An extinction-free view of the Hummingbird – ALMA & VLA observations

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Credit: Sir Royalty photos

SEES – IoA, Cambridge, 25.09.2015

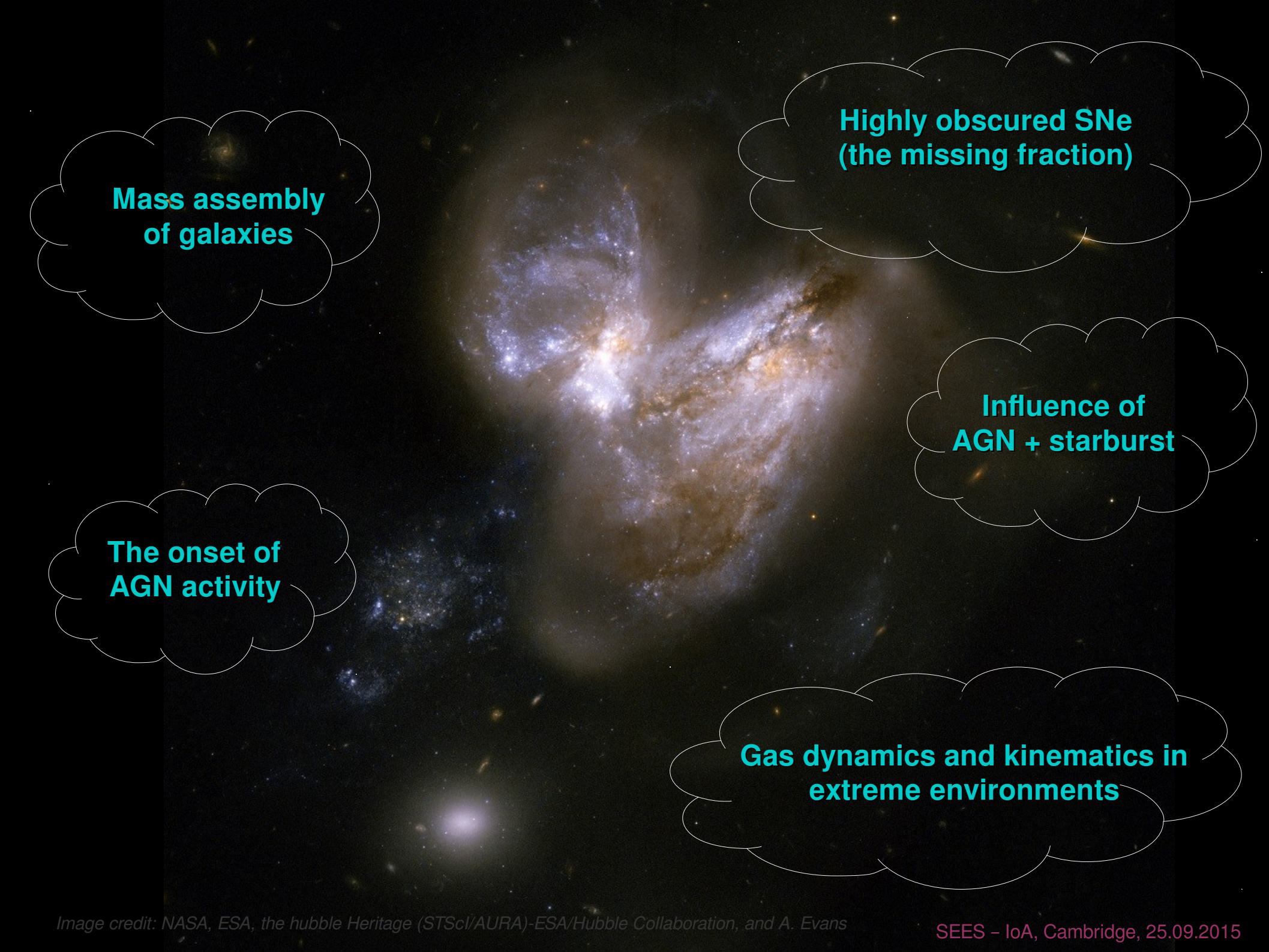


Image credit: NASA, ESA, the hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration, and A. Evans

Luminous Infra-Red Galaxy Inventory

(an e-MERLIN legacy project)

PIs: J. Conway & M. A. Pérez-Torres

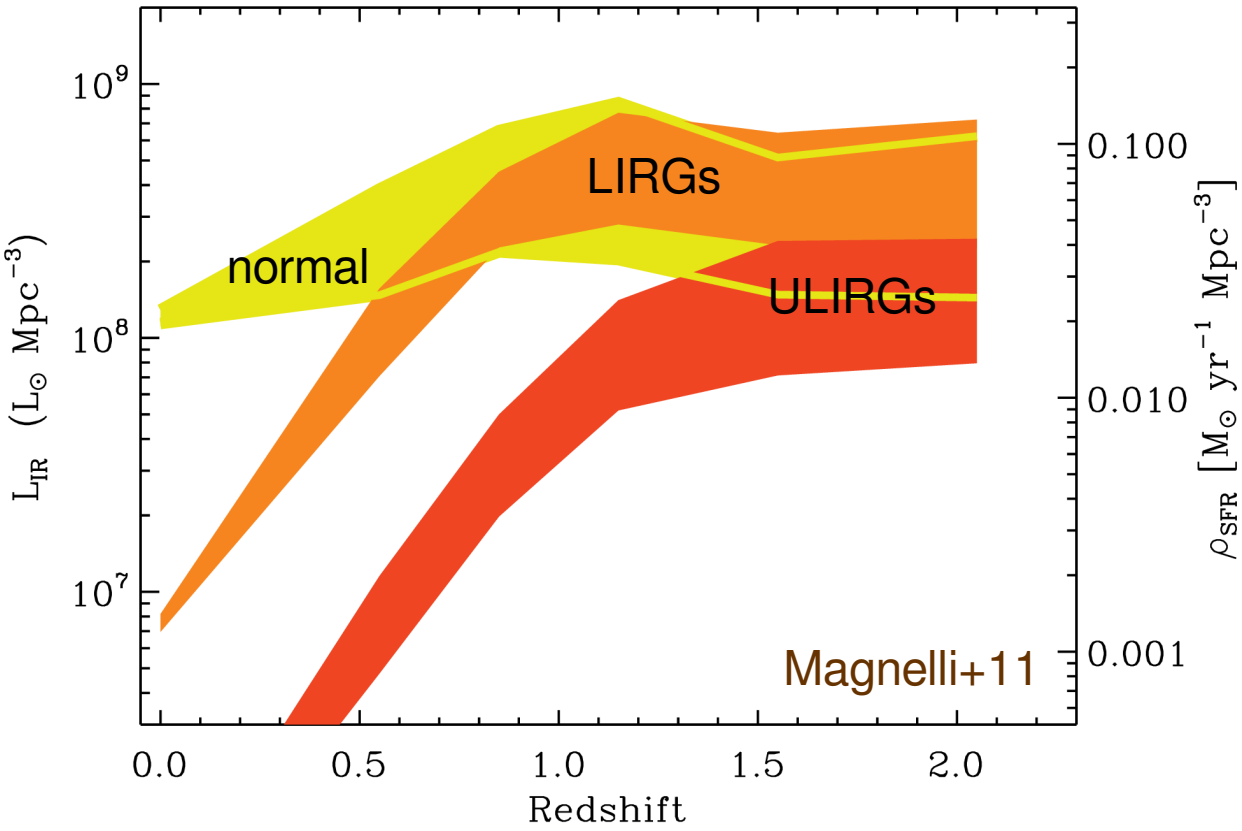
660 hr of e-MERLIN time (6 and 18 cm continuum observations plus spectral line) of a sample of the most luminous northern (U)LIRGs (L_{IR}>2.5x10^{11}L$_{\odot}$; D<250 Mpc; δ>8°).

- Trace gas dynamics and physical conditions.
- Establish a phenomenological sequence and time scale for the evolution of a nuclear starburst.

