Small scale structure of the IRC +10216 circumstellar envelope:

a key to the mass loss process and chemistry

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Keys to the mass loss process and chemistry

- Mass loss from AGB stars largely controls Galactic evolution. Yet this fundamental process is still poorly known;
- Circumstellar chemistry is well developed but its time dependence is not properly tested.

➢ IRC+10216 (CW Leo) is probably the best object where to study these two questions

IRC+10216 is the dusty envelope of the closest TP-AGB star: CW Leo. It has:

I. C. Leão et al.: The CSE of IRC+10216

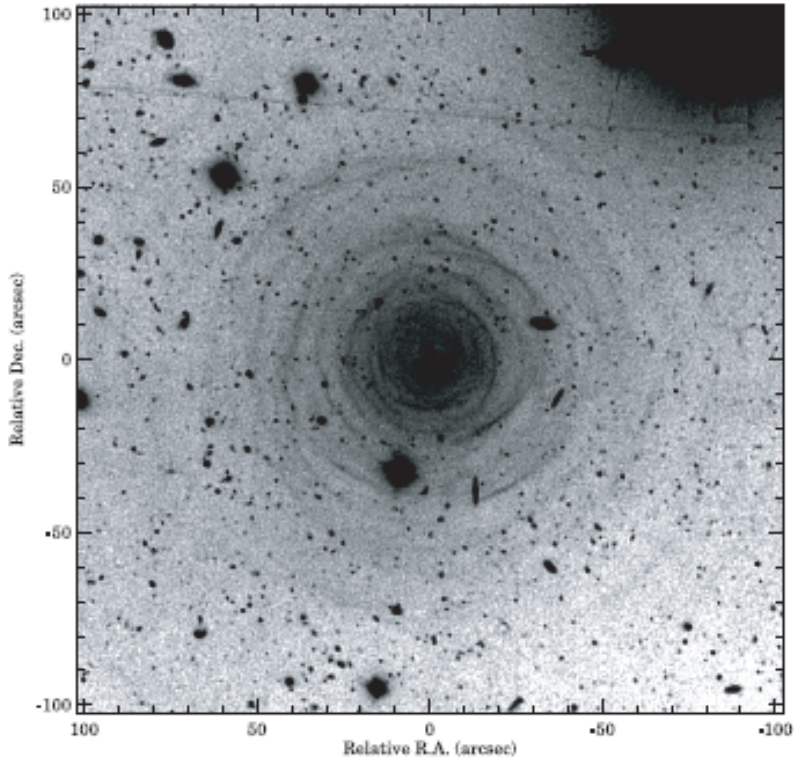
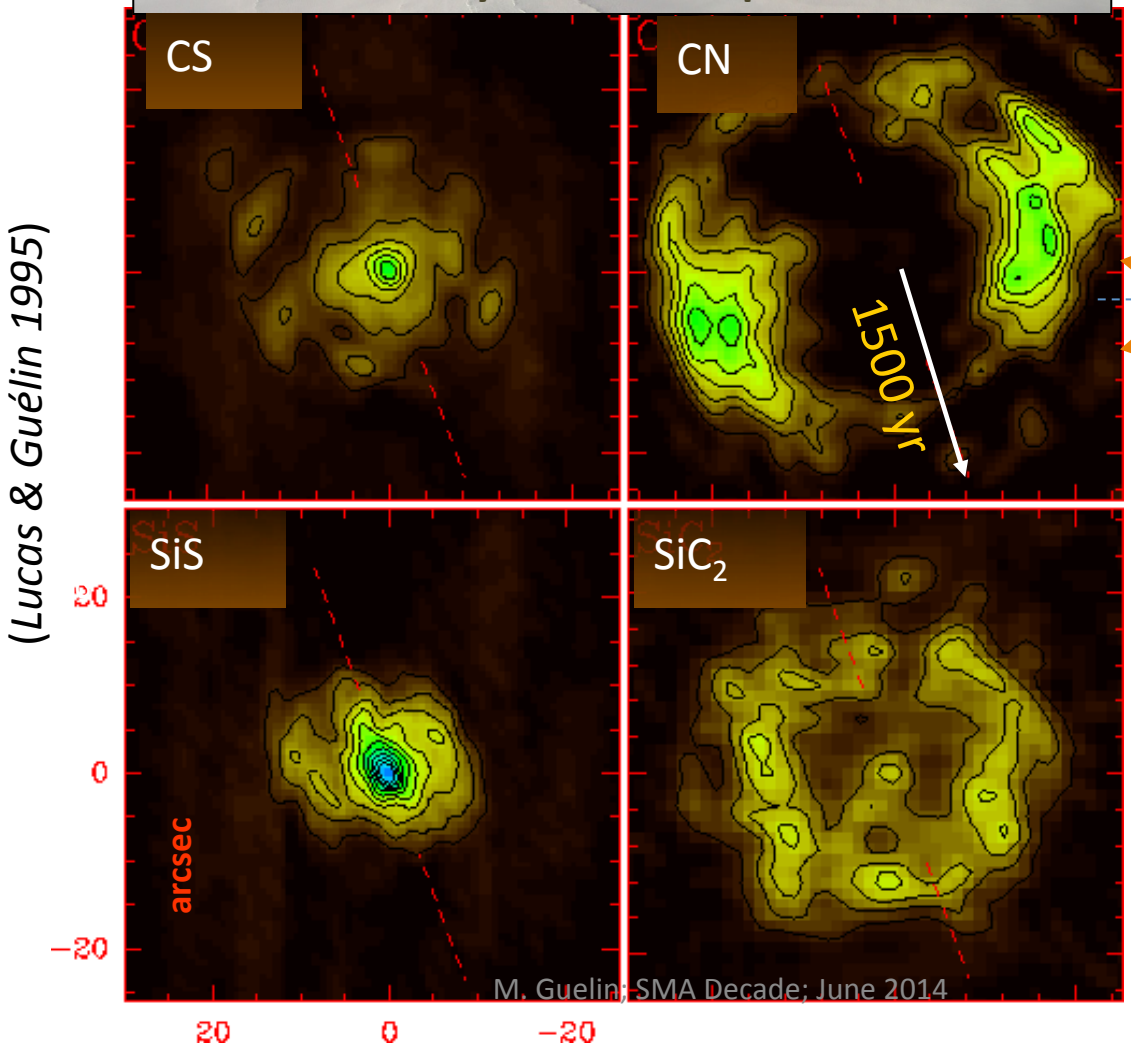


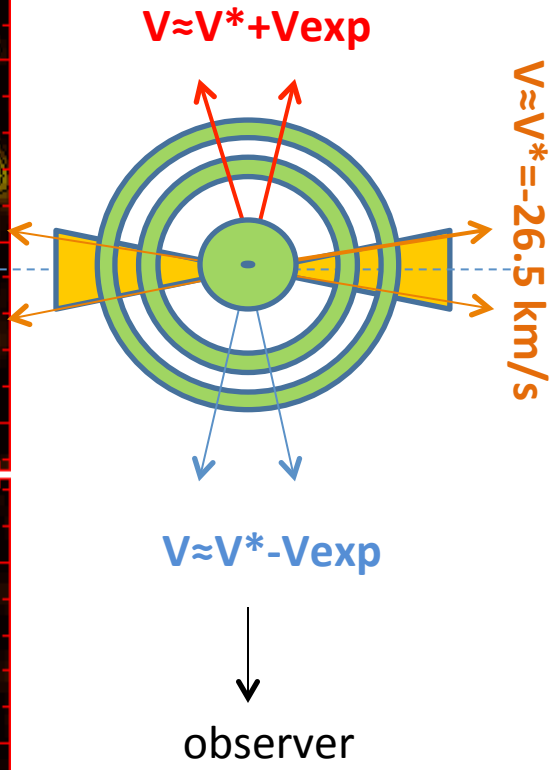
Fig. 3. FORS1 deconvolved *V*-band image of IRC+10216. North is up and East is left.

