Molecular Gas at the Galactic Centre: Prospects for using the Upgraded ATCA

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- **Introduction: Galactic Centre Molecular Clouds**

→ Physical properties of GC molecular clouds

→ Current status of instruments, observations, surveys

- **New Prospects for GC Molecular Observations**

→ Environments of young, massive stellar clusters

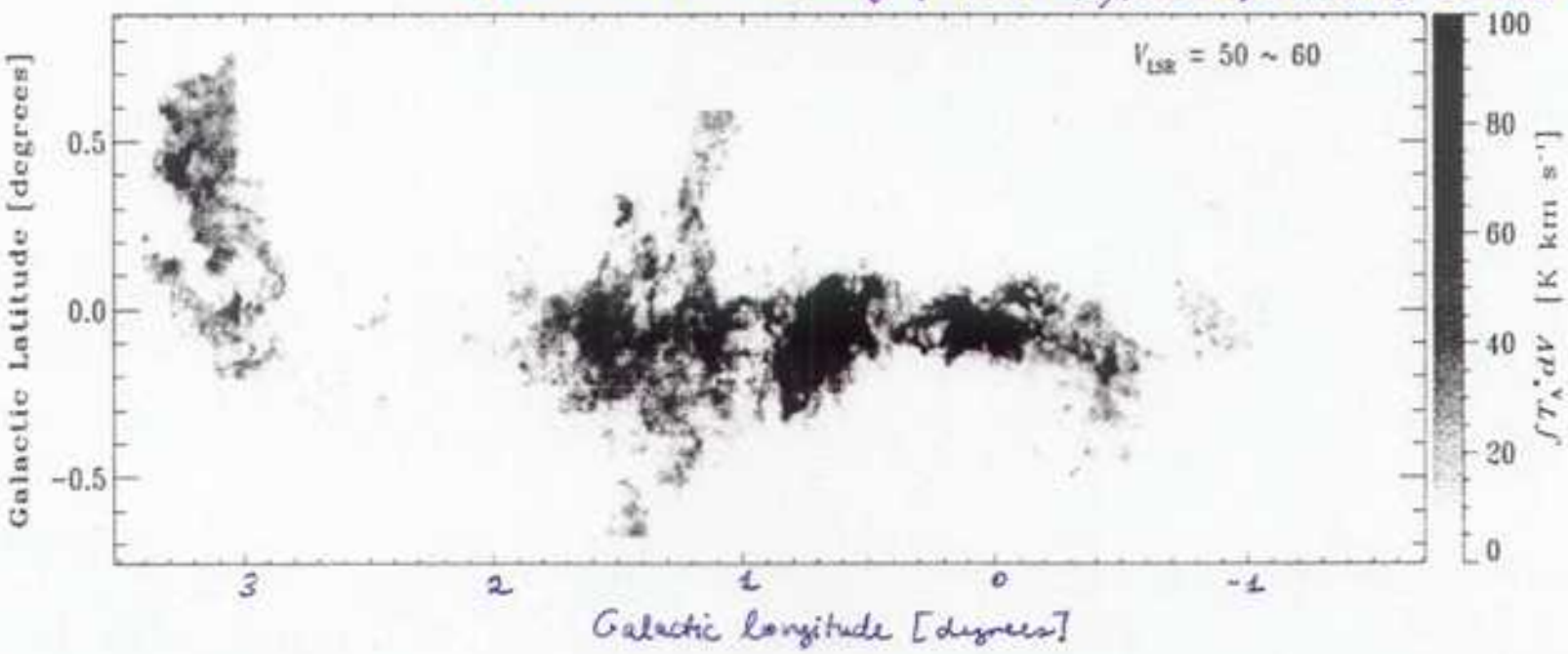
→ Interactions with magnetized non-thermal filaments (NTFs)

→ Correlations between X-ray and molecular emission

Physical Properties of Molecular Gas In/Around Galactic Centre (r<200 pc)

- warm: 30−200 K; average ~70 K ← points to a widespread heating mechanism
- dense: $n > 10^4$ cm^{-3} } required for stability
- large ΔV: 15-50 km s^{-1}
- velocities "forbidden": non-circular orbits (X_1, X_2)

2 populations of clouds
1. higher velocity (130-200 km/s); r ~ 180 pc "ring"
*** 2. lower velocity (<100 km/s), dense, massive clouds



"GC Molecular Cloud Complex" (CO emission; Oka et al. 1998)

- **Sgr A, B, C + HII regions - intense CO emission, large ΔV**

→~2-10 pc molecular filaments, arcs
→expanding arcs, shell-like features; sharp edges
→anti-correlation with radio cont. features
→association with WR stellar winds/clusters

