Ultra Luminous X-ray Sources and IMBHs

David Cseh
CEA Service d'Astrophysique

Supervisor
Stephane Corbel

Co-advisors
Rob Fender, Luciano Burderi and Elmar Koerding

Outline

- ULXs & IMBHs
- Main projects
  - IMBH in a Globular Cluster?
  - ESO VLT spectroscopy of ULXs & their environment
- Side projects
  - CDT quasars at $z > 3$
- Future projects and cooperations

ULXs & IMBHs

ULXs and IMBHs

- What is a ULX? (definition)

- off-nuclear
- apparent L (!) violate the **Eddington limit** (1.3×10^{38} erg/s) of a ~10-M_{sun} object

- Explanations:
  - 10^2- 10^4 M_{sun} IMBHs
  - beamed emission
  - super-Eddington accretion

- Best cases for IMBHs(?)
  - NGC 5408 X-1 (VLT spectroscopy, see later)
  - HLX ESO 243-49 ($L=10^{42}$ erg/s assuming **isotropic** emission)

ULXs and IMBHs

- What can be an IMBH?
  - a ULX
  - central BH of a Globular Cluster
  surface density profile & velocity disp. measure (M_{BH}- σ_*)
  - core collapse of 100-1000 M_{sun} Pop. III stars

- AIMS:
  - Find an IMBH: dynamically constrain mass via optical spectroscopy
  - Energetics of a ULX: using environment as a calorimeter /kinematic + radiative →
    models: eg. synchrotron, leptonic vs hadronic/

- Role of jets: kinematics, effect on environment, feedback(?)

Main Projects

IMBH in a Globular Cluster?

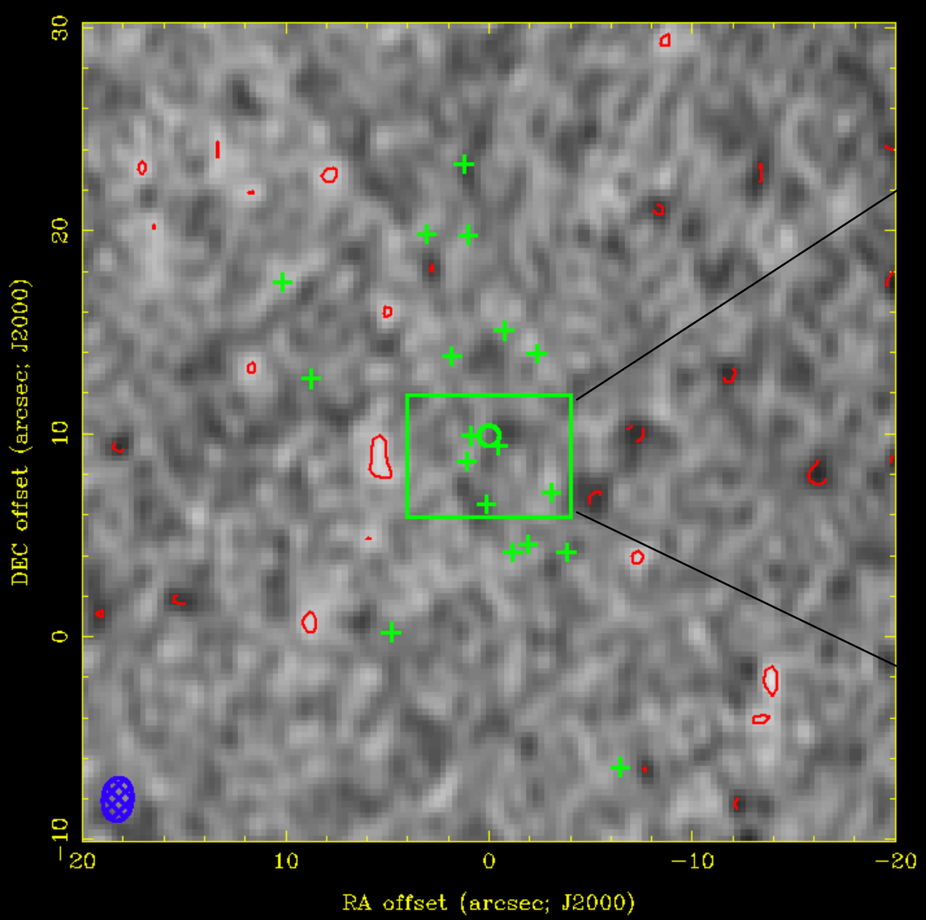
Globular cluster: NGC 6388

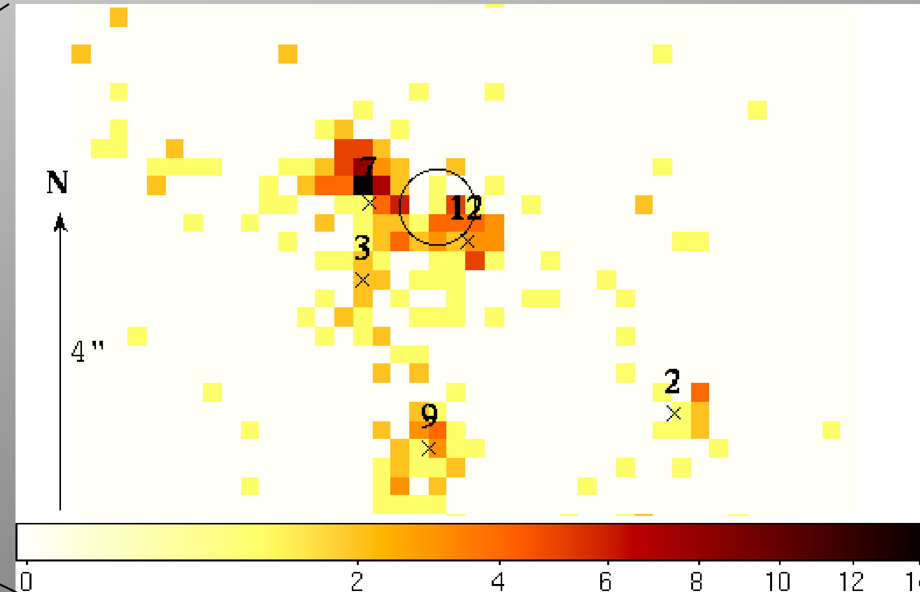
- The surface density profile has a cusp with a slope $\alpha = -0.2$ in the inner 1” of the GC. (Lanzoni et al. 2007)

- This slope is shallower than expected for a post core collapse cluster and is consistent with an IMBH of 5700 $M_\odot$.