- A **massive** envelope of **large** apparent size (several arcmin)
- A simple symmetrical shape
- A uniform expansion velocity (14.5 km/s)
  1 arcsec ~ 130 A.U.~50yr
- A **rich molecular content** (>80 molecular species, including all known **IS anions**)

Velocity-channel maps V=V*

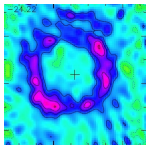


(*Lucas & Guélin 1995*)



IRC+10216: V-band vs CO

C_6H @ PdBI



Guelin et al. 1999

VLT –V-band optical image

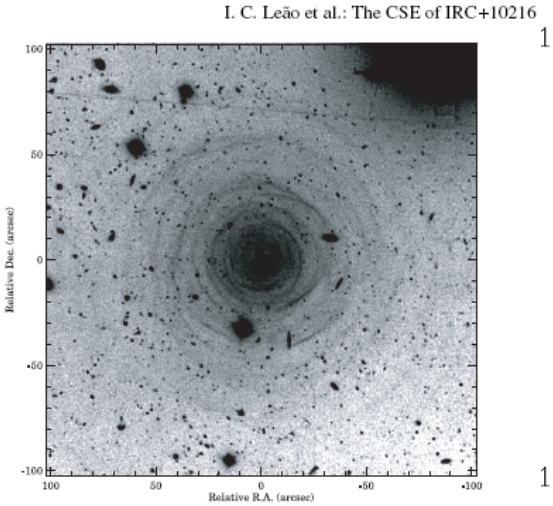
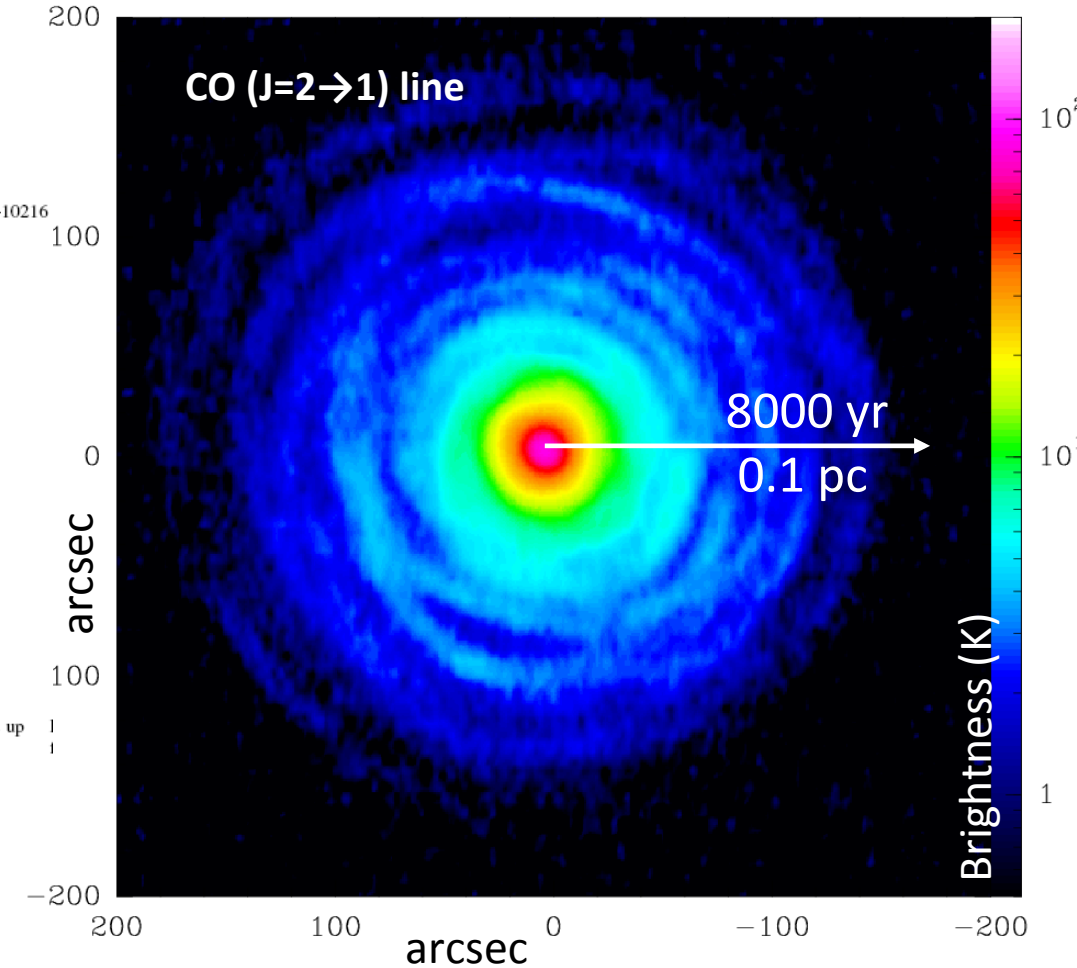


Fig. 3. FORS1 deconvolved *V*-band image of IRC+10216. North is up and East is left.

