A systematic study of dust and star formation in early-type galaxies with AKARI

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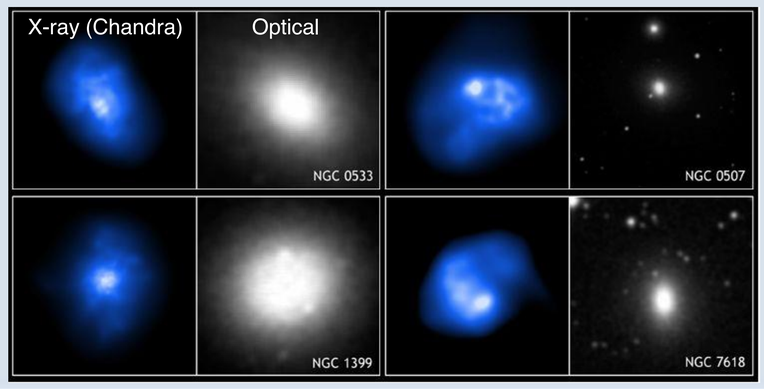
1. Introduction

- **Early-type galaxies (ETGs)**: elliptical (E) / lenticular (S0) galaxies
  - filled with hot X-ray plasma (destructive of dust)
  - dominated by old stars (less productive of dust)

  } no dust? no star formation?
  - However recent observations detect observable amounts of dust & PAHs from many ETGs, yet their supply channels are not well understood.

We perform a systematic study of dust and star formation for a large sample of ETGs.

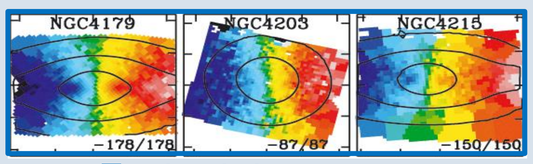
(http://chandra.harvard.edu/photo/2006/galaxies)



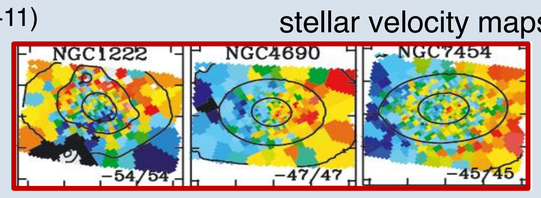
2. Sample & data

- **Sample: ATLAS^{3D} 260 ETGs** (M_K<-21.5, D<42 Mpc; Cappellari+11)
  - Kinematic classification (Emsellem+11)

stellar velocity maps



Fast rotator (224/260)
regular velocity field, ≒S0



Slow rotator (36/260)
complex velocity field, ≒E

- **Data**
  - AKARI all-sky surveys: 9, 18, 65, 90 & 140 μm bands
    New dust measurements for the ATLAS^{3D} ETGs (Kokusho+17)
  - 2MASS & WISE catalog: K, 3.6, 4.2, 12 & 22 μm bands
  - Literature measurements of the cold (CO & HI) & X-ray gas phases

3. Results & Discussion

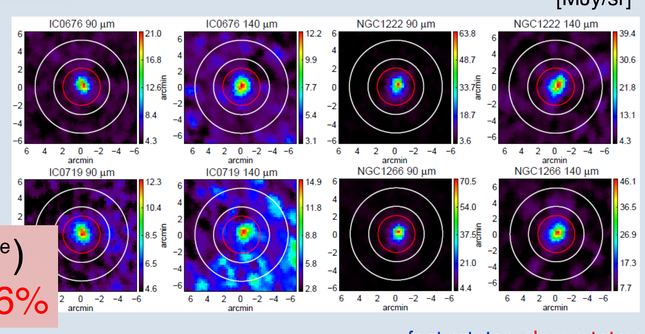
Dust emission

- Aperture photometry

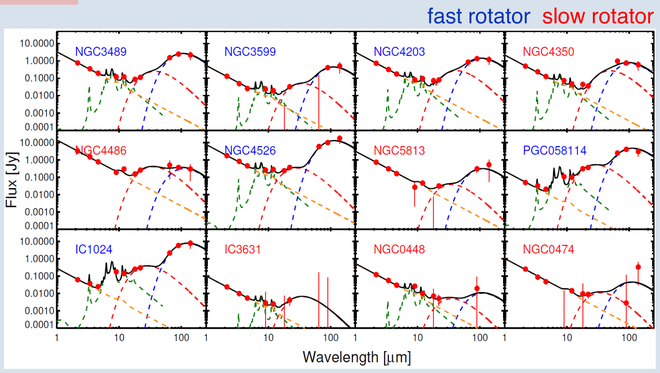
$R_{aper}=\sqrt{(2R_e)^2+(1.5D_{PSF})^2}$ R_e: effective radius
sky: $1.5R_{aper}$ —$2.5R_{aper}$ D_{PSF}: FWHM of PSF

