



TRACING NUCLEAR STAR FORMATION & FEEDBACK

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60pc

I BAND

H α

CO(1-0)

1 KPC

60pc

GALAXY NUCLEI
ARE DIFFERENT
ENVIRONMENTS

HIGHER SFR

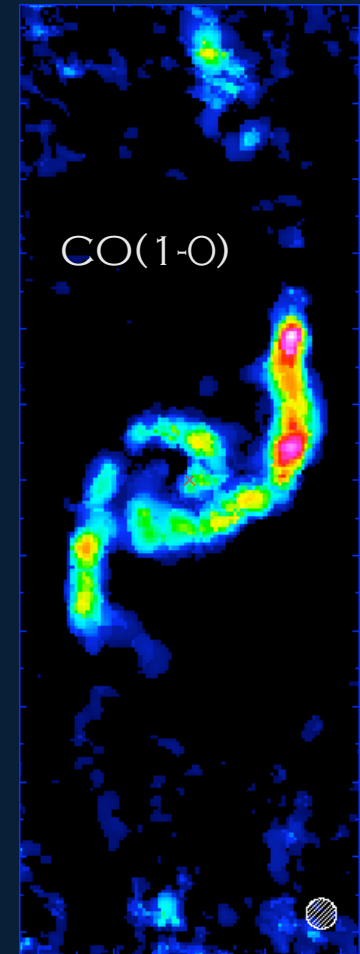
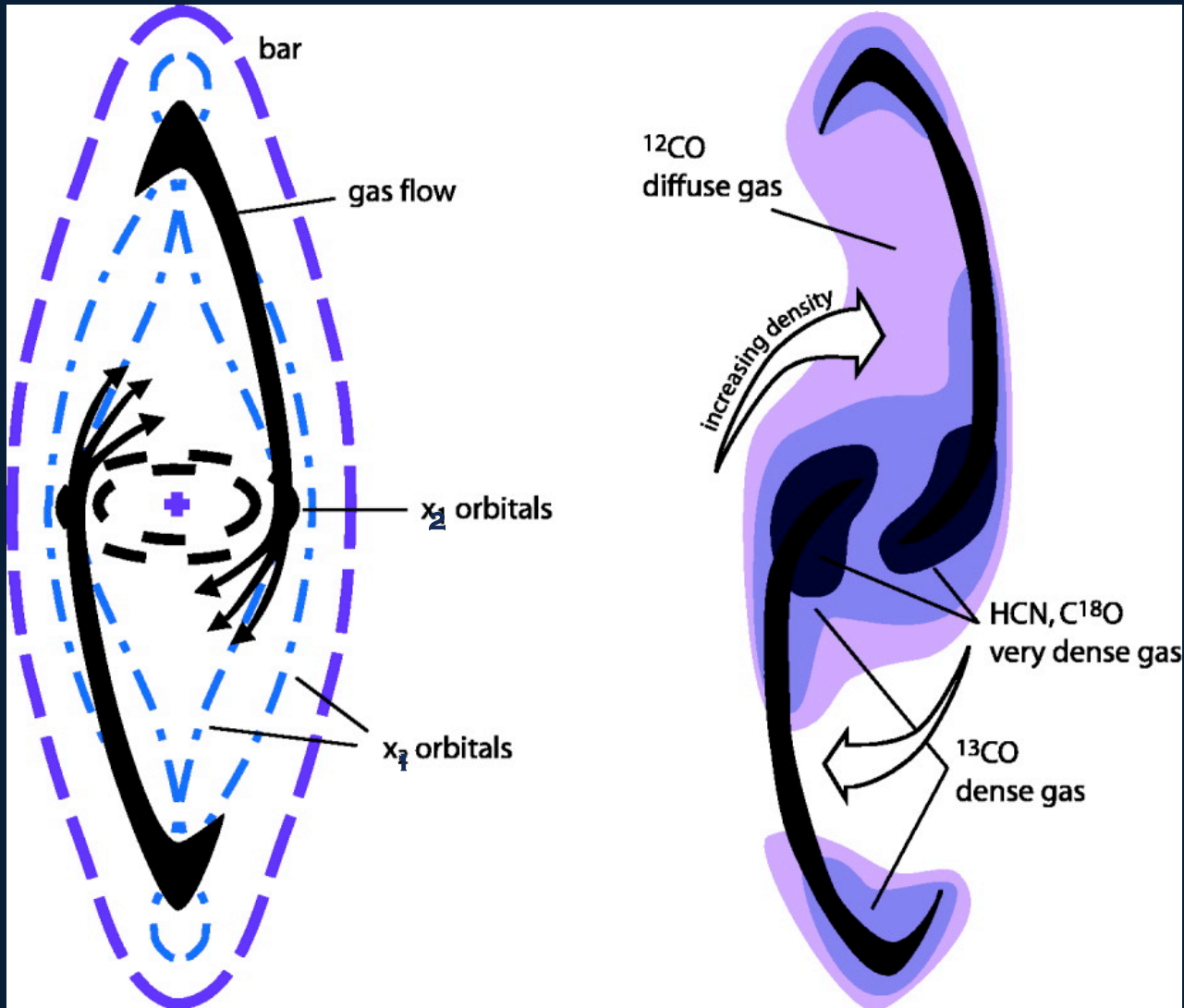
HIGHER
RADIATION FIELD

GAS CONSUMPTION
→ REPLENISHMENT

DYNAMICAL
TIMESCALES SHORT
< FEW 10 MYR

GAS IN BARS

BASICS



NGC 4303
SCHINNERER ET AL. (2002)

HOW TO TRACE NUCLEAR STAR FORMATION IN EXTERNAL GALAXIES

IRAM, PLATEAU DE BURE



HIGH SPECTRAL (FEW KM/S) & SPATIAL (<1") RESOLUTION

UP-GRADED IRAM PLATEAU DE BURE INTERFEROMETER:

~ 0.3" RESOLUTION (AT 1 MM)