Leao et al. 2006

CO@30-m telescope ; $v=v_*=-26$ km/s

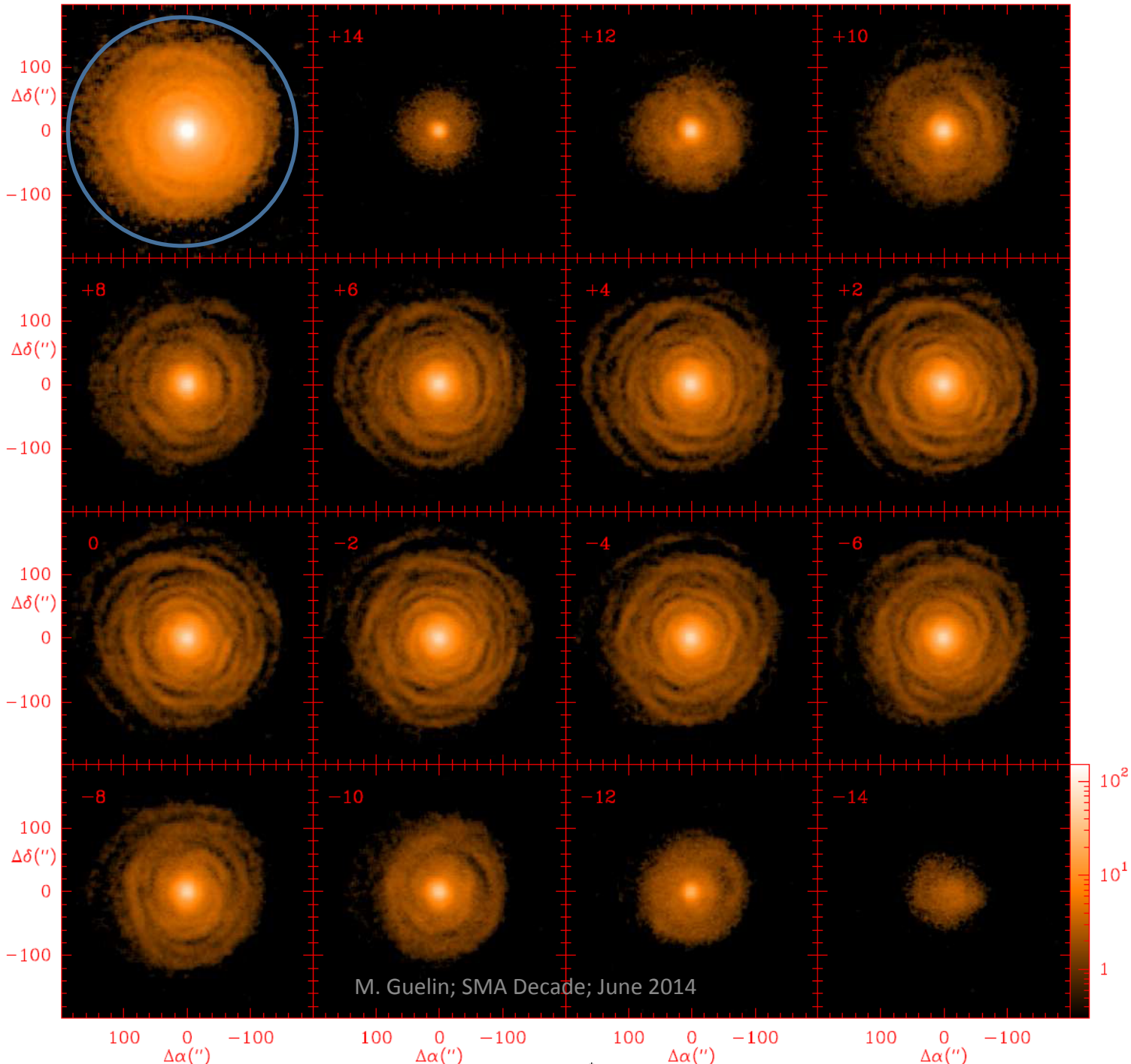


Cernicharo et al. 2014

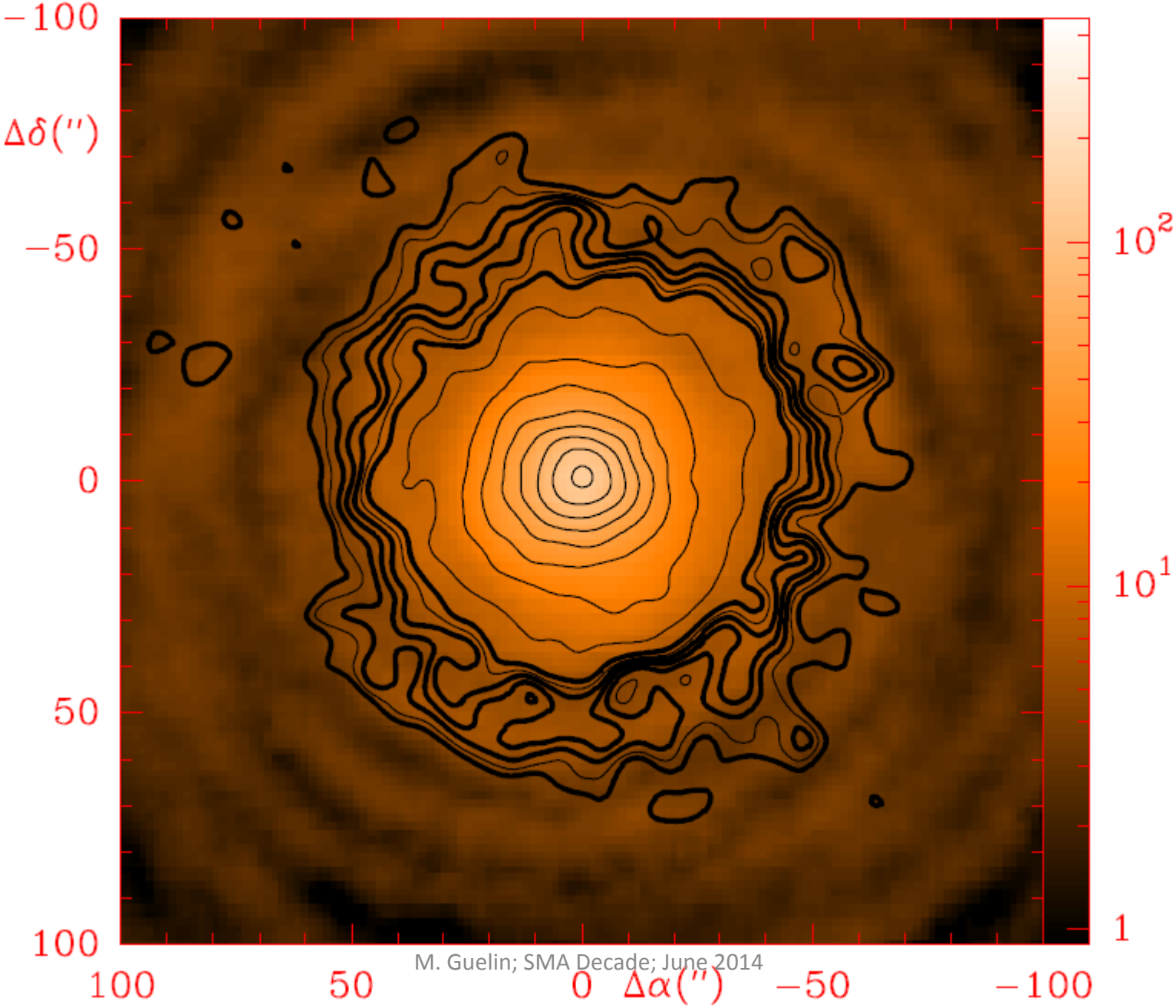
CO(2-1) velocity channel maps

IRAM 30m telescope

Cernicharo, Marcelino, Agundez & Guelin 2014



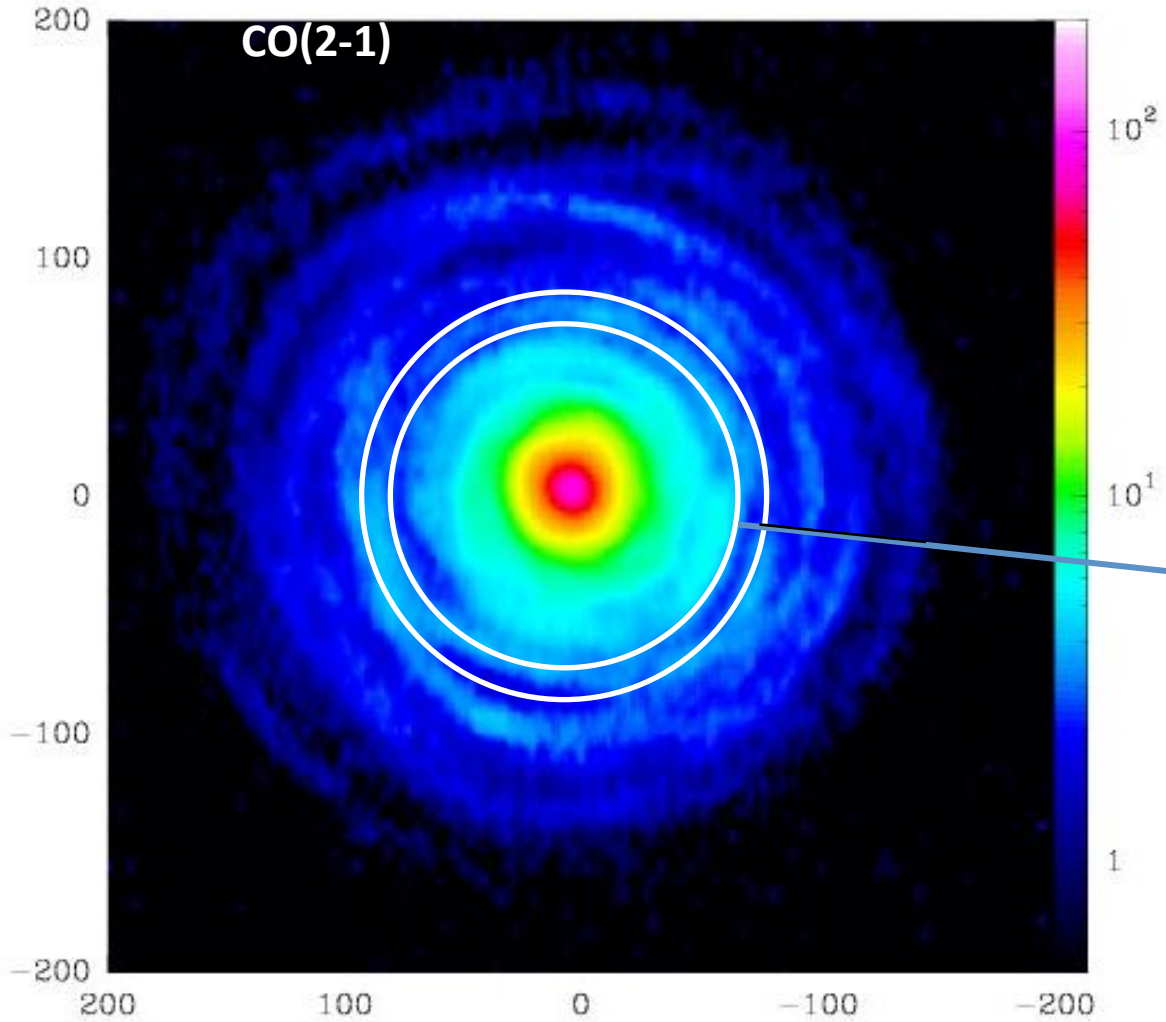
Velocity-integrated ^{13}CO(2-1) line (contours) on ^{12}CO(2-1) (color)

