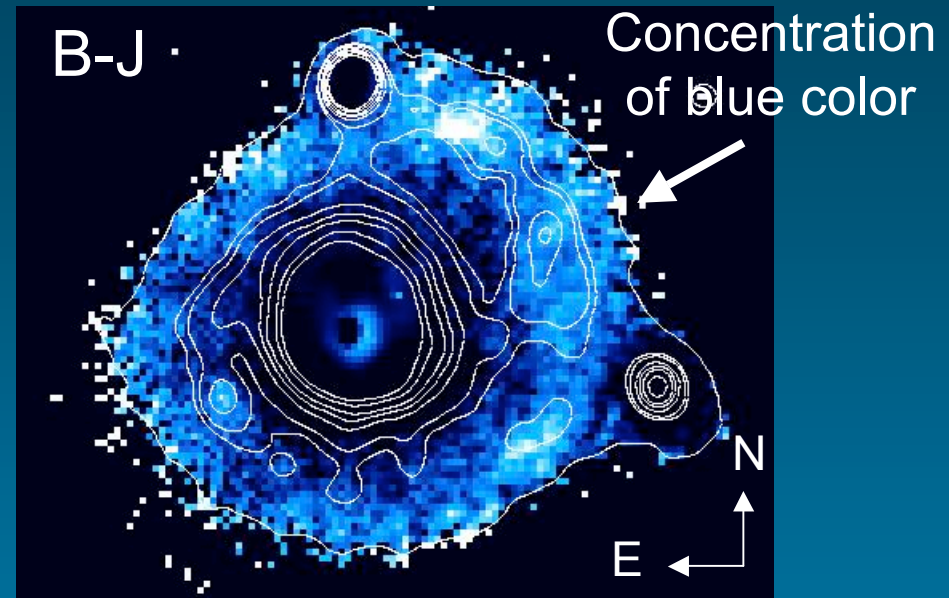
# Optical-NIR Color Composites

I Zw 1



ISAAC, EFOSC2

[Scharwächter et al. 2007]



Dark: red; Bright: blue

Possible indication of  
minor-merger enhanced  
star formation activity

# ULIRG-to-QSO transition stage?

I Zw 1

- Possible young stage of nuclear activity in I Zw 1 indicated by nuclear spectral characteristics → Young QSO
- Molecular ring as possible location of ongoing starburst → Aged ULIRG
- Spiral host galaxy: No recent major merger → Unlike typical ULIRGs!
- Further evidence for ongoing minor merger which may
  - Induce nuclear activity [*e.g. Hernquist & Mihos 1995*]
  - enhance Seyfert activity to QSO levels [*e.g. Corbin 2000*]
  - be unrelated to nuclear activity