A VLBI follow-up of a LIRGI sub-sample will provide direct measurements of the nuclear CCSN rate and will test the dominant heating mechanism in LIRGs (starburst + AGN) → Naím Ramírez-Olivencia (PhD student at IAA)

Luminous Infrared Galaxies

$10^{11} \leq L_{FIR}(L_\odot) < 10^{12}$



gas-rich galaxy mergers: enhancement of star formation and possibly triggering AGN activity

(e.g., Sanders & Mirabel,96)

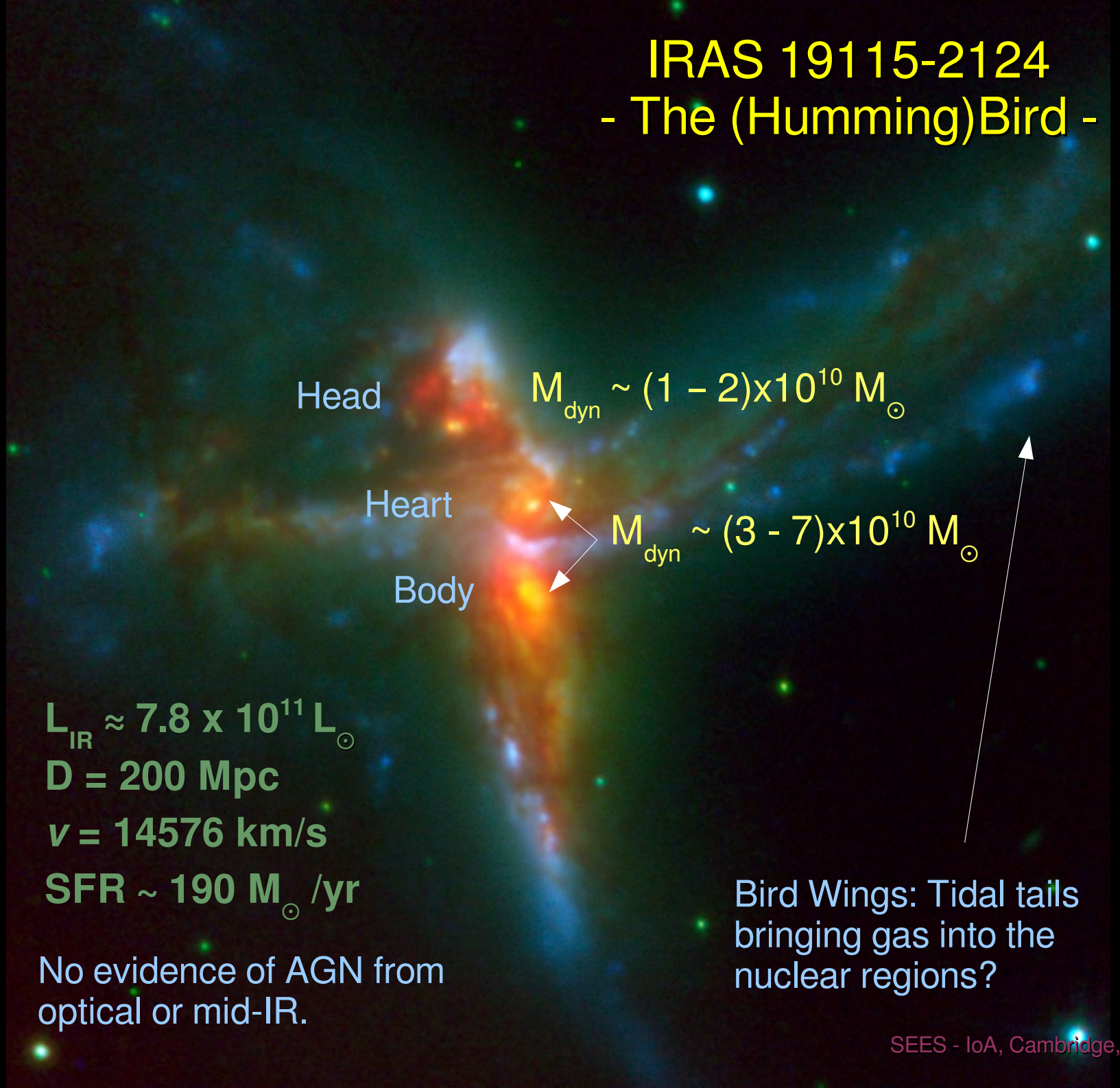
Central or off-nuclear SF?

Arp 220

(e.g., Scoville+15)

The Antennae

(e.g., Herrera+12)


IRAS 19115-2124
- The (Humming)Bird -
Väisänen+08
Head
M_{dyn} ~ (1 – 2)x10^{10} $M_\odot$
Heart
Body
M_{dyn} ~ (3 - 7)x10^{10} $M_\odot$
L_{IR} ≈ 7.8 x 10^{11} $L_\odot$
D = 200 Mpc
v = 14576 km/s
SFR ~ 190 $M_\odot$ /yr
No evidence of AGN from optical or mid-IR.
Bird Wings: Tidal tails bringing gas into the nuclear regions?
SEES - IoA, Cambridge, 25.04.2015

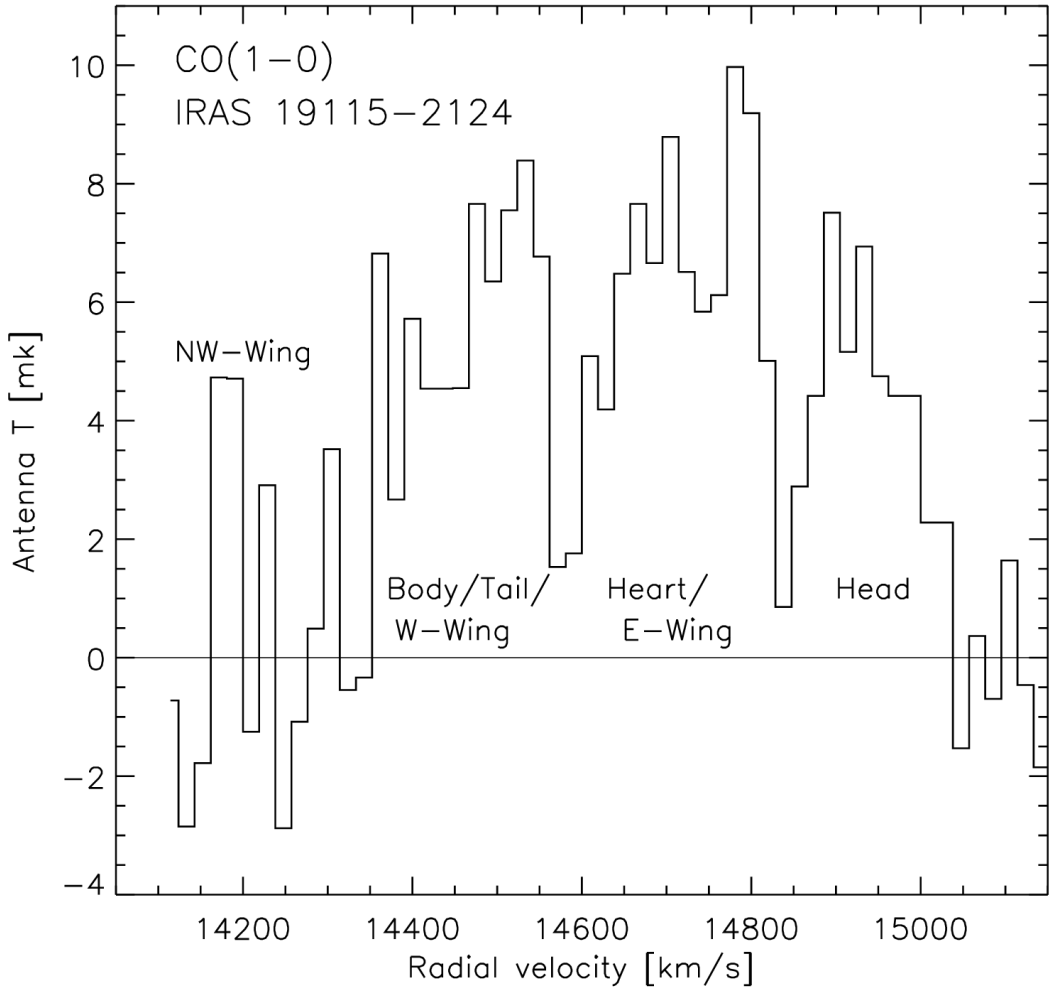
CO J=1-0 with single dish

SEST observations

Θ=44" (Mirabel+90)

$M_{H_2} \sim 3 \times 10^{10} M_{\odot}$

CO J=1-0 velocity components associated to the different NIR bright regions, based on optical spectroscopy (Väisänen+08).
So far, it seems to be simple!