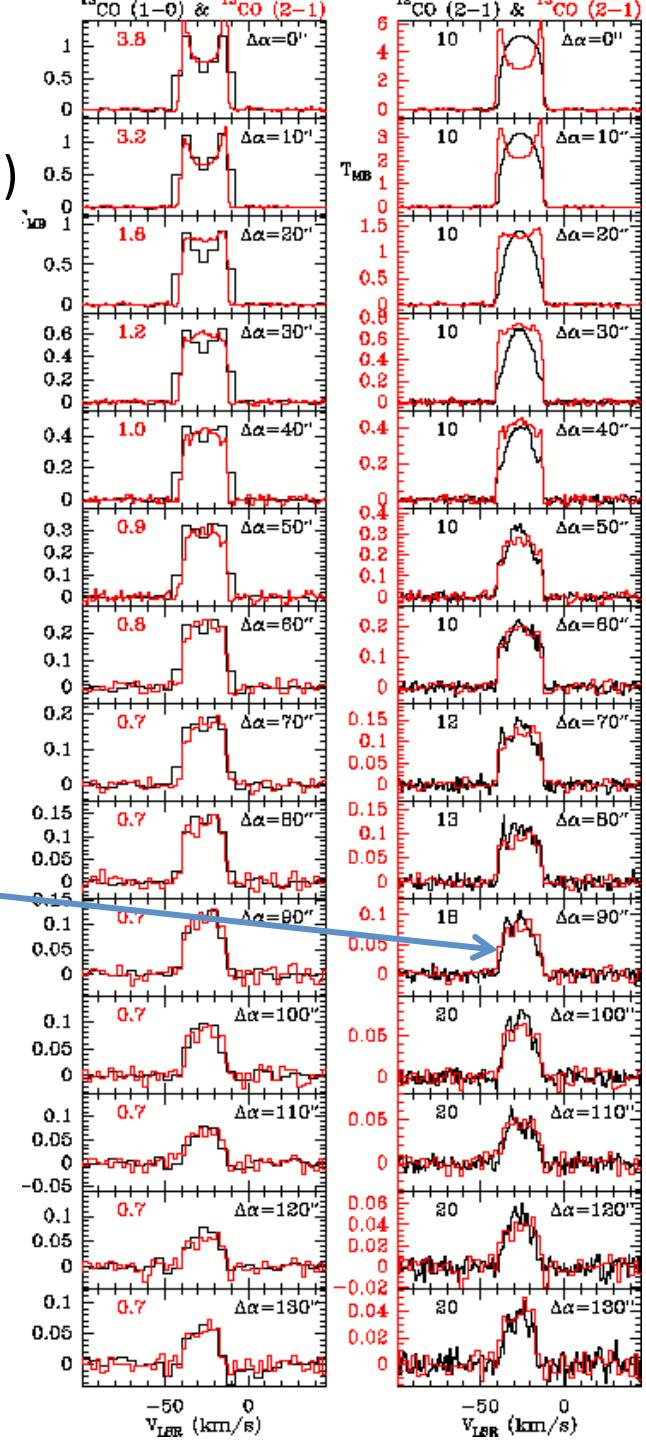


Average ^{12}CO and ^{13}CO line intensities over concentric 10”-wide rings ➔

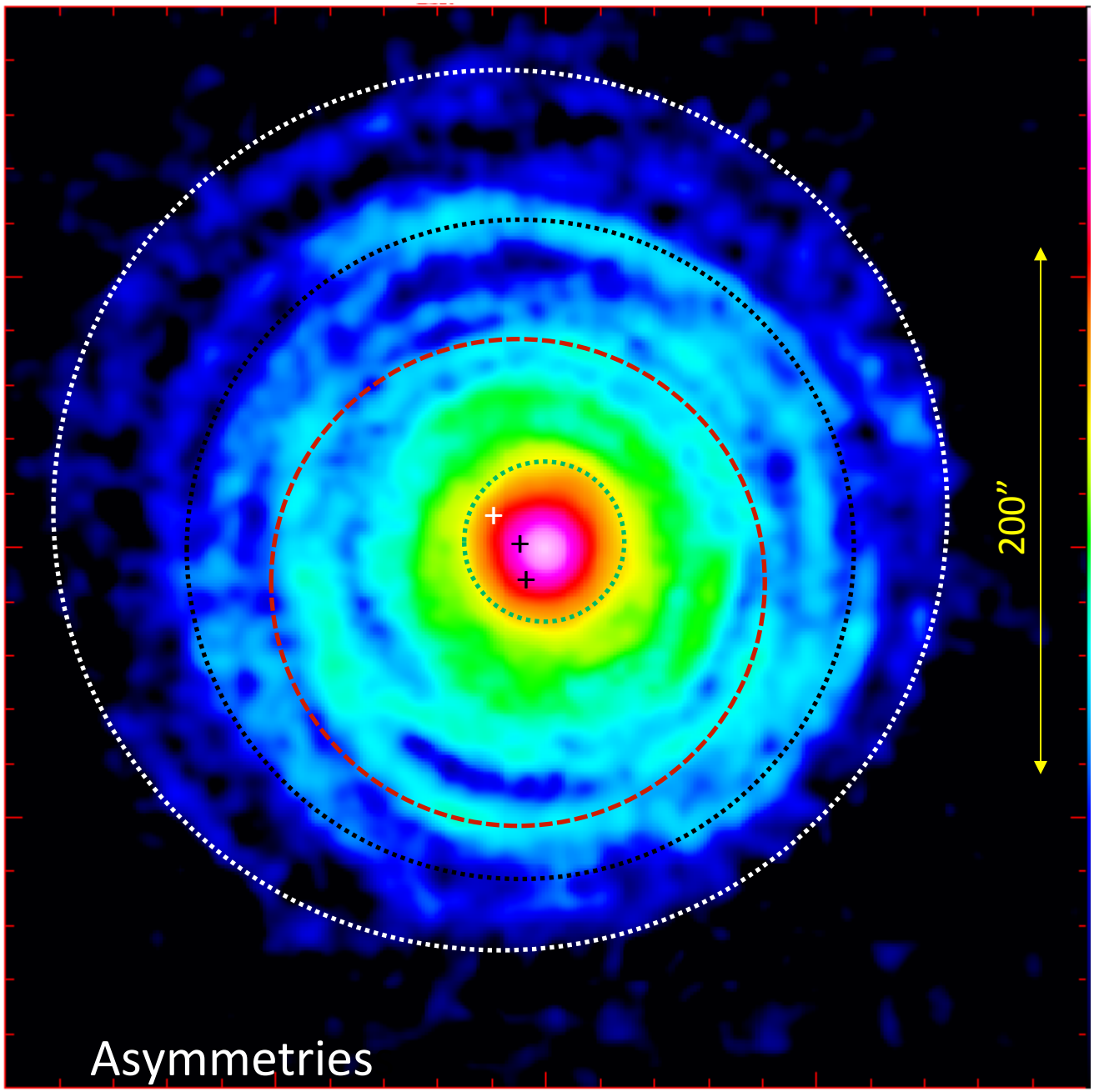
Assume ^{12}CO and ^{13}CO abundances are known (they are)

➡ derive average CO and H_2 volum densities as a function of radius





M. Guelin; SMA Decade; June 2014

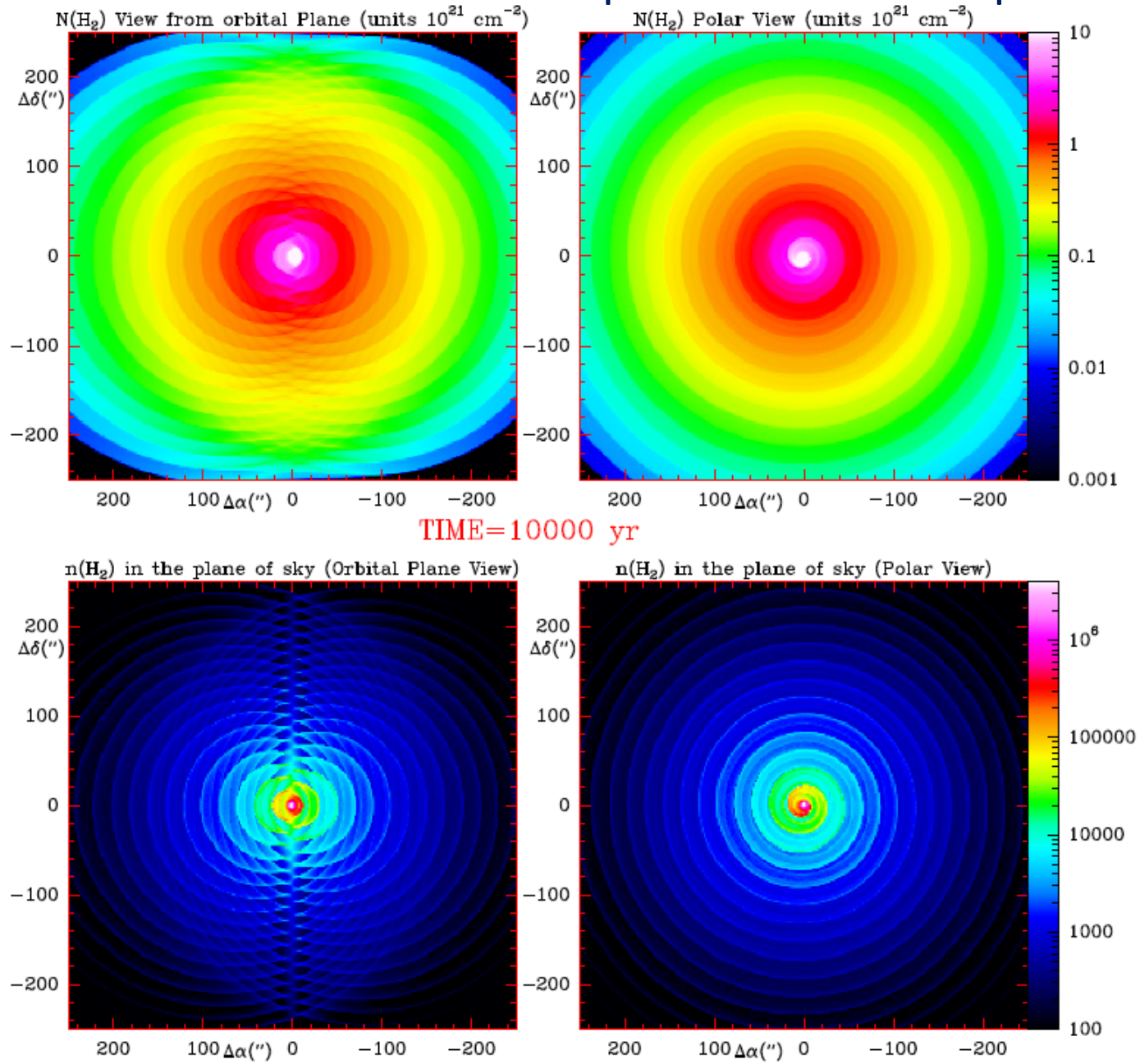

200″
Asymmetries

Derived Properties (1)