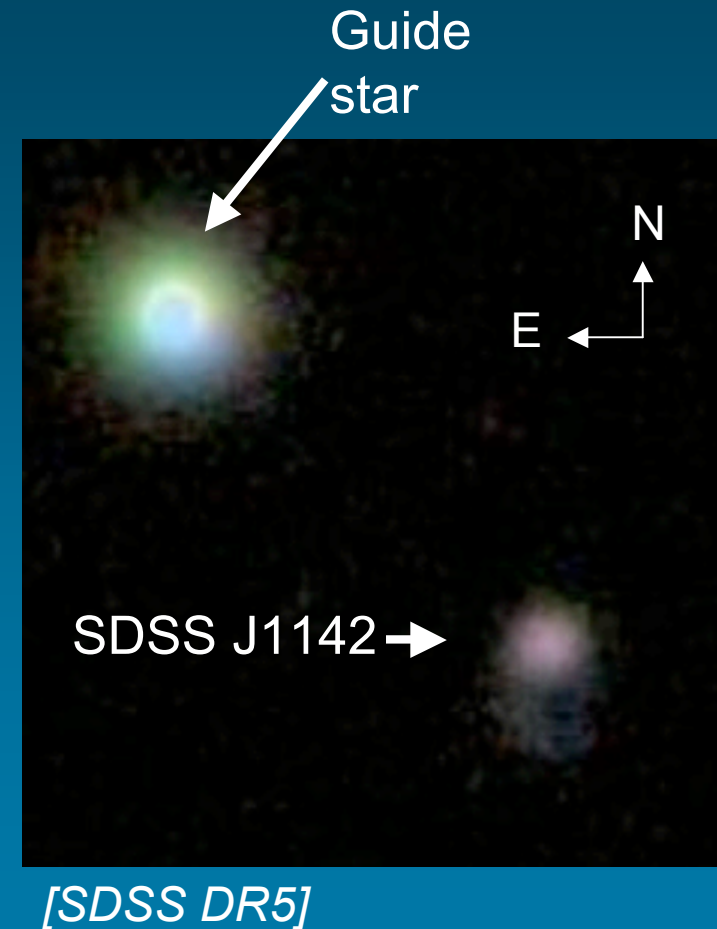
# SDSS J114203.40+005135.8

SDSS J1142

## In a nutshell

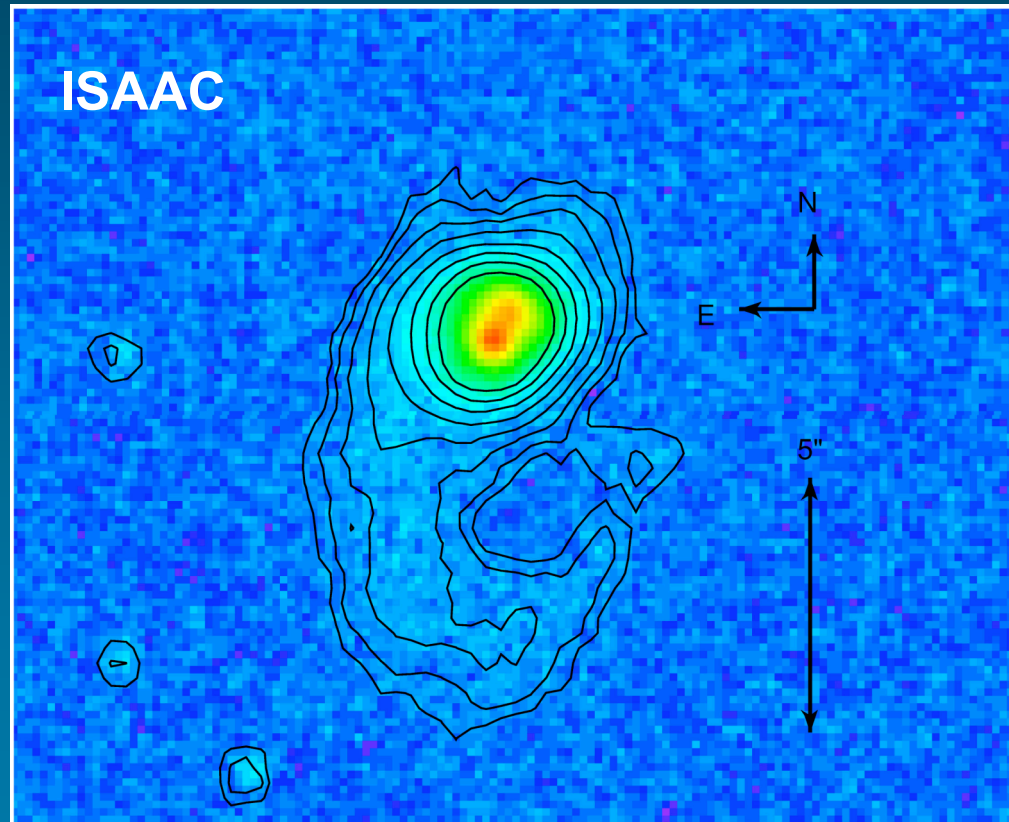
- $z=0.245$
- IRAS source
- Spectral characteristics of star formation activity  
*[Magliocchetti et al. 2002]*
- Radio source  
*[Magliocchetti et al. 2002]*

SDSS QSOs with  
nearby guide stars



# ISAAC Imaging

SDSS J1142



*[Work in progress]*

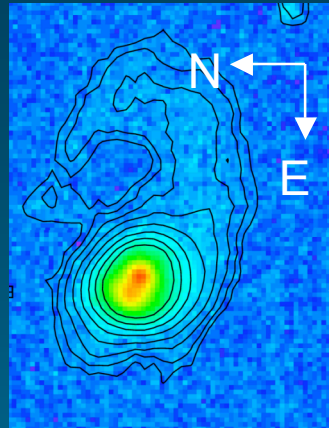
- First evidence for double structure in the central region

Two galaxy centers in the late stage of major merger, or hot spot from radio jet?

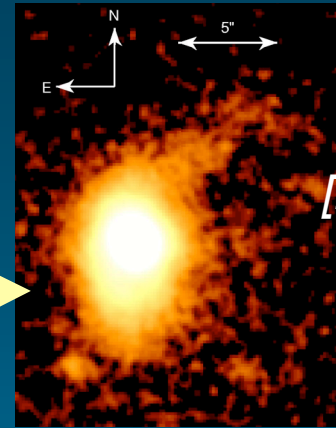
# 3C 48 Analog?

