THE INITIAL MASS FUNCTIONS IN THE SUPER–STAR CLUSTERS NGC 1569A AND NGC 1705-1

AMIEL STERNBERG
School of Physics and Astronomy, Tel Aviv University, Ramat Aviv, 69978, Israel; amiel@wise.tau.ac.il

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ABSTRACT

I use recent photometric and stellar velocity dispersion measurements of the super–star clusters (SSCs) NGC 1569A and NGC 1705-1 to determine their present-day luminosity/mass ratios \(L_\nu/M\). I then use the inferred \(L_\nu/M\), together with population synthesis models of evolving star clusters, to constrain the initial mass functions (IMFs) in these objects. I find that \(L_\nu/M\) in 1569A is contained in low-mass \(<1 M_\odot\) stars; however, in 1705-1 the IMF is either flat, with \(x \leq 2\), or it is truncated at a lower mass limit between 1 and 3 \(M_\odot\). I compare the inferred IMFs with the mass functions (MFs) of Galactic globular clusters. It appears that 1569A has a sufficient reservoir of low-mass stars for it plausibly to evolve into an object similar to Galactic globular clusters; however, the apparent deficiency of low-mass stars in 1705-1 may make it difficult for this SSC to become a globular cluster. If low-mass stars do dominate the cluster mass in 1705-1, the large \(L_\nu/M\) in this SSC may be evidence that the most massive stars have formed close to the cluster cores.

Subject headings: galaxies: individual (NGC 1569, NGC 1705) — galaxies: luminosity function, mass function — galaxies: starburst — galaxies: star clusters — globular clusters: general

1. INTRODUCTION

Recent optical and ultraviolet Hubble Space Telescope (HST) and near-IR speckle observations have revealed the widespread presence of luminous (\(L_\nu \gtrsim 10^7 L_\odot\)) and compact (\(r < 2\) pc) “super–star clusters” (SSCs) in a variety of star-forming galaxies (see, e.g., Holtzman et al. 1992; Whitmore & Schweizer 1995; Maoz et al. 1996; Tacconi-Garman, Sternberg, & Eckart 1996). The observations suggest that in starburst galaxies a large fraction of the OB stars are formed in compact SSCs, as opposed to more diffuse stellar associations.

The various photometric and spectroscopic observations are sensitive mainly to the massive stars (\(\gtrsim 3 M_\odot\)). Lower mass stars are generally not directly detectable. The total stellar masses of the SSCs are usually estimated using models that predict the luminosity/mass ratios \(L_\nu/M\) for an assumed set of parameters such as the cluster age and initial mass function (IMF). In most models the luminosity is dominated by the most massive (and observed) stars in the system, while the mass is dominated by the more numerous lower mass (and unobserved) stars. Application of such methods has led to inferred cluster masses ranging from \(10^4\) to \(10^6\) \(M_\odot\) depending on the particular SSC and model employed. The large inferred masses and the small observed radii have led to suggestions that the SSCs are young globular clusters.

NGC 1569 and NGC 1705 are two nearby dwarf galaxies. Each contains a prominent and well-studied SSC, designated 1569A and 1705-1 (Arp & Sandage 1985; Melnick, Males, & Terlevich 1985). Ho & Filippenko (1996a, 1996b) carried out high-resolution (Keck) spectroscopy of 1569A and 1705-1 and were able to measure the stellar velocity dispersions in these SSCs. The stellar velocities together with the small cluster sizes indicated by the HST observations (O’Connell, Gallagher, & Hunter 1994; Meurer et al. 1995; DeMarchi et al. 1997) imply cluster crossing times much shorter than the likely cluster ages. Ho & Filippenko (1996a, 1996b) concluded that the clusters are gravitationally bound and that the implied virial masses are as large as \(\sim 10^5\) \(M_\odot\). Ho & Filippenko (1996a, 1996b) also argued that 1569A and 1705-1 might evolve into objects similar to Galactic globular clusters.

The independent estimates of the total cluster masses made possible by Ho & Filippenko’s (1996a, 1996b) velocity dispersion measurements can be used to “invert” the usual analysis of the SSCs. In this paper I derive \(L_\nu/M\) for 1569A and 1705-1 based on the available observations. I then compare the observed \(L_\nu/M\) with model predictions for a wide range of initial conditions. My main goal is to constrain the IMFs in these clusters. I also address the question of whether the inferred IMFs are consistent with the observed mass functions (MFs) of present-day globular clusters.