FIR detection rates (S/N>3 in at least one of the 65, 90 & 140 μm bands)
Fast rotator: 42% Slow rotator: 46%

[MJy/sr]



fast rotator slow rotator



- SED fitting

star: power law
PAH: Draine&Li 07 model
warm & cold dust: $\propto \nu^2 B(T)$

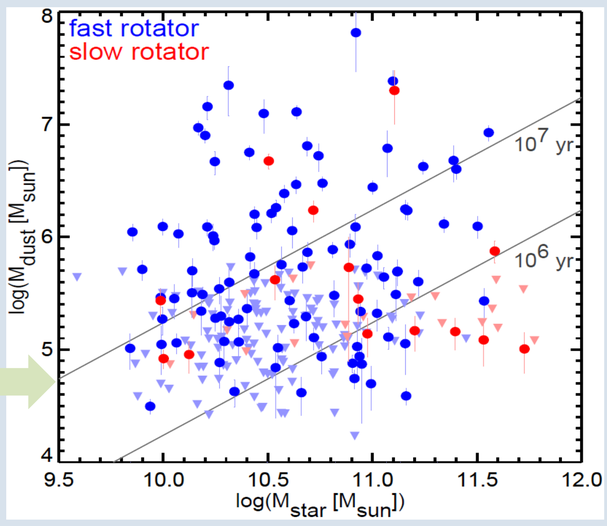
$$M_{dust}=\frac{F_\nu D^2}{\kappa_\nu B_\nu(T_{dust})}$$ κ_ν=13.9 cm²/g (@140 μm; Draine 03)

⇒M_{dust} (=M_{warm}+M_{cold}), L_{PAH}

Dust & stellar masses

- No correlation b/w M_{dust} & M_{star}
- Some ETGs are well above the expected M_{dust}
  ⇒Dust of external origin?

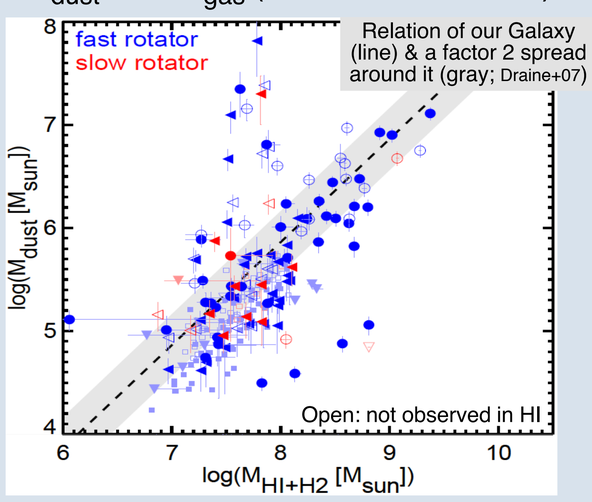
M_{dust} expected from the balance b/w supply from old stars ($\dot{M}_{dust}$=1.7×10^{-12} M_{star} [M_{sun}/yr]; Knapp+92, Cappellari+13) & destruction in X-ray plasma with denoted timescales



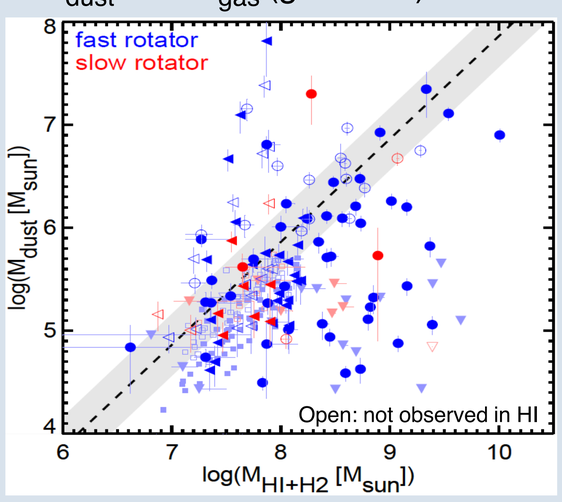
Dust & cold gas

(CO & HI measurements for 260 & 166 ETGs, respectively: Young+11, Serra+12, Young+14)

- M_{dust} vs. M_{gas} (central HI ~34"x45")