SDSS J1142

SDSS J1142  
(ISAAC)



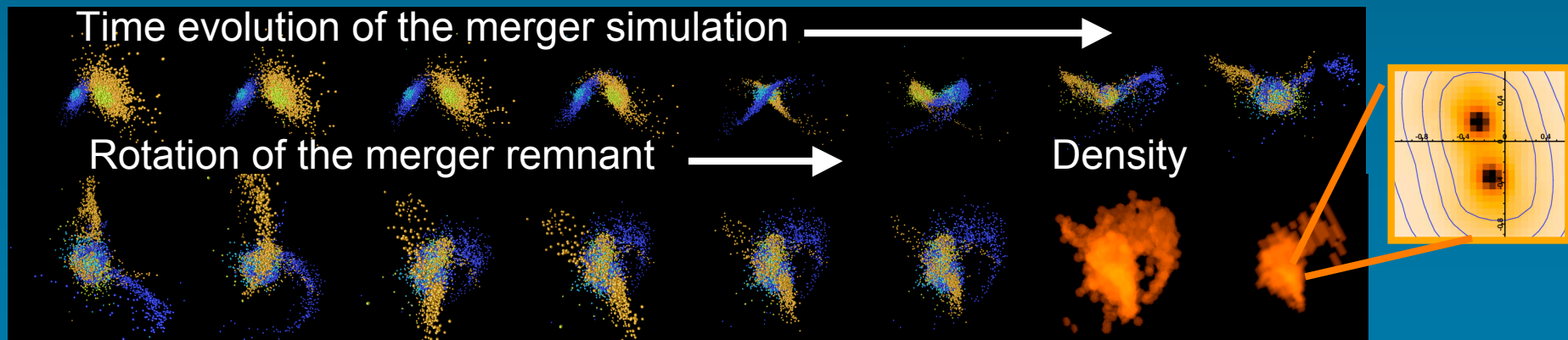
Flipped



3C 48  
(ISAAC)

[Zuther et al. 2003]

- Multi-particle merger simulation for 3C 48 [Scharwächter et al. 2004]