- **Mass loss rate**:
  - Large (>3) "short" term variations. Periodical?
  - Mild (≤ 2) "Long" term variations
    - $\dot{M} \approx 2\ 10^{-5}\ M_o$ **/yr** at t< 400 yr *(Agundez et al. 2012)*
    - $\dot{M} \approx 3.5\ 10^{-5}\ M_o$ **/yr** at t=2000 yr
    - $\dot{M} \approx 1.5\ 10^{-5}\ M_o$ **/yr** at t=4000 yr
    - $\dot{M} \approx 2\ 10^{-5}\ M_o$ **/yr** at t>8000 yr *(Mamon et al. 1988)*
- **Envelope mass** (180" or 8000 yr): $M \approx 0.16\ M_o$

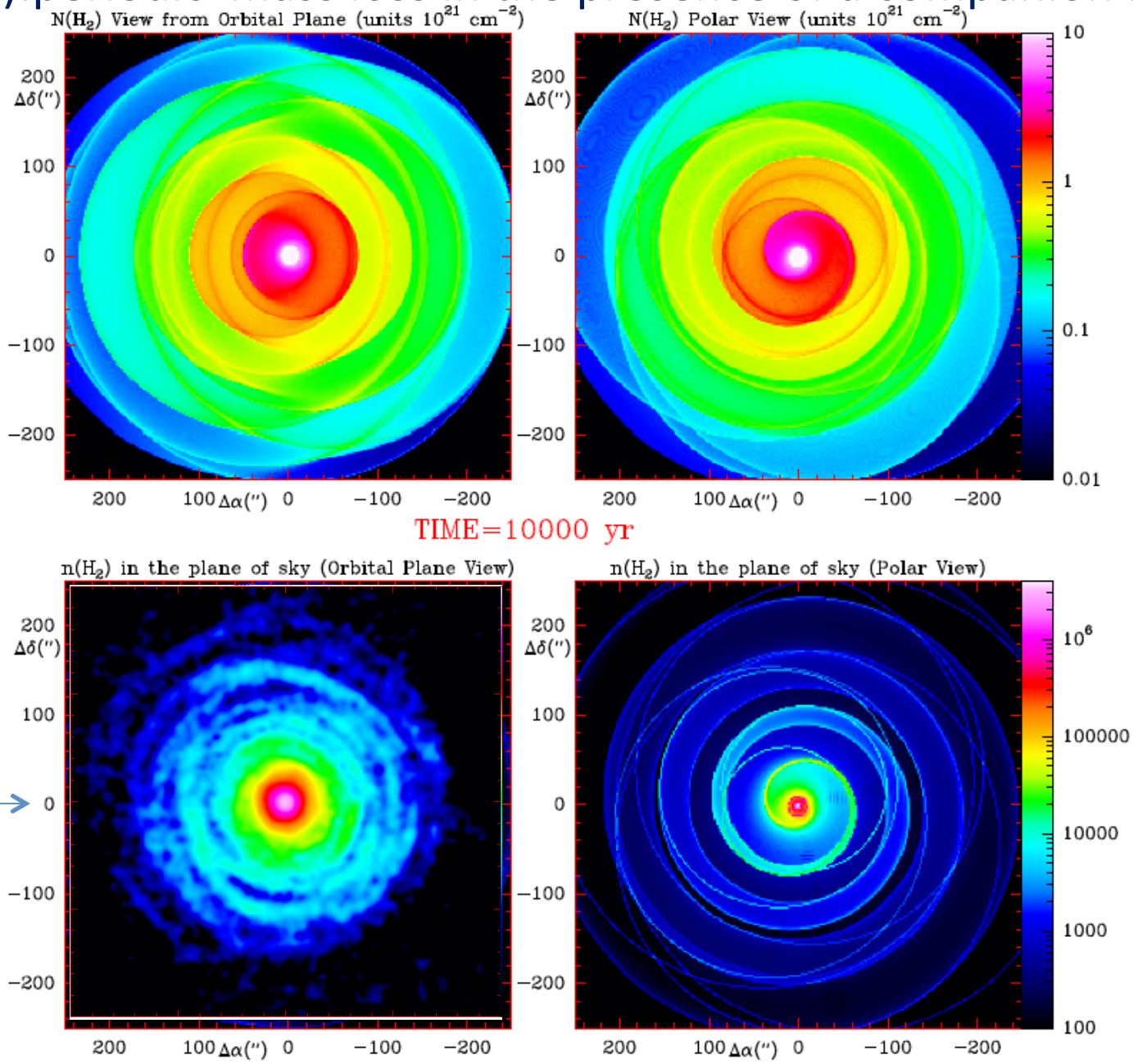
  since 70000 yr: $M \approx 1.4\ M_o$
- **NE/SW asymmetry & Non concentric shells**
  - →Mass Loss Mechanism?

Simulations 1):continuous mass loss in the presence of a companion star



Simulations 2):periodic mass loss in the presence of a companion star

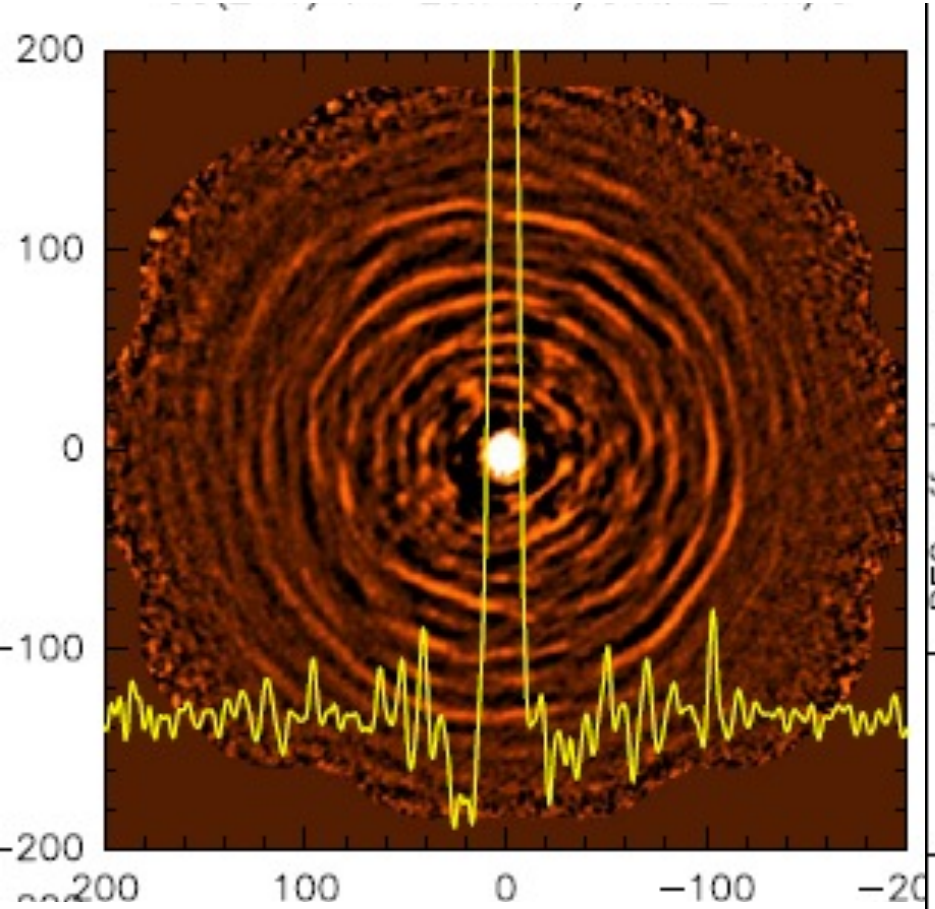
x10 mass loss enhancement caused by the close fly-by of a companion star with an orbital period of 800 yr.