3X MORE SENSITIVE ~ 10X FASTER

MULTI-LINE OBSERVATIONS → CHEMISTRY

NEW BAND: 2MM

NGC 6946

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CENTRAL MASS BUILD-UP

**MOLECULAR GAS KINEMATICS
AND**

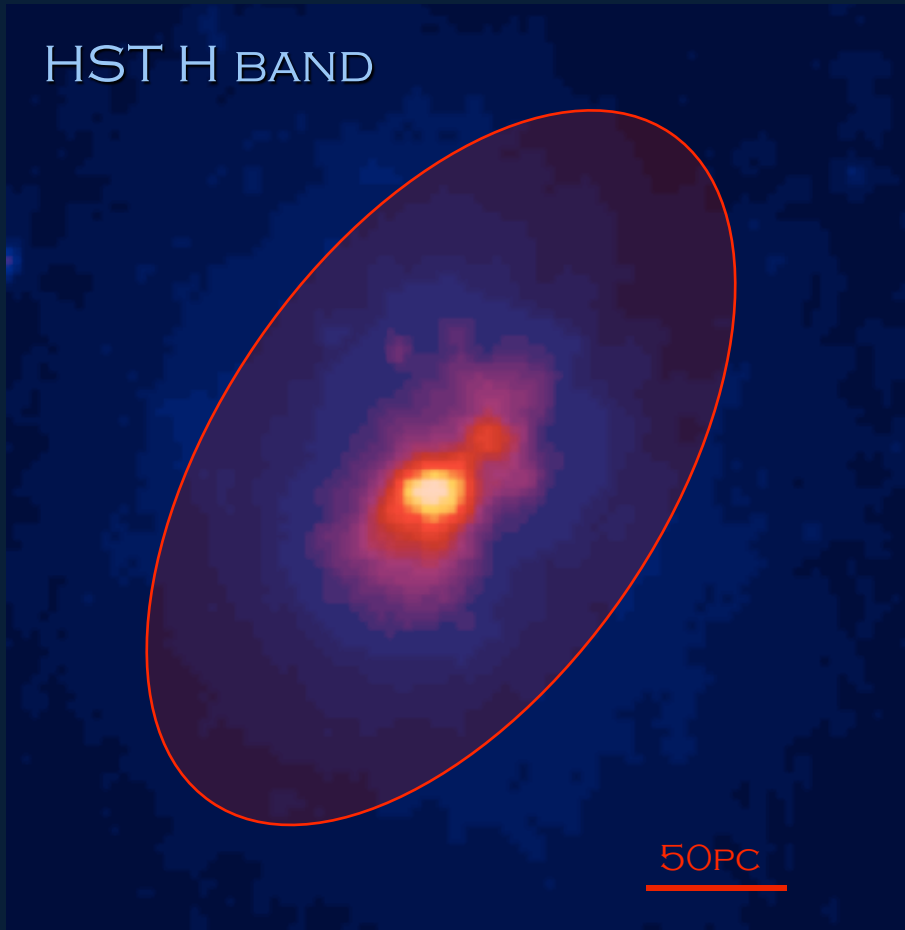
**STAR FORMATION TRACERS
AT HIGH SPATIAL RESOLUTION**

NUCLEAR REGION OF NGC 6946

STARS VS. MOLECULAR GAS

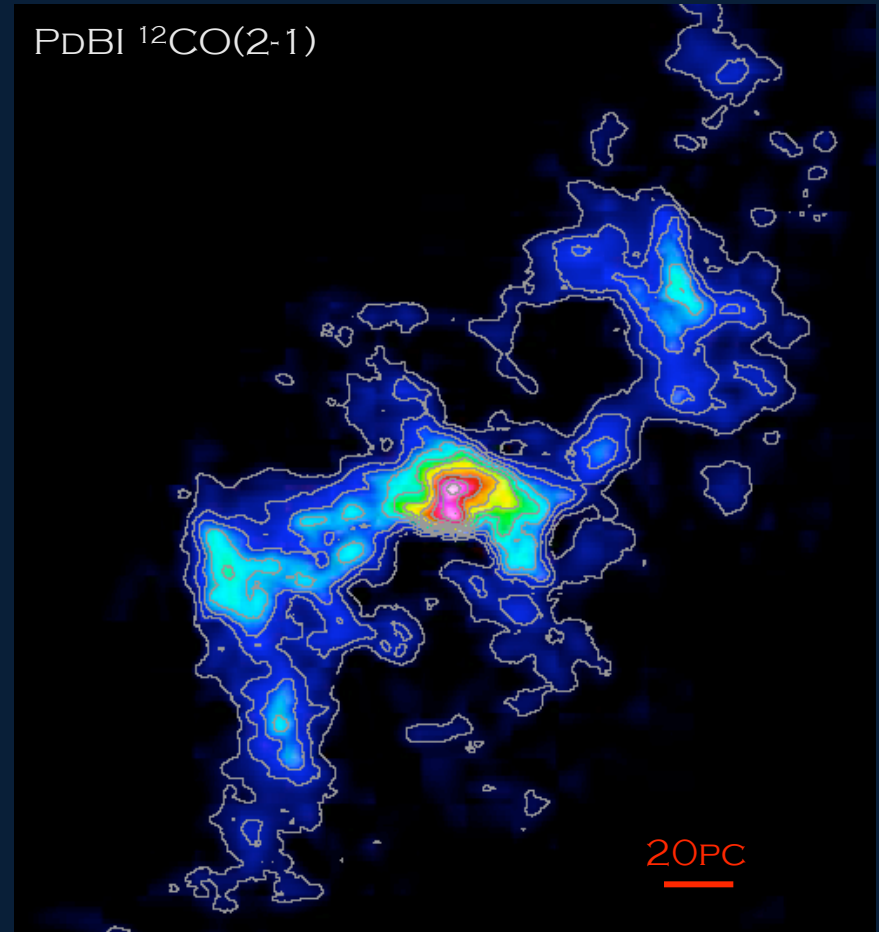
$D=5.5$ MPC; $1'' \sim 25$ PC
 $PA \sim 35^\circ$; $INCL. \sim 35^\circ$
LARGE-SCALE BAR