⇝ clouds like Sgr B2 contain large fraction of molecular mass

Current Status of GC MM-observations

- **Number of recent, large scale surveys**

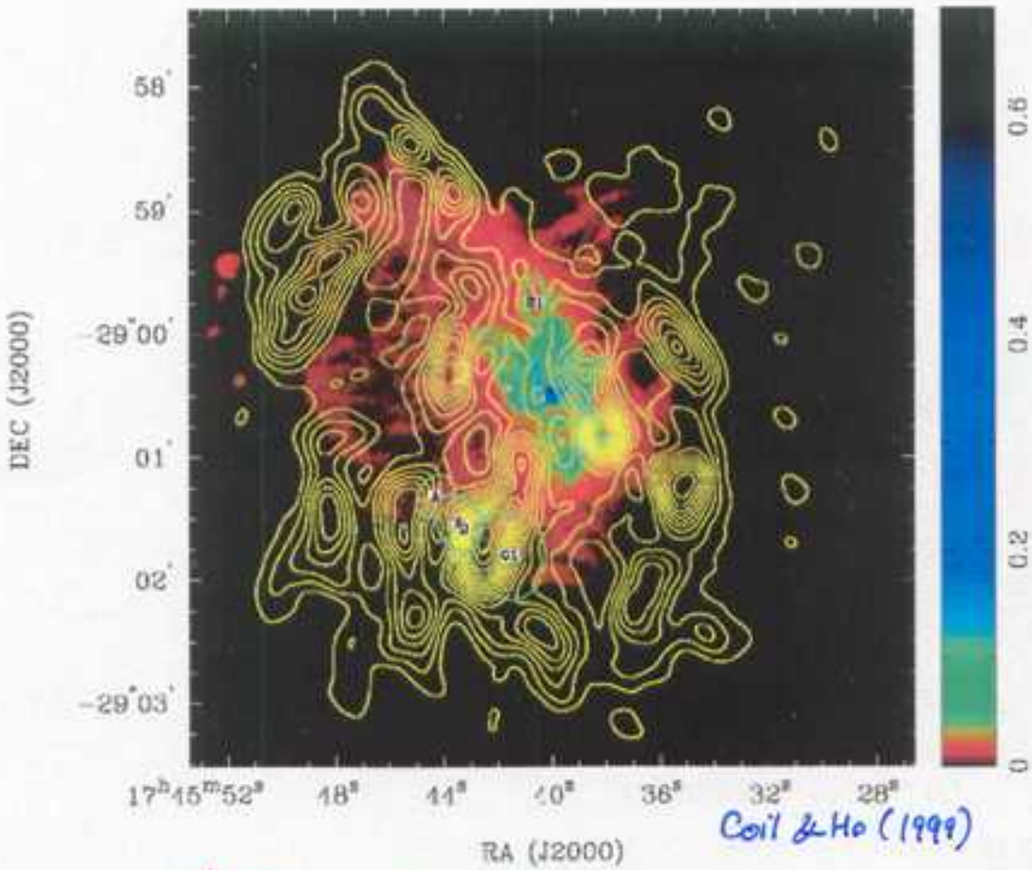
useful for ID

→ Nobeyama 45-m, ^{12}C0, ^{13}CO survey (Oka et al. 1998)
→ High resolution (17"), detailed images of inner 2 x 1 degrees

→ Tokyo-Onsala-ESO-Calan Galactic CO(2-1) survey (Sawada et al. 2001)
→ Lower resolution (9'), overall kinematics, structure

- **VLA/BIMA observations of central 15 pc (Sgr A)** ← Circum-nuclear disk (CND)

→ McGary et al. 2001; Wright et al. 2001
→ VLA: NH_3 (1,1), (2,2), (3,3) - resolution ~16"
→ BIMA: HCN(1-0), HCO^+(1-0), H42α - resolution ~13" x 4 "

