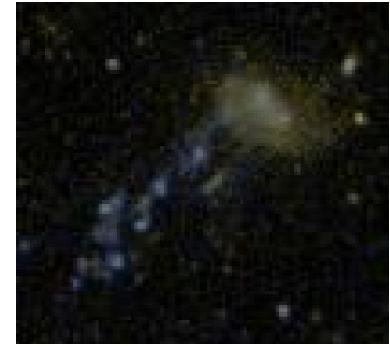
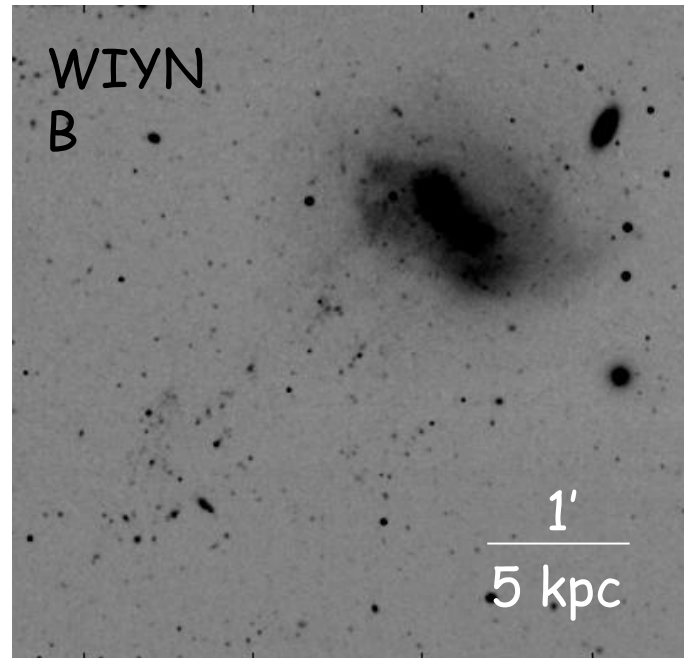


Caught in the Act:
A Dwarf Stripper in Action:
Stripped Completely Naked:
IC3418



- A dwarf galaxy whose gas was completely and recently stripped by ram pressure
- We are probably witnessing the transformation of a dwarf irregular galaxy into a dwarf elliptical galaxy by ram pressure stripping
- Could be breakthrough for understanding origin of dwarf elliptical galaxies in clusters

Virgo dwarf IC3418: **no HI**; 1-sided tail of young stellar associations & linear streams