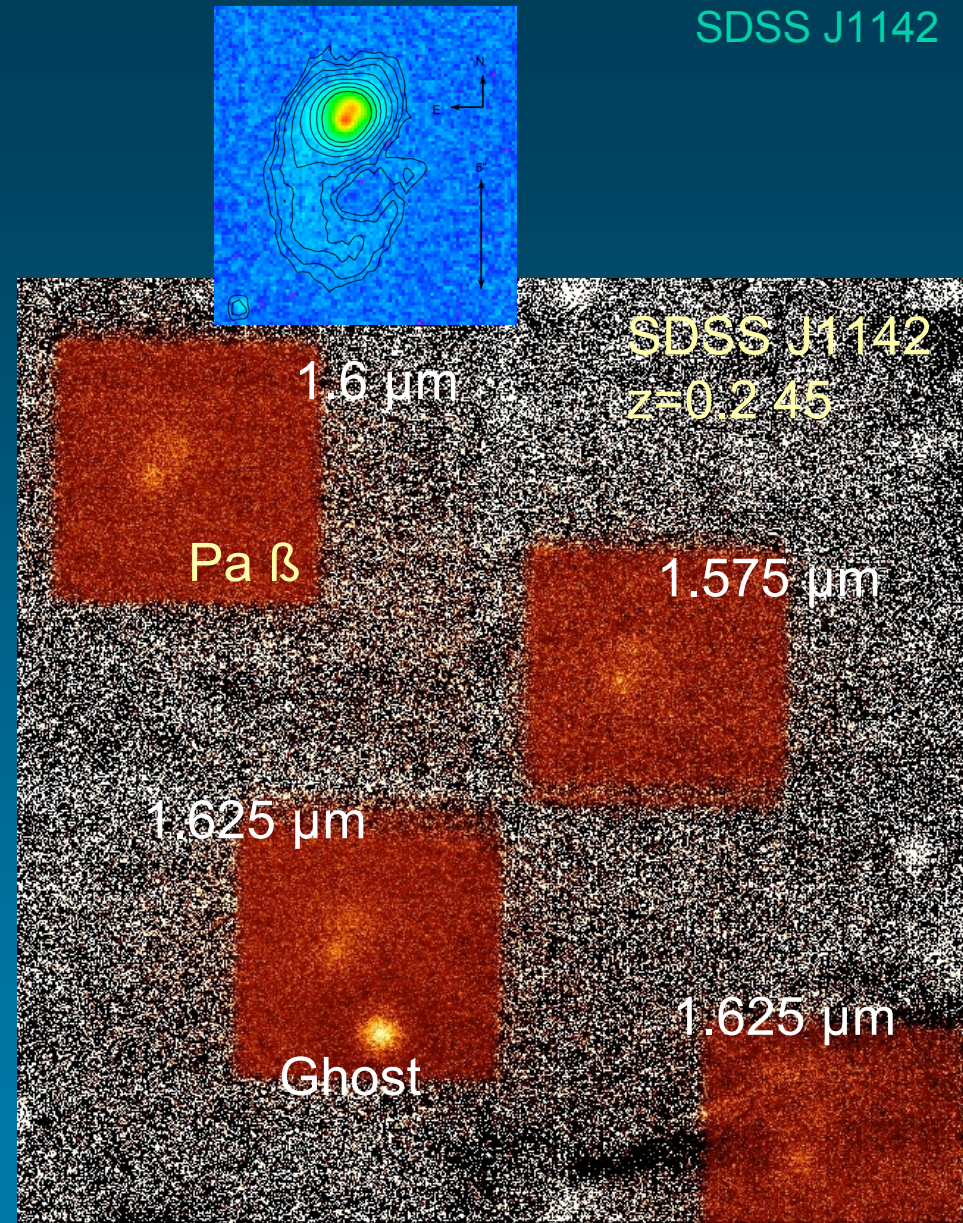




# NACO Imaging

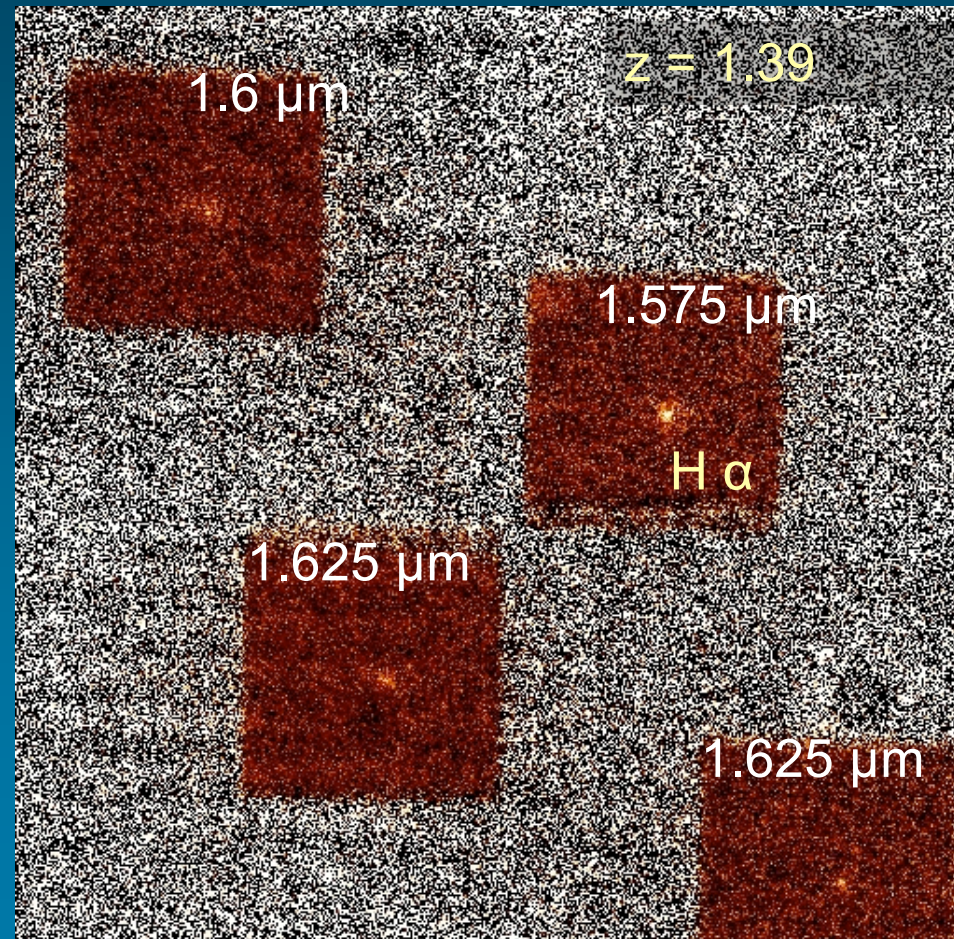
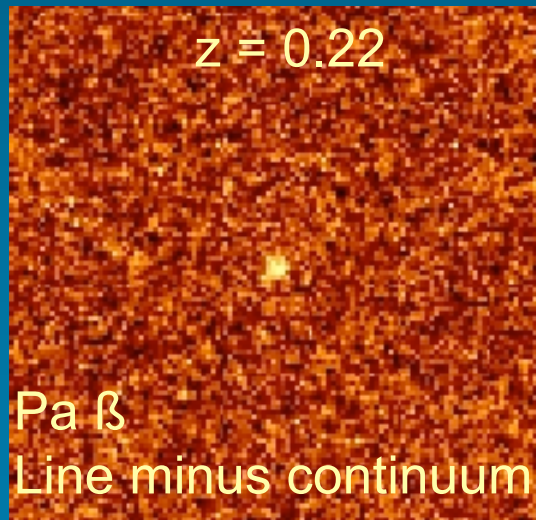
## Simultaneous Differential Imager (SDI)