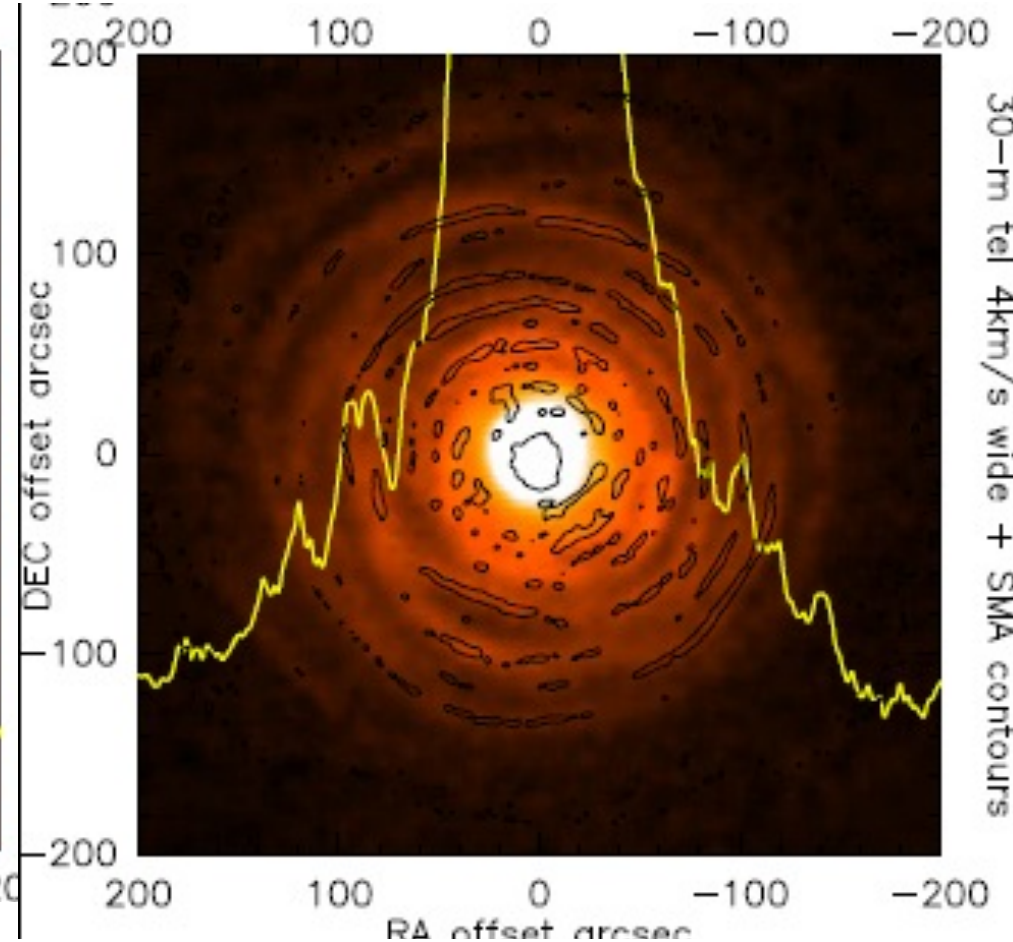


Observed

Cernicharo, Marcelino, Agundez & Guelin. 2014

New observations at the SMA: 157 field mosaic: Compact+SuperCompact configurations. HPBW ≈ 3”

