SWIMSとALMAでつなぐ系内外のガス・星形成の統計研究

S. Komugi (NAOJ Chile Observatory)

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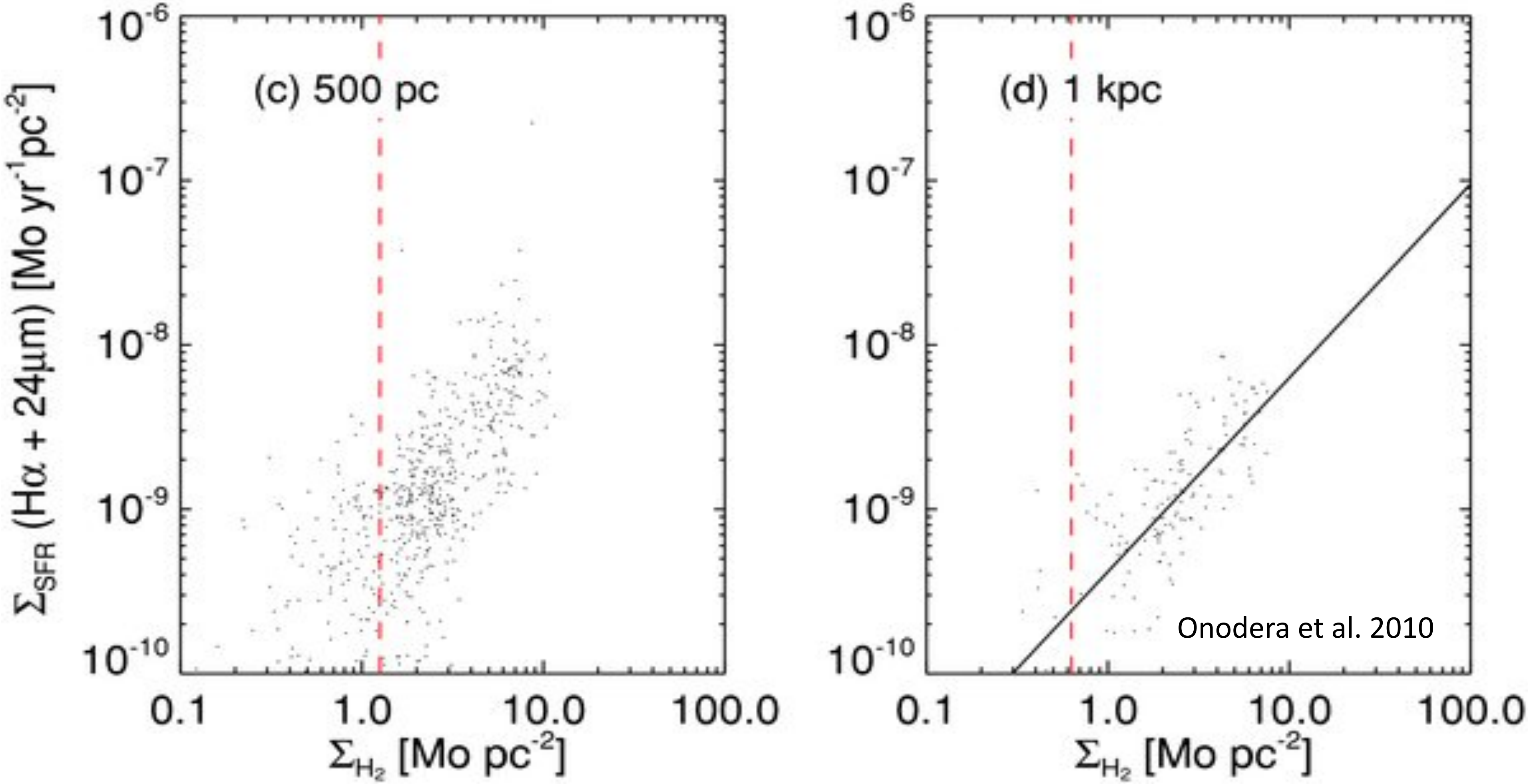
観測提案

- SWIMSで近傍の銀河をPaα NB imaging
- みんなが基準にするようなサンプル数 ~200
- 最初っからレガシー

- Local universeのSFRを個別領域で精密測定
- 星形成–星間物質の相変化の統計的理解

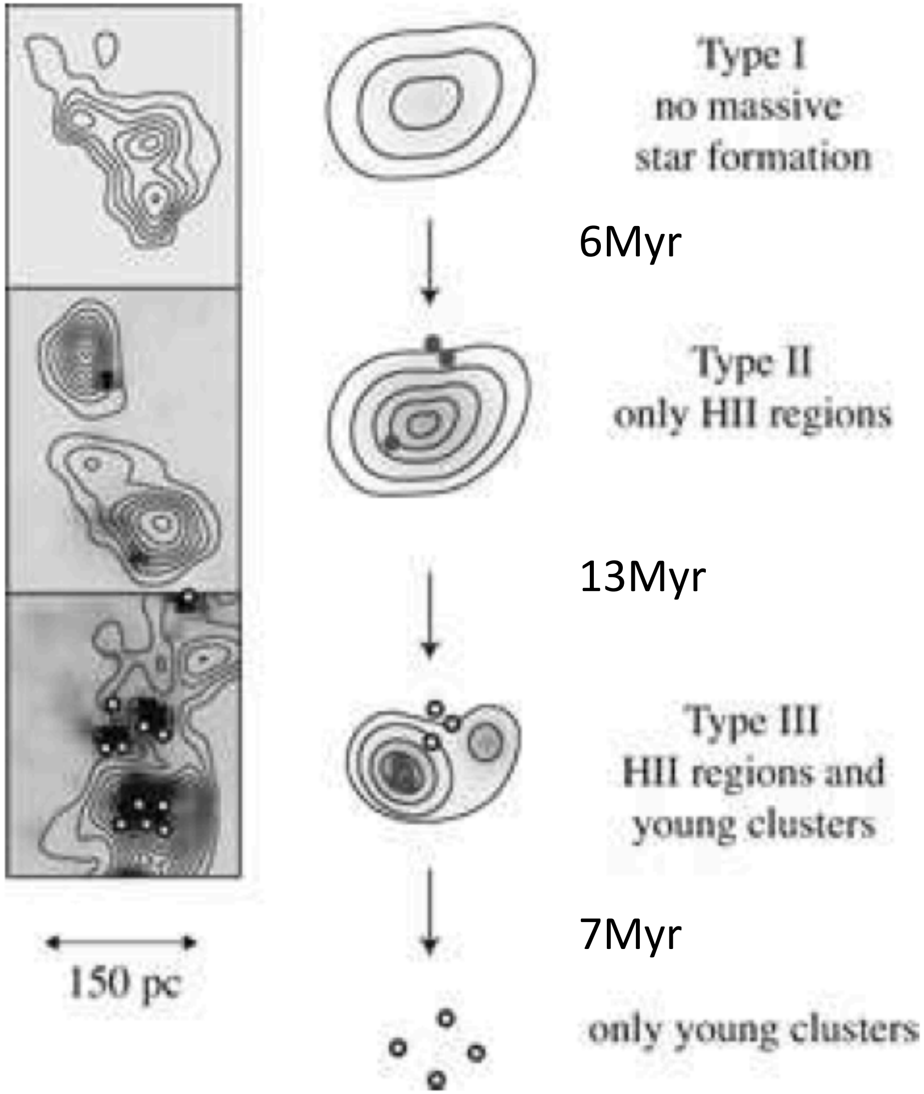
Schmidt-Kennicutt relation within M33



・100パーセクスケールではSK則が壊れる
・分子雲の平均に対する統計的性質としてのSK則

Schmidt-Kennicutt relation within M33

・分子雲進化の影響？
10Myr程度で進化
(Kawamura+ 09, Miura+ 12)



Kawamura+ 2009

High density gas tracer vs. SF

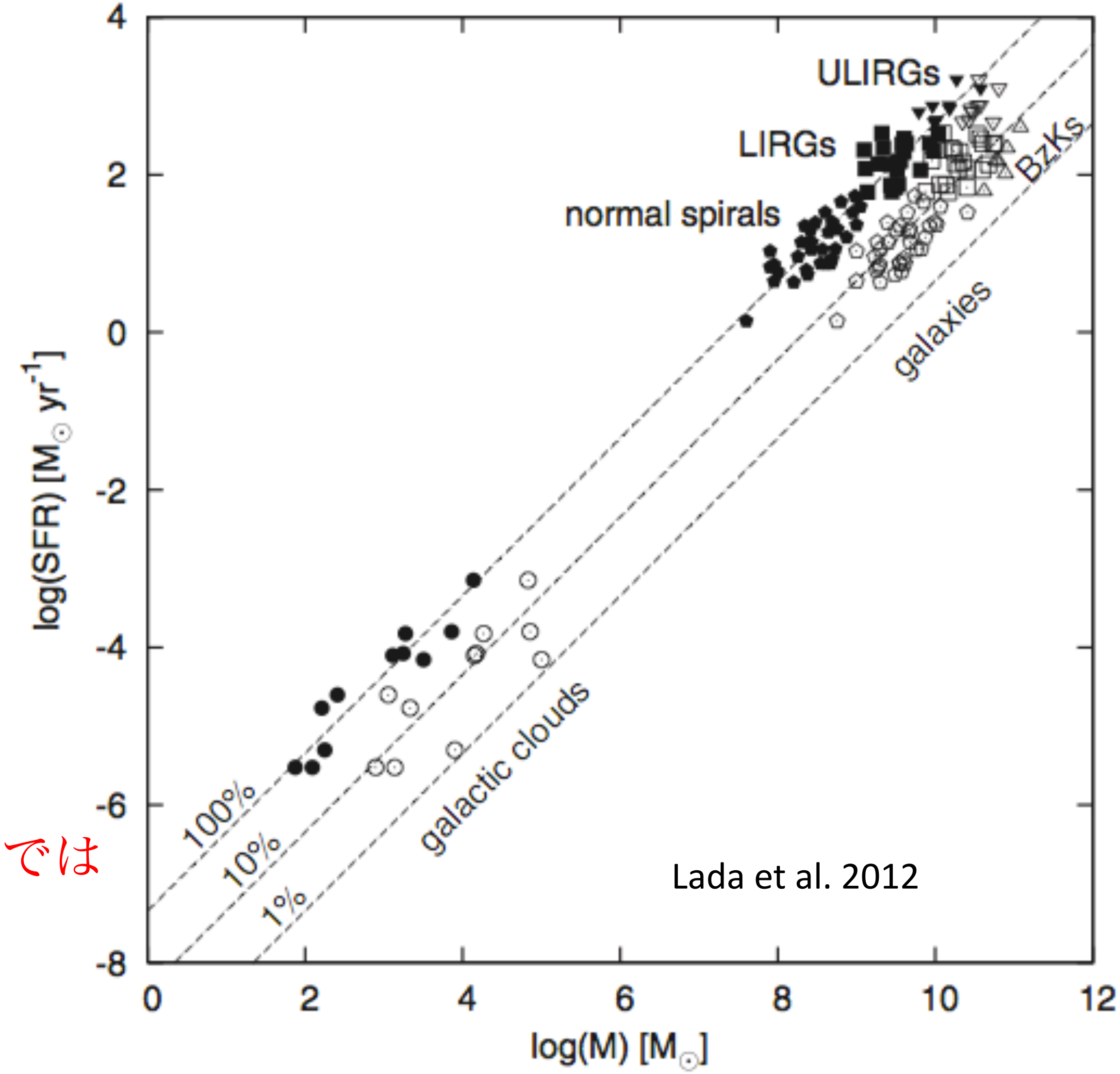
・dense gasに対するlinearなscaling relation (Gao+ 04, Komugi+ 07)