- Emission line gas in QSOs at high angular resolution (“tunable redshift” approach)
- SDSS J1142: Double structure clearly resolved
- Low S/N → so far...



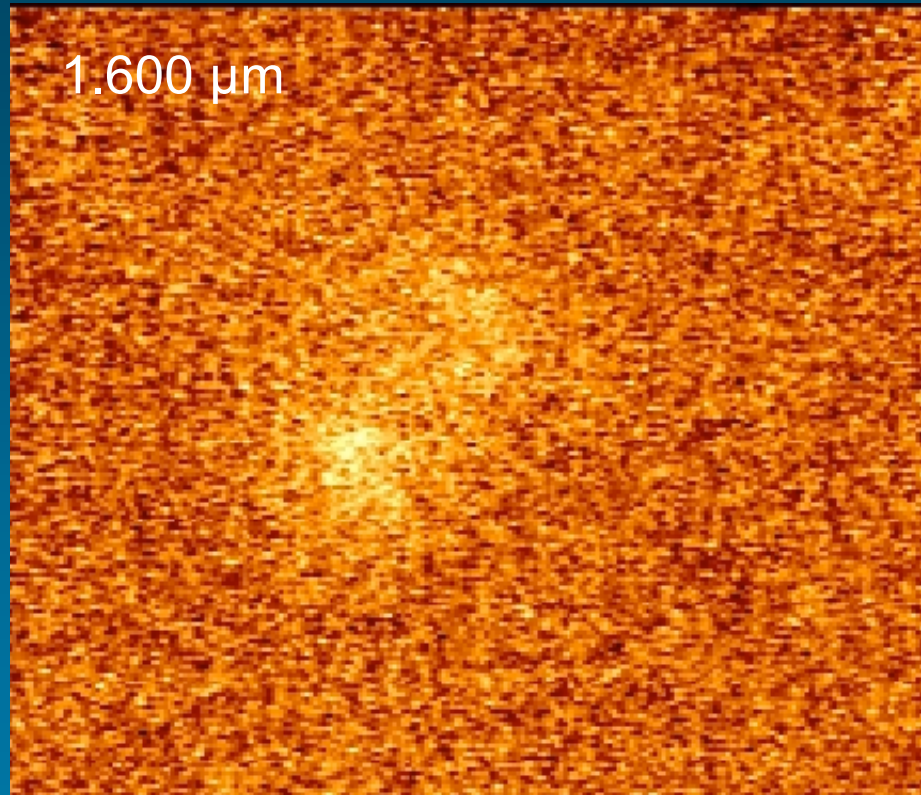
# Ongoing Program

- ... P80 program  
(UT 4 astronomers!!!)
- Laser guide star facility:  
improved Strehl, larger  
sample flexibility