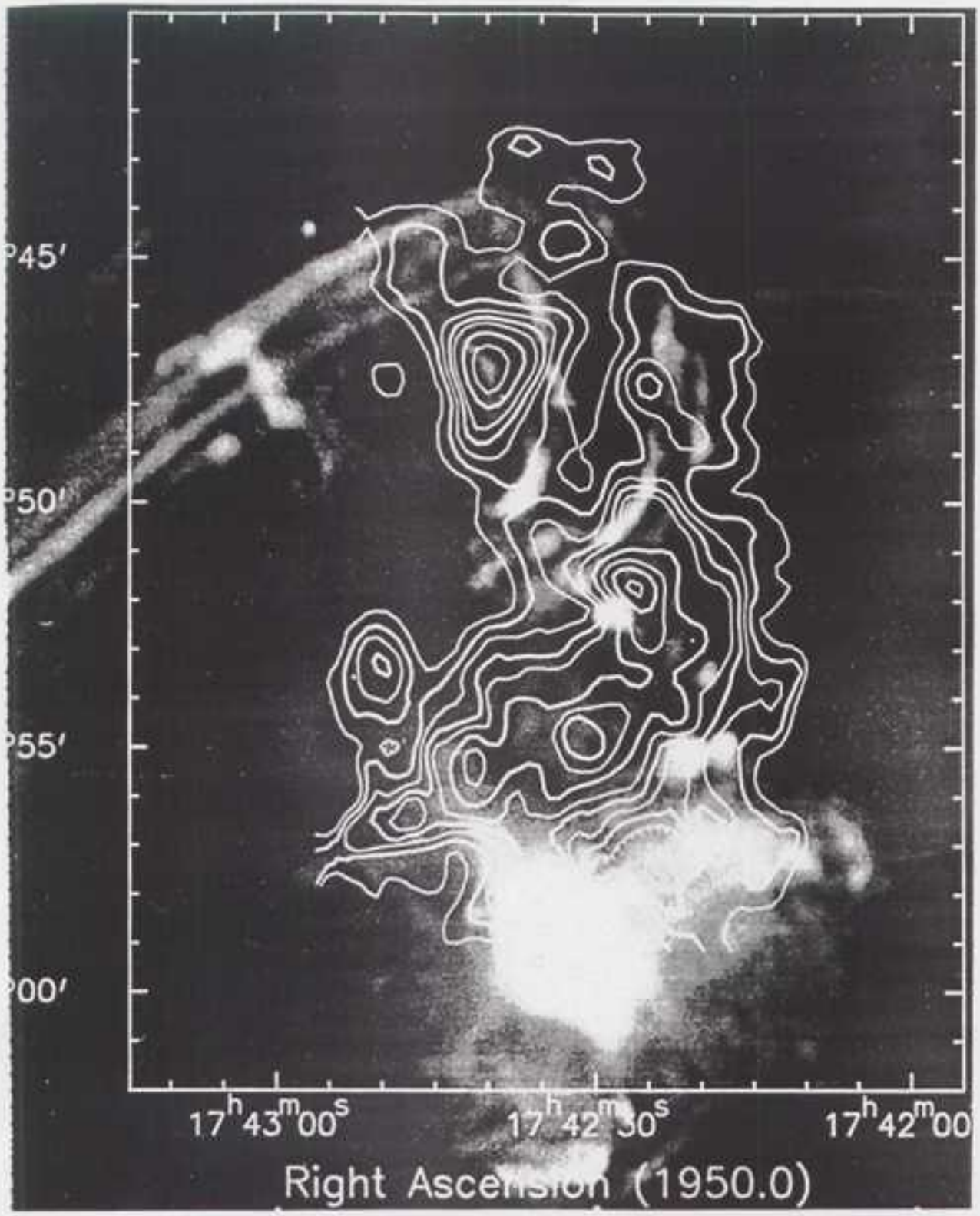


Coil & Ho (1999)

Colorscale: 6cm radio continuum: SgrA Complex
Contours: NH_3 integrated emission VLA

→ CND part of the SgrA* accretion disk (transitory or stable ?)
→ Filamentary <u>streamers</u> of molecular gas are infalling from the "20 km/s GMC" onto the CND (feeding & transport) onto SgrA*

Molecular Gas In/Around the RADIO ARC



Contours = IRAM 30m CS(2-1)
resolution ≈35″
(Serabyn & Güsten 87)

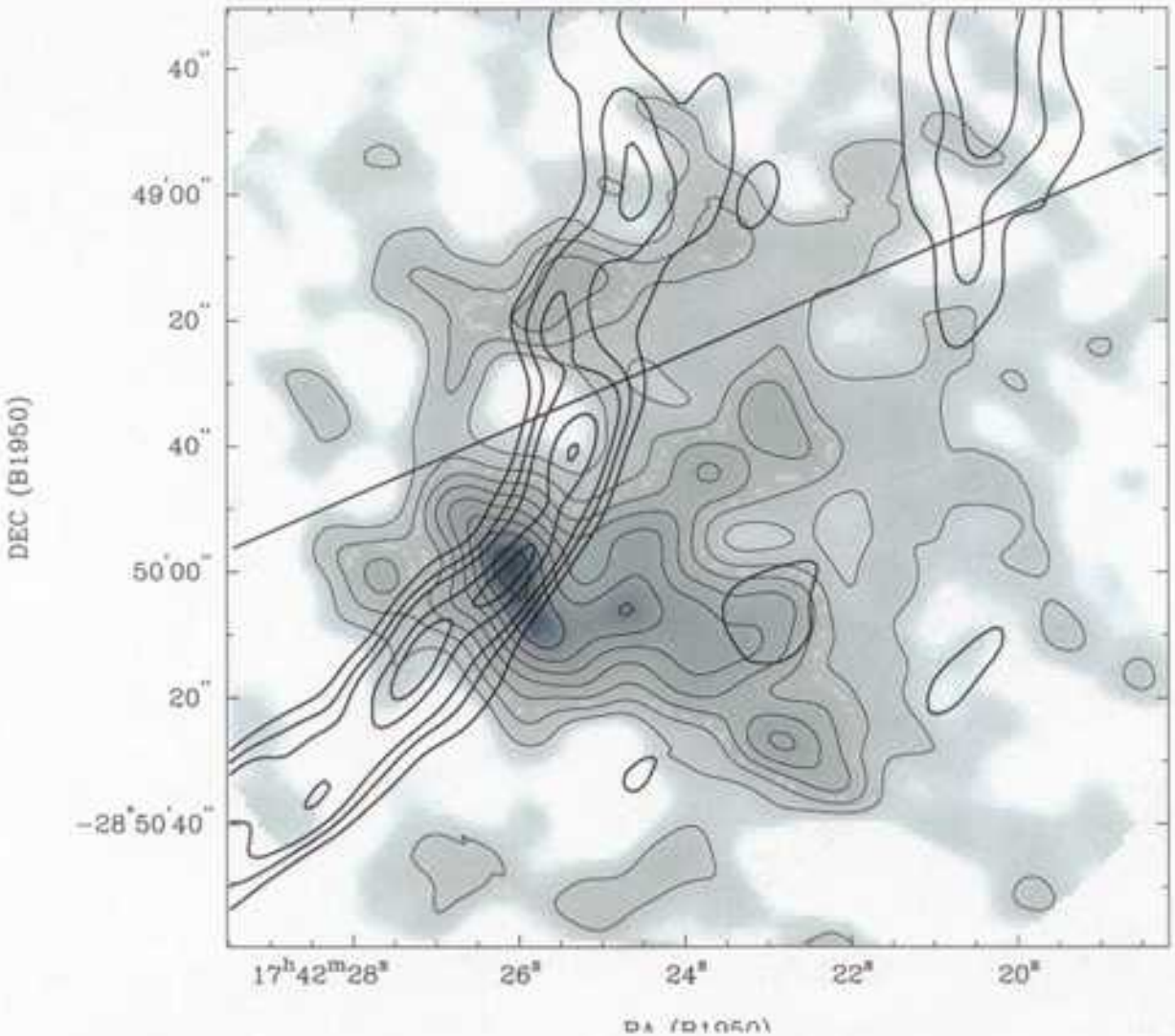
greyscale VLA
20cm radio continuum
(Yusef-Zadeh et al. 84)