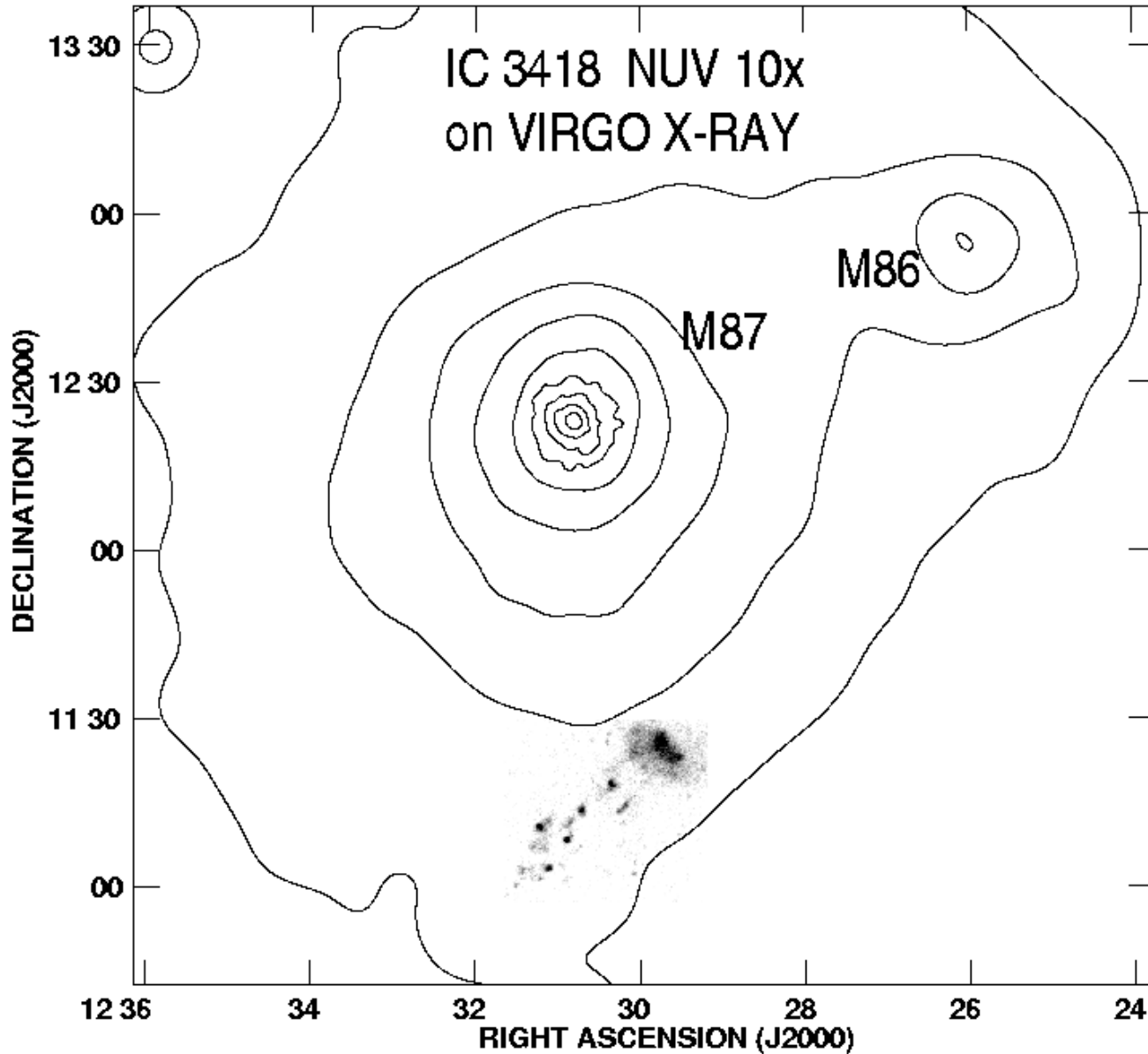


We are probably witnessing the transformation of a **dwarf irregular galaxy** into a **dwarf elliptical galaxy** by complete ram pressure stripping

IC3418

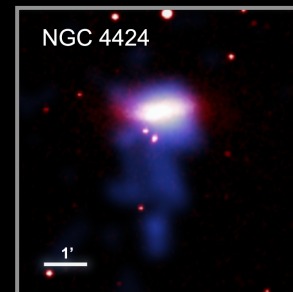
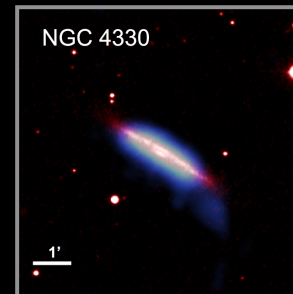
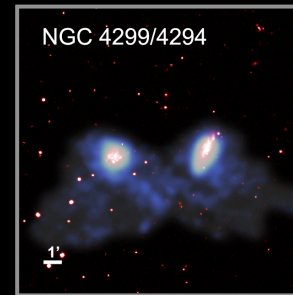
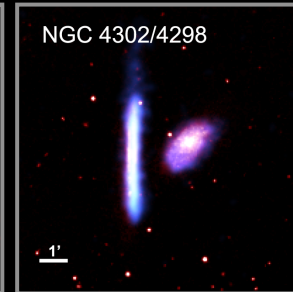
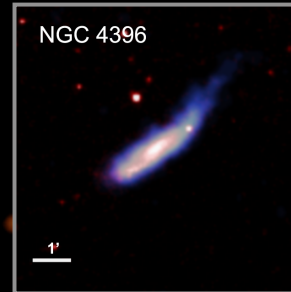
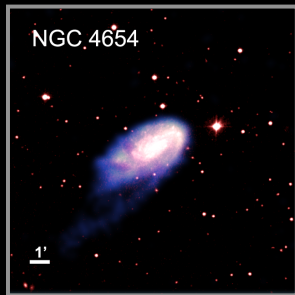
- $B=14.0$, $M_B=-16$
- $L = 10^9 = 0.1L^*$, $M_{\text{stars}} = 10^9 M_{\text{sun}}$
- 1 mag fainter and $\sim 5x$ less stellar mass than N4522, N4402, N4330
- Completely and quickly stripped, unlike all known Virgo spirals
- Lower in mass and closer to cluster center than best Virgo spiral stripping-in-action candidates

Location and tail angle

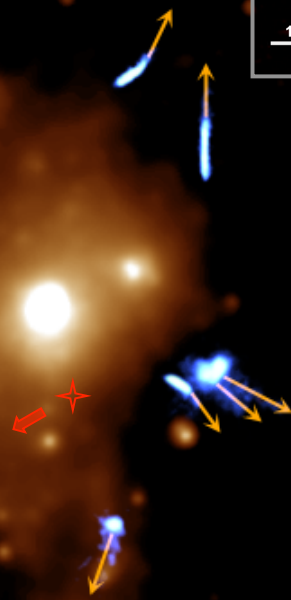


- Close to cluster center $1^\circ = 250 \text{ kpc} = 0.3R_{\text{vir}}$ from M87
- Projected tail angle more tangential than radial

Virgo Spirals with One-Sided HI Tails



- Tails of spirals highly radial, pointing roughly away from M87
- Consistent with gas stripping during first infall into cluster
- IC3418 closer to center, tail more tangential