・dense gas fractionがSFをdriveしている(Lada)

・dense gas → SFのタイムスケールは一定？

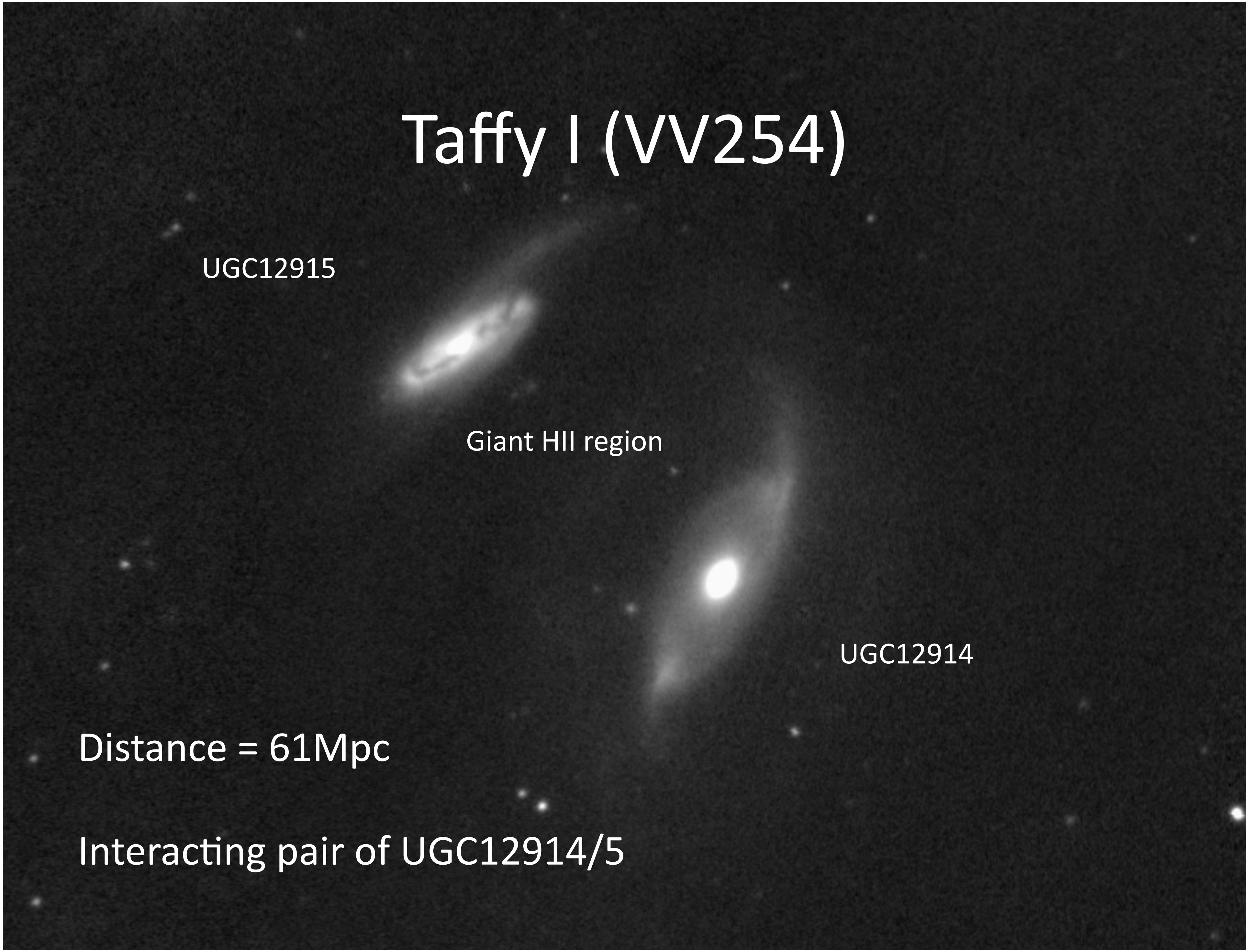
・しかしscatterは有意

・タイムスケールの影響を確かめるためには、例えば“年齢のそろった星形成領域ではSK則は有意にtightである”を示してもいい。



Lada et al. 2012

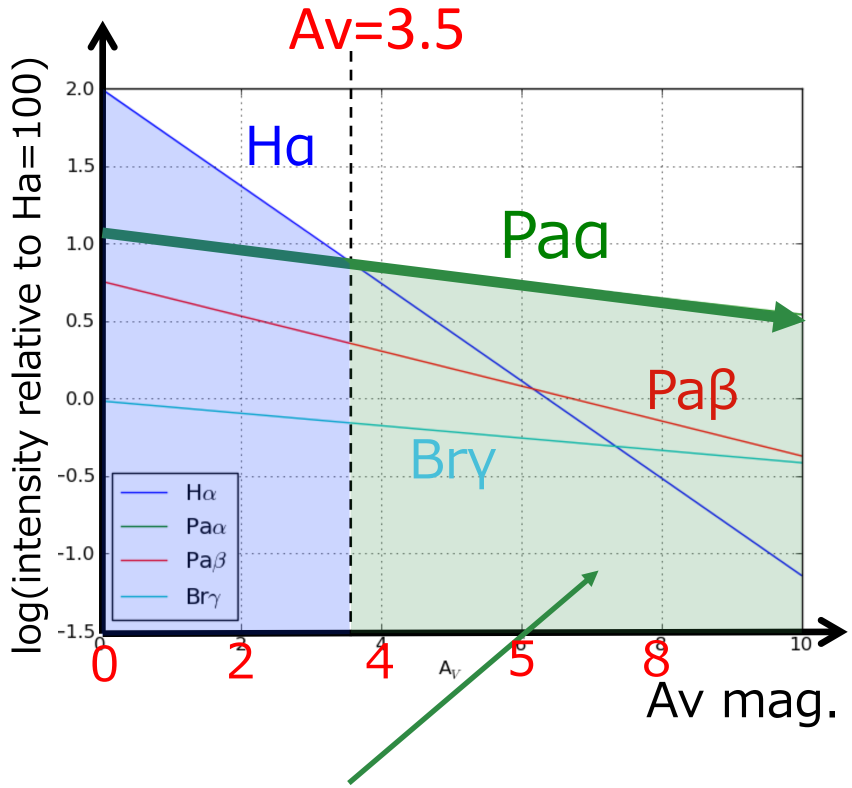
Taffy I (VV254)



Distance = 61Mpc

Interacting pair of UGC12914/5

Observing through dusty star formation using the Paα Hydrogen recombination line



Paα is strongest above A_V=3.5

※ assuming CaseB T=10^4 K

Paα at 1.875um;

1. Directly trace star forming regions ~10Myr old

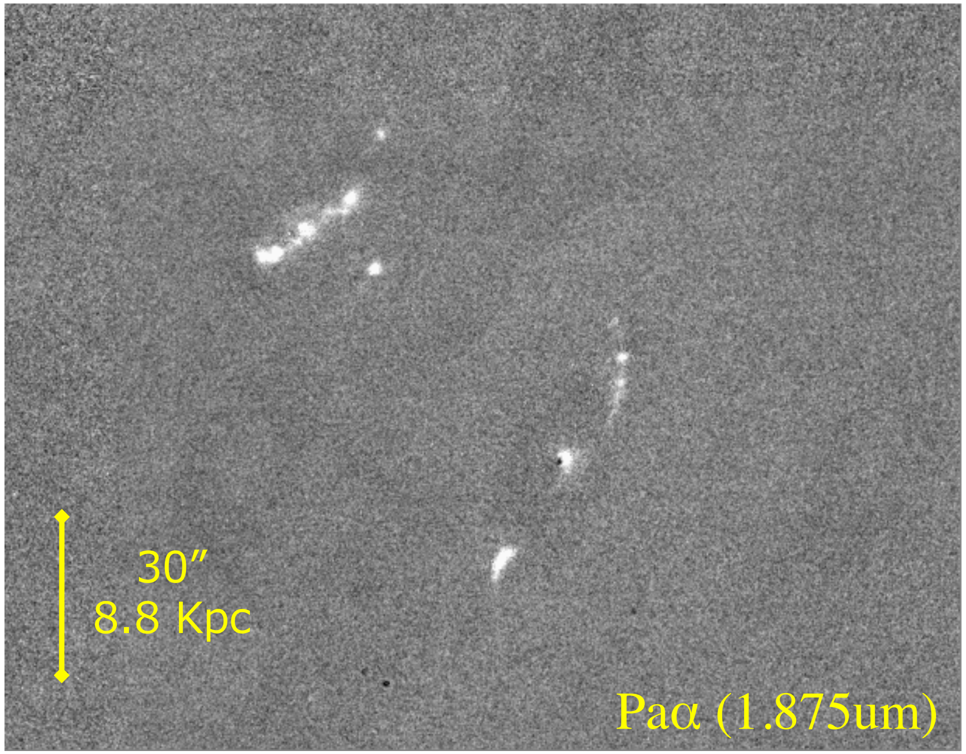
2. Affected less by dust, especially Above Av = 3mag.