- Idea:
  - Using fundamental plane to test the mass
    $\log L_X = 1.59 \log L_R – 1.02 \log M - 10.15$ (Kording et al. 2006)

  - Deep radio observation + reanalysis of Chandra data





Chandra X-ray image

ATCA radio image

- Using our radio r.m.s. level we find, the putative IMBH in NGC 6388 cannot be more massive than ~1500 $M_{\odot}$. *Cseh et al. 2010, MNRAS, 406, 1049*

- Simulations: shallow cusps might not indicate IMBHs (Vesperini et al 2010)

My visit at University of Iowa

Phil Kaaret, Cornelia Lang, Fabien Grise

ESO VLT spectroscopy of ULXs & their environment

What can we learn from spectroscopy?

- Optical spectrum:
  Emission from companion, disk, and surrounding nebula

  - Companion (continuum+absorbtion lines)

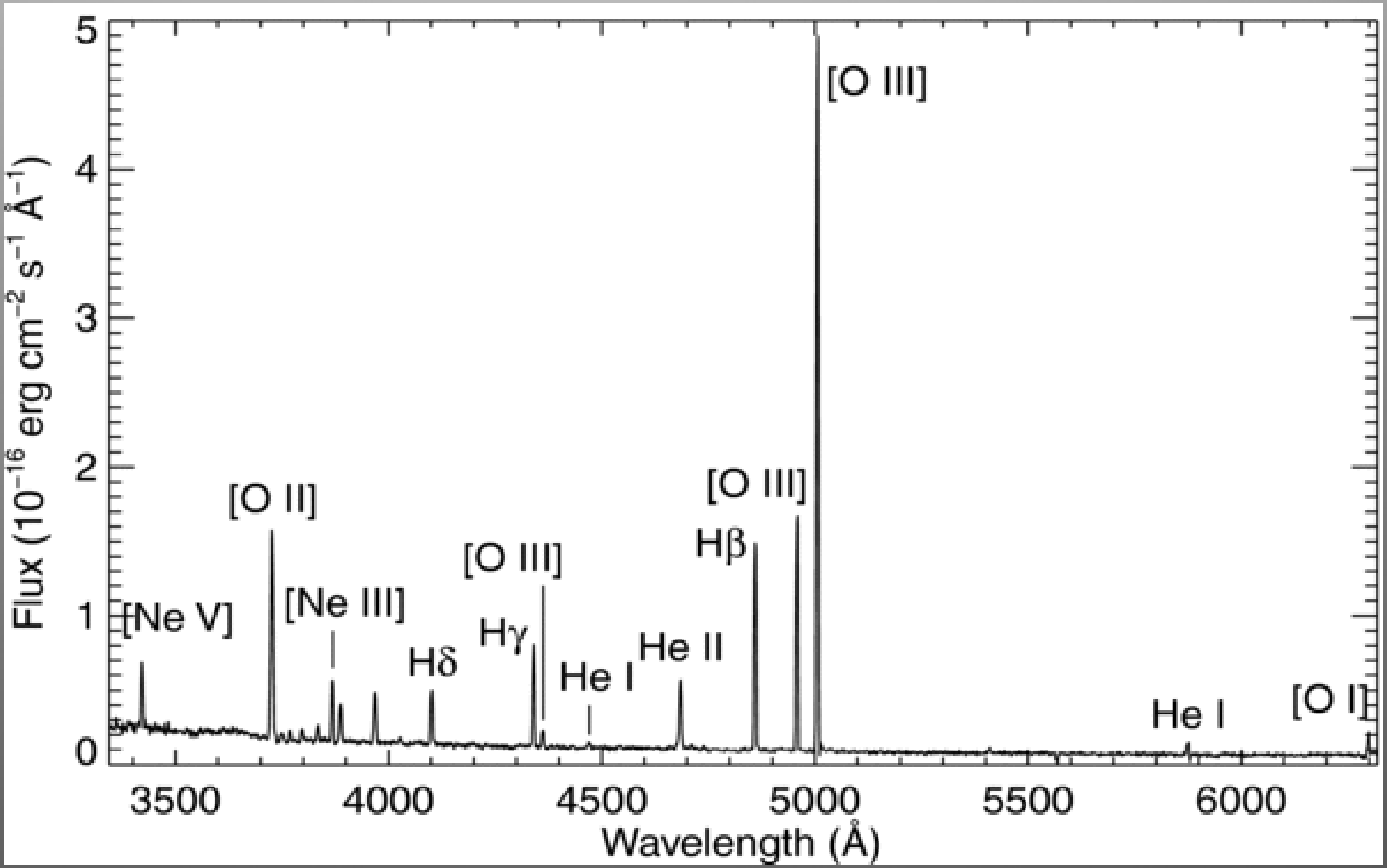
  - Disk (hot continuum, high excitation lines)
    → nature of acc. flow, X-ray flux, mass of the BH

  - Nebula (forbidden lines, continuum)
    → photoionized (high excitation lines) or shock ionized (jet inflated bubbles?), density, temperature

- AIM: - use optical & radio nebula as a calorimeter
  - dynamical mass estimation

Dynamical mass of NGC5408 X-1 ?

NGC 5408 X-1



- We see:
  - No absorbtion lines → companion too faint
  - continuum emission from disc
  - Nebular emission + high excitation lines

NGC 5408 X-1

- We know: (Kaaret & Corbel 2009)
  - optical light due to X-ray flux is reprocessed by the disc
    → **isotropic emission**, truly ULX
  - nebular temperature 17000 K → photoionized
  - probably no jets?

- New: we see accretion and nebular component of He II line
  - The broad component has a wavelength shift !