2. MODELS

Figures 1–4 display “population synthesis” computations of the time-dependent values of \(L_\nu/M\) for young clusters with ages between 1 and 100 Myr. In these models it is assumed that all of the stars form in a single instantaneous “burst.” Figure 1 shows the behavior for solar metallicity clusters with power-law \((m^{-2} dm)\) IMFs that extend from a lower mass limit \(m_l = 0.1 M_\odot\) to an upper mass limit \(m_u = 120 M_\odot\). Results are displayed for \(x\) ranging from 1.5 to 2.5 (\(x = 2.35\) for the Salpeter 1955 IMF). Figure 2 shows the behavior for low-metallicity (0.2 \(\times\) solar) clusters. Figure 3 displays the evolution of \(L_\nu/M\) for a Miller-Scalo IMF (Miller & Scalo 1979; Scalo 1986) and the IMF in the Galactic star-forming region NGC 3603 (Eisenhauer et al. 1998; see also § 5), for both solar and low-metallicity clus-
Power-law IMFs with \( \alpha < 2 \) are “flat” and are biased toward massive stars in the sense that the cluster mass diverges as \( m_i \) becomes large. IMFs with \( \alpha > 2 \) are “steep,” and the cluster mass diverges as \( m_i \) becomes small. Table 1 lists the initial mass fractions, \( f_M(<1) \), and stellar number fractions, \( f_N(<1) \), contained in stars with masses less than 1 \( M_\odot \) for each of the IMFs displayed in Figures 1–3. Table 1 also lists the mean stellar masses, \( \langle m \rangle \), for each of the IMFs.

Figures 1 and 2 show that for a given IMF, \( L_V/M \) reaches a maximum value at \( \sim 4 \) Myr and then decreases steadily afterward. The peak values of \( L_V/M \) are smaller in clusters that form stars sequentially rather than coevally. At any time the luminosity is produced by the most massive cool supergiants and the hot upper part of the main sequence. For example, for a total luminosity \( L_V = 10^7 L_\odot \) at 10 Myr, about half of the \( V \) light is produced by \( 2-4 \times 10^7 \) K and M supergiants (20–25 \( M_\odot \)), and the other half is produced by 5–15 \( \times 10^4 \) early B-type stars (5–20 \( M_\odot \)). At a fixed age \( L_V/M \) is smaller for “steeper” IMFs, i.e., for larger values of \( \alpha \), because of the larger fractions of low-mass stars. The luminosity peak occurs when the most massive (\( \sim 100 M_\odot \)) stars evolve off the main sequence. The luminosity decreases as the massive stars disappear and the “turnoff” point
The computations were carried out using the Geneva stellar evolutionary tracks et al. and bolo-(Schaerer 1993) and computed values of displayed in Figures and The mass

The models presented here include mass loss due to super-

than Wolf-Rayet stars) are formed et al.(Schaerer 1993).

The presence of WR stars implies a cluster age of ~4 Myr, while the presence of RSGs implies an age of ≥10 Myr. I assume here that the RSG (one-dimensional) velocity dispersion σ = 15.7 km s⁻¹ that Ho & Filippenko (1996a) observed in 1569A is of the brighter component that (for a distance of 2.5 Mpc) has a luminosity L_V = 3.1 × 10⁷ and a half-light radius r_h = 1.8 pc (De Marchi et al. 1997). The crossing time, t_c = 2r_h/σ = 2.3 × 10⁸ yr, is much shorter than the cluster age. Therefore, it is likely the SSC is gravitationally bound. For a bound system the virial mass M_v = 3σ²R/G, where R is the gravitational radius, and for a wide range of virialized stellar mass distributions M_v = 10σ²r_h²/G, where r_h is the projected half-mass radius (Spitzer 1987, p. 11). Assuming that light traces mass so that r_p = r_h, I infer a virial mass of 1.1 × 10⁶ M_☉, giving (L_V/M_v) = 28.9 for 1569-A. This value of L_V/M is indicated in Figures 1–3.