An extinction-free view of the Bird
-at high resolution-

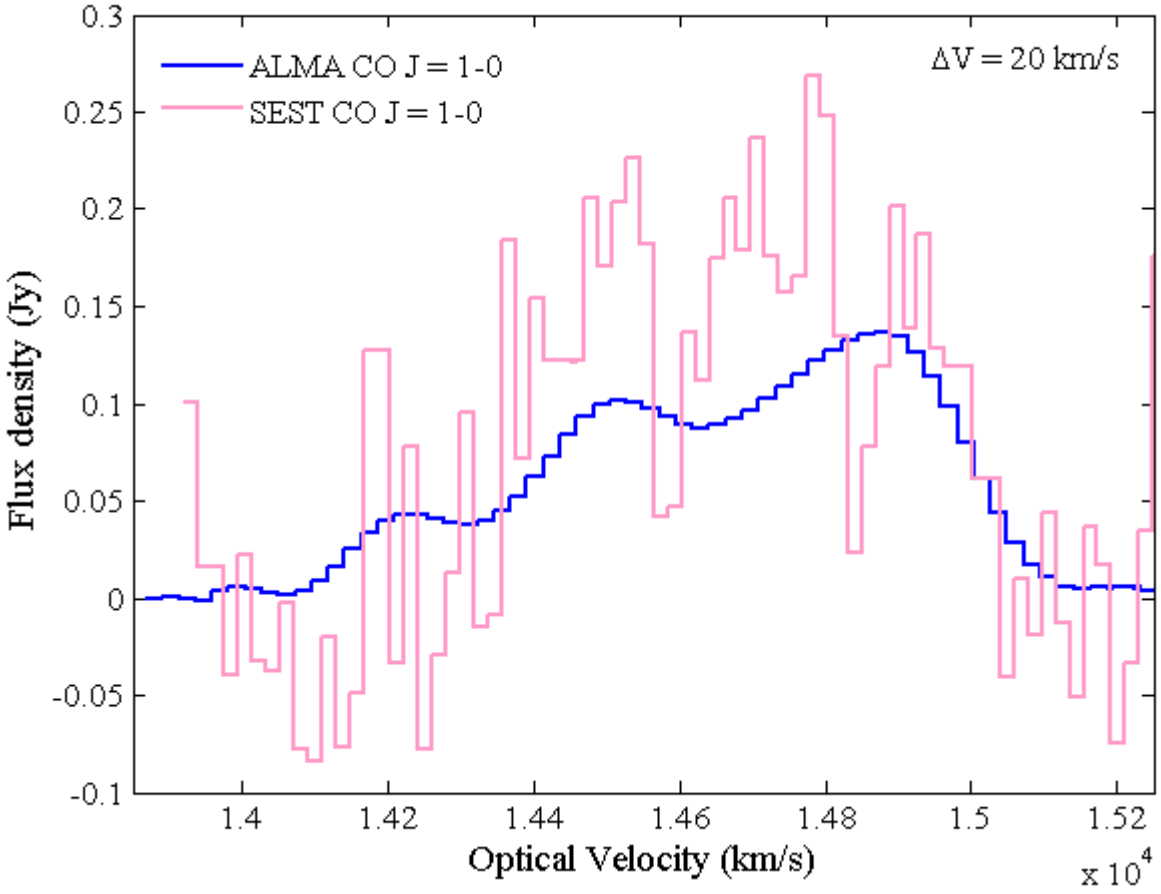
(sub-)mm

CO spectral line energy distribution (J=1-0, 3-2 & 6-5) + dust measurements (1 & 0.5 mm) with **ALMA**

cm

Radio emission at 1.5, 3, 6 and 10 GHz + HI with the **VLA**

CO J=1-0 (ALMA)



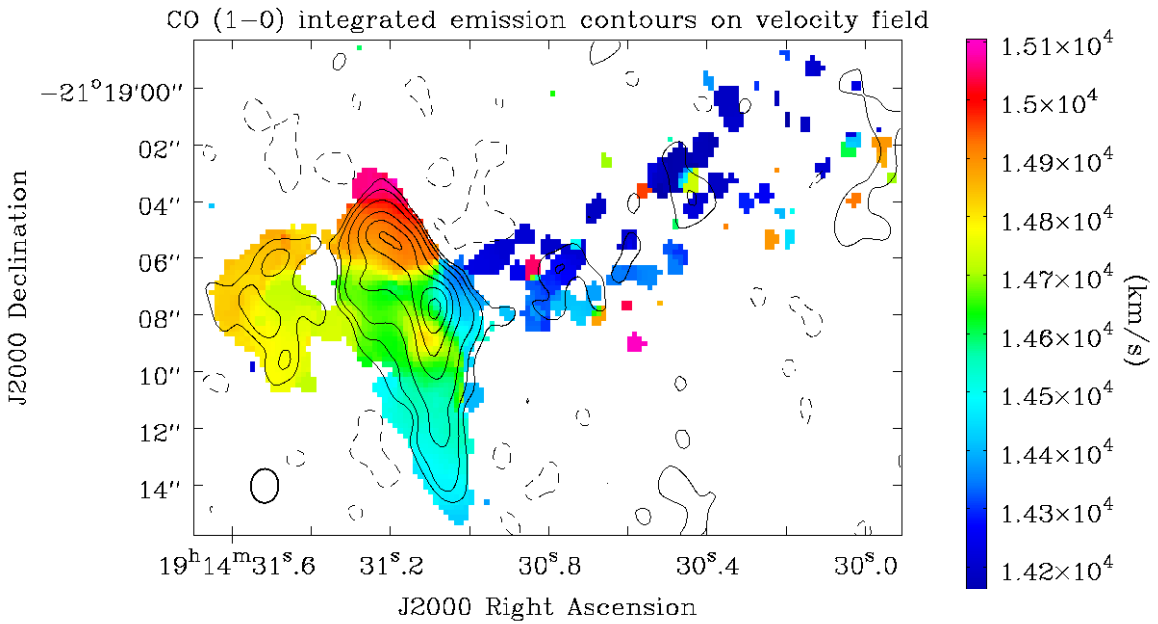
SEST
Θ=44" / Δv=20 km/s

ALMA
Θ=1"x1" / Δv=10 km/s
rms = 1.3mJy/beam

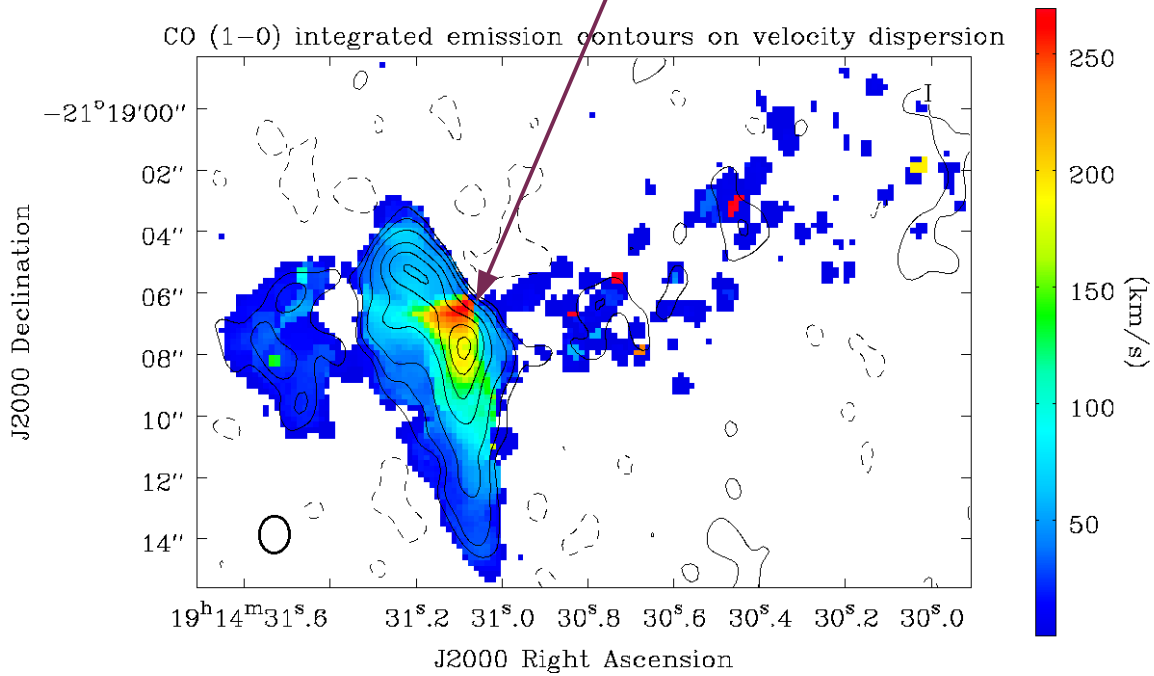
v = 14576 km/s

CO J=1-0 → variability?
Differences probably due to higher noise in SEST obs.