HST H BAND



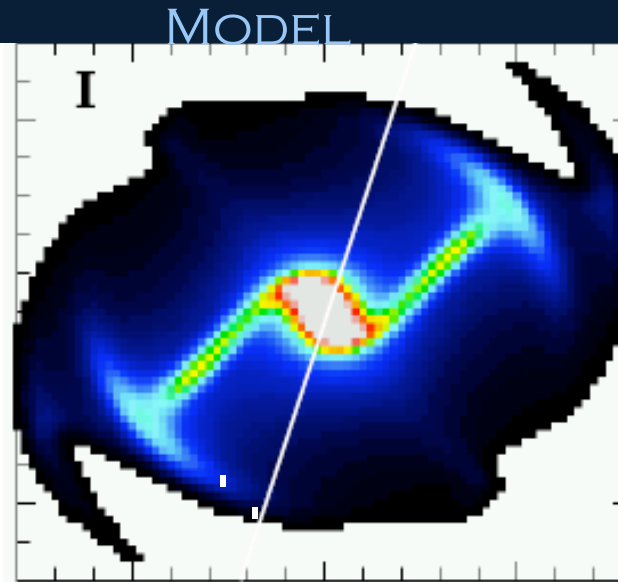
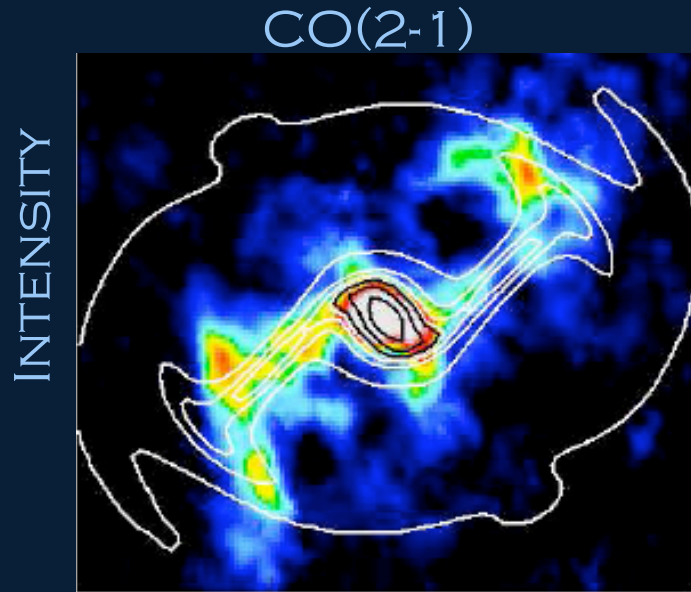
STELLAR BAR IN NIR w/
LENGTH $\sim 10'' - 15''$

PdBI $^{12}\text{CO}(2-1)$



GAS SHOWS CLASSICAL
RESPONSE PATTERN FOR A BAR

BAR-DRIVEN FUELING NGC6946

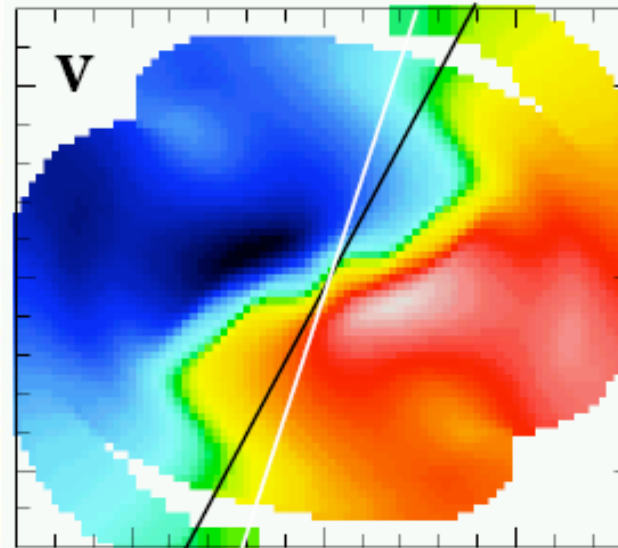
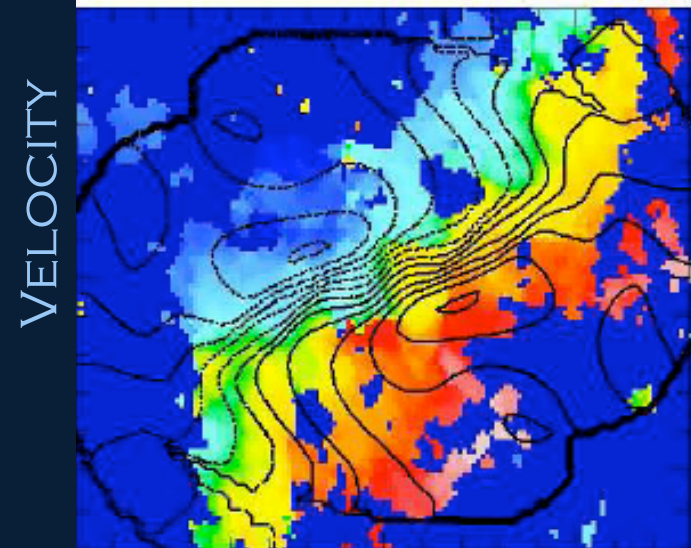


400PC LONG BAR
REDISTRIBUTES GAS

$\sim 10^7 M_{\text{SUN}}$
($R < 30 \text{ PC}$)

CR @ 260 PC

$\Omega_{\text{BAR}} = 510 \text{ KM/S KPC}^{-1}$



WHERE AND WHEN STARS FORM

CENTRAL 50PC OF NGC6946

PA α

3MM CONTINUUM

HCN(1-0)

FUELING VIA INNER BAR
MASS BUILD-UP OF $\sim 10^6 M_{\text{SUN}}$
IN CENTRAL 50PC
(OVER LAST ~ 10 MYRS)