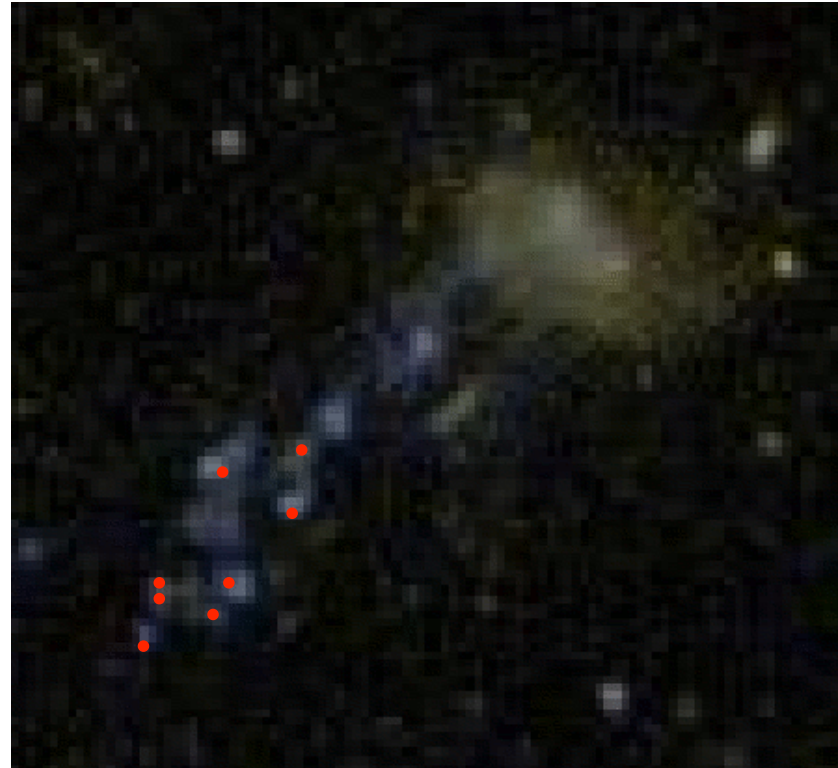
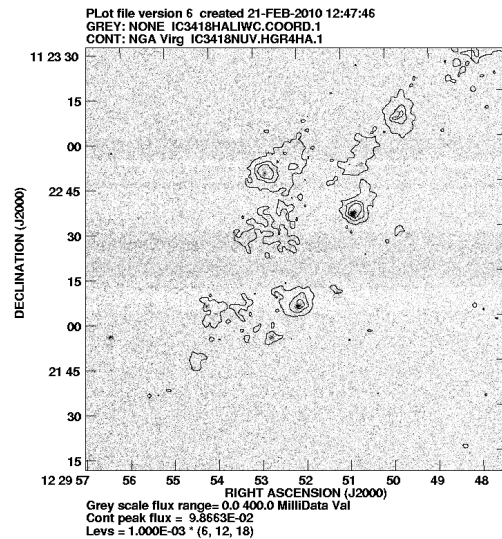


Chung et al 2007

Orbit of IC3418

- Projected tail angle 2x more tangential than radial
- Projected radial tail component is outward
- If 3D tail was more tangential than radial, and radial component was outward, then galaxy would be near but before closest approach (radial tail component outward)
- Due to projection effects, 3D tail could be either more tangential or more radial, radial component could be outward or inward
- Examination of plausible cluster orbits consistent with observed orbital parameters of IC3418 suggest it is more likely to be near but somewhat after closest approach (how near?)