CO J=1-0 More complex than we previously thought...

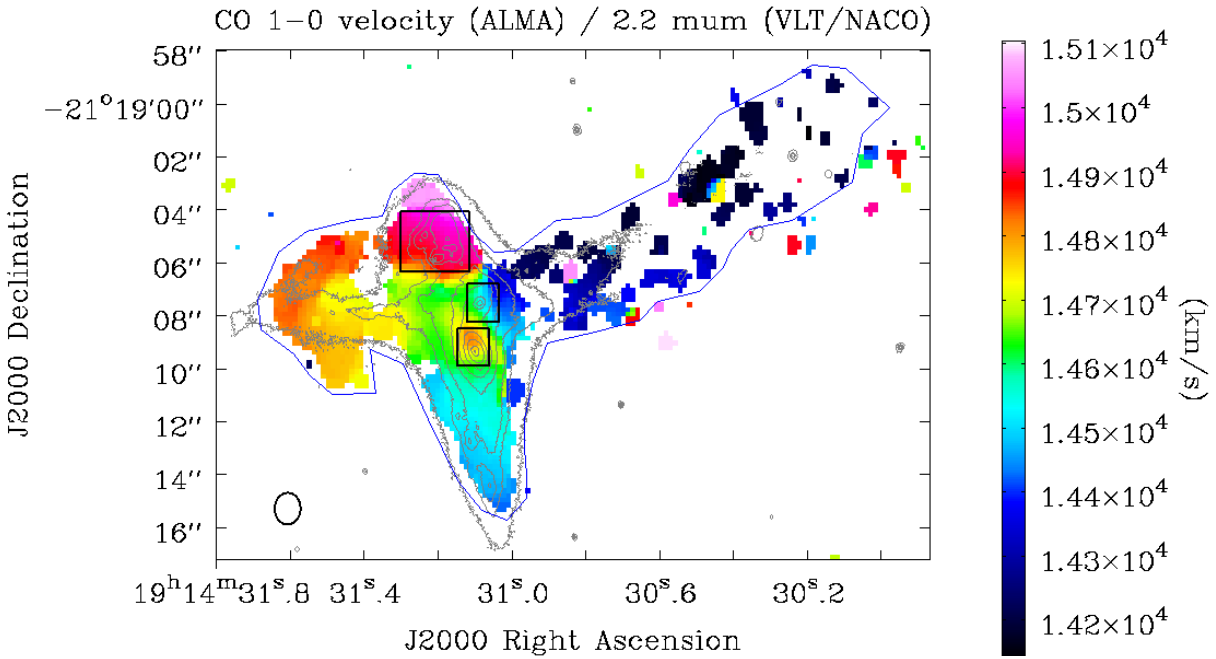


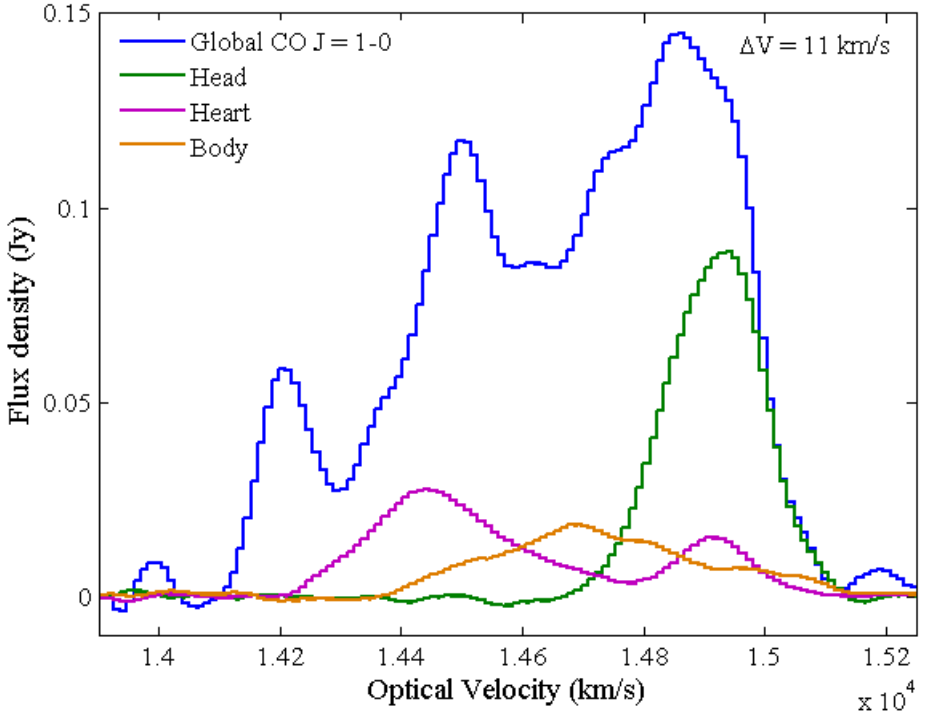
some gas from the Hummingbird wings is on top of the heart



High velocity dispersion – hindering further star formation in heart and body?

CO J=1-0 probing the association among velocity and spatial components





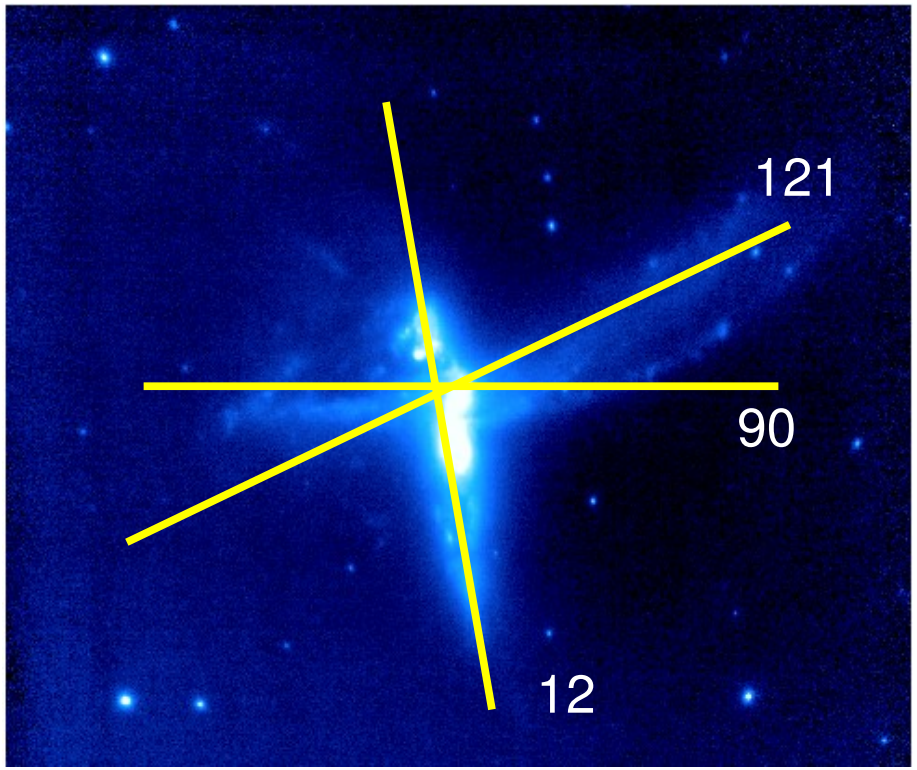
Fitting Gaussian components and assuming:

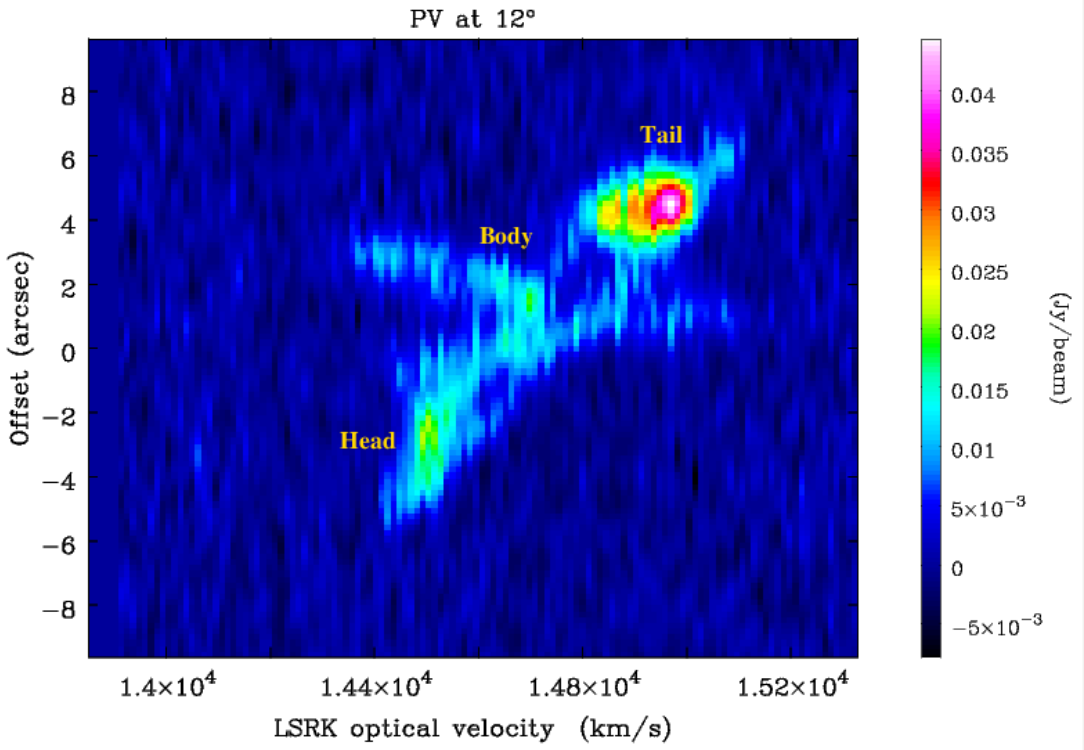
$\alpha_{CO} = 4.4\ M_\odot\ (K\ km\ s^{-1}\ pc^2)^{-1}$

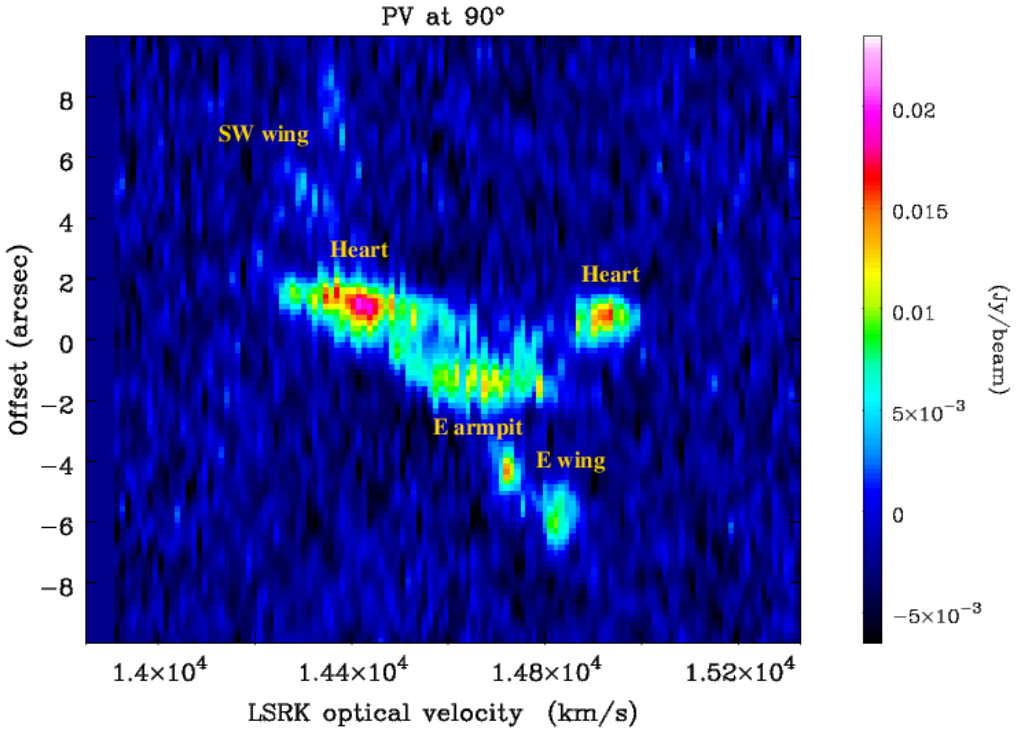
(Bolatto+13) we find:

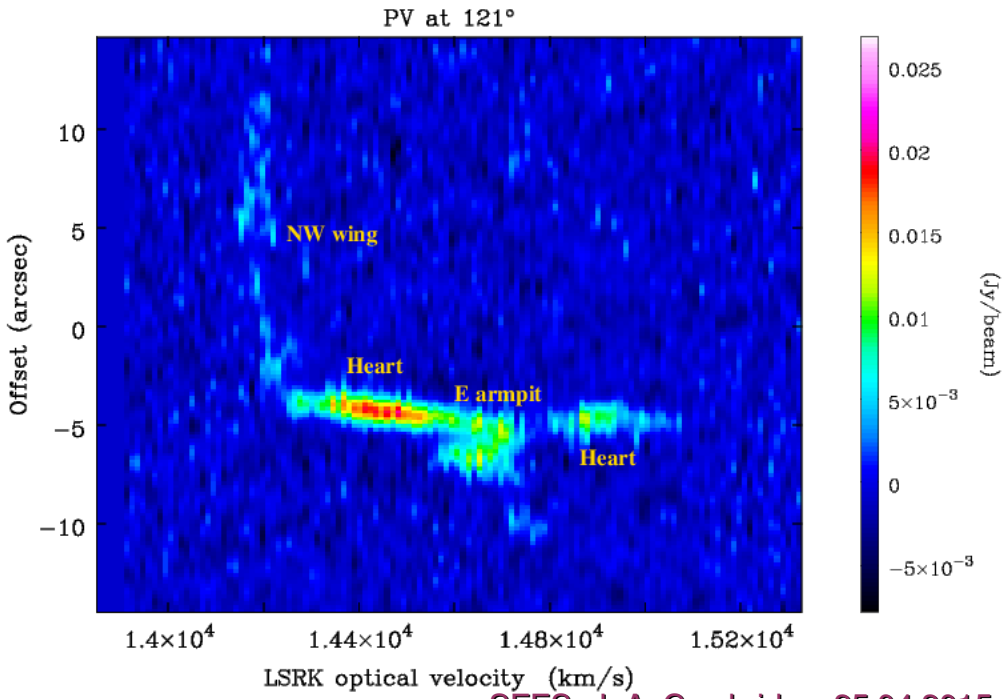
$M_{global} \sim 3.3 \times 10^{10}\ M_\odot$

20% in the head
10% in the heart
10% in the body
60% elsewhere!