- M_{dust} vs. M_{gas} (global HI)

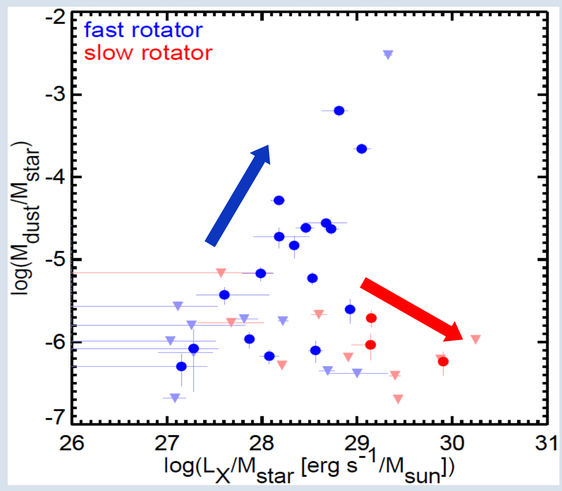


- Correlation b/w M_{dust} & central M_{gas} like late-type galaxies
  ⇒dense ISM of ETGs has M_{dust}/M_{gas} similar to late-type galaxies
- Inclusion of outer HI weakens the correlation
  ⇒dust-poor diffuse HI envelope?

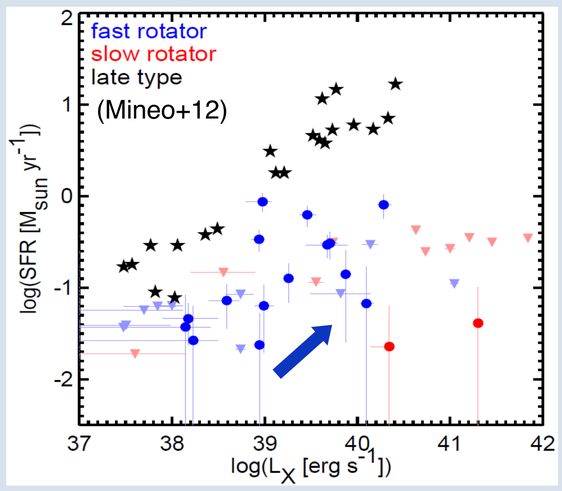
Dust & diffuse X-ray plasma

(X-ray point sources are removed, 42 ETGs observed with Chandra; Su+15)

- M_{dust}/M_{star} vs. L_X/M_{star}



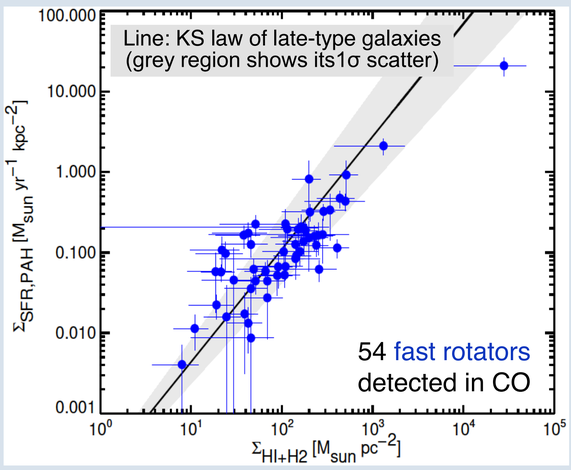
- SFR vs. L_X (L_{PAH}-based SFRs for ETGs; Kokusho+17)



- M_{dust}/M_{star} is correlated with L_X/M_{star} in fast rotators, whose SFRs are also correlated with L_X
  ⇒residual star formation may cause the dust-to-X-ray correlation
- M_{dust}/M_{star} is anti-correlated with L_X/M_{star} in slow rotators
  ⇒dust destruction in diffuse X-ray plasma

Star formation properties of fast rotators

- Kennicutt-Schmidt (KS) law:
  $\Sigma_{SFR} \propto (\Sigma_{gas})^n$
  (n=1.4 for late-type galaxies; Kennicutt 98)
- Fast rotators follow the KS law of late-type galaxies
  ⇒ Fast rotators form stars with efficiencies similar to late-type galaxies, suggesting that their star formation may not be suppressed



4. Conclusion

- Dust and PAH emission are detected from many ETGs, that may have acquired the cold ISM through external paths.
- Fast rotators show correlation between dust and X-rays, which appears to be caused by their higher current star formation activities than slow rotators.
- Fast rotators follow the KS law of late-type galaxies, suggesting that their star formation may not be strongly suppressed.

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