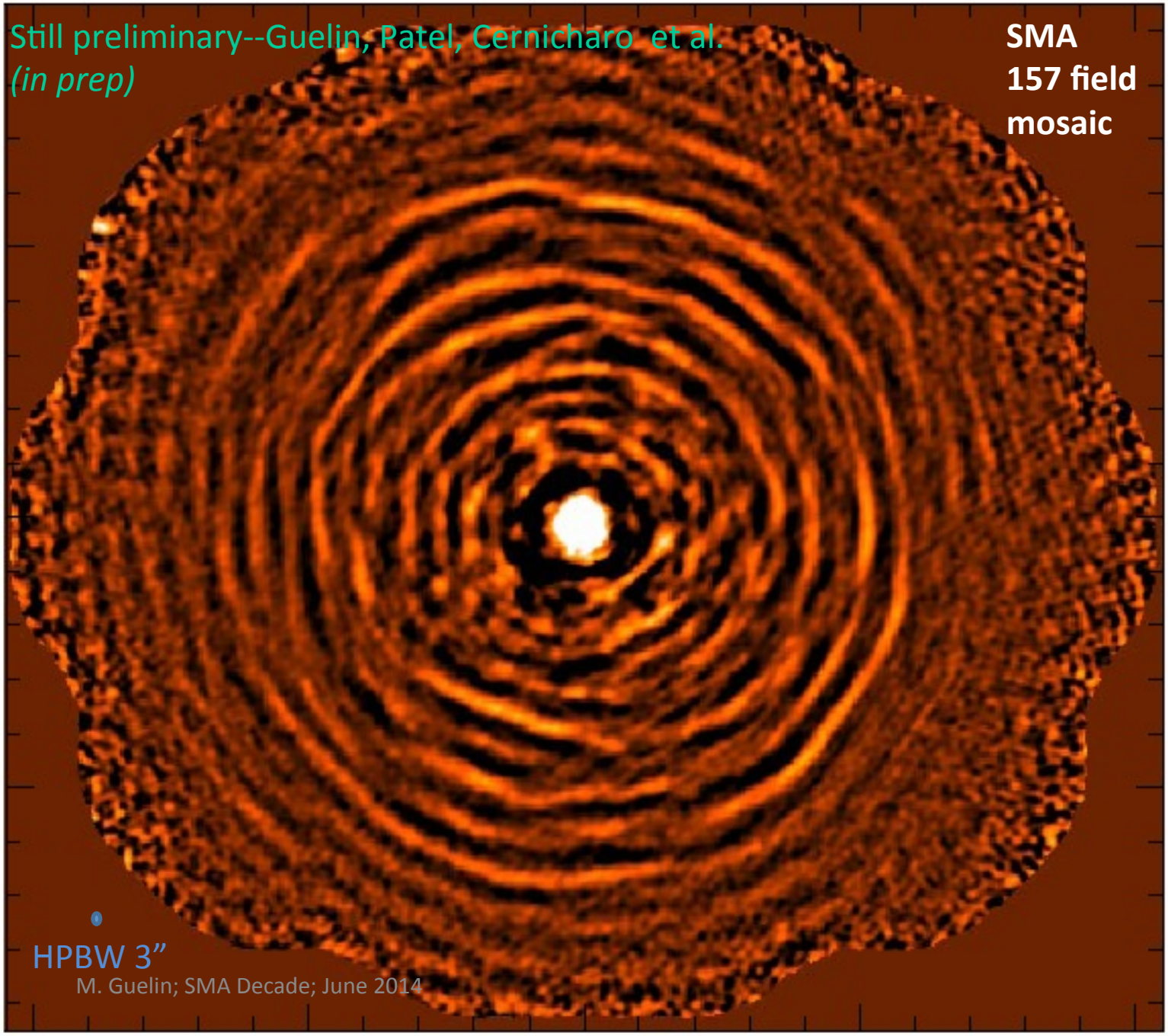




SMA (C+SC) –still preliminary
V=V*

IRAM 30-m
V=V*

CO(2−1) v=−26.7 km/s Δv=2 km/s



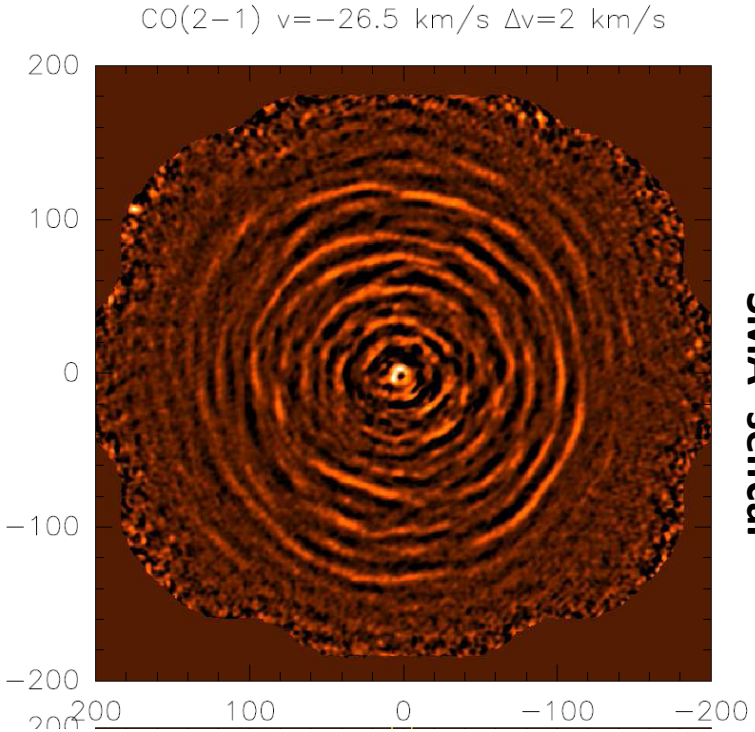
100

0

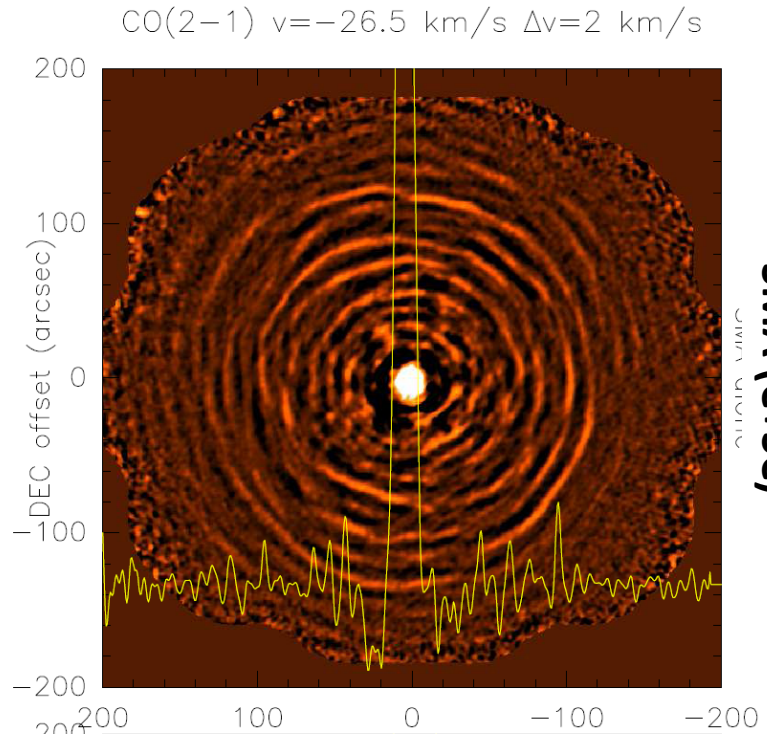
100

config C+D

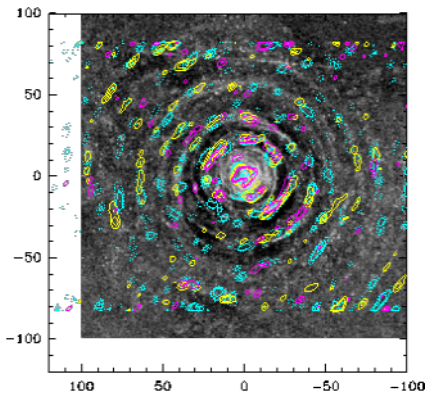
Still preliminary – Guelin et al. (in prep)



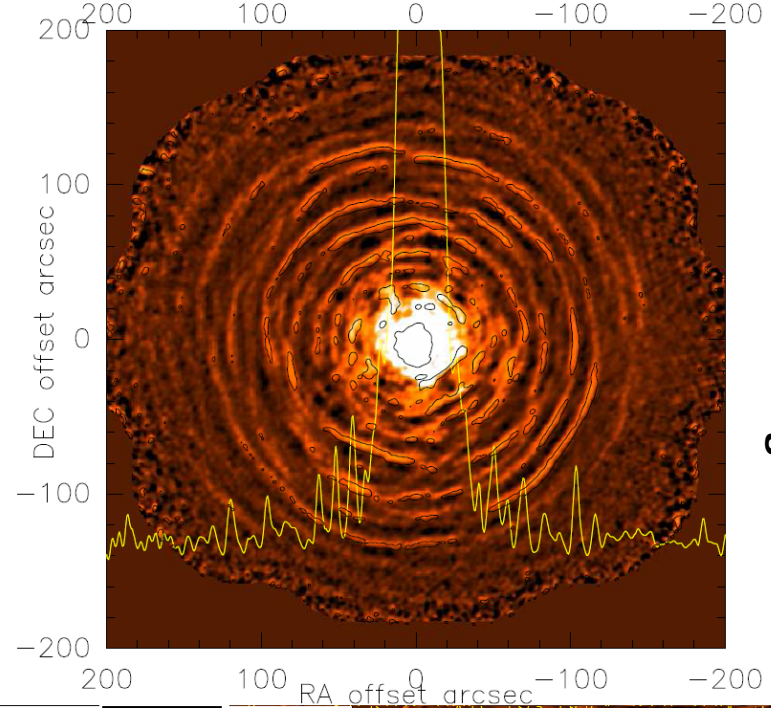
SMA -selfcal



SMA (C+SC)

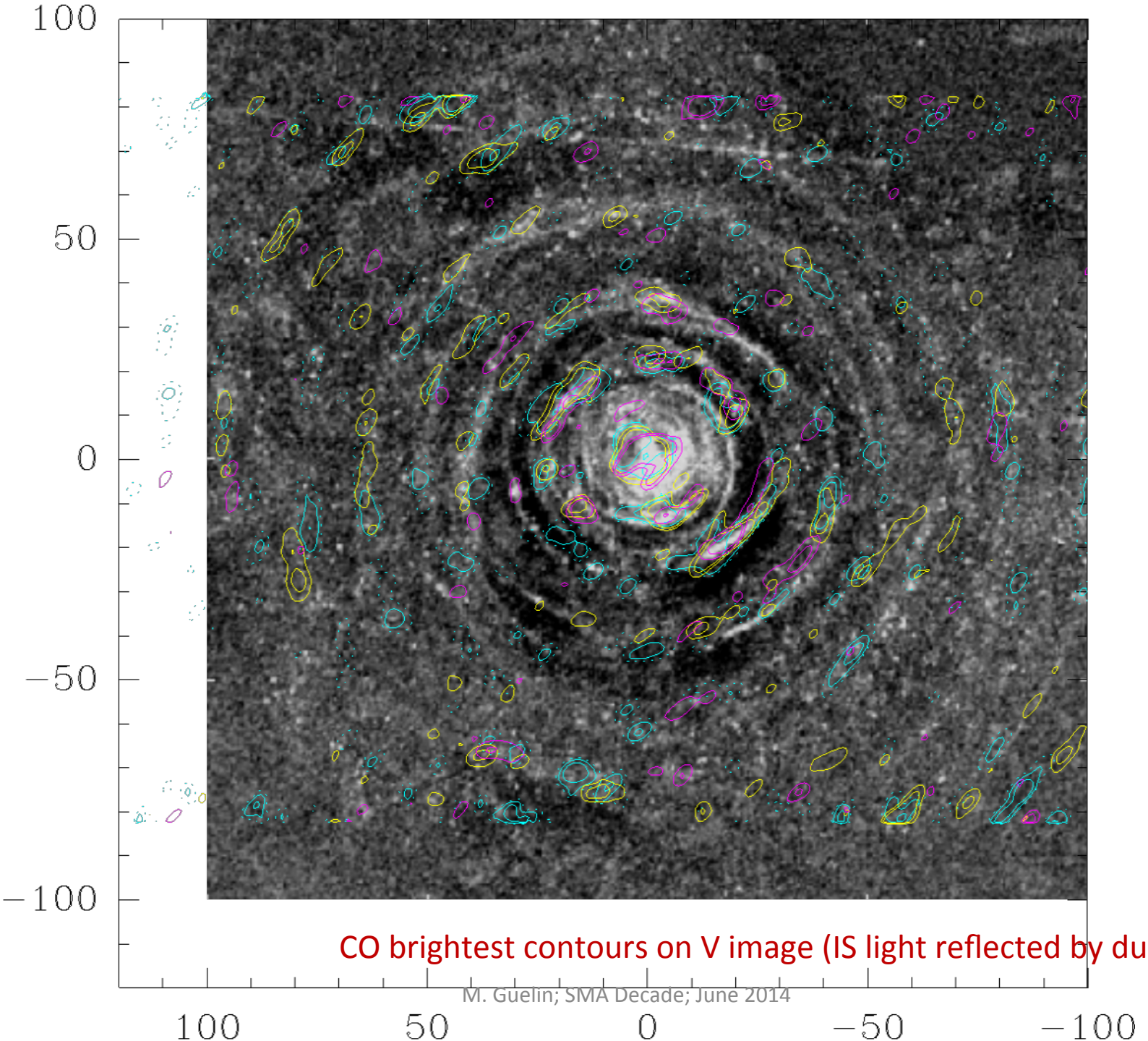


CO(2-1) highest contours on dust (V-band image)