20PC

SFR $\sim 0.1 M_{\text{SUN}}/\text{YR}$
AGE $\sim 5\text{-}10$ MYR

SFR $\sim 0.1 M_{\text{SUN}}/\text{YR}$
AGE \sim COUPLE MYR

SFR $\sim 0.06 M_{\text{SUN}}/\text{YR}$
AGE $\sim < \text{MYR}$



STAR FORMATION IN SMALL AREA OVER ~ 10 MYR

IC 342

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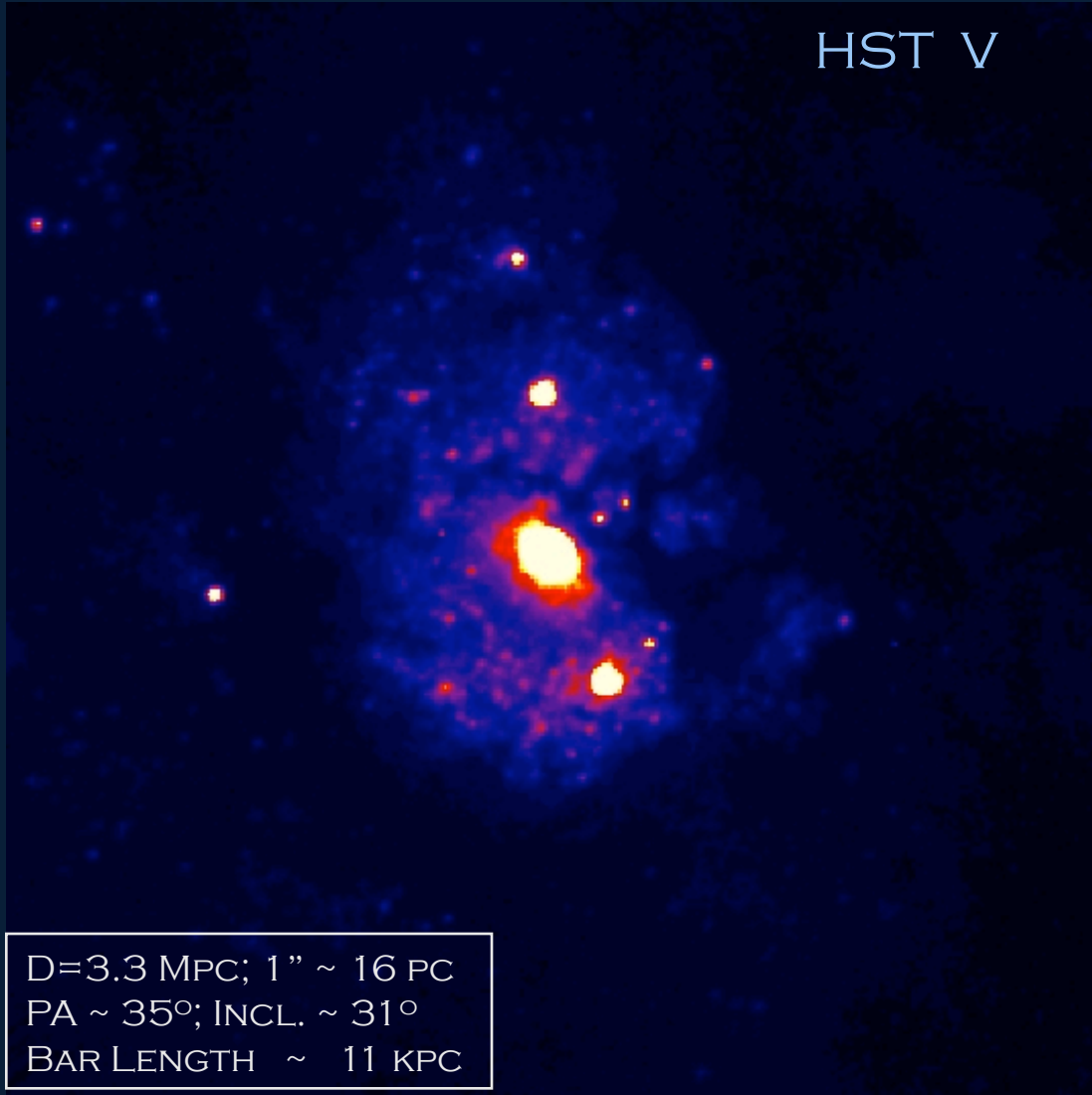
*NUCLEAR FUELING &
STAR FORMATION FEEDBACK*

IMPACT OF
NUCLEAR STAR FORMATION
ONTO
GAS FLOW

NUCLEAR CLUSTER IN IC342

A LATE-TYPE BARRED SPIRAL

HST V



NUCLEAR
STELLAR CLUSTER:

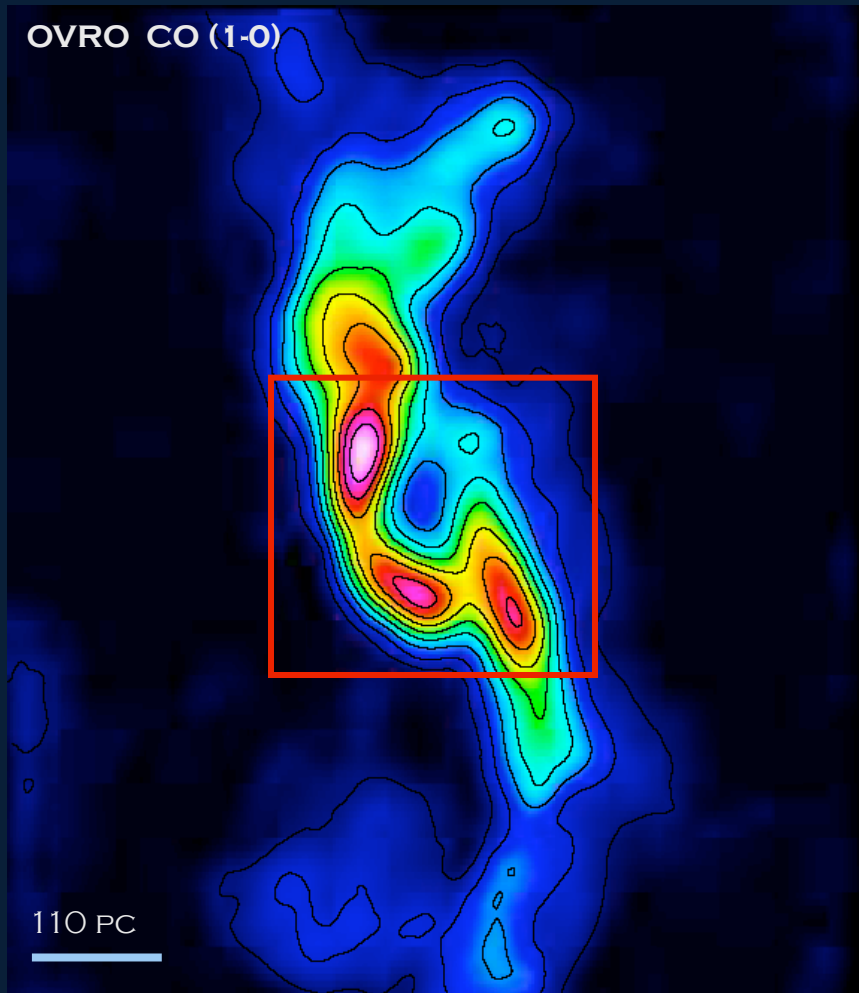
STAR FORMATION
~ 4 - 30 MYRS AGO

CLUSTER MASS
~ $10^7 M_{\text{SUN}}$

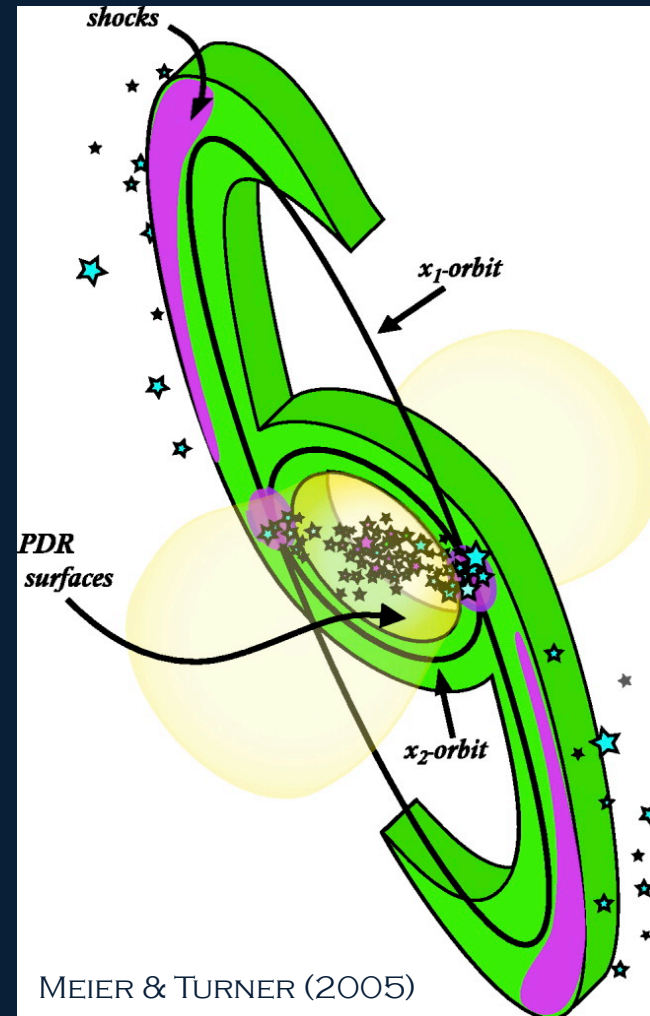
D=3.3 MPC; 1" ~ 16 PC
PA ~ 35°; INCL. ~ 31°
BAR LENGTH ~ 11 KPC

(BÖKER ET AL. 1997, 1999)

IC 342: DISTRIBUTION OF MOLECULAR GAS



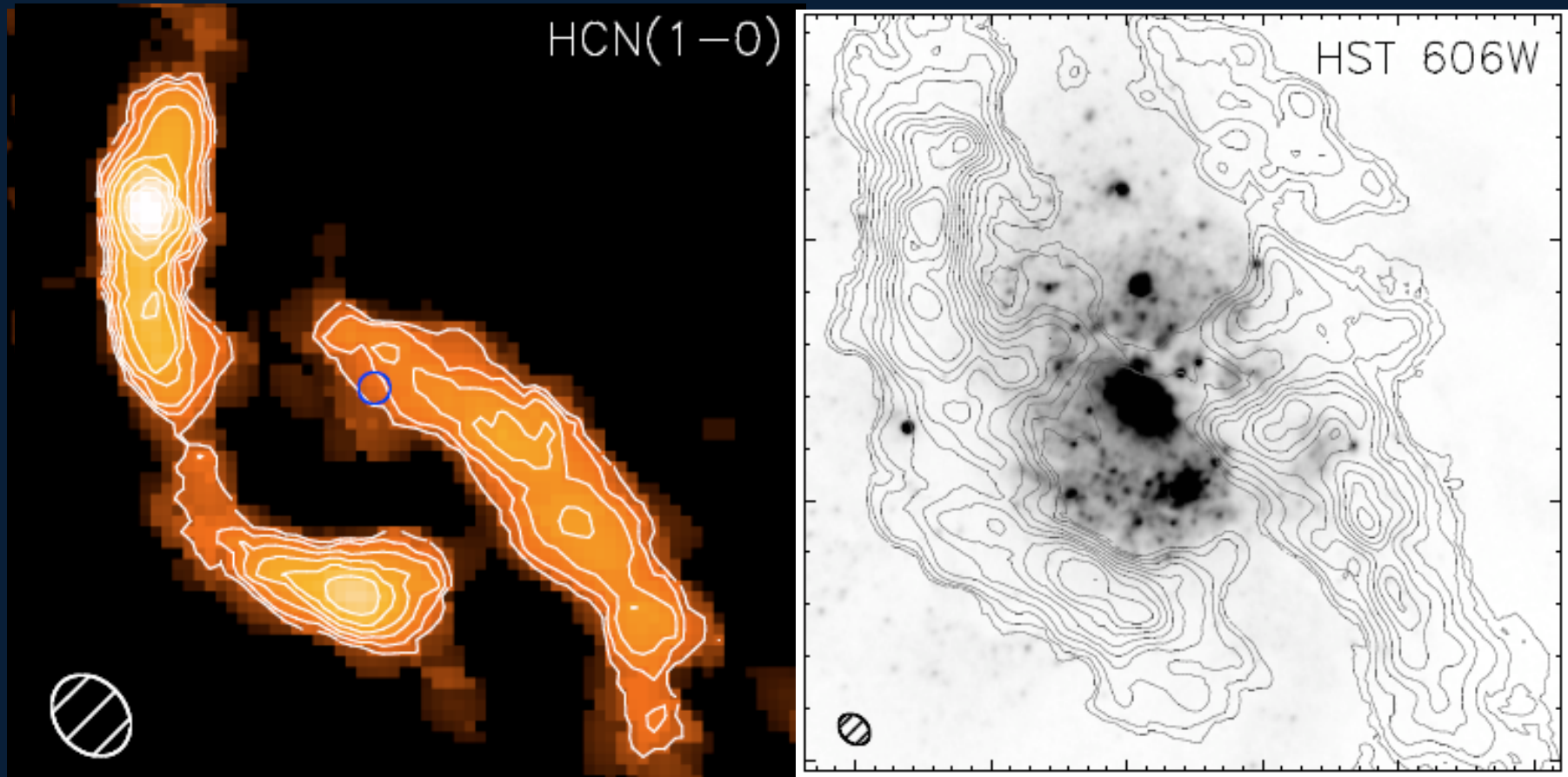
H_2 MASS (1') $\sim 4.4 \times 10^7 M_{SUN}$
MASSES $\sim 10^6 M_{SUN}$
DIAMETERS $\sim 20 - 50$ PC
(WRIGHT ET AL. 1993, LEVINE ET AL. 1994)