121
90
12

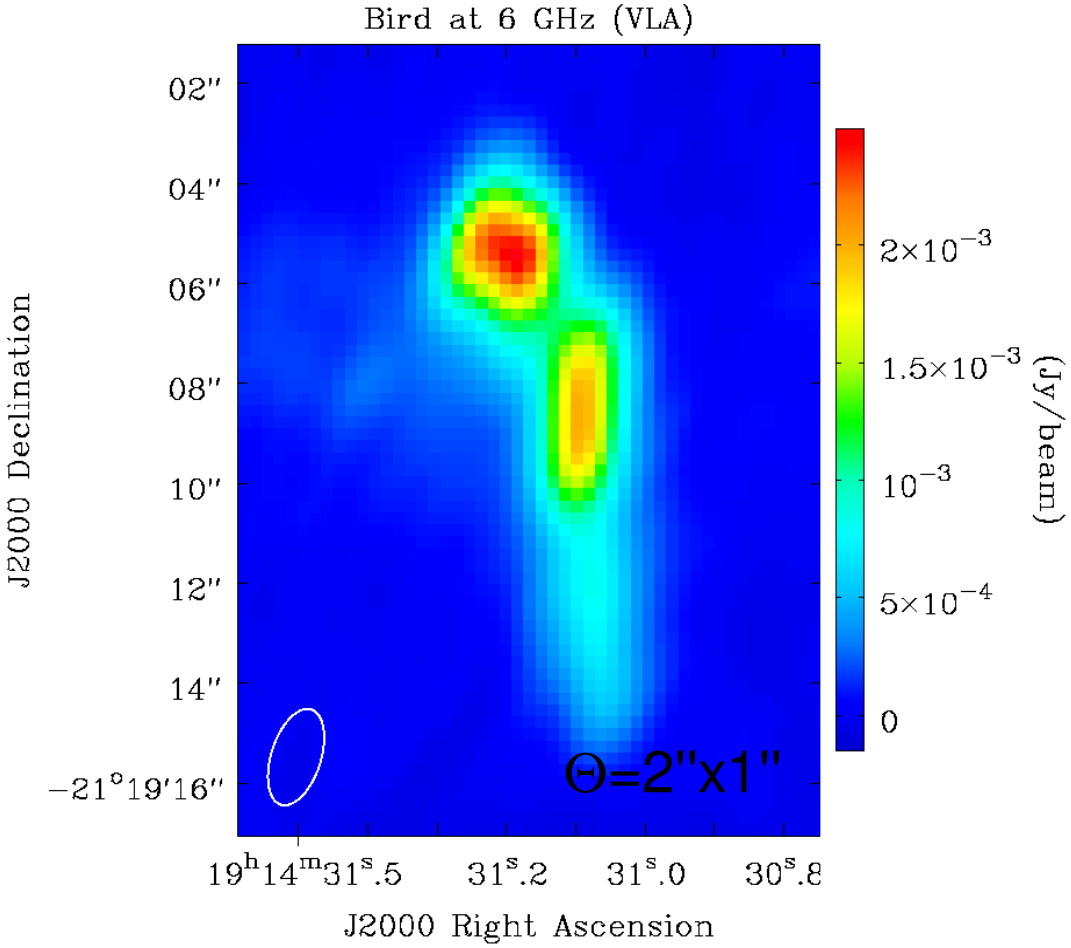

PV at 12°
Tail
Body
Head
Offset (arcsec)
LSRK optical velocity (km/s)
(Jy/beam)

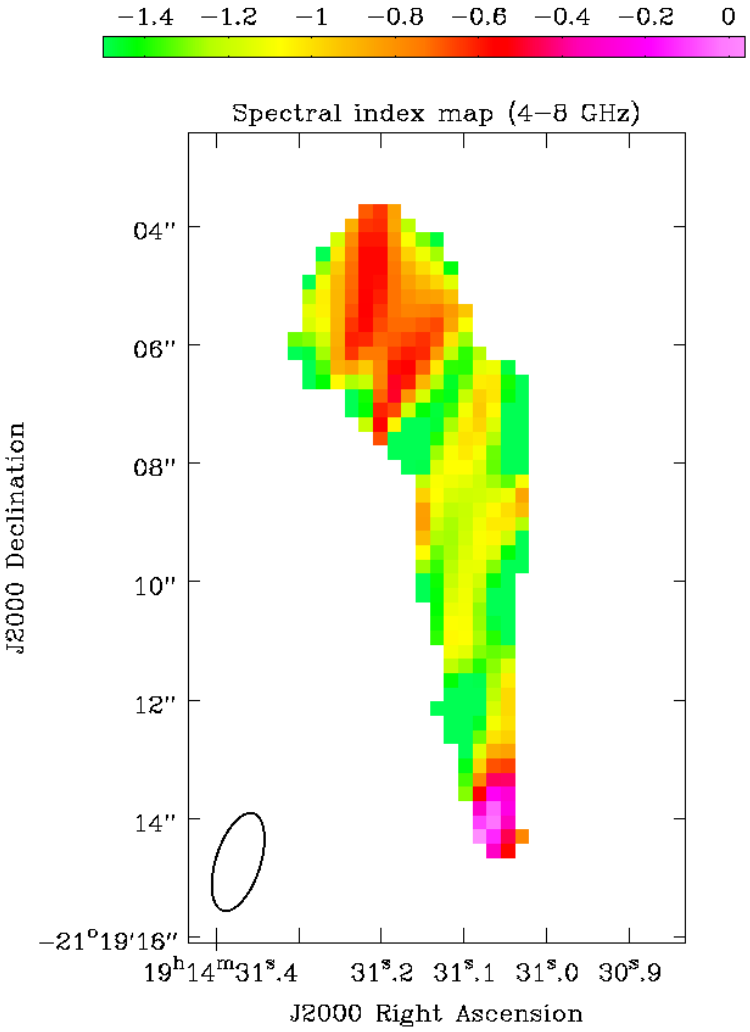

PV at 90°
SW wing
Heart
Heart
E armpit
E wing
Offset (arcsec)
LSRK optical velocity (km/s)
(Jy/beam)


PV at 121°
NW wing
Heart
E armpit
Heart
Offset (arcsec)
LSRK optical velocity (km/s)
(Jy/beam)

4-8 GHz radio emission (VLA)