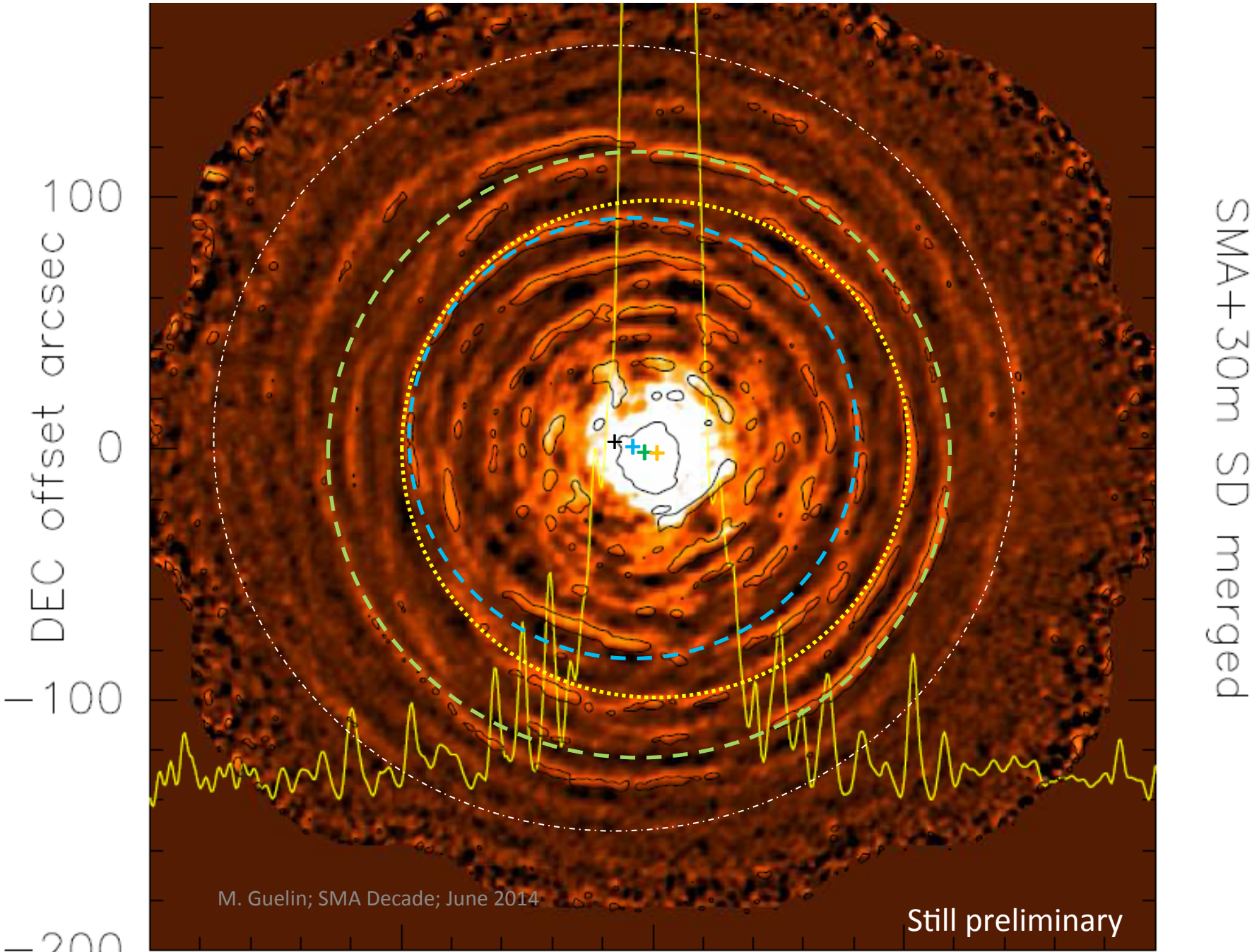


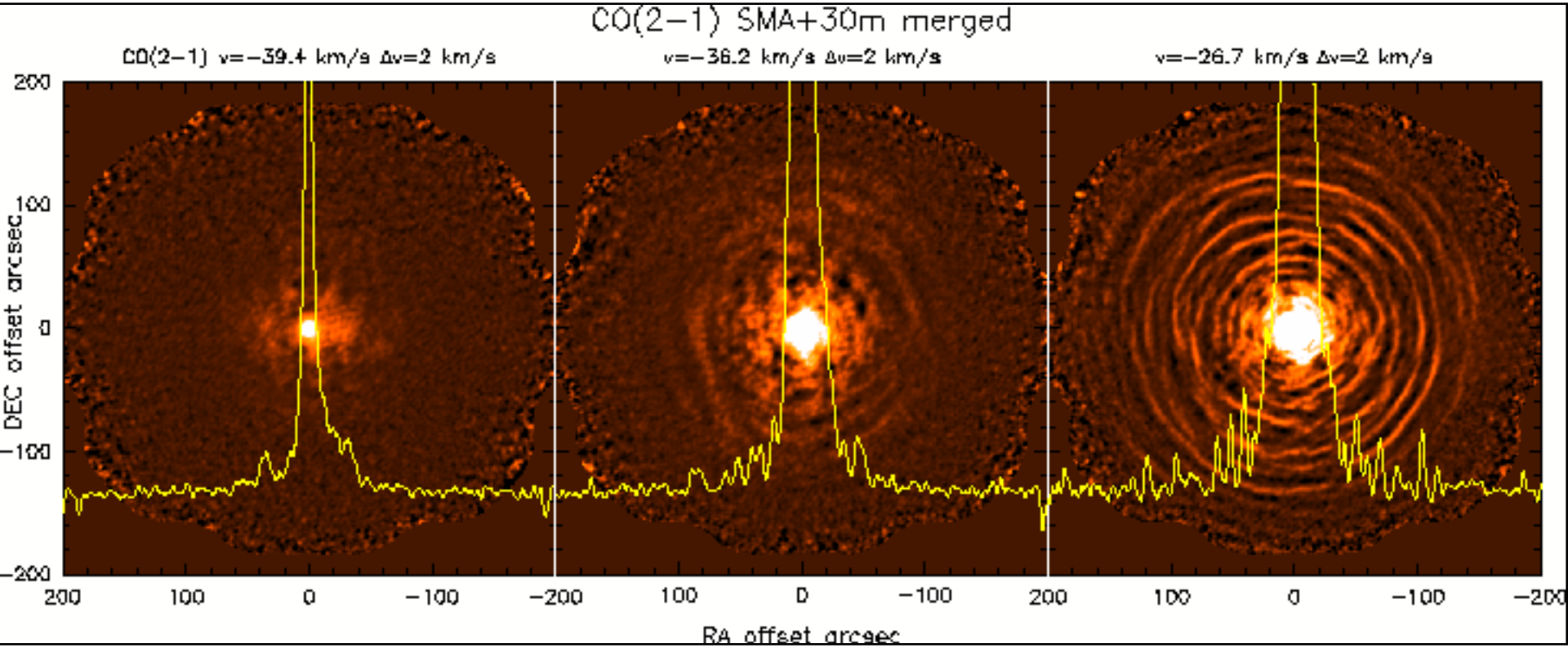
SMA+30-m merged

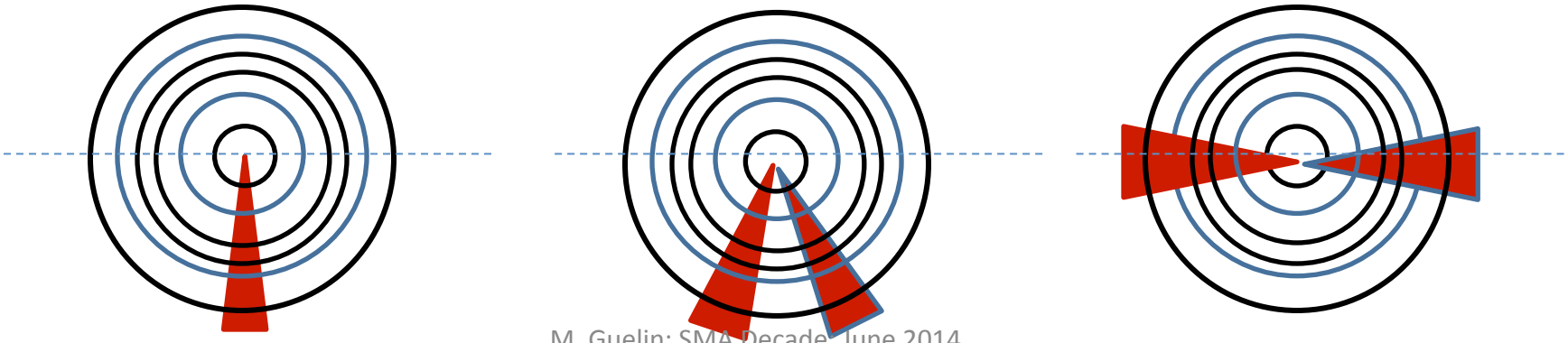
M. Guelin; SMA Decade; June 2014



CO brightest contours on V image (IS light reflected by dust)


SMA+30m SD merged
DEC offset arcsec
100
0
−100
−200
M. Guelin; SMA Decade; June 2014
Still preliminary


CO(2−1) SMA+30m merged
CO(2−1) v=−39.4 km/s Δv=2 km/s
v=−36.2 km/s Δv=2 km/s
v=−26.7 km/s Δv=2 km/s
DEC offset arcsec
RA offset arcsec
200
100
0
−100
−200



Derived Properties (2)

- Shells are **thin** (≈5”)
- Shell spacing appears much more **regular**
- Typical inter-shell time **800 yr**
- Shells are **not concentric** (confirmed)
- Shell-intershell density **contrast ≥ 10**

→ Can all be accounted for by periodic mass loss caused by the fly-by of a *companion star* on an elliptical orbit.

- Next steps: merge with higher resolution CO(2-1) PdBI and ALMA data (in progress); make CO(1-0) interferometric maps; CO(3-2)?