3. Strongest among recombination lines in the infrared

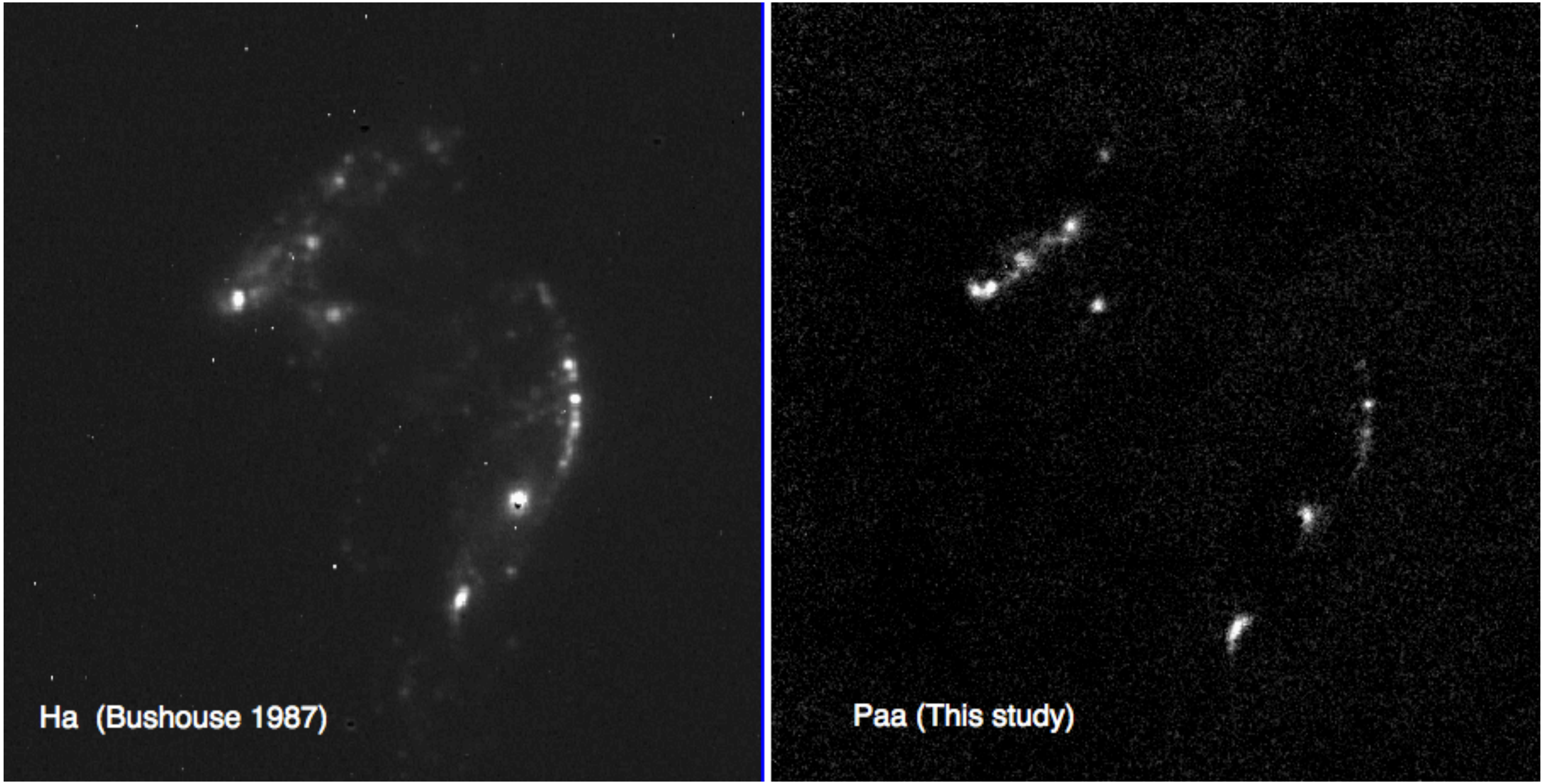
4. Severe water absorption at 1.8-1.9um

• Paα (1.875μm) imaging w/ miniTAO-ANIR

- 2010 Oct.9, 16, 17 (3 nights)
- Paα = 12420s, J = 540s, H, Ks = 2160s (used Paα-off filter@1.91μm to cover redshifted line)
- Seeing ~0”.5
- Continuum subtraction using pseudo-continuum from H+Ks, atmospheric calibration using ATRAN model (Tateuchi et al. in prep.)

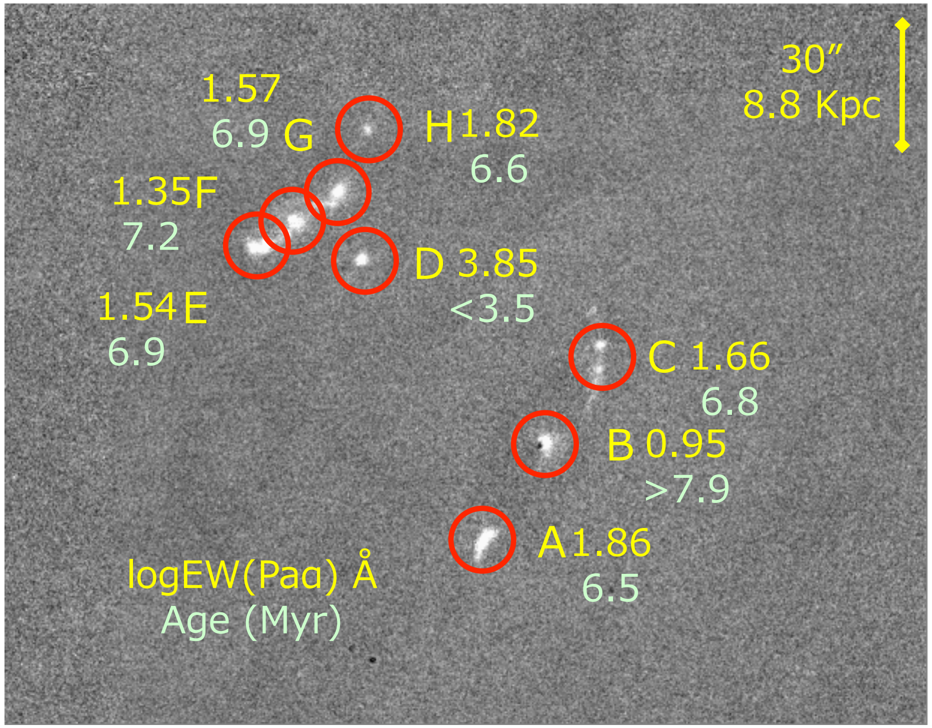


Star Formation in Taffy I

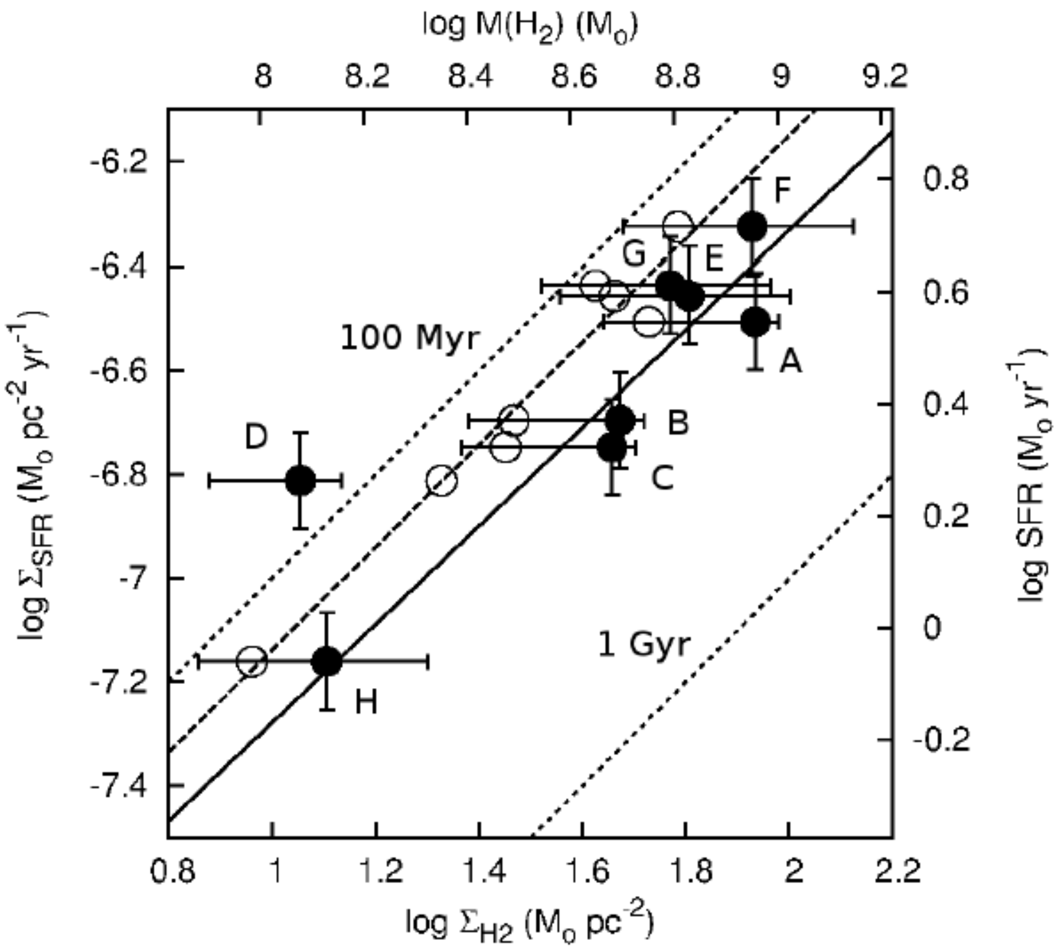


Paα blob age estimation

- Paα equivalent width EW(Paα)
- EW(Paα)-age relation from Starburst99 model
  (Leitherer+99, Diaz-Santos+10)
- 6/8 regions are ~7 Myr old
- bridge HII region is young
- blobs formed stars AFTER
  the collision (20Myr ago),
  AT ONCE except for the bridge



Matched-age SF relation in Taffy I



Komugi & Tateuchi et al. 2012

・small dispersion @ 700pc

σ = 0.06 dex for constant Xco,

σ = 0.1 for varying Xco

c.f. σ = 0.5 in M51 (Liu+11)

σ = 0.4 for M33 (Onodera+10)

・best fit is within uncertainties (25% for SFR, ~factor 2 for Xco)