# Tentative First Glance

SDSS J1142



# Role in the Evolutionary Sequence

SDSS J1142

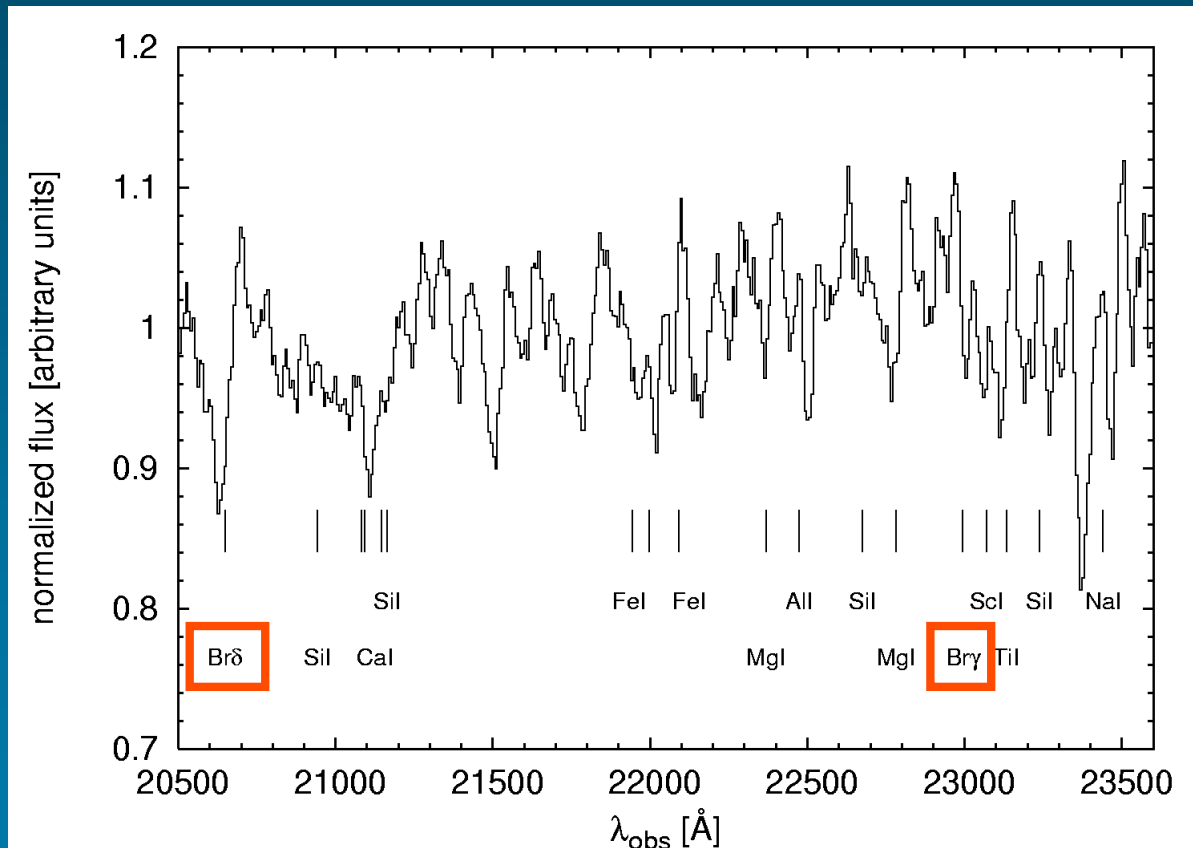
- Major merger remnant
- Indications for star formation activity

Interesting object for  
future detailed case study

# The Likely Companion

I Zw 1

## K-band spectrum (ISAAC)



No emission lines,  
perhaps  
absorption lines

➔ Old evolved  
stellar  
population

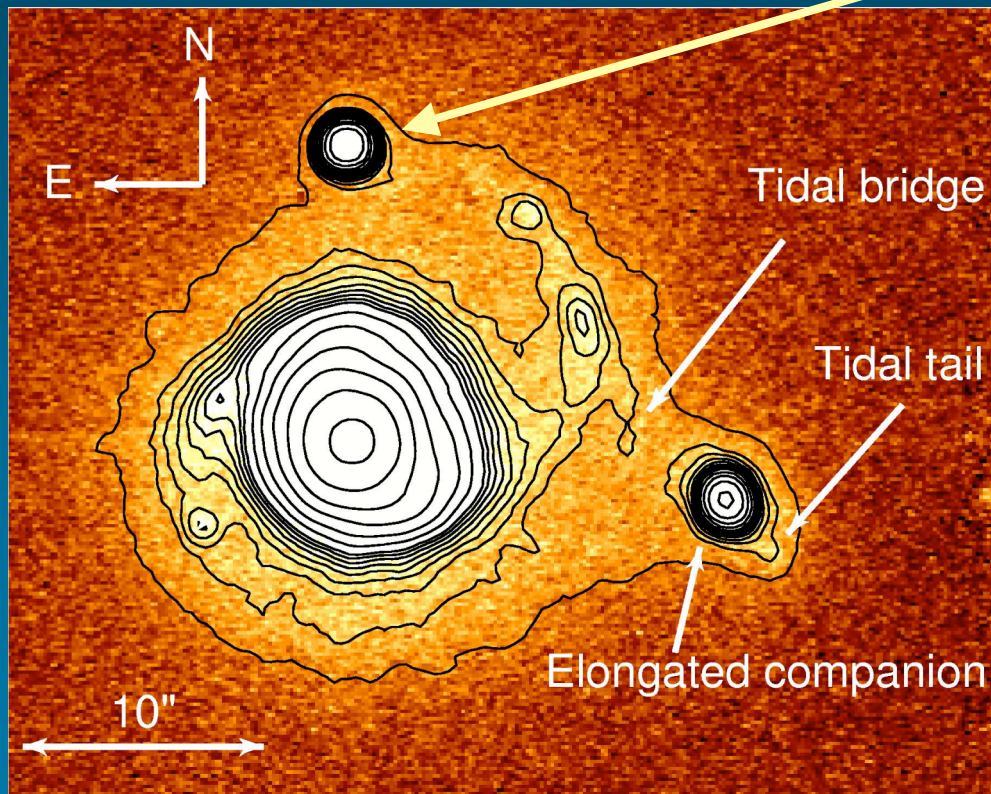
*[in agreement with  
Canalizo & Stockton  
2001]*