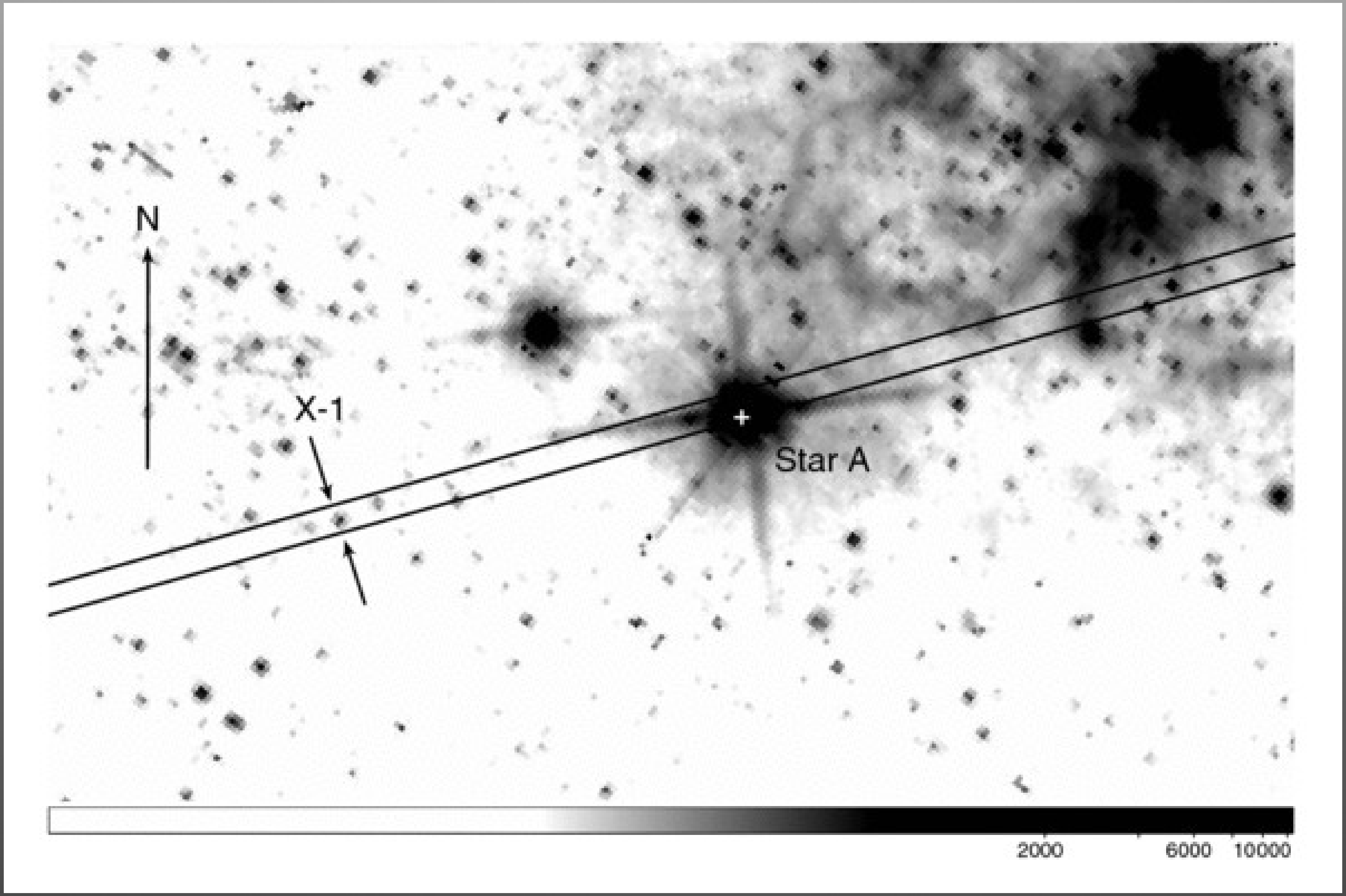
Very Large Telescope

- Location: Cerro Paranal
- 4 Unit + 4 Auxiliary Telescopes:
4 x 8.2 m + 4 x 1.8 m movable RCs
- Start 1999 April with 1 UT; operated by ESO

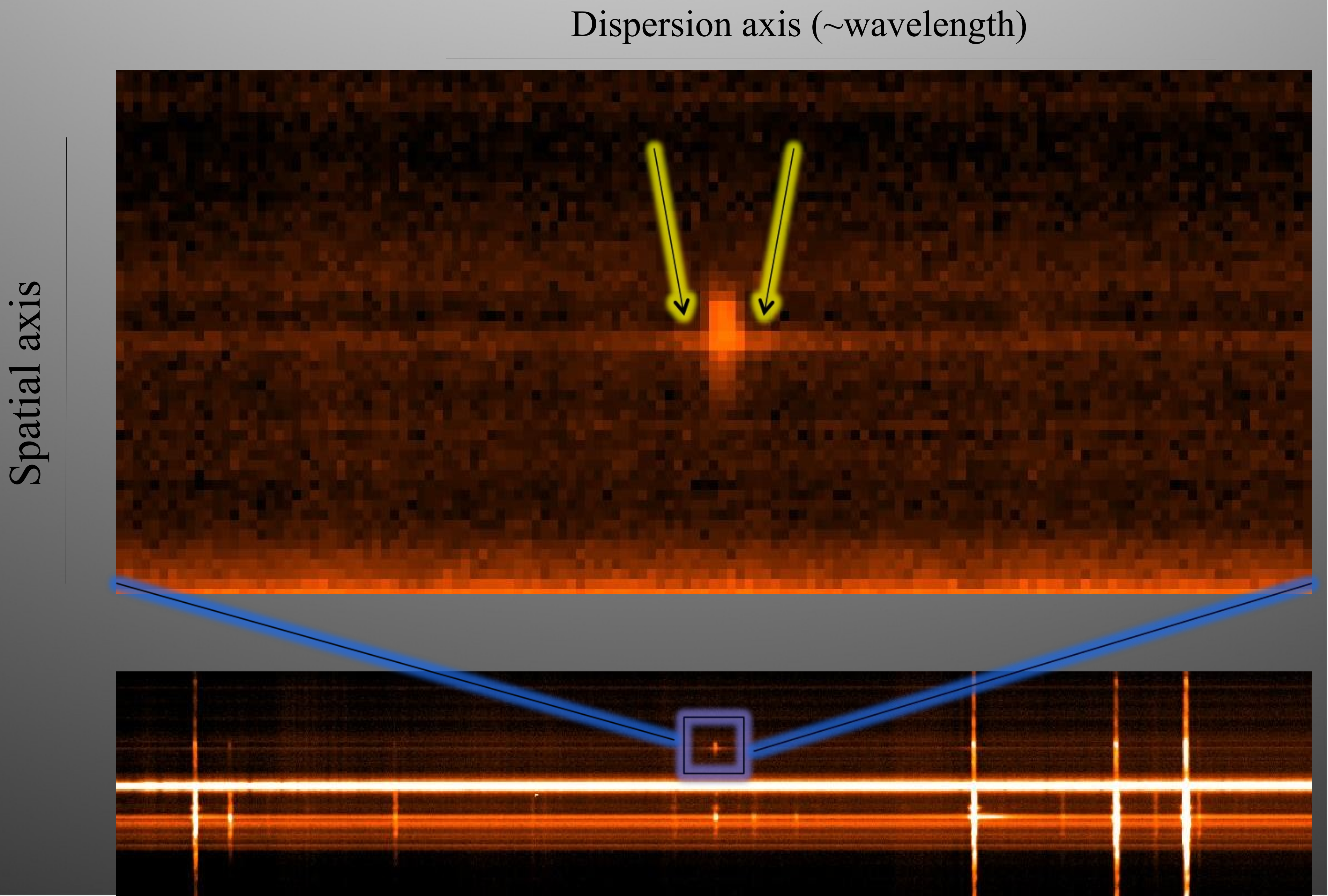
Observation:

FORS-2, slit 1”, blue 366-511 nm, red 575-731 nm
Dispersion ~0.36 Angstrom/pix
Exp time: 3 x 850 s each spectral range

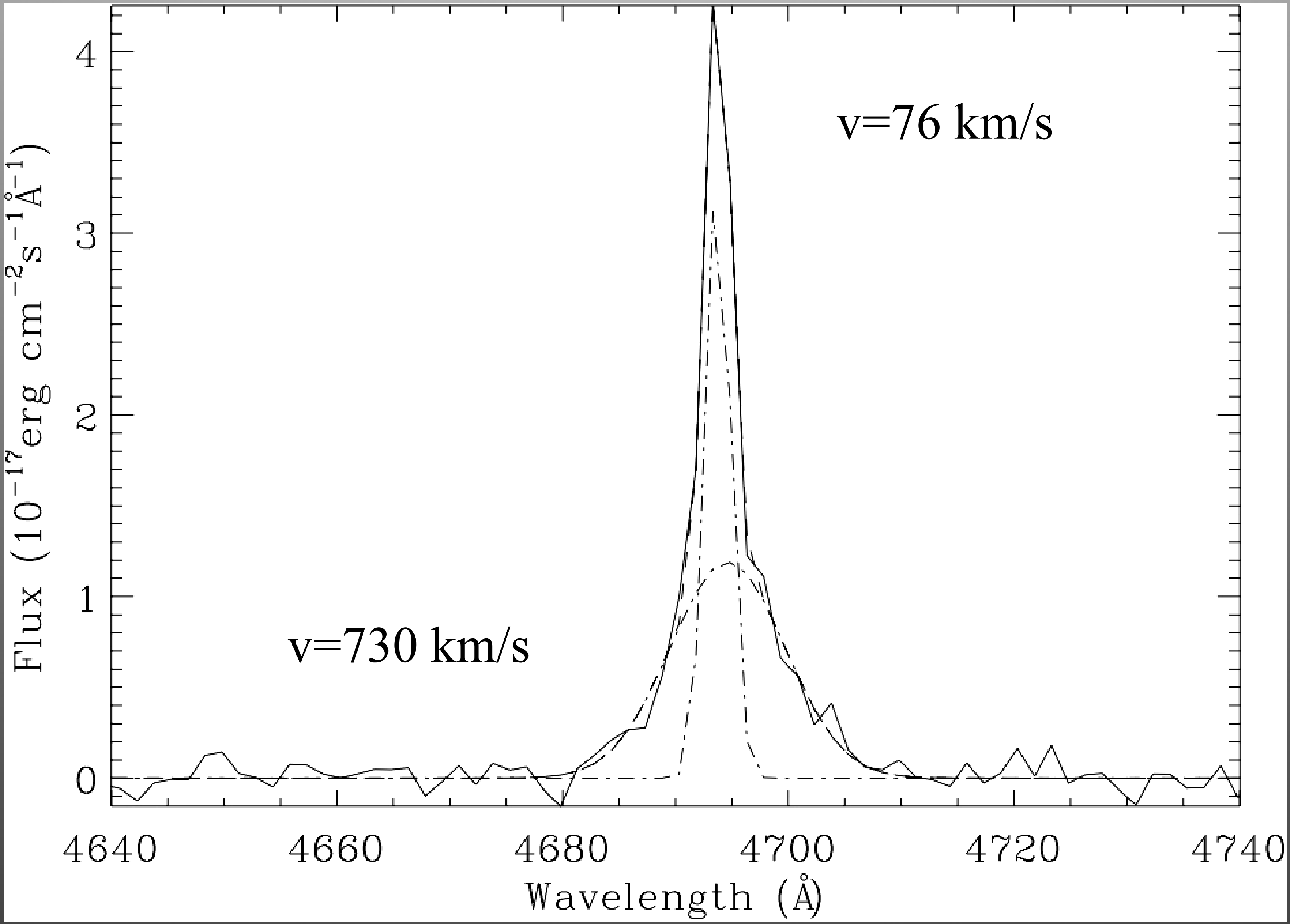
Acquisition and slit position



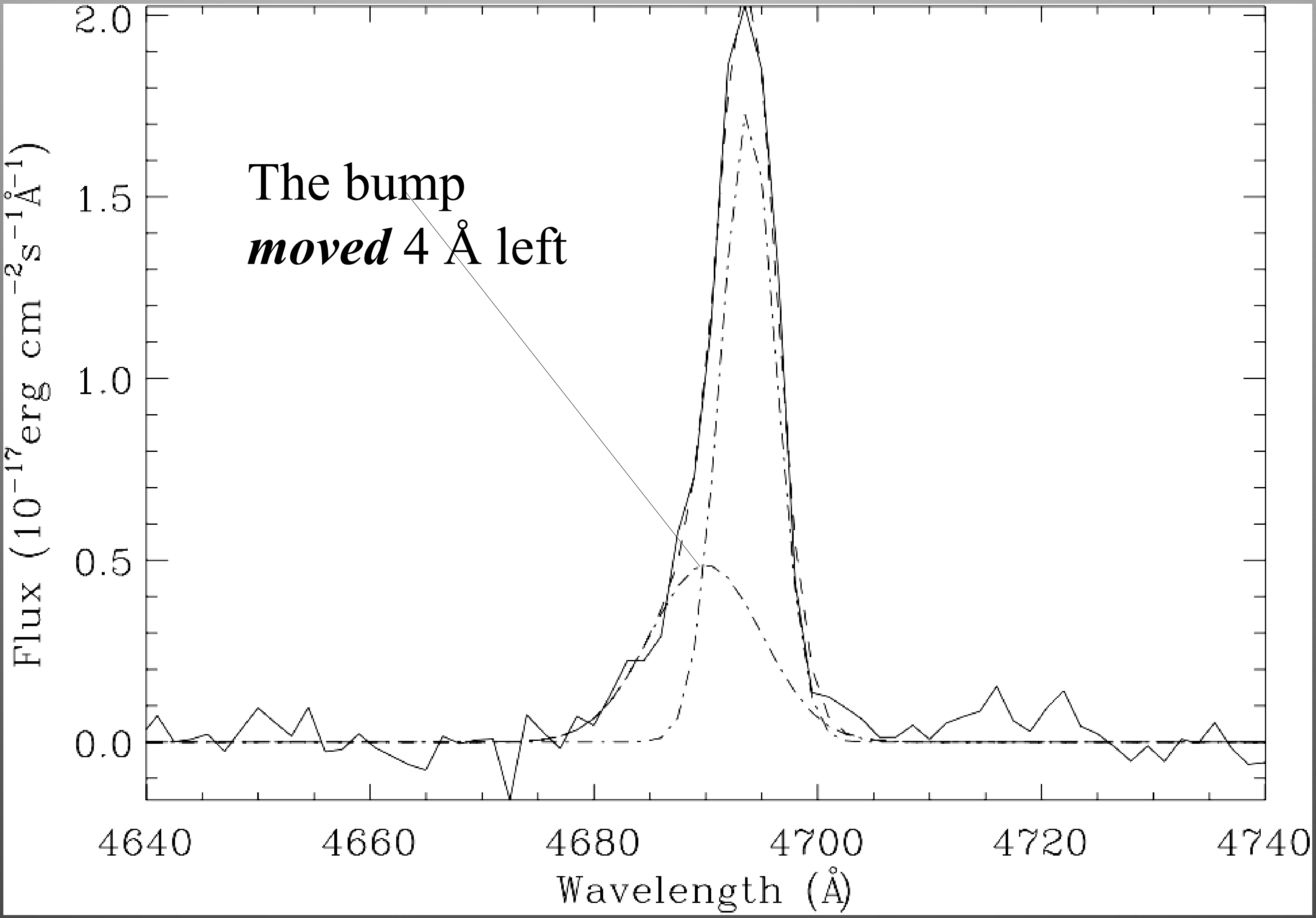
The He II line in 2D



He II line profile 1D



He II line profile (prev. obs.)



Current results