*curved thermal features = ARCHED FILAMENTS

Fig. 7. Contours of CS $J=2-1$ emission in the range -55 to $5\,\mathrm{km\,s^{-1}}$ superposed on a 20 cm continuum radiograph of Sgr A and the arc (Yusef-Zadeh et al., 1984). For this figure the data were convolved with a 35″ beam. The contour levels are 10, 15, 20, 25, 30, 40, 50, 70 K km s^{-1}

Zoom In: OVRO + 30m CS(2-1) image – integrated intensity shown in greyscale, 8.3 GHz VLA continuum contours (res 8")

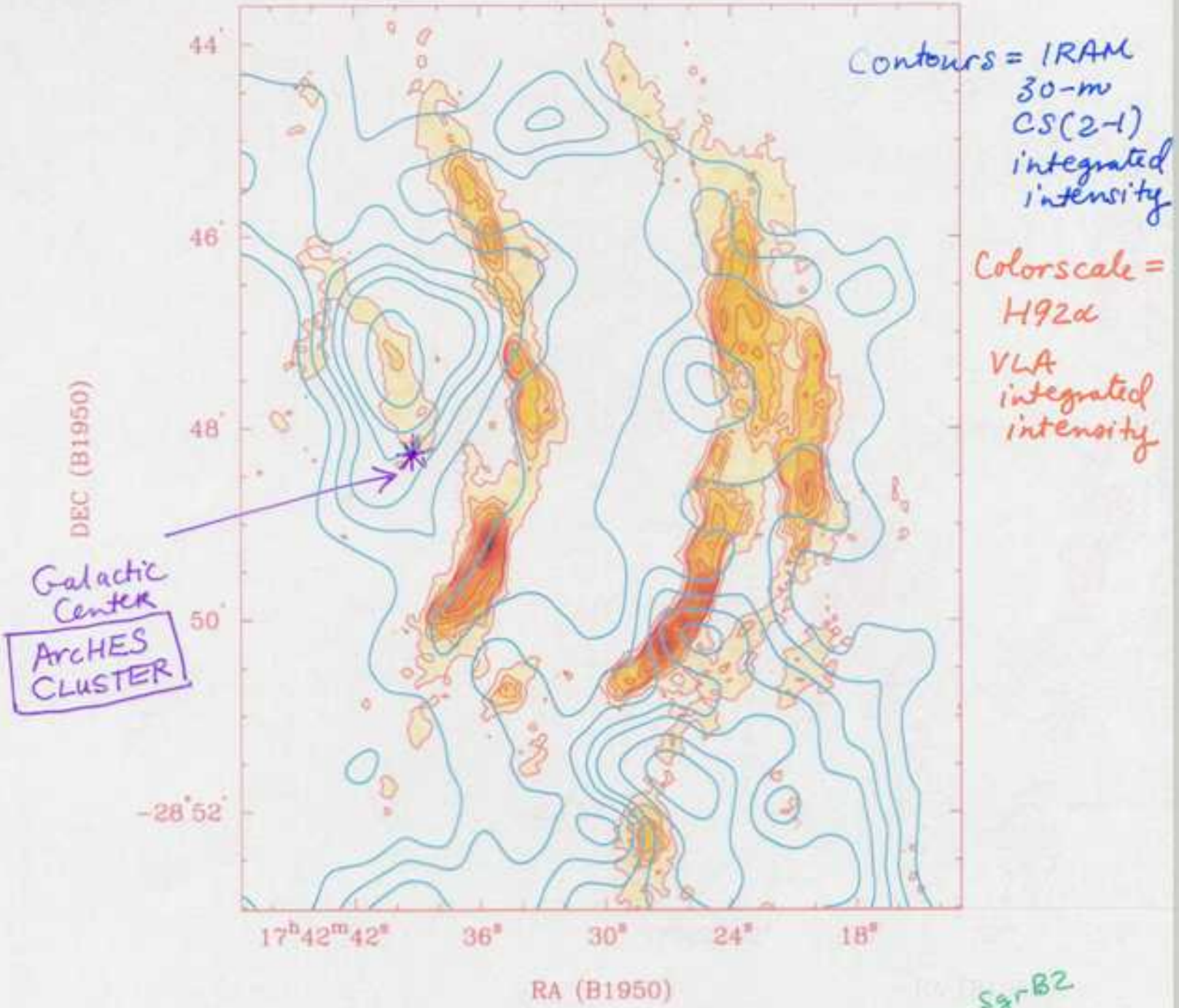
Lang, Goss & Morris 2001.