同年齢の星形成領域ではSK則は有意に分散が小さい

↓

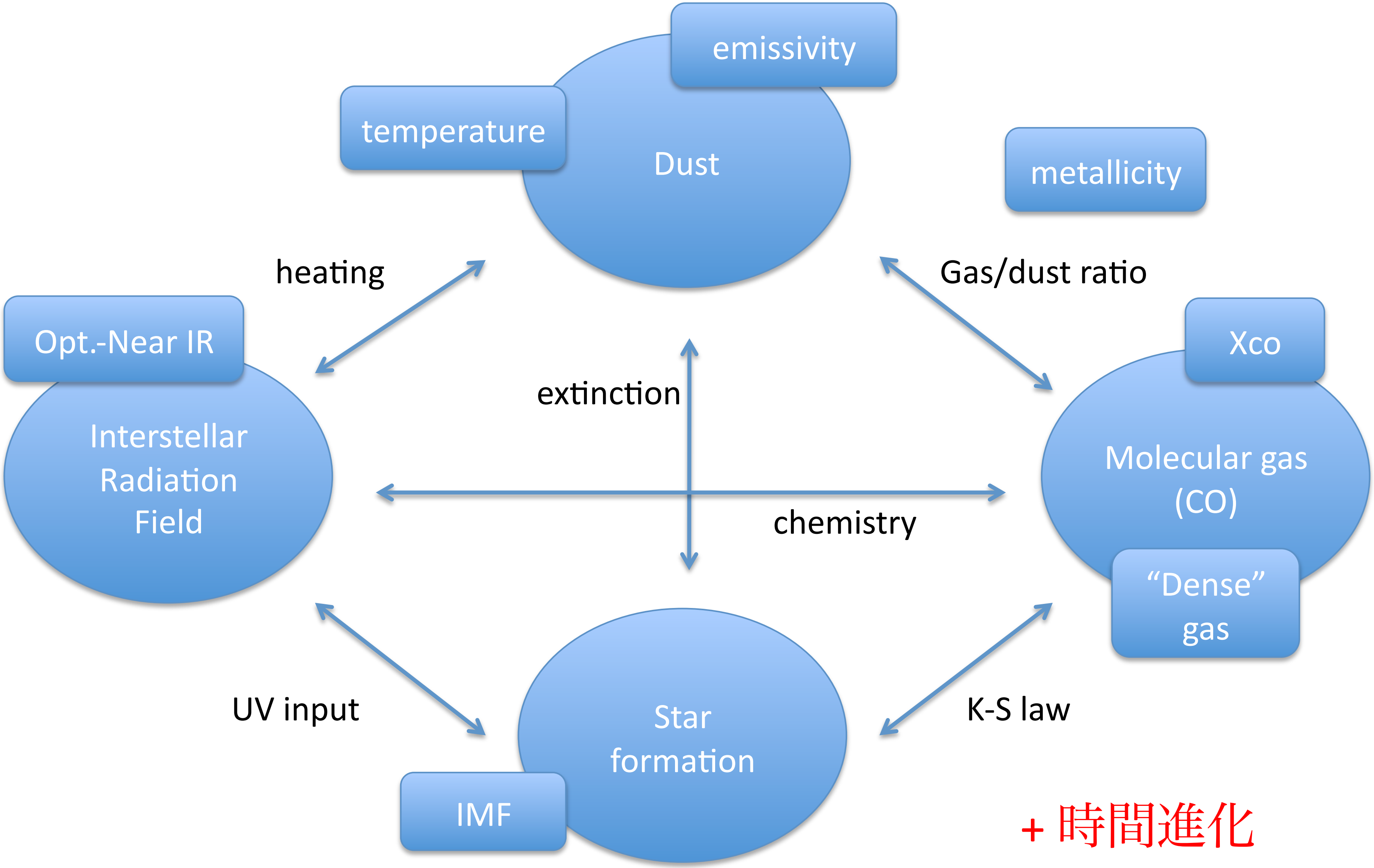
SK則の局所スケールでの分散は、GMCの年齢が関係している。

SWIMSの利点

- Paαのnarrow band imagingが出来る
  - ダスト減光が少ない (Hαがあればなお吉)
  - 簡便な星形成領域の年齢評価

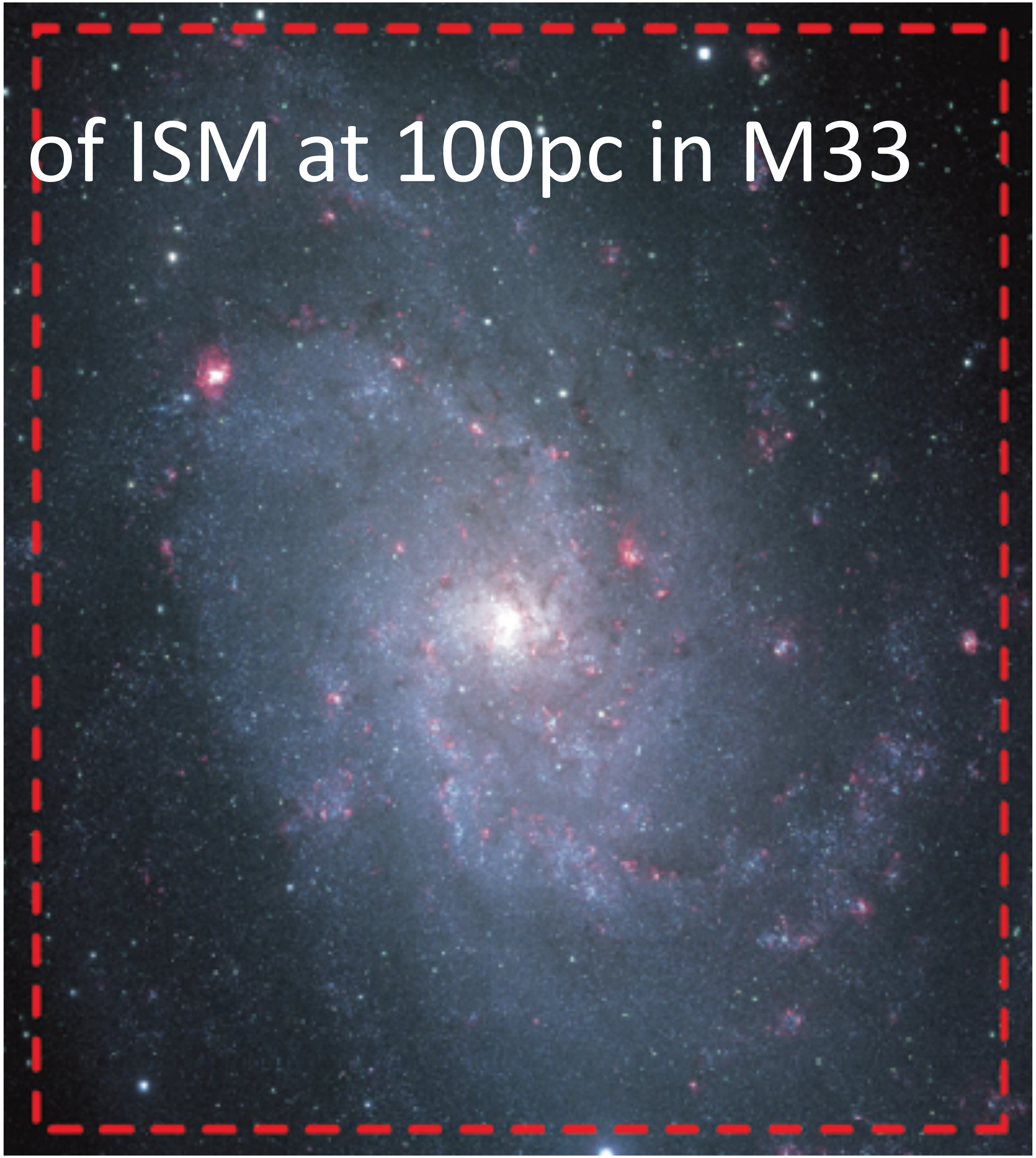
- 視野が広い
  - ANIR: 5’, SWIMS : 6-9’, HST : 1’, JWST : 2’.2