- We can resolve the accretion disc (broad) and the nebular (narrow) components of the He II line. (also Balmer-lines)

- Size of HeII line emitting region < 1.6 ± 0.3 AU for 1000 M_{sun}
  → Spatial origin of the broad component line is the disc

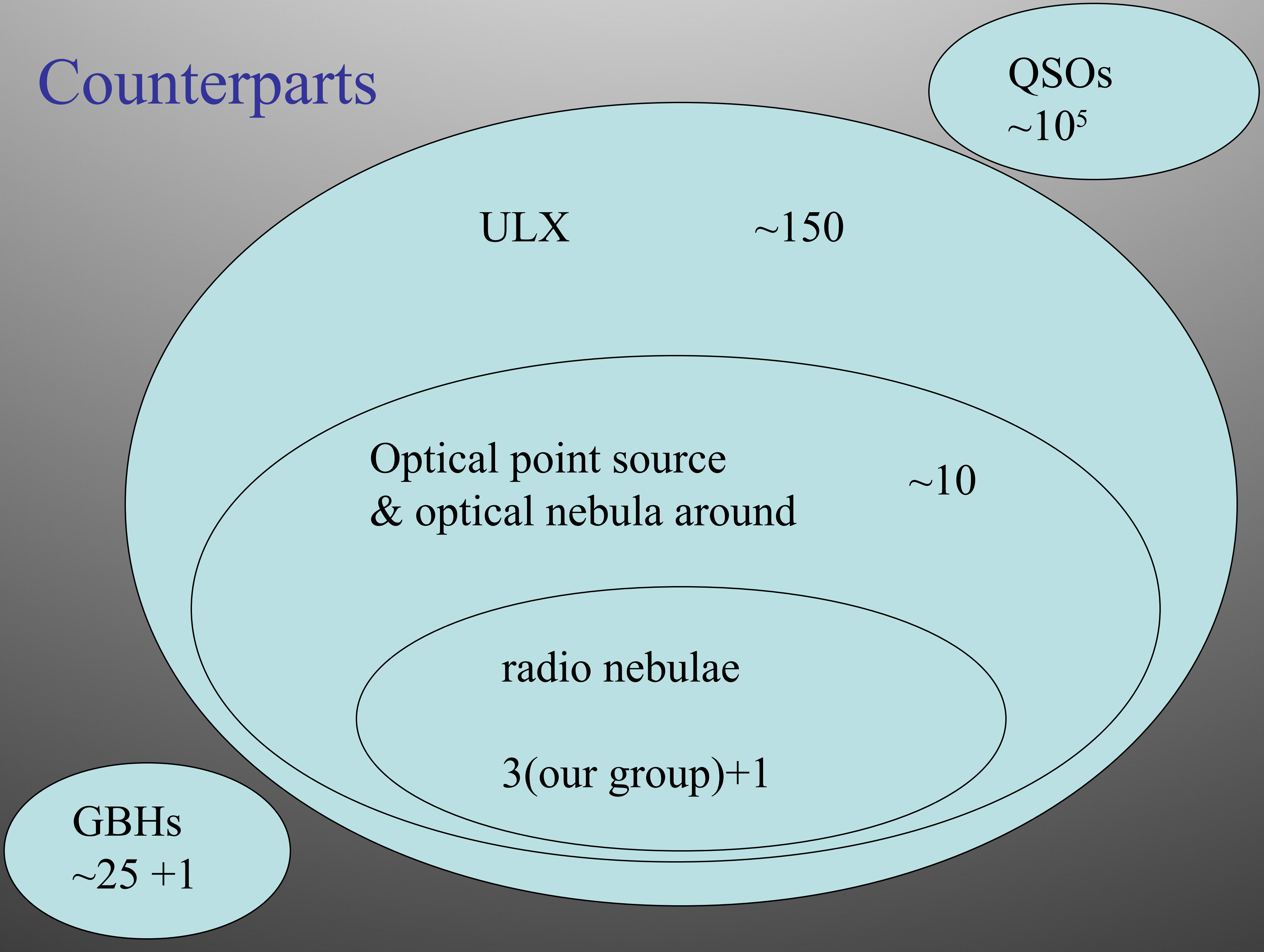
- Mass function: fm= 26.6 ± 14.8 $M_{sun.}$
  → $M_{companion} > 12\ M_{sun}$