What is needed:

- more complete (u,v) coverage (OVRO/BIMA-few hours)
- observations to detail morphology & velocity structures

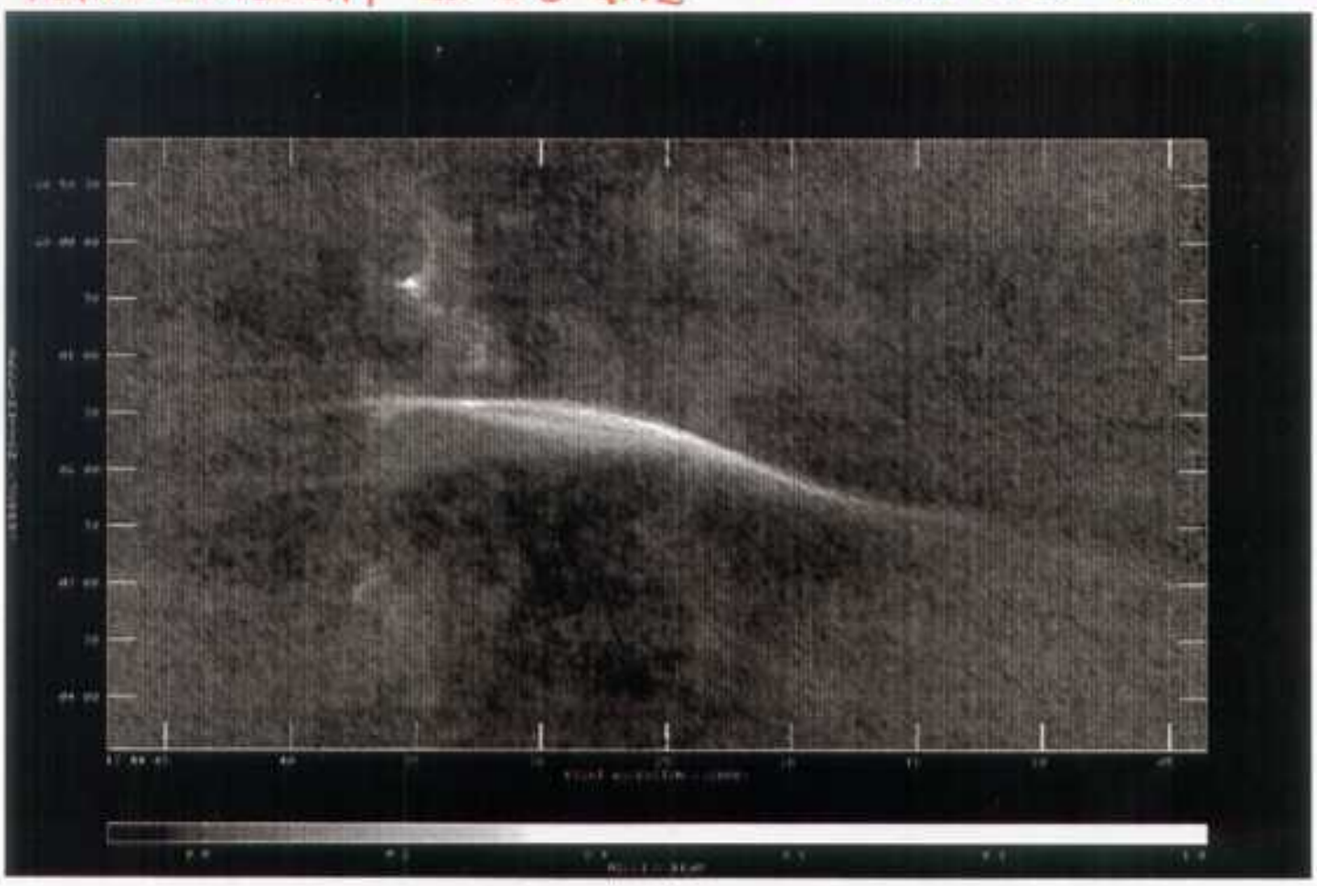
I. Molecular Gas near GC Massive Stellar Clusters



- Relationship between stellar clusters, ionized and molecular gas — Sgr B2, Sickle, Pistol
- Strong WR winds – morphological effects in molecular gas? — expanding structures, bubbles
- Formation of such clusters in these molecular clouds?

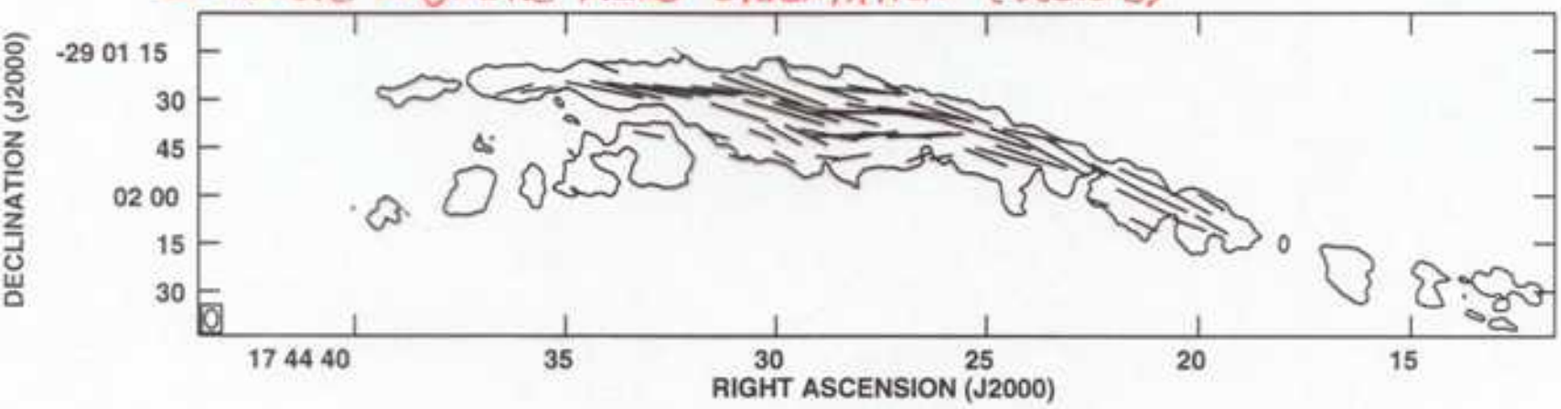
(II) Interactions between NTFs and molecular clouds