~40% of the total emission is in the head





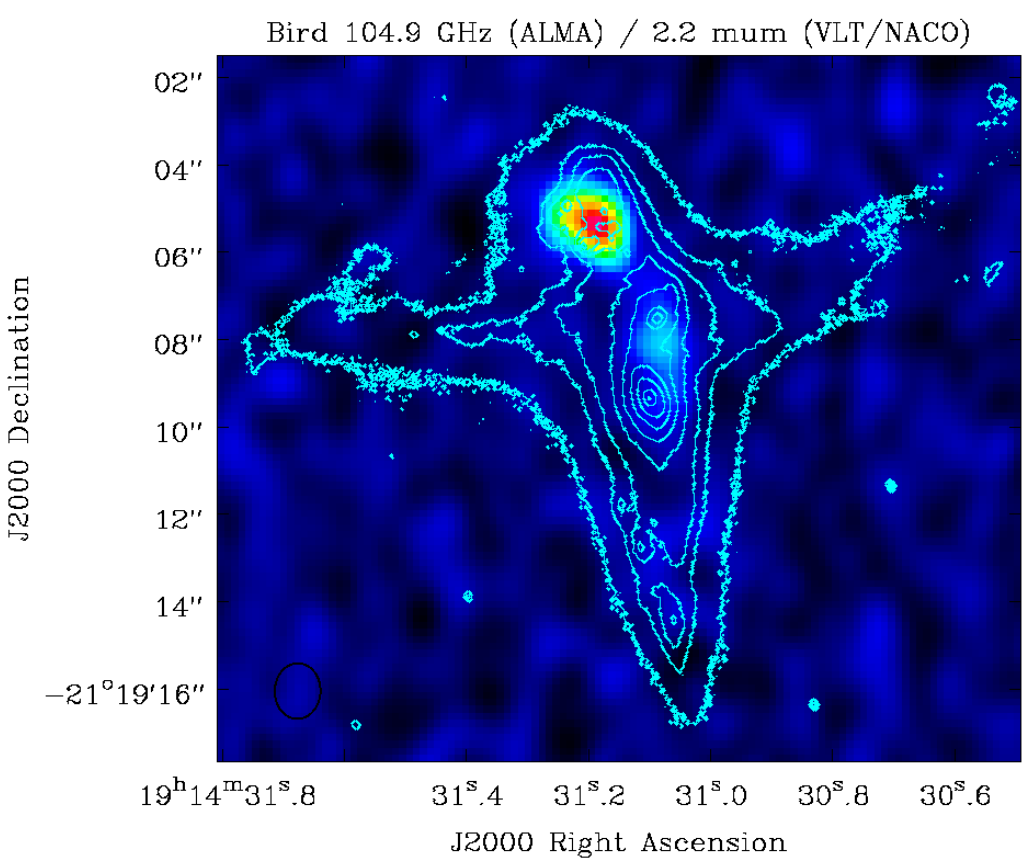
$S_{6GHz} \sim 11.4$ mJy

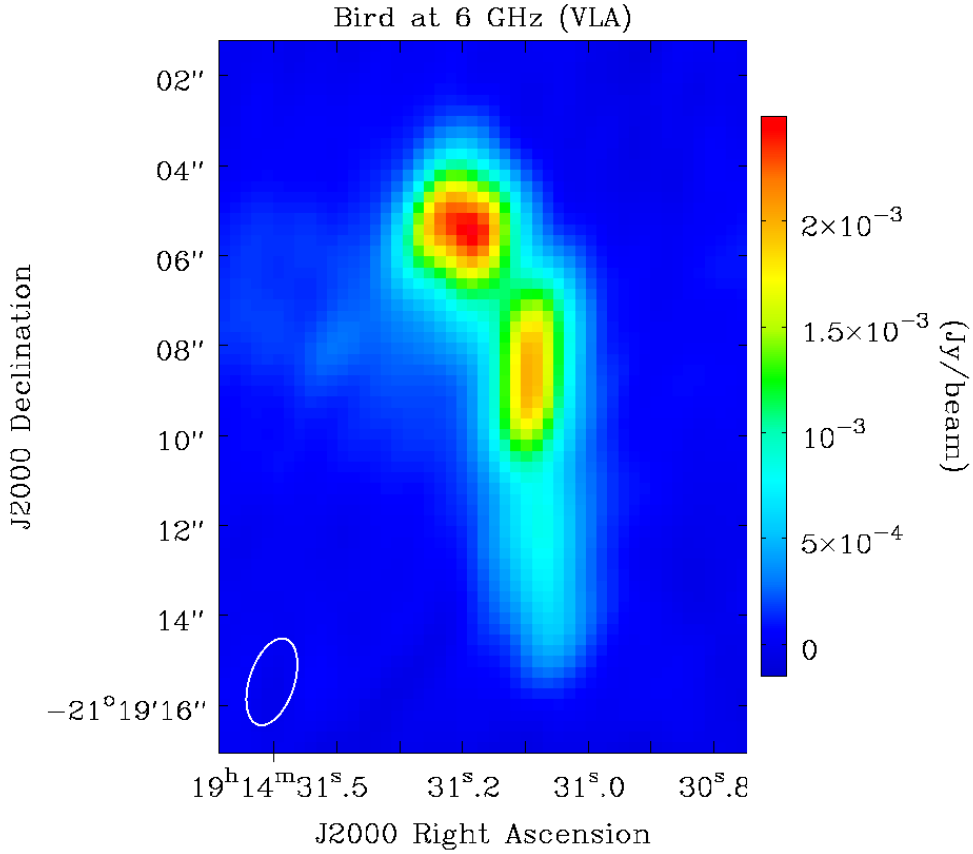
$S_\upsilon \propto \upsilon^\alpha$

$\Rightarrow$ SFR ~ 150 $M_\odot$ yr^{-1}

(using **Murphy+11**)

Continuum: mm vs. radio





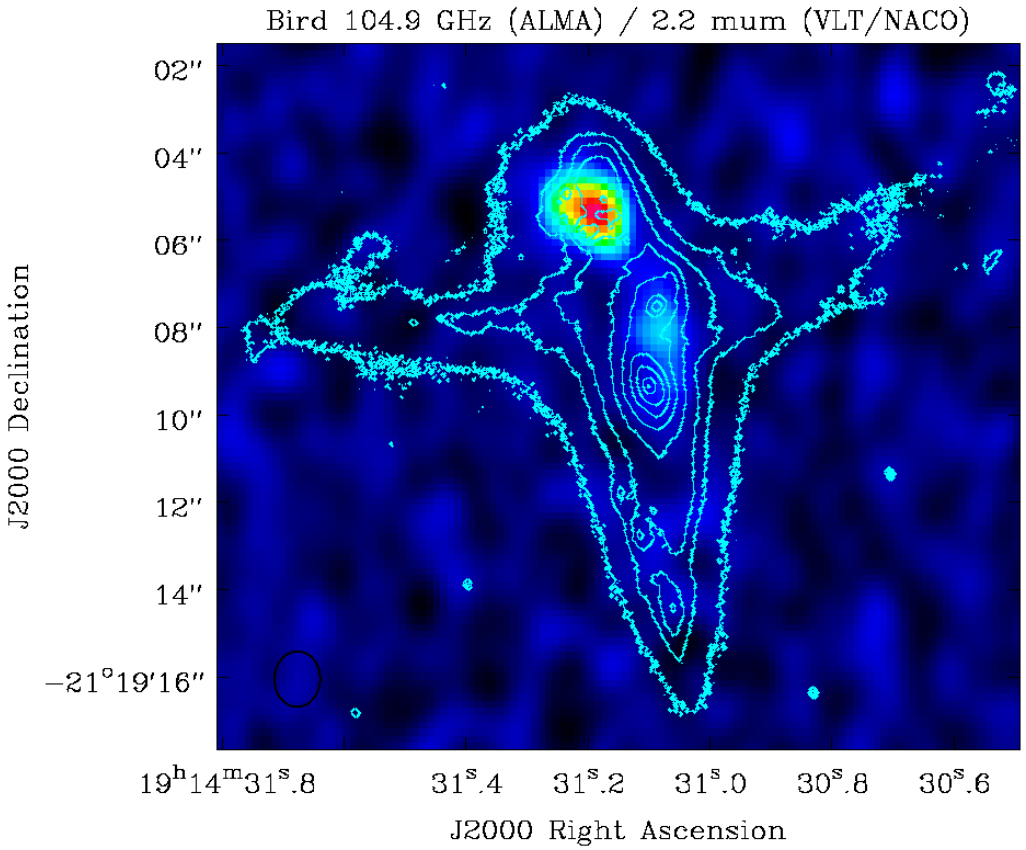
S_{104GHz} ~ 1.5 mJy

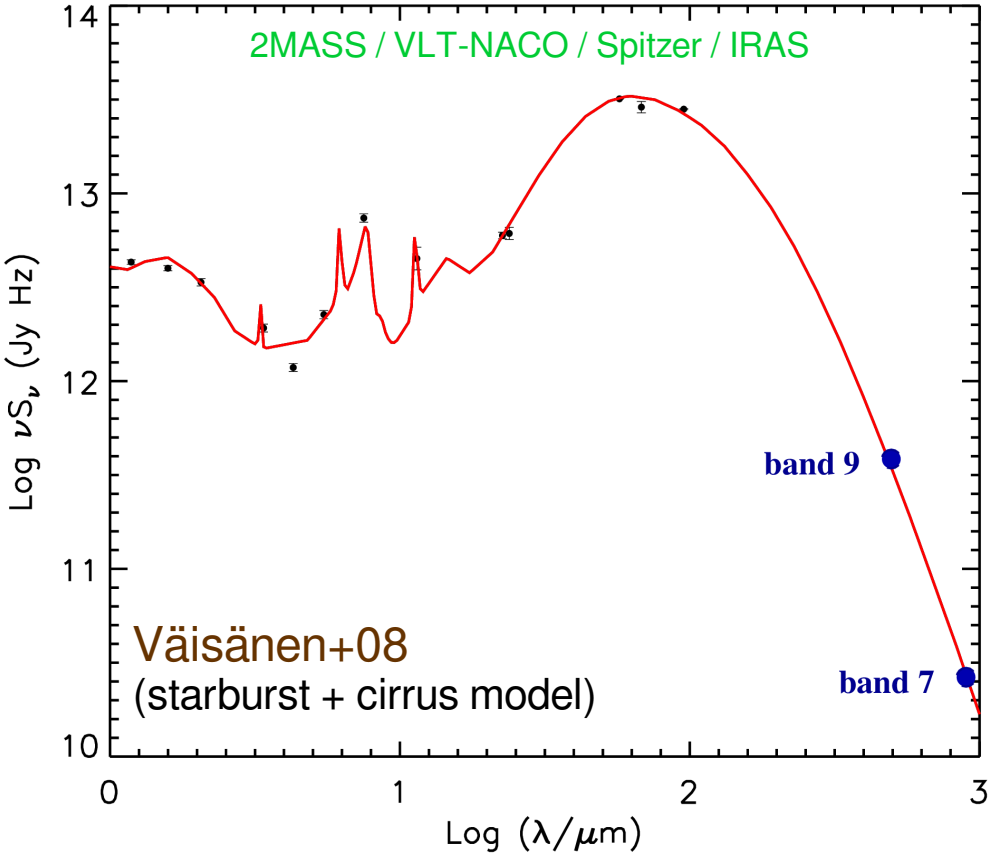
S_{6GHz} ~ 11.4 mJy

α = - 0.8 $\Rightarrow$ S_{104GHz} ~ 1.1 mJy

Dust emission or contamination?