The ISM at GMC scales



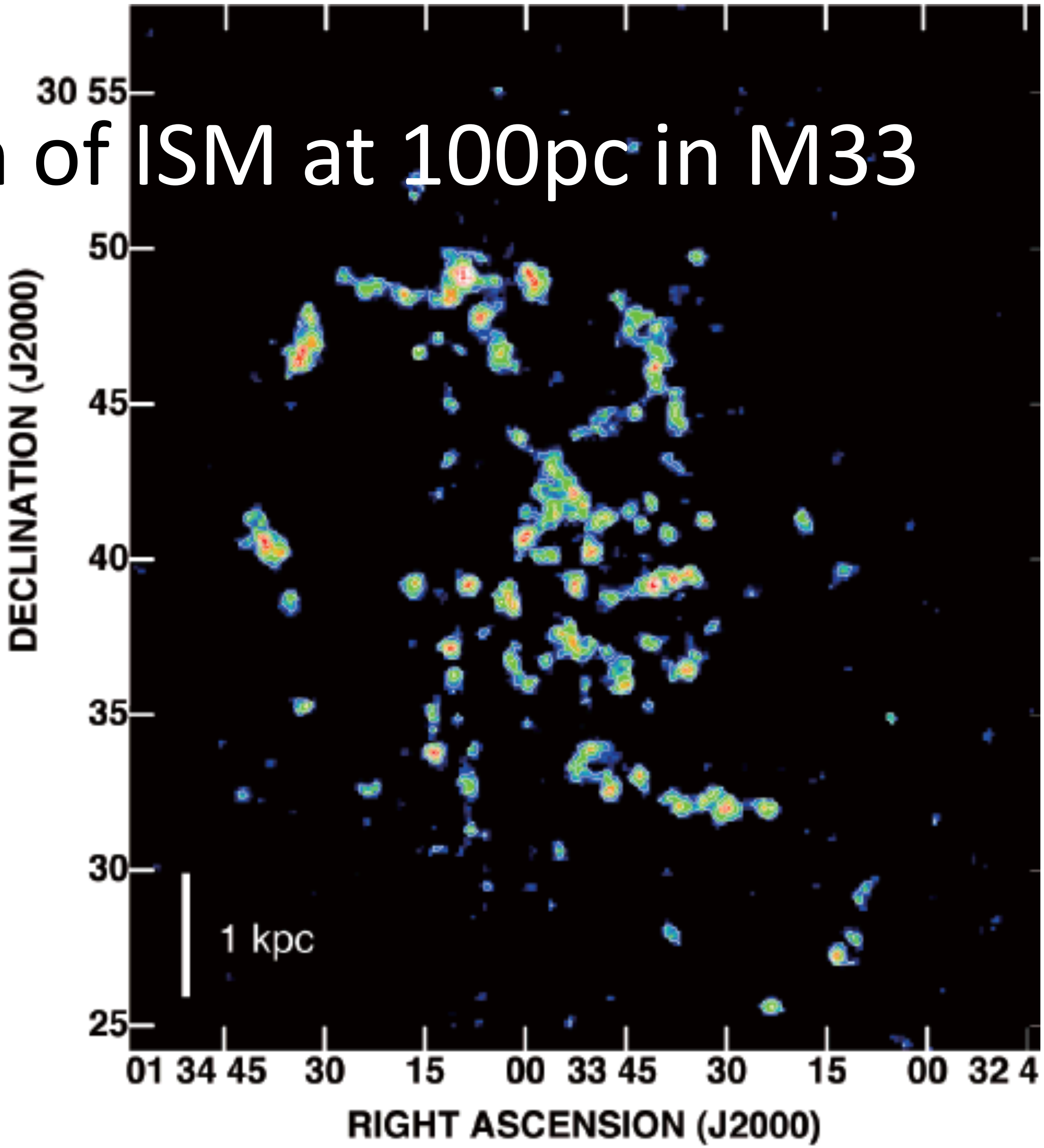
+ 時間進化

Interaction of ISM at 100pc in M33



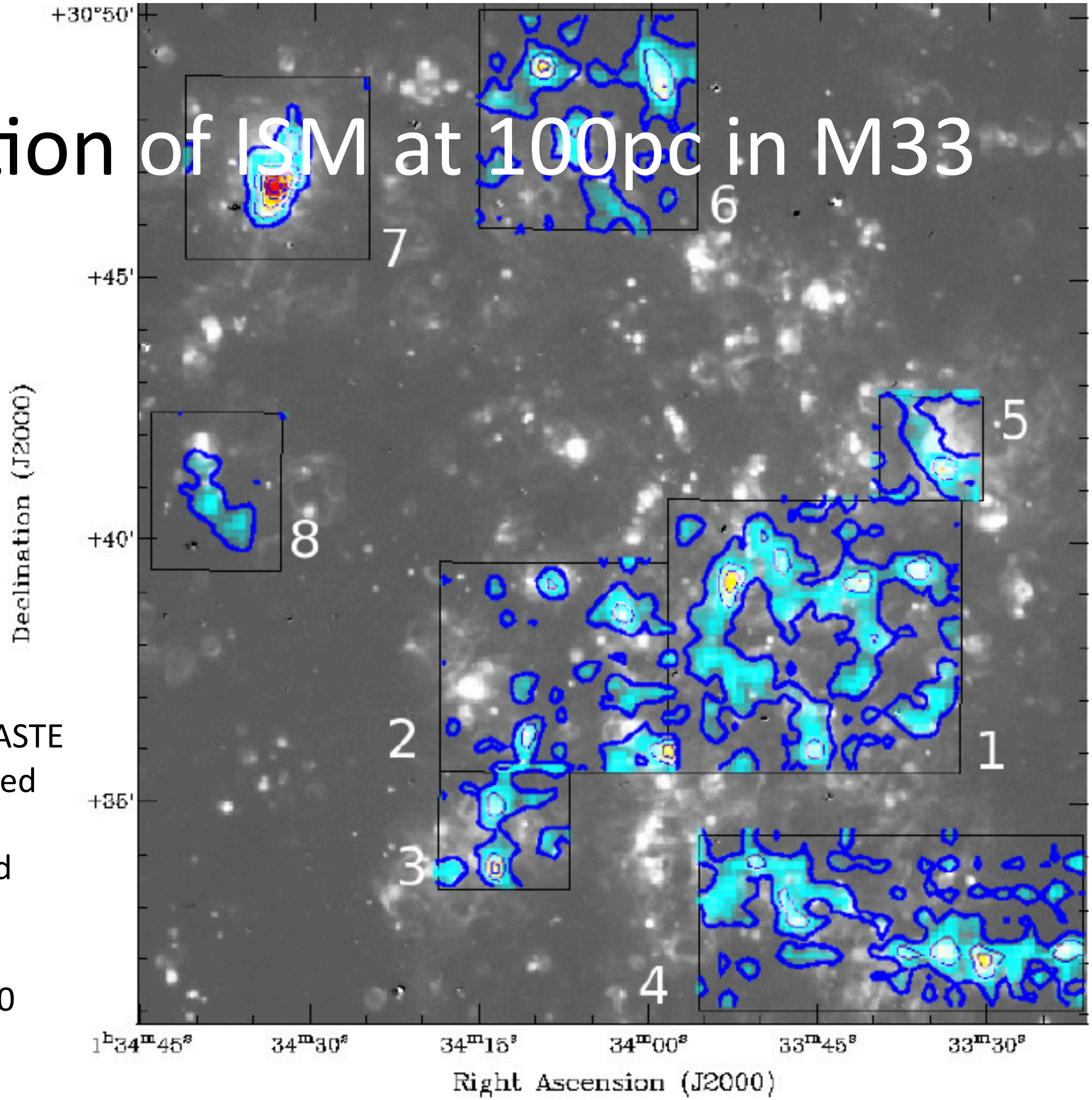
UBVRI @ Subaru Suprime-Cam
Arimoto et al.

Interaction of ISM at 100pc in M33



$^{12}CO(J=1\text{-}0)$ @ NRO 45m
Tosaki et al. (2011)
Catalog in progress

Interaction of ISM at 100pc in M33



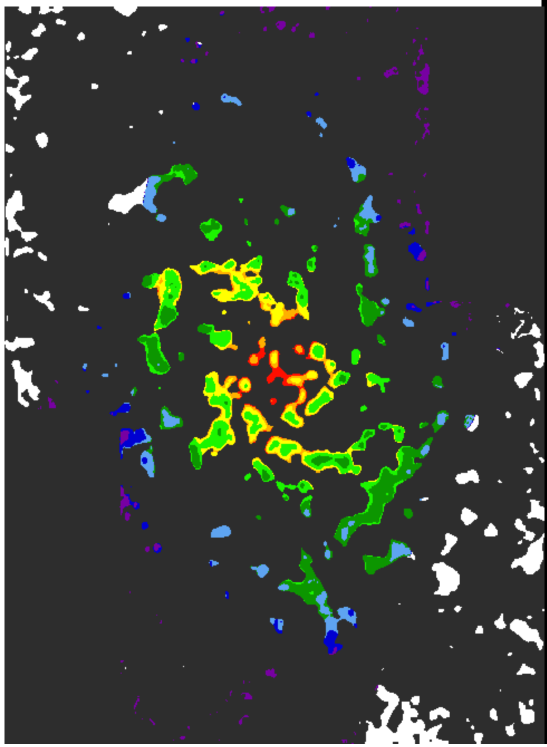
$^{12}CO(J=3-2)$ map @ASTE
Miura et al. submitted

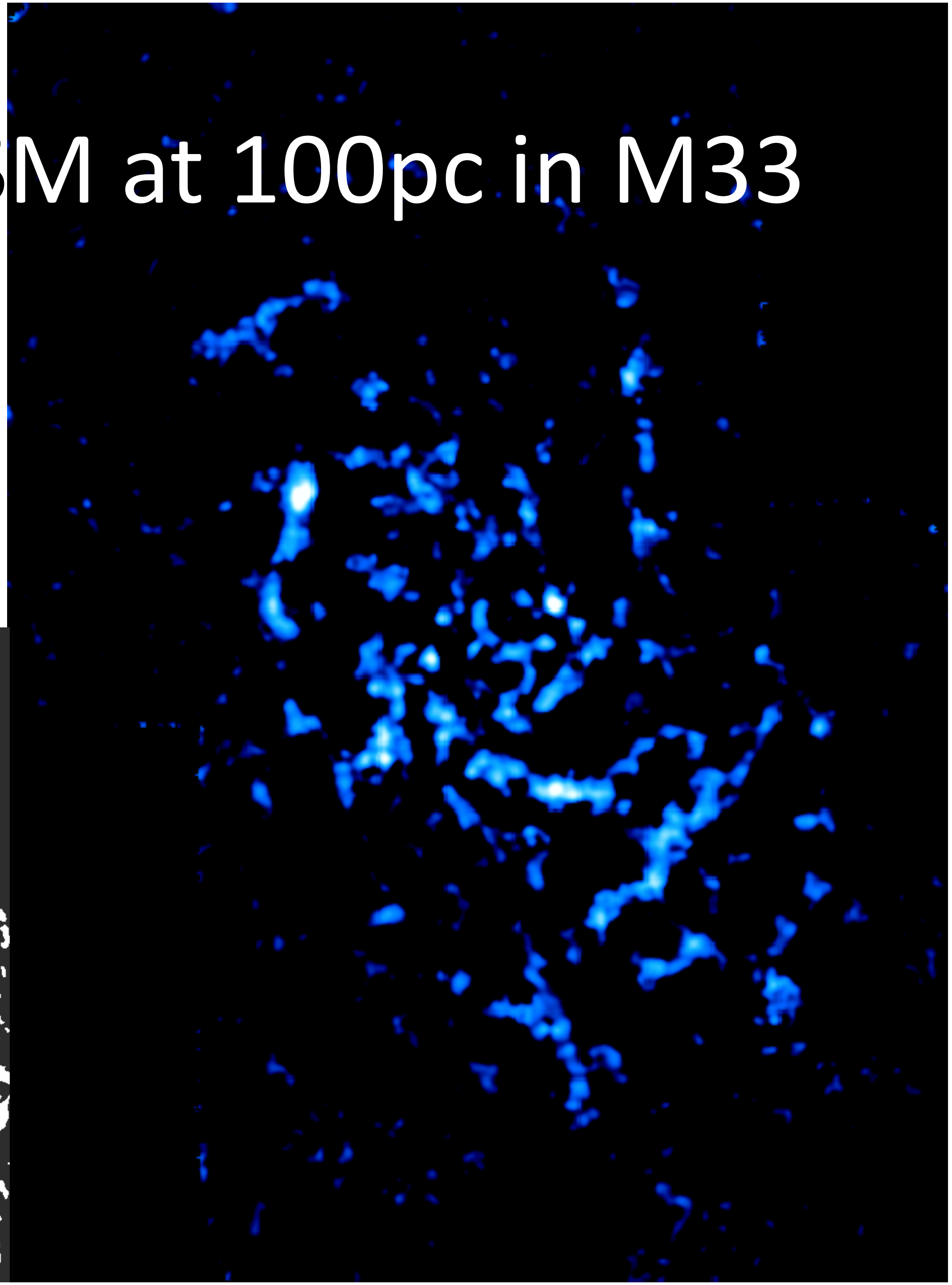
71 GMCs catalogued
L_{co}, r_{maj}, r_{min}, σ_v, T_{mb}

Radius range 20 ~ 40

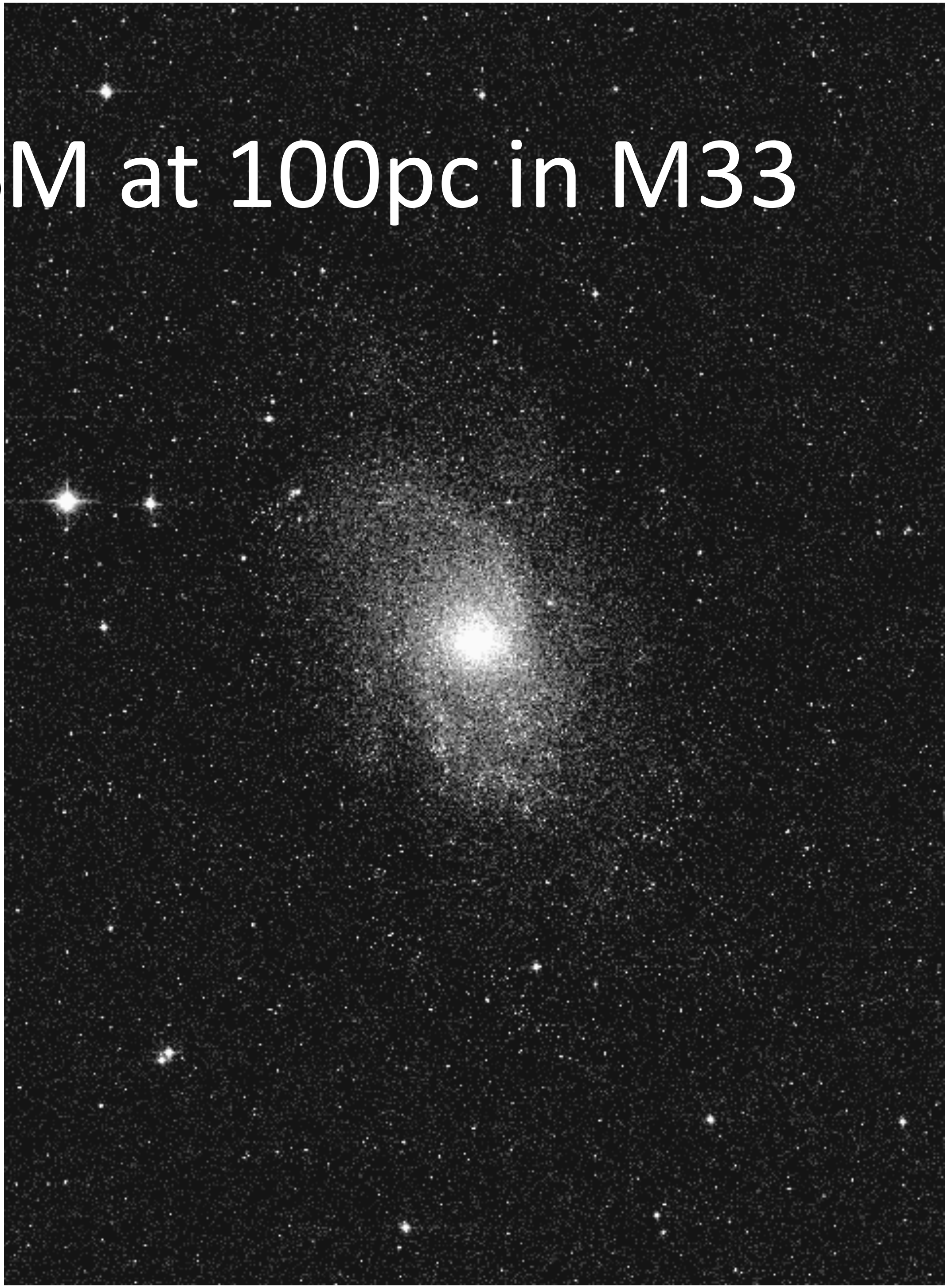
Interaction of ISM at 100pc in M33

1.1mm and dust temperature map
ASTE and Spitzer 160um
Komugi et al. (2011)