TOTAL INTENSITY at 8.3 GHz



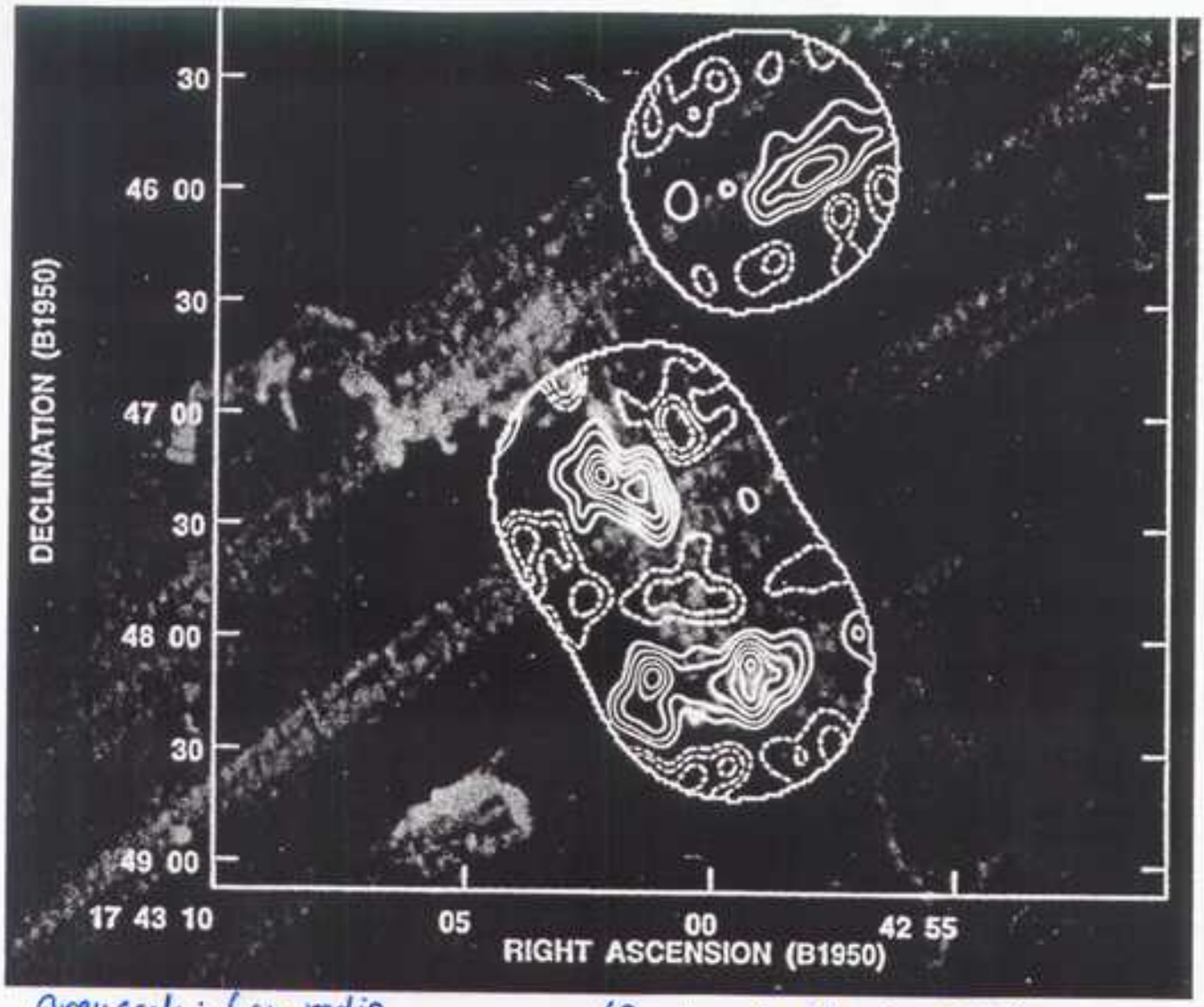
LINEARLY POLARIZED INTENSITY at 4.9 GHz

INTRINSIC MAGNETIC FIELD ORIENTATION (vectors)



⇒ filaments trace a magnetic field which is ⊥ to Galactic Plane

Contours: OVRO CS(2-1) ; res ~ 8"