The more distant cluster 1705-1 may be a simpler system (Meurer et al. 1992). Ultraviolet HST spectroscopy reveals an absence of WR and O-type stars, which suggests that 1705-1 is a ~10–20 Myr “postburst” object (Heckman & Leitherer 1997). O’Connell et al. (1994) measured an optical

### Table 1: Initial Mass Functions

| IMF | f_1 (< 10^4) | f_5 (< 10^5) | 〈m〉 |
|-----|-------------|-------------|------|
| a = 1.5 | 0.06 | 0.70 | 3.5 |
| a = 2.0 | 0.32 | 0.90 | 0.71 |
| a = 2.5 | 0.60 | 0.96 | 0.35 |
| a = 3.0 | 0.70 | 0.97 | 0.29 |
| Miller-Scalo | 0.31 | 0.78 | 0.89 |
| NGC 3603 | 0.18 | 0.82 | 1.31 |

* Initial mass functions in the range 0.1–120 M_☉.
* Initial cluster mass fractions in stars less massive than 1 M_☉.
* Initial stellar number fractions in stars less massive than 1 M_☉.
* Mean stellar masses.

### Table 2: Model Comparisons

| Model | Peak (L_V/M_☉) | 10 Myr (L_V/M_☉) |
|-------|----------------|-----------------|
| This paper | 63 | 31 | 38 |
| C96* | 63 | 80 | 27 | 27 |
| LH95* | 68 | 108 | 35 | 50 |

* Salpeter IMF between 0.1 and 120 M_☉. The C96 and LH95 values have been adjusted for supernova mass loss.
* Charlot 1996.
* Leitherer and Heckman 1995.

### Table 3: Super-Star Cluster Properties

| Object | D (Mpc) | Z (solar) | R_e (pc) | V (km s⁻¹) | L_V (L_☉) | M (M_☉) | (L_V/M_☉) | Age (Myr) |
|--------|---------|---------|---------|-----------|--------|--------|----------|---------|
| 1569A | 2.5 | 0.2 | 1.8 | 15.7 | 3.1 × 10⁷ | 1.1 × 10⁶ | 28.9 | 4–10 |
| 1705-1 | 5.0 | 0.45 | 0.9 | 11.4 | 3.4 × 10⁷ | 2.7 × 10⁴ | 126 | 10–20 |

* O’Connell et al. 1994.
* Devost et al. 1997; Kobulnicky & Skillman 1997.
* Meurer et al. 1995; De Marchi et al. 1997.
* Ho & Filippenko 1996a, 1996b.
* Gonzalez-Delgado et al. 1997; Heckman & Leitherer 1997.
half-light radius of 3.4 pc and a cluster luminosity \( L_V = 3.4 \times 10^{27} L_\odot \). Meurer et al. (1995) reanalyzed the O’Connell et al. (1994) data and argued that the half-light radius is actually only 0.9 pc. Ho & Filippenko (1996b) measured an RSG velocity dispersion of 11.4 km s\(^{-1}\) giving a crossing time of 1.6 \times 10^5 yr. For \( r_p = 0.9 \) pc the virial mass is 2.7 \times 10^5 \( M_\odot \), so that \( (L_V/M_\odot) = 126 \) in 1705-1. This value for \( L_V/M \) is also indicated in Figures 1–3. The viral mass is much smaller than the 10^6 \( M_\odot \) that Meurer et al. (1995) inferred for 1705-1 using their measurement of the UV luminosity, and a model UV luminosity/mass ratio for a cluster with a Salpeter IMF extending to 0.1 \( M_\odot \).

I note that Ho & Filippenko (1996a, 1996b) assumed that the half-light radii are equal to the gravitational radii (i.e., that \( r_p = R \)) and derived masses that are 10/3 times smaller than the virial masses I have inferred. Their mass estimates may be regarded as lower limits and would give \( (L_V/M_\odot) = 96.3 \) for 1569A and \( (L_V/M_\odot) = 419 \) for 1705-1.