Is the head driving the LIRG phenomena in the Bird?



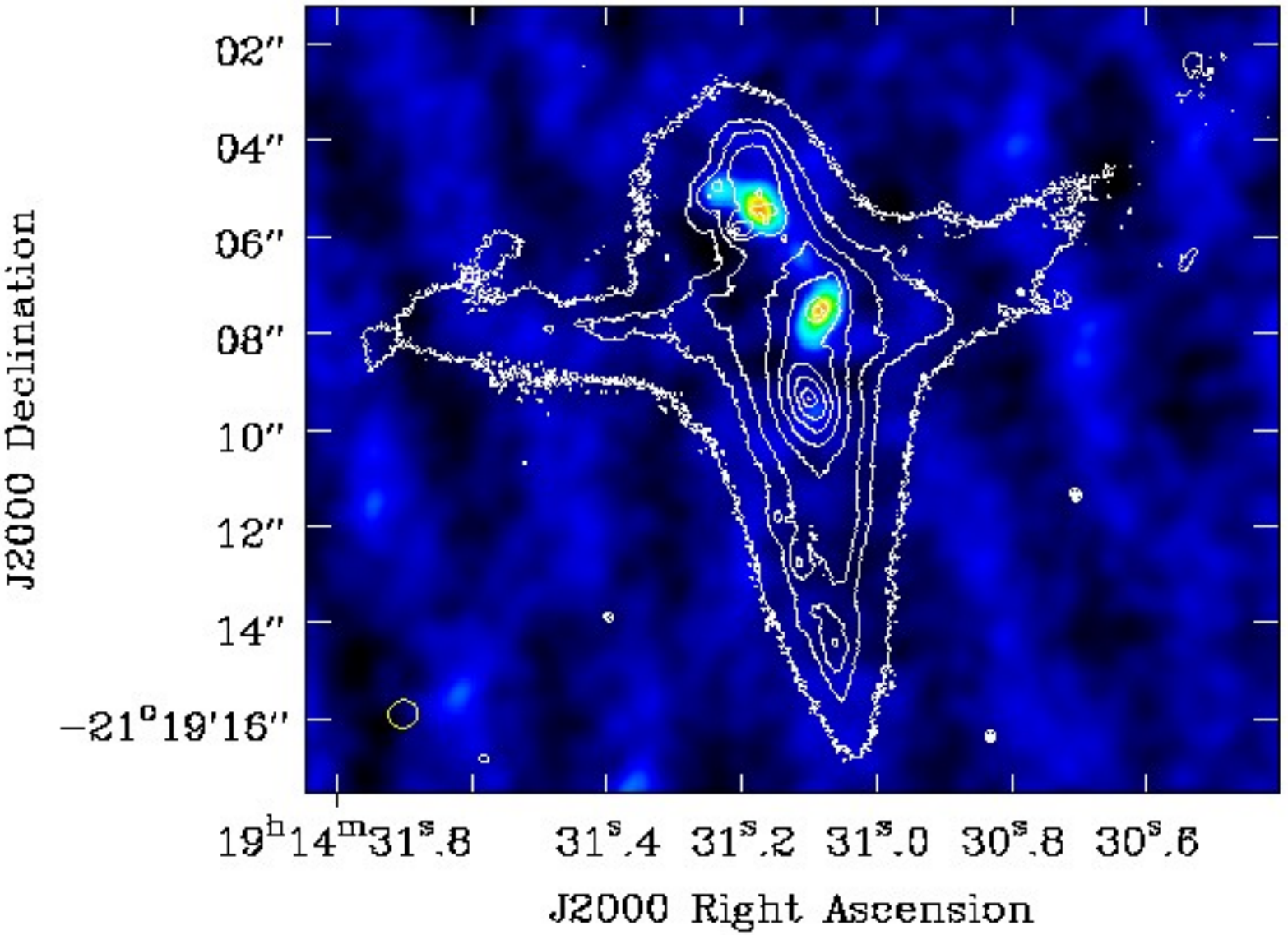


What about the heart and the body?
Continuum/dust depleted?

$S_{945\mu m}$ ~ 70 mJy

$S_{466\mu m}$ ~ 680 mJy

Dust detection



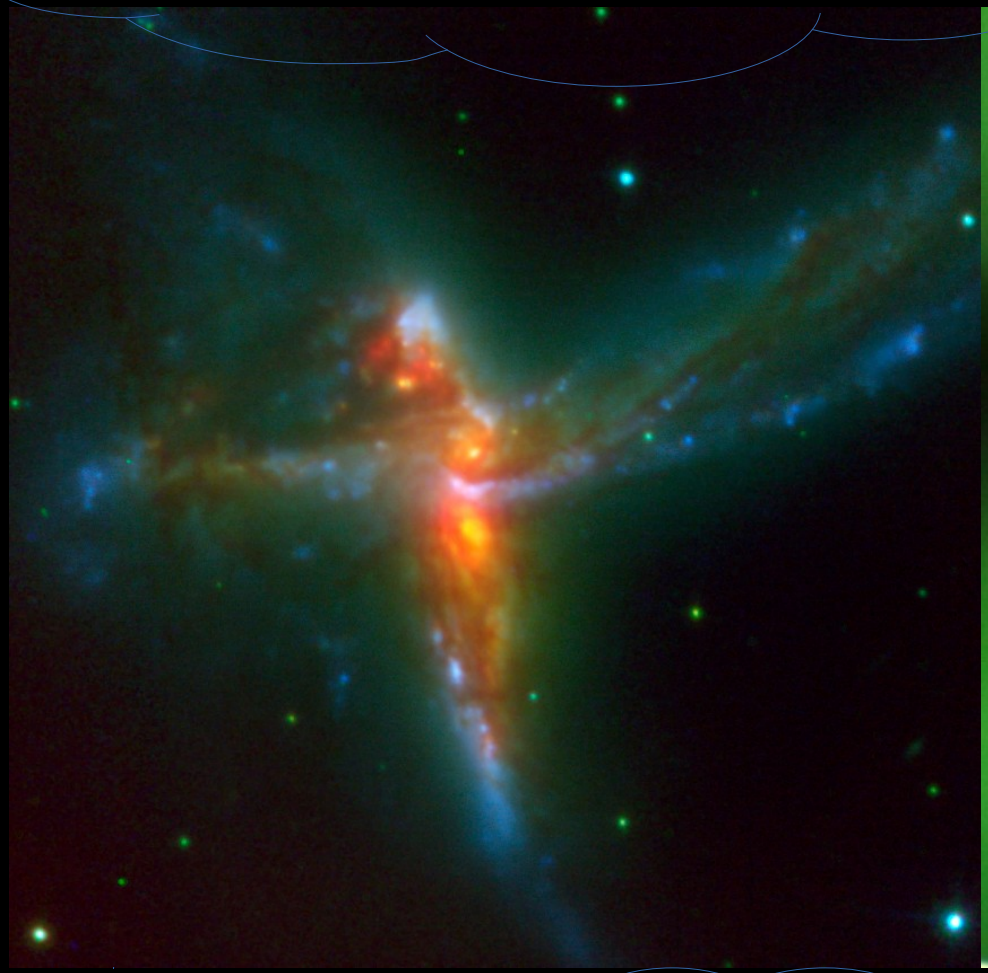
Expected:
$S_{466\mu m}$ ~ 680 mJy

Detected:
~57 mJy only

-nothing in the Body!-

Take away points

Molecular gas all over the Bird, but the head has the CO J=1-0 peak, as well as synchrotron emission typical of recent SF activity.



The highly extinguished body has an outflow: SF or AGN?

A very complex system – and a spectacular merger!