Interaction of ISM at 100pc in M33

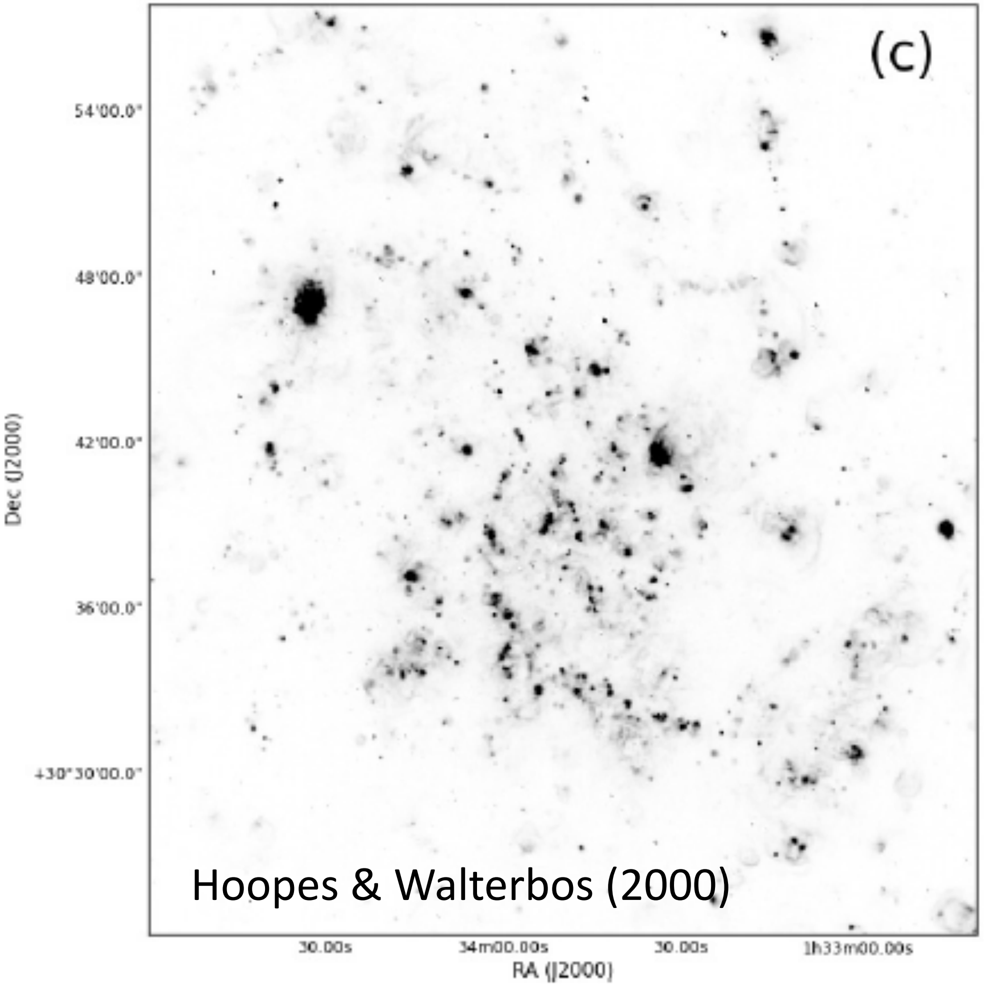


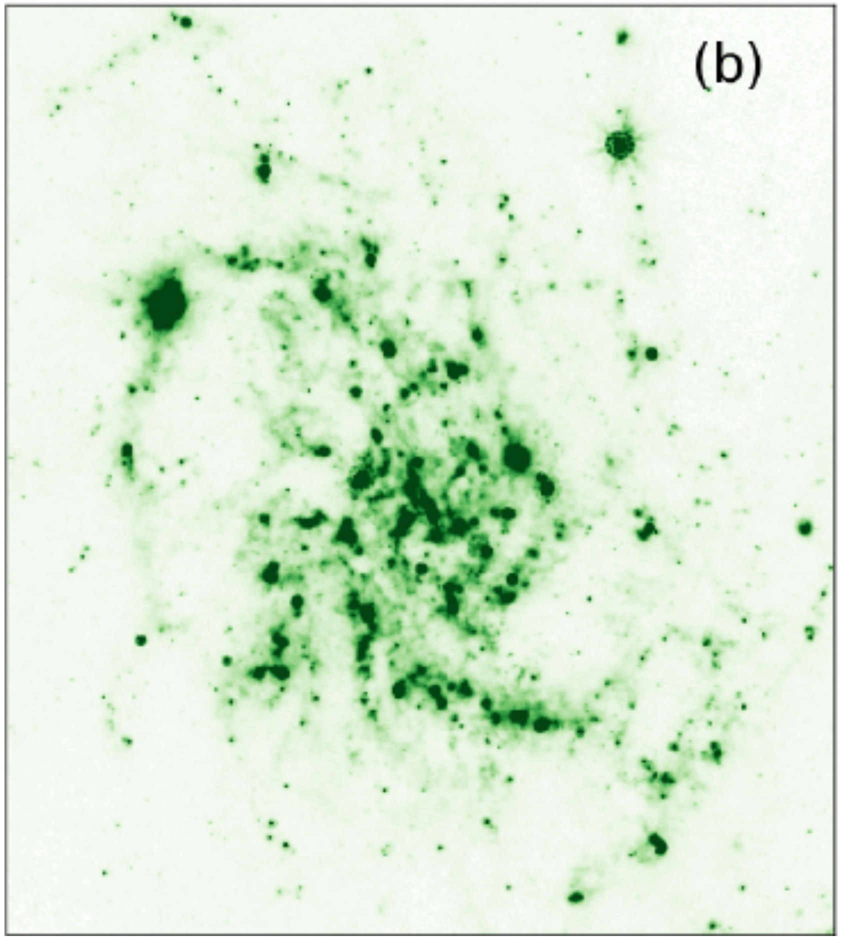
Ks band 2MASS image (2.1um)

Flux from old stellar populations

Interaction of ISM at 100pc in M33

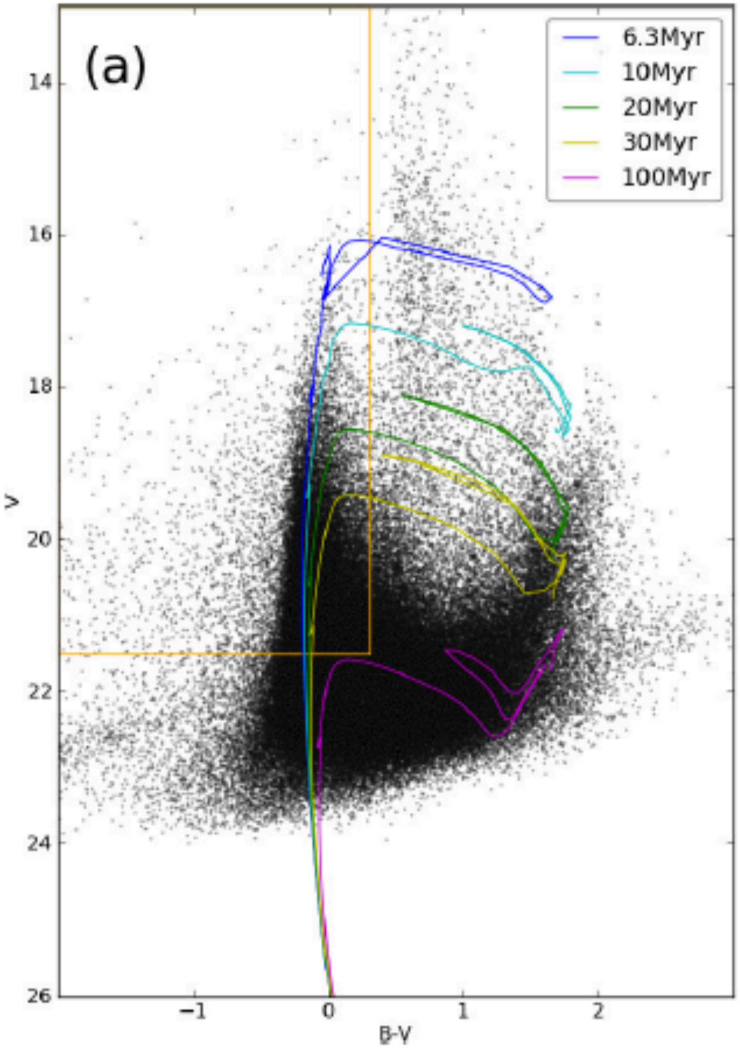
SFR = L(Hα) + 0.031 L(24um) : Calzetti (2007)