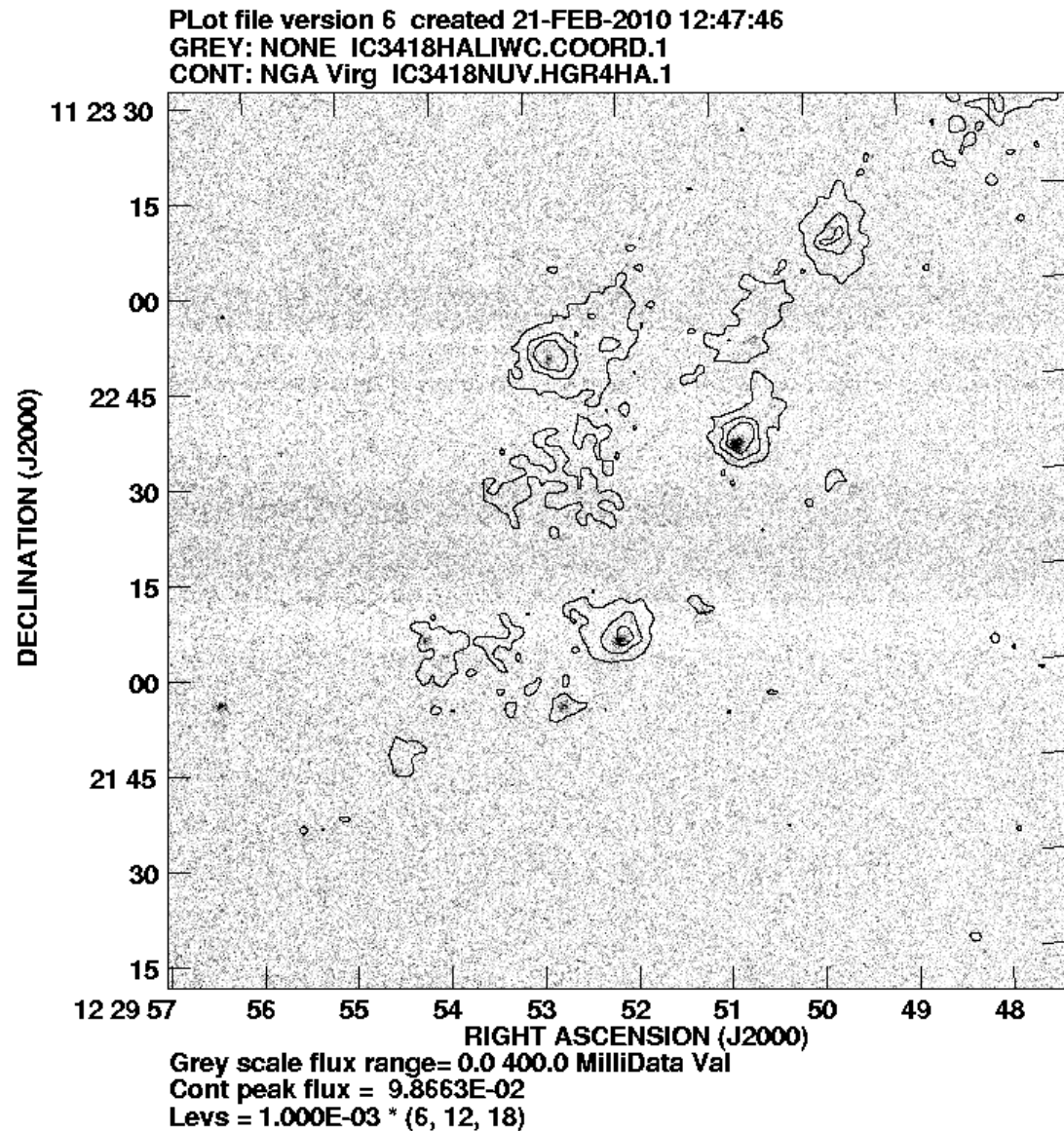
H-alpha in tail



- No H-alpha in main body or inner tail
- 8 HII regions in outer half of tail

H-alpha on NUV

- 3 brightest
outer tail UV
sources have
head-tail
morphology
with HII
region at head
("fireballs")



"fireballs"

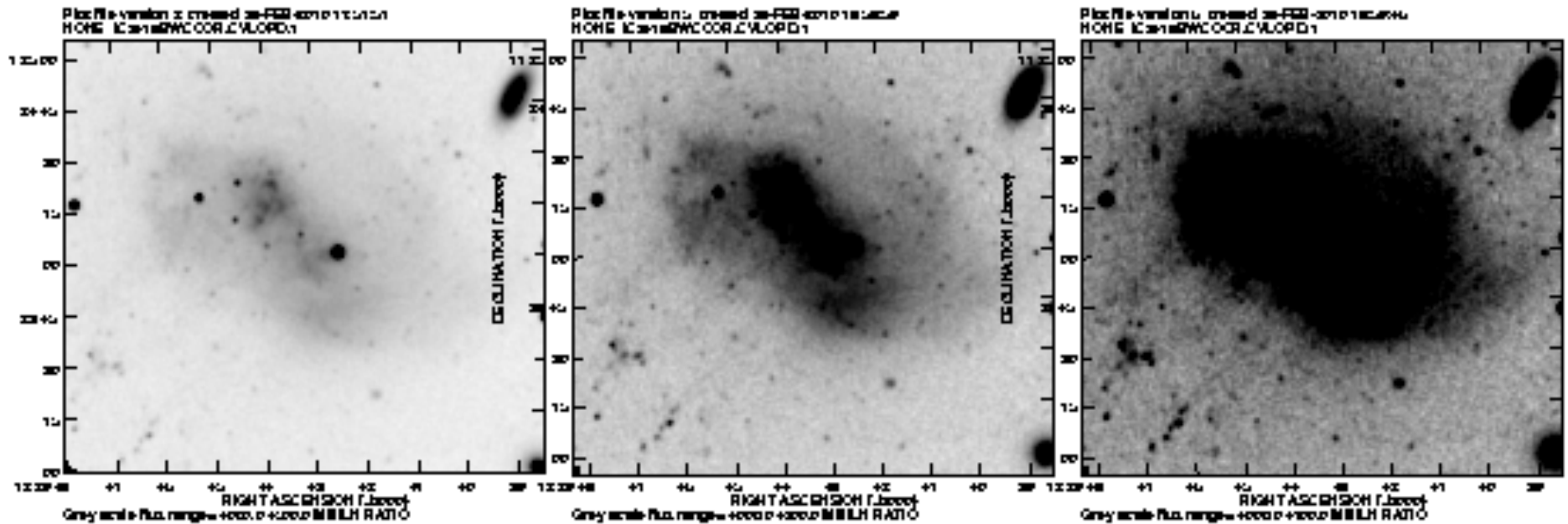
- Gas and youngest stars at outermost head of linear stellar streams
- Ram pressure continues to accelerate gas outwards, leaving behind trails of newly formed stars which decouple from the gas since they don't feel ram pressure

3 distinct zones of tail

- **Inner tail:** no H α , strong UV -- big gas clouds WERE there, but gas now pushed further out (time evolution effect)
- **Mid tail:** strong H α , strong UV -- big gas clouds still there
- **Outer tail:** medium H α , medium UV -- only smaller gas clouds have gotten this far out (mass segregation effect)

IC3418 WIYN imaging

main body: B-band



substructure + supergiants suggests recent star formation in central $30'' = 2$ kpc
"Plume" of extra blue light from $30'' - 1'$ on tail side