greyscale: 6cm radio continuum

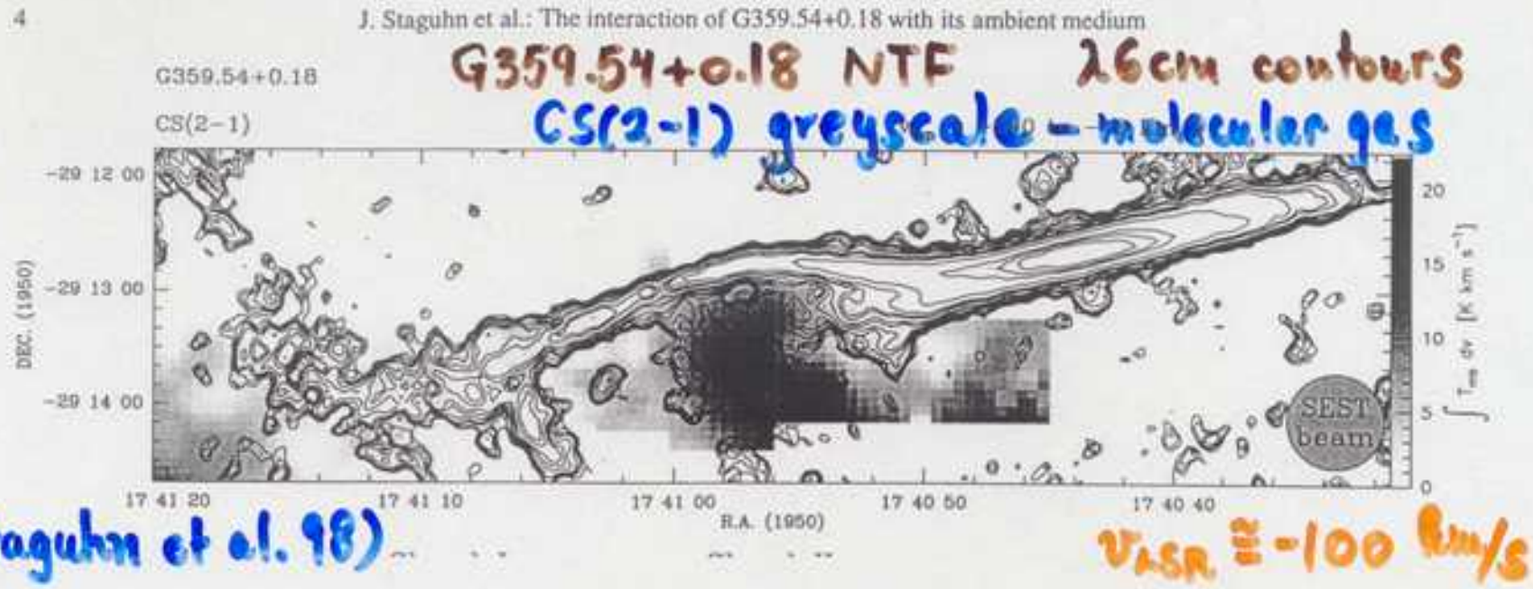
(Serabyn & Morris 1994)

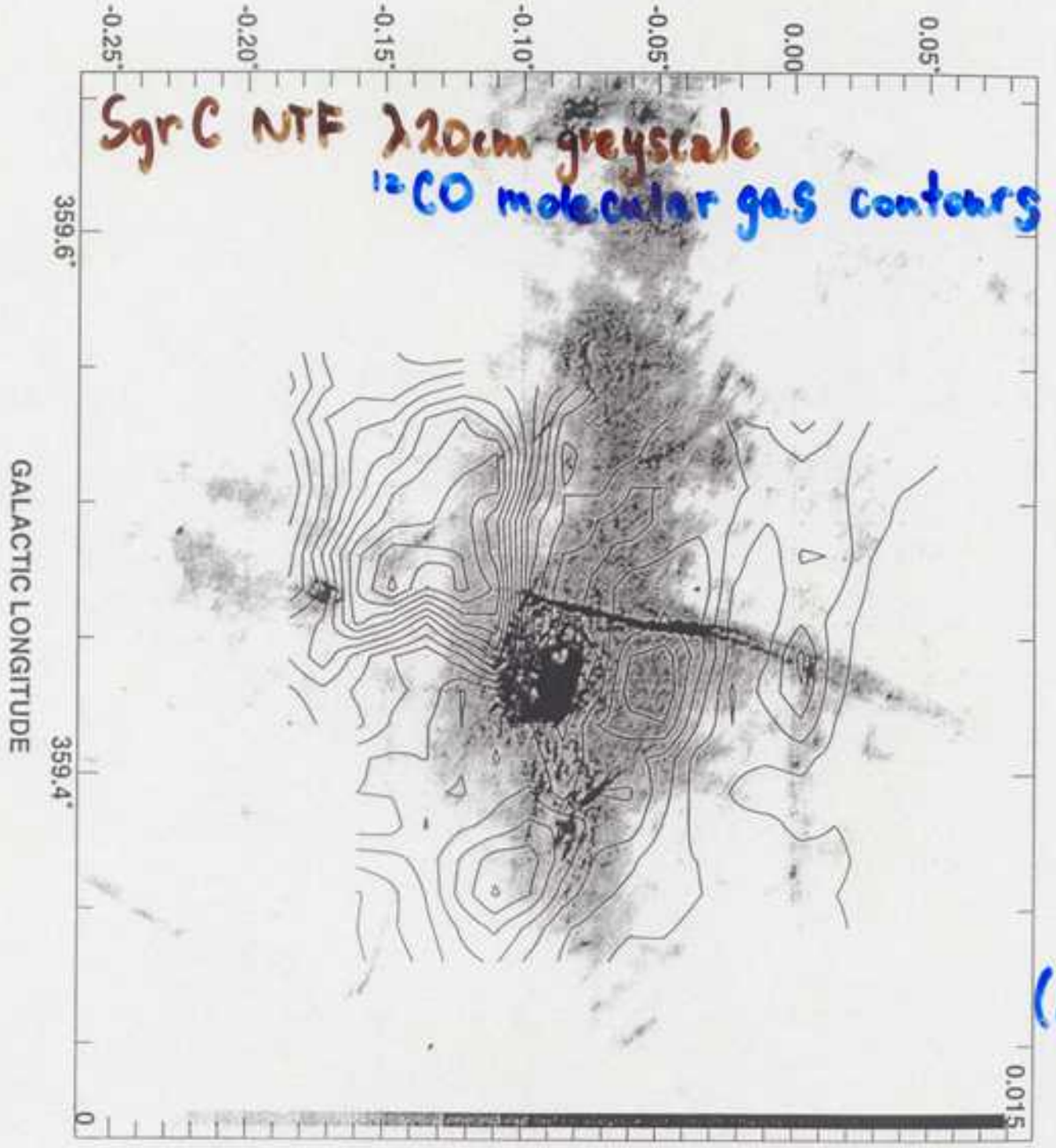
model:

magnetic reconnection at NTF/molecular cloud interfaces

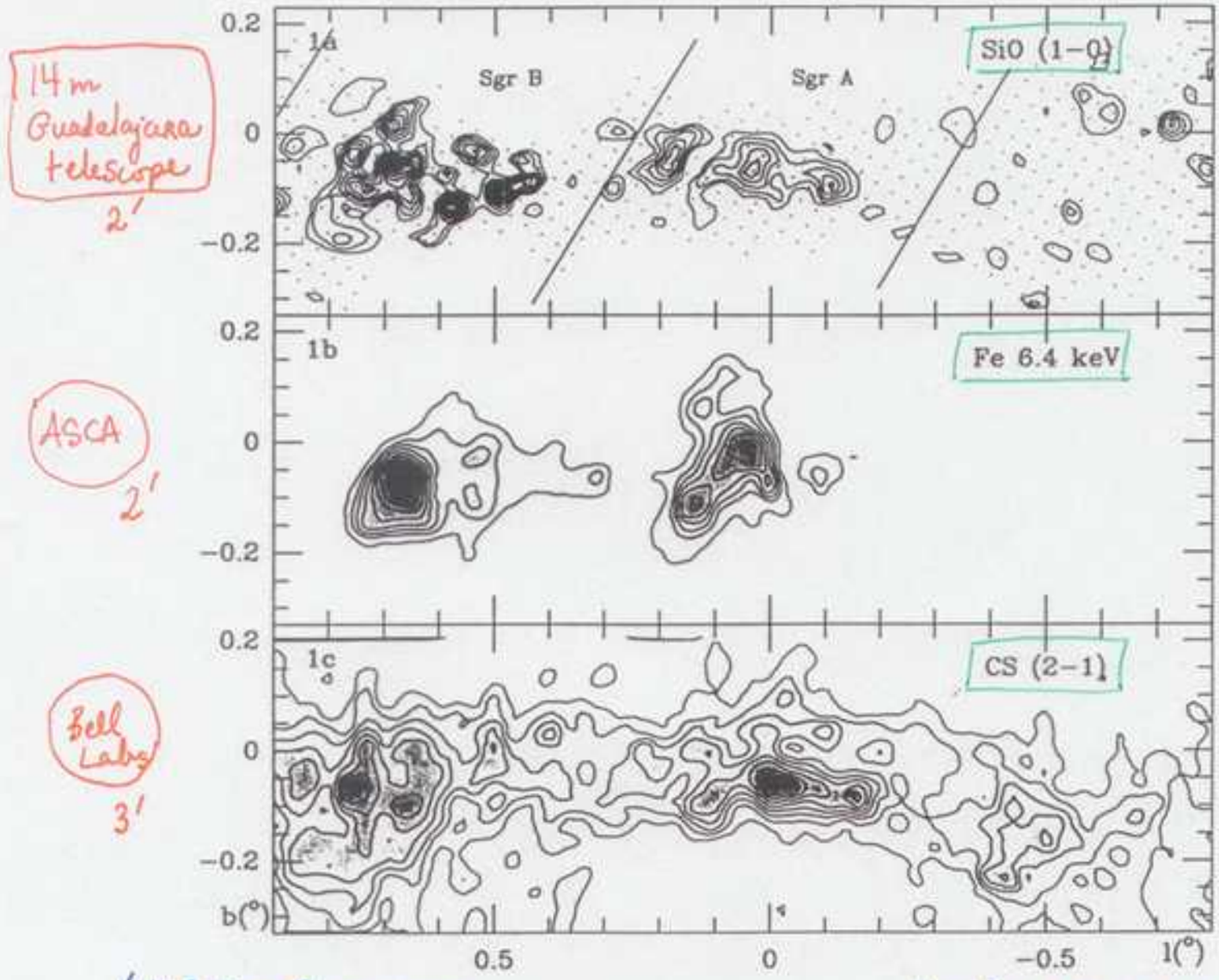
- at CLUMP positions, twisting and B-field reversal occurs between cloud field and inter-cloud field
- reconnection occurs
- accelerates e^-, which then spiral along external B-field lines (intercloud)

Two examples of NTF/cloud interactions:





III. Correlations between 6.4 keV X-rays and Molecular Material



6.4 keV = flourescence
neutral material exposed to hard X-rays

Martin-Pintado et al. 2000

- **Diffuse 6.4 keV emission in GMC SgrB & C** (*BeppoSax, ASCA, Chandra*)
  → Sidoli et al. 2001; Murakami et al. 2000; 2001ab

possible scenarios

- **X-ray reflection nebula: from energetic burst of SgrA*?**
  → change heating, chemistry of GC clouds
- **peaks of 6.4 keV correlate with expanding molecular shells/bubbles**
  → (Sgr B2, Martin-Pintado et al. 99; Radio Arc, Tsuboi et al. 97)
  ↳ massive clusters, stellar winds

→ HIGHER RESOLUTION !!

GC ideas for upgraded ATCA

→ Sgr A* – variability monitoring
mm – polarimetry

→ Polarization of molecular clouds
- to get B-field structure
- at precise positions near NTFs

→ CHANDRA GC Survey – covers inner $2^\circ \times 1^\circ$
– completely public data
– resolutions $< 1''$