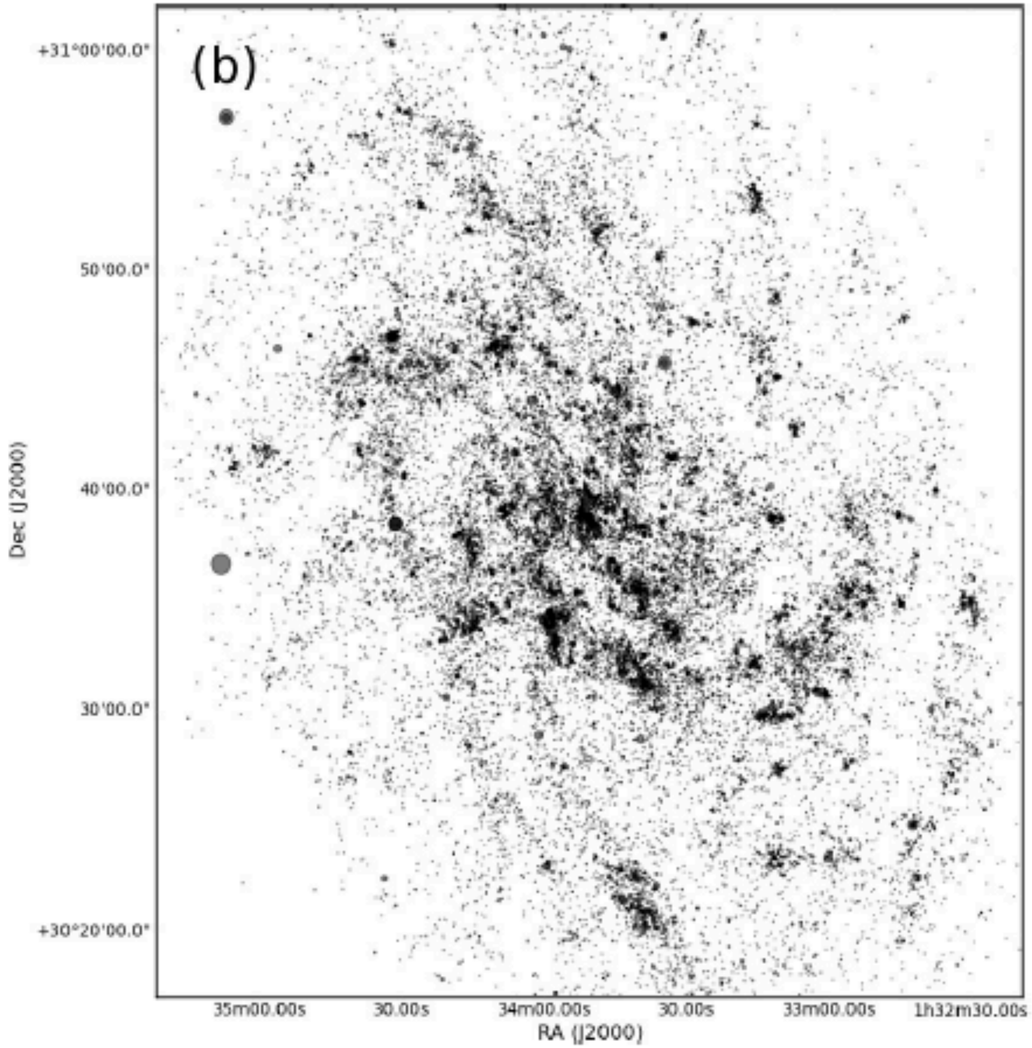




Interaction of ISM at 100pc in M33

BVRI Massey et al. (2006) and Padova Tracks





Interaction of ISM at 100pc in M33

GMC TYPE AND EVOLUTION OF THE GMCs

GMC Type	Observed Signature	Number of GMCs	LMC[a]
A	No H II regions or young stellar groups	1 (2%)	46 (24%)
B	With H II region(s), but no young stellar groups	13 (20%)	96 (50%)
C	With H II region(s) and young (<10-Myr) stellar group(s)	29 (45%)	49 (26%)
D	With H II region(s) and relatively old (>10-Myr) stellar group(s)	22 (34%)	...

[a]GMC Type in LMC (Kawamura et al. 2009). The definition of Types A, B and C in our classification correspond to their Types I, II and III, respectively.

57 GMCs with ^{12}CO(J=1-0) → M_{10} : total molecular gas

^{12}CO(J=3-2) → M_{32} : dense molecular gas

1.1mm → M_{dust} : dust mass (using T_{cold} map and β=2)

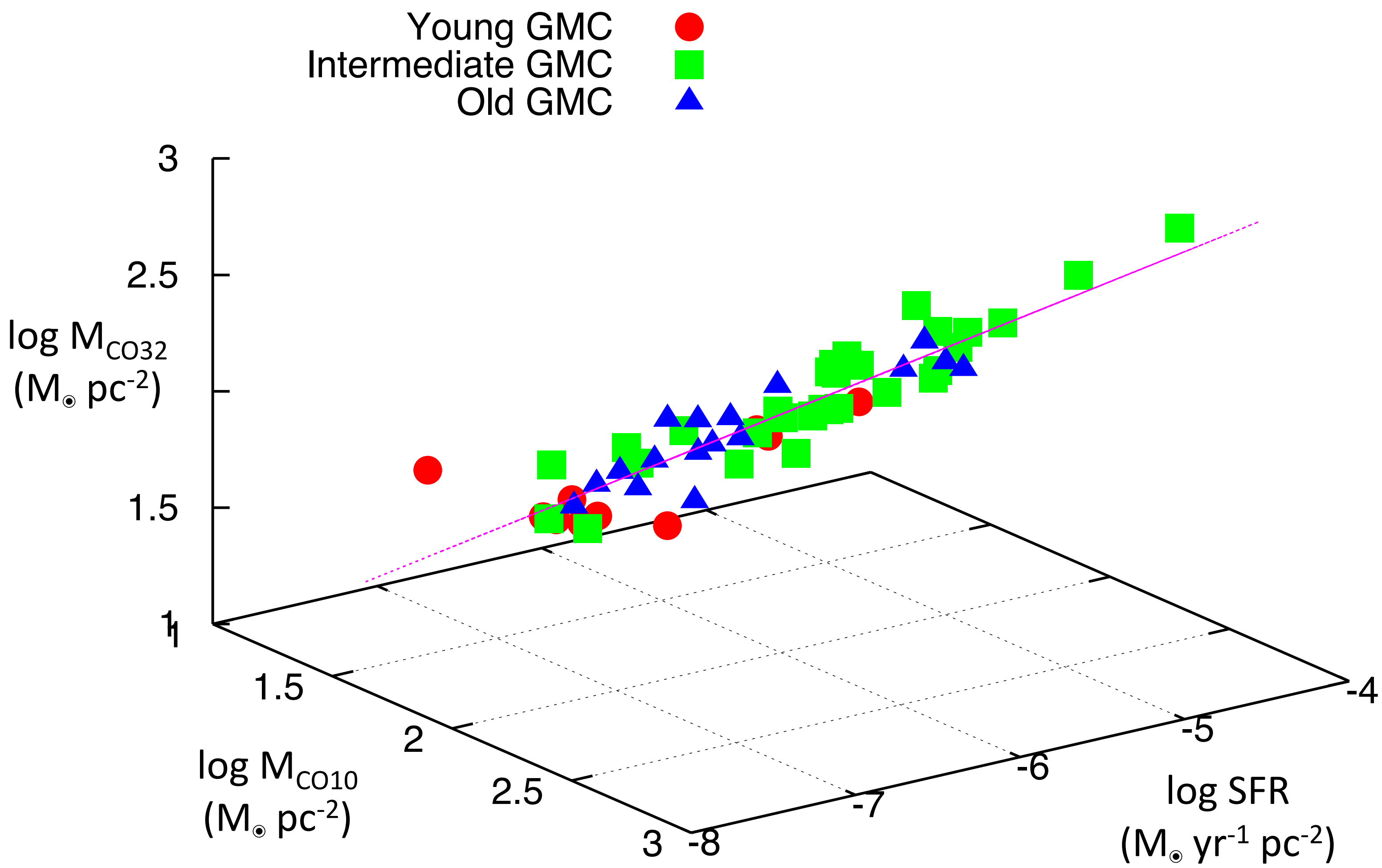
Ks band → K : measure of ISRF from old stellar pop.

Hα, 24um → SFR : star formation rate (UV photon)

Type → B, C, D : evolutionary stage

主成分解析を使って重要なパラメータを選定 → 2つの”平面”

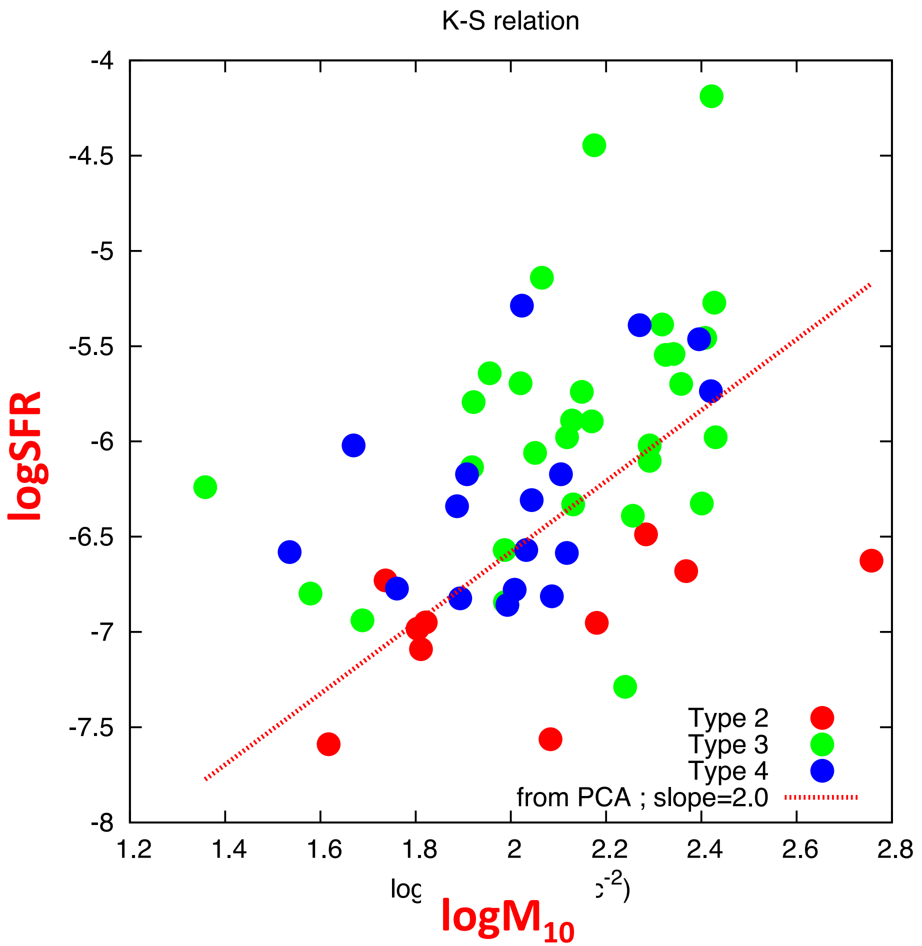
PC5 : SFR-M_{CO32}-M_{CO10} plane

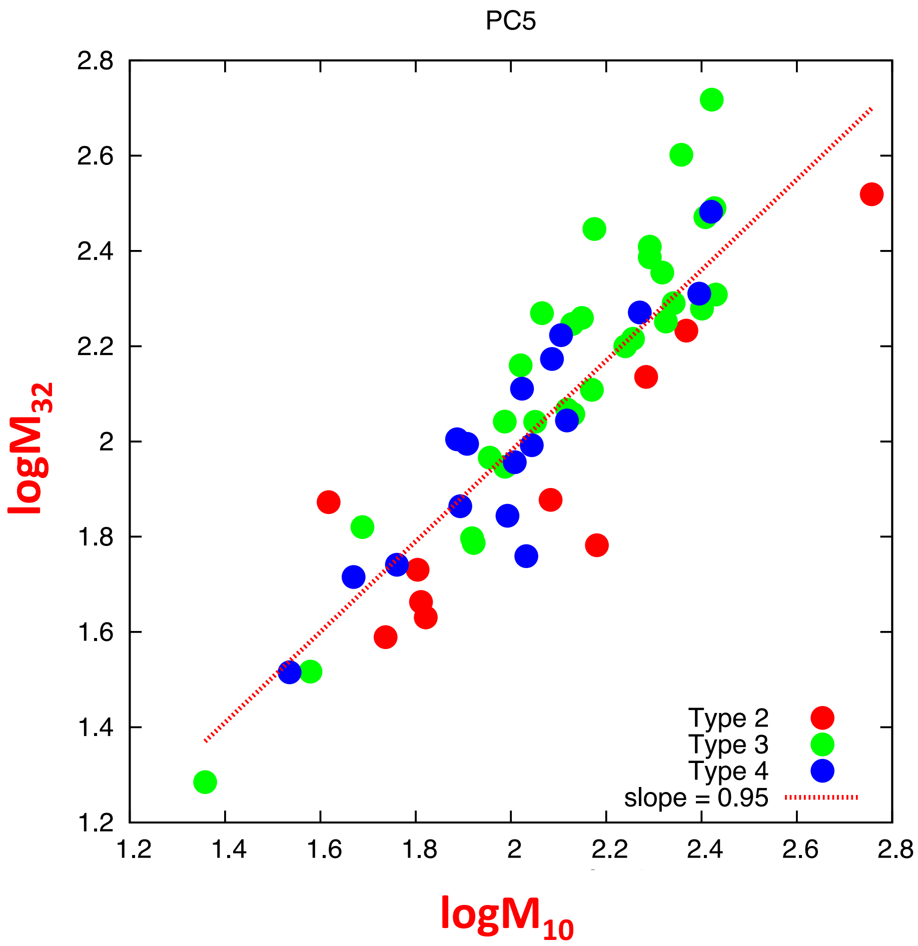


$\log M_{32} = (0.86 \pm 0.06) \log M_{10} + (0.12 \pm 0.02) \log SFR + 1.0 \pm 0.02$