UV and optical color images



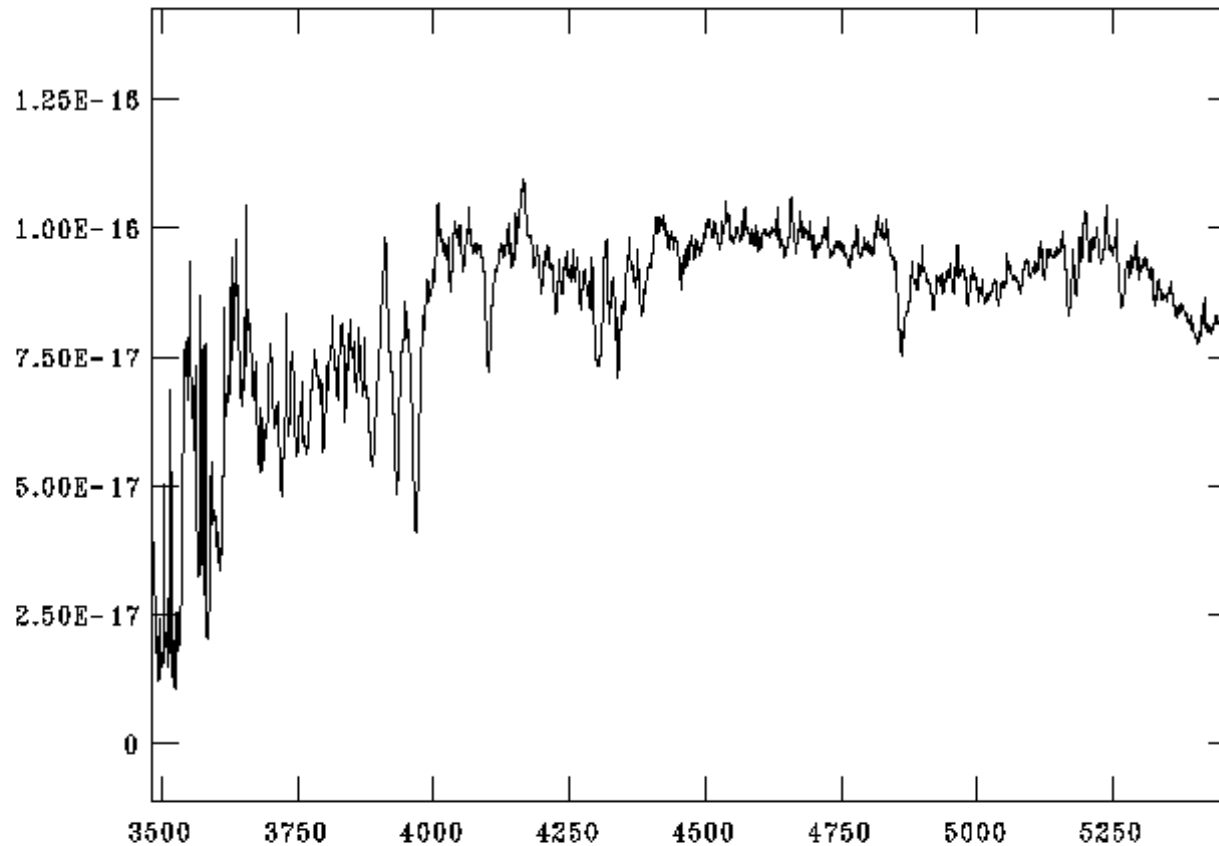
GALEX FUV+NUV



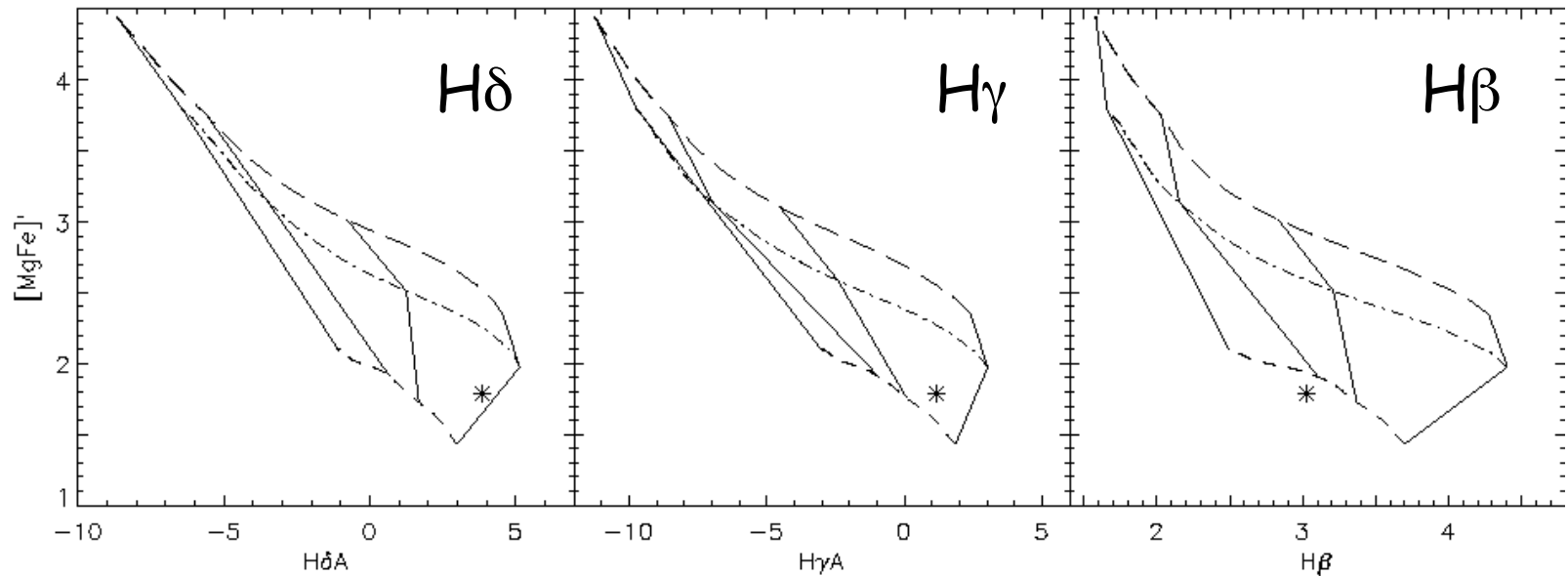
WIYN BVR

Keck spectrum of main body of IC3418