**Gas-poor  
dwarf elliptical**

# The I Zw 1 System

I Zw 1

J-band image (ISAAC)



[Scharwächter et al. 2003]

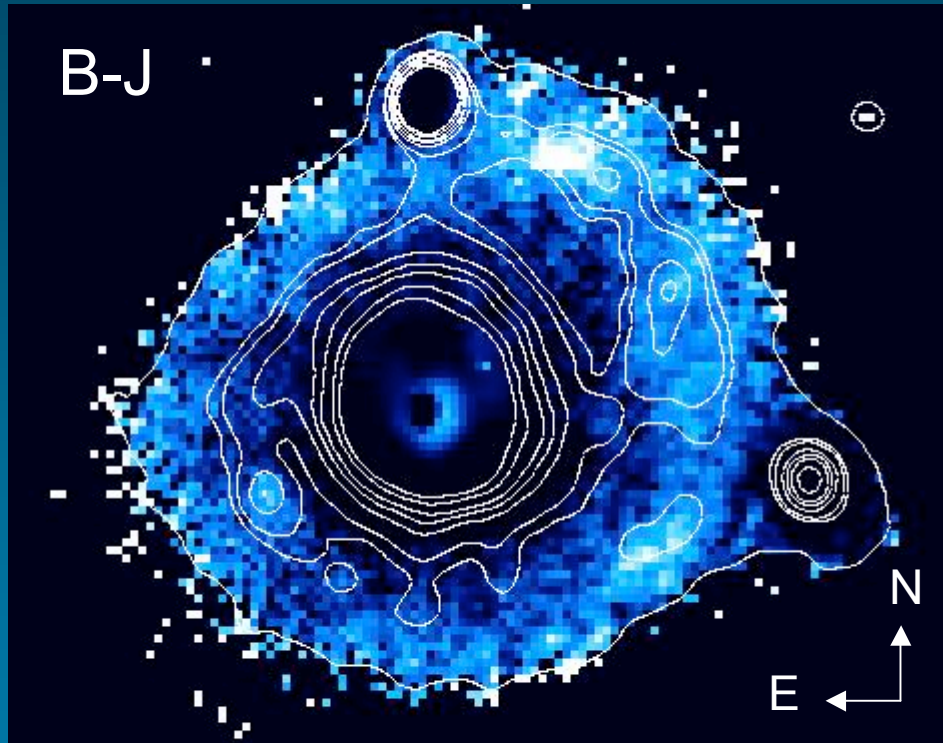
Foreground star  
*[Stockton 1982]*

As confirmed by  
ISAAC spectrum

Companion galaxy  
at approx. the  
redshift of I Zw 1  
*[Canalizo & Stockton 2001]*