Cseh et al. 2010 ApJL, in prep

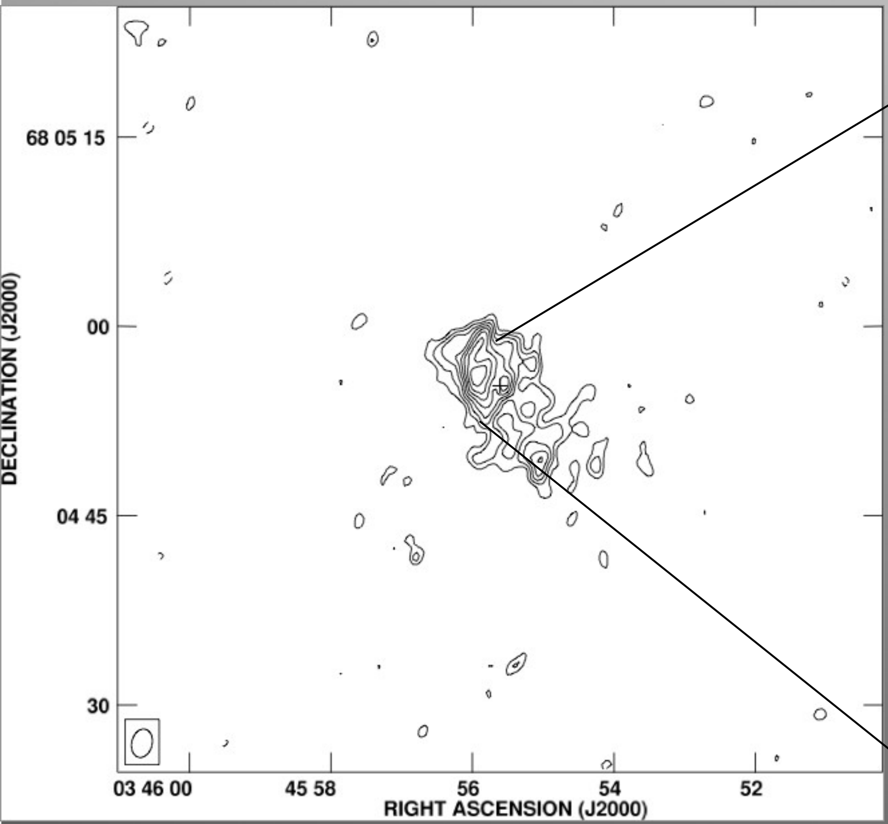
- We "only" need a radial velocity curve:
  ESO VLT proposal is in prep. (sep 30 deadline).

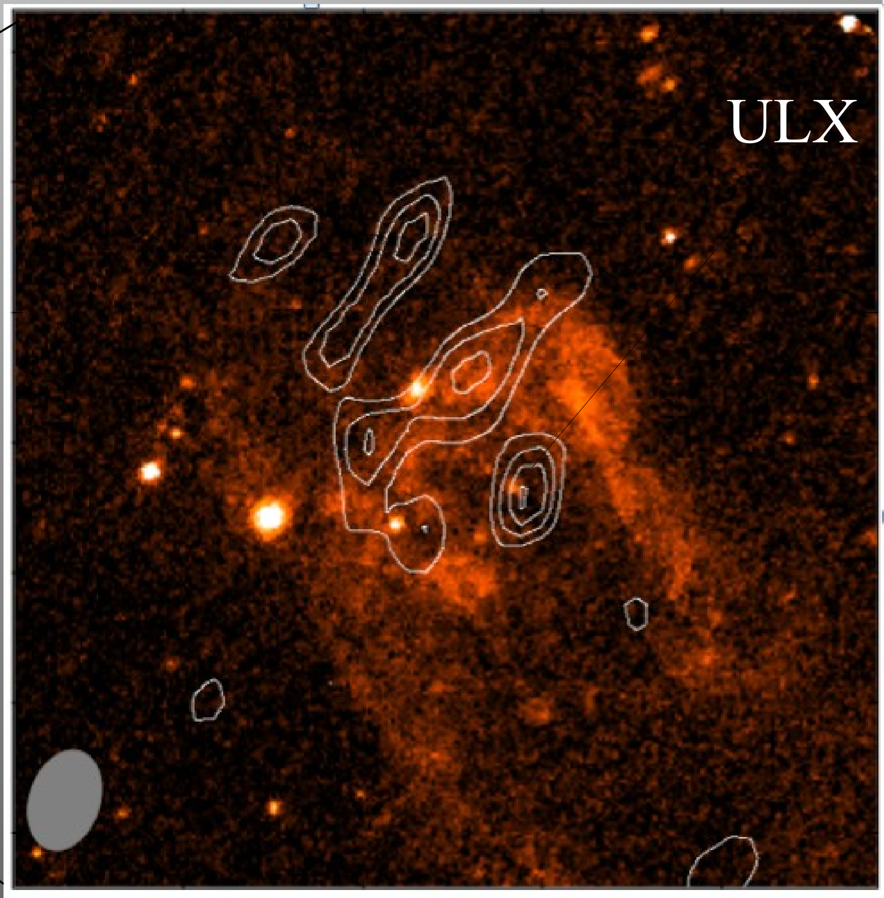
Counterparts & Environment of ULXs

Counterparts



A new discovery in radio: IC 342 X-1





Extended (220 pc) radio **nebula**

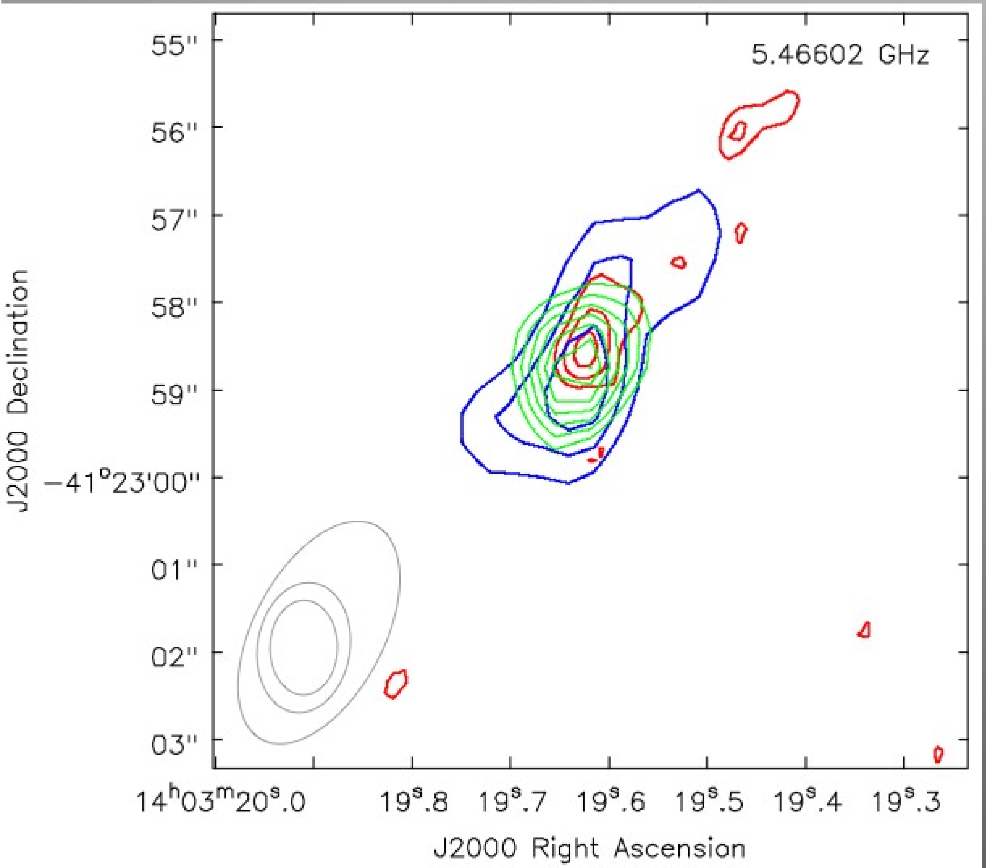
High-res. VLA overlaid HST Hα.