NOAO/IRAF V2.14.1 hugh@gumbo.astro.umass.edu Fri 14:49:18 11-Dec-2009
[ic3418_comb]: IC 3418 1200. ap:2 beam:2



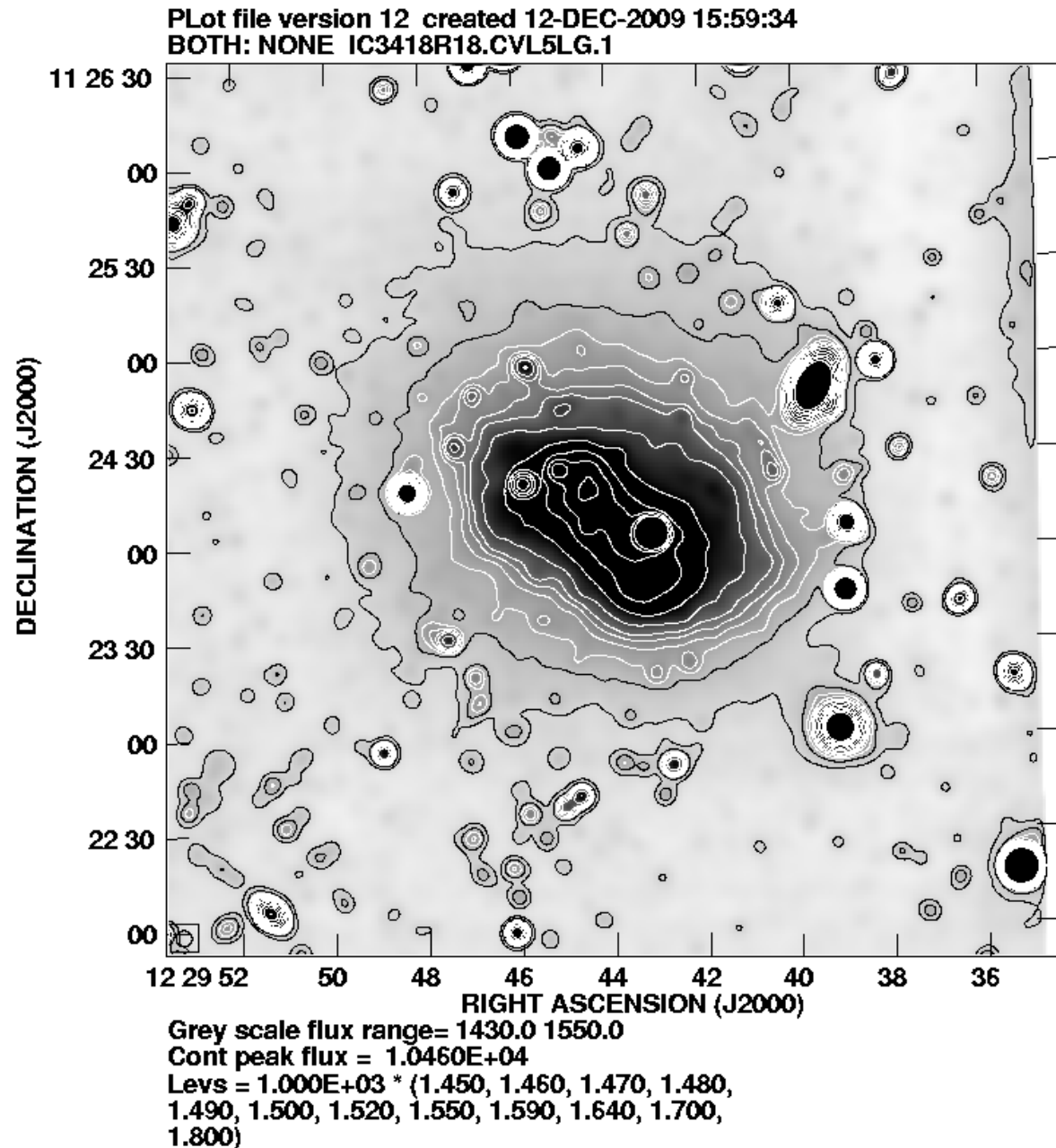
Line indices & models for main body of IC3418