scatter = 0.1 dex

KS law revisited

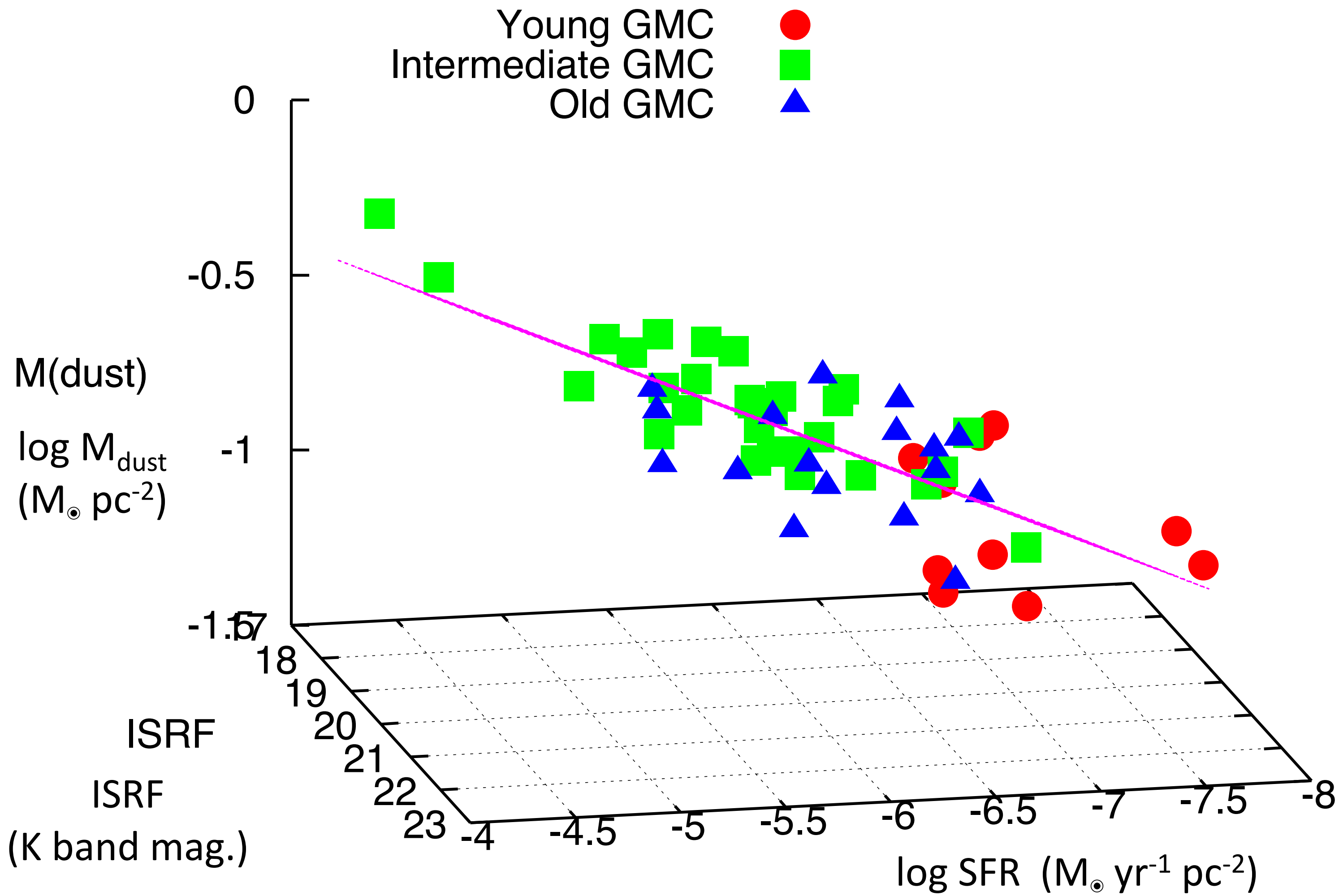




PC5 : SFR-M_{CO32}-M_{CO10} plane

- 従来のSK則の多変数への拡張
- 100pcスケールではSK則は”CO32/CO10比がSFRによってmodulateされたもの“と表現できる

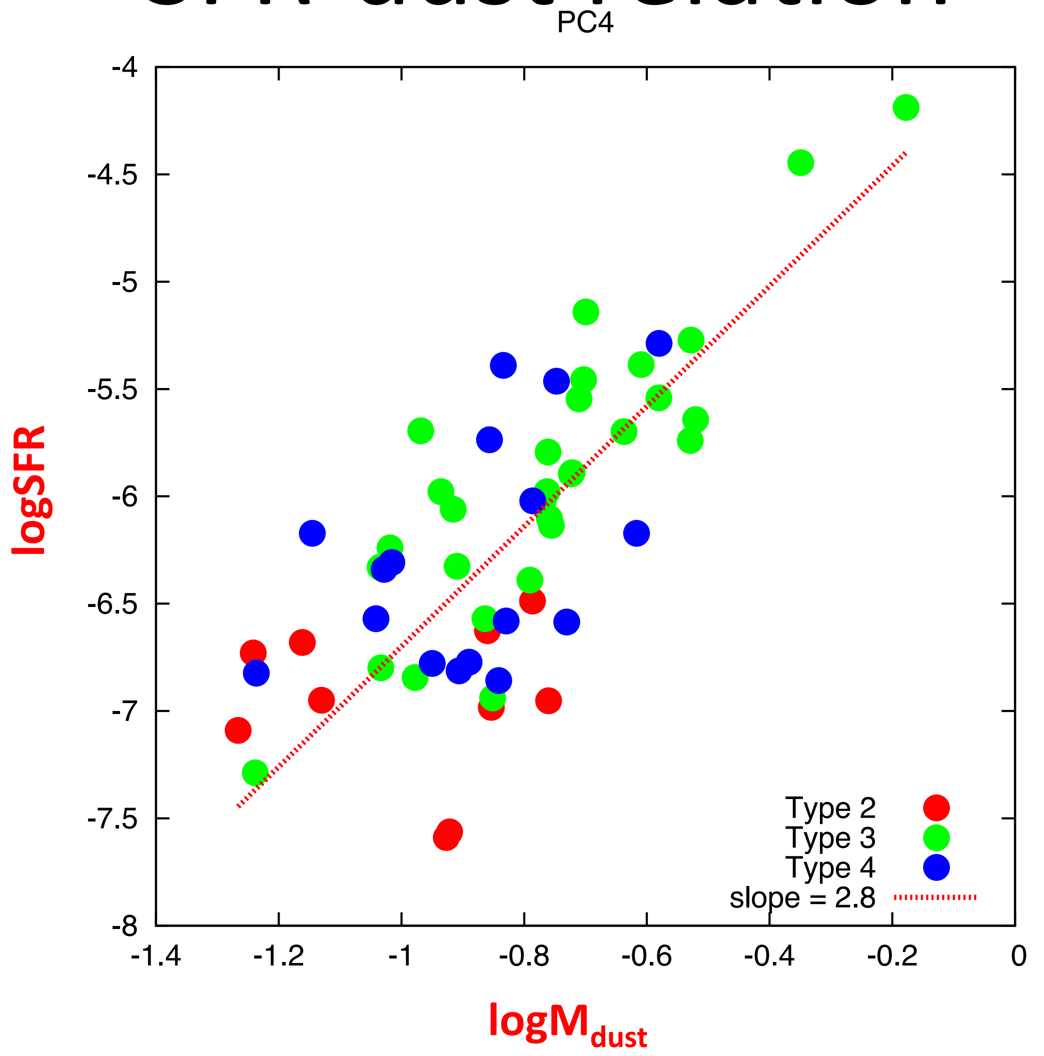
PC4 : SFR-M_{dust}-K_S plane



$\log SFR = (2.4 \pm 0.3) \log M_{dust} - (0.23 \pm 0.06) K_{mag.} + 0.15 \pm 1.2$

scatter = 0.4 dex

SFR-dust relation



PC4 : SFR-M_{dust}- K_S plane

- SFR-M_{dust} 関係はSFR-M_{CO32}やSFR-M_{CO10}よりもtight
- GMC進化をPC4平面上での移動として追う事ができる。

SWIMSへ。

- 星間物質+星形成相の”基本平面”のようなモノ
  - サブサンプルを積分する事でこれまでのscaling relationを統一的に理解できる（はず）→ e.g., galaxy main sequence
  - 空間分解できない銀河の内部の性質へ示唆を→銀河進化
- ただしM33でのcase studyなので一般化したい
  - 主成分解析はパラメータ追加の拡張が単純
  - サンプル数の増大がカギ
- 系外銀河の高分解能(100pc)観測
  - 年齢の評価、SFRの見積もりがネック → Paα
  - 高分解能のガス／ダストデータ取得の必要

観測提案

- GEISHA :
  Galaxy Evolution, Interstellar medium and Star formation History study from Atacama

- SWIMSで近傍銀河をPaα (+ Paβ) NB imaging
- 他(e.g., JWST)の追随を許さないサンプル
  - ~100銀河、数1000星形成領域 → 幅広いパラメータスペース
  - 広視野を生かした近い銀河（個別領域を同定）
  - e.g., $F_{(IRAS60um)}$ > 5Jy, V_{lsr} = < 1500 km/sで190天体
  - 新規のNBフィルタ制作も念頭に。
  - いろんなサイエンスに使える。世界に公開。
  - JWSTとの相補性→もちょっと遠いサンプルを。

- ALMAでのCOや他dense gas tracerの観測
  - 輝線、ダスト連続波の同時取得。ACA使用。