Diffuse emission of 2 mJy

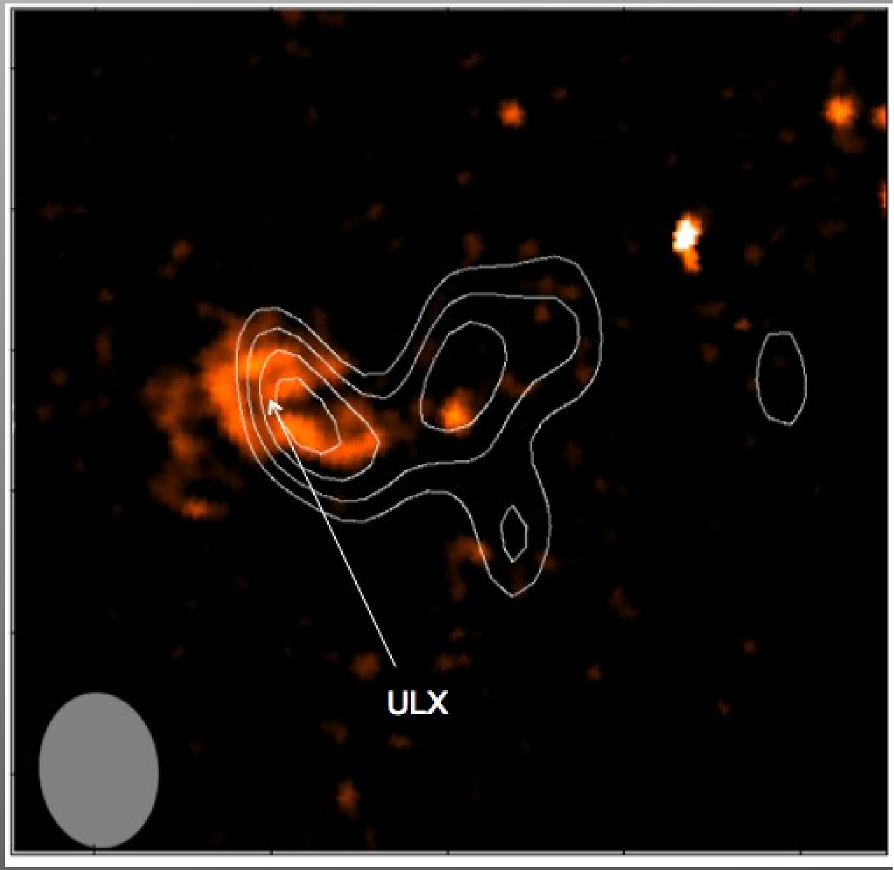
Compact object with flux density of 100 uJy

Other two radio nebula

NGC 5408 X-1



Holmberg II X-1



For NGC 5408 X-1: we resolve the nebula. (HST & Chandra)

Holmberg II X-1: we also obtained radio spectra

Results

- Mass estimated from the fundamental plane: ~10^4 M_{sun}
- Compare all 3 radio nebulae around ULX and microquasars:

Name	Energetics [erg]	Size [pc]	Spectral index
IC 342 X-1	9×10^{50}	220	n/a
Holmberg II X-1	3×10^{49}	50	-0.53
NGC 5408 X-1	4×10^{49}	35	-0.8
SS433	$(0.5\text{-}7) \times 10^{46}$	46	-0.9

- Assuming radiation via synchrotron emission, equipartition between particles and fields, and equal energy in electrons and baryons (Lang et al. 2007).

- But: - S26 → E_{kin} 99% (Soria et al. 2010)

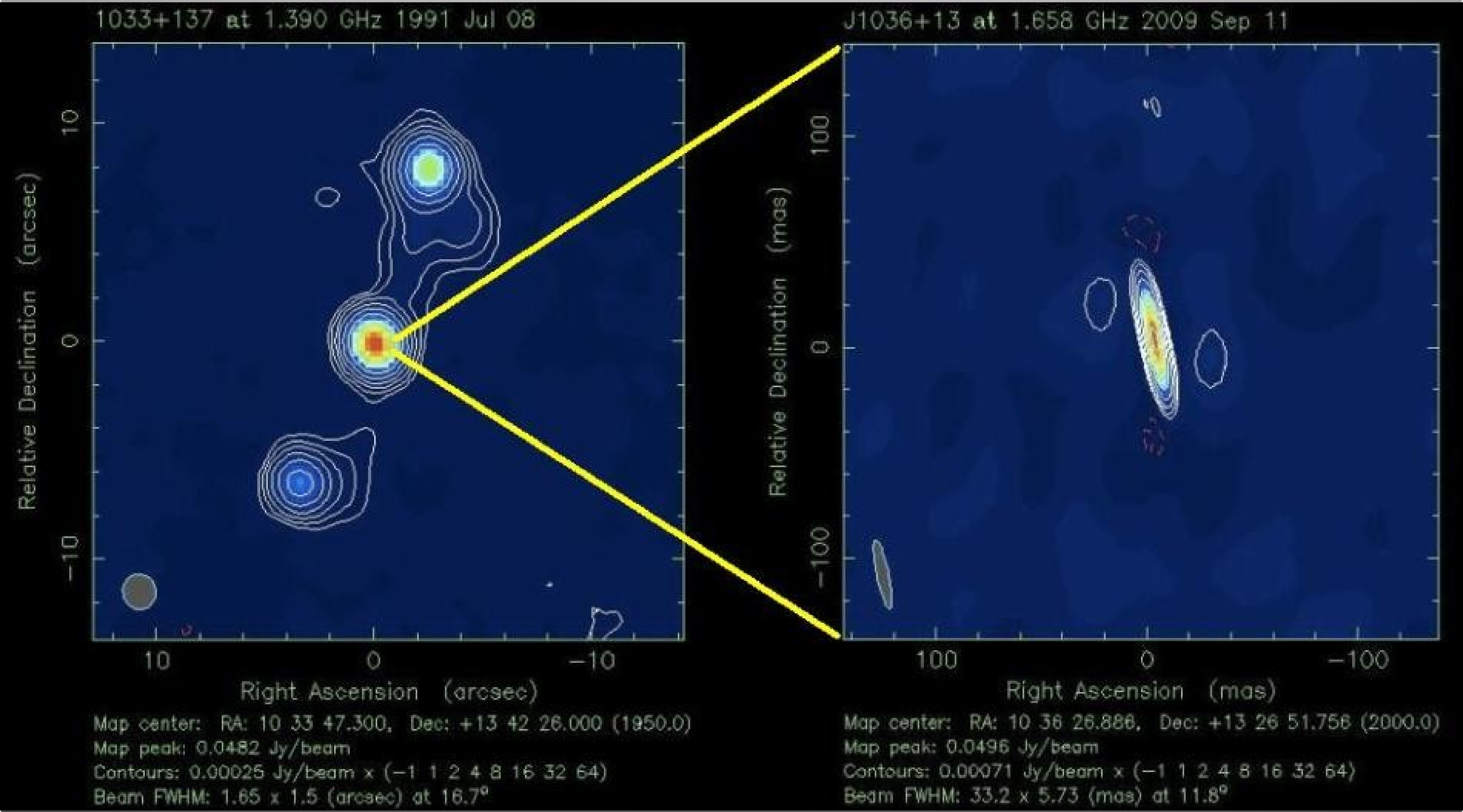
  - Hadronic model gives a factor of 10 hihger for the power.