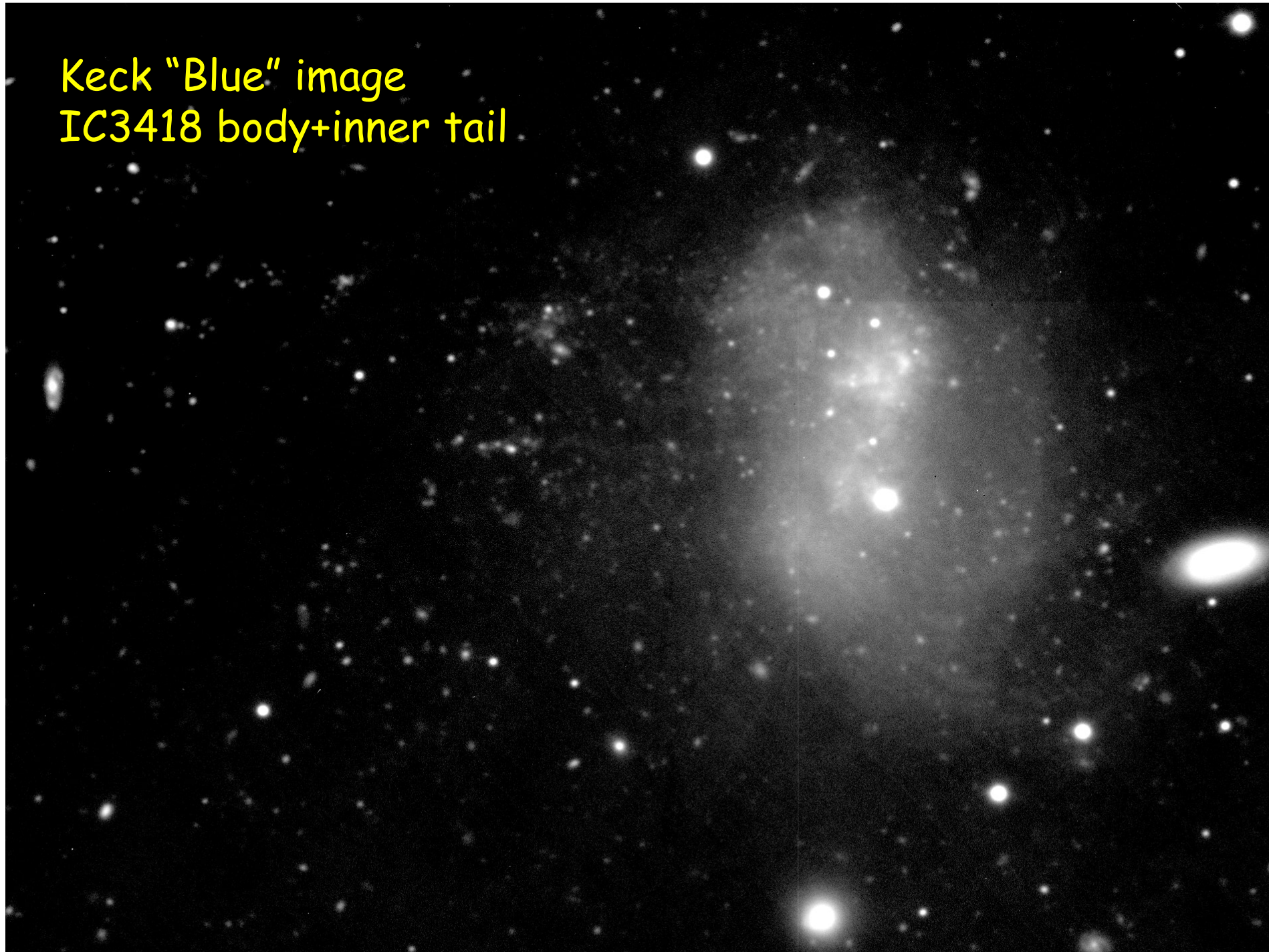
- Strong H-delta and H-gamma indicate star formation truncated 50-100 Myr ago