CHEMICAL STATE OF ISM
BASED ON MULTI-MOLECULE STUDY
(MEIER & TURNER 2005)

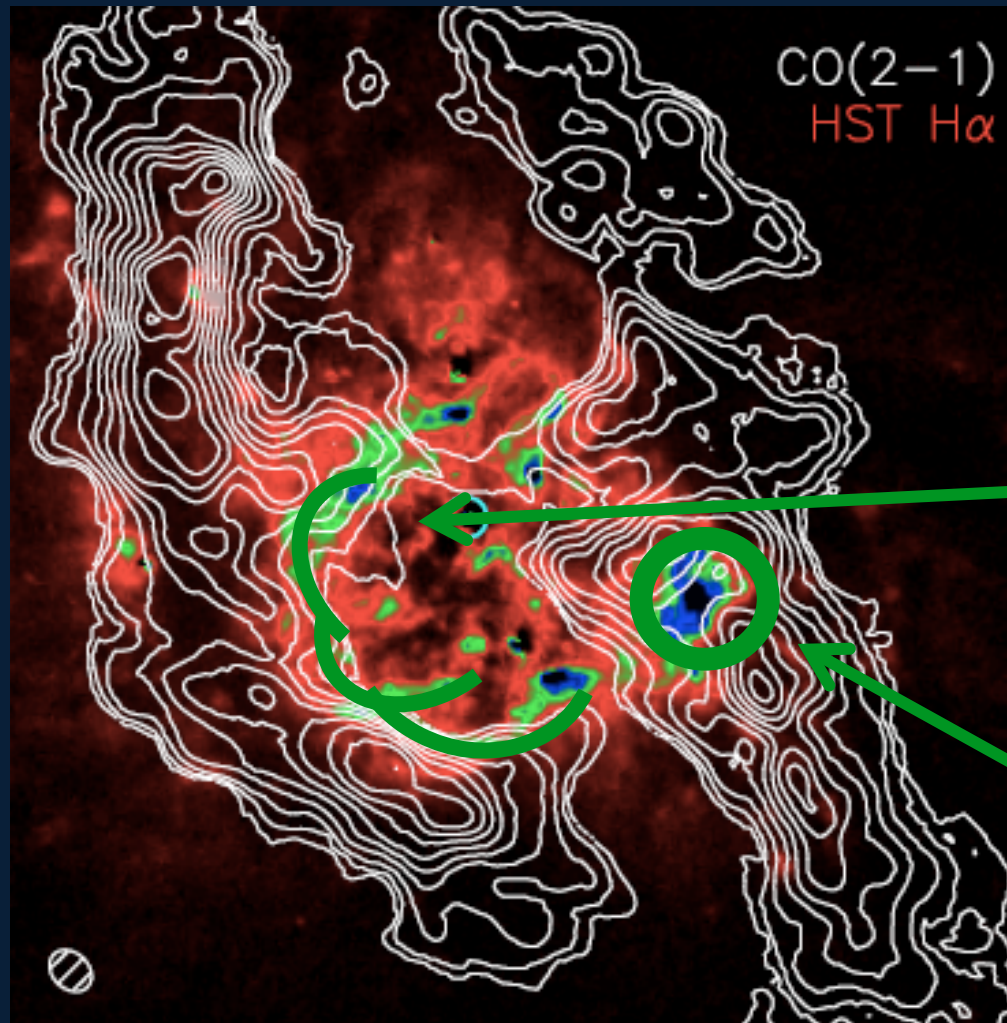
ZOOMING IN - IC342

GAS VS. NUCLEAR CLUSTER



MOLECULAR GAS & DUST COINCIDE
GAS REACHES CLOSE TO NUCLEAR CLUSTER
(EVEN MORE SO IN DENSE GAS)