The cluster IMFs can now be constrained by comparing the observed \( L_V/M \) with the models. Figures 1 and 2 show that if 1569A is emitting at close to the peak luminosity then the IMF must be very steep with \( \alpha > 2.5 \) even if \( m_l = 0.1 \ M_\odot \). Second, at the likely cluster age of 10 Myr the observed \( L_V/M \) is consistent with a Salpeter IMF \( (\alpha = 2.35) \) extending to \( m_l = 0.1 \ M_\odot \). Third, for cluster ages up to \( \sim 20 \) Myr, the predicted \( L_V/M \) ratios for a Miller-Scalo IMF are larger than the observed values. These three conclusions imply that a large fraction of the stellar mass in 1569A is contained in low-mass stars. For example, if \( \alpha = 2.35 \), then 60% of cluster mass is contained in stars with masses less than 1 \( M_\odot \) (see Table 1).

On the other hand, 1705-1 appears to be deficient in low-mass stars. First, the IMF in this cluster is consistent with a Salpeter IMF with \( m_l = 0.1 \ M_\odot \) only if it is emitting in the peak luminosity. This is unlikely, however, since many \( (\sim 5 \times 10^5) \) O and WR stars would then be present. Second, for a Miller-Scalo IMF the observed \( L_V/M \) in 1705-1 is larger than the predicted values at all cluster ages. Third, for a likely cluster age between 10 and 20 Myr, the measured \( L_V/M \) is consistent with a Salpeter IMF only if the IMF is truncated at values of \( m_l \) ranging from \( \sim 1 \) to \( 3 \ M_\odot \) (see Fig. 4). Alternatively, for ages between 10 and 20 Myr, the \( L_V/M \) is consistent with flat IMFs with \( x \) between 2 and 1.5. For these values of \( x \) the initial cluster mass fraction in \( m < 1 \ M_\odot \) stars ranges from 32% to 6% (see Table 1). It appears that the IMF in 1705-1 is biased toward high-mass stars.

### 4. COMPARISON WITH GLOBULAR CLUSTERS

The large masses and small radii of the luminous SSCs, and the fact that they appear to be gravitationally bound objects, have led to suggestions that they may be young globular clusters (Larson 1988; Lutz 1991; Holtzman et al. 1992). This idea, however, has remained controversial (Meurer 1995; van den Bergh 1995).

Ho & Filippenko (1996a, 1996b) applied the BC93 models to 1569A and 1705-1 and concluded that after fading for 10–15 Gyr these objects would attain \( (L_V/M_\odot) \) close to the values of \( \sim 0.5–1 \) observed in Galactic globular clusters (Mandushev, Spassova, & Staneva 1991). However, Ho & Filippenko (1996a, 1996b) assumed that the cluster masses are significantly smaller than their likely virial masses (see § 3). They also assumed that the SSCs are presently emitting at their peak luminosities. Furthermore, the BC93 models are restricted to a Salpeter IMF (with \( m_l = 0.1 \ M_\odot \)), and predict \( (L_V/M_\odot) \sim 0.1 \) for 10–15 Gyr clusters. Finally, the BC93 models do not account for cluster mass loss due to either stellar evolution or dynamical processes.

An alternative approach is to ask whether Galactic globular clusters could have evolved from objects with IMFs that are constrained by the \( L_V/M \) observed in 1569A and 1705-1.

Recent HST observations of Galactic globular clusters probe the luminosity functions and MFs from the turnoff mass \( (\sim 0.8 \ M_\odot) \) down to nearly the hydrogen-burning limit (King et al. 1998). The observations indicate that for masses in the range \( 0.1 \leq m \leq 0.5 \ M_\odot \) the MFs may be represented as power laws \( m^{-\alpha} dm \) with \( \alpha \) between \( \sim 0.5 \) and 1 (G. Piotto 1998, private communication). Luminosity profile studies and dynamical modeling (see, e.g., Meylan & Mayor 1991), as well as pulsar studies (Kulkarni, Narayan, & Romani 1990) provide limits on the globular cluster mass fractions contained in more massive evolved stellar components such as white dwarfs and neutron stars.

To compare globular cluster MFs with the IMFs in 1569A and 1705-1, I list in Table 4 the \( L_V/M \) for 10 Myr clusters assuming IMFs labeled “A”) that vary as \( m^{–0.8} \) for \( 0.1 \leq m < 0.8 \ M_\odot \) and as \( m^{–2} \) for \( 0.8 \leq m < 120 \ M_\odot \), as well as IMFs labeled “B”) that vary as \( m^{–2} \) for the entire range of \( 0.1–120 \ M_\odot \). The A-type IMFs are defined so that the distribution of \( m < 0.8 \ M_\odot \) stars initially resemble the observed (low-mass) MFs of Galactic globular clusters with additional power-law components extending to the highest mass stars.