"Deep" convolved R- band image

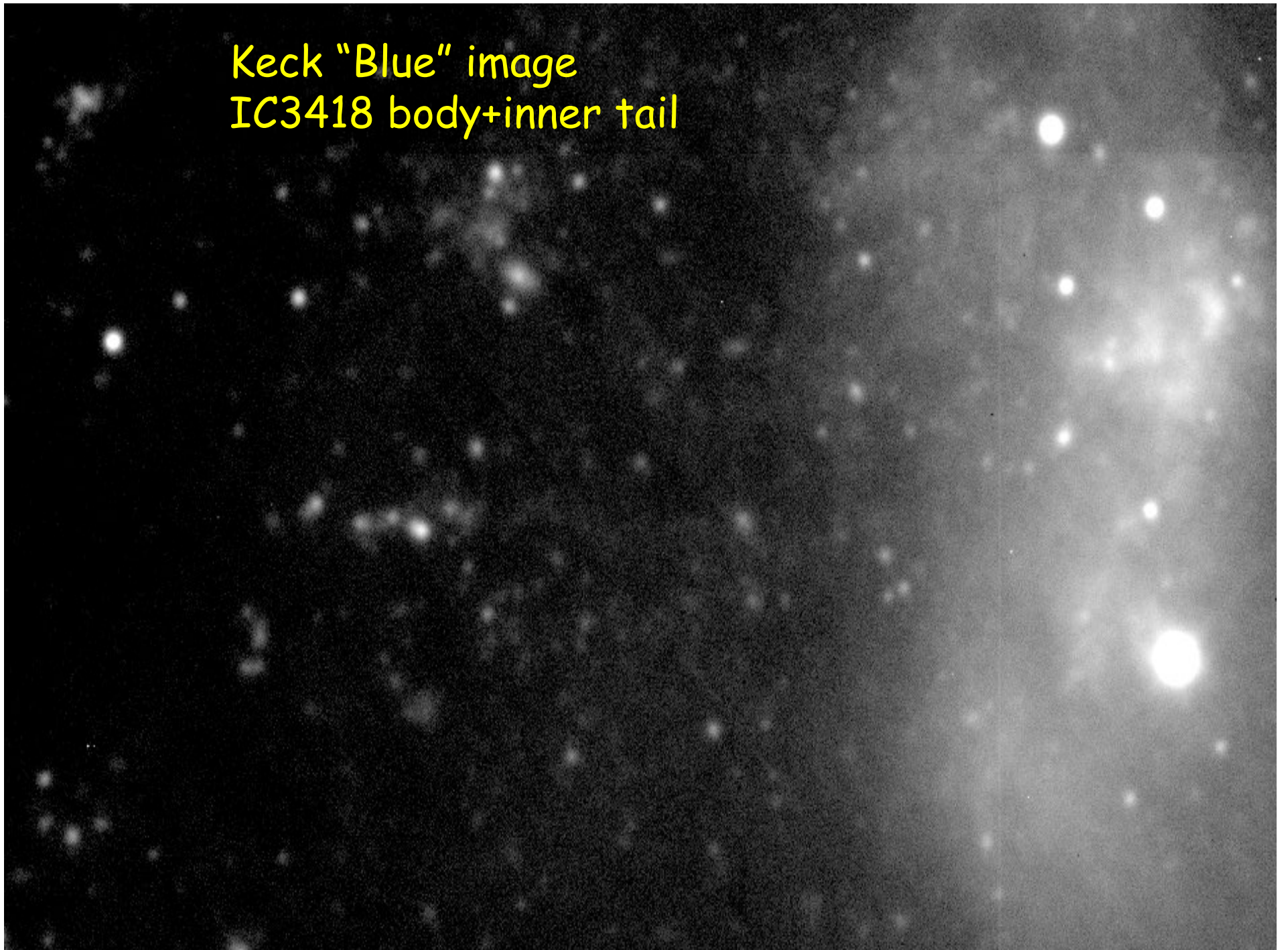
- Outer isophotes fairly regular
- One spiral/ tidal? arm in SW 1' from center
- Not strongly tidally disturbed



Keck "Blue" image
IC3418 body+inner tail



Keck "Blue" image
IC3418 body+inner tail



Is IC3418 a dIrr being transformed into a dE?

- Complete r.p.s. is a necessary stage in the transformation of a dIrr into a dE, and we are seeing clear evidence of this critical stage in IC3418
- Tidal disturbances also required to "fully make" a typical dE

dE's vs. dIrr's

- Similar masses, stellar mass distributions
- Both have ~exponential light profiles
- dIrrs have gas and ongoing SF, dE's don't
- dE's centrally concentrated in Virgo, dIrr's avoid center
- Some dE's exhibit low-level substructure, e.g. spiral arms & other features suggesting recent (disk) star formation --> consistent with gas-stripped dIrr's

dE's vs. dIrr's -- kinematics

- dIrr's dominated by rotation, $v/\sigma \sim 0.x$
- dE's have range of kinematic properties, but generally dynamically hotter; some have rotation at some radii, $v/\sigma \sim 2(0.x)$
- Not consistent with gas-stripping only, additionally requires tidal interactions (for dE population as a whole)

Making dE's from dIrr's

- Both gas stripping and tidal interactions required to produce the population of Virgo dE's from Virgo dIrr's
- Gas stripping happens during 1st core passage, tidal interactions occur numerous times as galaxy continues to orbit in cluster
- Each tidal interaction is different, producing variety in the kinematic and morphological properties of dE's

Is it plausible that both gas stripping & tidal interactions are required to make dE's?

YES

Every (small) galaxy which enters the cluster core is expected to be gas stripped

Virtually every galaxy which has made $>\sim 1$ orbit in the cluster is expected to experience $>\sim 1$ tidal disturbance

dIrr's are those dwarf galaxies that have not yet entered cluster core

dE's are those dwarf galaxies that have been in the cluster the longest, and have experienced both gas stripping and various degrees of tidal interaction

Holistic cluster galaxy evolution

Multiple interactions drive cluster galaxy evolution, different interactions occur at different times

Starvation -- removal of gas which would have accreted -- probably occurs as galaxies enter cluster outskirts ($\sim 2-3R_{\text{vir}}$)
SOME EVIDENCE

Ram pressure stripping removes most disk ISM gas the first time the galaxies enter intermediate parts of the cluster ($\sim 0.5-1R_{\text{vir}}$)
STRONG EVIDENCE, MAJOR EFFECT, FIRST INFALL

Gravitational interactions continue to act as galaxies orbit multiple times through the cluster, gradually destroying disks and building bulges
STRONG EVIDENCE, MAJOR EFFECT, CONTINUES OVER TIME

PREDICTION!

There should be an intermediate population which has been gas stripped but not yet strongly tidally disturbed; expect these to have younger stellar pops, more substructure, and colder stellar kinematics than other dE's

IC3418 could be such a galaxy, it has young stellar pops & substructure, don't yet know about kinematics