ONGOING FUELING? - IC342



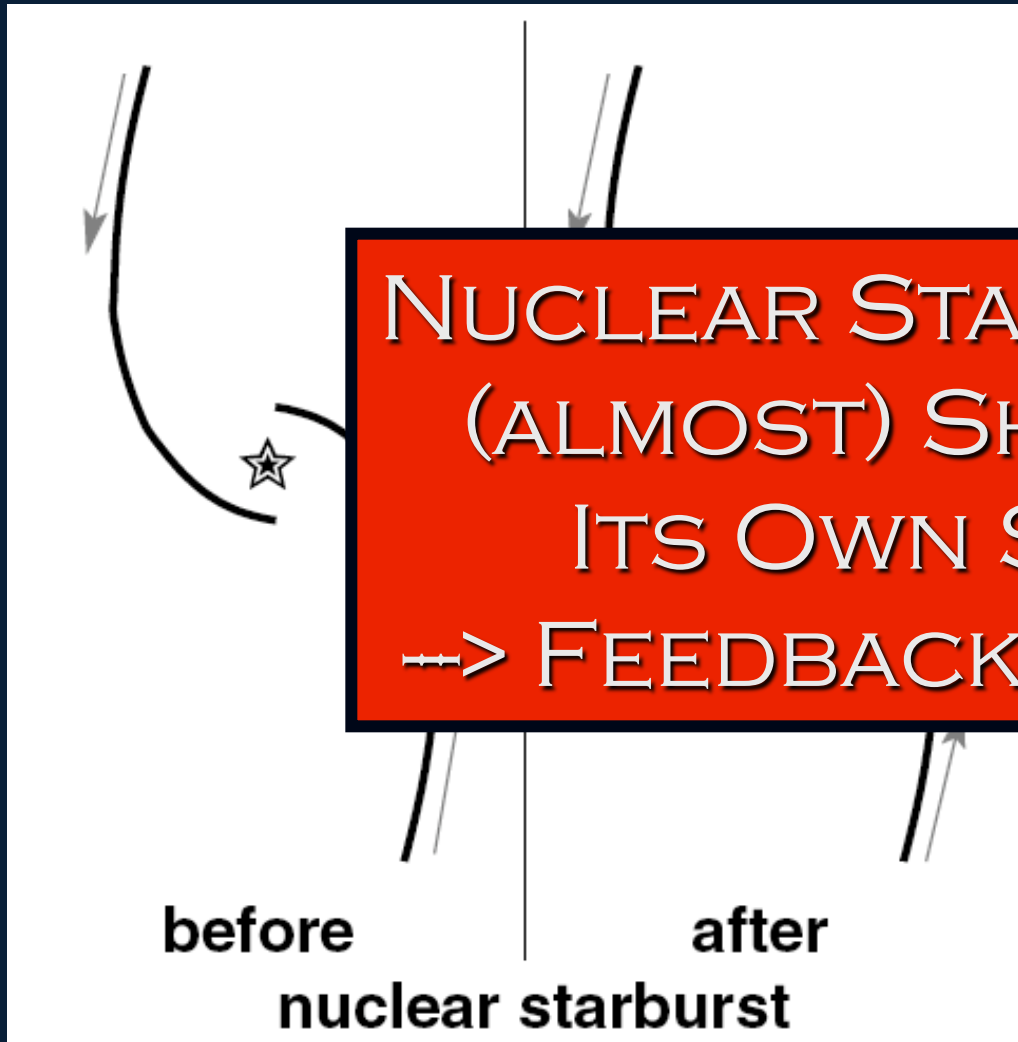
H α BUBBLE FILLS
CO CAVITY

→ STELLAR WINDS/SN
APPEAR TO
SHAPE INNER EDGE OF
EASTERN SPIRAL ARM

(OBSCURED) HII REGION

SELF-REGULATION OF STAR FORMATION

WHAT IS HAPPENING - SUGGESTED SCENARIO



NUCLEAR SF CHANGES
GAS FLOW

NUCLEAR STAR CLUSTER
(ALMOST) SHUTS OFF
ITS OWN SUPPLY
→ FEEDBACK PROCESS!

: ~ 3 MYRS

$L_{\text{MECH}} (0.55) \sim 1.52 \text{ ERG}$
 $E_{\text{GMC}} (2E6 M_{\text{SUN}}) \sim 2E52 \text{ ERG}$

SCENARIO PLAUSIBLE

WHAT'S NEXT:

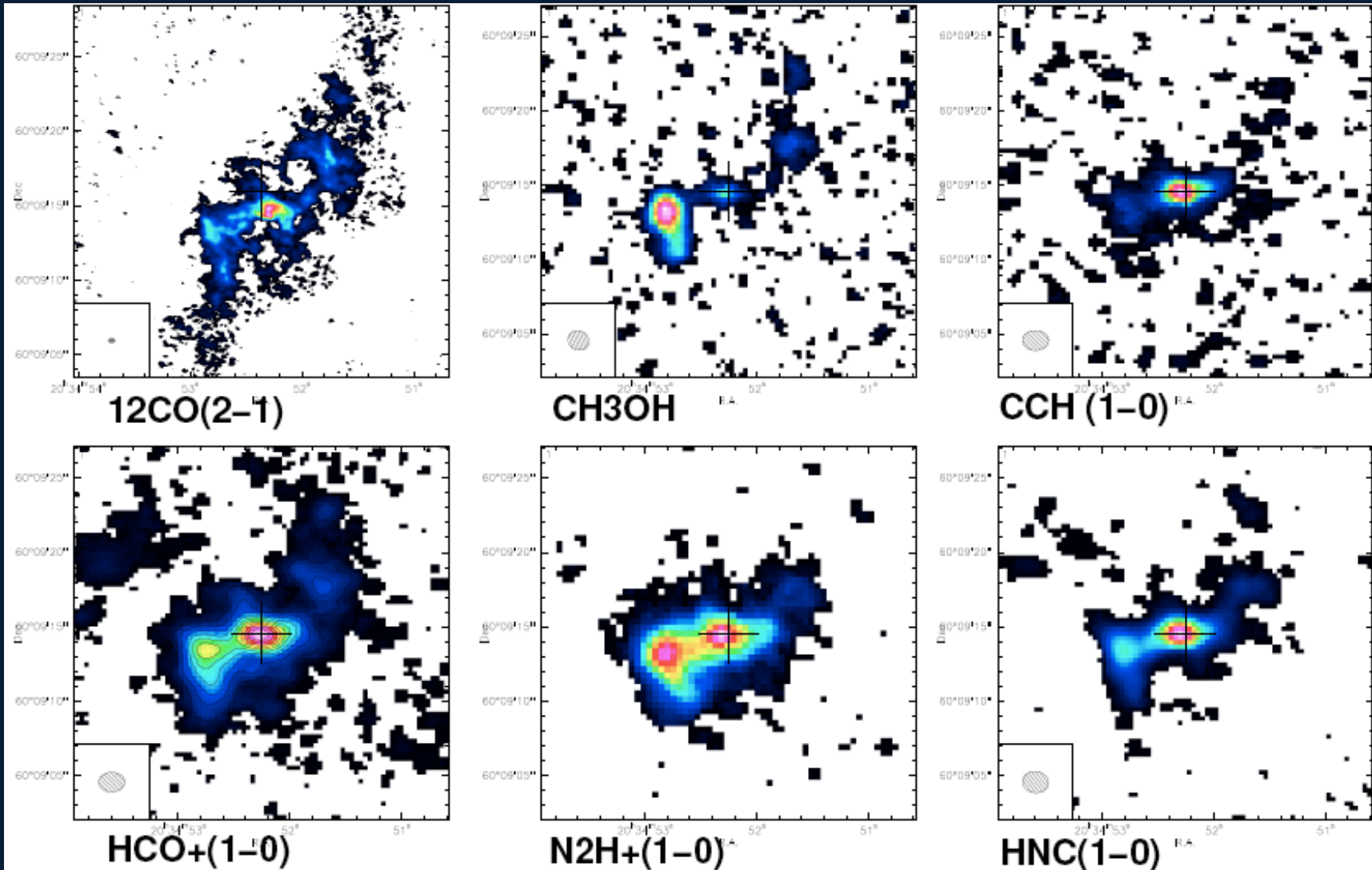
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***STAR FORMATION, ISM
AND GAS KINEMATICS***