- Similar for all 3 ULXs but at least 2 orders larger than SS433.

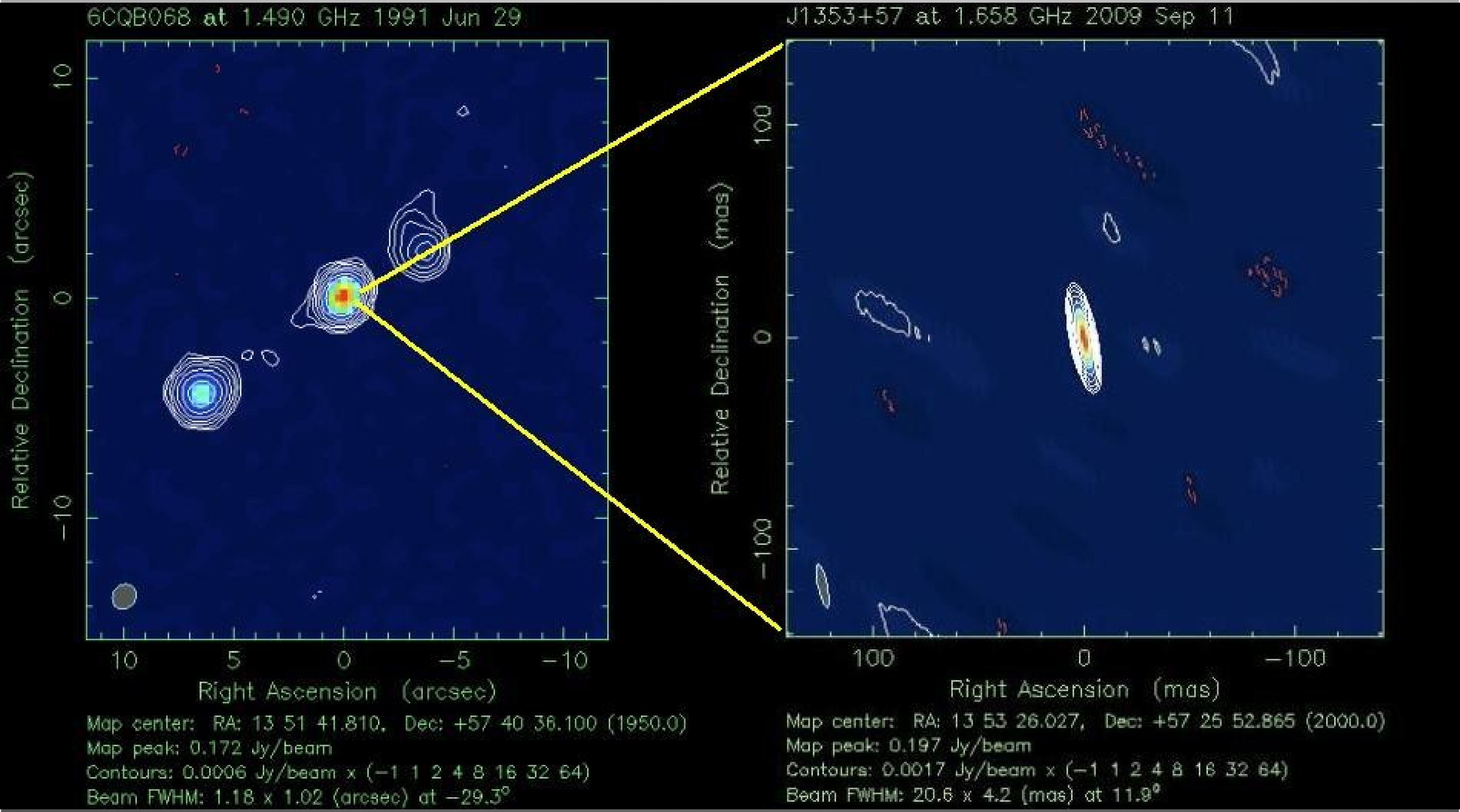
To be continued …

Side Projects

Core-Dominated Triples at z > 3



-We investigated the possibility that their CDT morphology can be a sign of restarted radio activity, involving a significant repositioning of the radio jet axis.



In summary, we found that it is not necessary to invoke large misalignment between the VLBI jet and the large-scale radio structure.

Cseh et al. 2010, A&A, accepted, in press

Other cooperations in 1st year

- S. Farell: HLX
- M. Coriat: GX 339-4
- S. Frey: AGN activity at early cosmological epochs

- Future projects and cooperations

Future plans

- Refining the fundamental plane using new data on GBHBs (?)
  (Nijmegen, E. Koerding)

- LEMMINGS (e-MERLIN) (?)
  (Southampton: R. Fender, T. Maccarone)

- Theory in 3rd year: Accretion disk of ULXs (?)
  (Cagliari, L. Burderi)

  - More X-rays? (visit other network institutes?)

- Side project possibilities:
  - Interaction of a relativistic jet with the ISM: GX 339-4
  - VLBI follow up of Cyg X-3

Summary on 1st year

- 2 accepted articles (+1 in prep.)
- 3 conference attendance + MW2
- 2 months in University of Iowa, US
- involved in 4 proposals (+2 in prep. (Sep. 30) PI of 1) /ESO VLT, ATCA, EVN, EVLA/

Thank you for your attention!