# Minor merger evidence

I Zw 1



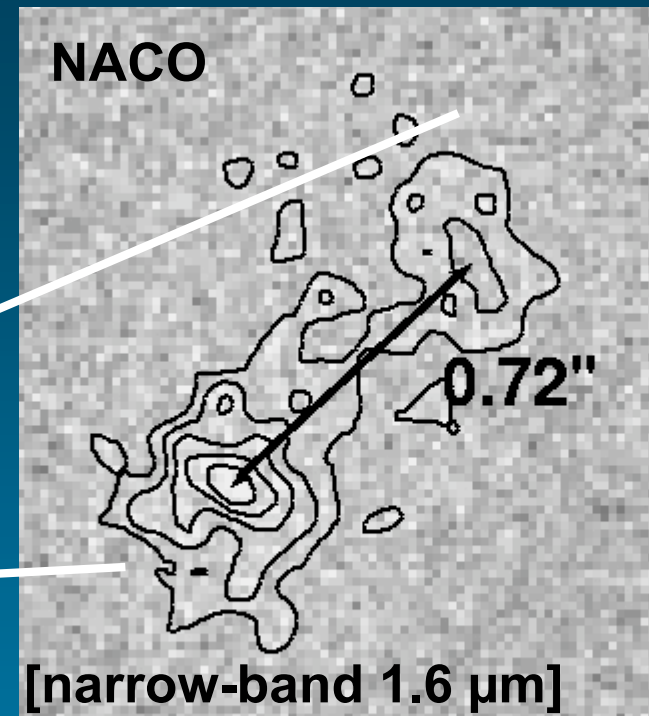
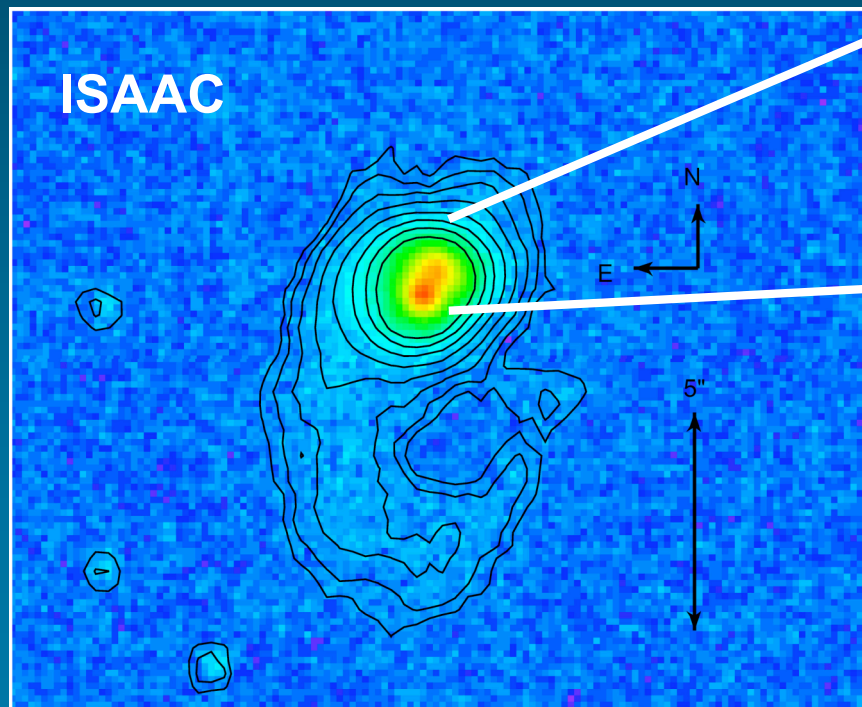
Bright: blue; Dark: red

- ▶ Concentration of blue color in western part of host
- ▶ Possible indication of star formation enhanced by tidal interaction

# ISAAC Imaging

SDSS QSOs

- First evidence



- Hot spot
- Second galaxy nucleus

[Work in progress]



# Collaborators

Andreas Eckart<sup>1</sup>, Valentin D. Ivanov<sup>2</sup>, Jari Kotilainen<sup>3</sup>,  
Melanie Krips<sup>4</sup>, Susanne Pfalzner<sup>1</sup>, Ivo Saviane<sup>2</sup>,  
Juha Reunanen<sup>5</sup>, Eva Schinnerer<sup>6</sup>, Rainer Schödel<sup>1</sup>,  
Johannes G. Staguhn<sup>7</sup>, Lowell E. Tacconi-Garman<sup>8</sup>,  
Jens Zuther<sup>1</sup>

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<sup>2</sup> ESO Chile

<sup>3</sup> University of Turku, Finland

<sup>4</sup> CfA (SMA project, Hawaii, Cambridge), USA

<sup>5</sup> Leiden Observatory, The Netherlands

<sup>6</sup> MPIA Heidelberg, Germany

<sup>7</sup> NASA/Goddard Space Flight Center, USA

<sup>8</sup> ESO Garching

# My life before Chile...

Solingen (Germany)  $\xrightarrow{40 \text{ km}}$

Cologne: Studies (University of Cologne), Ph.D. thesis  
(supervised by Andreas Eckart)  $\xrightarrow{12\,000 \text{ km}}$

ESO Chile in May 2005 (duty station: La Silla)



„Kölsch” – Beer  
in 0.2 l glasses



Carnival – just  
started on  
11/11 at 11:11