### TABLE 4

| Super–Star Cluster IMFs versus Globular Cluster MFs |
|-----------------------------------------------|
| \( (L_V/M_\odot) \) \( * \) |
| IMF \( * \) | \( x \) | \( 0.2 \times \) Solar | \( 0.5 \times \) Solar | \( M_{\odot}/M \) | \( f(<0.8) \) | \( f(WD) \) | \( f(\text{neutron}) \) |
| A …… | 1.5 | 187.0 | 287.9 | 0.33 | 0.25 | 0.47 | 0.28 |
| 2.0 | 100.0 | 140.7 | 0.43 | 0.42 | 0.48 | 0.10 |
| 2.35 | 58.3 | 70.7 | 0.53 | 0.52 | 0.44 | 0.04 |
| 2.5 | 40.4 | 59.0 | 0.56 | 0.55 | 0.42 | 0.03 |
| B …… | 1.5 | 175.6 | 270.3 | 0.37 | 0.37 | 0.39 | 0.24 |
| 2.0 | 74.3 | 104.5 | 0.58 | 0.68 | 0.27 | 0.05 |
| 2.35 | 30.9 | 37.5 | 0.75 | 0.82 | 0.17 | 0.02 |
| 2.5 | 17.8 | 26.0 | 0.81 | 0.86 | 0.13 | 0.01 |

* IMFs labeled A vary as \( m^{–0.8} \) for \( 0.1 \leq m < 0.8 \ M_\odot \) and \( m^{–2} \) for \( 0.8 \leq m < 120 \ M_\odot \). IMFs labeled B vary as \( m^{–2} \) for the entire range \( 0.1 \leq m < 120 \ M_\odot \).

\( L_V/M \) at 10 Myr.
Clusters with B-type IMFs initially contain much more mass in \( m < 0.8 \, M_\odot \) stars than do present-day globular clusters.

After \( \sim 15 \) Gyr the cluster masses will decrease as the massive stars evolve and lose mass. Table 4 lists the mass ratios \( M_{GC}/M_* \), where \( M_* \) is the SSC mass at 10 Myr and \( M_{GC} \) is the globular cluster mass at 15 Gyr assuming that all stars with initial masses \( m > 8 \, M_\odot \) become 1.4 \( M_\odot \) neutron stars, and that stars with initial masses in the ranges 0.8–1.5, 1.5–2.5, and 2.5–8 \( M_\odot \) become white dwarfs with masses equal to 0.6, 0.7, and 1.1 \( M_\odot \), respectively. Table 3 also lists the mass fractions \( f(<0.8), f(WD), \) and \( f(\text{neutron}) \), of the mass \( M_{GC} \) contained in \( m < 0.8 \, M_\odot \) main-sequence stars, white dwarfs, and neutron stars. In their dynamical study Meylan & Mayor (1991) concluded that \( f(<0.8) \sim 0.73, f(WD) \sim 0.25, \) and \( f(\text{neutron}) \sim 0.02. \) The dynamical estimate for \( f(\text{neutron}) \) is consistent with the number of neutron stars per unit globular cluster mass that Kulkarni et al. (1990) inferred from millisecond pulsar observations. Table 4 can be used to select an IMF that is consistent with the observed \( L_*/M \) in 1569A and 1705-1 and then to determine how these SSCs must evolve if they are to become objects with MFs similar to those in Galactic globular clusters.

The \( L_*/M \) of 28.9 in 1569A is too small to be compatible with any of the A-type IMFs (assuming a cluster age of \( \sim 10 \) Myr). As discussed in §3, the small observed \( L_*/M \) implies a large mass fraction in low-mass stars, such as a B-type IMF with \( \alpha = 2.5. \) For this IMF, evolution of the massive \( (m > 0.8 \, M_\odot) \) stars will reduce 1569A to 0.81 of its present mass (see Table 4). In addition, 1569A must lose at least 80% of its mass in low-mass stars for the MF to flatten to \( m^{-0.7} \, dm \) between 0.1 and 0.8 \( M_\odot. \) About half of the mass contained in WD and neutron star remnants would also have to be removed for the final MF to be consistent with the distribution \( f(<0.8) = 0.73, f(WD) = 0.25, \) and \( f(\text{neutron}) = 0.02. \) Dynamical studies show that processes such as tidal stripping and cluster evaporation are effective at removing low-mass stars from evolving globular clusters (Spitzer 1987, p. 11; Chernoff & Weinberg 1990), although the tidal forces acting on 1569A may be quite different from those acting on Galactic globular clusters. In any event, it appears that mass loss due to stellar evolution and dynamical processes must reduce 1569A to \( \sim 0.81 \times 0.24 = 0.19 \) of its present mass if it is to evolve into an object similar to Galactic globular clusters. The final cluster mass would be \( 2.0 \times 10^5 \, M_\odot. \)