**MOLECULAR GAS CHEMISTRY
UTILIZING MULTIPLE MOLECULES**

NEXT STEPS - NGC 6946

CHEMISTRY

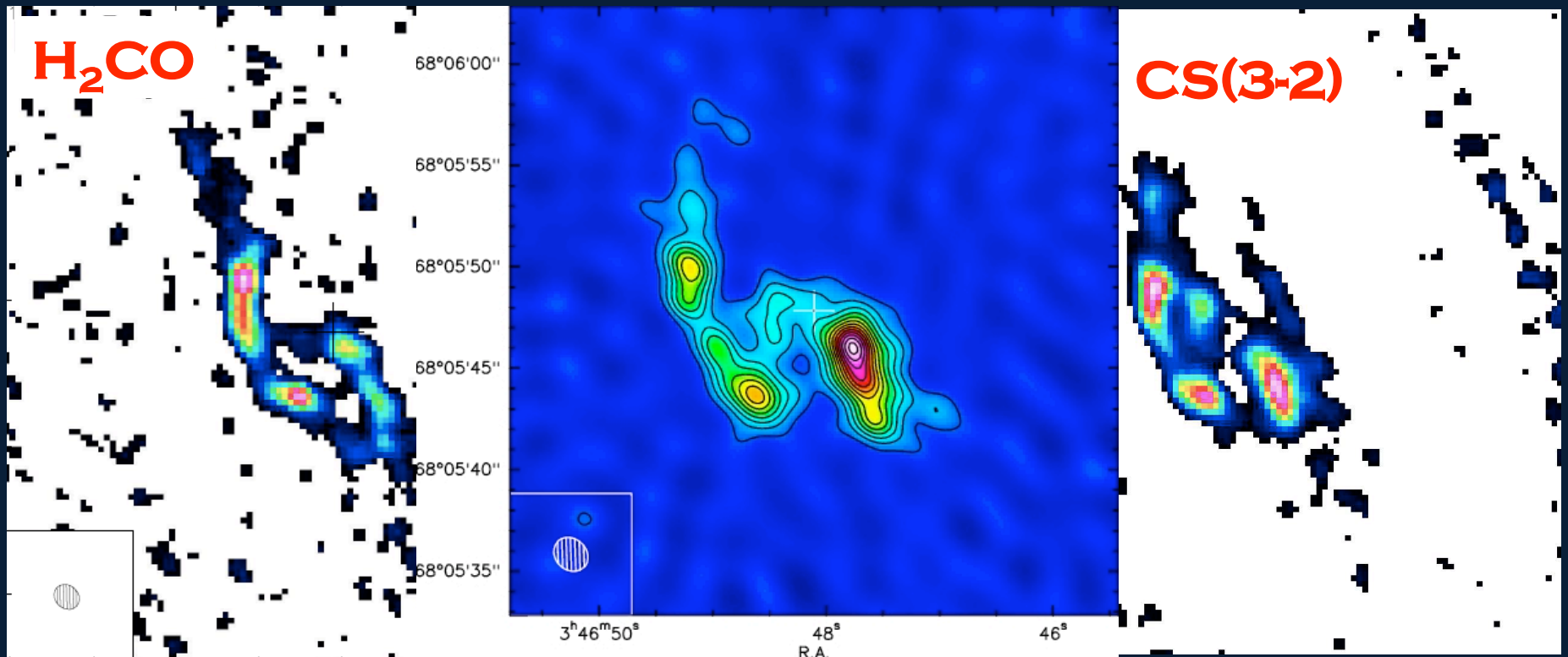


LOCATE: STAR FORMING GAS, SHOCKED GAS, PDRs

SCHINNERER, MEIER, BÖKER, DOWNES, EMSELLEM IN PREP.

NEXT STEPS – IC 342

CHEMISTRY @ 2MM



2MM LINE MAPS:

WHAT IS THE EXCITATION MECHANISM OF H_2CO ?

IS $\text{CS}(3-2)$ A GOOD PDR TRACER?

MM CONTINUUM – DUST TEMPERATURE/HEATING MECHANISMS

ALMA'S PROMISE

KINEMATICS

- 1 PC-SCALE RESOLUTION AT VIRGO DISTANCE
- SENSITIVITY OF FEW $10^4 M_{\text{SUN}}$ CLOUDS
- FUELING OF CENTRAL MASSIVE OBJECTS

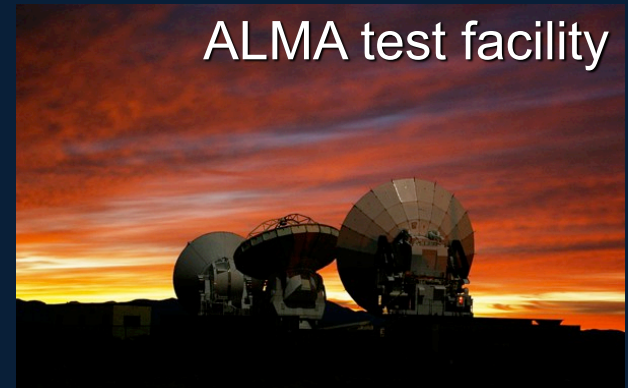
STAR FORMATION (FEEDBACK)

- FULL CENSUS OF MOLECULAR ISM
(MULTIPLE TRANSITIONS & MOLECULES)
- CHEMISTRY ON GALACTIC SCALES
(E.G. STAR FORMATION VS GRAVITY)
- (LOCAL) STAR FORMATION TRIGGERS

ALMA site



ALMA test facility



SUMMARY & CONCLUSION

FUELING NUCLEAR STAR FORMATION

- ONGOING GAS REDISTRIBUTION WITHIN DISK*
- BARS WORK (IN GENERAL, SMALL & LARGE)*
- SUSTAINED NUCLEAR FUELING FOR > 10 MYR*

STAR FORMATION FEEDBACK

- CAN ALTER GAS FLOW*
- SELF-REGULATED FUELING OF NUCLEAR SF*
=> REPETITIVE SF
TIME-VARIABLE
(MODELS)