As discussed in §3, the \( L_*/M \) of 126 in 1705-1 implies that if the IMF is steep (\( \alpha > 2 \)), it must be truncated at lower mass limits ranging from \( \sim 1 \) to 3 \( M_\odot. \) After 15 Gyr 1705-1 would then consist only of massive stellar remnants. Alternatively, the IMF in 1705-1 could be flat with a small mass fraction in low-mass stars. For example, 1705-1 could have an A-type IMF with \( \alpha \) between 2.0 and 1.5 (see Table 4). If \( \alpha = 2, \) evolution of the massive stars will reduce 1705-1 to 0.43 of its present mass. About 70% of the WDs and 90% of the neutron stars would have to be ejected via dynamical processes for the final MF to be consistent with \( f(<0.8) = 0.73, f(WD) = 0.25, \) and \( f(\text{neutron}) = 0.02. \) The total mass loss would then reduce 1705-1 to 0.43 \( \times 0.53 = 0.25 \) of its present mass, and the final cluster mass would be \( 6.8 \times 10^4 \, M_\odot. \) If \( \alpha = 1.5, \) the cluster mass would decrease to 0.12 of the present mass for a final mass of \( 3.2 \times 10^4 \, M_\odot. \) In this scenario all of the low-mass stars would have to be retained during the cluster evolution, since the MF initially is of the form \( m^{-0.7} \, dm. \) High-velocity kicks imparted by the core collapse explosions could remove the neutron stars (Drukier 1996; Fryer, Burrows, & Benz 1998). Removal of the WDs will be more difficult since tidal stripping and cluster evaporation preferentially remove the low-mass stars (Chernoff & Weinberg 1990). It appears that 1705-1 may not evolve into a globular cluster. If it does, dynamical mass losses must lead mainly to the removal of the massive stellar remnants.

5. DISCUSSION

I have used the observed values of \( L_*/M \) in 1569A and 1705-1 to constrain their IMFs. In 1569A the IMF must be steep, and a large fraction of the SSC mass is contained in low-mass \( (m < 1 \, M_\odot) \) stars. This cluster could plausibly evolve into a \( 2 \times 10^5 \, M_\odot \) object resembling Galactic globular clusters; however, in 1705-1 the IMF must be flat or truncated at a lower mass limit exceeding 1 \( M_\odot. \) Most of the cluster mass in 1705-1 is contained in high-mass stars, which implies that it may be difficult for this SSC to evolve into a globular cluster.

Several uncertainties could affect my analysis and conclusions. First, because \( L_*/M \) is proportional to distance and the distances to 1569A and 1705-1 are uncertain to within factors of \( \sim 1.5 (\text{Meurer et al. 1992; O'Connell et al. 1994}), \) the \( L_*/M \) could be 1.5 times smaller or larger than assumed here. Second, the observed luminosities have been corrected for internal extinction the could be much larger. The observations suggest that the internal extinction is very small (Meurer et al. 1992; Gonzalez-Delgado et al. 1997). I note, however, that the initial extinction in these objects was probably very large. The fact that the SSCs are gravitationally bound implies that they must have formed with high \((\sim 50\%) \) gas-to-star conversion efficiencies (Mathieu 1984; Lada et al. 1984). If the protostellar molecular cloud masses and sizes were approximately equal to the observed SSC masses and sizes, the initial molecular hydrogen \((H_2) \) gas densities must have been as large as \( \sim 10^5 \, \text{cm}^{-3} \), with corresponding \( H_2 \) column densities equal to \( \sim 5 \times 10^{23} \, \text{cm}^{-2}. \) For Galactic gas-to-dust ratios these column densities correspond to visual extinctions \( A_V \sim 100. \) So if the internal extinction is now very small any remaining gas must have been blown out very efficiently once the stars started forming. This also implies that the star formation was “instantaneous” rather than “continuous” in these SSCs.

Third, the velocity dispersions measured by Ho & Felli ppenko (1996a, 1996b) were based on observations of massive RSGs. If these stars have attained equipartition, and are dynamically segregated in the cluster cores, the RSG velocities would be smaller than the mean stellar velocities, and the RSG virial masses would underestimate the total cluster masses. However, equipartition occurs on a cluster relaxation time \( t_r \approx (N/8 \ln N)^{1/2} \) where \( N \) is the number of stars in the cluster and \( t_r \) is the crossing time (Bonnell & Davies 1998). Adopting a mean stellar mass \( \langle m \rangle = 1 \, M_\odot \) (see Table 1) and the cluster masses and crossing times derived in §3, it follows that \( t_r \gtrsim 100 \, \text{Myr}. \) It appears that the SSCs are too young for the RSGs to have undergone dynamical mass segregation. Alternatively, the massive stars may have formed preferentially closer to the protocluster cores (see, e.g., Hillenbrand 1997). The veloc-
ties could be independent of the stellar masses, but the observed half-light radii would provide lower limits to the true cluster sizes. The cluster masses would again be underestimated. If low-mass \((m < 1 \, M_\odot)\) stars do dominate the total cluster mass in 1705-1, its large value of \(L/v/M\) can be taken as evidence of mass segregation. I note that if the massive stars are spatially segregated the SSCs should appear more compact in the UV and near IR since such light is produced by the most massive stars, whereas a significant fraction of the optical light is produced by intermediate mass stars (see § 2).

Finally, if significant populations of RSGs exist in both components of 1569A (see § 3), it is possible that part of the signal measured by Ho & Filippenko (1996a) is due to relative motion between the components rather than an intrinsic stellar velocity dispersion. The inferred \(L/v/M\) for 1569A would then be larger. Additional high-resolution spectroscopy is required to clarify this point.

Recent stellar census studies of nearby young clusters provide direct probes of the high-mass portions of the IMFs in star-forming regions. In Galactic and Magellanic OB associations Massey et al. (1995) found that \(\alpha = 2.3 \pm 0.3\) between 3 and 120 \(M_\odot\). Near-IR adaptive optics imaging (Brandl et al. 1996) and optical HST imaging (Massey & Hunter 1998) of R136, the "core" (\(r < 2\) pc) of the 30 Doradus star-forming region in the LMC, imply an IMF with \(\alpha \sim 2.3\) from 120 \(M_\odot\) down to the confusion limit of about 2 \(M_\odot\) with no hint of a break near the observed low-mass limit. In the Galactic cluster NGC 3603, Eisenhauer et al. (1998) found that within the central parsec the MF is actually biased toward massive stars with \(\alpha \sim 1.7\) from the detection limit of ~1 to ~30 \(M_\odot\), steepening to \(\alpha \sim 2.7\) for higher masses. (This steepening may be because of the small cluster mass rather than to an intrinsic steepening of the IMF.) Hillenbrand (1997) found that the Orion Nebula Cluster is globally consistent with a Miller-Scalo IMF, but that within the central 0.3 pc the IMF is biased toward massive stars. It is unclear what these various observations imply about the IMFs in the much more massive systems 1569A and 1705-1. Nevertheless, Figures 1–3 illustrate that the IMF in 1569A may be similar to the global IMF in the Orion cluster, whereas the IMF in 1705-1 may be similar to the MF in NGC 3603.

Recent observations of many starburst galaxies indicate that a large, and perhaps dominant, fraction of the recent star formation has occurred in massive SSCs (O'Connell et al. 1995; Maoz et al. 1996; Tacconi-Garman et al. 1996). If most of the SSCs have steep IMFs similar to 1569A, this would imply that dynamically significant populations of low-mass stars are formed together with the observed high-mass stars; however, if most of the SSCs are similar to that of 1705-1, with flat or truncated IMFs, this would support the long-standing hypothesis (Rieke et al. 1980, 1993) that in starburst galaxies massive stars are formed preferentially. Additional dynamical measurements of SSC masses would be valuable.

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